Proceedings 7th British Insecticide and Fungicide Conference (1973)

SEED-FURROW APPLICATION OF PESTICIDES FOR THE PROTECTION OF SUGAR BEET SEEDLINGS FROM PEST DAMAGE

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Summary Pesticides applied in the seed furrow were tested in trials on both pest-infested and pest-free sugar-beet fields in 1970 to 1973. Aldicarb granules, methiocarb liquid and oxamyl granules or liquid, at rates of ¼ to 1 lb a.i./acre (280 to 1120 g/ha), were consistently beneficial in protecting seedlings from damage by soil pests, mainly pygmy beetle and millepedes. Bendiocarb, gamma-BHC (granules only), carbofuran, diazinon, mecarphon, 'AC 92100', 'CGA 12223' and 'PP 505' are worth further testing but many other materials were ineffective or phytotoxic.

Resumé L'application d'insecticides dans le sillon du semis a été experimentée en champs d'essais à la fois dans des champs de betteraves infestés et dans des champs non infestés de parasites, en 1972-1973. Les granules d'aldicarb, le methiocarb liquide ainsi que l'oxamyl, tant liquide que sous forme de granules, aux doses de ¼ à 1 lb M.A./acre (280 à 1120 g/ha), eurent une action nettement bénéfique pour protéger les semis des dégâts de parasites souterrains, surtout de l'atomaire et des iules. Bendiocarb, gamma-BHC (seulement les granules), carbofuran, diazinon, mecarphon, 'AC 92100', 'CGA 12223' et 'PP 505' réclament la poursuite d'essais complémentaires, mais beaucoup d'autre matières s'étaient révélées inefficaces ou phytotoxiques.

INTRODUCTION

At present all seed used to sow the sugar-beet crop in England is treated with 0.2% of dieldrin to protect seedlings against damage by wireworms (Agriotes spp.) (Dunning & Winder, 1965). However, this treatment is not effective against other soil-inhabiting pests of seedling sugar beet (Jones & Dunning, 1972) and changing methods of establishing the crop demand better protection of seedlings (Dunning, 1971). Two approaches are being made to improve seedling protection - to find a better seed treatment material than dieldrin, and to find a suitable material and formulation for seed-furrow treatment. Progress has been made in testing broader spectrum insecticidal seed treatments and, currently, methiocarb is the best available; its activity was first noted in trials of seed-furrow treatments (Dunning & Winder, 1971, 1973). Seed for 5% of the national crop in 1973 will have 0.2% of methiocarb incorporated in the seed pelleting material in place of dieldrin. Our earlier work showed the value of overall soil incorporation of gamma-BHC and this is increasingly being used by growers (Dunning & Winder, 1971) but, for the future, we favour seed treatment alone or in combination with seed-furrow treatment.

Griffiths (1968) reviewed work on wireworm control in potatoes and corn, where row treatment was invariably more effective than broadcast treatment, and pointed out that "materials that do well in the laboratory may not necessarily perform well in field conditions". The results of early screening trials in the field were reported previously (Dunning & Winder, 1966, 1971); this paper presents the results of trials in 1970 to 1973.

METHODS AND MATERIALS

Fields in which beet crops had suffered previously from pest damage were sampled in the winter and the soil fauna extracted; fields with the most pests, of single or mixed species, were chosen for trial sites. In 1971 to 1973, trials were also made on fields that had suffered damage by pygmy beetle (Atomaria linearis) in the previous year; growing sugar beet again on these sites, with the permission of the British Sugar Corporation, and of the M.A.F.F. in cyst-eelworm scheduled areas, ensured damage to seedling sugar beet from the pygmy beetles overwintering in the soil. Additional trials tested the materials at Broom's Barn in the virtual absence of known pests.

In all trials the plots were single rows, each 40-100 ft (12.2-30.5 m) long, separated by a discard row. The formulation of materials tested was decided by availability; where possible, both granule and liquid formulations were compared in 1972 and 1973. Ineffective or phytotoxic materials were discarded at the end of each year's trials. Granules were applied by a Horstine Farmery 'Microband' granule applicator mounted on the drill, and liquid formulations by a simple gravity-flow system with a 4 ft (122 cm) head; granules and liquids were placed in the bottom and on both sides of the V-shaped seed-furrow after seed placement at about 1 in (2.5cm) depth but before soil replacement, (Liquids: 23 & 33gpa in 1970 & '71-3 (258 & 371 l/ha)).

The effects of treatments were assessed by counting, on appropriate lengths of row of each plot, the seedlings immediately before singling and, later, the established plants; the vigour of seedling foliage was scored and, in some trials, the sugar yield was determined by harvesting, weighing and analysing the roots for sugar content.

No attempt was made to measure the decrease in numbers of pests aggregating in the row but, at two sites, the extent of damage was scored on the washed roots of samples of seedlings.

RESULTS

Tables 1-4 record, for 1970-73 respectively, some of the assessments made under the following column headings:

E% - % seedling establishment (the number of seedlings at the singling stage per 100 seeds sown)

VS - seedling vigour score (scale 1 = very poor to 5 = very good)

DS - root damage score (scale 1 = very slight to 5 = very extensive)

PP - number of plants, after singling, per 66 ft of row (x 396 = number per hectare; x 160 = number per acre)

SY - sugar yield in cwt/acre (x 125.5 = kg/ha)

The pests at each site are listed in decreasing order of importance in the Tables, together with the soil type and sowing date.

In the 1970 trials, pest damage was slight and seedling establishment was good; no treatment increased seedling numbers but some decreased them, especially the larger amount of fenthion and mecarbam at Seventh Drove, and of gamma-BHC and fenthion at Shouldham. However, root grazing by millepedes (Brachydesmus superus and Blaniulus guttulatus) and by pygmy beetle at Seventh Drove was sufficiently extensive to score visually; damage was more than halved by 10 oz a.i./acre of chlorpyrifos, heptachlor and aldicarb (Table 1).

At Boston and Welney in 1971, where beet was grown after beet in 1970, pygmy beetle damage was severe and seedling establishment was only 35% and 7% respectively. No treatment decreased seedling establishment; most increased it and some increased seedling vigour (Table 2). Plant population and sugar yield were measured at Boston, but not at Welney, where seedlings were too few on most plots for the trial to be continued. At Bottisham and Broom's Barn, seedling establishment was good and was not improved by any treatment; the larger amount of gamma-BHC, chlorpyrifos and fenthion decreased seedling numbers and vigour in both trials. Yield, determined only at Broom's Barn, paralleled the seedling vigour scores and was very severely decreased by 10 oz a.i./ acre (700 g/ha) of gamma-BHC, chlorpyrifos, fenthion, phoxim and dimethoate; the latter three materials were not tested further in 1972 and 1973.

In the 1972 trial at Benwick no seedlings established on the untreated plots of 24th March sowing because of severe damage from the large number of pygmy beetles that had overwintered in the field from the 1971 beet crop; the best treatments were 10 oz a.i./acre (700 g/ha) of carbofuran granules (44% seedling establishment), gamma-BHC liquid (24%), oxamyl granules (12%), methiocarb liquid (10%), aldicarb granules (10%), oxamyl liquid (6%), mecarphon liquid (4%). The trial was resown on 23 May with the treated rows in the line of the previous trial's discard rows. Pygmy beetle damage was again very severe and seedling establishment was only 1% on the untreated plots (Table 3). The larger amount of all insecticides, except 'AC 64475', greatly increased seedling and plant establishment and sugar yield. At Shouldham, damage by millepedes and pygmy beetle decreased seedling establishment to 41% of seeds sown on the untreated plots; seedling and plant numbers were further decreased by 10 oz of gamma-BHC/acre (700 g/ha) but increased by the same amount of all other materials, whether as liquid or granule, and by 1 oz (70 g) of liquid gamma-BHC, methiocarb, 'CGA 10576' and 'Bayer 92114'. At Magdalen, pest damage was slight; seedling establishment and plant population were increased only by 10 oz aldicarb/acre (700 g/ha), and were decreased by some treatments. At Broom's Barn, seedling establishment on the untreated plots was exceptionally good; it was decreased by several treatments especially by gamma-BHC, chlorpyrifos and 'CGA 10576', and no treatment increased it. Seedling vigour, plant population and sugar yield were also decreased by these three treatments.

In the three trials in 1973, seedling establishment was only 9% at Terrington Marsh (severe damage by pygmy beetle) and 59% at Marham (moderate damage by millepedes and pygmy beetle), but 76% at Broom's Barn (no pest damage observed) (Table 4). At Terrington Marsh and Marham seedling establishment was increased by most treatments; seedling vigour was increased by some treatments but was decreased on average by gamma-BHC and diazinon liquids and 'CGA 12223' granules. Considerable benefit was derived at both sites from only 4 oz/acre (280 g/ha) of many materials, especially bendiocarb, 'PP 505', 'AC 92100' and 'CGA 12223'. At Broom's Barn 16 oz/acre (1120 g/ha) of gamma-BHC liquid and 'CGA 12223' granules decreased seedling establishment, vigour and plant population.

DISCUSSION AND CONCLUSIONS

The soil-inhabiting pests of seedling beet are fairly uniformly distributed in the soil at the time of sowing, but aggregate in the rows as soon as the seeds start germinating (Baker 1971, 1972, 1973). Protection of the seedlings from damage can be achieved by seed treatment, seed-furrow treatment or overall soil treatment (Dunning & Winder, 1971). The latter method is usually reliable but can fail under severe pest pressure; with seed furrow placement, the pesticide is in the most effective position and better protection of seedlings can be achieved with the same amount of material (Dunning & Winder, 1973). However, the risk of phytotoxicity restricts the amounts of some materials that can be placed near the seed.

Our trials compared the relative efficiency of promising pesticides in increasing seedling establishment and growth in the presence of various pests and pest complexes, and compared their phytotoxicity in the absence of known pests.

The results of limited comparisons of granule versus liquid formulations in 1972 and 1973 suggest that mecarphon is insecticidally most active in granule formulation, especially when small amounts are applied, and that gamma-BHC and 'CGA 10576' are most phytotoxic in liquid formulation; in three trials in 1973, oxamyl was equally effective as a granule or liquid.

We make the following conclusions on the materials tested by seed furrow application; mainly for protection against pygmy beetle and millepede damage:

A. Rejected because ineffective, or no longer available or acceptable: carbaryl, DDT, heptachlor, tetrachlorvinphos (1972 trials only - results not shown in Table 3, 'AC 64475', 'Cytrolane', 'C 10015', Bayer 92114'.

B. Rejected because phytotoxic: gamma-BHC (liquid), chlorpyrifos, dimethoate, fenitrothion, fenthion, fonofos, mecarbam, phoxim, propoxur, 'CGA 10576'.

C. Need further testing: bendiocarb, gamma-BHC (granules), carbofuran, diazinon, mecarphon, 'AC 92100', 'CGA 12223', 'PP 505'.

D. Efficient (3 or more years' results): aldicarb granules, methiocarb liquid, oxamyl liquid or, preferably, granules.

Phytotoxicity, which was usually most pronounced in the Broom's Barn trials, leads to rejection of many materials, some of which are insecticidally active, and such materials cannot be contemplated for seed treatment. Of the materials in groups C & D, bendiocarb, mecarphon and 'PP 505' are being tested as seed treatments and methiocarb is already being used as a seed treatment on a limited commercial scale.

Whether the technique of applying pesticides in the seed furrow at sowing will develop commercially in England remains to be seen; it has done in France and Belgium (Dunning, 1972), where materials such as aldicarb, carbofuran and oxamyl are now being used in place of heptachlor.

Acknowledgements

We are most grateful to the growers, the British Sugar Corporation fieldmen, A.N. Baker, W.A. Thornhill, J.H.A. Dunwoody and Mrs. Margaret Shields for all their help.

Insecticides tested

Martin (1972) describes most of the compounds tested, viz aldicarb, bendiocarb, gamma-BHC, carbaryl, carbofuran, chlorpyrifos, 'Cytrolane', 'C 10015', DDT, diazinon, dimethoate, fenitrothion, fenthion, fonofos, heptachlor, mecarbam, mecarphon, methiocarb, oxamyl, phoxim, propoxur, tetrachlorvinphos. The exceptions are:-

'AC 64475'	2-(Diethoxyphosphinylimino)-1,3-dithietane
'AC 92100'	*S*-(*tert*-butylthio)methyl-*O*,*O*-diethyl phosphorodithioate
'Bayer 92114'	*O*-Ethyl-*O*-2-carbisopropoxyphenyl-*N*-isopropyl-thiono-phosphoric acid
'CGA 10576'	Organophosphorus compound
'CGA 12223'	" " "
'PP 505'	Oxime carbamate compound

Table 1 : Results of 1970 trials

Site		Seventh Drove, Ely			Shouldham, Norfolk	
Soil type		Loamy peat			Calcareous silty loam	
Pests		Brachydesmus, Blaniulus & Atomaria			Boreoiulus, Brachydesmus & Atomaria	
Sowing date		19 April			1 May	
⊠ Assessment		E%	DS	PP	E%	PP
Date		22.5	28.5	11.6	9.6	7.7
Control	* -	69	2.4	74	67	71
Liquid formulations						
gamma-BHC	1	68	1.6	75	72	79
	10	67	1.2	73	46--	36---
carbaryl	1	66	1.7	73	73	83
	10	67	1.9	74	62	73
chlorpyrifos	1	66	2.1	74	77	75
	10	62	0.7	73	52	68
DDT	1	65	1.9	74	75	80
	10	71	1.2	78	72	87+
fenthion	1	68	1.2	69	72	79
	10	50---	1.3	80+	18---	31---
fenitrothion	1	63	2.4	74	70	82
	10	65	1.6	71	66	79
heptachlor	1	69	1.3	75	76	82
	10	72	0.6	75	66	78
mecarbam	1	65	2.3	75	78	77
	10	49---	2.1	70	54	68
methiocarb	1	71	1.8	73	75	79
	10	69	1.5	75	49	71
oxamyl	1	69	2.4	70	72	80
	10	66	1.9	74	72	78
propoxur	1	68	2.1	74	75	72
	10	64	1.5	74	68	72
Granular formulations						
aldicarb	10	69	0.8	74	73	72
S.E.(diff)		4.57	-	2.62	7.54	7.41
d.f.		46	-	46	69	

*oz a.i./acre x 70.6 = g/ha

+, Significantly better than the control at P = 0.5
--, ---, Significantly poorer than the control at P = 0.1, 0.01

⊠ See text for explanation

Table 2 : Results of 1971 trials

Site		Boston, Lincs.				Welney, Norfolk		
Soil type		Silty loam				Very fine sandy loam		
Pests		Atomaria, Brachydesmus & Blaniulus				Atomaria & Brachydesmus		
Sowing date		15 April				6 April		
▣ Assessment		E%	VS	PP	SY	E%	VS	DS
Date		28.5	28.5	23.6	21.9	28.5	28.5	1.6
Control	• -	35	2.6	59	49	7	2.6	2.8
Liquid formulations								
gamma-BHC	1	70^{+++}	4.3^{+++}	76	61^{+}	26^{+++}	3.6^{+}	
	10	41	2.3	52	41	42^{+++}	2.9	4.0
carbaryl	1	43	2.4	64	53	10	2.3	
	10	61^{+++}	3.1	84^{++}	56	16	2.9	
chlorpyrifos	1	59^{+++}	3.4^{+}	81^{+}	56	7	2.8	
	10	54^{+++}	2.5	74	58	24^{+++}	2.8	
DDT	1	55^{+++}	3.3	79^{+}	60	12	2.6	
	10	70^{+++}	4.1^{+++}	86^{++}	58	30^{+++}	3.4	
diazinon	1	36	2.1	56	51	9	2.0	
	10	62^{+++}	3.0	84^{++}	46	37^{+++}	3.4	2.6
fenitrothion	1	41	2.3	68	49	3	1.6^{-}	
	10	57^{+++}	3.0	78^{+}	59	15	3.3	
fenthion	1	50^{++}	2.8	72	54	4	2.0	
	10	47^{+}	1.5^{--}	67	47	23^{++}	2.8	
heptachlor	1	63^{+++}	4.4^{+++}	77^{+}	58	22^{++}	3.0	
	10	63^{+++}	3.5^{+}	78^{+}	58	41^{+++}	4.3^{+++}	1.0
methiocarb	1	55^{+++}	3.8^{++}	78^{+}	53	12	2.6	
	10	68^{+++}	4.1^{+++}	79^{+}	60	59^{+++}	4.0^{++}	1.9
oxamyl	1	37	2.6	64	52	9	3.0	
	10	66^{+++}	4.4^{+++}	77^{+}	56	39^{+++}	3.6^{+}	2.2
phoxim	1	33	1.8^{-}	65	51	3	1.5^{-}	
	10	28	1.8^{-}	50	44	3	1.3^{--}	
propoxur	1	38	2.4	61	52	7	2.6	
	10	57^{+++}	3.0	73	47	47^{+++}	2.8	3.4
'C10015'	1	40	2.3	64	49	7	2.5	
	10	58^{+++}	3.9^{++}	67	53	52^{+++}	2.9	2.6
Granular formulations								
aldicarb	10	58^{+++}	4.5^{+++}	73	59	54^{+++}	4.0^{++}	2.6
dimethoate	10	52^{++}	2.4	78^{+}	48	43^{+++}	3.5^{+}	2.6
fonofos	10	48^{++}	2.4	77^{+}	53	12	2.9	
mecarphon	10	71^{+++}	3.6^{++}	109^{+++}	65^{++}	52^{+++}	4.0^{++}	2.6
'Cytrolane'	10	48^{+}	2.9	72	52	14	3.0	
S.E.(diff)		5.59	0.40	8.8	5.7	4.8	0.42	
d.f.		99		98		99		

•oz a.i./acre x 70.6 = g/ha

▣ See text for explanation

Table 2 cont/ : Results of 1971 trials

Site		Bottisham, Cambs.			Broom's Barn, Suffolk		
Soil type		Calcareous silty loam			Sandy loam		
Pests		*Archeboreoiulus* & *Blaniulus*					
Sowing date		31 March			16 April		
■ Assessment		E%	VS	PP	E%	VS	SY
Date		2.6	2.6	23.8	10.6	10.6	8.11
Control	-	62	2.5	83	73	3.1	66
Liquid formulations							
gamma-BHC	1	71	2.8	97^{+}			
	10	49^{-}	1.1^{--}	40^{---}	32^{---}	0.5^{---}	14^{---}
carbaryl	1	61	2.3	92			
	10	65	3.1	94	69	2.3^{-}	56
chlorpyrifos	1	63	3.0	92			
	10	50^{-}	1.3^{-}	82	41^{---}	1.0^{---}	40^{---}
DDT	1	64	3.4	90			
	10	70	2.9	103^{++}	71	2.8	62
diazinon	1	68	3.1	96^{+}			
	10	64	2.6	88	66	2.5	64
fenitrothion	1	65	2.8	92			
	10	59	2.4	92	60^{--}	2.1^{-}	59
fenthion	1	67	2.9	100^{++}			
	10	28^{---}	1.6	57^{---}	8^{---}	1.6^{---}	17^{---}
heptachlor	1	68	2.9	95^{+}			
	10	59	2.1	85	60^{--}	2.5	61
methiocarb	1	61	2.5	96^{+}			
	10	61	3.4	85	61^{-}	2.8	67
oxamyl	1	66	2.9	98^{+}			
	10	62	3.4	82	68	3.5	63
phoxim	1	65	2.5	89			
	10	53	2.3	80	33^{---}	1.5^{---}	38^{---}
propoxur	1	64	3.0	101^{++}			
	10	63	2.6	96^{+}	71	1.8^{--}	58
'C 10015'	1	74	3.1	95^{+}			
	10	63	2.5	90	71	3.4	66
Granular formulations							
aldicarb	10	68	3.1	84	76	3.4	65
dimethoate	10	51	1.9	76	46^{-}	1.3^{---}	41^{---}
fonofos	10				48^{---}	1.8^{--}	59
mecarphon	10				71	2.0^{--}	61
'Cytrolane'	10				66	2.1^{-}	57
S.E.(diff)		6.1	0.49	6.2	4.9	0.40	5.1
d.f.		87			57		

+, ++, +++, Significantly better than the control at P = 0.5, 0.1, 0.01
-, --, ---, Significantly poorer than the control at P = 0.5, 0.1, 0.01

Table 3 : Results of 1972 trials

Site		Shouldham, Norfolk		Benwick, Cambs.		
Soil type		Calcareous silty loam		Peaty loam		
Pests		Boreoiulus, Atomaria & Brachydesmus		Atomaria, Brachydesmus & Blaniulus		
Sowing date		21 April		23 May		
▣ Assessment		E%	PP	E%	PP	SY
Date	•	8.6	17.7	22.6	15.8	21.9
Control	-	41	47	1	3	1
Liquid formulations						
gamma-BHC	1	72^{++}	78^{++}	17^{++}	30^{+++}	12^{+++}
	10	28	22^{-}	72^{+++}	85^{+++}	26^{+++}
carbaryl	1	46	61			
	10	52	60			
chlorpyrifos	1	50	55	9	17	6
	10	73^{+++}	73^{+}	30^{+++}	47^{+++}	18^{+++}
diazinon	1	44	58	2	6	3
	10	82^{+++}	87^{+++}	14^{+}	29^{+++}	9^{++}
mecarphon	1	44	53	3	7	3
	10	55	62	40^{+++}	62^{+++}	21^{+++}
methiocarb	1	58	71^{+}	1	1	2
	10	74^{+++}	79^{++}	45^{+++}	67^{+++}	24^{+++}
oxamyl	1	45	47	3	9	3
	10	63^{+}	65	38^{+++}	68^{+++}	21^{+++}
propoxur	1	42	54			
	10	52	60			
'C 10015'	1	47	62	1	3	1
	10	63^{+}	71^{+}	33^{+++}	56^{+++}	19^{+++}
'CGA 10576'	1	62^{+}	70^{+}			
	10	65^{++}	73^{+}			
'Bayer 92114'	1	61^{+}	68^{+}			
	10	71^{++}	89^{+++}			
Granular formulations						
aldicarb	10	78^{+++}	91^{+++}	58^{+++}	77^{+++}	28^{+++}
carbofuran	10	70^{++}	74^{++}	54^{+++}	59^{+++}	17^{+++}
mecarphon	10			78^{+++}	85^{+++}	28^{+++}
oxamyl	10	68^{++}	76^{++}	62^{+++}	73^{+++}	25^{+++}
'AC 92100'	10			82^{+++}	82^{+++}	32^{+++}
'AC 64475'	10			1	2	0
'Bayer 92114'	10	73^{+++}	80^{++}			
S.E.(diff)		9.2	10.0	5.4	7.5	2.9
d.f.		93		81		

•oz a.i./acre x 70.6 = g/ha

▣ See text for explanation

Table 3 cont/ : Results of 1972 trials

Site		Magdalen, Norfolk			Broom's Barn, Suffolk			
Soil type		Peaty clay loam			Sandy loam			
Pests		*Atomaria*, *Archeboreoiulus*, *Brachydesmus* & *Polydesmus*			-			
Sowing date		24 March			19 April			
x Assessment		E%	VS	PP	E%	VS	PP	SY
Date		1.6	1.6	23.6	20.6	20.6	29.6	9.11
Control	* -	61	3.3	55	94	3.3	90	54
Liquid formulations								
gamma-BHC	1	61	3.4	53				
	10	63	2.8	47	32---	1.0---	41---	23---
carbaryl	1	52	3.3	47				
	10	53	3.1	48	80--	2.1---	86	45-
chlorpyrifos	1	59	3.8	43				
	10	47-	1.9---	47	60---	1.8---	79-	42--
diazinon	1	51	3.0	57				
	10	62	3.1	59	83-	2.5--	81	51
mecarphon	1	57	3.0	49				
	10	60	3.0	54	90	2.9	88	54
methiocarb	1	56	3.0	58				
	10	66	3.0	54	82-	3.4	83	54
oxamyl	1	57	2.8	50				
	10	60	3.6	61	89	3.3	85	58
propoxur	1	52	3.0	52				
	10	64	3.3	54	76---	1.5---	84	48
'C 10015'	1	59	3.1	55				
	10	60	3.3	56	88	2.4---	87	51
'CGA 10576'	1	46-	2.8	45				
	10	44--	2.8	48	36---	1.4---	51---	36---
'Bayer 92114'	1	55	3.1	54				
	10	63	3.1	51	74---	2.4---	86	54
Granular formulations								
aldicarb	10	70	3.5	66	96	3.6	89	57
carbofuran	10	68	3.3	61	88	3.3	86	53
oxamyl	10	69	3.8	54	93	3.3	91	56
'Bayer 92114'	10	69	3.6	53	81--	2.9	85	56
'CGA 10576'	10				36---	1.4---	55---	38---
S.E. (diff)		6.3	0.4	6.6	a 4.7 b 5.4	0.25 0.28	5.3 6.1	3.6 4.2
d.f.			87			70		

+, ++, +++, Significantly better than the control at P = 0.5, 0.1, 0.01

-, --, ---, Significantly poorer than the control at P = 0.5, 0.1, 0.01

a-between the control and any treatment

b-between any two treatments other than the control

Table 4 : Results of 1973 trials

Site		Marham, Norfolk			Terrington Marsh, Norfolk			Broom's Barn, Suffolk		
Soil type		Calcareous silty loam			Silt			Sandy loam		
Pests		Boreoiulus, Atomaria & Agriotes			Atomaria			-		
Sowing date		12 April			23 March			26 April		
■ Assessment		E%	VS	PP	E%	VS	PP	E%	VS	PP
Date		17.5	6.6	6.6	4.6	4.6	18.7	8.6	8.6	7.8
Control	• -	59	3.2	74	9	2.3	29	76	3.3	79
Liquid formulations										
bendiocarb	4	80^{+++}	3.4	83^{+}	29^{+++}	3.0	50^{++}	76	3.4	74
	16	72^{+}	2.4^{--}	79	30^{+++}	3.5^{++}	54^{+++}	69	2.5	77
gamma-BHC	4	76^{++}	2.5^{-}	66^{-}	25^{+++}	2.9	53^{+++}	70	1.3^{---}	61^{---}
	16	77^{+++}	1.5^{---}	50^{---}	15	1.3^{-}	17	31^{---}	0.5^{---}	10^{---}
diazinon	4	72^{+}	3.3	76	6	1.6	17	77	3.0	77
	16	61	2.6^{-}	74	9	2.1	32	60^{-}	2.4	64^{--}
mecarphon	4	59	3.3	66^{-}	13	2.3	31			
	16	75^{++}	3.1	76	25^{+++}	3.1^{+}	57^{+++}	83	3.0	77
methiocarb	4	71^{+}	3.0	83^{+}	17^{+}	2.8	41	83	3.4	75
	16	83^{+++}	4.0^{++}	82^{+}	22^{+++}	3.1^{+}	51^{++}	69	2.6	73
oxamyl	4	79^{+++}	3.5	76	17^{+}	2.6	42			
	16	81^{+++}	3.8^{+}	80	27^{+++}	3.3^{+}	60^{+++}	85	3.9	74
'CGA 12223'	4	74^{++}	3.4	79	23^{+++}	3.5^{++}	53^{+++}	77	3.6	75
	16	60	2.6^{-}	67	20^{++}	3.1^{+}	45^{+}	62^{-}	1.8^{--}	74
'PP 505'	4	82^{+++}	3.0	84^{++}	26^{+++}	3.4^{++}	60^{+++}	83	3.6	78
	16	76^{++}	3.1	80	35^{+++}	4.1^{+++}	68^{+++}	84	3.8	77
Granular formulations										
aldicarb	4	82^{+++}	3.8^{+}	82^{+}	18^{++}	3.0	41			
	16	82^{+++}	3.6	81	30^{+++}	3.7^{+++}	59^{+++}	83	4.1	75
gamma-BHC	4	71^{+}	3.3	76				83	2.9	77
	16	78^{+++}	2.3^{--}	57^{---}				84	1.4^{---}	44^{---}
carbofuran	4	76^{++}	3.6	83^{+}				86	3.9	74
	16	78^{+++}	3.6	83^{+}	34^{+++}	3.8^{+++}	67^{+++}	84	3.4	77
mecarphon	4	75^{++}	2.9	78	23^{+++}	3.0	51^{++}	89^{+}	3.4	80
	16	76^{++}	2.9	78	28^{+++}	3.3^{+}	59^{+++}	86	2.6	77
oxamyl	4	80^{+++}	3.4	79	21^{+++}	2.5	48^{++}			
	16	77^{+++}	3.8^{+}	82^{+}	27^{+++}	3.4^{++}	56^{+++}	87	4.0	77
'AC 92100'	4	74^{++}	3.5	81	31^{+++}	3.5^{++}	62^{+++}	87	3.0	78
	16	72^{+}	3.1	80	25^{+++}	3.3^{+}	53^{+++}	77	3.0	75
'CGA 12223'	4	72^{+}	3.0	77	26^{+++}	3.3^{+}	56^{+++}	81	3.4	77
	16	37^{---}	2.4^{--}	62^{--}	19^{++}	2.8	46^{+}	29^{---}	1.5^{---}	49^{---}
S.E. (diff)	μ_a	5.1	0.27	3.7	3.4	0.39	6.8)	6.1	0.48	4.4
	μ_b	6.5	0.34	4.7	4.1	0.48	8.3)			
d.f.			108			89			87	

•oz a.i./acre x 70.6 = g/ha µ see Table 3

+, ++, +++, Significantly better than the control at P = 0.5, 0.1, 0.01

-, --, ---, Significantly poorer than the control at P = 0.5, 0.1, 0.01

■ See text for explanation

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NOTES

Proceedings 7th British Insecticide and Fungicide Conference (1973)

EXPERIMENTS ON THE CHEMICAL CONTROL OF CARROT FLY IN CARROTS IN EAST ANGLIA IN 1968-72

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Summary The organophosphorus insecticide AC 92100 applied at sowing by the bow-wave technique and later as a foliage treatment gave 95-97% reductions of carrot fly (Psila rosae F.) larval attacks for at least 10 months on both mineral and peat soils. Isophenphos was almost as effective, but phorate gave inadequate protection in 1972 against late-season damage. When applied at sowing by bow-wave, phorate remained effective for only 23 weeks. A supplementary mid-season foliar treatment of phorate granules improved carrot fly control but gave unacceptably high insecticide residues in treated carrots.

In comparisons of mid-season foliage spray treatments following phorate bow-wave application, two high volume sprays of diazinon gave 85% reduction of carrot fly larvae. Chlorfenvinphos, iodofenphos, mecarbam and pirimiphos-ethyl sprays each gave over 70% reduction, but DDT was ineffective. Sprays directed towards the soil around the plant crowns were generally more effective than when applied to the foliage.

Deep side placement of insecticides by liquid injection to growing carrots gave inconclusive results against carrot fly and for husbandry reasons the method is not considered practicable.

INTRODUCTION

With resistance in carrot fly (Psila rosae F.) to aldrin and dieldrin confirmed in East Anglia (Gostick and Baker, 1968) and the imposition of a voluntary ban on the use of these organochlorines against the pest (Anon 1964, 1969), chemical control measures have recently relied largely on the organophosphorus insecticides phorate or disulfoton used as granules at sowing and supplemented in mid-season with foliar spray applications chiefly of DDT or chlorfenvinphos.

While these measures have given excellent results against carrot fly in the period from sowing until late October, thereafter damage increases until by January of the following year it is at unacceptably high levels. The larvae of the second and partial third generation continue feeding throughout the winter months while the carrots remain in the soil. Many crops destined for processing as well as the open market are left in the soil after reaching maturity, and may be harvested up to 14 months after sowing.

The close proximity of early and maincrop carrots in favourable soils, the frequent overlapping of crops from one season to the next and a succession of mild winters have proved conducive to a rapid increase in carrot fly damage.

The problem with carrot fly throughout the peat fens and in many upland mineral soils of East Anglia is thus one of trying to protect carrots against late-season damage by the pest, using insecticides which are relatively non-persistent and which leave acceptably low residues in treated carrots (see also Wheatley, 1969). This paper presents the results of our work on the chemical control of carrot fly over the period 1968-72. Attempts at cultural control will be reported elsewhere (Coppock, Maskell and Gair, in press) but have so far proved inadequate.

