Proc. 6th Br. Insectic. Fungic. Conf. (1971)

COMPARISONS OF SYSTEMIC AND PROTECTANT FUNGICIDES FOR DISEASE CONTROL ON FOUR SOFT FRUITS

F. Ó Ríordáin and T. Kavanagh
Agricultural Institute, Kinsealy Research Centre, Dublin, 5.

T.F. O'Callaghan
Soft Fruits Research Centre, Clonroche, Co. Wexford.

Summary Benomyl controlled *Pseudopeziza ribis* of black currant and gooseberry and *Elsinoe veneta* of raspberry. Triarimol was very effective against *Sphaerotheca mors-uvae* and *Puccinia pringsheimiana* of gooseberry as was triforine* against *P. ribis*. In 1970 thiophanate-methyl was equal to benomyl and dichlofluanid and better than thiabendazole for control of *Botrytis* of strawberry but in 1971 dichlofluanid was the only fungicide to give significant control of this disease. Of the other protectant fungicides results of note were the good effect of thiram against *Didymella applanata* of raspberry and of dithianon against *P. ribis*.

INTRODUCTION

Results of fungicide tests on black currants, gooseberries, raspberries, and strawberries against several diseases are given in this paper. As disease control in these crops, with the exception of gooseberries, was reported on in 1969 (Kavanagh & O'Callaghan, 1969, Ó Ríordáin, 1969 a & b), results since that date are given here. Benomyl was tested previously (ibid), but this and several other systemic fungicides are reported on here. These investigations were carried out at the Soft Fruits Research Centre, Agricultural Institute, Clonroche, Co. Wexford.

MATERIAL AND METHODS

Owing to the number of crops and experiments, details of experimental layout and methods of application are given under each crop together with the results. The fungicides used in all experiments were standard commercial formulations.

EXPERIMENTAL AND RESULTS

Leaf spot of black currant

Nine fungicides were compared for the control of leaf spot (*Pseudopeziza ribis*) on the cultivar Wellington XXX (Table 1). A randomised block design with five replicates was used. Plots consisted of a double row of close-planted bushes 7.3 m long. Except that six assessments were made per plot all other experimental details were similar to those already reported (Ó Ríordáin, 1969a)

In both 1970 and 1971, benomyl, dithianon and triforine gave better results than mancozeb, the standard material (Table 1). Propineb, which was included in the experiment in 1970 at 44.8 oz a.i./ac (3.1 kg/ha) gave very poor control of leaf spot and was not used in 1971. Poor control of leaf spot in both years was also given by thiabendazole. Triarimol gave poor results in 1970 but a new formulation used in 1971 gave better control.

* Triforine is the suggested name for piperazin - 1,4 - diyl - bis [1 -(2,2,2 - trichloroethyl) formamide]

Table 1

Effect of seven fungicides on leaf spot (%) of black currant, cultivar Wellington XXX

Fungicide	Oz a.i./ac (kg/ha) per application	1970			1971	
		14 Aug.	17 Sept.	23 Oct.	9 Aug.	10 Sept.
Benomyl	8.0 (0.6)	8.8 *	43.5 ***	86.9 ***	21.7	66.0 *
Dithianon	18.0 (1.3)	6.9 ***	36.1 ***	78.4 ***	18.2 *	61.0 **
Mancozeb	38.4 (2.7)	12.1	66.3	98.2	27.1	83.3
Thiabendazole	19.2 (1.4)	24.6 +++	94.4 +++	99.9	43.1 +++	91.6
Triarimol	1.3 (0.1)	18.5 +++	89.8+++	99.7	23.5	69.7
Triforine	8.5 (0.6)	7.4 **	37.2 ***	85.8 ***	22.2	63.5 *
Thiophanate-methyl	32.0 (2.2)	-	-	-	22.7	84.0

*, **, *** - significantly better than mancozeb at 5%, 1% and 0.1%
+++ - " worse " " " 0.1%

Leaf spot, mildew and rust of gooseberry

In both the leaf spot (P. ribis) and mildew (Sphaerotheca mors-uvae) experiments plots consisted of 12 bushes of the cultivar Careless planted 2.7 x 1.4 m. The leaf spot experiment compared nine fungicides (Table 2) in a randomised block design with four replicates. Leaf spot was assessed as previously described (Ó Ríordáin et al, 1966).

The development of leaf spot on gooseberries in both 1969 and 1970 was slow and the differences between the treatments were not great. Dithianon, however, gave very good control. The 1971 season was wetter resulting in a higher level of infection. Control by benomyl and dithianon was good, but that by BASF 3201F, dodine and thiabendazole was poor.

Powdery mildew was assessed bush by bush on a 0-5 scale (0= no disease, 5= all new shoots heavily mildewed). Four fungicides in two spray programmes were compared with an unsprayed control in both 1970 and 1971 (Table 3). The design was a randomised block with four replicates. Mildew was reduced significantly by all the treatments in 1970. In 1971 triarimol and triforine gave the best control. Triarimol significantly reduced the incidence of cluster cup rust (Puccinia pringsheimiana) in 1970 (Table 3).

The leaf spot experiment (Table 2) was also assessed for mildew control. In 1970 triarimol gave best control followed by benomyl and dithianon. Benomyl was the most effective in 1971 although good control was given by triarimol and triforine.

Cane spot, spur blight and Botrytis of raspberry

Experiments were carried out in commercial plantations in Co. Longford in addition to the Soft Fruits Research Centre, Clonroche. The experimental details were similar to those given previously (Ó Ríordáin, 1969b), but the number of canes assessed per plot was increased to 15.

Table 2

Effect of fungicides on leaf spot and shoot mildew on gooseberry, cultivar Careless

Fungicide	Oz a.i./ac (kg/ha) per application	Leaf spot (%)					Shoot mildew	
		22/10/'69	12/11/'69	17/9/'70	23/10/'70	10/9/'71	3/7/'70	26/7/'71
BASF 3201 F[1]	8.0 (0.6)	-	-	-	-	61.5 ++	-	2.98
Benomyl	8.0 (0.6)	-	-	34.5	92.1 +	25.0 ***	2.31 **	2.32 **
Captafol	25.6 (1.8)	12.7	61.4	26.0	76.6 *	-	3.17	-
Chlorothalonil[2]	18.0 (1.3)	12.1	68.3	37.6	96.5 ++	-	3.19	-
Dichlofluanid	16.0 (1.1)	38.3 +++	94.0 +++	82.6 +++	100.0 +++	-	3.21	-
Dithianon	18.0 (1.3)	11.6	48.1 ***	26.7	61.8 ***	29.9 **	2.46 **	3.31
Dodine	5.2 (0.4)	12.1	70.9	38.5	87.4	86.6 +++	3.50	3.13
Mancozeb	38.4 (2.7)	16.6	64.1	31.0	84.8	47.8	3.44	3.44
Maneb	38.4 (2.7)	13.3	68.5	-	-	-	-	-
Quinomethionate	4.0 (0.3)	46.2 +++	95.6 +++	-	-	-	-	-
Thiabendazole	19.2 (1.4)	-	-	59.7 +++	99.6 +++	88.7 +++	3.08	3.28
Triarimol	1.3 (0.1)	-	-	34.8	95.0 ++	53.1	1.48 ***	2.66 *
Triforine	8.5 (0.6)	-	-	-	-	55.4	-	2.72 *
Thiophanate-methyl	32.0 (2.2)	-	-	-	-	40.0	-	3.09

*, **, *** - significantly better than mancozeb at 5%, 1% and 0.1%
+, ++, +++ - " worse " " " 5%, 1% and 0.1%

1 BASF 3201 F is the code number for 1-(2'- methylthio - ethyl- carbamoyl) - 2 - methoxy - amino-benzimidazole.

2 Chlorothalonil is suggested name for tetrachloroisophthalonitrile.

Table 3

Effect of fungicides and spray programmes on mildew and rust of gooseberry, cultivar Careless

Fungicide	Spray Programme	Oz a.i./ac (kg/ha) per application	Shoot mildew 1970	Shoot mildew 1971	Rust 1970
Benomyl	4 sprays	8.0 (0.6)	0.65 ***	2.74	9.8
"	3 "	8.0 (0.6)	1.29 ***	2.73	5.5
Dinocap	4 "	8.0 (0.6)	0.71 ***	-	7.5
"	3 "	8.0 (0.6)	0.75 ***	-	7.3
Quinomethionate	4 "	4.0 (0.3)	0.71 ***	2.66 *	6.0
"	3 "	4.0 (0.3)	1.28 ***	3.26	8.3
Triarimol	4 "	1.3 (0.1)	0.02 ***	2.25 **	1.5 **
"	3 "	1.3 (0.1)	0.00 ***	2.51 *	3.3 *
Triforine	4 "	8.5 (0.6)	-	2.53 *	-
"	3 "	8.5 (0.6)	-	2.18 **	-
Control			4.02	3.74	9.3

*, **, *** - significantly better than the control at 5%, 1% and 0.1%.

As the 1970 season was exceptionally dry, cane spot (*Elsinoe veneta*) in raspberries was slight (Table 4). Benomyl, captafol, dichlofluanid, mancozeb and thiabendazole significantly reduced

Table 4

Effect of fungicides on cane spot, Botrytis and spur blight of raspberry cultivar Malling Jewel, 1970

Fungicide	Oz a.i./ac (kg/ha) per application	Cane spot spots per cane 24/9/'70	Botrytis Mean lesion length in cm 26/2/'71	Spur blight Mean no. of buds affected/cane 26/2/'71
Benomyl	8.0 (0.6)	1.2 *	45.5	2.20 *
Captafol	25.6 (1.8)	1.9 *	55.8	2.85
Dichlofluanid	16.0 (1.1)	4.5 *	38.3	2.58
Dithianon	18.0 (1.3)	7.2	20.3 *	2.33 *
Mancozeb	38.4 (2.7)	3.0 *	72.8	2.58
Thiabendazole	19.2 (1.4)	3.3 *	20.3 *	3.23
Thiram	51.2 (3.6)	7.2	35.0	1.98 **
Triforine	8.5 (0.6)	-	-	-
Control		15.1	57.3	3.10

*, ** - significantly better than the control at 5% and 1%

cane spot levels in an autumn count on the new canes. In a winter assessment Botrytis stem lesions (B. cinerea) were reduced significantly by dithianon and thiabendazole. Also at this time benomyl, dithianon and thiram showed significant control of spur blight (Didymella applanata) (Table 4).

In Co. Longford, benomyl gave very good control of cane spot in both Experiments I and II (Table 5). Thiram in Experiment II was the only fungicide to significantly reduce spur blight, but benomyl increased its incidence in Experiment I. In spring 1971 Experiment II was assessed for cane death. This was very severe in many plantations in the area. The results are complicated by the beneficial effect on the canes of shelter but it is evident that benomyl sprays in the previous spring reduced the amount of cane death. Dead canes which were examined had large numbers of perithecia of a Nectria sp. on their bases.

Table 5

Effects of three fungicides on cane spot, spur blight and on cane death of raspberry cultivar Malling Notable at two locations in Co. Longford, 1970.

Fungicide	Oz a.i./ac (kg/ha) per application	Cane Spot I Spots/ Cane	Cane Spot II Spots/ Cane	Spur Blight I	Spur Blight II	Cane Death II % Dead Canes/plot
Benomyl	8.0 (0.6)	2.8 ***	4.6 ***	2.06 ++	2.52	38.3 *
Dichlofluanid	16.0 (1.1)	16.3 ***	42.1	1.56	2.27	65.0
Thiram	51.2 (3.6)	34.9	31.8 ***	1.56	1.88 ***	52.5
Control		43.4	53.6	1.30	2.42	69.2

*, **, *** - significantly better than the control at 5%, 1% and 0.1%

++ - " worse " " " " 1%.

Botrytis of strawberries (B. cinerea)

These experiments were carried out on the cultivar Cambridge Vigour grown in rows on raised drills or ridges 91 cm wide with 46 cm between the plants. Spraying was done with a specially designed sprayer (O'Callaghan, 1966) which applied the fungicides to two rows at a time at 200 gal/ac (2246 l/ha) and 180 psi (12.6 at) through a triple arrangement of nozzles over each row. Except where otherwise stated three applications of each fungicide were given beginning at early flower and at about 10-day intervals. The experimental design was a randomized block with four replications of six treatments and 44 and 50 plants per plot respectively in 1970 and 1971. Results are presented in Table 6.

Table 6

A comparison of fungicides for their effectiveness in controlling Botrytis of strawberries, cv Cambridge Vigour, in 1970 and 1971

Fungicide	Oz a.i./ac per application (kg/ha)	Fruit yield in cwt/ac			
		1970		1971	
		Healthy	Diseased	Healthy	Diseased
Thiophanate-methyl	32.0 (2.2)	182.8 ***	1.5 ***	199.1	9.1
Dichlofluanid	32.0 (2.2)	175.3 ***	0.9 ***	201.1 *	5.5
Benomyl x 3[1]	8.0 (0.6)	174.2 ***	2.6 **	185.2	6.2
Benomyl x 2[2]	8.0 (0.6)	161.0 **	3.6 *	-	-
Thiabendazole (1970) (1971)	14.4 (1.0) 19.2 (1.3)	157.5 *	4.2 *	175.4	11.4
BASF 3201 F[3]	8.0 (0.6)	-	-	197.5	7.1
Control (unsprayed)	-	130.8	7.1	173.2	9.9

*, **, *** - significantly better than control at 5%, 1% and 0.1%

1 applied three times.

2 applied twice.

3 BASF 3201 F is the code number for 1-(2'-methylthio-ethyl-carbamoyl)-2- methoxy - amino - benzimidazole.

DISCUSSION

Two systemic fungicides benomyl and triforine gave better control of leaf spot of black currant than mancozeb which was the best of the dithiocarbamates previously tested (Ó Ríordáin, 1969a). The only non-systemic fungicide to equal these was dithianon. As benomyl can be applied up to harvest in contrast to the dithiocarbamates which cannot be used within a month of picking black currants for processing, this fungicide has an advantage in situations where leaf spot could become severe during the pre-harvest period. A further advantage of benomyl and some other systemic fungicides, is their wide spectrum, and on crops such as black currants and gooseberries, they control powdery mildew and Botrytis as well as leaf spot. However, the days of one fungicide controlling all diseases of a particular crop have not yet arrived as illustrated by the ineffectiveness of benomyl against rust of gooseberries. Triarimol gave excellent control of this disease as also of powdery mildew but was somewhat weak on leaf spot control.

In the case of cane spot of raspberry, seven fungicides previously tested all gave significant control (Ó Ríordáin, 1969b). Similar results were obtained with the seven fungicides including benomyl and thiabendazole tested at Clonroche in 1970 where disease levels were low. Under the more severe conditions in Co. Longford, benomyl gave more consistent control than dichlofluanid and thiram.

As reported previously (Ó Ríordáin, 1969b), spur blight was more difficult to control and results from the two locations were somewhat contradictory. Of the fungicides tested thiram gave best results but at Clonroche benomyl and dithianon also had a significant effect. Burchill and Swait (1971) also found benomyl and thiram to be effective against this disease but unlike their results dichlofluanid had no effect in these experiments. An interesting side effect of the use of benomyl was the reduction in cane death on the sprayed plots. As benomyl is effective against Fusarium (Staunton, 1971), the widespread occurrence of a Nectria species on the base of dead canes may explain this effect.

Each of the three systemic fungicides tested in 1970 for control of Botrytis of strawberries gave a significant increase in yield of healthy fruit by comparison with the control though thiabendazole was poorest in this respect. In 1971 dichlofluanid was the only fungicide to give a significant ($p < 0.05$) increase in yield of healthy fruit though plots sprayed with thiophanate-methyl and BASF 3201 F exceeded the control significantly at $p < 0.1$. Neither benomyl nor thiabendazole were better than the control in 1971. The failure of benomyl to increase yields is surprising in view of its good performance in 1970 and in previous years (Kavanagh & O'Callaghan, 1969). Dichlofluanid has not been surpassed by any of the systemic fungicides, a consoling fact in the face of reports of resistance among fungi to groups of systemic fungicides (Bollen and Scholten, 1971).

As both the 1970 and 1971 seasons were exceptionally dry and warm, the incidence of Botrytis was low. Nevertheless significant increases in yields of healthy fruit resulted from all of the fungicidal treatments in 1970 and some in 1971. Corresponding yields of diseased fruit were not obtained from the untreated control plots and the reasons for this have already been discussed (Kavanagh & O'Callaghan, 1969). This shows the inadvisability of neglecting to spray during the flowering period in dry seasons even though there is the possibility of applying benomyl before or during picking if weather conditions become adverse.

Acknowledgments

The authors wish to thank Mr. R. Cochran and the Statistics and Biometrics Department for analyses, Miss P. Newburn, Mr. J. Doyle and Mr. D. Kennedy for technical assistance. In connection with the extension experiments the authors acknowledge the help and cooperation of Mr. J.B. O'Connell, Instructor in Horticulture, and the growers concerned.

References

BOLLEN, G. J. and SCHOLTEN, G. (1971) Acquired resistance to benomyl and some other systemic fungicides in a strain of Botrytis cinerea in cyclamen. Neth. J. Pl. Path. 77, 83-90.

BURCHILL, R. T. and SWAIT, A. A. J. (1971) Raspberry spur blight (Didymella applanata). Rep. E. Malling Res. Stn. for 1970, 112.

KAVANAGH, T. and O'CALLAGHAN, T. F. (1969) A comparison of fungicides for the control of Botrytis of outdoor and protected strawberries. Proc. 5th Br. Insectic. Fungic. Conf. 139-144.

O'CALLAGHAN, T. F. (1966) A high-pressure, high-volume machine for Botrytis spraying in small plantations of strawberries. Irish J. agric. Res. 5, 283-284.

Ó RÍORDÁIN, F., KAVANAGH, T. and O'CALLAGHAN, T.F. (1966) Control of leaf spot (Pseudopeziza ribis Kleb.) of gooseberry. Irish J. agric. Res. 5, 121-128.

Ó RÍORDÁIN, F. (1969a), Experiences with 14 organic fungicides for the control of black currant leaf spot. Proc. 5th Br. Insectic. Fungic. Conf. 111-114.

Ó RÍORDÁIN, F. (1969b) Control of cane spot and spur blight of raspberry with fungicides. Proc. 5th Br. Insectic. Fungic. Conf. 155-158.

STAUNTON, W. P. (1971) Fusarium wilt of tomato. Meded. Rijksfacult. LandbWetensch. Gent. (In press).

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

CONTROL OF DISEASES OF SOFT FRUIT AND OTHER CROPS IN THE UNITED KINGDOM WITH THIOPHANATE METHYL

A.J. Gilchrist and R.J. Cole
May & Baker Ltd., Ongar Research Station, Essex

Summary Thiophanate methyl has been evaluated in replicated field trials during 1971 against diseases of strawberries, blackcurrants, dwarf beans, lettuces and bulbs and corms. In every instance it has given a satisfactory level of control equal or superior to that achieved using standard materials. Yields have been significantly greater than those from unsprayed plots and fruit finish has been excellent. Thiophanate methyl promotes vigorous, healthy growth of treated bushes and has shown itself to be completely free of phytotoxic limitations in all situations investigated to date.

INTRODUCTION

A series of replicated trials carried out in 1970 in top fruit and cereals showed thiophanate methyl to be a particularly effective fungicide with preventive and curative activity against a range of diseases. A programme of trials was therefore initiated during 1971 in order to evaluate the efficacy of thiophanate methyl against the major diseases of soft fruit and vegetables and of several other crops. In addition, Mercer (1971) has reported the wide fungicidal spectrum of thiophanate methyl in greenhouse and small plot trials in the United Kingdom while Aelbers (1970) Douchet et al (1970) Formigoni et al (1970) and Ishii (1970) have reported its efficacy against diseases of top and soft fruit overseas. Lhoste et al (1970) has demonstrated its activity against diseases of lettuce in France, while Ingram (1970) has already demonstrated its activity against blackcurrant powdery mildew in this country.

Replicated field trials were laid down in 1971 in blackcurrants, strawberries, dwarf beans, lettuce, bulbs and corms. Thiophanate methyl is also in process of evaluation at Government and other research stations against a wide range of diseases of glasshouse, food and ornamental crops.

METHOD AND MATERIALS

Ten field trials, replicated four times, were carried out in Kent on a range of strawberry varieties. One trial was located inside a 'walk-in' polythene tunnel, two were on strawberries grown under single row polythene tunnels and seven on strawberries grown in the open. Plot size was three rows wide by thirty feet long (or equivalent) and all treatments were applied three times at fortnightly intervals, i.e. at 20% blossom, full blossom and late blossom.

Seven field trials, replicated four times were carried out in Kent and the West Midlands on blackcurrants. Five trials were on cropping bushes of three different varieties and two were on bushes in their vegetative phase following machine harvesting, in all cases using single row five bush plots. Four sprays at fortnightly intervals from the grape stage were applied to the cropping bushes, and five sprays at three-weekly intervals throughout the season to the regrowth bushes.