MATERIALS AND METHODS

Sites

Details of the sites in East Anglia at which experiments were conducted are shown in Table 1. A number of additional trials gave abortive results, chiefly because of very little carrot fly damage, and have been excluded from this account.

Table 1

Details of trial sites

Trial No	Locality	Soil	Sowing date	Cultivar	Insecticide applications	Plot size (ac)	Treatments X replicates
1	Bagthorpe Norfolk	Sandy loam	10 April 1968	Asmer's New Stump Rooted	Granules at sowing, injection of liquids mid-season	1/109	18x1
2	Methwold Hythe Norfolk	Peaty loam	6 May 1968	Autumn King	Foliar sprays mid-season	1/242	9x3
3	Mepal Cambs	Peaty loam	21 May 1969	Chantenay Red-cored	Granules at sowing	1/290	8x4
4	Mepal Cambs	Peaty	15 May	Chantenay Red-cored	Granules at sowing, injection of liquids mid-season	1/242	9x3
5	Methwold Hythe Norfolk	Peaty loam	9 June 1969	Autumn King	Foliar sprays mid-season	1/247	10x3

Table 1 (continued)

6	Holme Fen Hunts	Peaty loam	3 June 1970	Autumn King	Sprays on foliage or soil mid-season	1/332	9x4
7	Holme Fen Hunts	Peaty loam	3 June 1970	Autumn King	Granules at sowing, early or late chlorfenvinphos sprays mid-season	1/332	5x4
8	Methwold Hythe Norfolk	Peaty loam	13 May 1970	Chantenay Red-cored	Phorate granules at sowing and applied to foliage mid-season	1/220	8x4
9	Trumpington Cambs	Sandy loam	20 April 1972	Cylinder	Granules at sowing and mid-season	1/697	5x5
10	Feltwell Norfolk	Peaty loam	26 April 1972	Cylinder	Granules at sowing and mid-season	1/872	9x4
11	Feltwell Norfolk	Peaty loam	27 April 1972	Cylinder	Granules at sowing, granules or sprays mid-season	1/290	21x3

Injection of liquid insecticides applied mid-season

Trial 1 Single rows at 16 in. centres were sown at a seed rate of 4.8 lb/acre, applying disulfoton 7.5% granules bow-wave at 20 lb product/acre to all plots. On 2 August liquid formulations of phorate, disulfoton, chlorfenvinphos, C10015, mecarbam, diazinon, Dursban and pirimiphos-ethyl were each injected at 0.6 and 1.0 lb a.i./acre respectively to a depth of 4 in. and 4 in. on either side of each row, using a liquid nitrogen injection machine towed by a Unimog at 2.5 mph. 100 carrots/plot were examined for carrot fly damage on 28 November 1968.

Trial 4 Single rows at 20 in. centres were sown at a seed rate of 1.5 lb/acre immediately after phorate 10% granules had been broadcast at 30 lb product/acre and harrowed into the soil. Chlorfenvinphos, mecarbam, diazinon, Dursban, pirimiphos-ethyl, iodofenphos and bendiocarb were injected at 2.33 lb a.i./acre in a similar manner to Trial 1 but with a Leaper-Ramsey injection machine on 6 August 1969. 100 carrots/plot were scored for carrot fly damage on 2 December 1969. Additional plots at both sites were used to measure the effects of the injection equipment alone on subsequent growth of carrots. Injection tines were set 4, 5 or 8 in. on either side of the single rows and to a depth of 2, 4 or 5 in.

Trial 3 Twin 6 in. rows at 30 in. centres were sown together with the granular insecticides shown in Table 2, applied as a bow-wave by a Horstine Farmery granule applicator attached to a Webb drill. 100 carrots/plot were examined for carrot fly damage on 28 October, 1969.

Foliar sprays applied mid-season

Trial 2 Carrots grown in 18 in. beds at 36 in. centres were treated on 14 and 30 August with chlorfenvinphos, C10015, iodofenphos, mecarbam, diazinon, Dursban, pirimiphos-ethyl or DDT, each at 1 lb a.i./45-55 gal/acre applied as a coarse spray directly over the carrot foliage using a knapsack sprayer. 70 carrots/plot were examined for carrot fly damage on 15 January, 1969.

Trial 5 Carrots were grown in 12 in. beds at 20 in. centres. The insecticides shown in Table 4 were each applied over the foliage by knapsack sprayer at 1 lb a.i./50 gal/acre on 31 July, 14 and 28 August, 11 and 25 September. 100 carrots/plot were examined for carrot fly damage on 15 December, 1969.

Trial 6 Carrots were grown in twin 6 in. rows at 24 in. centres and given phorate 10% granules at 2.8 lb a.i./acre bow-wave. The insecticide treatments hown in Table 5 were applied at 1 lb a.i./50-60 gal/acre on 5 August, 2 and 30 September, except for the single application of chlorfenvinphos at 2 lb a.i./100 gal/acre on 5 August. On one half of the plots, sprays were directed over the foliage; to the remainder, the sprays were directed to the soil immediately around the carrot crowns. 100 carrots/plot were examined for carrot fly attack on 11 January, 1971.

Trial 7 Carrots were sown in 6 in. rows at 24 in. centres with phorate 10% granules at 2.8 lb a.i./acre bow-wave. Chlorfenvinphos sprays, each at 1 lb a.i./ 50 gal/acre, were applied either on ten occasions at 14-day intervals, on five early occasions (sprays 1-5) or on five late occasions (sprays 6-10). Applications were made on 5 and 20 August, 2, 16 and 30 September, 14 and 28 October, 12 and 25 November and 9 December. 100 carrots/plot were examined for carrot fly damage on 18 January, 1971 when soil and carrot samples were also collected for residue analysis.

Granules applied at sowing and mid-season

Trial 8 Carrots in single rows at 30 in. centres were treated with phorate 10% granules at 3 lb a.i./acre bow-wave using a Horstine Farmery granule applicator. Mid-season treatments of phorate granules were applied as a band over the rows and were either left exposed or covered with soil. Deep side placement of phorate granules was obtained with coulters 3 in. on either side of the rows and 4 in. deep. 100 carrots/plot were examined for carrot fly damage on 26 January, 1971. Carrot samples were collected at frequent intervals throughout the season for residue analysis.

Additional unreplicated plots compared phorate with disulfoton, both applied bow-wave on 13 May at 3 lb a.i./acre. Assessment of carrot fly damage was made on 26 January, 1971.

Trial 9 Carrots were sown at 3 lb/acre in single rows at 15 in. centres using a Canadian cone seeder. Granular treatments (Table 8) were applied bow-wave at sowing or in mid-season as a 6 in. band over the rows and lightly raked into the soil. 70 carrots/plot were examined for root damage on 22 November, 1972.

Trial 10 Carrots were sown at 3 lb/acre in single rows at 15 in. centres using a Canadian cone seeder. Granular insecticides (Table 9) were applied at sowing or in mid-season as in Trial 9. 100 carrots/plot were examined for larval damage on 27 February, 1973.

Phorate granules applied at sowing followed by granules and/or sprays applied mid-season

Trial 11 Carrots in 5 in. beds at 30 in. centres were sown with phorate 10% granules at 2.7 lb a.i./acre applied as a bow-wave with a Horstine Farmery granule applicator. Mid-season granule treatments (Table 10) were applied as an 8 in. wide band over the rows, the granules then being lightly raked into the soil. Mid-season spray treatments were directed to the soil and were applied by knapsack sprayer at 2.0 lb a.i./100-115 gal/acre as a 1 ft wide band. 100 carrots/plot were examined for larval damage on 2 January, 1973.

The assessments of treatment effects in all trials are shown in the results as percentage roots attacked by carrot fly and as percentage reduction of larvae. The latter method and the basis for its compilation are described by Wheatley (1969).

RESULTS

Injection of liquid insecticides applied mid-season

Very little carrot fly damage was recorded in Trials 1 and 4. Severe slug damage at Trial 1 was effectively reduced by the carbamate C10015.

None of the injection tine treatments adversely affected plant growth, for only 4% roots were fangy when examined 17 weeks after treatment.

On another mineral soil site in Norfolk, insecticides were injected on 13 August, 1969 to single row carrots sown at 16 in. centres in mid-April. With a moderate infestation of couchgrass and lush growth of the carrot foliage, plant material accumulated in front of the moving injection tines and lifted the carrots out of the ground. Altering the distance of the tines to more than 4 in. from the carrot rows had the same effect, so the trial had to be abandoned.

Granules applied only at sowing

Table 2

(Trial 3)

Granules treatment 21 May 1969	Rate lb a.i./acre	% roots attacked by carrot fly on 28 Oct	% reduction of larvae
Phorate 10%	2.11	0.50	92
Chlormephos 5%	2.21	1.75	69
Fonofos 10%	2.30	2.25	61
Pirimiphos-ethyl 5%	2.00	2.50	58
Bendiocarb 5%	2.16	2.75	52
Disulfoton 7.5%	2.29	3.25	44
C10015 10%	2.20	4.75	18
Control (untreated)	-	5.75	-
S.E. of treatment mean	(21 d.f.)	± 0.66	

Although only a low second generation larvael attack developed at this site, all treatments except C10015 gave significant reductions of damage.

Foliar sprays applied mid-season

Table 3
Comparison of two applications of mid-season foliar sprays
(Trial 2)

Treatments 1 lb a.i./acre		% roots damaged by carrot fly 15 Jan	% reduction of larvae
Chlorfenvinphos	24%	5.7	74
C10015	50% wp	11.0	49
Iodofenphos	50% wp	3.3	85
Mecarbam	68%	7.1	68
Diazinon	40% wp	16.7	20
Dursban	25%	8.6	61
Pirimiphos-ethyl	25%	4.8	79
DDT	20%	20.9	0
Control (untreated)		20.5	-
S.E. of treatment mean (16 d.f.)		± 2.6	

Significant reduction of larval damage was given by iodofenphos and pirimiphos-ethyl ($\underline{P} < 0.001$), chlorfenvinphos ($\underline{P} < 0.01$) and by mecarbam and Dursban ($\underline{P} < 0.05$). DDT sprays were completely ineffective.

Table 4
Comparison of mid-season foliar spray applications
(Trial 5)

Treatments 1 lb a.i./acre		% roots damaged by carrot fly 15 Dec	% reduction of larvae
Mecarbam	68%	1.3	94
Iodofenphos	50% wp	4.0	80
Bendiocarb	25% wp	4.3	79
GS13006	40% wp	4.3	79
Pirimiphos-ethyl	25%	4.7	77
Chlorfenvinphos	24%	5.3	74
Dursban	25%	7.7	61
Ethion	50%	12.7	34
DDT	20%	15.3	20
Control (untreated)		18.7	-
S.E. of treatment mean (18 d.f.)		± 1.9	

All treatments except DDT gave significant reduction of carrot fly damage.

Table 5
Mid-season spray treatments applied to the soil or foliage
(Trial 6)

Treatments all with phorate granules 2.8 lb a.i./acre bow-wave	Carrot fly damage assessed 11-12 Jan			
	Soil/crown application		Foliage application	
	% roots attacked	% reduction of larvae	% roots attacked	% reduction of larvae
Chlorfenvinphos 1 lb a.i./acre	12.0	17	17.5	42
" 2 lb a.i./acre (one application only)	9.0	39	7.3	77
Fenitrothion 1 lb a.i./acre	10.3	29	23.8	17
Iodofenphos "	7.0	53	16.5	45
Bendiocarb "	10.8	26	18.8	37
GS13006 "	20.0	-	19.0	36
Dursban "	20.3	-	15.5	49
Pirimiphos-ethyl "	11.8	18	14.5	52
Control (phorate bow-wave)	14.3	-	28.0	-
S.E. of treatment mean (24 d.f.)	± 3.7		± 3.7	

A single application of chlorfenvinphos at 2 lb a.i./acre ($6\frac{2}{3}$ pt of 24% conc.) applied at high volume on 5 August significantly reduced the damage to late-lifted carrots when applied to the foliage or to the soil around the plant crowns. Three applications of iodofenphos, each at 1 lb a.i./acre, at 4 wk intervals gave 53% reduction ($\underline{P} < 0.05$). Damage was significantly reduced ($\underline{P} < 0.05$) by foliar applications of iodofenphos, Dursban and pirimiphos-ethyl. Of the eight treatments, five gave better control when the sprays were directed to the soil around the carrot crowns than to the foliage, fenitrothion being significantly so ($\underline{P} < 0.05$).

Table 6
Comparison of schedules of chlorfenvinphos (CFVP) foliar sprays
(Trial 7)

Treatments All spray applications at 1 lb a.i./acre	Carrot fly damage 18 Jan		CFVP residues 18 Jan			
	% roots attacked	% reduction of larvae	In soil		In carrots	
			ppm	lb a.i./ac*	Whole roots ppm	After peeling and boiling ppm
1. Control (untreated)	58.0	-	Nil	Nil	-	-
2. Phorate 10% gr at 2.8 lb a.i./acre bow-wave	42.3	37	-	-	-	-
3. Treatment 2 plus 10 CFVP sprays	17.3	78	6.23	4.98	2.60	0.12
4. " " 5 early CFVP sprays	25.0	67	3.20	2.56	1.51	0.11
5. " " 5 late CFVP sprays	36.8	47	7.11	5.69	1.00	0.06
S.E. of treatment mean (12 d.f.)	± 4.1					

* Assuming 8×10^5 lb air-dry soil per 6 in. acre

Ten mid-season sprays of chlorfenvinphos supplementing phorate granules at sowing (Table 6) gave 78% reduction of larvae. The five early spray applications made at fortnightly intervals in August and September gave a better control than the five late applications made from mid-October until early December.

Chlorfenvinphos residues in the soil at this site were analyses by ADAS colleagues at Cambridge. Residues in treatments 3 and 4 were roughly as expected in a light textured peat soil 6 months after application. The high residue levels in treatment 5 were probably attributable to 'earthing up'. Chlorfenvinphos residues in whole carrots, analysed by staff of Shell Research Ltd at Sittingbourne, were also high but were reduced by 93-95% by peeling and boiling.

Table 7
Methods and rates of phorate granule application
(Trial 8)

Phorate treatments			Carrot fly attack 26 Jan		Residues in whole carrots Total phorate and metabolites ppm	
Bow-wave	Mid-season					
13 May	13 Aug	7 Oct	% roots damaged	% reduction of larvae	8 wk after appl	16 wk after appl
Nil	Nil	Nil	22.0	-	0.02	0.02
3 lb a.i./acre	Nil	Nil	9.3	61	-	-
"	3 lb a.i./acre	Nil	5.5	77	-	-
"	" (covered)	Nil	2.5	90	0.88	0.64
"	1.5 lb a.i./acre	1.5 lb a.i./ac	4.8	80	-	-
"	" (covered)	" (covered)	8.5	64	-	-
"	3 lb a.i./ac (side)	Nil	5.0	79	-	-
"	1.5 lb a.i./ac (side)	1.5 lb a.i./ac (side)	5.8	76	-	-
S.E. of treatment mean (21 d.f.)			± 2.1			

All phorate granule treatments (Table 7) gave significant reduction of carrot fly damage. The only mid-season treatment to give significantly better reduction than the bow-wave treatment was 3 lb a.i./acre applied over the foliage on 13 August and lightly raking in the granules that fell on the soil. Residues of phorate and its metabolites were unacceptably high in whole carrots given this treatment.

Assessment of the single plots comparing phorate and disulfoton bow-wave treatment at 3 lb a.i./acre was made on 26 January 1971, when 9% roots were damaged on the phorate-treated plot compared with 22% on the disulfoton treated one.

Table 8

Phorate and AC92100 granules applied at sowing and mid-season

(Trial 9)

Treatment	Rate lb a.i./acre Bow-wave 20 April	Rate lb a.i./acre Mid-season 28 July	Carrot fly attack % roots attacked 22 Nov	Carrot fly attack % reduction of larvae
Phorate 10% granules	1.5	-	53	56
"	1.5	1.0	17	89
AC92100 10% granules	1.5	-	17	89
"	1.5	1.0	6	97
Control (untreated)	-	-	82	-
S.E. of treatment mean (15 d.f.)			± 3.4	

On the mineral soil at Trial 9 (Table 8), the organophosphorus insecticide AC92100 gave much better reduction of carrot fly damage than phorate ($P < 0.001$) when applied as a bow-wave at 1.5 lb a.i./acre. AC92100 was also significantly better than phorate ($P < 0.01$) when both were applied as a bow-wave at 1.5 lb a.i./acre and later over the foliage at 1.0 lb a.i./acre. Note that at this dual treatment rate, AC92100 gave 97% reduction of carrot fly damage from that of the control plots and maintained this effect for at least 10 months after sowing.

Table 9

Comparison of granular insecticides applied at sowing and mid-season

(Trial 10)

Treatment	Rate lb a.i./acre Bow-wave 26 April	Rate lb a.i./acre Mid-season 31 July	Carrot fly damage % roots attacked 27 Feb	Carrot fly damage % reduction from phorate tr. 1
1. Phorate 10% granules	3.0	Nil	75	-
2. "	3.0	2.0	26	78
3. AC92100 10% granules	3.0	Nil	26	78
4. "	3.0	2.0	7	95
5. "	2.0	Nil	31	73
6. Carbofuran 10% granules	3.0	Nil	73	6
7. "	3.0	2.0	69	16
8. Isophenphos 5% granules	3.0	Nil	40	63
9. "	3.0	2.0	20	84
S.E. of treatment mean (24 d.f.)			± 3.7	

At the corresponding peat site (Table 9), AC92100 was again significantly better than phorate when applied as a bow-wave at 3.0 lb a.i./acre ($P < 0.001$), and when the granules were applied at 3.0 lb a.i./acre at sowing and later as a foliar treatment at 2.0 lb a.i./acre. The dual treatment of AC92100 granules gave over

90% reduction of damage 11 months after sowing. A bow-wave application of 20 lb a.i./acre was not significantly different from the 3.0 lb rate.

Isophenphos granules applied as a bow-wave at 3.0 lb a.i./acre were also significantly better ($P < 0.001$) than phorate but not when the insecticides were applied both at sowing and at 2.0 lb a.i./acre in mid-season. Carbofuran granules were ineffective against the pest.

Phorate granules applied at sowing followed by granules and/or sprays applied mid-season

Table 10
Comparison of granules and sprays applied mid-season
(Trial 11)

All plots treated with phorate 10% granules at 2.7 lb a.i./acre bow-wave

Mid-season treatments all at 2.0 lb a.i./acre		Carrot fly attack	
31 July	17 October	% attacked roots 2 January	% reduction of larvae
Nil	Nil	46	-
Disulfoton granules	Nil	48	0
"	Chlorfenvinphos spray	37	27
Phorate granules	Nil	40	19
"	Chlorfenvinphos spray	39	21
Chlorfenvinphos granules	Nil	32	39
"	Chlorfenvinphos spray	41	15
Triazaphos granules	Nil	41	15
"	Chlorfenvinphos spray	42	12
Pirimiphos-ethyl spray	Nil	26	52
"	Pirimiphos-ethyl spray	37	27
Chlorfenvinphos spray	Nil	27	49
"	Chlorfenvinphos spray	18	69
Bromophos spray	Nil	34	33
"	Bromophos spray	30	43
Iodofenphos spray	Nil	26	51
"	Iodofenphos spray	27	49
Orthene spray	Nil	28	48
"	Orthene spray	43	10
Diazinon spray	Nil	13	78
"	Diazinon spray	9	85
S.E. of treatment mean (40 d.f.)		± 6.5	

At the peat site (Table 10), one or two mid-season foliar spray applications of diazinon w.p., each at 2.0 lb a.i./acre, gave a marked reduction of damage ($P < 0.001$) to late lifted carrots below that sustained in plots treated only with phorate granules at sowing. Significant reductions in attack were also obtained by two mid-season sprays of chlorfenvinphos, each at 2.0 lb a.i./acre ($P < 0.01$), by single spray applications of pirimiphos-ethyl or chlorfenvinphos or one or two sprays of iodofenphos ($P < 0.05$).

Mid-season foliar granule treatments of disulfoton, phorate, chlorfenvinphos or triazaphos alone or followed by a spray application of chlorfenvinphos, or one or two spray applications of bromophos or Orthene did not give significant reduction of root damage.

DISCUSSION

Wheatley (1972) has shown that insecticides applied as a deep side placement to growing carrots are in the best position to affect invading carrot fly larvae. Damage was so low at both liquid injection sites (Trials 1, 4) that the results are inconclusive as far as carrot fly control is concerned.

However, the injection technique can only be used in crops drilled in single rows and, judging from our experience, ones which are weed free and do not have lush foliage.

Insecticides applied as granules at sowing were reasonably effective when attacks were light (Table 2), with phorate giving sufficient protection for carrots harvested before November, but not when heavy attacks occurred as at other sites (Tables 6, 7, 8, 9, 10).

Some form of insecticidal treatment is thus usually necessary to supplement granules applied at sowing. The candidate materials iodofenphos, mecarbam, pirimiphos-ethyl and chlorfenvinphos (in decreasing order of effectiveness) applied two, three or five times at 1.0 lb a.i./50 gal/acre to carrot foliage in mid-season (Tables 3, 4, 5, 6, 10) gave over 70% reduction of attack. Dursban gave 50-60% reduction. GS13006 gave good results at one site (Table 4) but was ineffective at another (Table 5), while the carbamate C10015 only gave 49% reduction of larvae (Table 3). Fenitrothion was generally ineffective but significantly better when applied to the soil around the carrot crowns rather than to the foliage (Table 5). Diazinon foliar sprays also gave variable results (Tables 3, 10), being more effective when applied to the carrot crowns, while DDT was completely ineffective as a foliar treatment (Tables 3, 4) and its use is now being actively discouraged for carrot fly control.

Ten spray applications of chlorfenvinphos, at fortnightly intervals from early August until mid-December, failed to give complete protection from carrot fly damage and left unacceptably high residues in the soil and carrots (Table 6). The fact that five early sprays of chlorfenvinphos were more effective than five late ones suggests that larvae hatching from eggs laid during August and September contribute most to late-season damage. This has been confirmed in cultural experiments (Coppock, Maskell and Gair, in press) and mid-season control measures need to be timed accordingly.

Results from Trial 6 (Table 5) suggest that mid-season sprays give better results if applied to the soil around the carrot crowns than to the carrot foliage. In the case of some insecticides applied in mid-season in Trial 11 (Table 10), one spray application was superior to two, possibly because of deleterious effects against predators of carrot fly eggs and/or larvae.

One advantage in substituting granules for sprays as mid-season treatments is to eliminate the need to transport large volumes of water. Phorate granules applied in mid-season as well as at sowing (Table 7) gave marked reduction of carrot fly damage but unacceptably high residues in the carrots. AC92100 granules were even more effective than phorate (Tables 8, 9) and isophenphos slightly so (Table 9), but residue levels in carrots treated with both materials have yet to be determined and are likely to be unacceptably high.

Of the currently available granular insecticides, phorate gave best results until 1972, when it was much less effective in experimental plots (Tables 8, 9) and in commercial crops, and tests are now being made to determine whether or not carrot fly in East Anglia has developed resistance to this insecticide.

Acknowledgements

We thank colleagues at Cambridge for help in field and laboratory work, chemists at ADAS Cambridge and Shell Research Ltd, Sittingbourne for residue analyses and carrot growers for their invaluable co-operation.

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Proceedings 7th British Insecticide and Fungicide Conference (1973)

TWO SOIL INSECTICIDES FOR THE CONTROL OF CABBAGE ROOT FLY AND CARROT FLY

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Summary Results are presented from trials with isophenphos and carbofuran to test their effectiveness for the control of cabbage root fly and carrot fly. Carbofuran was the more effective against cabbage root fly when the materials were applied as granular formulations, but drenches of isophenphos were also effective. The performance of isophenphos appeared to be more dependent upon correct soil placement, whereas the greater solubility of carbofuran combined with its toxicity to adult root flies may explain the generally good results from surface and sub-surface granule treatments.

Preliminary results indicate that isophenphos provides more lasting control of carrot fly, where its lower solubility may be advantageous.

INTRODUCTION

Cabbage root fly (Erioischia brassicae) became resistant to dieldrin in Great Britain during the early 1960s (Coaker et al, 1963; Gostick and Baker, 1968) and similar problems with organochlorine insecticides have arisen in other parts of the world. For instance, growers in Washington, USA, noticed the failure of organochlorines to protect their crops from cabbage root fly in 1959 (Howitt and Cole, 1962) although resistance was not reported from New York State until 1966 (McEwen et al, 1967). In Britain efforts were made to find alternatives to dieldrin as quickly as possible. A considerable number of materials and their effectiveness for cabbage root fly control have been reported including: diazinon, mecarbam, chlorfenvinphos, bromophos, trichloronate, parathion, phorate, thionazin and dimethoate (Coaker and Finch 1965; Rosborough, 1966, 1968; Makepeace and Smith, 1965; Trought and Heath, 1965; Coghill, 1969; Geering and Bond, 1969). In 1968 a scheme for testing new materials was initiated by the Agricultural Development and Advisory Service. Prior to the scheme's commencement 28 compounds had been evaluated by workers at the National Vegetable Research Station, Wellesbourne (Rolfe, 1969). In Britain the following materials are currently recommended by Agricultural Chemicals Approval Scheme for use against cabbage root fly: aldrin, gamma-BHC, dieldrin (now limited by agreement with the Pesticides Safety Precautions Scheme), chlorfenvinphos, diazinon, dimethoate, fonofos, phorate (partial control only), thionazin and trichlorphon (for Brussels sprout 'button' attack).

A similar situation developed on the carrot crop and populations of carrot fly (Psila rosae) were found, after 1967, to have developed marked resistance to cyclodiene insecticides and cross resistance to gamma-BHC (Wright and Coaker, 1968). Although Approved organophosphorous alternatives are available to the carrot grower, these materials do not have sufficient persistence to adequately control the larvae hatching from eggs laid in the late summer and early autumn. Hence the search continues for new effective materials. The limitations and problems in the performance of organophosphorous insecticides for carrot fly are discussed by Wheatley (1969).

This paper describes field experiments to test two soil insecticides for cabbage root fly control, and some reference is made to preliminary results obtained on carrot fly.

METHOD AND MATERIALS

Experimental Chemicals: 5% carbofuran on calcite granules, size 0.6 - 1.2 mm, coded Bayer 5687b; 10% carbofuran on pumice granules, size 0.5 - 1.0 mm, coded Bayer 6529; 5% isophenphos* on pumice granules, size 0.5 - 1.0 mm, coded Bayer 6189; and 50% isophenphos e.c., coded Bayer 6435.

Standard comparison materials: 10% chlorfenvinphos granules (Birlane granules); 24% chlorfenvinphos e.c. (Birlane 24); 5% dimethoate granules (Rogor granules); and 10% disulfoton on Fullers Earth granules (Disyston FE-10).

Trials on transplanted brassica crops with experimental granular formulations.

1972: Granules were used at given rates per unit area applied along the rows. Sub-surface applications were made by hand at planting to simulate placement by the Leeds-type coulter as manufactured by Horstine Farmery Limited. This coulter deposits the granules between the surface of the soil and the transplant roots. The positioning of the hand-applied granules could not have been precisely the same in each small plot trial, however the sub-surface treatments may be regarded as band applications incorporated into the surface layers of the soil to varying depths. The intention was to apply a 2 - 3" (5.0 - 7.6 cm) band at approximately 2" (5.0 cm) below the soil surface, just above the transplant roots. Surface applications were made by 'pepper-pot' along the transplant rows as a 6" (15.2 cm) wide band. The size of plots varied between trials but was approximately 20 m^2. Plant spacing was dependent upon local practice. The trials were designed as randomised replicated blocks except where otherwise indicated in the Tables.

1973: Replicated trials were designed to study a range of carbofuran rates applied along a unit length of row. The methods of application, both surface and sub-surface, were carried out as described above. Once again plot size was approximately 20 m^2 in most trials, although occasionally they were slightly larger.

Trials to test isophenphos dips and drenches on brassica transplants: Two trials, one in 1972 and another in 1973, were conducted using Bayer 6435 applied as dip and drench treatments. Emulsions of varying concentrations were prepared and for the dip treatments the transplant roots were held in the insecticidal liquid for approximately 5 seconds and planted within a few minutes of treatment. The drenches were applied as 100 ml of emulsion per plant within 24 hours after transplanting.

A number of parameters were used to measure the effectiveness of materials, these included:

(a) Grading of roots according to the percentage of damaged cortex to obtain a Root Damage Index (Rolfe, 1969).

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* Suggested common name

(b) Numbers of larvae and/or pupae on the roots and in the soil immediately surrounding them.
(c) Counts of wilted and dying plants.
(d) Vigour grading at appropriate times on a 1 - 9 scale.
(e) Numbers of marketable heads, sometimes quality grading and weight.
(f) Observations on other pests and assessments where necessary.

For the sake of clarity not all of these parameters are included in tables of results.

1973 trial to test experimental granular formulations on radishes: Radishes were drilled at various intervals and different linear rates of Bayer 5687b were compared with chlorfenvinphos granules. Granules were sprinkled along pre-marked drilling lines, along which the seed drill travelled after treatment to simulate the 'bow-wave' technique. Radishes were harvested when mature, cut into halves longitudinally and assessed for percentage cabbage root fly attack using the key depicted in Figure 1. Root Damage Indices were calculated based on the method described by Rolfe (1969).

Carrot fly trials with experimental granular formulations: Granules of Bayer 6189 and Bayer 6529 were applied at different rates per unit area along pre-marked drilling lines using a 'pepper-pot' technique. Seed was then drilled through the band of granules to simulate the 'bow-wave' technique. Trials were conducted in 1972 and 1973, using 20 m^2 plots and four replicates. Carrots were sampled during growth from untreated areas to monitor carrot fly attack. Assessments were made by counting the number of roots with carrot fly attack.

RESULTS

Table 1
Results from carrot fly trial, Littleport, Cambridgeshire, 1972

Cultivar: Autumn King Drilled: 17/5 Assessed: 1/11

Treatments (a.i.)	% attacked roots (Angles)	% Control
isophenphos gr. 1.0 kg/ha	8.22	84.3
isophenphos gr. 2.5 kg/ha	2.03	97.1
isophenphos gr. 5.0 kg/ha	0	100
carbofuran gr. 1.0 kg/ha	17.17	48.6
carbofuran gr. 2.5 kg/ha	9.60	74.3
carbofuran gr. 5.0 kg/ha	4.98	90.0
disulfoton gr. 1.12 kg/ha	12.47	70.6
Untreated control	23.09	—
% attack on untreated		17.5
LSD 5%	9.35	
1%	12.73	

Crop vigour and quality: The results presented do not reflect the excellent early vigour of the plants, and the high quality of the produce, particularly cauliflowers, following carbofuran treatment. In certain trials curds were graded and, for example, at Norton in 1973, 41.4% of curds at the lowest carbofuran rate and 81.9% at the highest were in the top three marketable grades compared with 34.8% from the standard chlorfenvinphos treatment.