Spray applications on strawberries were made using a Dorman high volume sprayer mounted on a Gutbrod mini-tractor, and on blackcurrants using an Evers & Wall high volume sprayer mounted on a landrover. Both were operated via the power take-off and the sprays applied by hand lance. All treatments were applied initially at 100 g.p.a., with the volume increasing slightly as foliage and new growth developed. The dose rate of 1 lb a.i./acre (1.1 kg/ha) of a 50% w.p. or 0.1% a.i. was chosen as the optimum rate from the 1970 trial work. Two other rates, ¾ lb a.i./acre (840 g/ha) and 1½ lb a.i./acre (1.7 kg/ha) were included in the 1971 trials.

Two field trials, replicated four times were carried out in Lincolnshire on tulips. Plot size was 4' x 20' and four sprays were applied at fortnightly intervals using a fixed dosage ground crop machine spraying at 21 gal/acre.

Four field trials, replicated four times were carried out on dwarf beans in the eastern counties. Plot size was 6'6" x 33' and treatments were applied high volume at full bloom using a knapsack sprayer. Trials were also carried out on lettuce, using sprays and dust formulations of thiophanate methyl.

RESULTS

Strawberries

Grey mould (Botrytis cinerea). Due to a great deal of wet weather during June, the incidence of grey mould has been fairly high. The incidence was particularly heavy on certain of the trial sites which had been chosen on the basis of susceptible varieties, old plants, and dense, bushy foliage. Assessments of grey mould were carried out on all sites two to three weeks after the third spray (see Table 2). Further assessments carried out three to four weeks after the third spray indicated that all treatments began to lose effectiveness approximately three weeks after the final spray under conditions favouring the development of grey mould.

Table 1

Strawberries: yield of marketable fruit

Treatment and dose rate (a.i./100 gal)	Weight of marketable fruit as cwt/acre, mean single fruit weight (grammes) in brackets		
	Site 5 Cambridge Vigour	Site 7* Redgauntlet	Site 11 Royal Sovereign
thiophanate methyl ¾ lb	77.8ab (6.35)	176.4a (14.85)	61.1a (5.27)
thiophanate methyl 1 lb	74.8ab (6.40)	186.5a (14.90)	44.5ab (5.55)
thiophanate methyl 1½lb	92.0a (6.77)	202.7a (14.65)	56.1ab (5.38)
dichlofluanid 2 lb	90.6a (5.94)	205.0a (14.85)	56.0ab (5.78)
benomyl ½lb	83.0a (6.16)	194.0a (14.60)	70.2a (5.06)
control	56.9 b (4.31)	165.5a (11.78)	24.1 b (4.68)
area harvested	single 20' row	single 25' row	single 12' row

*Mean fruit weight from the first two picks only

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

Table 2

Control of grey mould on strawberries

Treatment and dose rate (a.i./100 gal)	Percentage of infected fruit in a sample of at least 50 mature fruit per plot Site No. and variety							
	1+	3+	4+	6	7	8	9	10
	Redgauntlet	Redgauntlet	Cambridge Vigour	Cambridge Vigour	Redgauntlet	Cambridge Favourite	Merton Princess	Herald
thiophanate methyl $\frac{3}{4}$ lb	3.9a	4.0a	2.0a	4.7a	5.4a	4.3a	1.0a	6.0a
thiophanate methyl 1 lb	3.9a	2.0a	1.4a	3.3a	6.6a	4.0a	2.0a	10.0a
thiophanate methyl $1\frac{1}{2}$lb	3.9a	1.5a	1.0a	3.2a	3.7a	6.1a	1.0a	6.5a
dichlofluanid 2 lb	-	2.5a*	15.7 b**	3.3a	4.2a	4.7a	9.0a	5.5a
benomyl $\frac{1}{2}$lb	5.5a	4.0a	3.6a	5.0a	4.5a	9.6a	5.0a	6.5a
control	26.3 b	14.0 b	18.8 b	13.8 b	9.1a	16.7a	18.0 b	17.0 b

\+ fruit grown under polythene tunnels

* thiram applied under tunnels instead of dichlofluanid

** captan applied under tunnels instead of dichlofluanid

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

Full yield determinations were carried out on three sites which were picked over four times. All treatments yielded consistently more fruit than the controls. Extra plots at several sites were sprayed at double rate (i.e. 2 lb a.i./acre) to provide samples of fruit for residue analysis and taint testing after jamming, quick freezing and canning. A triangular taint test on fresh strawberries carried out with the Ongar Research Station tasting panel failed to show any off-flavours or taints associated with the use of thiophanate methyl.

No signs of phytotoxicity were found at any site, either in the field or under polythene tunnels and fruit of all varieties treated with thiophanate methyl had a clear bright attractive fruit finish.

Blackcurrants

Table 3

Control of leaf spot on blackcurrants

Blackcurrant leaf spot assessed by Preece key i.e. total leaves and infected leaves on each of five shoots on each of two bushes per plot, counting only leaves larger than a five penny piece in size.

Treatment and dose rate (a.i./100 gal)		Percentage of leaves infected with leafspot					
		Site 3	Site 4	Site 5	Site 6	Site 6*	Site 7
thiophanate methyl	¾ lb	0.0a	0.0a	0.0a	1.6a	53.7 b	9.7a
thiophanate methyl	1 lb	0.0a	3.1a	0.0a	0.3a	29.4a	2.8a
thiophanate methyl	1½ lb	0.0a	6.4a	0.0a	1.7a	26.9a	0.0a
drazoxolon	1 lb	0.0a	12.5a	0.0a	3.4a	62.5 b	30.5 b
benomyl	½ lb	0.0a	0.0a	0.0a	2.4a	30.0a	4.5a
control	-	55.4 b	73.5 b	50.6 b	83.9 b	97.5 c	95.9 c
variety		Baldwin	Wellington XXX	Baldwin	Baldwin		Malvern Cross
Date of assessment		7.9.71	7.9.71	7.9.71	10.8.71	24.9.71	7.9.71

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

* Site 6 assessed according to Corke key (Clarke & Corke 1956): figures show mean of scores by two independent assessors.

Leafspot (<u>Pseudopeziza ribis</u>). Leafspot appeared before harvest on only one site (site 7), on the controls only. The controls became almost defoliated before leafspot appeared on any of the treated bushes. This pattern was repeated on other sites at later dates, so it was not possible to use the Corke key for treated bushes and the use of the Preece key even for infections greater than 5% was felt to be more accurate. By early September, leafspot had occurred on four of the five cropping phase sites and on one of the two regrowth sites. Later in September, an assessment using the Corke key revealed distinct differences between treatments.

American gooseberry mildew (*Sphaerotheca mors-uvae*). Mildew first appeared on one of the regrowth sites early in June and on three cropping sites around harvest (mid-July). Infections also occurred on the remaining sites but were so slight or inconsistent as to make assessments inconclusive.

Mildew assessments were made according to the following keys:-

Mildew key for cropping phase bushes (Each of ten terminals per bush scored)

0: No lesions on terminal
1: Few lesions on lower surface of terminal
2: Numerous lesions on lower surface of terminal
3: Few lesions on upper surface of terminal with slight necrosis on lower surface
4: Numerous lesions on upper surface of terminal with heavy necrosis on lower surface
5: Defoliation

Mildew key for growing phase bushes (First ten leaves on each of five shoots per bush scored)

0: No lesions on leaf
1: One or two lesions on lower surface of leaf
2: Three or four lesions on lower surface
3: Many lesions on lower surface
4: Complete infection of lower surface
5: Complete infection of lower surface plus lesions on upper surface and petioles
6: Brown necrosis particularly on lower surface
7: Defoliation

Table 4

Control of American gooseberry mildew on blackcurrants

Mildew assessed on two bushes per plot, ten terminals on each bush selected at random and scored according to the key for cropping phase bushes, except for site 5 which was scored according to the key for growing phase bushes (see text).

Treatment and dose rate (a.i./100 gal)		Mean mildew score per plot			Mean mildew score per leaf	
		Site 3	Site 6	Site 7	Site 5	
thiophanate methyl	¾ lb	1.38a	0.91a	4.20 b	0.26a	0.75a
thiophanate methyl	1 lb	1.66ab	0.93a	3.34a	0.22a	0.89a
thiophanate methyl	1½lb	1.71ab	0.84a	3.70ab	0.15a	0.88a
drazoxolon	1 lb	2.31 bc	0.70a	3.98 b	0.26a	0.90a
benomyl	½ lb	1.40a	0.83a	3.71ab	0.32a	0.92a
control	-	2.98 c	1.86 b	4.25 b	1.94 b	5.47 b
variety		Baldwin	Baldwin	Malvern Cross	Baldwin	
date assessed		11.8.71	27.7.71	11.8.71	15.6.71	10.8.71

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

Table 5

Blackcurrants: Harvest Assessments

The mean weight in grammes of mature fruit, and the mean number of mature and green fruit per 25 strings, picked from each of two bushes per plot.

Treatment and dose rate (a.i./100 gal)		Mean weight of mature fruit per 25 strings per plot			Mean number of green fruit per 25 strings per plot	Mean number mature fruit per 25 strings per plot		
		Site 4	Site 6	Site 7	Site 7	Site 4	Site 6	Site 7
thiophanate methyl	¾ lb	190.1a	160.6a	167.4ab	14.8a	203.6ab	230.1a	227.1a
thiophanate methyl	1 lb	185.0a	154.3a	154.0ab	8.6a	200.0ab	210.4a	201.4a
thiophanate methyl	1½lb	186.6a	158.0a	143.6 b	12.4a	218.4a	202.6a	190.4a
drazoxolon	1 lb	164.5ab	167.1a	171.9a	13.5a	196.6ab	228.2a	207.1a
benomyl	½ lb	174.5ab	175.6a	158.2ab	10.6a	189.6ab	215.5a	196.5a
control	-	150.0 b	142.8a	103.1 c	52.4 b	180.9 b	217.2a	127.4 b
variety		Wellington XXX	Baldwin	Malvern Cross	Malvern Cross	Wellington XXX	Baldwin	Malvern Cross

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

The level of mildew infection on site 7 was difficult to assess accurately due to the heavy leafspot infection on the controls. It was found that terminals heavily infected with leafspot had some degree of resistance to mildew, consequently the mildew score was lower on the controls than might have been expected. The control bushes, particularly at site 7 and at certain other sites, had markedly reduced extension growth compared to the treated bushes.

Grey mould (Botrytis cinerea). Assessments carried out at harvest failed to reveal the presence of grey mould at any of the cropping sites. At three sites some of the bushes were deliberately left unpicked but no infections of grey mould occurred even a month after harvest. At one site trays of fruit from each treatment were stored for a week but very little infection occurred and the picture was confused by the development of Phycomycete fungi.

It was not feasible to carry out full yields on any of the sites so instead harvest assessments were carried out on three sites as shown in Table 5. All treatments yielded a consistently greater weight and number of fruit per 25 strings than did the controls but there were no consistent differences between the treatments. It was found that fungicidal treatment did not appear to affect the mean berry weight. On site 7 the fruit on the treated bushes matured earlier than that on the control bushes which, when harvested still had a significant proportion of immature fruit.

Extra plots at several sites were sprayed at double rate (2 lb a.i./acre) to provide samples of fruit for residue analysis and taint testing after juicing, jamming and canning. Bushes treated with thiophanate methyl in all cases bore large dark green leaves and healthy extension growth.

Bulbs and Corms

Tulip fire (Botrytis tulipae). Infections of tulip fire developed on one site only, an assessment of which, carried out two weeks after the last spray, is shown on Table 6. The following assessment key was used:-

Score 0 = no spotting - leaf free of lesions
Score 1 = up to 5 "aggressive" lesions per leaf (i.e. few scattered spots)
Score 2 = 6-10 " " " " (i.e. slight spotting)
Score 3 = 11-20 " " " " (i.e. moderate spotting)
Score 4 = 21-50 " " " " (i.e. severe spotting)
Score 5 = more than 50 " " " and leaf starting to senesce

Three weeks later the disease had progressed further, but disease incidence was still significantly lower on treated plants than on the controls. Additional trials with thiophanate methyl are still in progress involving pre-storage and pre-planting dips and field sprays on gladiolus, daffodil, narcissus and iris.

Dwarf beans

Grey mould (Botrytis cinerea). Since no signs of disease were apparent on the beans shortly before harvest, disease was induced by dragging with a rake and spraying Botrytis spore suspensions. The degree of infection, assessed at harvest, was low and variable, consequently although all treatments controlled the disease, there were no consistent differences between the treatments themselves. However, all treatments increased yield compared to the unsprayed controls, even where disease incidence was negligible.

Table 6

Control of tulip fire by foliar sprays

Disease assessed on 25 plants per plot by scoring top and bottom leaves

Treatment and dose rate (a.i./acre)		Disease rating (Mean score) 5.5.71
thiophanate methyl	¾ lb	1.2 bc
thiophanate methyl	1 lb	0.9abc
thiophanate methyl	1½lb	0.8ab
maneb	1½lb	0.7a
benomyl	½ lb	1.3 c
control	-	2.2 d

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

Lettuce

Grey mould (Botrytis cinerea). The trials were carried out rather late in the year when the temperature was above the critical infection temperature (14°C). Subsequently, despite spraying a Botrytis spore suspension, the disease failed to develop until the end of the season when two control plants became infected.

DISCUSSION

The results obtained using thiophanate methyl against diseases of soft fruit in 1971 are very encouraging. During a season favouring the development of strawberry grey mould, the degree of control obtained was equal to or better than the standard materials used. The strawberry yield figures obtained were rather variable since it was only feasible to pick small areas. Nevertheless, they do show that thiophanate methyl brings about an increase in yield over unsprayed plots, comparable with that obtained using standard materials. It was felt that some yield increase was also obtained in the absence of disease but it was not possible to demonstrate this in the 1971 trials. The mean berry weight from plots sprayed with thiophanate methyl was greater than that from unsprayed plots and equal to, if not greater than, that from plots sprayed with standard materials.

Harvest assessments carried out on blackcurrants show that bushes sprayed with thiophanate methyl yielded significantly more fruit both in numbers and weight per twenty-five strings than did unsprayed bushes, but the mean berry weight was unaffected by fungicidal treatment.

Thiophanate methyl gave a satisfactory level of control of mildew and leafspot, the disease level on treated bushes being significantly less than on unsprayed bushes. The mildew control at Site 5 was quite acceptable considering a three weekly spray regime on bushes regrowing vigorously from ground level to a height of 4-5 ft.

Results obtained against tulip fire and grey mould of dwarf beans are also encouraging, as are those in many other disease situations against which thiophanate methyl is currently being evaluated.

Thiophanate methyl has shown itself to be completely non-phytotoxic when used in all the above crops (including strawberries grown under polythene tunnels) at rates of up to 2 lb a.i./acre and crop vigour and fruit finish has been enhanced by its use.

Acknowledgements

The authors acknowledge the assistance of their colleagues at May & Baker Ltd. in the execution of this work.

References

Aelbers, A. (1970) 22nd International Symposium on Crop Protection, Ghent, pp 126-134.

Clarke, G.M. and Corke, A.T.K. (1956) Rep. Agric. Hort. Res. Stat. Univ. Bristol. 1955.

Douchet, J.P., Lhoste J. and Quere, G. (1970) 22nd International Symposium on Crop Protection, Ghent, pp 135-141.

Duncan, D.B. (1955) Biometrics 11, pp 1-7.

Formigoni, A., Castagna, G. and Ciocca, P. (1970) 22nd International Symposium on Crop Protection, Ghent, pp 96-108.

Ingram, J. (1970) 21st Ann. Rep. Luddington Exptl. Hort. Sta., Part 1 pp 40-41.

Ishii, K. (1970) VIIth International Congress of Plant Protection, Paris, p. 200.

Lhoste, J., Douchet, J.P. and Penchi, L. (1970). Phytiat. Phytopharm. 19, (4), pp 167-170.

Mercer, R.T. (1971). Pestic. Sci. (in press).

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

THIABENDAZOLE - BROAD SPECTRUM FUNGICIDE - FIELD EXPERIENCE OF ITS PERFORMANCE ON A RANGE OF CROPS IN THE UNITED KINGDOM

M.R.L.W. Ayers and D. Gunary
Rothwell Plant Breeders Limited, Lincoln

Summary Results of trials are reported which show that thiabendazole has given significant control of the Wilt complex of Carnations, *Botrytis cinerea* and *Pseudopeziza ribis* of Blackcurrants and *Verticillium albo-atrum* of Hops. Significant activity against turf disease is also reported. Comments are made on the use of thiabendazole on some other crops.

INTRODUCTION

The spectrum of anti-fungal activity of thiabendazole was reported to this Conference by Weinke, K.E. *et al* (1969). At that time there was little experience of its use in the United Kingdom. Since then field trials have been conducted in the United Kingdom on a range of crops and diseases. This paper seeks to report the results of some of the trials. The effect of thiabendazole on storage diseases of apples, mainly *Gloeosporium* species, is discussed by Pleisch *et al* (1971), and on other apple diseases, *Venturia inaequalis* and *Podosphaera leucotricha* by von Keyserlingk and Wihrheim (1971), already presented at this Conference.

METHOD AND MATERIALS

Material The chemical, physical and toxicological properties of thiabendazole have been described elsewhere, Weinke, K.E. *et al* (1969). Thiabendazole has commercial clearance under the Pesticides Safety Precautions Scheme for use on a wide range of fruits, vegetables, ornamentals and glasshouse crops.

The formulation of thiabendazole used in the trials reported here is PBA 13 which is a 60% wettable powder and has been shown to be superior to previous formulations of thiabendazole. (Private communication Wagner 1971). Rates of application given in the tables are given in terms of the active ingredient.

In all trials spray applications were to run off and drenches were applied at a rate of 2 gallons per sq. yd. The trials were laid out as randomised blocks and replicated four or more times. Samples from trials in 1971 have been taken for further studies of residue and taint. Previous samples have shown low residues and no taints.

The details of treatment and the assessments made differed from trial to trial and are discussed along with the results.

RESULTS

Carnations

Phytotoxicity   Trials were initiated in 1971 to assess the levels of thiabendazole which could safely be applied to carnation crops of various ages. These trials were conducted on crops which were six months and twelve months old at the time of the first application. Three varieties featured in the trial started at six months and eight varieties in the trial started at twelve months old. The plot size was 56 plants.

Results to date indicate that carnations will tolerate thiabendazole from six months after planting when treated at fourteen-day intervals with either 0.2% spray or 3.6g. per sq. yd. drench.

Wilt control and crop performance   A trial was conducted in 1969-70 to investigate the effectiveness of thiabendazole against the *Fusarium* complex causing wilt in carnations. Treatments were:

1. Four drenches of 1.8g. per sq. yd. at three monthly intervals.

2. Six sprays of 0.1% at two monthly intervals.

3. Four drenches and four sprays (as above) at three monthly intervals.

The effects of thiabendazole on wilt eleven months after the commencement of treatment is reported in Table 1 and the effects on vigour in Table 2.

Table 1

THE EFFECT OF THIABENDAZOLE ON CARNATION WILT (W. Sussex 1970)

Treatment	Mean wilted plants per plot
Nil	27.83
Thiabendazole drench	16.33 **
Thiabendazole spray	13.67 ***
Thiabendazole drench + spray	13.83 ***

** Significantly different from untreated at 1% level.

*** Significantly different from untreated at 0.1% level.

Table 2

THE EFFECT OF THIABENDAZOLE ON CARNATION VIGOUR (W. Sussex 1969/70)

(Accumulative number of shoots more than 5ft. high)

Treatment	Date and Record 18.8.69	5.11.69	5.1.70
Nil	686	846	1232
Thiabendazole drench	881	904	1502
Thiabendazole spray	773	864	1588
Thiabendazole drench + spray	931	931	1629

These results show a significant reduction in wilt as a result of either drench or spray treatment. The wilt control was reflected in an improvement in vigour.

A further series of trials to control carnation wilt was conducted on one year old crops during 1971. Treatments were:

1. Drenches of 1.8g. per sq. yd. at monthly intervals.
2. Drenches of 3.6g. per sq. yd. at two monthly intervals.
3. Sprays of 0.1% at monthly intervals.
4. Sprays of 0.2% at two monthly intervals.

The extent of wilt control brought about by various treatments with thiabendazole is reported in Table 3.

Table 3

THE EFFECT OF THIABENDAZOLE ON CARNATION WILT (W. Sussex 1971)

(Increase in total wilted plant numbers after treatment)

Treatment	Site 1	Site 2
Nil	173	215
Thiabendazole monthly drench	113	101
Thiabendazole two monthly drench	222	203
Thiabendazole monthly spray	192	281
Thiabendazole two monthly spray	150	143

From this table it can be seen that monthly treatment with 0.02% thiabendazole drench has brought about the greatest degree of wilt control.