Table 2

Results from 1972 cabbage root fly trials with isophenphos and carbofuran granular formulations

Location	Thanet, Kent				Tarleton, Lancs			Gosberton, Lincs			*** Norton, Suffolk		Frating, Essex	*** Norton, Suffolk	
Crop	Cauliflower				Cauliflower, Cabbage			Cauliflower			Cabbage		Cabbage	Cabbage	
Cultivar	Sutton's Perfection				Asmer Early Head, Coronet			Super Festival			Primo		Derby Day	Primo	
Planting date	27/4				21/4			27/4			18/5		14/3	18/5	
Treatment date	27/4				21/4			27/4			18/5		12/5	18/5	
Assessment date	12/7		5,6/7		5,28/7		5/7	3/8		31/7	18/7		30/6	18/7	
Active ingredient	RDI (Angles)	% reduct. in RDI	no. markt. curds	wt. markt. curds (kg)	RDI (Angles)	% reduct. in RDI	dead + wilts/plot **	RDI (Angles)	% reduct. in RDI	pupae/10 roots	RDI	% reduct. in RDI	pupae/10 roots	RDI	% reduct. in RDI
isophenphos 1.0 kg/ha surface	49.2	11.1	16.5	16.1	19.0	10.6	0.89	33.9	51.2	43.0	—	—	15.0	—	—
" 1.0 kg/ha sub surface	28.7	63.7	29.5	42.5	—	—	—	37.6	42.9	42.5	—	—	—	1.4	96.0
" 2.5 kg/ha surface	36.8	44.0	30.3	44.9	22.5	34.8	0.49	25.5	70.7	14.0	—	—	8.5	—	—
" 2.5 kg/ha sub surface	27.5	66.4	32.8	44.8	—	—	—	34.3	50.3	20.3	—	—	—	0	100
carbofuran 1.0 kg/ha surface	22.1	66.7	29.8	43.9	7.0	87.9	0.15	16.1	84.4	13.8	—	—	3.3	—	—
" 1.0 kg/ha sub surface	21.5	78.8	36.5	48.8	—	—	—	17.9	84.2	18.3	7.1	87.9	—	—	—
" 2.5 kg/ha surface	23.7	74.6	31.3	42.0	0	100	0.27	6.9	95.0	3.8	—	—	9.0	—	—
" 2.5 kg/ha sub surface	20.3	80.8	34.0	46.8	—	—	—	14.1	90.1	5.8	0	100	—	—	—
chlorfenvinphos 1.0 kg/ha surface	30.1	60.9	20.3	21.8	16.8	48.5	0.35	26.8	68.6	24.5	—	—	10.0	—	—
" 1.0 kg/ha sub surface	26.1	69.5	30.8	40.0	—	—	—	32.9	53.0	15.3	—	—	—	—	—
Untreated	51.0	—	16.3	15.6	22.4		1.01	52.5		86.8	58.9		34.3	35.6	
RDI on untreated		64.3				16.5*			65.6			58.9			35.6
LSD 5%	5.8		9.9	20.3	7.2		0.31	13.2		19.2	NA		14.2	NA	
1%	7.8		13.3	27.3	9.9		0.43	17.8		25.9			19.6		

* low mean due to one exceptionally good untreated plot. ** $\log_{10}$ n+1 transformation. *** not replicated.

Table 3

Results from 1973 cabbage root fly trials with carbofuran granular formulation

Location	Spalding, Lincs			Tarleton, Lancs			Peacehaven, Sussex		
Crop	Cauliflower			Cauliflower			Cauliflower		
Cultivar	Super Festival			All Year Round			Snowball		
Planting date	9/5			11/5			17/4		
Treatment date	9/5 (11/5)			11/5			17/4 (10/5)		
Assessment date	16/7		12-16/7	22/6		30/7	2/7		26/6
Active ingredient	RDI (Angles)	% reduct. in RDI	markt. curds	RDI (Angles)	% reduct. in RDI	markt. curds	RDI (Angles)	% reduct. in RDI	markt. curds
carbofuran 0.46g/10m surface	6.7	87.1	78.8	63.3	9.7	14.3	2.0	98.9	39.8
" 0.46g/10m sub surf.	0	100	76.5	37.9	55.9	38.5	1.9	99.0	46.0
" 0.62g/10m surface	0	100	102.5	68.9	5.2	20.0	3.0	97.6	43.0
" 0.62g/10m sub surf.	0.9	99.8	74.0	32.0	67.1	39.8	0	100	41.0
" 0.93g/10m surface	0	100	84.8	45.2	42.4	40.5	0	100	42.5
" 0.93g/10m sub surf.	0	100	74.5	22.6	77.5	54.8	0	100	48.5
" 1.55g/10m surface	0	100	75.0	52.1	29.5	36.8	0	100	46.8
" 1.55g/10m sub surf.	0	100	91.3	24.6	80.0	55.5	0	100	50.5
" 0.05g/plant	0	100	80.0	—	—	—	0	100	45.8
" 0.02g/plant	0	100	81.8	—	—	—	0	100	39.0
chlorfenvinphos 0.7g/10m surf.	—	—	—	84.8	0	9.8	—	—	—
" 0.7g/10m sub surf.	14.7*	61.9*	71.5*	38.6	53.8	50.0	9.5	91.8	43.0
Untreated	26.4	—	73.8	79.0	—	6.8	40.9	—	22.5
RDI on untreated		21.3			87.9			45.9	
LSD 5%	8.4		NS	16.6		16.0	4.9		8.3
LSD 1%	11.4			22.4		21.4	6.7		11.1

- CONTD. -

Location	Norton, Suffolk			Peacehaven, Sussex	Pershore, Worcs			Broadway, Worcs	
Crop	Cauliflowers			Cauliflower	Cabbage			Cauliflower	
Cultivar	Delta			Snowball	Early Head			Driancourt	
Planting date	26/4			10/5	17/4			20/4	
Treatment date	26/4			10/5 (11/5)	17/4 (1/5)			19/4 (4/5)	
Assessment date	10/7		29/6	27/7	28/6		28/6	31/7	
Active ingredient	RDI (Angles)	% reduct in RDI	markt. curds	markt. curds	RDI	% reduct in RDI	markt. heads	RDI (Angles)	% reduct in RDI
carbofuran 0.46g/10m surface	54.5	25.5	21.8	20.0	14.1	76.7	70.5	45.3	32.8
" 0.46g/10m sub surf.	—	—	—	26.0	10.8	82.2	75.5	40.7	42.9
" 0.62g/10m surface	49.9	34.3	24.0	21.0	5.9	90.3	74.8	34.9	55.7
" 0.62g/10m sub surf.	—	—	—	22.5	10.0	83.5	74.0	39.3	46.5
" 0.93g/10m surface	46.2	41.5	19.0	17.3	24.2	60.1	73.5	37.7	49.8
" 0.93g/10m sub surf.	—	—	—	20.8	4.8	92.1	75.8	33.8	58.6
" 1.55g/10m surface	36.6	59.8	23.5	15.8	7.0	88.4	79.8	36.5	52.4
" 1.55g/10m sub surf.	—	—	—	26.3	7.2	88.1	71.3	37.9	57.0
" 0.05g/plant	—	—	—	8.0	—	—	—	21.9	75.5
" 0.02g/plant	—	—	—	13.0	—	—	—	26.8	72.0
chlorfenvinphos 0.7g/10m surf.	55.5	23.8	11.5	—	—	—	—	—	—
" 0.7g/10m sub surf.	—	—	—	22.3	7.7	87.3	70.5	43.8	44.7
Untreated	66.7	—	5.3	2.0	60.6	—	65.3	58.0	—
RDI on untreated		88.9				60.6			75.1
LSD 5%	9.8		8.4	6.0	NA		12.7	12.4	
LSD 1%	13.2		11.2	8.1			17.1	16.7	

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* Dimethoate gr. 0.73 g/10m. Surface application date in brackets.

Table 4

Results from cabbage root fly trials with isophenphos as dip and drench treatments

Location	Norton, Suffolk, 1972							Norton, Suffolk, 1973				
Crop	Cabbage							Cauliflower				
Cultivar	Primo							Delta				
Planting date	16/5							26/4				
Treatment date	16/5							26/4				
Assessment date	28/7						20/7	15/7				29/6
Active ingredient	RDI (Angles)	% reduct. in RDI	larvae/ 10 roots	larvae/ 10 roots*	pupae/ 10 roots	pupae/ 10 roots*	markt. heads	RDI (Angles)	% reduct. in RDI	pupae and larvae/10 roots	pupae and larvae/10 roots*	markt. curds
isophenphos 0.05% drench	0	100	0	0	0	0	18.3	31.2	68.8	0.8	1.06	16.8
" 0.1% drench	—	—	—	—	—	—	—	32.4	67.2	0.5	0.97	19.0
" 0.25% drench	—	—	—	—	—	—	—	31.3	69.3	0.3	0.84	15.5
" 0.5% drench	4.1	96.9	0	0	0	0	15.8	—	—	—	—	—
" 0.05% dip	15.4	72.7	2.0	0.35	5.00	0.75	20.3	—	—	—	—	—
" 0.1% dip	—	—	—	—	—	—	—	53.1	28.7	10.3	3.15	10.5
" 0.25% dip	—	—	—	—	—	—	—	49.4	36.0	15.3	3.90	16.8
" 0.5% dip	2.0	98.4	0.3	0.08	0	0	20.5	—	—	—	—	—
azinphos-methyl 0.05% drench	11.6	83.5	3.3	0.43	3.50	0.50	19.5	—	—	—	—	—
chlorfenvinphos 0.05% drench	—	—	—	—	—	—	—	37.4	58.2	1.0	1.14	16.3
" gr. 0.70g/10m surface	4.5	92.7	0.8	0.20	6.25	0.64	21.0	55.5	23.7	11.0	3.31	11.5
" gr. 0.70g/10m sub surface	0	100	1.8	0.38	1.50	0.39	23.8	—	—	—	—	—
Untreated control	34.1	—	19.8	1.06	23.00	1.38	16.0	66.7	—	12.8	3.35	5.3
RDI on untreated		32.6							88.9			
LSD 5%	9.0			0.41		0.36	NS	9.8			1.10	8.4
1%	12.2			0.56		0.50		13.2			1.48	11.2

* $\log_{10}$ n+1 transformation

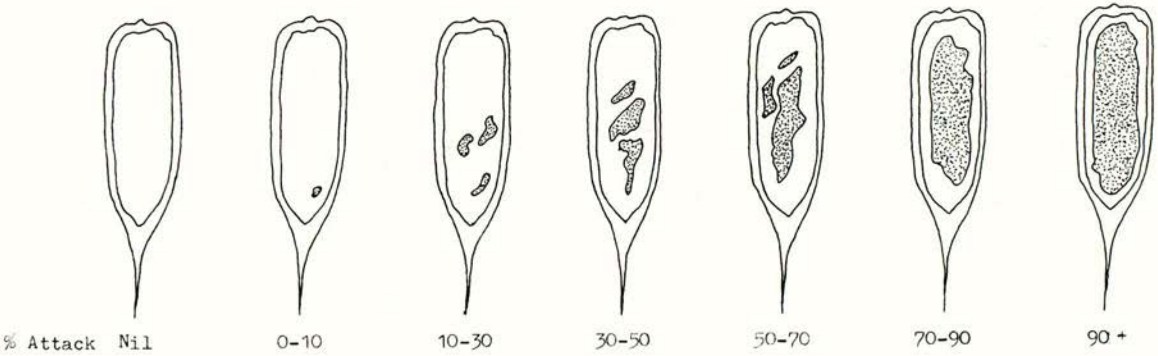
Table 5

Results from 1973 cabbage root fly trial with carbofuran granular formulation on radishes cv. French Breakfast

	Drilling 1		Drilling 2		Drilling 3		Drilling 4		Drilling 5		Drilling 6	
Drilling date	18/4		2/5		16/5		21/5		1/6		4/6	
Assessment date	8/6		15/6		13/7		12/7		1/8		2/8	
Active ingredient	RDI (Angles)	% reduct. in RDI	RDI (Angles)	% reduct. in RDI	RDI (Angles)	% reduct. in RDI	RDI (Angles)	% reduct. in RDI	RDI (Angles)	% reduct. in RDI	RDI (Angles)	% reduct. in RDI
carbofuran 0.31g/10m	6.9	92.7	12.5	85.3	24.8	22.8	19.3	48.6	10.7	39.8	4.4	43.6
" 0.46g/10m	14.0	74.0	10.2	88.4	19.1	52.8	14.9	65.3	7.9	75.6	2.2	92.0
" 0.62g/10m	2.1	99.3	5.5	95.1	21.7	39.9	16.8	54.5	3.8	87.4	3.1	89.0
" 1.55g/10m	3.3	96.6	4.3	95.8	14.9	63.9	12.3	77.6	5.3	84.1	0.7	98.5
chlorfenvinphos granule 0.70g/10m	10.0	84.4	13.2	81.8	22.9	27.7	12.2	77.8	10.1	44.6	0.9	97.8
Untreated control	32.2	—	32.6	—	28.4	—	27.0	—	15.7	—	10.1	—
RDI on untreated		29.1		32.4		22.9		21.3		7.8		4.0
LSD 5%	11.3		8.0		9.4		7.2		7.7		6.0	
1%	16.0		11.1		13.1		10.0		10.6		8.3	

Figure 1

Grading scheme for root fly damage to radishes



Other pests Carbofuran proved to have a wide spectrum of activity. Control of aphids (*Brevicoryne brassicae*), flea beetle (*Phyllotreta* spp) damage, and cabbage stem weevil (*Ceutorrhynchus quadridens*) was recorded in trials where these pests occurred.

DISCUSSION

Isophenphos and chlorfenvinphos granules gave the same performance in controlling cabbage root fly (Table 2) in the Kent trial when surface applied, but the lowest rate of isophenphos was unaccountably inferior to other treatments. In the same trial control of root damage was improved consistently with sub-surface application, but was statistically significant only in the case of isophenphos ($P>0.05$). Under some conditions, sub-surface placement of chlorfenvinphos granules can greatly improve control (J. R. Kelly personal communication). In the results of the trial in Lincolnshire (Table 2) however, there was a consistent trend with all chemicals in favour of surface treatment, although none of the differences were significant. Carbofuran, in all trials, gave a better performance than chlorfenvinphos and isophenphos. Further trials with carbofuran granules in 1973 (Table 3) confirmed its effectiveness. Extremely low and, in some cases, nil RDIs were recorded, particularly where lower levels of attack occurred. There was no consistent evidence to suggest that levels of control were greatly influenced by sub-surface placement of carbofuran; however in the Lancashire trial, on moss soils, differences between surface and sub-surface treatments were significant. Isophenphos drenches (Table 4) were very successful against a high attack and in 1973 gave a performance better than a standard chlorfenvinphos granule treatment. Carbofuran is approximately 5 - 6 times more water soluble than chlorfenvinphos, whilst isophenphos is about 5 times less water soluble than the latter. It may be postulated that the very good root fly control and the early vigour of carbofuran treated plants may be due to its rapid dispersal through soil moisture films. In addition, carbofuran was seen to kill adult cabbage root flies around the base of plants and this may explain the good results with spot treatments of granules at Broadway in 1973 (Table 3). Adult mortality has been recorded previously by Judge *et al* (1968) using carbofuran drenches, and Geering and Bond (1969) suggested that death of adults might contribute to the success of dimethoate surface treatments. The work on radishes confirmed the effectiveness of carbofuran and also that the lowest rate was probably insufficient.

Unfortunately, the carrot fly trials proved disappointing due to low pest incidences, however, the results of a 1972 trial (Table 1) show that isophenphos was better than carbofuran in reducing late damage. The problem demands season-long effectiveness and it is probable that the lower water solubility of isophenphos is advantageous by decreasing the movement and dispersal of active ingredient. Good results with isophenphos against carrot fly are reported at this conference (Maskell and Gair, 1973), and in regional trials in Scotland where first generation attack was as high as 75% on untreated plots very good control was obtained with both isophenphos and carbofuran (M. W. Shaw personal communication).

Acknowledgements

The author wishes to thank all of his colleagues in Bayer Agrochem Ltd, who have helped produce the experimental data, and particularly the Trials Officers who conducted the field experiments.

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NOTES

Proceedings 7th British Insecticide and Fungicide Conference (1973)

EVALUATING INSECTICIDES AGAINST ONION FLY:

SUGGESTIONS FOR IMPROVING EXPERIMENTAL PROCEDURES

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Summary Onion seed freshly treated with insecticides was sown in a field plot. This was subsequently covered by a large cage into which laboratory-reared flies were released when germination was complete. The type of data needed to assess the effects of insecticide treatments on germination, protection of the onions and yield is discussed and the results are summarised by a ranking method to reveal the relative performances of the treatments. Dieldrin at the recommended dose of 35g a.i./kg seed was the best treatment tested. Diazinon, isophenphos and pirimiphos-ethyl at 10 or 20g a.i./kg seed were less effective in overall performance. Diazinon and isophenphos had slight adverse effects on germination. At the same doses, chlorfenvinphos was very phytotoxic and mecarphon did not control the pest. The method appeared to be satisfactory and could form the basis for a standardised procedure for evaluating insecticides against onion fly.

Sommaire Des semences d'oignon traitées avec des insecticides furent ensemencées dans un petit terrain. Ensuite, le sol fut couvert par une grande cage dans laquelle, après la germination, des mouches de l'oignon élevées en laboratoire furent libérées. On examine les données necessaire à une évaluation des effets produits par divers insecticides sur la germination, la protection des oignons et le rendement. Un résumé des resultats permet un classement qui révèle les mérites relatifs des traitements. La dose recommendée de dieldrine, 35g de m.a./kg de semences, fut la plus éfficace. Le diazinon, l'isophenphos et le pirimiphos-éthyl à 10 ou 20g de m.a./kg produisirent des résultats legèrement défavourable à la germination. Les mêmes doses de chlorfenvinphos furent tres phytotoxique et le mecarphon ne parvint pas a maitriser cette peste. Cette methode parut satisfaisante et pourrait servir de base à une procedure normalisée, destinée à évaluer l'éficacité des insecticides contre la mouche de l'oignon.

INTRODUCTION

For almost 20 years onion seed has been very effectively protected against onion fly larvae (Delia antiqua), and/or bean seed fly larvae (Delia platura), by a dieldrin seed-dressing, but there is now an urgent need to find substitutes for use in the U.K. Not only have some local populations of these pests developed resistance to dieldrin, but the seed dressing formulation of dieldrin has been withdrawn from the U.K. market for commercial reasons.

Attempts to evaluate insecticides against onion fly larvae during the past decade have not often been successful. The uncertainty of attack on trial sites, even where the pest had previously affected commercial crops, has hampered progress to find alternative compounds.

Brassicas can be readily infested by cabbage root fly (Erioischia brassicae) under semi-natural conditions using a large field cage (Finch, 1969). It is not difficult to rear large numbers of onion flies in artificial conditions (Ticheler, 1971) and so the possibility of infesting onions by releasing artificially-reared onion flies into a large cage in the field was therefore investigated at Wellesbourne in 1973. A suitable experimental design was also needed to determine the performance of several treatments simultaneously within the cage, despite likely systematic trends in the level of infestation. The type of data necessary to assess the overall value of candidate insecticides, simply and unequivocably, and with a minimum of effort, was also considered.

Assessment of insecticide performance

As with other similar problems, there are two main aspects of the performance of candidate chemicals to consider when they are evaluated for onion fly control, their efficiency and their effectiveness (Wheatley, 1974). The efficiency of insecticidal treatments concerns their ability to reduce the attacking population of the pest, usually a density independent characteristic of the control measure. In practice, the efficiency can be expressed directly as the percentage reduction in the pest population resulting from the treatment, or indirectly, and less precisely, in terms of the percentage reduction in pest damage. The effectiveness of treatments, however, depends on the interactions of numerous factors such as changes in infestation levels and plant density as well as the efficiency of the control measures. Phytotoxicity also has an important influence on the ultimate effectiveness of insecticides applied as seed dressings, or to the soil near the seed at sowing time.

To evaluate insecticides for onion fly control, therefore, information is needed on their effects on the germination of the seed, their efficiency to protect the seedlings from attack until harvest and on their effectiveness in terms of final yield of the crop, the resultant of the effects and interactions of all relevant factors.

Effects on germination are manifested either as a change in the rate of germination or in the viability of the seed (total % germinating). To determine the rate of germination, those germinating from a known number of seeds must be counted on two or more occasions before germination is complete. The final numbers germinating indicate any effect on viability. Whereas most previous workers have determined final plant stand when germination was complete, few have provided data indicating effects on rates of germination (e.g. Howitt, 1958; Missonnier et al., 1966a,b).

Damage by the first generation of larvae has been determined by counting the numbers of plants attacked and/or surviving in mid-season, expressed as % plants attacked (Wright, 1939; Rawlins & Gonzalez, 1966), damaged (Finlayson et al., 1959; Carden, 1959) or killed (Jørgensen, 1959; Perron & Lafrance, 1962), sometimes on more than one date (Carden, 1959).

Effects on the crop at harvest have been assessed from the numbers and weights of surviving bulbs (e.g. Carden, 1959, 1965) and sometimes the undamaged bulbs have been recorded separately (Finlayson et al., 1959). The effectiveness of the treatments has been summarised as a "% increase" compared with the untreated crop (e.g. Wright, 1939; Perron & Lafrance, 1960).

Choice of insecticides

The dieldrin seed-dressing was used as a standard against which candidate materials could be compared. Diazinon has featured successfully in many trials in North America (Howitt, 1958; Perron & Lafrance, 1962; Rawlins & Gonzalez, 1966) and Europe (Carden, 1965; Missonnier et al., 1966a,b) although it has sometimes reduced the numbers of treated plants and is incipiently phytotoxic. The wettable powder formulation, although no longer marketed in the U.K., was used in this experiment to minimise the risk of phytotoxicity. The toxicity of chlorfenvinphos to anthomyid larvae is well authenticated and the liquid seed dressing, approved for the control of wheat bulb fly (Leptohylemya coarctata) was therefore investigated. A micro-encapsulated formulation of pirimiphos-ethyl supplied as a liquid was included on the basis of the manufacturer's report of its success against onion fly in trials in Europe, and two experimental compounds, isophenphos and mecarphon, were also included for primary evaluation.

METHODS AND MATERIALS

Insecticides and treatments

The insecticides used were dieldrin plus thiram seed dressing (Dieldrex B; 75% dieldrin, 10% thiram), chlorfenvinphos (Birlane; 32.2% a.i. liquid seed dressing), isophenphos (B 5528; 20% a.i. w/w seed dressing), diazinon (Basudin 40; 40% a.i. w.p.), mecarphon (15% a.i. w/w powder formulation), pirimiphos-ethyl (PP211; 20% a.i. encapsulated, liquid seed dressing).

5g batches of seed (moisture content 10%) were treated at rates equivalent to either 10 or 20g a.i./kg of seed, except those treated with dieldrin at the recommended rate (34.5g a.i./kg). The chlorfenvinphos and pirimiphos-ethyl liquid formulations were applied by shaking the appropriate amounts with the seed in a stoppered 100ml conical flask. Seeds to be treated with mecarphon and diazinon powders, or sticker only, were first stirred with 0.2 - 0.4ml 1% methyl cellulose sticker. When the seed was uniformly coated, the required amount of powder was added gradually while the seed was being stirred. The dieldrin dressing was applied to the dry seed without sticker. All batches of seed were air-dried and sown within 24h of being treated.

Site and design of experiment

The onions, cv. Rijnsburger, were sown in plots 1m long in freshly tilled sandy-loam soil at Wellesbourne on 17th April 1973. Fifty seeds were placed 2cm apart, in a 1m-long, V-shaped wooden trough which was then tilted to transfer the seeds to a 2cm-deep groove pressed into the fine tilth. The seed was covered with soil which was then gently consolidated.

To allow for both random and systematic variations in fertility, seed-bed quality and infestation levels, 6 replicates were used for each treatment, the blocks being arranged in a 2 x 3 layout. The experiment involved a total of 51 rows 2m long with the rows orientated north-south, spaced 30cm apart, and each comprising 2 contiguous 1m plots in adjacent blocks. Each block consisted of 17 1m-long plots, with the outermost and every fourth row sown with untreated seed to form a systematic grid from which the infestation pattern could be determined.

Field cage

The cage used was 15.2 x 3.0 x 1.8m high, constructed of Tygan mesh (10 mesh/cm) supported on a tubular steel frame (Finch, 1969). The skirt of the cage was buried in the soil when the cage was erected over the onions on 8th May.

Flies

The onion flies were reared as described by Soni (1971). After emergence, they were kept in small cages at 18 ± 2°C, 65 ± 5% r.h., with a 16h-photoperiod of 2700 lx and fed on a diet of 10% sucrose, Yeastrel and brewers' yeast, as used for cabbage root flies (Finch & Coaker, 1969). The flies were kept from 1 to 14 days until sufficient had been accumulated to release and during this time they were denied oviposition sites. Most of the 555 females were therefore gravid when released throughout the field cage, with 572 males, at 16.15h on 25th May. The onions were then about 5cm high (1-2 true leaves). At the time of release into the cage, the weather was warm and sunny and remained so for a further day before becoming overcast with heavy showers. Within 10 days, seedlings were dying and a substantial infestation was evident by 13th June.

Assessments

To determine whether the seed dressings were phytotoxic, the numbers of seedlings germinated/m row (plot) were counted on 11th May (N_1) and again on 25th May (N_2). Very few seeds germinated after this date and N_2 therefore also represented the total germination and a measure of seed viability.

It was not possible to determine the efficiency of the treatments directly by counting numbers of eggs laid or larvae present in the roots. However, it was obvious when the roots were harvested that almost all of the young plants attacked by the first generation of larvae were killed and hence the efficiency was determined indirectly from N_2 and the numbers present on 25th June (N_3), a month after the flies were released into the cage.

The intensity and uniformity of infestation were determined from the numbers of plants present in the untreated plots (N_2, N_3) at each position in the cage.

To determine the overall effectiveness of the treatments, the numbers and total weights of damaged and undamaged plants surviving/plot/m were recorded when the plants were lifted on 31st July (Table 1), before they were fully mature and before attack by the second generation occurred. So few were damaged (Table 1) that only the data for the undamaged plants was used to derive the additional parameters needed to assess the effectiveness of the treatments (Table 2).

Calculations

Only some of the parameters recorded directly (Table 1) are useful in themselves as descriptions of the performances of treatments, and other aspects must be assessed by deriving secondary parameters from the raw data. The derived parameters for the present experiments are shown in Table 2 and are self-explanatory with the exception of the estimate of efficiency, the column headed Protection % (Y). These values were derived by the following formula:

$$\left[1 - \frac{(N_2\text{untr} \times N_2\text{tr}) - (N_2\text{untr} \times N_3\text{tr})}{(N_2\text{untr} \times N_2\text{tr}) - (N_3\text{untr} \times N_2\text{tr})} \right] \times 100\%$$

This formula calculates the difference between the numbers of plants killed on treated and adjacent untreated plots, adjusts for differences in the numbers of seeds germinating (N_2) and expresses the efficiency, Y, as a percentage of the number of untreated plants killed. For example, if 40 seedlings were present in an untreated plot on 25th May (N_2untr) before the flies were introduced, and only 10 remained on 25th June (N_3untr) then 75% of the seedlings in that position in the cage had succumbed and were deemed to have been attacked. If 40 seedlings were also present on an adjacent treated plot on 25th May (N_2tr) and 30 remained on 25th June (N_3tr), then presumably 20 of the 30 attacked seedlings were fully protected and the treatment was therefore 67% efficient. To eliminate the influence of different infestation levels, the average efficiencies were derived from the values of Y calculated independently for the 6 replicates of each treatment.

RESULTS

Table 1 shows the raw data as mean values for the 6 replicates, Table 2 gives the parameters derived from the raw data, and this information has been further summarised in Table 3 by assigning the treatments a rank according to their merits for each characteristic.

Insecticide characteristics

Dieldrin (+ thiram): The dieldrin/thiram seed treatment was not discernibly phytotoxic, these treated seeds being the quickest to germinate, and no other treatment resulted in significantly more seedlings germinating/m row. It protected 84% of the attacked seeds, an efficiency exceeded only by the chlorfenvinphos liquid seed dressing. The dieldrin treatment also yielded the most undamaged bulbs/m, the greatest total weight of onions/m and the largest bulbs of any treatment. It was therefore outstandingly the best treatment, being not measurably phytotoxic, satisfactorily efficient and very effective.

Diazinon: There was a 14% impairment in germination at the higher but not at the lower rate (Table 2), confirming the incipient phytotoxicity of diazinon. It was 80 to 84% efficient in protecting attacked plants, comparable with dieldrin, but there were fewer and smaller bulbs, especially at the higher dose.

Pirimiphos-ethyl: This formulation was not significantly phytotoxic at the doses used (Tables 1 and 2) ($P = 0.01$), and it was 74 to 82% efficient. It was less effective than dieldrin in terms of yield, but comparable with diazinon.

Isophenphos: This compound significantly reduced seed viability at the higher dose used ($P = 0.05$) and slowed germination at both doses ($P = 0.01$). It was thus incipiently phytotoxic, although 68-82% efficient in protecting the young plants. At the lower dose the yield was apparently inferior to those obtained with the same dose of diazinon and pirimiphos-ethyl.

Chlorfenvinphos: This compound was very phytotoxic at both doses used, delaying and reducing germination so that, despite its very high efficiency (77 to 97%) in protecting the seedlings, its overall effectiveness was negative in that the yield was 36 to 50% less on average than from the untreated crop.

Mecarphon: The germination of seed treated with this compound was delayed, especially at the higher dose, which also enhanced onion fly damage (21%) and decreased yield compared with that from untreated seed. This compound was therefore ineffective.

Observations on the method

The onions: An average of 78% of untreated seed germinated and there were no significant differences ($P = 0.05$) in germination between the blocks of the experiment, indicating the uniformity of the seed bed conditions. Subsequently the plants grew satisfactorily within the cage and there were no obvious interactions between the treated and untreated single-row plots.

The infestation: Shortly after the flies were put into the cage, distinct trends in the numbers of dying plants were apparent in the untreated plots. Most plants died in the north-east corner of the cage and a marked trend occurred along the northern half of the long axis. The block arrangement enabled the systematic trends in the infestation pattern to be determined. The infestation was adequate for assessing insecticide performance and analyses of variance of the raw and of some derived data revealed acceptable standard errors, permitting satisfactory comparisons of all types of performance characteristics.

Calculations: The calculation of effects on rate of germination was adequate to reveal any major effects. The indirect assessment of efficiency was based on the assumptions that all attacked, unprotected young plants die and that the same percentage of plants would be attacked irrespective of plant density. Neither assumption is entirely correct but the errors introduced in making these assumptions were apparently unimportant in this experiment.

The expression of results as a % change (increase or decrease) relative to the untreated samples is a satisfactory way to compare relative performances. If the calculation is done on a "within-block" basis before means are taken, the influence of differing infestation levels is largely eliminated. However, the % change values must be treated with caution. They are very sensitive to the absolute values for the untreated plots and can lead to exaggerated relative improvements of several hundred % if the untreated values are small. Negative values in Table 2 refer to instances when treated seed was worse than untreated seed. Such adverse effects of treatments usually indicate low efficiency against the pest, coupled with a broad-spectrum of insecticidal activity against other sometimes beneficial, soil-inhabiting organisms, and/or chronic phytotoxicity.

DISCUSSION

The choice of chemicals provided a cross-section of likely effects. The results confirmed the pre-eminence of dieldrin for protecting onion seed against onion fly attack. Its advantages showed up in all of the parameters and its value was reflected by its overall ranking. In contrast, chlorfenvinphos was efficient in controlling the pest at a dose of 20g a.i./kg seed but it was so phytotoxic that its overall effectiveness was apparently worse than with no treatment. The incipient phytotoxicity of diazinon was confirmed, as was its efficiency to protect the onions against attack by the first generation of the pest (e.g. Howitt, 1958). Pirimiphos-ethyl was not significantly phytotoxic, although the seed was sown in a sandy loam soil and was therefore most vulnerable. Its safety in this respect countered its slightly lower efficiency against the pest.

The treatments with diazinon, isophenphos, pirimiphos-ethyl and especially dieldrin (plus thiram), which were the most effective in preventing plant losses, resulted in substantially improved yields as compared with the yield from untreated seed. The bulbs were either of similar size or only slightly smaller than those obtained from the untreated seed although they were growing at much higher plant densities. However, because of acute phytotoxicity and lack of protection respectively, the chlorfenvinphos and mecarphon treatments did not permit any better plant survival than occurred with the untreated seed and yet they produced much smaller bulbs. This suggests that they may have had chronic adverse effects on the growth of the onions.

The method used to evaluate the performance of the insecticides within the field cage has wider potential application. Natural infestations on uncovered plants are usually not uniform and a systematic grid of untreated plots is probably preferable to the conventional fully randomised layout since the pattern of attack over an experiment can be determined. In this way, localised comparisons of performance can be obtained to indicate more accurately the effects of treatments. To obtain a maximum of suitable information with a minimum expenditure, not only the designs of field trials but also the data collected should be standardised, since similar data are needed if confident judgements are to be made on the overall performance of candidate insecticides. The ability of the ranking test to summarise information from several measured and derived variables appears to be worth further consideration especially since there are statistical analyses for ranking tests. By incorporating the results from field trials at different sites in different years into a summary ranking table, not only the relative merits but also the consistency of individual treatments could be readily discerned. Any tendencies for exceptional behaviour under particular conditions would be apparent and the overall rating of the chemicals could be more readily interpreted than from results presented as raw or simple derived data.

The experimental design achieved all of the initial objectives, providing a maximum of information with a high degree of certainty of obtaining a result at the expense of a minimum of effort.

Acknowledgements

We thank Mrs. C.M. Sanderson for her technical assistance, Dr. D.G. Finlayson for helpful preliminary discussions and also those Agrochemical Companies which supplied the insecticides.

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Table 1

Effects of treatments on the number of onion seeds germinating, the number of plants surviving attack by onion fly larvae and the yields of damaged and undamaged bulbs at harvest: observed values

TREATMENT			PLANT STAND (number/m)			YIELD (31 July)			
						Undamaged		Damaged[a]	
Insecticide	Formulation (a.i.)	Dose (g a.i./kg seed)	Germination 11 May	Germination 25 May	Survival 25 June	Bulbs (No./m)	Weight (g/m)	Bulbs (No./6m)	Weight (g/6m)
Dieldrin	75% s.d. (+ 10% thiram)	35	35	40	38	37	562	1	18
Mecarphon	15% powder	10	16	35	21	20	261	2	17
		20	9	36	18	16	126	0	0
Diazinon	40% w.p.	10	30	38	35	34	473	4	24
		20	28	34*	33	31	425	4	48
Chlorfenvinphos	32.2% liquid s.d.	10	2	22*	20	20	186	0	0
		20	0	15*	17	17	122	2	12
Pirimiphos-ethyl	20% encaps s.d.	10	29	38	35	32	527	10	126
		20	27	36	33	31	444	2	34
Isophenphos	20% w/w s.d.	10	22	37	32	31	479	3	22
		20	17	34*	31	30	451	2	16
Methyl cellulose	1%		33	41	17	16	249	2	12
Untreated			W[b] 31	37	14	11	195	4	62
			C 29	40	20	18	282	7	124
			E 32	40	27	20	335	3	48
S.E.D.				2.2	3.0	58.3			
d. of f.				70	70	70			

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a Totals/treatment = /6 replicates = /6m

b Located in the west (W), centre (C) or east (E) of each block

* Differ significantly from the untreated, $P = 0.05$

Table 2

Values derived to indicate the overall performance of the treatments against onion fly

TREATMENT		PLANTS				UNATTACKED BULBS						
		Rate of germination		Total germination	Protection (Y)	Size: Mean weight	Comparison with untreated plot means					
							Difference			% change		
Insecticide	g a.i./ kg seed	$100N_1/N_2$ [a]	% change [b]	% change [b]	%	g/bulb	No./m	g/m	g/bulb	No./m	g/m	g/bulb
Dieldrin	35	72	14	2	84	15	23	344	-0.3	161	157	-1
Pirimiphos -ethyl	10	63	0	-4	82	17	18	289	-1.8	118	121	-5
Diazinon	10	67	6	-4	80	14	20	248	-2.5	143	110	-13
Diazinon	20	65	3	-14	84	14	17	190	-3.0	121	81	-17
Pirimiphos -ethyl	20	61	-3	-7	74	14	14	193	-0.7	76	77	-3
Isophenphos	20	46**	-27	-14	82	15	16	214	-1.4	105	90	-6
Isophenphos	10	50**	-21	-6	68	16	14	204	-0.9	79	74	-3
Methyl cellulose		67	6	4	-30	16	3.5	41	-3.0	28	20	-10
UNTREATED		63	0	0	0	W 18 C 16 E 17				0	0	0
Mecarphon	10	43*	-32	-11	20	13	3.4	11	-1.4	21	5	-9
Chlorfenvin- phos	20	0**	-100	-62	97	7	1.2	-124	-9.2	8	-50	-51
Chlorfenvin- phos	10	11**	-83	-44	77	9	1.1	-106	-6.7	6	-36	-39
Mecarphon	20	30**	-52	-8	-21	8	-0.1	-135	-10.0	-1	-52	-59

a, S.E.D. 4.9 for 70 d. of f.
b, from untreated

* Differ significantly from the untreated, $P = 0.05$
** Differ significantly from the untreated, $P = 0.01$

Table 3

Ranking of performance of treatments for each parameter based on the "% changes" (Table 2) attributable to the treatments

TREATMENT		EFFICIENCY	EFFECTIVENESS						
			Phytotoxicity		Yield of unattacked bulbs				
Insecticide	g a.i./ kg seed	Protection of plants	Rate of germination	Total germination	Number	Weight	Size	$\sum$ Ranks	Ranked overall performance
Dieldrin	35	2.5	1	2	1	1	2	9.5	1
Pirimiphos-ethyl	10	4.5	5.5	4.5	4	2	5	25.5	2
Diazinon	10	6	2.5	4.5	2	3	9	27	3
Diazinon	20	2.5	4	10.5	3	5	10	35	4
Pirimiphos-ethyl	20	8	7	7	7	6	3	38	5
Isophenphos	20	4.5	9	10.5	5	4	6	39	6
Isophenphos	10	9	8	6	6	7	4	40	7
Methyl cellulose		13	2.5	1	8	8	8	40.5	8
UNTREATED		11	5.5	3	12	10	1	42.5	9
Mecarphon	10	10	10	9	9	9	7	54	10
Chlorfenvinphos	20	1	13	13	10	12	12	61	11
Chlorfenvinphos	10	7	12	12	11	11	11	64	12
Mecarphon	20	12	11	8	13	13	13	70	13

Proceedings 7th British Insecticide and Fungicide Conference (1973)

CHLORPYRIFOS - A BROAD SPECTRUM SOIL INSECTICIDE

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Summary   Chlorpyrifos is a broad spectrum organophosphorous insecticide of moderate to low toxicity to mammals. Extensive trials have been carried out in Europe for the control of soil insect pests using rates between 0.5 kg a.i./ha and 4 kg a.i./ha depending on the pest, formulation and method of application. Good control has been obtained of the following: Wireworms (*Agriotes* spp.), cutworms (*Agrotis* spp., *Euxoa* spp.), pigmy mangold beetle (*Atomaria linearis*), cabbage root fly (*Erioischia brassicae*), leatherjackets (*Tipula* spp.), wheat bulb fly (*Leptohylemyia coarctata*), onion fly (*Delia antiqua*), bean seed fly (*Delia platura*), and symphylids (*Scutigerella immaculata*). Phytotoxicity is not a problem when the chemical is applied using correct dosages and methods of application. Crop residues are well within accepted tolerance limits.

INTRODUCTION

Chlorpyrifos is a broad sprectrum organophosphorous insecticide, introduced in 1965 by the Dow Chemical Company and tested under the code "DOWCO"* 179 and trade name "DURSBAN"*. It has been found to be effective for the control of a wide range of insect and other arthropod pests of plants, animals and man (Kenega *et al* 1965). Developed initially in the U.S.A. for the control of cockroaches, turf pests and mosquitoes, chlorpyrifos was introduced into Europe in 1967 and has since been tested against a wide range of insect pests on many crops (Komblas, 1970).

This paper reports some of the trials carried out for the control of soil insects.

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* (Trademarks of the Dow Chemical Company).

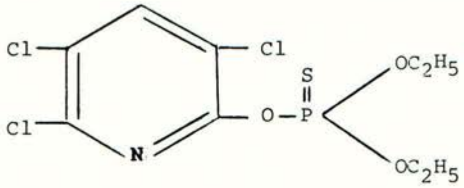
METHODS AND MATERIALS

The formulations tested were a 48% w/v emulsifiable concentrate; 25% w/w wettable powder; 5% w/w and 10% w/w granules; a 40% w/w seed dressing and baits.

PHYSICAL AND CHEMICAL PROPERTIES

Chemical Name : O,O - diethyl O - (3,5,6 - trichloro - 2 pyridyl) phosphorothioate.

Chemical Structure:



Molecular Formula : $C_9 H_{11} C_{13} NO_3 PS$

Molecular Weight : 350.6

Appearance : White granular crystalline solid

Odour : Mild mercaptan

Melting point : 41.5° - 43.5° C

Vapour Pressure : 1.87×10^{-5} mm. Hg. at 25° C
8.15×10^{-5} mm. Hg. at 35° C

Solubility : Soluble in most organic solvents. Extremely low solubility in water.

Stability : Stable under normal storage conditions. Rate of hydrolysis increases with increasing temperature, pH, moisture and ultra violet light.

TOXICITY

Chlorpyrifos has a moderate toxicity to mammals by acute oral administration. The LD_{50} for male rats is 135 mg/kg and for rabbits is 1,000 to 2,000 mg/kg. The acute dermal LD_{50} for rabbits, when chlorpyrifos is applied in solvent solutions, is about 2,000 mg/kg. In two year feeding studies the no effect level for chlorpyrifos, as judged by cholinesterase depression, was established at 0.3 mg/kg/day for dogs and 0.1 mg/kg/day for rats.

King (1969) reported very little or no effect on earthworms (Lumbricus terrestris) at rates up to 4.4 kg a.i./ha. Chlorpyrifos is toxic to fish and shrimps.

MODE OF ACTION

Chlorpyrifos is active by contact, stomach and vapour action. There is no systemic activity in either plants or animals. Residual activity is much shorter when applied to aerial parts of the plants than when applied as a soil treatment.

In soil chlorpyrifos is strongly adsorbed by soil particles and organic matter as evidenced by only slight loss due to volatilisation and high resistance to leaching.

The hydrolyis and oxidation half-life in soil or water with a high organic content is about 90 days (Smith 1966, Schaffer, et al, 1970).

RESULTS

Cutworms (Agrotis spp. Euxoa spp.)

In Canada extensive laboratory and field tests showed that chlorpyrifos was very active against Euxoa messoria, Agrotis ipsilon and Peridroma saucia. (Harris and Svec, 1968, 1971). Even the 4th and 5th instar larvae were controlled effectively.

In Holland, during 1970, four trials were carried out with chlorpyrifos, as a 2% bait at 1.2 kg a.i./ha, compared with standard parathion at same rate (Table 1.). The crop was lettuce and baits were broadcast 7 - 10 days before planting and raked into the soil immediately before planting.

Table 1.

Holland - Control of Cutworms in Glasshouses

	Number of damaged plants				Number of live cutworms caught			
Trial Number	1	2	3	4	1	2	3	4
Control	6	81	102	40	4	75	22	-
Parathion	3	11	11	19	2	7	3	-
Chlorpyrifos	10	6	8	22	7	4	3	-

Data from Italy (Zambelli et al, 1971) showed that chlorpyrifos applied as both a spray and granules performed well against cutworm on maize (Table 2). Granules were broadcast pre-emergence and the spray was applied at crop emergence.

Table 2

Italy - Control of Cutworm on Maize

Chemical	Rate kg a.i./ha	Application Method	Mean No. of Plants Attacked	
Chlorfenvinphos	2	Granule	622	d
Parathion	4	Granule	427	bc
Diazinon	2.5	Granule	516	cd
Chlorpyrifos	1.5	Granule	256	abc
Chlorpyrifos	2	Granule	330	ab
Chlorpyrifos	2.5	Granule	218	ab
Chlorpyrifos	1.02	Spray (e.c.)	100	a
Control	-	-	667	d

Duncans' multiple range test: figures suffixed by the same letter are not significantly different at the 5% level. (Duncan 1955).

Registration for commercial use has been obtained in Holland, Greece and Turkey.

Wheat Bulb Fly (Leptohylemyia coarctata)

Maskell (1970) reported that chlorpyrifos, applied as a seed dressing to wheat, gave a good control of wheat bulb fly larvae but was phytotoxic.

In small scale screening trials (Maskell,F.E., A.D.A.S.; Personal Communication), chlorpyrifos applied as foliar spray to wheat at 0.67 kg a.i./ha was better than standard dimethoate at the same rate. No phytotoxicity was observed. Further replicated trials will be carried out to confirm this result.

Wireworms (Agriotes spp.)

Griffiths et al (1969) reported that in laboratory pot tests chlorpyrifos, at 4 ppm. and 8 ppm. mixed into the soil, controlled wireworms 103 days after treatment and was one of the more active compounds tested.

In field trials chlorpyrifos, fonofos and dimethoate at 3.36 kg a.i./ha all controlled wireworms but were not as effective as aldrin, though Griffiths suggested that this may have been due to the method of application.

In Italy, (Zambelli et al 1971), and France, from 1970 to 1972, several trials were carried out with granular formulation of chlorpyrifos for the control of wireworm (Tables 3 and 4). Both broadcast and row treatments were made and all the chemicals incorporated.

Table 3.

Summary of French Trials-Control of Wireworm in Maize and Spring Wheat

Chemical	Broadcast kg a.i./ha	% Emergence Maize	% Emergence Spring Wheat	Row g a.i./ha	% Emergence Maize
Chlorpyrifos	3.0	115(5)	144(3)	300	130(5)
Fonofos	4.0		141(3)	300-350	131(5)
Parathion	5.0	118(5)			
Control	-	100(5)	100(3)	-	100(5)

Figures in brackets represent number of trials. Assessed two months after sowing.

Table 4.

Italy - Control of Wireworm in Potatoes.

Chemical	Broadcast kg a.i./ha	% Control wireworm Trial 1.	Row kg a.i./ha	% Control wireworm Trial 2.	Trial 3.
Chlorpyrifos	2.5	82.7 a	1.25	73.3 a	87.1 a
Heptachlor			1.0	42.2 ab	
Parathion	4.0	37.0 bc	2.0		67.6 ab
Parathion			2.5	66.7 a	
Phorate			2.0	26.7 abc	
Diazinon	2.5	24.7 bc	1.25		87.1 a
Gamma-BHC			1.85		48.4 ab
Chlorfenvinphos	2.0	64.2 ab	1.0		45.2 ab
Control		0.0 c		0.0 bc	0.0 bc

Duncan's multiple range test: figures suffixed by the same letter are not significantly different at the 5% level.

Chemicals were applied as granules and incorporated.

The effective rate, when chlorpyrifos is applied as a broadcast treatment, may vary from 2.5 to 4 kg a.i./ha depending on soil conditions and the persistence required.

Registration for commercial use has been obtained in France and Greece.

Pigmy Mangold Beetle (*Atomaria linearis*)

Many trials have been carried out in Germany, the U.K. and Eire for the control of pigmy beetle on sugar beet. Feeney (1971) reported that chlorpyrifos was effective against pigmy beetle when applied as a soil surface band spray. All insecticides were applied as sprays or granules to the closed furrow after the seed was sown (Table 5). Results expressed as average number of plants per half plot (19.2 m).

Table 5.

Eire - Control of Pigmy Mangold Beetle in Sugar Beet

Chemical	Ciba 10015		Chlorpyrifos		Fenthion		Phorate	
Rate kg a.i./ha	0.55	1.1	0.55	1.1	0.55	1.1	11	22
Treatments	255.5	261.7	286.0	278.7	254.5	256.5	290.5	280.5
Control	212.2	211.5	224.5	244.5	238.0	256.0	261.0	249.5
Difference	43.2	50.2	61.5	34.2	16.5	0.5	29.5	31.0

S.E. for all plots ± 20.9

Chlorpyrifos at 0.55 kg a.i./ha gave a 27% increase in plant stand. At 1.1 kg a.i./ha one abnormal single replicate gave a greater plant count in the control than in the treatment. Dunning and Winder (1971, 1972) reported variable results with chlorpyrifos when the insecticide was placed in the furrow close to the seed. In one trial applying the chemical in this way caused phytotoxicity.

In Germany, one years commercial use has shown that 0.96 kg a.i./ha applied as an overall surface spray post-sowing of sugar beet is an effective alternative to gamma-BHC.

Leatherjackets (*Tipula* spp.)

In the U.K. in 1973 J.M. Rayner (A.D.A.S.- Personal Communication) reported that chlorpyrifos, applied as a soil surface spray at 720 g a.i./ha in 225 litres water, gave 92% control of leatherjackets.

Table 6.

Control of Leatherjackets in Spring Barley

Block	Leatherjackets/24 cores/plot ($10\ m^2$) I	II	III	IV	Total	Population of Leather-jackets/ac.
Control	13	7	8	11	39	203,000
Chlorpyrifos	1	0	1	1	3	15,000

This is considered to be a high degree of control for this pest (Rayner 1969) and confirms results obtained in previous years.

Cabbage Root Fly (*Erioischia brassicae*)

Unpublished data obtained from trials carried out in the U.K., Holland, France and Italy, indicate that chlorpyrifos shows potential for the control of cabbage root fly.

In 1972 Murdoch (A.D.A.S.;Personal Communication) reported excellent control when chlorpyrifos was used as a 0.1% drench (⅛ pint/ plant) or as a 20 second dip at 0.02% and 0.1% a.i..

Wheatley and Percival (1972) reported that when 10% chlorpyrifos granules were applied as surface or sub-surface bands to summer cauliflowers (spaced at 61 cm x 46 cm) an effective control was obtained, but over a restricted range of doses, the optimum being 1 kg a.i./ha.

Preliminary results from trials carried out by The Boots Company Ltd. in 1973 showed that 5% chlorpyrifos granules, at 4 kg a.i./ha (treated) as a surface band, performed as well as standard 10% chlorfenvinphos granules at the same rate. The chlorpyrifos 10% granules were less effective than the 5% granules.

Commercial registration has been obtained in Holland.

Bean Seed Fly (*Delia platura*)

Trials for the control of bean seed fly with chlorpyrifos were carried out in Holland and France, (Tables 7 and 8).

Table 7.

Holland - Control of Bean Seed Fly with Seed Dressings

Chemical	Application rate (g/a.i./30 kg seed)	Crop Development (0-40 scale)*	% Plants Attacked
Aldrin	14	31.75	35
Fenitrothion	42	34.0	24
Chlorpyrifos	42	36.75	0.6
Control	-	21.0	64

* 0 = Zero Development. 40 = Complete Development.

Table 8.

France - Summary of Trials for Control of Bean Seed Fly

Chemical	Application rate (a.i./ha)	% Healthy Plants	No. of Trials
Chlorpyrifos	2 kg broadcast	180	2
	4 kg broadcast	190	2
	0.4 kg row	126	2
Fonofos	2 kg broadcast	156	2
	3 kg broadcast	172	2
	0.4 kg row	123	2
Control	-	100	4

Chemicals applied as granules and incorporated.
(0.4 kg a.i./ha row treatment = 1 g 5% granules/m of row).

Registration for commercial use has been obtained in France.

Onion Fly (*Delia antiqua*)

Missonnier and Brunel (1972) reported trials carried out in France with chlorpyrifos 5% granules broadcast and incorporated into the soil for the control of onion fly (Table 9).

Table 9.

Summary of Two Trials for the Control of Onion Fly

Chemical	Rate kg a.i/ha	Weight of Bulbs per plot		No. of Bulbs per plot	
		Trial 1.	Trial 2.	Trial 1.	Trial 2.
Chlorpyrifos	4	7.43	3.75	85.2	128.4
Trichloronate	2.5	5.06	3.4	77.5	135.0
Fonofos	2	5.5	3.95	73.5	126.8
Control	-	1.44	0.85	21.2	55.6
Least significant difference between any two treatments	1%		1.27		34.96
	5%	3.46		39.3	

In 1973 M. Saynor (A.D.A.S.; Personal Communication) reported that preliminary results from three trials showed chlorpyrifos was effective as a seed dressing on onions at 10 g a.i./kg seed. From the three trials the mean numbers of damaged plants per plot (1 row x 2.75 m) were chlorpyrifos. 0.6 and control 12.0. Assessments were made 10 to 17 weeks after sowing.

Symphylids (Scutigerella immaculata)

In France, Berjon and Anglade (1973) reported that in laboratory tests chlorpyrifos gave a good control of symphylids. Huraux (1973) reported that a row application of 300 g a.i./ha of chlorpyrifos 5% granules provided a similar control of symphylids to 500 g a.i./ha of phorate or 1000 g a.i./ha of parathion applied in the same way. All granules were incorporated.

Further trials are in progress using chlorpyrifos at 500 g a.i./ha (0.6 g of 5% granules per meter of row) to determine whether efficacy can be further improved.

DISCUSSION

The extensive trials carried out in Europe, covering a wide range of crops and insect pests, show that chlorpyrifos is a highly effective broad spectrum soil insecticide.

A summary of the major pests controlled in trials during commercial usage in Europe is given in Table 10. Effective rates vary between 0.4 kg a.i. and 4 kg a.i/ha depending on the degree of pest susceptibility, formulation and method of application. If the pest is a sub-surface feeder incorporation may be necessary to obtain effective control. Incorporated granules have the longest residual efficacy and surface sprays the shortest. Soil conditions also have some influence, the chemical being most effective in moist, light soils with a low organic content.

Residue work has shown that, at the effective rates of use, residues are well within accepted tolerance levels (W.H.O. 1973). As the chemical is not systemic residues cannot be detected in untreated aerial parts of the plant.

Table 10.

Summary of European Trials with Chlorpyrifos

Pest	Crops	Effective Rate (kg a.i./ha)		Formulation
		Row	Broadcast	
Wireworm	Sugar beet, Maize, Wheat	0.5	2.5-3	Granule.
	Potatoes.	1.25	2.5-4	Granule.
Cutworm	Vegetables, Maize, Sugar beet, Potatoes, Tobacco.	0.4-0.5	1.2	Granule.
			0.5-1.0	Bait, Spray.
Pigmy Beetle	Sugar beet.	0.5	1	
Cabbage Root Fly	Brassicas	1	4	Granule, Spray.
Leatherjackets	Cereals		0.7	Granule, Spray.
Wheat Bulb Fly	Wheat		0.6	Spray.
Onion Fly	Onion		4	Granule.
Bean Seed Fly	Beans, Maize	0.4	4	Granule, Spray.
Symphylids	Maize, Vegetables.	0.5	4	Granule.

Chlorpyrifos is generally non-phytotoxic when used at the correct dosage and method of application. Some crops (e.g. melon, cucumber and tomato) are sensitive to the chemical, especially when in the seedling stage. Others, such as sugar beet and cereals in northern European countries,are affected only if the chemical is applied as a seed dressing or in close proximity to the seed.

Commercial use in several countries has shown chlorpyrifos to be a reliable, safe and broad spectrum insecticide both for soil and foliar applications and it is rapidly becoming established in European agriculture.

Acknowledgements

The authors wish to thank The Boots Company Ltd. for providing data from their trials.

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Proceedings 7th British Insecticide and Fungicide Conference (1973)

SOIL TREATMENTS WITH CHLORMEPHOS, A NEW INSECTICIDE

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Summary Between 1959 and 1973, field trials were carried out to demonstrate the value of chlormephos as an alternative soil insecticide to the organochlorine compounds. Excellent results were obtained, in particular against wireworms (Agriotes sp.), millipedes (Blaniulus guttulatus) and symphilids (Scutigerella immaculata) which are the main pests of maize and sugar beet. Moreover, chlormephos was also effective against root flies and other soil insects such as white grubs (Melolontha melolontha) and mole crickets (Gryllotalpa gryllotalpa). Phytotoxicity on the crop was also examined and the product appears to be tolerated for the applications envisaged. Chlormephos has also been successfully tested in many other countries. Depending upon the pest and crop, the application rates vary between 2 to 4 kg a.i. for broadcast applications and 0.3 to 0.6 kg a.i./ha for band treatments. This work has thus enabled us to perfect a marketable 5% granular formulation under the name DOTAN®.

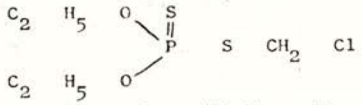
INTRODUCTION

Chlormephos is a new active ingredient discovered by Murphy Chemical Ltd.

Its favourable characteristics led us to examine it, in particular with a view to finding a replacement for the organochlorine soil insecticides.

I. Nature: presentation of the active ingredient

a) Chemical properties - It consists of:
S-chloromethyl - O.O diethyl phosphorothiolothionate



known as chlormephos with the reference number MC 2188.

It has a molecular weight of 234.6.

b) Physical properties:
The technical product is a yellow brown liquid with a density of 1.26 (at 20°C). The vapour pressure of chlormephos is approximately 5.7×10^{-2} mm Hg at 30°C. Its solubility in water is low: 60 ppm.

c) Formulation:
Chlormephos is presented in the form of a semolina-type granule, containing 5% a.i. This formulation is known under the trade name DOTAN®.

II. Toxicity

a) Summary: Acute Toxicity: The LD50 for oral toxicity in rats is approximately

12 mg/kg with the technical product; percutaneous LD50 being approximately 27 mg/kg (for the pure product).

Semi-chronic Toxicity (3 months): maximum acceptable daily dosage (the highest concentration with no toxic effects is 6.7 ppm) is 0.39 mg/kg for rats. A daily dosage of 50 ppm added to the food did not lead to mortality or toxic symptoms in dogs (beagle) after 3 months.

Toxicity in fish: for *Rosbora heteromorpha*, LC50 is 1.5 mg/l after unlimited exposure.

Toxicity in birds: Oral LD50 on chickens is 130 mg/kg (product diluted in ethyl acetate). LD50 on quail is 260 mg/kg.

Inhalation Toxicity: LD50 (1h) for rats is 3.8 mg of chlormephos/l.of air.

Cutaneous Toxicity with 5% granules (5G): LD50 for male rats is 6300 mg/kg.

Chlormephos 5G has no irritant action on the eyes (test on rabbits).

b) Antidotes: Antidote to be used for treatment of suspected poisoning is PAM or, more effectively, PAM in association with atropine sulphate.

c) Precautions for use: Application of granules limits toxicity risks; however, all the standard recommendations should be observed for use, handling and storage of toxic products employed in agriculture.

III. Residues

a) In the soil: From the various studies undertaken, the residues, at normal rates of dosage were found to be approximately 0.02 ppm 100 days after application.

b) In the plants: A negligible residue based on the safety factor of 1/2000 of the no-effect level would be 0.014 ppm. The residues found in maize, potatoes and sugar beet are well below this value for a normal rate of application.

The level does not exceed 0.003 ppm in the cob and 0.014 ppm on the stalk and leaves when the plant has reached 3/4 ripeness.

IV. Method of Action

Chlormephos acts principally by contact and by vapour. It has no systemic activity.

This paper presents results obtained, in particular, on maize and sugar beet.

METHOD AND MATERIALS

Over the last four years a number of trials with chlormephos 5G have been made.

The trials were principally concerned with determining the performance of soil treatments against wireworm larvae (*Agriotes* sp.), millipedes (*Blaniulus* sp.) and symphilids (*Scutigerella immaculata*), the main soil pests attacking the crops concerned. Different rates of a.i./ha were compared when applied as broadcast treatments (followed by surface incorporation) and band applications to the seed-bed on different soil types and pest population levels.

Crop safety aspects were also studied.

Chlormephos has also been tested throughout the world with results confirming and supplementing those obtained in France. The experiments were laid out as randomized blocks (four to six replicates) or Latin square designs on crops which were clearly attacked by pests.

Other trials to determine the behaviour of the insecticide and practical applications were also made.

RESULTS

A. On Maize

1. Trials with wireworm larvae

a) The results obtained from several trials are shown in Table I.

Table 1

Number of maize plants after treatment with insecticide

Products	Kg a.i. per ha Broadcast treatment	Band treatment	Trial Reference Numbers Pa 40/71	Pa 47/71	Gr 72/72	Gr 70/72	Db 47/73	Db 53/73	Db 57/73	Gr 93/73	Gr 97/73	Gr 98/73
Chlormephos 5G	2		152	124								
Chlormephos 5G	3		166	138								
Chlormephos 5G	4		177	148								
Chlormephos 5G		0.3125	168	140	118	125	105	255	126	168	314	253
Chlormephos 5G		0.5					113	267	133	167	307	280
Fonofos 5G	4											
Fonofos 5G		0.3125	158	130	119	122	110	252	127	164	297	233
Lindane W.P.90	1.5		180		120	112						
Aldrin Dust 5%	4			144								
Control			100	100	100	100	100	100	100	100	100	100
Intensity of infestation			severe	severe	moderate	average	weak	very severe	average	severe	very severe	very severe
L.S.D. at 0.05			20	20	13	10			15	17	36	39
coefficient of variation %			8.8	8	8.3	6.4			8.8	8.9	10	14

The maize plants were well advanced plants at sampling ensuring a normal yield.

Chlormephos 5G was effective against wireworms at the rate of 0.3125 kg a.i. (i.e. 6.25 kg/ha or 0.5 g of granules/m of soil with approximately 80 cm between the rows) applied as a band treatment to the seed-bed.

b) Table 2 shows results from trials in which there was a moderate infestation of wireworms.

The results thus obtained confirm the satisfactory performance of chlormephos.

Table 2

Maize infested by a moderate attack of wireworm

Products	kg a.i./ha		% of stalks infested		
	Broadcast Treatment	Band Treatment	G 16/71	L 62/71	Gr 70/72
Chlormephos 5G	2		2.73	1.4	
-	3		1.34	0.5	
-	4		1.57	0	
-		0.3125	1.91	1	1
Fonofos 5G	4				
-		0.3125	2.01	0	5
Lindane W.P.90	1.5		0.46	3	0.8
Untreated Control			13.81	15	18.3

c) Table 3 shows results obtained in a trial (Gr 58/72) in which the infestation by wireworms was very severe.

Under these conditions, which only occur rarely, chlormephos 5G performed very well when applied as a band treatment to the seed-bed at a rate of 0.5 g/m of row (i.e. 0.3 kg a.i./ha).

Table 3

Maize infested by a severe attack of wireworm

Products	Assessment on 19/6 (1 month after sowing)		Percentages of Stalks	Assessment on 17/7 (2 months after sowing)		
	Healthy	Affected	Dead or Absent	Healthy	Affected	Dead or Absent
Chlormephos 5G 0.31 kg a.i./ha in band treatment	86.3	9.1	4.6	80.8	7.4	11.8
Fonofos 5G 0.31 kg a.i./ha broadcast application	76.7	13	10.3	67.7	12.3	20
Lindane W.P.90 1.5 kg a.i. broadcast application	93	5.7	1.3	94.4	1.9	3.7
Untreated control	34.8	21.7	43.5	18.2	14.4	67.4

d) The results shown in Table 4 (reference Gr 70/72) illustrate the effect that a severe wireworm infestation can have on the crop yield and on the height of the plants.

Table 4

Maize infested with a severe attack of wireworm

Products	(3 months after sowing)		(6 months after sowing)
	Average ht. of plants	No. of plants	No. of ears c.f. 100 for control
Chlormephos 5G	1.24 m	166	207
Fonofos 5G	1.16 m	151	195
Lindane W.P.90	1.27 m	154	199
Control	1.03 m	94	100
L.S.D.at 0.05			40
Coefficient of variation %			17

Rates of application shown in Table 3.

e) Other Results: Chlormephos has also been tested outside France. Table 5 shows a summary of results from trials carried out in the U.K., Belgium, Holland, Italy, Germany, Switzerland, and Denmark against wireworms on maize.

Table 5

Control of wireworm on maize

Products	kg a.i./ha		Percentage of plants in comparison with the untreated control											
	Broadcast treatment	Band treatment	1	2	3	4	5	6	7	8	9	10	11	12
Chlormephos 5G (1)	2		108	107	110	154	128	125	152	-	-	192	315	237
	3		113	105	107	141	149	140	166	-	-	195	330	287
	4		-	-	112	141	137	150	178	-	-	192	317	209
Chlormephos 5G		0.31 (2)	-	-	-	-	-	142	168	125	113	-	-	-
		0.375 (3)	-	-	-	-	-	-	-	135	109	-	-	-
Fonofos 5G (1)	3		-	-	-	-	-	-	-	-	-	-	-	259
	4		111	106	107	146	116						275	
" "		0.31 (2)	-	-	-	-	-	131	159	112	103			
Aldrin	2.5	-	-	-	-	-	-	-	-	-	-	171	-	211
	4	-	-	-	-	-	-	145	-	-	-	-	-	-
Heptachlor	1.6	-	-	-	-	-	-	-	-	-	-	-	250	-
Lindane	1.5	-	-	-	-	-	-	-	180	-	-	-	-	-
Control			100	100	100	100	100	100	100	100	100	100	100	100

(1) sometimes 10G
(2) 0.5 g granule/linear m
(3) 0.6 g " " "

2. Trials on symphilids

a) Results from the Laboratory Tests: Mr. Anglade, of INRA, Bordeaux, showed that chlormephos used at 310 ppm gave a 98% mortality as a contact toxicant.