The significance of these results will be discussed later.

Tulips

A trial was established in 1971 to spray tulips to control Tulip Fire (*Botrytis tulipae*). The crop was sprayed on six occasions at fourteen-day intervals. There were no signs of phytotoxicity even at the highest level of 0.09% thiabendazole. It is intended to examine the effects of these treatments plus dip treatments on the development of disease and the crop during subsequent growth. The weight of bulbs recorded from each treatment is presented in Table 4 which shows an unexpected bonus in terms of an increase in yield resulting from thiabendazole treatments.

Table 4

THE EFFECT OF THIABENDAZOLE SPRAY ON YIELD OF HARVESTED TULIP BULBS (Lincolnshire 1971)

(kg. bulbs per 24 metres of row)

Treatment	Variety: Most miles	Variety: London	Variety: Top score
Nil	31.5	48.6	22.0
0.03% Thiabendazole spray	37.5	49.5	22.2
0.06% Thiabendazole spray	39.2	47.8	24.6
0.09% Thiabendazole spray	39.1	46.0	24.8

Blackcurrants

No phytotoxicity was apparent on varieties Baldwin and Wellington XXX when four pre-harvest sprays and one post-harvest spray were applied at 0.09% thiabendazole.

Table 5 demonstrates the yield increase following treatment with thiabendazole and the considerable reduction in the quantity of Leaf Spot (*Pseudopeziza ribis*) in trials in Suffolk.

Table 5

THE EFFECT OF THIABENDAZOLE SPRAY ON YIELD AND LEAF SPOT IN BLACKCURRANTS (Suffolk 1971)

Treatment	Site I Yield (kg/ha)	Site I % Leaf Spot 25.8.71	Site II % Leaf Spot 20.9.71
Nil	10.290	91.5	78.2
0.03% Thiabendazole spray	10,480	25.0	20.0
0.06% Thiabendazole spray	12,080	15.0	7.5
0.09% Thiabendazole spray	14,440	11.2	4.0

In these trials the levels of Grey Mould (*Botrytis cinerea*) and Mildew (*Sphaerotheca mors-uvae*) were too low to give meaningful assessments.

No yield data was collected at Site II due to severe frosts during the flowering period. Leaf Spot was later developing at Site II.

A third trial was conducted in 1971 in which Botrytis infection was sufficiently high to record the effectiveness of thiabendazole. The results of this trial are given in Table 6 which shows that there is a substantial degree of control of Botrytis resulting from four thiabendazole applications.

Table 6

THE EFFECT OF THIABENDAZOLE SPRAY ON BOTRYTIS IN BLACKCURRANTS (W. Sussex 1971)

(Number of infected centres per 25 sample units)

Treatment	Date of Assay		
	3.6.71	25.6.71	5.7.71
Nil	151	55	23
0.03% Thiabendazole spray	44	13	10
0.06% Thiabendazole spray	41	12	4
0.09% Thiabendazole spray	35	2	2

The assessment method was based on 50 linear feet of growth bearing currants per plot made up of 25 two foot units. The number of Botrytis infected centres were recorded per unit.

Hops

It has been suggested that thiabendazole may be effective in controlling mild (fluctuating) Hop Wilt (*Verticillium albo-atrum*). A trial was consequently initiated in 1971 to look at the effects of various drench treatments on the development of this disease. Three drenches were applied at six-weekly intervals on 27th April, 8th June and 20th July. The plot size was four hills which had shown wilt symptoms in previous years. The effect of these treatments on Hop Wilt is summarised in Table 7.

Table 7

THE EFFECT OF THIABENDAZOLE ON MILD (FLUCTUATING) HOP WILT (Herefordshire 1971)

(Total score for degree of infection)

Treatment	Date of Assay			
	28.6.71	20.7.71	10.8.71	10.9.71
Nil	0	42	29	39
1.8g Thiabendazole drench	0	21	13	13
3.6g Thiabendazole drench	0	15	17	5

This data shows that fluctuating wilt was reduced by these drench treatments on the bine (col. 1-3) and on the cones (col. 4). The score was assessed on a 0-10 scale as shown below:

Assessment Scale on Hops for Wilt

0	Normal healthy plant and/or cones
1	Plant showing some chlorosis
2	Plant showing up to 25% chlorosis
3	Plant showing up to 50% chlorosis
4	Plant showing up to 75% chlorosis and some necrosis
5	Plant showing up to 25% necrosis
6	Plant showing up to 35% necrosis
7	Plant showing up to 50% necrosis
8	Plant showing up to 60% necrosis
9	Plant showing up to 75% necrosis
10	Plant showing complete necrosis

Cucumbers

The effects of drench application at 1.8g and 3.6g thiabendazole to cucumbers under glass demonstrated that these levels of application were phytotoxic. Spray applications at 0.03% and 0.06% thiabendazole also gave mild symptoms of phytotoxicity. The varieties in this trial were Butchers Disease Resistant, Sporu and Green Spot. It is concluded that the PBA 13 formulation of thiabendazole should not be used as a regular treatment on this crop at rates as high as 1.8g drench and 0.03% spray. Further trials are required at lower rates.

Turf

Preliminary trials on turf have shown that thiabendazole has a marked effect on Fusarium Patch disease (Fusarium nivale) and Red Thread disease (Corticium fuciforme). Trials were thus initiated on bowling greens, tennis courts and golf courses to examine these effects. Trials are currently in progress but early signs are that treatment of infected turf with thiabendazole brings about a rapid improvement of green colour.

Weather conditions have been more suited to the development of Corticium than Fusarium and therefore it is the control of the former disease that is reported here.

Thiabendazole was applied at 1.2 oz, 2.4 oz and 4.8 oz per 1000 sq. ft. The water rate was 25 gallons per acre. The effect of treatment is shown in Table 8.

Table 8

THE EFFECT OF THIABENDAZOLE ON CORTICIUM DISEASE
(Essex and Hertfordshire 1971)

(Number of red threads per sq. ft.)

Treatment	Essex	Hertfordshire
Nil	15.8	20.7
1.2 oz Thiabendazole spray	7.3	7.1
2.4 oz Thiabendazole spray	3.0	6.5
4.8 oz Thiabendazole spray	-	3.3

Three applications were made at the Essex site and two at the Hertfordshire site. The plot size was 40 sq. yd. Applications were made at fourteen-day intervals. The above assessments were made two weeks after the last application.

Potatoes

Hirst and his co-workers at Rothamsted have reported elsewhere (References 1,2,3) the effectiveness of thiabendazole powder on Skin Spot (*Oospora pustulans*), Silver Scurf (*Helminthosporium solani*), Black Scurf (*Rhizoctonia solani*) and Gangrene (*Phoma exigua*). Following upon these trials field-scale experiments have been done with early-stage multiplication crops of the following potato varieties: Desiree, Vanessa, Avenir, Sirtema, Bonte Desiree and Jaerla. Treatment of tubers with a 2.5% thiabendazole power brought about no reduction in emergence or in development of the growing crop. The effect of these treatments on crop yield and on subsequent health of the tubers has still to be assessed. It is planned to go ahead with further field-scale trials during the coming season using a prototype commercial dresser.

Other Crops

Trials are still in progress looking at the effectiveness of thiabendazole on other fruit, vegetable and ornamental crops and results of these will be reported in due course.

DISCUSSION

The wide range of fungicidal activity of thiabendazole reported by Weinke *et al* at the previous meeting of the Conference is likely to lead to its effective commercial use on a range of crops in the United Kingdom. Apart from its effectiveness on the apple crop reported elsewhere, thiabendazole brings about practical control of a number of diseases under commercial style tests.

The reduction in the amount and in the rate of development of Carnation Wilt can have significant advantages for the carnation grower. This disease develops most rapidly in the second year of the carnation crop and thiabendazole sprays and drenches have been shown to reduce the rate of development of the disease and to increase the vigour of the remaining crop.

Although a trial was not found in which Botrytis and Leaf Spot were present simultaneously on the blackcurrant crop, the results of trials reported here would suggest the effective use of this chemical on blackcurrants. The substantial increase in yield resulting from this treatment would justify the four applications which are recommended.

It is significant that the effectiveness of thiabendazole is frequently greatest when it is applied as a soil application and is absorbed through the root system. Thus drenches of carnations and of hops and the powdering of potato tubers bring about very substantial reductions in disease level. Similarly, the control of turf diseases indicates the continuing activity of this product when in contact with soil. The effectiveness and stability of performance of thiabendazole when applied in this way would suggest that short-term inactivation of this chemical in soil does not occur although in the long term no build up would appear likely (Hamer - Private communication, 1970).

The encouraging results which have come from the trials programme would confirm the suggestion that the newer PBA 13 formulation of thiabendazole is significantly active against a wide range of diseases.

Acknowledgments

The authors gratefully acknowledge the assistance of co-operating growers and the technical assistance provided by Miss Rosie Gowing. Thanks are also due to Mr. Peter Hamer for providing some of the experimental data.

References

1. HIDE, G.A., HIRST, J.M. and GRIFFITHS, R.L. (1969) Proc. 5th Insectic. Fungic.Conf. 2, 310-314
2. HIRST, J.M. (1969) Rep. Rothamsted exp. Stn. 1969, 139-175
3. HIRST, J.M., HIDE, G.A., GRIFFITHS, R.L. and STEDMAN, O.J. (1970) J.R.A.S.E. 131, 87-106
4. VON KEYSERLINGK, N. and WIHRHEIM, S.E. (1971) Proc. 6th Insectic. Fungic. Conf. Vol 3.
5. PLEISCH, P. et al (1971) Proc. 6th Insectic. Fungic. Conf.
6. ROBINSON, H.J. et al (1964) Journal of Invest. Dermatology 42, 479
7. STARON, Th. and ALLARD, A. (1964) Phytiatrie-Phytopharmacie 13, 163
8. STARON, Th. et al (1966) Phytiatrie-Phytopharmacie 15, 129
9. WEINKE, K.E. et al (1969) Proc. 5th Insectic. Fungic. Conf. 2, 340

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

SOME RESULTS OBTAINED IN THE UNITED KINGDOM USING DODEMORPH FOR THE CONTROL OF POWDERY MILDEWS IN ROSES AND OTHER ORNAMENTALS

A.J.P. Frost and Naomi Pattisson
BASF United Kingdom Limited, Ipswich, Suffolk.