The LC50s were for:

parathion (which was the standard)	:	308 ppm
chlormephos	:	28 ppm
fonofos	:	27 ppm

Chlormephos and fonofos are the most effective materials which have been tested to date.

b) Results from field trials: Table 6 shows the results obtained from a trial (reference Pa 43/71) on maize severely infested by symphilids.

Table 6

Control of symphilids on maize

Products	kg a.i./ha	Number of Plants Affected	Healthy	Total
Chlormephos 5G	0.3 (1)	8	150	158
Parathion methyl	1	44	99	143
Control		28	73	101

(1) 0.5 g of Gr/linear m applied to a band to the seed-bed.

B. On Sugar Beet

Field experimentation on sugar beet is difficult because of the irregularity of the infestation and the difficulty in carrying out assessments (for myriapods in particular).

The value of chlormephos as a replacement for heptachlor was demonstrated.

Table 7 shows results obtained from several trials.

It can be seen that the rate of 0.3 to 0.4 kg a.i./ha (i.e. 6 to 8 kg of chlormephos 5G) applied as a band to the seed-bed, (i.e. 0.27 to 0.36 g of granules/row spaced at intervals of 45 cm) gave a good protection against wireworms and millipedes.

Table 7

Control of wireworms and millipedes on sugar beet

Products Trial Reference	kg a.i./ha	Percentage of plants in comparison with untreated control Millipedes Dominant + Wireworms L 47/71	F 1/71	F 2/71	+ Wireworms Ra 57/73	+ Centipedes RR 77/73	Wireworms Dominant Ra 66/73	Ra 83/73	Ra 84/73	Ra 95/73
Chlormephos 5G	3(1)	132								
Chlormephos 5G	4	127								
Heptachlor 5G	4	109								
Chlormephos 5G	0.3(2)		172	178						
Chlormephos 5G	0.35				127					
Chlormephos 5G	0.4		185	185		128	268	232	596	158
Chlormephos 5G	0.5						255	196	619	137
Chlormephos 5G	0.6					143			637	141
Chlormephos 5G	0.7				127					
Chlormephos 5G	0.8					140				
Heptachlor 5G	0.4		156	185						
Parathion 5G	0.5				114					
Parathion 5G	0.6					119	212	166	328	122
Control		100	100	100	100	100	100	100	100	100
Intensity of infestation		average	severe	severe	average	average	very severe	very severe	extremely severe	severe
L.S.D. at 0.05					13	14	39	33	140	26
Coefficient of variation					10.4	8.1	12.7	13.7	26	

(1) Broadcast treatment

(2) Band treatment

C. Other Results

a) Against Wireworms: In addition to the results obtained from trials on maize and sugar beet crops, summarised above, other experiments were carried out both in France and abroad on crops of wheat, barley, potatoes, strawberries, beans and tomatoes. They confirmed the effectiveness of chlormephos against wireworms.

b) Against Costelytra zealandica: Results obtained in New Zealand indicated the effectiveness of chlormephos against this grub, which is an economically important pasture pest.

Materials were incorporated into the soil at different concentrations and re-infested two weeks later.

Table 8

Material	Rate ppm	Soil treatment August 1970		Topical Treatment 0.6 ml/plant 7.8.70	
		% Control		Rate mg/ml	% Control
		After 2 weeks	After 4 weeks		
Chlormephos	10	100	100	10	100
	2	100	100	1	87
	0.4	92	100	0.1	13
Diazinon	10	100	100	10	100
	2	100	100	1	48
	0.4	29	83	0.1	9

c) Against Mole Cricket: A trial on tomato, paprika and fennel showed that chlormephos behaves well against this pest.

Table 9

Products	kg a.i./ha	% infestation
Chlormephos 5G	2.5	0
Control		32

d) Against Grubs: The results of work carried out on Melolontha melolontha larvae by Mr. Bourdin of INRA at Versailles are given below.

The soil was treated and divided into two parts. One was used immediately in order to check the effectiveness of the product. The other was submitted to outside climatic conditions for 35 days and then checked for persistency of action of the materials.

Table 10

Products	kg a.i./ ha	Mortality Percentage Immediate Effectiveness (contamination at T) T + 5	 T + 26	 Persistency of Action (contamination at T + 35) C + 12	 C + 33
Chlormephos 5G	5	25	100	33	50
	10	42	100	83	92
Parathion 5G	5	25	100	0	0
	10	8	100	8	8
Control		0	0	0	0

Chlormephos is seen to be effective against larvae of grubs.

e) Against Root Flies attacking Vegetables: Field trials have been carried out in France or abroad against:

Cabbage root fly (*Hylemia brassicae*)
Onion fly (*Hylemia antiqua*)
Seed corn maggot (*Phorbia platura*)
Carrot rust fly (*Psila rosae*)
Crane flies (*Tipula* sp.)
March flies (*Bibio* sp.)

They show that chlormephos has a degree of effectiveness against soil Diptera, but varies according to the conditions. Better results were obtained, for example, against onion fly and against seed corn maggot than against cabbage root fly; at rates of 3 to 4 kg a.i./ha as a broadcast, band treatment being also possible.

D. Phytotoxicity

During the trials conducted on various crops and, in particular, on maize and sugar beet, normal application rates of chlormephos did not produce phytotoxicity. Phytotoxicity trials, using double rate confirmed the tolerance of crops treated. Under certain conditions, phytotoxicity did occur from band treatments in which the concentration of active ingredient around the seed was high; care is therefore necessary to avoid over-dosage when treating narrow bands.

Potatoes were badly affected, and chlormephos is not recommended for use on this crop in France.

CONCLUSIONS

Extensive experimentation carried out on maize emphasizes the extremely good performance of chlormephos against wireworms.

The average rate of use for broadcast treatment is 3 kg a.i./ha (2 kg provides a satisfactory protection and 4 kg is necessary in certain cases).

The results also show that band treatment to the seed-bed provides a satisfactory and convenient method of protection of the crop. Chlormephos is therefore recommended at 0.5 g of a 5% granular formulation/m of row on maize crops averaging 80 cm between the rows; this is equivalent to 6 - 7 kg of granules/ha, (0.3 to 0.35 kg a.i./ha).

On sugar beet pests chlormephos, applied as a broadcast treatment, performed well at 3 kg a.i./ha compared with heptachlor. In this case, band applications to the seed-bed should contain 8 kg/ha of 5G (i.e. 0.4 kg a.i./ha), on beet crops planted in rows 45 cm apart.

NOTES

Proceedings 7th British Insecticide and Fungicide Conference (1973)

FIELD TESTS OF INSECTICIDES FOR THE CONTROL OF BEAN SEED FLY (DELIA CILICRURA)

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Summary In experiments carried out over three seasons, pirimiphos-ethyl, applied as a seed dressing, proved to be a promising material to replace dieldrin for the control of bean seed fly (Delia cilicrura) in dwarf beans (Phaseolus vulgaris). Where this chemical was used in combination with thiram or drazoxolon crop emergence was excellent, but seed treatment with combinations of chlorpyrifos, dimethoate or mercarphon, with thiram, did not result in such satisfactory plant stands. In more limited work, diazinon and triazophos seed treatments proved extremely promising.

Of five materials tested in granular formulations and applied in the furrow with the seed, the most effective were oxamyl and triazophos.

INTRODUCTION

Bean seed fly (Delia cilicrura) is an important pest of dwarf and runner beans (Phaseolus vulgaris & P. coccineus). Unprotected seed can be attacked by the larvae in the soil, thus making it more susceptible to fungal attack and consequently emergence is often reduced; those attacked seedlings which do emerge are weakened by damage to the inside of the stem. Under adverse conditions many of these seedlings do not survive. Seed used in the U.K. has in the past been dressed with a mixture of dieldrin and thiram or dieldrin and captan, but in recent years this treatment was not always satisfactory.

In 1971 quite severe damage was recorded on the Thornhaugh trial ground, in spite of treatment with the standard dieldrin and thiram dressing. Under cool wet conditions, in which emergence was slow, the pest seriously reduced plant stands. Gostick & Baker (1966) reported finding dieldrin-resistant bean seed fly (Delia spp.) while carrying out sampling for cabbage root fly (Erioischia brassicae) resistance. It therefore seemed necessary to find alternative materials; preliminary investigations were started at PGRO in 1971, and more extensive work was carried out in 1972 and 73. The problem has been made more acute by the difficulty in obtaining dieldrin seed dressings in this country at the present time. Seed dressings, soil-applied granules and sprays applied to the surface after drilling have been tested in this work, although it was realised that a seed dressing offers the most convenient and cheapest form of protection. The work reported was undertaken with dwarf beans, although the results will also have relevance to the runner bean crop.

METHOD AND MATERIALS

In 1971 and 72 the experiments were carried out on the Thornhaugh trial ground, while in 1973 additional sites were used in commercial bean crops. The seed was sown by hand in single row plots, in rows 6 ft long in 1971 and 12 ft long in 1972 and 1973; in the latter two years 100 seeds per row were sown. Three or four replications were employed in a randomised block layout. The experiments were assessed when plant emergence was complete, this being approximately five to six weeks after sowing and in 1971 twenty plants were removed and the stems split open to enable internal damage to be recorded. In 1972 and 1973 plant emergence was also recorded and all the plants were examined.

The seed treatments were applied as slurries, with the exception of the dieldrin and thiram and the BHC and captan treatments which were applied as dry powder dressings. Thiram was applied as a slurry to the seed used in the control plots, those treatments where a fungicide did not feature as part of the seed dressing, and on the plots treated with granules. The granular treatments were applied along the open drill before the seed was covered with soil, while the spray treatment, used in 1971, was applied at a volume of 50 gal/ac to the soil surface in a band approx. 9-10 in wide over the row, after the seed had been covered.

Seed dressing formulations of dimethoate, diazinon and triazophos were not available and liquid or wettable powder formulations were used. In the case of the liquid formulations of diazinon and triazophos the seed remained very 'sticky' and would be unsuitable for commercial use in farm drills.

The granular treatments were applied at 10 or 20 lb of product per acre, along the rows, which were 18 in apart. Dimethoate and triazophos were formulated as 5% granules while oxamyl, chlorfenvinphos and pirimiphos-ethyl were 10% granules. All rates are presented in terms of active ingredient.

RESULTS

The crop emergence and percentage of damaged plants are presented in tables 1-3. In all years quite a high level of attack was recorded on the control plots, with the exception of site 3 in 1973, where the level was too low to enable damage to be accurately assessed. Crop emergence, at this site, in the absence of the pest, serves as a useful indication of possible phytotoxic effects of the treatments on germination.

Table 1
1971 results

Treatment	Rate	Application	% damaged plants
Pirimiphos-ethyl + thiram	3570 + 1670 ppm	Seed treatment	2.5
gamma BHC + captan	3350 + 446 ppm	" "	1.3
Dieldrin + thiram	3350 + 446 ppm	" "	1.3
Pirimiphos-ethyl†	1.0 lb a.i./ac	Granules	10.0
Chlorfenvinphos †	1.0 lb a.i./ac	"	5.0
Pirimiphos-ethyl†	0.8 lb a.i./ac	Surface spray	6.3
Thiram (Control)	1500 ppm	Seed treatment	20.0

† Seed treated with thiram at 1500 ppm

In 1971 all the seed dressing treatments gave good control, although gamma BHC and captan reduced the vigour of the seedlings slightly. The granule and surface spray treatments were less effective, although no deleterious effects on the crop were recorded.

Table 2
1972 results

Treatment	Rate	Application	Percentage Emerged plants	Percentage Damaged plants
Pirimiphos-ethyl + drazoxolon	730 + 270 ppm	Seed treatment	74	4.0
Pirimiphos-ethyl + drazoxolon	1460 + 540 ppm	" "	70	6.6
Chlorpyrifos + thiram	935 + 1500 ppm	" "	57	5.3
Chlorpyrifos + thiram	1870 + 1500 ppm	" "	50	5.3
Dimethoate + thiram	450 + 1500 ppm	" "	58	8.0
Dimethoate + thiram	900 + 1500 ppm	" "	50	2.6
gamma BHC + captan	1675 + 223 ppm	" "	44	5.3
Dieldrin + thiram	1675 + 223 ppm	" "	62	1.3
Dimethoate †	0.5 lb a.i./ac	Granules	75	6.6
Dimethoate †	1.0 lb a.i./ac	"	63	6.6
Triazophos †	0.5 lb a.i./ac	"	72	6.6
Triazophos †	1.0 lb a.i./ac	"	70	4.0
Oxamyl †	1.0 lb a.i./ac	"	80	4.0
Oxamyl †	2.0 lb a.i./ac	"	79	2.6
Chlorfenvinphos †	1.0 lb a.i./ac	"	75	4.0
Chlorfenvinphos †	2.0 lb a.i./ac	"	67	9.3
Thiram (Control)	1500 ppm	Seed treatment	56	16.0
L.S.D. (P = 0.05)			12	N.S.
C of V			15.5%	6.2%

† Seed treated with thiram at 1500 ppm.

In 1972 the mixture of pirimiphos-ethyl and drazoxolon proved the most successful seed treatment giving excellent crop emergence, and good control of damage. While the control of plant damage was not as good as that given by the standard dieldrin and thiram treatment, the rather poor crop emergence with the latter may indicate that more seedlings were severely damaged and failed to emerge than with pirimiphos-ethyl. Useful reduction of plant damage was achieved with chlorpyrifos and thiram, dimethoate and thiram and with gamma BHC and captan, but all adversely affected crop emergence, the gamma BHC in particular giving very poor plant stands. The granular treatments generally gave good crop emergence, although in all cases the emergence on the high rates was below that on the low rates. They also provided useful control of plant damage, with oxamyl and triazophos the most effective.

Crop emergence was excellent at all sites in 1973 and the only treatments which reduced emergence were the high rate of diazinon (liquid formulation) at all sites, mercarphon with lower emergence at sites 1 and 3 and dieldrin and thiram at site 3. Pirimiphos-ethyl with drazoxolon at the low rate, gave a similar reduction of damaged plants to dieldrin and captan and was more effective at the high rate. Diazinon liquid formulation gave almost complete control at both sites and was slightly more effective than the wettable powder formulation, while triazophos also gave excellent control. Mercarphon was inconsistent, giving no control at site 1, but control at site 2. No explanation can be given for this anomaly, apart from differences in seedbed conditions and soil types, since the same seed was used at both sites. At Thornhaugh (site 1) the soil was a silty loam with a pH of 8.1 and 4.5% organic matter and the seed was sown into a very dry seedbed, although rain fell within seven days. At Old Leake (site 2) the soil was a peaty loam, but here the seedbed was moist when the seed was sown and some rain fell after sowing. The dimethoate granules also gave inconsistent results and the rather dry seedbed may also have affected their performance at site 1.

Table 3
1973 results

Treatment	Rate	Application	Percentage emerged plants			Percentage damaged plants			
			Site 1	Site 2	Site 3	Site 1	Log. transf.	Site 2	Log. transf.
Pirimiphos-ethyl + drazoxolon	1000 + 350 ppm	Seed treatment	97	97	93	1.8	0.85	1.5	0.86
Pirimiphos-ethyl + drazoxolon	2000 + 700 ppm	" "	97	97	97	1.0	0.52	0.0	0.00
Diazinon (liq.) + thiram	1000 + 1500 ppm	" "	98	100	96	0.3	0.17	0.3	0.17
Diazinon (liq.) + thiram	2000 + 1500 ppm	" "	91	96	95	0.3	0.17	0.3	0.17
Diazinon (w.p.) + thiram	1000 + 1500 ppm	" "	97	99	97	2.5	1.21	0.3	0.17
Diazinon (w.p.) + thiram	2000 + 1500 ppm	" "	98	100	96	2.3	1.07	0.0	0.00
Triazophos + thiram	1000 + 1500 ppm	" "	99	99	94	0.3	0.17	0.0	0.00
Triazophos + thiram	2000 + 1500 ppm	" "	94	100	95	0.3	0.17	0.5	0.27
Mercarphon + thiram	100 + 1500 ppm	" "	94	98	93	9.5	1.90	0.5	0.27
Mercarphon + thiram	200 + 1500 ppm	" "	94	100	92	12.3	2.52	1.3	0.58
Dieldrin + thiram	1675 + 223 ppm	" "	98	98	90	1.5	0.69	1.8	0.72
Dimethoate ≠	0.5 or 1.0 lb a.i./ac ø	Granules	95	97	97	5.8	1.79	0.3	0.17
Thiram (Control)	1500 ppm	Seed treatment	97	100	97	10.3	2.11	10.5	2.02
L.S.D. (P = 0.05)			N.S.	4	N.S.		0.81		0.87
C of V %			3.9	2.9	4.9		46.9		93.3

≠ Seed treated with thiram at 1500 ppm

ø 0.5 lb a.i./ac at site 2 and 1.0 lb a.i./ac at sites 1 and 3

Taint tests

Produce taken from plots treated with pirimiphos-ethyl in 1972 and 1973 was canned or frozen and no taints were detected in the 1972 samples. The results of samples taken in 1973 are not yet available.

DISCUSSION

Three years data is available on pirimiphos-ethyl, used as a seed treatment either in mixture with thiram or drazoxolon, and it has consistently resulted in high crop emergence and satisfactorily controlled the amount of damaged seedlings. The improved plant emergence with this treatment, compared to the standard dieldrin treatment, recorded in 1972, may have been due either to the better protection of the germinating seed from attack by bean seed fly larvae by the pirimiphos-ethyl or the more effective fungicidal effect of drazoxolon compared to the thiram used in the standard treatment. No adverse effects have been seen on the development of the plants following the use of pirimiphos-ethyl and drazoxolon and the results indicate that this mixture is a promising treatment for bean seed fly control. There has been no indication that dieldrin resistant bean seed flies have been present at any of the sites and the percentage of damaged plants on the dieldrin treated plots has been consistently low, ranging from 1.3 to 1.8%. Even at the Thornhaugh trial ground, where severe damage was recorded on dieldrin-dressed seed in 1971, in later experiments the dieldrin treatment gave excellent control, although seedbed conditions were much more favourable for rapid emergence than in 1971. Damage is likely to be more severe under cold, wet conditions when the seed is exposed to attack for longer periods and where even slight damage may allow diseases to become established. More information is therefore required to establish the effectiveness of pirimiphos-ethyl on dieldrin-resistant bean seed fly.

The information available on the mixture of gamma BHC and captan suggests that while it appears to be almost as effective as dieldrin in preventing damage to the seedlings, it is likely to reduce plant stands. There could also be some risk of taint from gamma BHC and this material does not appear to be a satisfactory seed-dressing for dwarf beans.

Chlorpyrifos and dimethoate do not appear to be promising seed treatments, neither giving very good crop emergence, but diazinon and triazophos, used in 1973, gave excellent results and further work with these materials would be justified, particularly if seed dressing formulations become available. Even when used as a wettable powder slurry, diazinon was effective. These results confirm those of Judge & Natti (1971), who found that a mixture of diazinon and thiram was the most effective treatment in experiments to control seed-corn maggot (Hylemya platura) in lima beans, and Gould (1965) and Coghill (1965) who both found diazinon effective against bean seed fly.

The inconsistent results with mercarphon suggest that its activity may be markedly affected by soil conditions and thus it is unlikely to be a satisfactory treatment for general use.

The granule treatments appear capable of giving reasonable control of bean seed fly, although they have seldom proved to be as effective as the best seed-dressings. In almost all instances the 10 lb per acre rate of the materials proved as effective in preventing damage as the 20 lb rate and gave slightly better crop emergence. There was little difference between the performance of the various granules, although oxamyl and triazophos appeared to be slightly more effective than the others. The practical problems involved in accurately applying granules to a crop such as dwarf beans, the relatively high cost and the need for specialised equipment make the use of granules unlikely, unless satisfactory seed treatments cannot be developed.

Only limited information is available for spray treatments applied to the soil after sowing and such a treatment seems unlikely to be as effective as seed-dressing.

To ensure consistently high yields it is essential that the optimum plant population is achieved and poor stands due to bean seed fly can have serious effects on profitability. Dwarf bean seed is costly and it is imperative that seed dressings are available which effectively control insect and fungal damage and thus allow the minimum amount of seed to be used.

Acknowledgements

The authors wish to thank the farmers who provided sites, the chemical companies who supplied materials, the Statistical Department, Rothamsted Experimenta Experimental Station for analysis of data and the Campden Food Preservation Research Association for taint tests.

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Proceedings 7th British Insecticide and Fungicide Conference (1973)

AN APPRAISAL OF SYSTEMIC FUNGICIDES FOR THE CONTROL OF CLUBROOT OF BRASSICAE

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Summary In studies on the fungicidal control of clubroot in direct-drilled brassicae, pot tests of soil mixes showed the EBC- and MBC-forming benzimidazoles to be the most effective systemic compounds with low phytotoxicity. In subsequent soil-incorporation field tests, increasing doses of from 8-32 kg a.i./ha of benomyl and thiophanate-methyl gave increasing control of the disease, the latter compound being somewhat more effective. However, neither gave sufficient control to justify the expense of the treatment.

In field tests of pelleted seeds, benomyl at up to 200g a.i./100g seed gave no control of the disease, although at 70g a.i./100g in pots there was a slight lowering of infection.

Growth of plants in sterile soil containing benomyl conferred little protection on them when they were transplanted to infested soil.

Current indications are that the fungicides tested are likely to be effective only when used as transplant dips, for which purpose 0.1% benomyl was as effective as 10% calomel.

Sommaire Pendant les investigations de la lutte de l'hernie de chou par les fongicides, dans les choux sémés directement, des essais poursuivies sur des mélanges de sol en pots, ont demontrés que les benzimidazoles EBC- et MBC-formants sont les composés systemiques les plus efficaces de phytotoxicité peu élevé. Les investigations subsequents sur les essais de champ dans lequels les composés ont été incorporés dans le sol, aux doses allant de 8 à 32kg m.a./ha de bénomyl et de thiophanate-méthyl, ont fait preuve que les dégâts de la maladie ont étés reduits seuriblement de mésure que la dose augmentant. Le thiophanate-méthyl s'est prouvé un peu efficace que le bénomyl. Cependant, ni l'un ni l'autre ne donnait pas au éffet suffisant à justifier la dépeuse de traitement.

Des essais en champ oú l'on a employé des sémis en boulette, le bénomyl aux doses au niveau de 200g m.a./100g sémis s'est montré inefficace contre la maladie, bien qu'au niveau de 70g/100g sémis en pots on a obtenu une réduction assez petit de l'infection.

Les plantes soulevées en sol stérile en lequel le bénomyl avait été incorporé n'ont pas manifesté d'avanatage après avoir été transplantées dans le sol infecté.

Dans l'état actuel des choses, il est probable que les fongicides employées dans ces essais seront utilisées effectivement seulement pour le trempage des racines avant transplantation: pour cet emploi le bénomyl à 0.1% se montre assez efficace que le calomel à 100%.

INTRODUCTION

Although clubroot in direct-drilled brassicae has been virtually uncontrollable by fungicidal treatments, these have sometimes proved effective on transplants by root dipping, by treating the soil ball (e.g. with pot-raised cauliflowers), or by dry application to the planting hole. Calomel (and to a lesser extent quintozene and ziram) has been predominantly used in these ways and some success has also derived from its application as a post-planting drench.

The addition of appreciable quantities of mercurial compounds to field soil is undesirable and is prohibited in some countries. Reports that certain systemic fungicides would control clubroot indicated that they might prove reliable alternatives.

Soil incorporation tests in pots, using either cabbages or cauliflowers, were made by Jacobsen and Williams (1969; 1970), Finlayson and Campbell (1971) and Murtomaa and Uoti (1972), all of whom obtained promising control with benomyl. Murtomaa and Uoti also obtained some evidence that benomyl might be of value in the field when drenched onto the soil surface around transplants. Van Assche and Vanachter (1970) and Vanachter, Raemaekers and Van Assche (1971) reduced infection on cauliflowers by incorporating benomyl, thiophanate or thiophanate-methyl in the soil of the pot-ball.

Recent studies at Wellesbourne have extended the appraisal of systemic fungicides for clubroot control. This report summarises the findings to date, together with some of those by other workers, and attempts to assess the potential of the compounds against clubroot.

METHODS AND MATERIALS

Pot tests - the methods used were as previously described (Buczacki, 1973). Chemicals were mixed in a sterilised peat/soil mixture of pH 5.0 - 5.1, to which had been added Plasmodiophora brassicae resting spores (at the rate of 10^6/g dry soil) extracted from infected roots of rape (Williams, 1966; Buczacki, 1973). In each test there were four replicate pots of each chemical at several dose rates sown with ten seeds of cabbage cv. Golden Acre. Dose rates up to 1000 mg a.i./kg dry soil (or less if the fungicides were phytotoxic) were tested and calomel at 50 and 250 mg a.i./kg seed was always included as a standard treatment. There were ten control pots of infested untreated soil. Percentage infection and severity of clubbing were assessed after 42 days.

Tests of seed pelleting - technical grade benomyl was pelleted on to cabbage seed by shaking the seed alternately with the fungicide and with drops of 1% methyl cellulose. The seed was graded by weight and used in pot and field tests.

Field tests of incorporated fungicides - chemicals were incorporated by hand-raking to 10cm depth in infested field soil, in which the seeds were then sown.

Plants were assessed for percentage infection, disease severity and head weight 5 months after sowing.

Treatment of transplants*- bundles of 40-50 drawn plants of cauliflower cv. Barrier Reef were swirled for 1-2 min in suspensions of 0.1% benomyl or 10% mercurous chloride in 1% methyl cellulose or in methyl cellulose alone, planted out within 20 min and each plant watered-in with 0.5 l of water. Other plants were drenched after planting with 0.5 l of water containing 0.05% benomyl. Wilting was recorded after 6 weeks and percentage of marketable heads and clubroot severity after 18 weeks.

EXPERIMENTAL

Pot tests - results with nineteen chemicals are given in Table 1. Only those at 50 and 250 mg a.i./kg are given as these are the rates at which the control given by benomyl and calomel (the two hitherto most effective chemicals) can be detected. The data are means of percentage infected plants and clubroot severity on them in two fully replicated experiments.

The four benzimidazole compounds benomyl, BAS3460F, NF35 and thiophanate-methyl together with Hoe 6052, triarimol and Hoe 2873 were the most effective in controlling the disease. However, Hoe 6052 stunted plants at 250mg a.i./kg while triarimol did so at 500mg a.i./kg (not shown in Table 1). In a further test, thiophanate-methyl gave total control at 25mg a.i./kg.

Effect on clubroot of pelleting seed with benomyl - doses of 8 and 70g a.i./100g seed were tested in artificially infested soil in pots and doses of 40, 70 and 200g a.i./100g seed in a field test. The pot test was performed similarly to the fungicide tests described above while the field test made in 1972 on heavily infested ground at the Welsh College of Horticulture, Flintshire, comprised four randomised plots of each treatment with twelve control plots. Each plot was sown with cabbage cv. Golden Acre, subsequently thinned to give 25 plants per plot and assessed for clubroot 5 months after sowing (Table 2).

In the pot test the 70g a.i./100g dose reduced the number of infected plants but none of the treatments had any effect in the field.

Field test of incorporated fungicides - benomyl and thiophanate-methyl together with calomel were tested at doses of 8, 16 and 32kg/ha on an infested site at Scrane End, Lincolnshire, in 1972. The experiment comprised four randomised plots of each treatment and twelve untreated control plots. Results are shown in Table 3.

The two highest doses of thiophanate-methyl significantly lowered percentage infection. Disease severity was also lowered by these treatments although not significantly so. The high head-weight figure for 8kg/ha of thiophanate-methyl was not significant.

Pre-treatment of plants with benomyl - plants were raised in pots in sterile soil containing 0, 250, 500 or 1000 mg a.i./kg benomyl and transplanted after 4 weeks into infested soil (10^6 spores/g). Roots were carefully washed before transplanting and the plants were assessed for clubroot 6 weeks later (Table 4).

Although the pre-treatment with all doses of benomyl resulted in a significant decrease in disease severity, there was no comparable difference in percentage infection.

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* This experiment was made by Mr R.J. Cook, ADAS, Wye, Kent, who has kindly given permission for a description to be included in this paper.

Table 1

Pot tests of systemic fungicides

Chemical	Formulation	50 mg a.i./kg		250 mg a.i./kg	
		% infected plants	Clubroot severity[1]	% infected plants	Clubroot severity[1]
Benomyl	50% w.p.	100	3.3	0**	-
BAS 3460F	50% w.p.	95	3.2	0**	-
NF 35	50% w.p.	8**	2.3*	0**	-
Thiophanate-methyl	50% w.p.	0**	-	0**	-
NF 48	95% tech.	84	2.5	60*	2.2*
Thiabendazole	60% w.p.	67*	3.0	69	3.0
Tridemorph	75% e.c.	24**	1.3**	36**	1.2**
Dodemorph	40% e.c.	26**	1.3**	10**	2.0**
Carboxin	75% w.p.	14**	1.2**	-[3]	-[3]
Oxycarboxin	75% w.p.	32**	1.5**	-[3]	-[3]
BAS 3271F	50% w.p.	61*	1.2**	0[2]**	-[2]
BAS 3170F	50% w.p.	94	3.3	-[3]	-[3]
Hoe 6052	50% w.p.	6**	2.0*	3[2]**	1.0[2]**
Hoe 2873	30% e.c.	13**	1.3**	3**	2.0**
Triarimol	4% w.p.	9**	2.7	0**	-
Dimethirimol	12.5% e.c.	87	1.9**	84	1.3**
Ethirimol	50% e.c.	34**	1.7**	17**	1.8**
Triforine	20% e.c.	75	2.4*	3**	1.0**
A-2151	50% w.p.	81	1.7**	44**	1.1**
Calomel	4% dust	42**	1.7**	0**	-
Untreated control		98	3.0	98	3.0

* significantly different from control (P = 0.05)
** significantly different from control (P = 0.01)

[1] max. 5; on infected plants only. [2] plants stunted. [3] plants killed

N.B. Manufacturer's code numbers used for chemicals with no accepted common name as follows:

BAS 3460F = methyl benzimidazol-2-yl-carbamate; NF 35 = 1,2-di-(3-ethoxycarbonyl-2-thioureido) benzene; NF 48 = 2-(3-methoxycarbonyl-2-thioureido) aniline; BAS 3271F = N-cyclohexyl-2,5-dimethyl-furan-3-carboxamide; BAS 3170F = 2-iodine-benzanilide; Hoe 6052 = 2-methyl-5,6-dihydro-4-H pyran-3-carboxylic acid anilide; Hoe 2873 = 2-(O-O-diethylthione phosphoryl)-5-methyl-6-carbethoxy-pyrazolo(1.5.a) pyrimidine; A-2151 = 4-tertiary butyl-7-decylamino-3,4,5,6-tetrahydro-2 H-azepine-chlorohydrate.

Table 2

Pot and field tests of seed pelleted with benomyl

Test	Dose (g a.i./100g seed)	% emergence	% infection	Clubroot severity (max.5)
Field	200	38*	87	2.6
	70	51	90	2.7
	40	56	94	2.3
	Nil	51	96	2.9
Pot	70	56	60*	3.4
	8	77	87	3.2
	Nil	87	89	3.7

* significantly different from control (P = 0.05)

Table 3

Effects of soil-incorporated benomyl, thiophanate-methyl and calomel on clubroot and crop yield

Treatment	Dose (kg/ha)	% infection	Clubroot severity (max.5)	Head weight (g)
Benomyl	8	100	2.7	614
Benomyl	16	79	2.7	545
Benomyl	32	63	1.6	538
Thiophanate-methyl	8	84	2.0	711
Thiophanate-methyl	16	46**	1.8	505
Thiophanate-methyl	32	46**	1.5	549
Calomel	8	94	2.5	709
Calomel	16	84	2.1	641
Calomel	32	72	2.0	510
Control		83	2.3	581

** significantly different from control (P = 0.01) - there were no other significant differences at P = 0.05

Table 4

Effect on clubroot development of pretreating cabbage plants with benomyl

Benomyl content of pretreatment soil (mg a.i./kg)	Disease recorded 6 weeks after transplanting	
	% infected plants	clubroot severity (max.5)
0	100	3.4
250	91	2.5*
500	99	2.5*
1000	97	2.6*

* significantly different from control ($P = 0.05$)

Transplant treatments - four randomised plots each of 80 plants of each treatment and four control plots were planted on an infested site at Preston, Kent, in 1972. Results are given in Table 5.