Summary Tests were conducted with dodemorph used alone, and as a special mixture with dodine. Dodemorph, at a concentration of 0.1% active ingredient, applied as a programme at 10 day intervals or as a single eradicant spray, gave excellent control of powdery mildew (Sphaerotheca pannosa) on roses under glass. Similar results on roses outdoors were obtained with a spray programme commenced before mildew became established. With high levels of infection on roses outside it was necessary to increase the concentration of percentage active ingredient, or to reduce the interval between applications.

Observations on other ornamentals indicated that Aster, Clematis, Crataegus, Prunus laurocerasus, Quercus and Solidago could safely be treated with dodemorph, and useful control of powdery mildews obtained.

INTRODUCTION

Dodemorph is the common chemical name for 4-cyclododecyl-2,6-dimethyl morpholinacetate. Reports of the chemical structure and properties have been presented on previous occasions (J. Kradel et al. - 1969).

Results obtained with dodemorph in Germany during the period 1963-69, summarised by J. Kradel et al. (1970), indicated that the material is very effective in controlling powdery mildews in a wide range of ornamental plants, but particularly against powdery mildew of roses (Sphaerotheca pannosa).

This paper is an attempt to summarise the results obtained with dodemorph against powdery mildew of roses in the United Kingdom during the period 1970-71. A note on the effect on other ornamentals is also included.

METHODS AND MATERIALS

All trials quoted were laid down in a randomised block design, with a minimum of three replicates. Materials were applied using pressurised sprayers, with application to 'run-off'.

Assessment methods varied considerably, but those most commonly used were:-

1) Estimation of the percentage of the leaf covered with mildew using standard diagrams as described by T.V. Price (1970).

2) Division of the leaf into quarters and recording the presence or absence of mildew in each quarter.

3) Counting the number of leaflets infected with mildew and expressing this figure as a percentage.

In each case assessment was carried out on the underside of the leaf, with only young growth being examined.

Formulations used:-

BAS 2382F - an emulsifiable concentrate containing 40% w/v dodemorph

BAS 3101F - an emulsifiable concentrate containing 28% w/v dodemorph plus 5.8% w/v dodine

The formulation including dodine was developed primarily for use on outdoor roses, the dodine being included to control blackspot (Diplocarpon rosae) and rust (Phragmidium spp.); however, neither of these diseases occurred in any of the trials.

RESULTS

The effect of a single application of dodemorph on the level of powdery mildew on roses under glass is illustrated in Table 1; the effect of a spray programme is illustrated in Tables 2 and 3. In Table 2 the spray programme commenced before mildew appeared and in Table 3 the spray programme commenced when mildew was already established.

Table 1

The effect of a single application of dodemorph against powdery mildew on the c.v. Interflora under glass

Treatment	conc. a.i. %	% mildew infection 5 days after treatment
Untreated	-	34.5
BAS 2382F	0.1	1.8
Dinocap	0.1	13.2

Site - Sussex
Sprayed - 15.8.70 Assessed 20.8.70

Table 2

The effect of a programme of applications of dodemorph against powdery mildew on the c.v. Carol under glass

Treatment	% Mildew Infection		
Untreated	60	60	70
BAS 2382F	0	0	0
Assessment date	17.5.71	26.5.71	9.6.71

Site - Herts.

Dodemorph (at a concentration of 0.1% a.i.) was applied at 9-10 day intervals, commencing on the 28th April, before the disease appeared.

Table 3

The effect of two applications of dodemorph against powdery mildew on the c.v. Baccara under glass

Treatment	% Mildew Infection	
Untreated	75	60
BAS 2382F	75	10
Assessment date	21.6.71*	21.7.71

* at 1st application

Site - Herts.

Dodemorph (at a concentration of 0.1% a.i.) was applied on the 21st June and the 30th June, when the disease was established.

The treatment of rose rootstocks under glass, although resulting in good control, was less effective than treatment of Hybrid Tea roses. The effect of a spray programme is illustrated in Table 4.

Table 4

The effect of a programme of applications of dodemorph against powdery mildew on rootstock sp. Rosa canina under glass

Treatment	% Mildew Infection		
Untreated	40	75	85
BAS 2382F	20	5	40
Assessment date	17.5.71	26.5.71	9.6.71

The final assessment was made 14 days after the last application.

Site - Herts.

Dodemorph (at a concentration of 0.1% a.i.) was applied at 9-10 day intervals, commencing on the 28th April.

A number of trials were laid down in 1970 to compare two formulations of dodemorph (each applied at 2 concentrations) with dinocap for the control of high levels of mildew infection on roses grown outside at sites in Suffolk and Wilts. The results on three varieties are summarised in Table 5. Spray intervals varied between 5 and 18 days.

Table 5

The effect of applications of dodemorph against powdery mildew on roses outside

Treatment	Conc. a.i. %	% Mildew Infection		
Untreated	-	54	90	93
BAS 2382F	0.1	31	49	55
"	0.2	2	23	41
BAS 3101F	0.084	17	30	45
"	0.168	5	15	35
Dinocap	0.1	21	73	80
Cultivar		Message	Crimson Glory	Christian Dior

Dodemorph applied as a programme to roses outside, commencing before the disease became established, gave good control throughout the season as is shown in Tables 6 and 7.

In both trials, dodemorph (at a concentration of 0.1% a.i.) was applied at 14-day intervals, commencing on the 30th June 1971.

Table 6

The effect of a programme of applications of dodemorph on established bushes of the c.v. Frensham outside

Treatment	% Mildew Infection				
Untreated	4.6	11.7	15.3	12.4	15.8
BAS 2382F	4.2	2.8	2.9	2.6	3.1
Assessment date	23.7.71	30.7.71	6.8.71	13.8.71	20.8.71

Site - Silwood Park, Ascot, Berks.

Table 7

The effect of a programme of applications of dodemorph on one year old bushes of the c.v. Frensham outside

Treatment	% Mildew Infection					
Untreated	4.6	21.2	9.3	6.5	9.0	10.8
BAS 2382F	0.7	3.8	2.2	1.3	1.1	1.3
Assessment date	19.7.71	28.7.71	4.8.71	9.8.71	16.8.71	23.8.71

Site - Silwood Park, Ascot, Berks.

In a trial carried out on rose rootstocks, programmes of spray applications of dodemorph (at a concentration of 0.1% active ingredient) at 7 and 10 day intervals were compared for control of mildew, as is shown in Table 8.

Table 8

The effect of varying the application interval of spray programmes of dodemorph

Treatment	Spray Interval	% Mildew Infection					
Untreated		5.9	18.9	54.7	64.8	72.2	73.2
BAS 2382F	7 days	5.1	11.9	24.6	16.5	16.3	30.0
"	10 days	6.4	15.6	35.6	26.9	26.0	48.9
Assessment date		*13.7.71	23.7.71	4.8.71	13.8.71	25.8.71	4.9.71

*Assessment at 13.7.71 indicates disease levels at commencement of spray programmes.

Site - Shardlow, Derby.

Dodemorph was applied at a concentration of 0.1% a.i., on rose rootstocks sp. R. canina Pfänder.

Dodemorph has been applied to a number of ornamentals other than roses, but no quantitative results are available. It has however, been demonstrated that the material may be safely applied to Aster, Clematis, Crataegus, Prunus laurocerasus, Quercus and Solidago, at rates of 0.1 - 0.2% active ingredient, with useful control of powdery mildew being obtained.

DISCUSSION

The results quoted show that dodemorph applied at a rate of 0.1% active ingredient gave excellent control of powdery mildew on bush roses growing under glass. A programme of applications at 10 day intervals gave complete protection against the disease, while a single application had an extremely good eradicant effect. Ideally the grower would apply a protectant programme, with applications at 10 day intervals; however, as dodemorph shows very good eradicant activity, the interval may be extended and applications made whenever mildew makes an appearance.

It must, of course, be remembered that, with an eradicant spray, the chemical cannot repair the damage already caused by the disease, and so the mildew must not be allowed to develop to high levels before spraying.

Dodemorph proved slightly less effective in controlling powdery mildew on rootstocks grown under glass, although it did give good control. To compensate for the slightly lower level of activity, it may be necessary to either reduce the spraying interval, or increase the concentration of active ingredient.

On roses grown outdoors the situation is rather more complex. Very good control was achieved with a programme of sprays of dodemorph at 14 day intervals, when spraying was commenced before mildew became established. The level of control appeared to be slightly better on maiden bushes than on established bushes. To control the disease under adverse conditions, i.e. to eradicate high levels of infection during conditions which favour development of the disease, the rate of application should be increased above 0.1% a.i. Results show that an increase in disease control was obtained by either increasing the concentration of the active ingredient, or by reducing the time interval between applications.

A wide range of other ornamentals are affected by various powdery mildews, and evidence has shown that on a number of them, dodemorph gave useful control with no damage to the host plant.

Acknowledgments

The authors wish to thank Dr. B.E.J. Wheeler and Dr. E.J. Evans for permission to reproduce their results, and also to thank Messrs. H.C. May, J.L. Bedford and T. Osborne for their help with the trials programme. Thanks are also due to the growers who assisted in this trials work.

References

Kradel, J et al. (1967) Proc. British Insecticide and Fungicide Conf., 170

Kradel, J et al. (1970) Internal Report of BASF Agricultural Research Station, Limburgerhof.

Price, T.V. (1969) Ann. appl. Biol (1970), 65, 231 - 248

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

CONTROL OF DISEASES OF FIVE VEGETABLE CROPS WITH SYSTEMIC FUNGICIDES

E.W. Ryan, W.P. Staunton & T. Kavanagh
Agricultural Institute, Kinsealy Research Centre, Dublin, 5.

Summary Systemic fungicides gave satisfactory control of a number of vegetable diseases. Benomyl controlled both Botrytis (B. cinerea) and anthracnose (Colletotrichum lindemuthianum) of French beans when applied at full bloom at a rate of 0.5 lb a.i./ac or greater. Thiophanate-methyl and dichlozoline * also gave good control of Botrytis. For control of white rot (Sclerotium cepivorum) of onions, benomyl applied to seed gave control comparable to that obtained with calomel. Dusting of onion sets with benomyl increased survival in soil infested with S. cepivorum. Benomyl applied as a drench at 100 mg a.i. per plant controlled Fusarium wilt of tomatoes when applied at fortnightly intervals. It also had a therapeutic effect when applied to plants already infected with Fusarium. Dipping chicory roots in a solution of benomyl before forcing gave good control of Sclerotinia rot. Benomyl applied as a drench controlled powdery mildew (Sphaerotheca fuliginea) of cucumbers grown in sphagnum peat but drenching with dimethirimol and triarimol was ineffective in this growing medium.