Table 5

Effect on clubroot and crop yield of dipping or drenching cauliflower transplants

Treatment	% wilting after 6 weeks	% marketable heads at harvest	Clubroot severity (max.5) at harvest
0.1% benomyl dip	2	51	2.4
0.05% benomyl drench	1	48	1.8
1% methyl cellulose dip	21	29	3.9
10% calomel dip	2	43	1.3
Control	26	34	4.2

The benomyl drench and calomel dip were similarly effective in decreasing clubroot severity and increasing crop yield. The benomyl dip, however, while having less effect on the disease, resulted in the highest yield.

DISCUSSION

The systemic fungicides giving the best control of clubroot and low phytotoxicity were those members of the benzimidazole group that break down to the fungitoxic principles methyl benzimidazol-2-yl-carbamate (MBC) or ethyl benzimidazol-2-yl-carbamate (EBC). The pyrimidine compound Hoe 2873 was the only other chemical to combine effective control with absence of phytotoxicity. Although more tests have been made of the effect of benomyl, it is now apparent that thiophanate-methyl may be superior to it. It was originally hoped that useful control in direct-sown crops could have been achieved at economically practicable rates but this was not so when the fungicides were incorporated uniformly over a whole site. More effective control might be achieved with higher dose rates but the high cost would necessitate confinement of the compound to the drill or to a narrow band. Such treatments are under test but even if effective, they seem unlikely to be economically feasible.

The alternative fungicidal treatment for the direct-drilled crop, that of applying the chemical to the seed, was of no value in controlling the disease. Further tests showed that if the weight of benomyl on the seed was increased much above 200g a.i./100g seed, the emergence fell to unacceptably low levels.

Although pretreatment with benomyl conferred slight protection against cabbage clubroot, its effects were too slight to warrant the use of the chemical in seed beds as a protection for drawn plants. Its usefulness to the transplanted crop would therefore be limited to dip treatments and the promising results reported herein generally support those of other unpublished tests in this country. The benomyl dip treatment cost £1.25/ha and was at least as good as the 10% calomel treatment costing £30/ha. The value of methyl cellulose or other materials to aid fungicidal effectiveness is as yet uncertain and we are studying this aspect further. The fact that the drench was as effective as the dip is of interest but its cost at £125/ha renders it economically unjustifiable.

The economics of controlling a disease of comparatively low value crops, such as most brassicas, will always limit the choice of treatment. The present studies indicate that unless a chemical with truly spectacular effectiveness against clubroot becomes available, the prospects of fungicidal control of the disease in direct-drilled crops seem remote. For treatment of transplants, however, the systemic fungicides offer considerable promise as substitutes for calomel.

Acknowledgements

I am grateful to the many chemical companies who supplied materials for evaluation, and to Mr R. J. Cook for making his unpublished findings available to me. I wish also to thank the Principal and staff of the Welsh College of Horticulture, Mr B. Woodward of Scrane End, Lincs., and ADAS officers for their helpful co-operation. I am grateful to Miss S. E. Cadd for technical assistance and also, for help with field experiments, to Mrs J. G. Ockendon and Miss P. S. Clare.

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Proceedings 7th British Insecticide and Fungicide Conference (1973)

RECENT STUDIES ON THE FUNGICIDAL CONTROL OF WHITE ROT DISEASE OF SALAD ONIONS

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Summary Two experiments on the control of white rot disease of salad onions were conducted during 1972-73, on artificially infected sites, to test fungicides applied as seed coatings. Benomyl, thiophanate-methyl, 'BAS 3460F', dicloran and calomel reduced white rot whereas thiabendazole and drazoxolon were ineffective. Benomyl and thiophanate-methyl gave good control in summer and winter crops whereas calomel and dicloran were effective only in the summer crop.

Résumé Deux essais de moyens de lutte contre la pourriture blanche des petits oignons étaient appliqués pendant 1972-73 sur parcelles infestées artificielles, pour examiner les fongicides appliqués à l'enrobage des semences. Les fongicides, Bénomyl, thiophanate-methyl, BAS 3460F dicloran et calomel ont reduit la pourriture blanche mais le thiabendazole et le drazoxolon étaient sans effet. Le bénomyl et le thiophanate-methyl ont donné les très bon résultats en été et en hiver mais le calomel et le dicloran étaient efficaces en été seulement.

INTRODUCTION

White rot disease is caused by the soil borne fungus Sclerotium cepivorum. Survival is by means of long lived sclerotia (Coley-Smith, 1959) which germinate in the presence of onion roots (Coley-Smith, 1960). The generally accepted means of control of the disease in the salad crop is by coating the seeds with fungicide (Croxall et al, 1953; Fletcher, 1964). Of the commonly used fungicides calomel is expensive and sometimes gives only moderate control (Fletcher, 1964; Fletcher et al, 1971). Dicloran which is much cheaper has been reported to control the disease (Fletcher et al, 1971; Lafon and Bugaret, 1968) but results in Britain have been very variable. The authors have therefore tested some of the newer systemic fungicides. Ryan et al (1971) have already reported good control using benomyl as a seed dressing at rates as low as 62.5g a.i./kg seed.

Salad onions may be sown successionally throughout the summer, later sowings being overwintered and harvested the following spring. As control measures which are effective on the summer crop could not be assumed to be satisfactory for the overwintered crop because of the longer period at risk, tests were conducted on both types of crop.

METHOD AND MATERIALS

Sclerotia harvested from cultures of S. cepivorum, grown on sterilised sugar beet seed, were dried at room temperature, spread on to a field plot at the rate of 70,000 sclerotia per m^2 and raked into the top few inches of soil. Onion seed (cv. White Lisbon) was coated with fungicide in a rotating drum using a 1-2% solution of methyl cellulose as a sticker and dried at room temperature. Treatments are expressed as the wt (g) active ingredient added to 100g seed. Treated seed was drilled by hand at a rate of 1g (untreated seed rate) per metre of row (c. 30kg/ha). The summer experiment was drilled on 19th April, 1972 and harvested on 15th August; the overwintered experiment was drilled on 10th August, 1972 and harvested on 20th April, 1973. Plots contained 18 m of row and treatments were replicated four times in randomized blocks. Plant stand was recorded 2 months after drilling and the incidence of white rot was assessed at regular intervals throughout the experiments. It was apparent that white rot was progressively reducing plant numbers in some treatments to such an extent that its incidence on the surviving plants was an unsatisfactory measure of the effects of the treatments. These were therefore assessed by determining the percentages of the 2-month stands that were still healthy at harvest.

RESULTS

Summer trial 1972 Emergence was highest in the calomel treatment and lowest in the control and dicloran (15g a.i./100g seed) treatments (Table 1); otherwise emergence was not affected by the high rates of the fungicide added. White rot was present seven weeks after drilling but was negligible in the benomyl, thiophanate-methyl, calomel and dicloran (50g a.i./100g seed) treatments. At harvest, calomel treatment gave the highest survival and highest yield. Treatment with benomyl, thiophanate-methyl and dicloran (50g and 15g a.i./100g seed) gave fairly high yields and over 70% survival whereas dicloran at 4g a.i./100g seed gave only 59% survival and in the thiabendazole, drazoxolon and control treatments most of the onions had succumbed to the disease.

Overwintered trial 1972-73 Emergence was lower than in the summer trial; there were no differences between benomyl, thiophanate-methyl, methyl-benzimidazole-carbamate, 'BAS 3460F' (Bavistin), calomel and dicloran (50g a.i./100g seed) treatments but emergence was reduced in the two remaining dicloran treatments and in the control (Table 2). White rot was present nine weeks after drilling but was negligible in all but the control treatment. At harvest, the best control was given by benomyl and 'BAS 3460F' treatments followed by thiophanate-methyl; the highest yields were obtained in the 'BAS 3460F' treatment followed by thiophanate-methyl and benomyl treatments. Reducing the rate of benomyl, thiophanate-methyl and 'BAS 3460F' down to 5g a.i./100g seed did not markedly reduce the control.

Calomel and dicloran treatments were less effective and survival was half that in other treatments.

DISCUSSION

Promising control on these very heavily infested plots was obtained in both trials by benomyl, thiophanate-methyl and 'BAS 3460F' and the satisfactory control obtained with applications as low as 5g a.i./100g seed in the overwintered trial confirms the results obtained by Ryan et al (1971) and indicates the advisability of testing even lower doses, especially of 'BAS 3460F'. At the rate of 5g a.i./100g seed, the cost of the treatment is very much less than that of calomel.

The fact that neither calomel nor dicloran gave as effective control on the overwintered crop as the systemic fungicides suggests that the systemic properties of

Table 1

Effect of fungicidal seed treatment on the incidence of white rot disease

Summer trial 1972 : 4-metre row records

Compound	Rate*	Total no. onions at 7wks (8 June)	% white rot	No. healthy onions remaining at 15wks (2 August)	% survival	yield (kg)
Benomyl	15	527	0.1	387	73.4	2.4
Thiophanate-methyl	15	539	0.2	426	79.0	2.9
Calomel	50	634	0.03	611	96.4	3.9
Dicloran	50	502	0.7	431	85.9	2.9
Dicloran	15	444	2.3	322	72.5	2.1
Dicloran	4	565	6.3	333	58.9	1.7
Thiabendazole	15	470	9.5	81	17.2	0.7
Drazoxolon	25	541	16.1	27	5.0	0.2
Untreated control	-	449	25.5	15	3.3	0.1
L.S.D. (P = 0.05)		70		51		1.3

* g (a.i.) of compound per 100g seed

Table 2

Effect of fungicidal seed treatment on the incidence of white rot disease

Winter trial 1972-73 : 4-metre row records

Compound	Rate*	Total no. onions at 9 wks (2 Oct)	% white rot	No. healthy onions remaining at 36 wks (20 April)	% survival	Yield (kg)
Benomyl	25	384	0	294	76.6	1.4
	15	361	0.2	312	86.4	1.6
	5	354	0	275	77.7	1.4
Thiophanate-methyl	25	461	0.9	279	60.5	1.7
	15	424	2.0	277	65.3	1.7
	5	389	3.4	324	55.0	1.3
'BAS 3460F'	25	461	0.8	377	81.8	2.2
	15	489	0.4	388	79.3	2.2
	5	416	1.1	297	71.4	2.1
Calomel	50	434	0	195	44.9	0.7
Dicloran	50	484	0.2	134	27.7	0.6
	15	299	0.2	120	40.1	0.7
	4	314	1.4	53	16.9	0.2
Untreated control	-	333	17.6	1	0.3	0.01
L.S.D. (P = 0.05)		62		76		0.7

* g (a.i.) of compound per 100g seed

the latter may have rendered their fungicidal effect more persistent.

Compounds of the benzimidazole type have been shown, however, to have hormonal effects as well as controlling other pathogens. Although, therefore, the effects of the systemic compounds on plant survival in the present tests are considered to be related primarily to protection against white rot, their other properties cannot be ignored.

Acknowledgements

Thanks are expressed to Miss P. Clare, Mrs E. Street and J. Ward for technical assistance.

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Proceedings of 7th British Insecticide and Fungicide Conference (1973)

COLLABORATIVE ADAS TRIALS ON THE CONTROL OF WHITE ROT DISEASE OF SALAD ONIONS

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Summary Experiments on the fungicidal control of white rot disease of salad onions were conducted during 1971-73 on naturally infested commercial sites. In 1971, experiments on the summer crop compared calomel and two dicloran formulations. Calomel gave the best but only moderate control; that given by the dicloran treatments was poor. In 1972-73 experiments on the autumn and overwintered crops showed that thiophanate-methyl, BAS 3460F and benomyl reduced the incidence of white rot and resulted in increased yields. Other compounds tested were less effective. In all the experiments, calomel gave the highest emergence.

Résumé Des essais de moyen de la lutte contre la pourriture blanche des petits oignons par des fongicides étaient appliques pendant 1971-73 sur des parcelles commerciales qui étaient infestées naturellement. En 1971 il y avait deux essais sur la culture d'été en comparant calomel avec deux formulations de dicloran. Calomel a donné des meilleurs resultats mais ceux étaient modérés seulement. Il se trouva que les resultats des formulations de dicloran étaient maigres. En 1972-73 deux essais sur la culture d'automne et d'hiver demonstraient que thiophanate-methyl, BAS 3460F et benomyl ont enrayé la maladie et ont augmenté les rendements. Des autres composés n'étaient pas aussi efficaces. Dans tous les essais calomel a donné les meilleures levees.

INTRODUCTION

White rot disease of salad onion, caused by the fungus (Sclerotium cepivorum) is responsible for loss of crop in most seasons, more especially where susceptible crops are grown intensively. In recent seasons severe white rot attacks have been recorded on susceptible crops of salad, pickling, bulb onions and leeks. In some seasons, losses have been serious. At present, commercial control of the disease is afforded by coating the seed with fungicide prior to drilling. Croxall, Sidwell and Jenkins (1953) and Wiggell (1956) demonstrated that the white rot fungus can be effectively controlled by pelleting salad onion seed with technically pure calomel, although in practice this treatment sometimes gives only moderate control of the disease. Commercial growers have adopted the calomel seed treatment

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but have adjusted the amount of calomel applied depending on, the price of calomel, the level of white rot infection in the land to be cropped and the frequency of susceptible crops in the cropping sequence. The price of calomel fluctuates depending on world demand and because of its present high cost the treatment - at recommended rates - is uneconomic on salad onions which are drilled at a high seed rate of 26.5 kg/ha. Also, the undesirable hazards to which operators are exposed when applying calomel and the possible toxic residues of mercury in both soil and plant tissues emphasised the need for a safer, cheaper and effective alternative compound.

Attempts to find alternative materials to calomel have been reported by Keyworth and Bramley (1966). Variable results have been obtained with dicloran, both overseas and in the United Kingdom (Locke, 1965, 1968; Tichelaar, 1966, 1968, 1970; Lafon and Bugaret 1968; Fletcher et al, 1971). Ryan et al, (1971) reported control of white rot with benomyl applied as a seed dressing at low rates.

Experiments reported here, compared the effectiveness against white rot disease of calomel, dicloran and a range of systemic fungicides applied as seed dressings to the summer and overwintered salad onion crop.

METHODS AND MATERIALS

The salad onion cv. White Lisbon was used in all the trials. Fungicides to be tested were coated on to seed using methyl cellulose as a sticker, 13.3 g/l. of water at the rate of 0.25 1./kg of seed. The treated seeds were dried at room temperature. Field experiments in Worcestershire (Pershore) and Essex (Aveley) were machine drilled at the commercial sowing rate of 26.5 kg/ha. Treatments were replicated in randomised blocks, each block contained randomised drills of treated seed with an untreated drill adjacent. The treated and untreated drills ran the whole length of the experimental area. Emergence counts were made 8 weeks after drilling and the incidence of white rot was assessed at regular intervals throughout the life of the crop. Terminal assessments of white rot incidence, total weight and weight of marketable (healthy) crop were made at harvest. Assessments were made on random 1 ft. lengths of drill lifted from every drill in all the blocks. In 1971 pure calomel and dicloran formulations (4% a.i. dust and 50% a.i. w.p.) were compared; in 1971/72 and 1972/73 calomel was compared with either benomyl, thiophanate-methyl, calomel/dicloran, dicloran, benomyl/thiram, thiabendazole and methyl-benzimidazole carbamate (BAS 3460F). Treatments are expressed in the tables as the weight (g) active ingredient added to 100 g seed. Seed in the untreated control treatment received the methyl cellulose sticker.

RESULTS

Summer Trial (Pershore and Aveley 1971) - Tables 1 and 2

Emergence was highest in the calomel treatment and lowest in the untreated control. At each site white rot infection was recorded approximately 12 weeks after sowing. The level of infection at the Aveley site was high and the disease rapidly increased in the 2 to 3 weeks before harvest. Calomel gave the best control but the level of control was only moderate; 33% infection was recorded (Aveley) in this treatment at harvest. The dicloran treatments gave poor control and yield of healthy plants at Aveley were less than 50% of that obtained from the calomel treatment.

Overwintered Trial (Aveley 1971/72) - Table 3

Emergence was highest in the calomel treatment and lowest in the benomyl treatment. At the November assessment the benomyl and thiophanate-methyl treatments showed the lowest incidence of white rot infection. At harvest the thiophanate-methyl treatment gave the lowest number of plants infected and the highest yield of marketable plants, followed by benomyl/thiram and benomyl treatments. Both dicloran treatments gave poor control of the disease, yields of these and the calomel treatment were not significantly ($P=0.01$) better than that given by the untreated control.

Autumn Trial (Pershore 1972) - Table 4

Emergence was again highest in the calomel treatments; emergence in the benomyl and thiophanate-methyl treatments were only slightly better than the untreated control. Successional disease assessments were made on 4 occasions at about fortnightly intervals, the first 8 weeks after sowing when 71.5% infection was recorded in the untreated control. At harvest, 90% infection was recorded in this treatment and 13.9 and 14.6% infection in the thiophanate-methyl and benomyl treatments respectively. Significant ($P=0.01$) yield increases were given by the benomyl and thiophanate-methyl treatments compared with the calomel and untreated control treatments.

Overwintered Trial (Aveley 1972/73) - Table 5

Calomel and untreated control gave the highest emergence. Amongst other treatments, the trend was for emergence to be lowest when the amount of active ingredient applied was highest. Good control of white rot was given by the high rate (25 g a.i./100 g seed) thiophanate-methyl treatment, followed by BAS 3460 F and benomyl, each at the high rate. The high level of control given by these treatments was reflected in the number and weight of healthy plants at harvest. The thiophanate-methyl treatment, for example, gave a 391% increase in weight of healthy plants over that given by the untreated control.

DISCUSSION

The 1971 experiments showed calomel to be more effective than either of the dicloran formulations tested, although calomel gave only moderate control of the disease. Promising control was given by the systemic fungicides especially thiophanate-methyl and BAS 3460 F, best control was generally obtained with the highest rates tested. The effective control of white rot and increase in yield given by these treatments in both the autumn and overwintered crops justifies further work to examine the effects of these compounds when used at lower rates, especially on the overwintered crop. In all the experiments the calomel treatment gave the highest emergence and there was a suggestion that the systemic fungicides lowered emergence. For example, in the 1971-72 Aveley experiment, the emergence given by benomyl was lower than untreated control and in the later experiments, emergence in some of the systemic fungicide treatments was lowest in those which received the highest amount of active ingredient. The possibility of pre-emergence phytotoxicity with some of these treatments, when used at high rates, should not be discounted. Alternatively, seedling losses caused by soil-borne pathogens, may be responsible, against which the systemic fungicides are ineffective. This aspect of the work requires further study.

Acknowledgements

These trials were conducted in collaboration with the National Vegetable Research Station. Thanks are due to Professor W.G. Keyworth and Dr. A. Entwistle for helpful discussion and to Dr. G.H. Freeman for guidance and statistical analyses. Thanks are also expressed to Mr. A.G. Thorpe and Mrs. E.M. McGann for technical assistance and to the commercial growers, on whose land these trials were conducted.

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TABLE 1

Effect of fungicidal seed treatment on the incidence of white rot disease and yield

Summer trial - Pershore 1971

Sown - 2.4.71
Harvested - 19.7.71

Treatment	Rate*	Emergence**	% White Rot*** 2.7.71	% White Rot*** 12.7.71	% White Rot*** 19.7.71	Total Weight (g)	Total Weight Healthy (g)	Total Number	% Number Healthy***
Calomel	50	185	2.7	7.8	15.0	900	787	99	71
Dicloran	4	174	2.1	16.8	27.0	1009	740	87	60
Dicloran w.p.	4	181	4.5	26.1	28.0	884	613	84	58
Control-untreated	-	129	10.7	25.8	28.0	816	553	60	56
L.S.D. (Between treatments)	-	44.03	8.32	14.79	11.56	227.24	197.32	34.37	13.18
L.S.D. (Treatments and Control)	-	35.93	6.79	12.07	9.43	185.43	161.02	28.04	10.76

* g (a.i.) of compound per 100 g seed

** Number seedlings in 5 x 1 ft drill lengths

*** Transformed data

TABLE 2

Effect of fungicidal seed treatment on the incidence of white rot disease and yield

Summer trial - Aveley 1971

Sown - 2.4.71
Harvested - 8.7.71

Treatment	Rate*	Emergence**	% White Rot***		Total Weight (g)	Total Weight Healthy (g)	Total Number	% Number*** Healthy
			29.6.71	8.7.71				
Calomel	50	448	13.8	33.0	1176.8	813.5	303.5	52.0
Dicloran	4	273	39.8	52.1	769.8	342.3	172.5	36.1
Dicloran w.p.	4	327	45.5	52.3	616.2	286.4	157.6	33.9
Control-untreated	-	311	56.4	62.75	511.1	178.0	158.4	24.2
SED min.	-	15.1	3.2	3.4	78.5	69.2	17.5	3.1
SED max.	-	20.0	4.2	4.5	103.8	91.5	23.1	4.1

* g (a.i.) of compound per 100 g seed

** Number seedlings in 10 x 1 ft drill lengths after 8 weeks

*** Transformed data

TABLE 3

Effect of fungicidal seed treatment on the incidence of white rot disease and yield

Overwintered trial - Aveley 1971/72

Sown - 2.9.71
Harvested - 10.5.72

Treatment	Rate*	Emergence**	% White Rot*** Nov. 1971	Number White Rot May 1972	Total Weight (g) May 1972	Weight Marketable (g) May 1972
Calomel	50	210.0	4.5	9.0	185.0	118.0
Dicloran	4	160.3	4.9	23.5	214.0	93.0
Dicloran	10	209.2	2.0	30.8	300.0	140.0
Benomyl	25	121.0	1.9	10.5	432.0	282.0
Benomyl/Thiram	15/15	149.3	2.8	12.8	468.0	311.0
Thiophanate-methyl	25	146.8	1.8	5.0	644.0	462.0
Control-untreated	-	161.9	3.1	15.5	149.0	74.0
L.S.D. (P = 0.05)	-	34.15	3.02	10.72	101.62	80.67
L.S.D. (P = 0.01)	-	46.42	4.11	14.59	138.13	109.65

* g (a.i.) of compound per 100 g seed

** Number seedlings in 5 x 1 ft drill lengths after 8 weeks

*** Transformed data

TABLE 4

Effect of fungicidal seed treatment on the incidence of white rot disease and yield

Autumn trial - Pershore 1972

Sown - 20.7.72
Harvested - 9.11.72

Treatment	Rate*	Emergence**	% White Rot***				Number plants/ft	Weight 100 plants (g)
			28.9.72	12.10.72	26.10.72	9.11.72	9.11.72	9.11.72
Calomel	50	40.4	18.0	32.6	53.4	50.7	29.8	727
Thiophanate-methyl	25	33.7	2.8	7.3	10.9	13.9	34.3	1047
Benomyl	12.5	32.8	1.5	6.6	13.2	14.6	34.8	993
Calomel/Dicloran	6.25/10	39.3	14.9	28.7	62.5	76.5	29.6	644
Control-untreated	-	31.6	71.5	86.6	93.0	90.7	15.4	600
L.S.D. (P = 0.05)	-	4.3	16.3	20.1	13.6	12.2	9.5	136.3
L.S.D. (P = 0.01)	-	5.9	22.6	27.6	18.7	16.8	13.8	187.8

* g (a.i.) of compound per 100 g seed

** Mean number seedlings in 10 x 1 ft drill lengths after 8 weeks

*** Transformed data

TABLE 5

Effect of fungicidal seed treatment on the incidence of white rot disease and yield

Overwintered trial - Aveley 1972/73

Sown - 27.7.72
Harvested - 21.3.73

Treatment	Rate*	Emergence**	% White Rot*** 28.11.72	% White Rot*** 21.3.73	Total Number Plants 21.3.73	Total Number White Rot 21.3.73	Total Number Healthy 21.3.73	Total Weight (kg) Healthy 21.3.73	% Increase over Control
Calomel	50	48.5	19.4	9.7	2152	210	1942	11.41	200.2
Benomyl	25	33.0	8.1	2.7	1902	53	849	16.43	291.1
	12.5	30.0	9.6	10.6	1686	180	1506	12.01	201.3
	6.25	35.7	13.6	8.8	2181	192	1989	14.20	205.2
Thiophanate-methyl	25	35.9	4.5	0.8	2713	23	2690	22.02	391.1
	12.5	39.0	2.5	3.2	2736	90	2646	19.95	354.3
Thiabendazole	25	37.3	16.2	5.3	2121	114	2007	14.01	248.8
	12.5	45.3	17.0	13.0	1838	244	1594	11.15	198.0
BAS 3460F (MBC)	25	31.3	6.2	1.1	1810	20	1790	18.53	329.1
	12.5	33.5	11.6	2.7	2182	60	2122	15.98	283.8
Control-untreated	-	47.2	36.0	37.7	1210	463	747	5.63	100.0

* g (a.i.) of compound per 100 g seed

** Mean number seedlings in 10 x 1 ft drill length after 8 weeks

*** Transformed data

NOTES

Proceedings 7th British Insecticide and Fungicide Conference (1973)

FALLOWING AND FUMIGATION EXPERIMENTS ON THE CONTROL OF NETTLEHEAD AND RELATED VIRUS DISEASES OF HOP

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Summary In a series of field experiments in hop plantations, fallowing and soil fumigation were compared in attempts to control nettlehead and related diseases associated with infection by arabis mosaic virus, which is transmitted by the dagger nematode *Xiphinema diversicaudatum*.

Although several years of bare fallow had little effect on populations of the vector compared to the high mortality caused by injecting soils with a mixture of dichloropropene and dichloropropane (D-D), fallowing was as effective as fumigation in preventing the infection of hops planted after 21 months. In other trials infection was prevented entirely after a 2-year bare fallow or by growing crops of strawberry or rye grass for 3 years.

Possible control measures are discussed, especially for the benefit of growers anxious to replant severely affected sites, with a minimum of delay, using the new high-yielding varieties.

Une série d'essais dans des houblonnières a comparé la mise en jachère avec la fumigation du sol pour lutter contre le nettlehead ("tête d' ortie") et les maladies semblables. Ces maladies proviennent de l'infection par le virus de la mosaïque de l'arabette (arabis mosaic virus) transmis par le nématode *Xiphinema diversicaudatum*.

La mise en jachère pendant plusieurs années a eu peu d'effet sur la population de nématodes par comparaison à l'injection au sol d'un mélange de dichloropropene et de dichloropropane (D-D), qui a entraîné une forte mortalité. Cependant la jachère s'est révélée aussi efficace que la fumigation pour empêcher l'infection par le virus de houblon planté après 21 mois de jachère. Dans d'autres essais l'infection a été empêchée complètement après un traitement comprenant ou une jachère nue pendant deux ans ou la culture de fraisiers ou de ray-grass pendant trois ans.

Les mesures de lutte à employer sont discutées, surtout par rapport aux houblonniers qui veulent replanter le plus rapidement possible leurs houblonnières infestées avec les nouvelles variétés de houblon à haut rendement.

INTRODUCTION

Nettlehead and split leaf blotch diseases of the hop (Humulus lupulus) are caused by widespread and prevalent viruses. Growers have long been advised to plant Ministry-certified 'A plus' stocks of the best available health status (Legg, 1964). However, specific control measures could not be recommended because of the limited information available on the etiology of the diseases and their mode of spread.

The situation changed when nettlehead and severe split leaf blotch diseases and the even more widespread condition known as bare bine were associated with infection by an unusual strain of arabis mosaic virus (Bock, 1966; Thresh and Pitcher, 1971). Growers can now be much more discriminating in selecting sites and planting material. In addition field experiments were started on fallowing and fumigation regimes on severely affected sites. The preliminary results now presented indicate the excellent prospects for decreasing reinfection by fallowing prior to replanting, especially when combined with the use of a nematicide.

MATERIALS AND METHODS

The main fallowing/fumigation experiment was carried out at a site near Headcorn, Kent, where nettlehead has long been prevalent and the dagger nematode Xiphinema diversicaudatum was present at a mean population of 18.5 per 200 ml soil. The area was cleared of hops in March 1968 and divided equally into six main plots. Three were selected at random and treated with D-D in early October 1968 at the rate of 560 l/ha. The fumigant was applied by hand injector gun at a depth of 15 cm after deep ploughing and repeated cultivations.

One fifth of each plot was replanted in late October, 1968 and similar sub-plots were replanted in the four succeeding years. Each of the six-sub-plots consisted of a 5 x 3 array of 15 plants at a regular square spacing of 1.8 m x 1.8 m. The three untreated plots were subdivided and planted in a similar way.

Weed control received particular attention throughout the experiment. A paraquat/simazine regime was used successfully, except in the summer of 1968, when many hop seedlings developed. Initially there was also much regeneration from the hop shoots, runners and other remaining pieces of stem which were dug out or killed by spot applications of aminotriazole.

Soil fumigation with D-D was tried elsewhere in Kent and at the ADAS Rosemaund Experimental Husbandry Farm, Hereford, where split leaf blotch disease was locally severe. In other experiments, still in progress, D-D was applied by one of three types of tractor-drawn machine. These were the Achincruive, Leaper-Ramsay and Egedal injectors, designed originally for treating potato, sugar beet and nursery soils, respectively. The Leaper-Ramsay machine was the easiest to use as the jets were least likely to become blocked and the fumigant was delivered at a constant pressure in a way that made it easy to measure and standardise the volume applied.

All sites were replanted with certified rooted cuttings raised in East Anglia and free initially from arabis mosaic virus (AMV). The incidence of this virus was assessed annually each April or May. It was convenient to use a serological test and, except after long periods of very hot weather, drops of leaf sap containing AMV formed clear specific lines in agar gels on reacting with suitable dilutions of antiserum.

Nematode numbers were estimated following extraction by a modification of Cobb's decanting and sieving method (Flegg, 1967) from soil samples taken at a depth of 15-30 cm.

RESULTS

Untreated Headcorn plots

Dagger nematode populations Populations remained high in the untreated plots for 19 months after grubbing (mean 21.0 per 200 ml soil). Thereafter there was a slow decline in the numbers detected to a mean of 10.0 after 54 months. Populations were very variable but did not differ markedly between plots replanted with hops and those still in bare fallow, even after almost 5 years. This result was unexpected considering the excellent weed control achieved throughout the trial, after the first year, which deprived the nematodes of any alternative host plants.

Virus infection AMV was not detected in the shoots of any of the replants during their first year of growth and none developed symptoms. However 11% of the plants had become infected with AMV by the second year in sub-plots planted after the minimum fallow period of 8 months and the rate of infection increased to 67% in succeeding years. Many of the AMV-infected plants developed symptoms of nettlehead disease, whereas all the AMV-free plants remained symptomless. No plants contracted AMV in sub-plots replanted after bare-fallow periods of 21 months or longer, despite the fact that the nematode populations had not fallen appreciably. These data indicate the striking effect of prolonged bare fallow in decreasing the infectivity of dagger nematodes surviving in the soil.

D-D treated Headcorn plots

Dagger nematode populations Pre-treatment samples had revealed similar numbers of dagger nematodes in the untreated plots and those later fumigated with D-D (mean 18.5 per 200 ml). After treatment, dagger nematodes occurred in samples from only six of the fifteen fumigated sub-plots (overall mean 0.3 per 200 ml).

For 3 years the populations remained low but one of the fallowed plots sampled after 45 and 74 months yielded 20 and 74 nematodes per 200 ml of soil, respectively (means 1.5 and 6.1). There was clear evidence of nematode breeding along one edge of this plot and to a lesser extent in neighbouring plots. All adjoined a 4 m-wide grass headland bordered by a hedgerow of woody perennials whose roots had invaded the margins of the experimental plots.