INTRODUCTION

In this paper we present results obtained at Kinsealy Research Centre on the use of systemic fungicides for control of the following diseases: Botrytis and anthracnose of French beans, white rot of onion, Fusarium wilt of tomato, Sclerotinia rot of chicory and powdery mildew of cucumber. In the past these diseases have been of considerable importance and some of them were difficult or uneconomic to control using the common non-systemic, protectant fungicides.

MATERIALS AND METHODS

Owing to the number of crops and experiments, experimental details are given under each crop, together with the results. The fungicides used in all experiments were standard commercial formulations.

EXPERIMENTAL DETAILS AND RESULTS

French Beans.

Botrytis (B. cinerea) and Anthracnose (Colletotrichum lindemuthianum). Fungicidal applications were by hydraulic knapsack sprayer at volumes between 50 and 70 gal/ac (468-818 l./ha). Individual plots were four rows of beans 46 cm apart and varied in length from 4.5 to 7.5 m. In all cases, 3 m of the two centre rows were harvested and rated for disease. In some experiments, plants were sprayed with a spore suspension of C. lindemuthianum 4 weeks after sowing, and pods were examined for Botrytis and anthracnose; in other experiments, no inoculation was carried out and only Botrytis occurred.

* dichlozoline is suggested name for 3-(3,5-dichlorophenyl)- 5,5-dimethyl oxazolidinedione -2,4

Prior to systemic fungicide trials, single and repeated applications of thiram and dichlofluanid were tested. A significant, though slight, reduction in Botrytis was obtained only with two applications of dichlofluanid. For control of both Botrytis and anthracnose, benomyl, dichlofluanid and fentin acetate with maneb were applied at full flower, 12 days after full flower, and at both times (Table 1). Benomyl was the most effective fungicide and gave good control of both Botrytis and anthracnose; the earlier application was the more effective and gave control equal to two applications. In a subsequent experiment the optimum rates of benomyl for control of Botrytis and anthracnose were 0.5 lb and 0.75 lb a.i./ac (0.6 and 0.8 kg/ha) respectively.

Preliminary results from a comparison of systemic fungicides indicate that thiophanate methyl, benomyl and dichlozoline are effective against Botrytis, but poor control was obtained with thiabendazole.

Table 1

A comparison of three fungicides and three application schedules for the control of Botrytis and anthracnose of French beans

Fungicide	Rate a.i. lb/ac	(kg/ha)	Time of application[1]	Diseased pods (%) Botrytis	Anthracnose
Benomyl	1.0	(1.1)	E	0.2***	1.0***
			L	2.4***	1.8***
			E + L	0.4***	1.4***
Dichlofluanid	3.0	(3.4)	E	7.7	3.1**
			L	6.1*	6.5
			E + L	5.1**	2.4***
Fentin acetate	0.6	(0.7)	E	8.0	6.1*
with maneb	0.2	(0.2)	L	6.6	7.8
			E + L	7.0	5.2*
Unsprayed control			-	9.1	10.5

*, **, *** - significantly better than control at 5%, 1% and 0.1% respectively.

1. E = full flower; L = 12 days after full flower.

Onions

White rot (Sclerotium cepivorum). Onion seed, cv. White Lisbon, was treated with calomel at two rates and benomyl at four rates using a 'Polycel' sticker as described by Fletcher (1964). Treated seed was allowed to dry in shallow trays for 4 days before sowing in the field on April 19 using a five-row Stanhay seeder. The soil was inoculated 3 days before sowing by raking in inoculum of S. cepivorum growing on a beet seed medium at the rate of 37.5g inoculum/m^2. Individual plots were five rows 25 cm apart and 2.5 m long with four replications. Onions were harvested and examined for disease on September 15. All treatments reduced disease, the four rates of benomyl giving control approaching that of the calomel treatments (Table 2).

Table 2.

Effect of seed treatments on white rot incidence in onions, cv. White Lisbon

	Fungicide and rate (g a.i./kg seed)						Untreated Control
	Calomel		Benomyl				
	1000	500	500	250	125	62.5	
White rot (%)	49	59	61	57	62	66	81

Onion sets, cv. Rijnsburger, were dusted with benomyl at five rates, a little water, 2 - 3 ml/kg, being sprayed on the sets to improve adhesion at the highest two rates. Immediately after treatment on April 21 the sets were planted in the field in soil inoculated with S. cepivorum (75 g inoculum/m^2) and in non-inoculated soil. Individual plots consisted of 125 sets in five lines 25 cm apart and 1.5 m long, with four replications in inoculated and two in non-inoculated soil. Bulbs were harvested and examined for disease on September 16. Few diseased bulbs were found but, in the inoculated soil, treatment of sets increased the number of plants that survived (Table 3). However, in both inoculated and non-inoculated soil there were fewer survivors from sets treated at high rates of benomyl than from those treated at lower rates.

Table 3

Effect of benomyl treatment of sets on survival of onion plants, cv. Rijnsburger, in soil inoculated with S. cepivorum and in non-inoculated soil

		Rate of benomyl (g a.i./kg sets)					
		10	5	2	1	0.5	0
Survival (%)	Inoculated	80	85	87	90	94	46
	Non-inoculated	86	84	91	94	91	96

Tomatoes

Fusarium wilt (Fusarium oxysporum f.sp. lycopersici). Benomyl is reported to be effective against this disease (Thanassoulopoulos et al, 1970). In experiments to confirm and enlarge on these results under Irish conditions the Fusarium -susceptible tomato cultivar Eurocross BB was used. Plants were grown in a glasshouse at an air temperature of 24 to 27°C. Benomyl was applied as a drench at various rates and times before and after inoculation to plants grown in peat-filled, 12 cm plastic pots inoculated with a Fusarium spore suspension. Drenches containing 20 mg a.i. applied at up to 3-week intervals gave effective control of Fusarium wilt. Benomyl was also tested for effectiveness against Fusarium wilt of larger tomato plants under semi-commercial growing conditions. Plants were grown in polythene-lined troughs divided into plots 90 cm wide by 90 cm long by 45 cm deep containing Fusarium-infested peat. A completely randomised design with four replications and four plants per replicate was used. Benomyl at 100 mg a.i. in 200 ml water per plant was applied as a drench at two intervals, 14 and 28 days. The plants were grown until fully mature and were rated visually for disease. Both treatments significantly ($P < 0.01$) reduced the level of disease compared with the untreated control, the 14-day being better than the 28-day interval.

Following a preliminary trial in which a benomyl drench had a therapeutic effect on *Fusarium* wilt, an experiment was done to determine the time period after infection within which this effect could be exerted. Plants in peat-filled pots were inoculated with *Fusarium* by pouring a spore suspension (4×10^6 spores/ml) around the base of the plant. The plants were treated with benomyl at 20 mg a.i. in 20 ml water per plant at different times after inoculation. Before each treatment, petiole sections were taken from each of the plants and tested for *Fusarium*; a second test was done 2 weeks after treatment. Plants tested one or two weeks after inoculation and before treatment were 60 - 70% *Fusarium*-infected but following treatment no *Fusarium* could be isolated from the same plants. Plants tested either 3 or 4 weeks after inoculation and before treatment were 100% infected but following treatment these remained 100% infected. This indicates that under the conditions of this trial benomyl had a therapeutic effect when applied up to 2 weeks after inoculation with *Fusarium*.

Chicory

Sclerotinia rot (*Sclerotinia sclerotiorum*). Trials were done comparing benomyl and a non-systemic fungicide for control of *Sclerotinia* rot on chicory roots. All experiments consisted of five treatments in a randomised block design with four replications. Disease was assessed on individual roots at the end of the forcing period by a visual rating based on a scale 0 = no disease to 4 = roots completely rotted.

In the first experiment roots stored for 5 weeks were placed in a forcing bed and fungicides were sprayed over them in 567 ml water per plot. Although some of the treatments produced a significant effect on disease, only 39% of the roots in the best treatment produced marketable chicons (Table 4).

Table 4

Effect on Sclerotinia rot and yield of chicons of (I) spraying fungicides on to the roots in a forcing bed and (II) dipping the roots in fungicides before forcing

Fungicide	(I) Spray treatment			(II) Pre-forcing dip		
	Rate (g a.i./m^2)	Disease[1]	Yield[2]	Rate (g a.i./~~m^2~~ litre)	Disease[1]	Yield[2]
A Benomyl	0.2	2.3	34	1.6	1.2	42**
B Benomyl	2.2	1.6	31	3.9	0.2***	57***
C Dicloran 25% & PCNB 26%	20.0	1.0**	39**	0.8	0.3***	55***
D A and C		0.9**	37*		0.3***	43**
E Water (control)		1.9	23		2.1	14

*, **, *** - Significantly better than control at the 5%, 1% and 0.1% levels

1 Mean disease rating of all roots in the plots (Scale 0 = no disease to 4 = roots completely rotted).

2 Percentage roots producing marketable chicons.

In a second experiment chicory roots which were stored for a 4-week period in heaps received a 10-second fungicidal dip treatment before being placed in a forcing bed. Up to 57% of the roots receiving the dip treatment produced marketable chicons compared to 14% of those which were untreated (Table 4).

Cucumbers

Powdery mildew (Sphaerotheca fuliginea). Sphagnum peat has been successfully used as a sole medium for cucumber production. Kavanagh (1971) found evidence that dimethirimol did not control powdery mildew of cucumbers in this medium. An experiment was therefore conducted comparing dimethirimol at normal and double strengths with benomyl and triarimol all applied as drenches to cucumbers grown in peat (Table 5). The cucumbers cv. Sporu were inoculated with powdery mildew when the plants had two rough leaves and were drenched with the fungicides on October 10 when they were less than 1 m high. Leaf assessments were made on a scale of 0 to 10 (0 = no disease, 10 = leaf completely covered with mildew). In the first assessment on November 6 the leaves on the main stem were assessed. As the plants were grown on a bench and were stopped when they reached a height of about 1.3 m, they produced many laterals. In the second assessment, therefore, on November 26, both the main stem leaves and the leaves on the laterals were assessed (Table 5).

Table 5

Comparison of three fungicides applied as a drench in a 15cm radius around cucumber plants in sphagnum peat for control of powdery mildew

Treatments[1] (a.i.)	Leaf Assessments (Scale 0 to 10) Main Stem (6/11/69)	Main Stem (26/11/69)	Laterals (26/11/69)
Dimethirimol @ 20 ml/plant of a 0.02% soln.[2]	4.2	4.5	2.7
Dimethirimol @ 20 ml/plant of a 0.04% soln.	4.0	4.6	2.6
Benomyl at 100 mg in 200 ml water/plant	0.0***	1.0***	1.0**
Triarimol at 0.02 g in 100 ml water/plant	4.0	4.4	3.1
Control (water only)	4.4	4.4	2.6

, * - significantly better than control at 1% and 0.1% respectively.