Virus infection The high mortality of the vector nematodes caused by D-D treatment was associated with a decreased incidence of

AMV and nettlehead compared with the untreated plots. The 11% AMV-infection recorded after 5 years in the sub-plots replanted after 8 months represented 83% control. As in the untreated areas, no AMV infection occurred in sub-plots treated and replanted after fallow periods of 21 months or longer, indicating that the few nematode survivors of D-D had also lost their infectivity.

Results from other sites

The results obtained at other sites are consistent with those obtained at Headcorn. Invariably, much reinfection with AMV occurred within 2 years when sites with a previous history of nettlehead and/or severe split leaf blotch were replanted immediately or within a few months of removing the previous crop. Near Horsmonden, for example, there was 64% infection in plots replanted immediately, compared with only 7% infection in adjacent untreated plots replanted after a 1-year fallow. There was no infection in comparable plots treated with D-D at 840 l/ha using the Egedal injector. Elsewhere there has been little reinfection on replanting after a 1-year fallow and even less in comparable D-D treated plots.

It is necessary or desirable to leave land unplanted for at least one growing season to ensure adequate preparation of the soil for injection. The low level of reinfection encountered in such circumstances, even in untreated plots, has made it difficult to compare the effects on AMV of different rates, placement and methods of injecting D-D.

At the Rosemaund site a hop planting that was severely affected by split leaf blotch was grubbed and replanted with healthy stocks after 3 years. Throughout the intervening period some plots were kept bare by herbicides and others planted with hop, strawberry or perennial rye grass. Populations of dagger nematodes increased under strawberry and rye grass but were little changed in the bare fallow and hop areas. Nevertheless, there was no infection in the strawberry, grass or bare fallow plots within 2 years of grubbing and replanting the whole area with hops. However, reinfection was almost total in plots in which hop plants had been grown, despite the relatively low nematode populations (mean of 5.0 per 200 ml soil).

DISCUSSION

Various nematicides have been used by other workers in Britain and elsewhere to treat soils containing populations of virus infective nematodes. D-D has been effective in preventing the subsequent reinfection of crops of strawberry and raspberry by viruses of the nepo group (Taylor & Gordon, 1970). It has been much more difficult to prevent the reinfection of longer-lived and deeper-rooted crops such as grapevine. The most successful measures against grape fanleaf and related viruses transmitted by *Xiphinema index* have involved double applications of high rates of D-D applied to a depth up to about 1 m by very heavy machinery after special preparation of light sandy soils. (Raski & Schmidt, 1972).

Considerable difficulties have also been encountered in treating hop soils, which tend to be very heavy and difficult to cultivate adequately to the required depth. Problems are also caused by uncertain weather and for much of the year soil conditions do not permit effective treatment. Moreover, hop roots exploit a very large volume of soil and one nematode per 200 ml soil sample is equivalent to approximately 12,000 around the roots of one mature hop plant. Even a treatment that causes 99% mortality leaves many potential vectors unharmed.

Thus it is not surprising that the fumigation of hop soils has given somewhat disappointing results. It is at present impossible to recommend a chemical treatment that will allow the immediate replanting of a severely affected site without serious risk of reinfection. Some control may be achieved under favourable circumstances, but it is doubtful whether the effect is sufficiently great to justify the expense unless there is an interval of at least 1 year between grubbing and replanting with healthy stock. The year out of hop required for preparing the soil for fumigation results in a drastic decrease in the infectivity of those nematodes that survive the necessary cultivations.

The marked effectiveness of a prolonged fallow period in preventing reinfection was totally unexpected at the outset, yet in all experiments and all other observed sites the amount of reinfection decreased with increasing interval between plantings. This was not accompanied by a corresponding decrease in the nematode populations and must therefore have been due to their failure to transmit. This view is supported by laboratory studies (Valdez *et al*., 1973), indicating that dagger nematodes may lose their infectivity with AMV after 36 weeks starvation.

The substantial control of nettlehead achieved by 1-year fallow must have been one of several advantages which led empirically to the adoption of this traditional hop-growing practice. Unfortunately, 1 year of bare fallow is not completely effective and growers are reluctant to adopt longer periods because of the loss of revenue and because weed control is now more easily achieved by the use of herbicides. There is a special incentive at present to replant at the earliest possible opportunity, using the new high-yielding varieties and to meet the demand for hops with a high content of alpha-acid. In these circumstances some growers are fumigating severely affected sites with D-D or dichloropropene during the year out of hops. Alternatively, they are advised to grub in the autumn immediately after harvest and replant untreated land with mist-propagated cuttings 21 months later; so losing only one full crop. Longer periods of fallow would be more acceptable to growers if alternative crops could be recommended. This emphasises the importance of the latest results, in which strawberries or a grass ley grown for 3 years were as effective as bare fallow in preventing the infection of a subsequent hop planting. For all replanting it is essential to use 'A plus' certified stock and so avoid reintroducing AMV to the surviving nematodes, which would then be able to resume transmission.

Acknowledgements

Grateful acknowledgements are made to Shellstar Ltd and the Dow Chemical Co. Ltd for fumigants, to the Hops Marketing Board for sponsoring the Kentish trials and to the Director of Rosemaund Experimental Husbandry farm for providing facilities for trials in collaboration with Mr. F.J. Dickens.

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Proceedings 7th British Insecticide and Fungicide Conference (1973)

THE CONTROL OF SEED-BORNE AND SOIL-BORNE PATHOGENS WITH PP395

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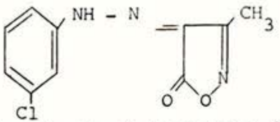
Summary PP395 is a new fungicide of low mammalian toxicity. It is active against a wide range of fungi, but appears most useful for the control of soil and seed-borne pathogens. Applied as a drench or incorporated into compost, PP395 is highly effective against damping off in glasshouse ornamentals and against root rot of forced bulbs caused by *Pythium ultimum*. It has also given promising field results when applied as a seed or soil treatment to control damping off (*Pythium* spp.) and sore-shin (*Rhizoctonia* solani) on cotton, *Pythium* spp. on peanuts and peas, wilt of peppers (*Phytophthora capsici*), bunt of wheat (*Tilletia caries*) and snow mould (*Fusarium nivale*) on rye.

Résumé PP395 est un nouveau fongicide a faible toxicité. Il est actif contre un grand nombre de champignons, mais il semble plus utile pour traiter les maladies provoquées par le champignons du sol ou transmises par les semences. Par arrosage ou par incorporation dans le terreau, PP395 est très efficace pour les plantes en serre, lors de la fonte des semis des plantes ornementales et de la pourriture des racines des bulbes, causées par le *Pythium ultimum*. Il a aussi donné des résultats prometteurs en plein champ, utilisé comme pour le traitement des graines ou du sol, pour lutter contre le *Pythium spp* et le Rhizoctone noir (*Rhizoctonia Solani*) du coton, le *Pythium spp* des arachides, le mildiou du piment (*Phytophthora capsici*), la carie du blé (*Tilletia caries*) et le *Fusarium nivale* du seigle.

INTRODUCTION

PP395 is the code number of a fungicide discovered at the Jealott's Hill Research Station of ICI Plant Protection Ltd. The chemical name is 4-(3-chlorophenylhydrazono)-3-methyl-5-isoxazolone and the proposed common name is metazoxolon.



PP395 is a chemical analogue of drazoxolon (Geoghegan, 1967), having the advantage of a lower mammalian toxicity. The acute oral LD50 to female rats is 3340 mg/kg, and the dermal toxicity for the same species is LD50 > 1000 mg/kg. It does not penetrate skin readily and in test animals it did not cause skin or eye irritation. Long-term feeding tests are in progress.

PP395 is particularly effective against species of Pythium and it has been tested most extensively against these pathogens. However it has a wider spectrum of antifungal activity, which extends to other important seed and soil-borne pathogens such as Phytophthora, Fusarium and Tilletia. The fungicide is not systemic and therefore it has little effect on loose smuts (Ustilago spp.), and wilt diseases caused by Fusarium and Verticillium species. PP395 sprays are active against a wide range of foliage diseases; this aspect is at an earlier stage of field evaluation and will not be considered here.

The present paper reports glasshouse and field data obtained during 1972-73 with several formulations of PP395.

MATERIALS AND METHODS

Formulation

The following formulations have been used in investigations of the efficacy of PP395.

An aqueous semi-colloidal suspension ('Col' formulation) containing 400g PP395 per litre which can be used to prepare drenches, dips or seed dressings.

A dispersible grain containing 10% w/w PP395 which may be mixed directly into soil and compost, or used to prepare drenches.

A dust containing 10% w/w PP395 which may be mixed directly into soil or compost.

A powder seed dressing (PSD) containing 25% w/w PP395.

Application

The term drench is used to denote a dilute liquid preparation of PP395 which is applied directly to the growing medium in which seeds, seedlings, plants or bulbs have been planted. The volume of diluted material used varied according to the sizes of the pots or boxes, but was sufficient to wet the compost or soil thoroughly.

PP395 grains and dust have been incorporated into compost at the time of mixing. In the case of field-applied soil treatments grain or dust has been distributed evenly along the open furrow at planting.

Liquid and powder dressings were applied to seed by shaking seed and dressing together in a suitable container.

Bulbs dips were prepared by pre-mixing PP395 with a small quantity of water + 0·1% 'Agral' 90 wetter, and then transferring to a larger volume of water in a container suitable for dipping bulbs.

Trial details

The several trial methods used in these investigations are well documented: glasshouse ornamentals (McCain and Byrne 1966), forced bulbs (Anon 1971), cotton (Borum and Sinclair 1968), peanuts (Sturgeon and Shackelford 1972).

RESULTS

Glasshouse ornamentals

Numerous research workers in the UK have reported excellent results with PP395 on a wide range of ornamental species, including both bedding plants and pot-grown plants. Only a small amount of chemical is necessary to control Pythium in these crops, but it should be applied both at seed sowing and at the transplanting stage.

Antirrhinums have been used as the main test species since they are grown in large quantities and they are extremely susceptible to Pythium. Trials with infected compost have shown that at seed sowing, a drench of PP395 is the most effective method of application. However, transplanting seedlings into compost pre-treated with PP395 grains produced more high quality plants (Table 1).

Table 1

Control of Pythium ultimum in antirrhinums with PP395

	Treatment applied at		
	Seed sowing	Transplanting	
Treatment	Mean seedling wt (g/100mg seed sown)	Mean wt/ seedling (g)	Percentage number stunted or dead
Compost drench: 'Col' 15g a.i./50 l water	13·7	18·7	19·3
Pre-treated compost:grain 1 g a.i./36 l compost	11·6	23·5	12·5
Pre-treated compost: Terrazole 1 g a.i./36 l compost	8·8	-	-
Nil	4·0	6·2	36·5
LSD ($P = 0·05$)	3·7	5·2	8·1

Bulbs

For the production of cut flowers, bulbs are planted in trays of soil and vernalised at 5-10°C for several weeks. After this time they are transferred to glasshouses where temperatures approximate to 25°C. Pythium is often present in the soil used to fill the bulb trays and can cause serious losses during the forcing period.

In trials in Eastern England on forced tulip bulbs, PP395 applied as a drench directly after planting gave good disease control in soil heavily infected with Pythium (Table 2). A pre-planting dip also gave promising results.

Table 2

Control of Pythium spp. in forced tulip bulbs with PP395

Treatment	Percentage number of flowers		
	1st Grade	2nd Grade	Low Grade
Soil drench after planting (grain) 6 g a.i./litre/m^2 soil	38·9	11·8	48·6
Bulb dip ('Col') before planting 2·5 g a.i./l	34·3	11·5	53·0
Terrazole (W.P.) bulb dip before planting 2·0 g a.i./l	34·2	7·1	54·8
Nil	27·2	13·9	58·7
LSD (P = 0·05)	5·7	4·9	4·9

Peppers (Capsicum)

Many trials against soil-borne *Phytophthora* diseases in various crops are still in progress. In Spain good control of *Phytophthora capsici* on pepper seedlings was achieved with a root dip prior to planting out the seedlings, followed by a soil drench immediately after planting. (Table 3). Although this control persisted for several weeks, laboratory experiments indicate that for long-term diseases control repeat applications may be necessary.

Table 3

Effect of PP395 on Phytophthora capsici on Pepper Seedlings

Treatment	Percentage number dead plants days after treatment	
	14	28
Root/soil drench ('Col') 1 g a.i./2 l water	2·2	20·0
Nil	38·6	50·8
LSD (P = 0·05)	14·8	16·5

Field crops (excluding cereals)

Plant establishment in many field crops is commonly reduced by one or more soil-borne pathogens belonging to the genera *Pythium*, *Rhizoctonia* and *Fusarium*. In trials conducted in several countries, PP395 treatment has proved effective in increasing seedling emergence in a variety of crops including peas, cotton, peanuts and celery. The data presented in Table 4 show the effect of seed and soil treatments on the emergence of cotton and peanut seedlings. *Pythium* and *Fusarium* predominated in these trials, but in the Australian trial some *Rhizoctonia* was present.

Table 4

Effect of PP395 on Emergence of Cotton and Peanut Seedlings

	Percentage Seedling Emergence		
	Australia Cotton seed treatment	USA Peanut 'in furrow' treatment	
PP395 - PSD 1 g a.i./kg seed	45	PP395 - dust 1·7 kg/ha	90
2 (thiocyanomethylthio) benzothiazole ('Busan 72') 1g a.i./kg seed	39	Captan/PCNB dust 1·2 kg a.i. each/ha	84
Nil	18	Nil	78
LSD (P = 0·05)	16		

Peas

Treatment of peas with PP395(PSD) at 0·5g a.i./kg has given excellent control of *Pythium* in U.K. trials; performance was equivalent to that of drazoxolon and superior to that of thiram each applied at the same rate.

Cereals

PP395 seed treatments have been tested for the control of snow mould (*Fusarium nivale*) and bunt (*Tilletia caries*). Rye seed naturally infected with *F. nivale* and wheat artificially inoculated with 5 g bunt spores per kg seed were used for these trials. Each treatment was replicated six times and each replicate consisted of a single 4-metre row. The rye was assessed for seedling emergence, and at ear emergence the number of bunted wheat ears was counted. The results of these trials are presented in Table 5.

Table 5

Control of Fusarium nivale on rye and Tilletia caries on wheat with PP395

	Percentage Seedling Emergence - Rye		Percentage bunted ears - Wheat
PP395 (PSD) 1 g a.i./kg seed	67·6	PP395 (PSD) 1 g/kg seed	3·8
Benomyl (W.P.) 1 g a.i./kg seed	62·0	Maneb (PSD) 1·5 g/kg seed	1·7
'Agrosan' (PSD) 0·02 g Hg/kg	49·1	'Ceresan' (PSD) 0·03g Hg/kg seed	0
Nil	47·4	Nil	34·5
LSD (P = 0·05)	9·6		6·5

DISCUSSION

The data presented in this paper show that PP395 is a very effective fungicide for the control of several important seed-borne and soil-borne pathogens. The low mammalian toxicity, lack of phytotoxicity and ease of handling make it a safe fungicide for use in both agriculture and horticulture. Formulations are available which make it possible to use the chemical in all relevant crop/disease situations.

Small scale trials and grower trials have shown that *Pythium* infection in ornamental plants can be almost completely prevented by incorporating grains into the growing medium before seedlings are transplanted. At the seed sowing stage, however, a drench has proved more effective. The reason for this appears to be that in compost pre-treated with PP395 there are too few grains at the surface to protect the germinating seed. In practice an effective fungicide programme would be to use a drench (1·5 g ai PP395/10 l water) to wet compost thoroughly immediately after seed sowing, followed by transplanting seedlings into compost treated with grains at 1 g/36 l compost. Trials on horticultural food crops (e.g. tomato, lettuce, celery) are in hand.

Although *Pythium* can cause serious losses in forced bulbs, other pathogens including *Fusarium* spp. and *Botrytis* spp., against which PP395 has not proved sufficiently active, may cause even greater losses in some circumstances. These fungi are carried in the bulbs and are commonly controlled with fungicide dips, which have no effect on *Pythium*. Since good control of Pythium has been achieved by dipping bulbs in PP395 suspension prior to planting in infected soil, the addition of PP395 to the standard fungicide dips will give more complete protection and increased flower yields. PP395 also shows considerable potential as a seed treatment on a wide range of crops. Thus in addition to giving good control of soil-borne pathogens attacking cotton peanuts and peas, PP395 has proved effective against two important seed-borne pathogens of cereals, *Fusarium nivale* and *Tilletia caries*. Further work is in progress to establish the full potential of the product.

I wish to acknowledge the work of my colleagues within Plant Protection Ltd., both at Jealott's Hill Research Station and at the Overseas Research Units.

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Proceedings 7th British Insecticide and Fungicide Conference (1973)

ONION NECK ROT AND ITS CONTROL

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Summary Observations and experiments in 1972 on neck rot of onions caused by Botrytis allii showed that, although this disease only became evident in store, a major source of the pathogen was infected seed. Disease spread could not be seen in the field as no obvious symptoms occurred but tissue incubation tests showed such spread to be considerable and mainly to moribund leaf tissue from which the necks of maturing plants were invaded shortly before harvest.

When bulbs were stored for 6 months, little or no spread occurred but infected bulbs became progressively more rotten.

Dusting the seeds with benomyl (1 g a.i. per kg seed) reduced neck rot from 50% to 8%.

Sommaire Nos observations et essais en 1972 sur la pourriture du collet d'oignon provoquée par Botrytis allii ont demontré que, bienque cette maladie ne se manifestât que dans la conservation en séchoir, la graine infectée formait une source majeure du pathogène. La maladie, une fois déployée, ne se voyait pas en plein air puisqu'il n'y avait pas de symptômes évidents mais des essais sur l'incubation de tissu ont montré que le déploiement etait considerable et cela surtout dans le tissu de feuilles moribond. Le pathogène a quitté les feuilles et envahi les collets de plantes mûrissantes peu avant la récolte.

Quand on a emmagasiné les bulbes pour six mois, il n'y avait peu on point de déploiement mais les bulbes infectées se sont progressivement pourries.

En poudrant les graines avec du bénomyl (1 g a.i. par kg de graine) nous avons réussi à réduire de 50% à 8% la pourriture de collet.

INTRODUCTION

Neck rot, caused by Botrytis allii, attacks bulb onions in store causing 5-10% wastage in average years. In the past 3 years, however, much higher losses than these have occurred (up to 50% in some stores). The reason for such outbreaks was not apparent but to meet the need for adequate control measures, research on the problem was begun at the National Vegetable Research Station, Wellesbourne, in 1972.

Because the typical rotting of the onion necks develops only in store, control measures tested in the past have included late field sprays, windrowing and bulb drying procedures all of which were designed to protect and seal off the neck tissues from infection. These measures, although causing some reduction in levels of neck rot, have failed to eliminate the disease.

In the present research it was considered important to establish the main sources of infection and the mode of spread of the pathogen before attempting to produce remedial treatments. This report is concerned with the role of seed-borne infection in the development of the disease and with methods for its control.

METHOD AND MATERIALS

To test for the presence of B. allii, onion seeds were incubated on prune lactose yeast agar (Talboys, 1960) containing streptomycin and erythromycin (Maude, 1963). After 7 days at 21°C, typical B. allii conidiophores were identified by low power binocular microscope on the agar surrounding the seeds. Similarly, whole plants were incubated on moist cellulose in enclosed polythene containers and examined for the presence of the typical conidiophores which served to identify the pathogen.

RESULTS

The fungus on the seed

The fungus has been reported once on seeds in Britain (Moore, 1948) but the significance of seed-borne infection has never previously been studied in this country. Evidence from Holland (Anon, 1969), however, indicates that the incidence of neck rot in store can be reduced by dusting onion seeds with benomyl before sowing.

In 1972, fifteen of the thirty-eight samples of commercial bulb and pickling onion seed tested at Wellesbourne proved to be infected. Incidence of infection ranged from 0.1-20%. In 1973, twenty-five of the thirty-five samples tested bore the fungus with an infection incidence ranging from 0.1-75%. The fungus was often deep-seated and was not removed by surface sterilising seeds for 1 minute in 25% chloros (3% available chlorine).

Development of infection in the crop

In laboratory and glasshouse tests, seedlings were observed to become infected by the growth of hyphae into the tips and sides of the cotyledons from the seed testas attached to them. Spread of disease was traced in the field among plants grown from a 20% infected seed sample. This spread was not visible in the field as the foliage appeared largely uninfected and the presence of the fungus could be detected only by the incubation of the plant tissue. This showed, however, that 20% of the seedlings (cotyledon + first leaf stage) were infected in late May and that the fungus had spread to 55% of the plants by late June (4-5 leaf stage) and to 70% of the windrowed bulbs in mid-September.

The spores which were the agents of this spread were borne initially on the necrotic tissue of the older leaves from which they were transmitted to the moribund tissue of other leaves, then sometimes causing systemic invasion of the green leaf tissue.

In a few commercial crops close to harvest, sporulating mycelium of B. allii could be seen mainly on the necks and sides of bulbs. Such infections were predictive of a heavily diseased crop and of a subsequent high incidence of neck rot on the bulbs in store.

Relationship between disease in the crop and in store

Onion bulbs were taken from field plots which had been shown by tissue incubation tests to contain respectively 70, 28 and 3% infected plants and were kept in a ventilated store (maintained at approx. 44°F) after windrowing and drying in a warm air stream. After 2 months' storage, respectively 55, 6 and 1% of the bulbs from the three plots had developed neck rot. The incidence of neck rot in the store was thus clearly correlated with the incidence of infection on the plants in the field. During the next four months there was no spread of the disease in the store but there was a progressive deterioration of the infected bulbs. It thus appeared probable that the final incidence of neck rot in the store was pre-determined by the extent of field infection. This, in turn, was related to the percentage of infected seeds and the subsequent spread of disease in the field. Elimination of seed-borne infection thus appeared to be a primary requirement for effective control of the storage rot.

Disease control

In 1972, seeds from a commercial sample with 20% seed infection gave bulbs of which 50% showed neck rot in store whereas bulbs raised from the same seed treated with benomyl (1 g a.i. per kg seed) showed only 8% neck rot. Observations during growth of the plants showed that whereas 15% of the plants from untreated seeds were infected at the seedling stage, those grown from seed treated with benomyl were completely healthy at this time. The 8% neck rot in the bulbs from these initially healthy plants thus probably arose by later spread of the fungus from infected plants grown from untreated seeds which were only 2 yd away. It is thus probable that when adequate isolation of crops can be ensured, seed treatment will give even greater control of the storage rot. This is now being tested.

It is apparent from this experiment that B. allii may spread into commercial onion crops from external sources. Experiments on spraying plants with B. allii spores showed that inoculations in May and June gave much more neck rot in store than inoculations in July, August and September. The use of benomyl sprays applied in the early stages of crop growth is therefore being evaluated.

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NOTES

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FACTORS AFFECTING ROTTING CAUSED BY NECTRIA GALLIGENA IN STORED APPLES

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Summary The application of fungicides for the control of apple scab (Venturia inaequalis) during the period from bud burst to mid July significantly reduced the incidence of rots caused by Nectria galligena in the stored crop; the fungicides benomyl, methyl benzimidazole carbamate (MBC) and methyl thiophanate were particularly effective.

Losses were also related to the CO_2 content of the store atmosphere. Fewer rots developed in apples stored in 4% CO_2 than in those stored in air. Rots increased with CO_2 concentrations greater than 4% and in one year the number of rots in unsprayed apples stored in concentrations greater than 8% CO_2 was considerably larger than in those stored in air.

Picking on different dates had no effect on the number of rots in apples stored under identical conditions.

Sommaire L'application de fongicides, utilisés pour le contrôle de la tavelure du pommier (Venturia inaequalis) pendant la periode allant du débourrement à la mi-juillet, a reduit de façon significative l'apparition de pourritures, causées par Nectria galligena, dans les récoltes stockées dans des locaux de conservation. Les fongicides suivant benomyl, methyl benzimidazole carbamate (MBC) et methyl thiophanate se sont montrés particulièrement efficaces.

Des pertes de CO_2 ont aussi été notées dans l'atmosphère du local de conservation. On a observé moins de cas de pourritures pour les pommes conservées dans une atmosphère a 4% de CO_2 que pour celles conservées en atmosphère normale. On a constaté une augmentation du nombre de pourritures dans le cas de concentrations en CO_2 supérieures à 4%. En un an, le nombre de pourritures relevé chez les pommes non traitées et conservées dans une atmosphère à plus de 8% de CO_2, s'est revélé être plus important que dans le cas de conservation en atmosphère normale.

Des dates différentes de récolte n'ont pas montré d'effet sur le nombre de pourritures chez les pommes conservées dans des conditions identiques.

INTRODUCTION

Losses in stored apples, cv Bramley's Seedling due to rotting by Nectria galligena can be severe in Ireland (Swinburne, 1964; Kavanagh and Glynn, 1966). Infections of the fruit occur before harvest but remain latent until the apples have been in store for 2 - 3 months (Swinburne, 1971). The accumulation of benzoic acid around the infection site apparently prevents the immediate development of the rot

(Brown and Swinburne, 1971) but ultimately metabolic changes within the ripening apple enable the fungus to degrade benzoic acid and colonise the fruit (Brown and Swinburne, 1973).

Reduction of losses in stored apples can be achieved both by those measures which reduce the numbers of infections and those which reduce the number of infections which develop into rots. The application of fungicides between bud burst and mid July to control apple scab (*Venturia inaequalis*) reduce the incidence of *N. galligena* rots in the stored crop (Swinburne and Cartwright, 1974). Infections of apples by *N. galligena* commonly occur through scab lesions (Swinburne, 1970a). Fungicides applied during this period may also reduce the numbers of spores discharged from wood cankers (Corke *et al*, 1972), thereby directly reducing the incidence of fruit infections. The application of some fungicides 2 weeks before harvest does reduce fruit infection (Swinburne and Cartwright, 1974) but such sprays are difficult and costly to apply and they have proved commercially unacceptable.

The date of picking had little effect on the number of rots which occurred in barn stored fruit (Swinburne, 1971) but this remains to be confirmed for fruit held in refrigerated gas stores. Early picking is recommended to reduce the incidence of *Gloeosporium* rots (Edney, 1958). The considerable differences between losses encountered in commercial refrigerated gas stores were thought to be due, in part, to the CO_2 concentration of the store atmospheres (Swinburne, 1970a). A survey experiment demonstrated that the number of *N. galligena* rots in comparable crops was related to the range of CO_2 concentrations during the store period (Swinburne, 1970b). More recently a direct relationship between the rate of rotting and the mean CO_2 concentration has been established (Swinburne, 1973). Inoculated apples rotted more slowly in an atmosphere containing 2.5% CO_2 than in air or higher concentrations of CO_2. The rate of rotting increased with increasing concentrations greater than 2.5% and rots expanded more quickly in atmospheres with $\geqslant$ 8% CO_2 than in air.

The experiments reported here were designed to compare the relative value of various scab fungicide regimes on *Nectria* rotting in apples held in different store conditions.

METHOD AND MATERIALS

The fungicides, prepared as shown in Table 1a and b, were applied to randomly assigned plots in each of three blocks in an orchard of mainly Bramley's Seedling apple trees approximately 60 years old. Each plot spanned three rows of trees, but observations were restricted to three central trees. The fungicides were applied with triple nozzle, broom headed lances at a pump pressure of 350 lb/in^2; trees were sprayed to the point of run-off.

Table 1a

Fungicides and formulations used in 1971

Fungicide	Formulation	Concentration per 100 gal	Spray interval days
dodine	25% w/v liquid	28 fl oz	14
dithianon A	60% col	14 fl oz	14
dithianon B	60% col	10 fl oz	10
thiabendazole	60% w p	1.4 lb	14
benomyl	50% w p	0.5 lb	14
triarimol	4% w p	1.4 lb	14

Table 1b

Fungicides and formulations used in 1972

Fungicide	Formulation	Concentration per 100 gal	Spray interval days
dodine	20% w/v liquid	25 fl oz	10
benomyl	50% w p	0.5 lb	14
dithianon	60% col	10 fl oz	10
MBC	50% w p	0.75 lb	10
triforine	20% ec	20 fl oz	10
thiabendazole	60% w p	1.0 lb	10
dodine	24% w/v liquid	20 fl oz	10
methyl thiophanate	70% w p	0.75 lb	10

A randomly selected sample (4 x 40 lb boxes) of apples was picked from each of the three recorded trees in each plot at the end of September in both years of the experiment. One box from each sample was placed in each of four pre-cooled refrigerated gas stores. The remaining space in each store was filled with Bramley's Seedling apples from various sources. Three of the stores were sealed approximately 7 days after picking the experimental samples and an attempt was made in both years to obtain CO_2 concentrations of 4, 8 and 12% respectively. The desired concentrations were reached within 15 days of sealing in 1971 but unknown factors limited those obtained in 1972/3 (Table 2).

Table 2

CO_2 concentrations (%) recorded in stores in 1971/72 and 1972/73

	Store	Mean	Max	Min
1971/72	1	11.9	13.5	9.2
	2	8.0	9.1	5.4
	3	4.2	6.1	3.1
	4	0.5	2.2	0.0
1972/73	1	8.1	9.1	5.7
	2	5.3	6.6	4.8
	3	4.2	4.8	2.8

The unsealed store used in the 1971/72 season was ommited from the 1972/73 experiment. The store temperatures in both years were between 3.5 - 5.5°C. In both years the percentage apples rotted by N. galligena and the percentage fruit scabbed was recorded after 6 months in store. The methods of scab assessment have been previously described (Cartwright, 1965).

To test the effect of the date of picking on the incidence of rots a randomly selected sample of sixteen 40 lb boxes of apples was picked in an orchard in Co. Armagh on 16, 23, 29 September and 12 October 1971. Four boxes from each sample were placed in each of the four stores sealed in 1971 and the apples were examined 6 months later for the percentage of apples rotted by N. galligena.

RESULTS

Fungicide treatments

The application of fungicides to control apple scab resulted in significantly fewer rots in the stored crops of both seasons in all store conditions (Fig 1 and Table 4). Benomyl gave significantly better control of rots than the other fungicides used in 1971, whilst benomyl, MBC and methyl thiophanate were equally effective and gave significantly better control than the other fungicides used in 1972. Although most fungicides significantly reduced the percentage of apples with scab in 1971 none of them was particularly effective (Table 3); dodine, dithianon and benomyl gave similar levels of control. Apple scab infection periods were particularly numerous and severe in the 1971 season and were coupled with extremely difficult spraying conditions (Cartwright, 1972). Spraying conditions in 1972 were less difficult than in 1971 and with the exception of triforine the fungicides effectively controlled apple scab; MBC, benomyl, methyl thiophanate, thiabendazole and dodine being equally effective. Like apple scab, rotting by N. galligena was more severe in 1971 than in 1972 (Fig 1 and Table 4). However, there was little correlation between the results obtained for apple scab and rotting in either year. For example, although benomyl and dodine were equally effective in controlling apple scab in each year, benomyl gave significantly better control of rots than dodine in each year. Similarly, although that fungicide in 1971 which was least effective against apple scab was also least effective against rots, this was not so in 1972.

Table 3

Apple Scab Infection 1971

Treatment 1971	Percentage Fruit Infected
dithianon A	18.0^a
dithianon B	20.0^a
benomyl	20.0^a
dodine (25% w/v)	22.0^a
thiabendazole	33.0^b
triarimol	71.0^c
Unsprayed control	99.9^d

a, b, c, d – values followed by the same letter do not differ significantly (at P = 0.01).

Fig 1

The effect of various fungicide programmes and the concentration of CO_2 in the store atmosphere on the percentage *N. galligena* rots

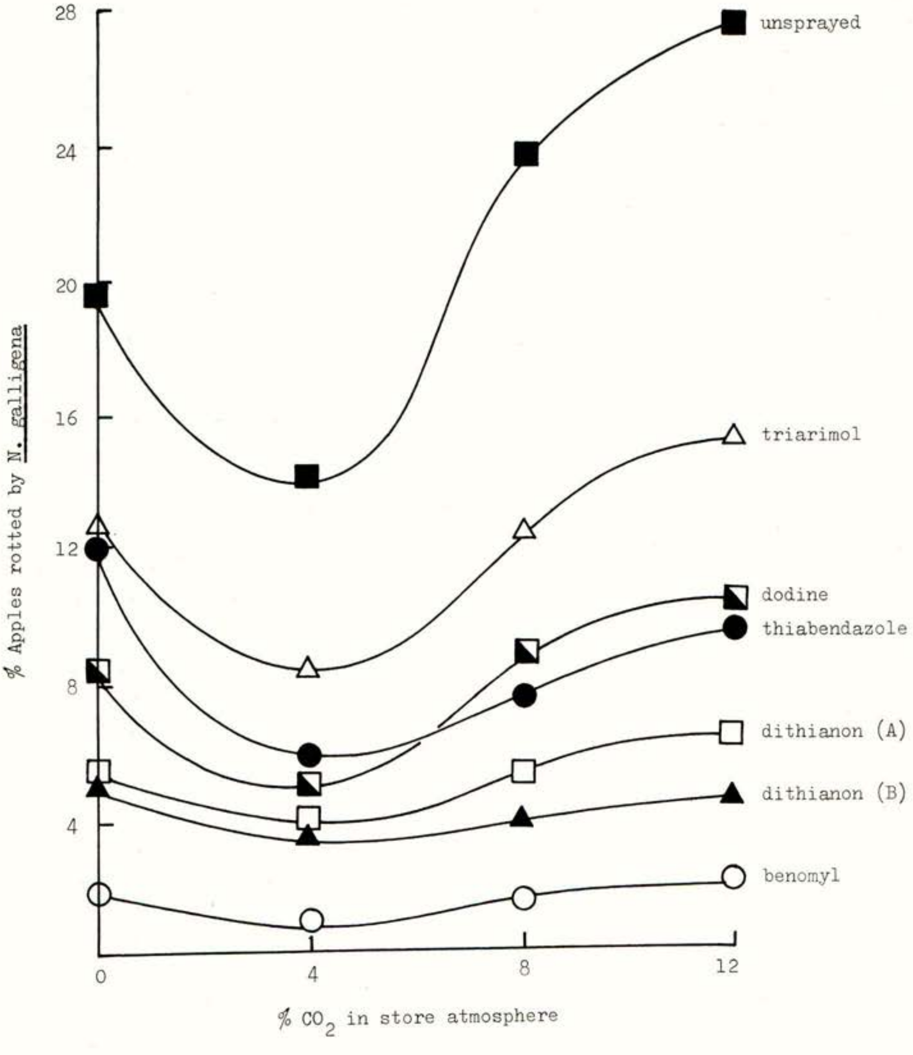

Table 4

The effect of various fungicide programmes and the concentration of CO_2 in the store atmosphere on the percentage *N. galligena* rots and the percentage fruit with scab

Fungicides	% CO_2			Mean % fruit rotted by *N. galligena*	Mean % fruit infected with scab
	4.2	5.3	8.1		
MBC	0.1	0	0	$< 0.1^{a}$	0.9^{a}
benomyl	0.2	0	0.2	0.1^{a}	0.9^{a}
methyl thiophanate	0.1	0.6	0	0.4^{a}	0.9^{a}
dodine (20% w/v)	2.2	2.3	1.6	2.0^{b}	2.2^{a}
triforine	3.4	5.2	6.3	5.0^{c}	42.2^{b}
thiabendazole	3.2	5.8	6.5	5.2^{c}	3.1^{a}
dithianon	4.5	5.9	5.6	5.3^{c}	8.8^{c}
dodine (24% w/v)	5.0	7.2	7.2	6.5	3.5^{a}
unsprayed controls	4.3	8.3	6.0	6.2^{d}	70.8
Mean % fruit rotted in each store	2.6^{e}	3.9^{f}	3.7^{f}		

a, b, c, d, e, f - values followed by the same letters do not differ significantly (at $P = 0.01$).

Store conditions

CO_2 concentrations of the stores also had a significant effect on rotting in both years. In 1971, fewer rots developed in apples stored in 4% CO_2 than at higher or lower concentrations. In apples that had been treated with fungicides rotting in the unsealed store was not significantly different from that in stores at 8 and 12% CO_2. In unsprayed apples rotting in stores at 8 and 12% CO_2 was significantly higher than in the unsealed store. Fewer rots were obtained in the apples in the lowest concentration in 1972, namely 4.1%, than at 5.3 or 8.1% CO_2, but there was no significant difference in amount of rotting in the latter concentrations.

Date of picking

Date of picking had no significant effect on the percentage rots which developed in any one store, but significantly fewer rots developed in all picks stored in 4% and 8% CO_2 than in higher or lower concentrations (Table 5).

Table 5

The percentage of rots caused by N. galligena in apples picked on different dates and stored in various concentrations of CO_2

	% CO_2			
Date of picking	0	4	8	12
16 ix 71	7.4	6.0	4.1	8.4
23 ix 71	8.4	4.3	5.5	9.7
29 ix 71	8.2	4.5	6.3	7.2
12 x 71	6.3	2.1	3.9	7.3

DISCUSSION

That rotting in refrigerated gas stores was equally severe in apples picked on dates almost one month apart confirms earlier results obtained with apples stored in barns (Swinburne, 1971). This together with other available evidence (Swinburne, 1971) suggests that those infections which develop into rots take place sometime between mid August and mid September.

A small proportion of the infection of apples by N. galligena does take place through scab lesions (Swinburne, 1970a) and therefore control of fruit scab must partially account for the reduction of rots achieved with some fungicides. However, the poor correlation between the percentage fruit scabbed and rotted indicates that this effect is not particularly important. Fungicides applied to wood cankers can reduce the number of spores released (Corke et al, 1972) sometimes over long periods of time. Reductions in rotting with some of the programmes tested here might be attributable to their direct effect on spore production during the critical period. Further experiments are required to test the spore supressant properties of these compounds. Byrde et al (1973) have shown that toxic residues can be detected in apple bark up to 7 months after the application of benomyl and thiophanate methyl. Such residues could have directly protected fruit against the infection by N. galligena one month or so after the final application.

The differences in rotting between apples stored in different concentrations of CO_2 parallels earlier results obtained with inoculated apples (Swinburne, 1973). Obviously infections only develop into rots in store under certain conditions. The CO_2 concentrations which most effectively retard ripening, in terms of fruit colour and texture in Bramley's Seedling are 8 - 10% CO_2 (Kidd and West, 1927), but at these concentrations rotting reaches maximal levels. Edney (1964) found that Gloeosporium rots were relatively less severe in apples stored in the absence of CO_2 even though apples "ripened" more quickly than in the presence of CO_2. The loss of resistance of Bramley's Seedling apples to N. galligena in the presence of CO_2 is apparently related to the ability of the fruit to accumulate benzoic acid (Swinburne, 1973). Concentrations of CO_2 greater than 5% give marginally better keeping quality (Kidd and West, 1927) and growers must balance this advantage against the risk of increased losses from rotting by N. galligena.

Acknowledgements

The authors wish to acknowledge the help given by Dr. A. E. Brown, Plant Pathology Research Division, Mr. G. Stevenson, Biometrics Division and field staff of the Horticulture Centre, Loughgall; also Cyanamid (Gt Britain), B.A.S.F., Cela-Merck, Du Pont, Plant Protection, Elanco, May & Baker and Rothwell Plant Health Limited for supplying fungicide samples.

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NOTES

Proceedings 7th British Insecticide and Fungicide Conference (1973)

CONTROL OF STORAGE DISEASES OF APPLES AND PEARS WITH THIOPHANATE-METHYL

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Summary Thirty-one trials were carried out over two years in the major fruit-growing areas of the U.K. using thiophanate-methyl as a pre- and post-harvest treatment for the control of storage rot diseases of apples and pears.

Late-season sprays at 0.05% HV or 1 lb a.i./ac MV and dip suspension of 0.1% w/v gave good control of *Gloeosporium* (bitter rot), *Nectria* (eye rot) and *Sclerotinia* (brown rot). The mid-season foliar spray programme appeared to have some influence on disease control.

Under high infection pressure, best results were given by two late sprays followed by a dip. Dipping (or drenching) alone was insufficient.

Sommaire Trente-et-un essais ont été effectuées en deux années dans les principales regions de vergers du Royaume-Uni utilisant le fongicide méthylthiophanate, avant et après la récolte, pour la lutte contre les maladies de conservation des pommes et poires.

L'applications la en fin de saison aux doses de 0.05% HV ou 1 lb m.a./ac BV et un plongeon à 0.1% conc. out été efficaces contre le *Gloeosporium*, *Nectria*, et *Sclerotinia*. Les traitements à la demi-saison se sont aussi montrés efficaces contre ces maladies.

Dans les conditions très contaminées les meilleurs résultats ont été obtenus par deux applications tardives et un plongeon ultérieur. Un plongeon (ou le trempage) seul ont été insuffisant.

INTRODUCTION

Replicated experiments in Cox orchards in 1970 showed that two sprays of thiophanate-methyl (trade name 'MILDOTHANE'*) at 0.05% HV or 1 lb a.i./ac LV applied mid-August and early September gave better control of *Gloeosporium* (bitter rot) and *Sclerotinia* (brown rot) than three late-season sprays of captan at 0.1% or 2½ lb a.i./ac. (Cole et al. 1971).

Grower trials were initiated in 1971 to test this finding on a larger scale. New replicated work was also undertaken the same year to investigate the effect of thiophanate-methyl after seasonal sprays of captan, because both storage rot and routine applications had previously been based mainly on the same fungicide.

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in 1972 post-harvest dips and drenches of thiophanate-methyl were evaluated under experimental and commercial conditions in relation to pre-harvest treatments and an attempt was made to obtain some information on Nectria (eye rot) control. Six replicated trials on Cox apples with sufficient disease levels are reported for 1971 and a further three for 1972, all in Essex or Kent.

METHODS AND MATERIALS

High volume applications were made using a Dorman fruit sprayer mounted on a Gutbrod mini-tractor: trees were sprayed to run-off at 200-250 gal/ac. using a single hand lance at a pressure of 200 lb/in^2. Medium volume applications were made using a Victair sprayer mounted on a Massey Ferguson 135 vineyard tractor: a volume of 95 gal/ac. was applied at a pressure of 45 lb/in^2. Nine tree plots were used at the medium volume sites and single or two-tree plots at the high volume sites. There were three replicates. In 1971 three late-season 'storage rot' sprays of thiophanate-methyl, benomyl, or captan were applied after a seasonal scab/mildew programme usually of captan with dinocap. In 1972 thiabendazole was included and post-harvest 'dips' of all treatments (except captan) were introduced as an alternative, or in addition, to a full or restricted storage rot spray programme. Dip treatments were carried out by immersing bushel or 30 lb boxes of apples for about one minute in suspensions in a fibre-glass tank. Fruit was normally dipped within four hours of picking.

The unreplicated grower trials in both years (22 reported) were more widespread and covered the major fruit growing areas. In 1971 growers were asked to consider continuing to apply thiophanate-methyl in comparison with a standard fungicide up to early September if they felt that the infection risk was high on apples destined for long-term storage. The 1972 user trials were essentially a practical exercise mounted to gain experience of the usage of thiophanate-methyl as a post-harvest dip or drench treatment on growers' holdings or at packhouses. Of the 10 sites, 6 used 'home-made' equipment - 2 drenches, 4 tank dips - and the remainder used recently-introduced commercial machines, either the Edmonds conveyorised chemical deluging plant with an output of 120 bins per hour or the 'Hudson Major' drenching machine Mk.II with an output of up to 17 tons per hour. In total nearly 13,000 bushels of fruit were dipped, including the major dessert apple varieties, Bramleys and Conference pears. Dip and drench depletion studies were conducted, and at the Bramley site ethoxyquin was added at the grower's request.

The commercial wettable powder formulation of thiophanate-methyl (50% w/w a.i.), 'Mildothane', was used throughout.

With the exception of one site at Ongar (short-term barn storage) fruit was kept in commercial cold stores for periods ranging from 11 to 22 weeks. On removal from store, samples of fruit were recorded as sound or unsound, and the rots identified wherever possible.

RESULTS

Both the replicated and grower trial results from the 1971/72 and 1972/73 work are presented in the following tables and commentary. All apples were Cox's Orange Pippin unless otherwise stated.

Table 1

Control of bitter rot (Gloeosporium) and brown rot (Sclerotinia) in stored apples using foliar sprays, 1971/72

(a) High volume - 200 gal/ac. - Percentage Fruit Infected (Mean of 3 replicates)

Angular transformed data is in brackets

Orchard Location	Type of Store	Storage Period (Weeks)	Type of Rot Disease	3 sprays - late July/early August, mid-August, mid-September Thiophanate methyl 0.05%	Benomyl 0.025%	Captan 0.01%	Control - No storage rot sprays	S.E.(±) Treatment Means
Ardleigh	Cold	19	Bitter	(4.6) 0.4	(4.4) 0.3	(11.0) 3.1	(26.6) 18.7	1.9
Frating	Cold	17	Bitter	(2.8) 0.1	(2.8) 0.1	(2.7) 0.1	(10.9) 3.5	2.2
			Brown	(1.8) 0	(5.3) 0.7	(2.7) 0.1	(10.5) 3.2	3.2
Goudhurst	Cont.Atmos.	26	Brown	(1.8) 0	(5.0) 0.7	(8.2) 2.1	(11.8) 4.2	4.6
Ongar 1	Cold	15	Bitter	(5.4) 0.6	(5.2) 0.6	(12.8) 4.9	(22.1) 12.9	1.6
Ongar 2	Barn	9	Bitter	(2.5) 0.3	(2.1) 0.2	(10.5) 3.3	(20.4) 12.1	2.3
			Brown	(6.8) 1.4	(4.7) 0.7	(10.3) 3.2	(19.9) 11.6	3.1

Seasonal fungicide programme: captan (dithianon at Goudhurst) with dinocap.

(b) Medium volume - 95 gal/ac. - Percentage Fruit Infected (Mean of 3 replicates)

Site	Rot	Thiophanate-methyl 1 lb/ac		Benomyl ½ lb/ac	Captan 2½ lb/ac	Control	S.E.(±) Treatment Means
Ardleigh	Bitter	(1.0)	0	(6.2) 0.8	(17.0) 7.6	(30.8) 24.6	1.5
Frating	Bitter	(3.0)	0.3	(3.3) 0.4	(9.0) 1.9	(15.8) 6.5	1.8
	Brown	(3.7)	0.4	(4.1) 0.4	(5.3) 0.8	(9.6) 2.7	2.9
Gt. Horkesley (15 weeks in cold store)	Bitter	(1.8)	0	(6.1) 1.0	(2.9) 0.1	(10.5) 3.2	2.1
	Brown	(2.4)	0.1	(7.0) 1.4	(7.8) 1.7	(7.6) 1.6	2.6

Seasonal fungicide programme: thiophanate-methyl ← captan/dinocap →

Table 2

Control of rotting in cold-stored apples using foliar sprays, Grower Trials 1971/72

A = % rotted fruit, B = No. of storage rot sprays

			Seasonal and Storage Rot Spray			
		Weeks	thiophanate-methyl		captan	
	Vol.	in	1 lb/ac		$2\frac{1}{2}$ lb/ac	
Site location	gal/ac	Store	A	B	A	B
Challock, Kent	100	16	1.2	0	2.2	0
Chilham, Kent	50	16	3.6	0	2.8	0
Stourmouth, Kent	60	16	0	1	0.3*	0
Shottenden, Kent	50	20	4.0	1	5.5*	0
Crowborough, Sussex	50	15	1.6	1	2.5	0
Lynsted, Kent	150	16	0	1	0.5	1
Snitterfield, Warwicks.	125	22	0.6	2	2.5	3
Ardleigh, Essex	35	15	0	3	3.5	3
Barnston, Essex	50	16	0.6	3	0.3	3
Langham, Essex	100	16	0.2	3	1.9	3
Frating, Essex	33	16	2.7	3	6.0	3
Wickham Bishops, Essex	50	16	0.6	3	2.3	3
Mean % rotted fruit			1.25		2.5	

* dithianon

Dip and Drench Depletion studies

At one site (Cambridge) 600 gals. of suspension were prepared containing 0.1% w/v thiophanate-methyl and eight samples were taken at regular intervals during the day's dipping of 624 bushels of Bramleys. At a second site (Chelmsford), 325 gals. were made up to the same concentration as a drench and the eighth sample taken after 250 bins of Cox had been treated. Analysis of the samples showed that there was no differential removal of active ingredient during dipping or drenching, hence replenishment at the standard 0.1% a.i. was recommended. The Chelmsford samples were retained for a 4-day period during which the thiophanate-methyl content changed very little. In practice, though, earlier replacement was necessary because suspensions became too dirty when continually in use.

Mixture with Ethoxyquin

Ethoxyquin, for scald control om Bramleys, was added to thiophanate-methyl at the Cambridge site. There was no incompatibility of the mix which was safe to the fruit and there was no loss of effectiveness in disease (soft rot) and scald control.

Table 3

Control of rots in cold-stored apples using foliar sprays and post-harvest dips, 1972/73

Volume: 200 gal/ac. Seasonal programme: captan/dinocap

% Fruit infected (mean of 3 replicates)

Angular transformed data is in brackets

	Spray Timing ⌿ % a.i.			Dip % a.i.	Hadlow, Kent		Ardleigh, Essex		Canterbury, Kent	
					% Brown Rot		% Bitter Rot		% ≠ Nectria (eye) rot	
Treatment	1	2	3							
Thiophanate-methyl	.05	.05	.05	-	(19.1)	10.7	(2.4)	0.1	(12.6)	4.7
" "	.05	.05	-	-	(23.9)	16.4	(2.4)	0.1	(12.1)	4.3
" "	.05	.1	-	-	(21.9)	13.9	(2.4)	0.1	(13.4)	5.2
" "	.05	.05	-	.1	(10.4)	3.2	(1.8)	0	(9.9)	2.9
" "	.05	-	-	.1	(19.3)	10.9	(3.4)	0.2	(12.7)	4.7
" "	-	-	-	.1	(18.5)	10.0	(3.4)	0.2	(16.4)	7.5
Benomyl	.025	.025	.025	-	(21.0)	12.8	(1.8)	0	(13.0)	4.9
"	-	-	-	.05	(17.9)	9.4	(4.5)	0.5	(21.2)	13.0
Thiabendazole	.06	.06	.06	-	(17.0)	8.5	(4.1)	0.4	(19.7)	11.3
"	-	-	-	.12	(19.1)	10.7	(3.9)	0.3	(19.3)	10.8
Captan	.1	.1	.1	-	(23.8)	16.3	(7.2)	1.4	(14.9)	6.5
"	.1	.1	.1	.1*	-	-	(2.8)	0.2	(8.0)	1.8
Control (water)	-	-	-	H_2O	(24.5)	17.2	(13.0)	5.0	(23.9)	16.3
Control (untreated)	-	-	-	-	(20.4)	12.1	(18.7)	10.2	(23.7)	16.0
S.E. treatment means					± 5.4		± 2.7		± 4.1	
Period in cold store (weeks)					11		17		15	

⌿ 1 = mid-July 2 = early August 3 = late August/early September

* thiophanate-methyl

≠ Because of identification difficulties, there is the possibility that a small proportion of bitter rot (Gloeosporium) infection may be included here.

Table 4

Post-harvest treatment with thiophanate-methyl at 0.1% by Growers or Packhouses, 1972/73

Location	Variety	Type of treatment	Bushels treated	Unit used	Weeks in Store	Conclusions/comment
Chelmsford, Essex	Cox	Edmunds drench	5,700	Bin	9	Low level of brown rot.
Ledbury, Herefs.	Cox	Hudson drench	100	Bin	13	Good control of various rots.
Doddington, Kent	Cox	Edmunds drench	160	Bin	8	Good control of brown rot.
Chartham, Kent	Cox	Dipping by hand	24	Box	18	2.4% rots on control < 1% rots on dipped fruit.
Ardleigh, Essex	Cox/Laxton's Superb	Home-made drench	4,200	Bin	16	See Table 5 (Excellent bitter rot control)
Royston, Herts	Laxton's Superb	" "	600	Box/Bin	14	Negligible disease.
Wilburton, Cambs.	Bramley	Dip (600 gal tank)	624	Box	18	Good control of various rots.
Wilburton, Cambs.	Conference pears	" " "	360	Box	19	Good control of various rots.
Hemingstone, Suffolk	Golden Delicious	Edmunds drench	100	Bin	4	Negligible disease.
Plaxtol, Kent	Conference pears	Dip (400 gal tank)	1,000	Box	8	Good control of brown rot (low level).

Table 5

Control of rots in stored apples using foliar sprays and post-harvest drenches, 1972/73

Site: Ardleigh, Essex
Date of Drenching: 29.9.72
Seasonal Programme: Captan/dinocap

Quantity treated: 4,200 bushels (300 bins)
Date of assessment: 29.1.73

Late-season Storage Rot Sprays	Post-harvest drench		No. of bins assessed	% Fruit infected			
				Bitter rot	Brown rot	Other rots	Total rots
3 X thiophanate-methyl at 0.05%	thiophanate-methyl	0.1%	9	0.5	0.3	0.3	1.02
	benomyl	0.05%	9	0.6	0.3	0.4	1.33
	nil		9	0.6	0.3	0.3	1.19
2 X thiophanate-methyl at 0.05%	benomyl	0.05%	9	0.5	0.4	0.3	1.24
	nil		1	1.8	0.2	0.2	2.29
3 X captan at 0.1%	thiophanate-methyl	0.1%	9	0.5	0.2	0.4	1.05
	benomyl	0.05%	9	1.2	0.2	0.3	1.71
	nil		2	5.3	0.7	0.5	6.45
None	thiophanate-methyl	0.1%	2	3.9	0.5	0.4	4.84
	nil		1	11.9	1.2	0.3	13.3

DISCUSSION

Although in the 1971 grower trials thiophanate-methyl reduced fruit rotting by 50% (average) compared to captan, disease incidence was fairly low following a dry July and September. Only five growers put on the full complement of late-season storage-rot sprays (Table 2). In the replicated trials that year, irrigation ensured higher disease levels at two sites (Ongar), but the incidence of bitter rot was more variable (4 to 25%) than brown rots (1 to 6%) on the controls receiving no storage rot sprays (Table 1). Three late-season sprays of benomyl or thiophanate-methyl at high volume reduced these rots to a low level and were an improvement over captan. There was an indication that thiophanate-methyl used low volume from June to September was even better than just using it late-season after captan.

In 1972 only one replicated trial (Ardleigh) gave a sufficiently high level of bitter rot: three sprays of captan after a captan/dinocap seasonal programme reduced the disease from 11 to 2%; thiophanate-methyl as a spray or dip, or combination of the two, reduced the disease to below 1% (Table 3). At Hadlow, brown rot was more difficult to control, two sprays and a dip of thiophanate-methyl being the most effective treatment. A site devastated by wood canker yielded data on eye rot control: pre-harvest sprays of thiophanate-methyl or benomyl gave a useful reduction of disease, but as with brown rot, dips alone were insufficient. This was confirmed in a grower trial (Table 5), in which unsprayed controls gave over 13% rotted apples (mainly bitter rot), which were reduced to 5% with a dip, but to around 1% with sprays and a dip. The further user trials confirmed the safety of thiophanate-methyl dips to the main commercial varieties of apples and to Conference pears, and disease control was generally acceptable (Table 4).

Our main conclusions are that storage rot sprays of thiophanate-methyl applied to apples at 1 lb a.i./ac MV or 0.05% w/v HV in late July to early September gave good control of bitter rots Gleosporium spp., brown rots Sclerotinia spp. and Nectria eye rot. Earlier post-blossom sprays applied at the same rate contributed to disease control of the cold-stored fruit. Post-harvest dips or drenches of thiophanate-methyl at 0.1% w/v also assisted in disease control, but were not a complete replacement for storage rot sprays.

Acknowledgements

The authors wish to acknowledge the assistance of colleagues at May & Baker Ltd in carrying out the replicated work and to the many growers who co-operated in the large-scale trials.

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Proceedings 7th British Insecticide and Fungicide Conference (1973)

POST HARVEST CONTROL OF BROWN ROT ON STONE FRUIT BY TRIFORINE

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Summary Triforine (= Cela W 524), a systemic fungicide, has shown good activities against stone fruit brown rot using a 20% EC formulation. At least two sprays of 125 ppm a.i. in the spray wash are recommended for the control of brown rot on the fruit before picking and two sprays of at least 200 ppm or a dip of at least 250 ppm should be used for the control of brown rot on stored fruit. Higher concentrations or more applications seem to exert little influence. Like other compounds on the other hand, triforine treatments cannot give a guarantee of complete control.

Résumé Triforine (= Cela W 524), fongicide systémique formulé comme concentré émulsifiable à 20%, s'est révelé efficace contre la moniliose des fruits à noyaux. Pour le contrôle de la moniliose avant la récolte, deux applications de 125 ppm de la matière active sont recommandées; d'autre part, on préfère deux traitements de min. 200 ppm ou un trempage de min. 250 ppm pour la protection des fruits sur stock contre la moniliose.

Les concentrations plus élevées ainsi que le nombre d'applications semblent avoir peu d'influence. Comme d'autres produits comparables, la triforine ne peut pas donner la garantie d'un contrôle complet.

Triforine (= Cela W 524) was introduced here in 1969 and 1971 (ADLUNG et al. 1971; CLIFFORD et al., 1971; O'RIORDAIN et al., 1971; SCHICKE et al., 1969 and 1971). Meanwhile the 20% EC is being sold under the trade names Saprol, Funginex or Triforine 20 in several countries for use against the main diseases of cereals, cucumbers, roses and other ornamentals. Against mildews, rusts and other foliar diseases, toxicological and environmental data favour the formulated product for the control of some fruit and storage rots. The LD50 oral in rats is above 16,000 mg/kg body weight for the active material and above 6000 mg/kg for the formulation. The no effect level for rats is 500 mg of triforine in the daily diet. With up to 16,000 ppm active material in the diet, neither fetotoxic nor teratogenic effects have been observed. According to these data, a residue tolerance of at least 3 ppm may be expected. On the other hand, residue data on apples, cucumbers (EICHLER 1972), cherries and peaches were always lower than 3 ppm immediately after the last application of a full spraying schedule, on apples and peaches for instance after 8 to 10 treatments containing 250 ppm of active ingredient each.

Until the benzimidazoles came on the market, no satisfactory chemical control was achieved against brown rot, one of the most serious problems in stone fruit growing areas, mainly in Australia, Japan, New Zealand and the USA. In storage trial results the untreated plots often show fruit decay of more than 50 and up to 100% after five to ten days' storage.

The causal pathogen belongs to the genus Sclerotinia (= Monilinia, Monilia), several species of which are recorded. According to KOTTE (1958), those Sclerotinia species which form conidia typical of Monilia have been gathered into the new genus of Monilinia. WORMALD (1955) recorded the species of S. fructigena and S. laxa both causing the brown rot of the fruit on the tree, but S. laxa is the main pathogen of blossom blight, whilst S. fructigena causes mainly storage rot. VON ARX (1968) recorded S. fructigena as being present on Pyrus species, whereas S. laxa has been found on Pyrus and Prunus species.

Recently KEMP (1971) recorded S. fructicola as being the main problem in New Zealand, causing symptoms of blossom blight, fruit rot, twig cankers, twig death, mummified fruit and shot hole effects on foliage. Japanese investigators speak of S. cinerea (unpublished) and Monilia fructicola (KITAJMA et al., 1973). In the United States M. fructigena is recorded as being the causal pathogen of brown rot on cherries, peaches and plums. Since several species are therefore to be expected, brown rot control may vary from locality to locality or even from trial to trial.

GILPATRICK et al. (1972) were the first to record triforine, formerly known as Cela W 524, as being highly effective against brown rot on plums. Recently some results obtained with triforine using the 20% EC, CA 70203 (i.e. 200 ppm are contained in a 0.1%

formulated product) against brown rot on cherries and peaches have been published in Fungicide and Nematicide Tests, Results of 1972 (1973) (CHANDLER; CLAYTON; JONES et al.; LANDIS et al.; SZKOLNIK; ZEHR). Therefore I want to give a survey of all data available concerning brown rot control by triforine.

Altogether more than thirty different trials have been recorded to our knowledge including triforine for the control of brown rot on stone fruit. Triforine has been used on peaches mainly, the most important stone fruit crop, but also on apricots, cherries and plums. The trials included spraying and dipping treatments. Evaluation was made upon the effect of brown rot decay at picking and after different storage periods, both after natural and artificial infections. Examples of these evaluations are given in Table 1 and Table 2.

Table 1

Control of brown rot on peaches by spray treatment

Loss at harvest and after storage of sound looking fruits

(Unpublished data from foreign institutes)

a) Australia 1972
Sprays to drip off, 26.1, 9.2, 18,2
Harvest 21.2

Treatment	a.i.	% fruit infected by brown rot		
	ppm	Picking	5 days - storage -	10 days
Check		16.8 c	88.7 c	99 c
Triforine	200	3.8 ab	0 a	26 b
Triforine	400	1.5 a	0 a	10 a
Benomyl	250	8.5 b	7.5 b	29 b

(Letters in common indicate no significance at the 5% level as determined by Duncan's multiple range test)

b) Japan 1972
Sprays 6.6, 13.6, 26.6, 5.7
Harvest 5.7

Treatment	a.i.	% fruit infected by brown rot		
	ppm	Picking	5 days - storage -	10 days
Check		37.9	13.2	27.1
Triforine	200	0.6	0.4	1.6
Triforine	250	0.0	1.6	6.0
M-thiophanate	467	0.9	1.4	4.1

Table 2

Control of brown rot on peaches by dipping

Loss after storage of sound looking fruits, naturally infected

(Unpublished data from foreign institutes)

a) Australia 1972

Treatment	a.i. ppm	% fruit infected by brown rot 5 days	- storage - 10 days
Check		16	76
Triforine	250	4	4
Benomyl	250	3	3

b) Australia 1973

Treatment	a.i. ppm	% fruit infected by brown rot 3 days	- storage - 7 days
Check		98	100
Triforine	250	0	0
Benomyl	250	2	0

It is clearly shown that triforine has a good biological activity against brown rot infection both on the fruit on the trees and in storage.

Of course trial results vary widely due to the different places and conditions, perhaps even to different species of the fungus. It is therefore impossible to give statistical assessments. It has been found however that with triforine and benzimidazoles the variation in the results is quite in the same range. The biological efficacy of triforine is at least the same as that of the benomyl type benzimidazoles.

As far as triforine is concerned, the trial results obtained from Japan, New Zealand, Australia and the USA may be interpreted in the following manner.

Brown rot control of stone fruit before picking time

Although triforine shows good biological activity, it is impossible to guarantee 100% control. If the infection pressure is high, some infected fruit will be found on the tree. This residual infection is independent of the triforine concentration in the spray wash, 125 ppm being the lowest dosage tested. The number of treatments has little influence on fruit decay, 1 to 7 treatments being tested. It seems however that at least two sprays should be recommended. In this spraying schedule it is of little significance whether the last spraying was done on the 10th or 3rd day before assessment. Good control therefore should be expected by spraying 10 to 14 days and 3 to 5 days before picking.

Brown rot on stored fruit

Here again no complete control can be guaranteed. This also is to be seen in Table 1. In general however, the increase of infected fruit after treatment by triforine is only slight by extending the storage period up to 20 days.

Spraying seems to be more effective than dipping. Compared with sprays, the concentration of the dipping solutions should be increased.

Generally speaking, increasing the concentration of the spray wash above 250 ppm has little influence on the brown rot control of stored fruit. The rate should however be at least 200 ppm a.i. in the spray wash. No trial using less than 200 ppm resulted in 100% brown rot control.

As in the control of brown rot on the fruit on trees, the number of applications has little influence on the brown rot control on stored fruit, so the recommendation again is two sprays at the same intervals. However sprays just one day before or even on the picking day achieved satisfactory brown rot control on stored fruit.

Another very serious problem in peach storage may be caused by the transit rot, Rhizopus nigricans. In dipping trials triforine has shown activity against this pathogen. There are however trials in which this compound has failed to control this transit rot. In combination with DCNA (= 2,4,6-dichloro-4-nitro-aniline), triforine has always been superior to the standards (see also SZKOLNIK, 1972). If brown rot and transit rot are expected, a combination of these two compounds should be recommended.

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