1 After treatment water was added where necessary to bring all treatments up to 200 ml/plant

2 Equivalent to a dilution of 1 part commercial product to 60 parts water.

Benomyl gave excellent control but none of the other treatments were effective.

DISCUSSION

Systemic fungicides show distinct promise for control of many vegetable diseases. As a substitute for tin-based fungicides, benomyl was found very effective against Septoria blight of celery (Ryan and Kavanagh, 1971). For disease control in French beans, systemic fungicides are particularly promising since they control two very serious diseases, Botrytis and anthracnose, either of which can cause severe losses. In addition to demonstrating the effectiveness of systemic fungicides against Botrytis, Corbin and Woon (1970) also found that they controlled Sclerotinia rot of French beans. Increases in yield in these experimental plots and in commercial trials indicate that the fungicides are effecting more than protection of developing pods - they are probably also preventing flower abortion or stimulating plant growth, or both.

For control of white rot of onion, Lafon and Bugaret (1968) found that dicloran seed treatment was fairly satisfactory, but was not as effective as calomel. The favourable results obtained with benomyl seed dressing of onions against white rot are particularly timely since mercury-based dressings are being increasingly frowned upon. Because of the relatively large bulk of benomyl to be applied by comparison with calomel, further work will be needed on the best method of applying and sticking it to the seed. The dusting of sets does not appear to pose any technical difficulties but further study is needed to determine the optimum rate of application of benomyl.

In the long term the use of resistant cultivars is likely to be the best method of Fusarium wilt control in tomatoes. However, where these are not available or not used, an outbreak of this disease during the growing season can be controlled by application of benomyl as a soil drench. This drench has the added advantage of controlling other common tomato diseases e.g. Botrytis or Cladosporium leaf mould. A definite therapeutic effect of benomyl applied within a certain time after infection with Fusarium was shown in these experiments.

Dipping chicory roots in fungicide solutions before forcing was the best method of Sclerotinia rot control. Benomyl gave as good control as a PCNB - dicloran mix and is moreover less toxic.

One of the advantages of systemic fungicides is the increased interval between sprays which they have made possible e.g. benlate at 14- or 20 day intervals instead of 10 for apple scab control. On cucumbers for powdery mildew control the change has been even more dramatic - one soil drench with dimethirimol every six weeks instead of 10-day foliar spraying (Elias et al, 1968). The medium in which the crop is grown appears to play an important role in the effectiveness of this fungicide. Though dimethirimol is very effective in loam, it was ineffective in sphagnum peat even at double the recommended concentration due to its adsorption by the organic medium. Placing the fungicide very close to the base of the stem might improve the uptake of the material in this medium (Shephard, 1969). Though effective as a foliar spray (Gramlich et al 1969), triarimol did not give control as a drench at least in this growing medium. Benomyl on the other hand was very effective in sphagnum peat and gave protection for at least six weeks.

Perhaps the greatest deficiency of the systemic fungicides so far available for control of vegetable diseases is their ineffectiveness against the downy mildews and other diseases caused by Phycomycetes. In fact, their use may on occasion lead to an increase in these diseases. For instance, the use of benomyl instead of dithiocarbamates for control of Botrytis in tomatoes leads to an increase of blight (Phytophthora infestans) (Staunton - unpublished). This problem is recognised by manufacturers who are now producing systemic fungicide - dithiocarbamate combinations. Ringing the changes on available fungicides will also be necessary in view of reports of resistance to groups of systemic fungicides (Bollen & Scholten, 1971).

Acknowledgments

The authors wish to thank Mr. T. Cormican and Miss P. Newburn for technical assistance.

References

BOLLEN, G. J. & SCHOLTEN, G. (1971) Acquired resistance to benomyl and some other systemic fungicides in a strain of Botrytis cinerea in cyclamen. Neth. J. Pl. Path. 77, 83-90.

CORBIN, J. B. and WOON, G. (1970) Fungicide and Nematocide Tests 25 , 63.

ELIAS, R. S., SHEPHARD, M. C., SNELL, B. K. and STUBBS, J. (1968) 5-n-Butyl-2-dimethylamino-4-hydroxy-6-methylpyrimidine: a systemic fungicide. Nature, Lond. 219, 1160.

FLETCHER, J. T. (1964) The control of onion white rot using a pure calomel seed dressing and a new sticker. Pl. Path. 13, 182-184.

GRAMLICH, J. V., SCHWER, J. F. and BROWN, I. F. (1969) Characteristics and field performance of a new, broad spectrum systemic fungicide. Proc. 5th Br. Insectic. Fungic. Conf. 576-583.

KAVANAGH, T. (1971) Disease considerations in relation to crop production on peat soils. H.E.A. Conf. Dublin, 1971. (to be published in Scient. Hort.).

LAFON, R. and BUGARET, Y. (1968) Les traitements des semences d'Oignon contre le pourriture blanche. Phytiat. -Phytopharm. 17, 67-72.

RYAN, E. W. and KAVANAGH, T. (1971) Comparison of fungicides for control of leaf spot (Septoria apiicola) of celery. Ann. appl. Biol. 67, 121-129.

SHEPHARD, M. C. (1969) Personal communication.

THANASSOULOPOULOS, C. C., GIANOPOLITIS, C. M. and KITSOS, G. T. (1970) Control of Fusarium wilt of tomato and water melon with benomyl. Pl. Dis. Reptr. 54, 561-564.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

CONTROL OF SOME DISEASES OF FREESIAS, GLADIOLUS AND TULIPS WITH BENOMYL AND THIABENDAZOLE

D.R. Humphreys-Jones
Agricultural Development and Advisory Service, Cambridge

Summary Good control of Freesia seedling rot (*Fusarium oxysporum*) and *Fusarium moniliforme*), Gladiolus core rot (*Botrytis gladiolorum*), dry rot (*Sclerotinia gladioli*), corm rot (*Fusarium oxysporum f. gladioli*) and Tulip bulb rot (*Fusarium oxysporum f. tulipae*) was obtained by treatment of their respective seed corms and bulbs with benzimidazole fungicides.

INTRODUCTION

The Fusaria are well known for their importance in causing losses in flower bulb crops. (Gould 1967, Price and Goodenough 1971). The years 1969 and 1970 will be remembered by tulip growers in Eastern England for the serious losses to their Darwin Hybrid varieties due to Fusarium bulb rot "Sour". Up to the recent introduction of the benzimidazole group of fungicides various mercury based fungicides have been used and given good control but their use as dips is not permitted in the United Kingdom unless carried out in premises approved under the Factories Act. Experiments on the use of benzimidazole fungicides for the control of Fusarium diseases of Freesia (Scholten 1970), gladiolus (Forsberg 1969, 1970 Magie 1968, 1969, 1970, 1971), Paul et al (1970), narcissus (Gould and Miller 1970, 1971) and tulip (Gould 1970, Rooy and Vink 1969, 1970, Schenk 1971) have been carried out in various parts of the world.

As this paper covers experiments on freesias, gladiolus and tulips it has been divided for convenience into three parts as follows:-

(a) Control of seed-borne Fusarium diseases of Freesias.

(b) Control of core rot, corm rot and dry rot of Gladiolus.

(c) Effect of timing of benomyl and thiabendazole bulb dips on the control of Fusarium bulb rot of tulips.

(a) Control of seed-borne Fusarium diseases of freesias

METHOD AND MATERIAL

Seeds of Red, White and Blue diploid Solent strains of freesias were soaked in water for 72 hours then spread out evenly on to filter paper on moist peat, covered with black polythene and incubated at 13°C until the seed showed signs of germination. At this stage half the seed was sprayed with 250 ppm benomyl in water and the black polythene replaced. Three days later the germinated seed was planted out into $3\frac{1}{2}$ in whale hide pots containing a sand peat mix at the rate of 5 germinated seeds per pot and one hundred pots per treatment. The pots were then put out in the standing ground until September when they were brought in under glass.

RESULTS

Table 1 gives the number of healthy seedlings per block of 10 pots six weeks after planting.

Table 1

Control of seed-borne Fusarium diseases of freesias

Variety Treatment	White		Blue		Red	
	Control	Benomyl	Control	Benomyl	Control	Benomyl
	11	50	34	38	40	48
	17	48	20	46	34	48
	19	48	27	40	38	46
	19	50	29	40	37	49
	12	50	22	42	30	47
	13	49	23	43	23	48
	14	49	44	41	12	45
	17	49	27	41	12	49
	11	50	29	44	20	48
	10	50	36	38	24	45
Totals	143	493	291	413	270	453

SE = 84

Statistical analysis showed that there was considerable chemical/variety interaction, i.e. the treatment was not consistent. The trend shows that the disease can be controlled to some extent by benomyl although the only statistically significant increase in emergence counts was in the white variety - which appears more susceptible to the disease.

Investigations on the cause of seedling failure yielded isolates of Fusarium oxysporum and Fusarium moniliforme, identification being confirmed by the Commonwealth Mycological Institute, Kew. Confirmation of pathogenicity of the Fusarium oxysporum isolate from seed, seed debris and seedlings, was obtained by application of Kochs postulate (Humphreys-Jones 1970). Pathogenicity of F. moniliforme has already been established (Smith 1967). No phytotoxic symptoms were noted on the benomyl treated seed throughout the growth of the ensuring crop.

(b) Control of core rot, corm rot and dry rot of gladiolus

METHOD AND MATERIAL

Gladiolus cormels of the variety Joli Coeur selected from a stock known to be heavily infected with the above three diseases were given the following treatments as soon as possible after lifting, cleaning and grading (22 days).

1. Soaked in a tank containing 0.2% thiram in water for 24 hours at 30°C, dried and then stored at 5°C.

2. Kept in store at 5°C until 5 January 1970, then soaked for 2 days at ambient temperature followed by 30 minutes at 55°C, then dried and stored at 5°C.

3. Soaked in 0.1% benomyl in water at ambient temperature for 30 minutes, then dried and stored at 5°C.

4. Control. Soaked in sterile water for 30 minutes at ambient temperature then dried and stored at 5°C.

There were four plots of 100 equal sized cormels per treatment and the experiment was laid down as a latin square.

RESULTS

Table 2

Assessment of healthy and diseased gladioli cormels at harvest on 5 October 1970

Treatment	% Healthy Corms	% Corms infected with Fusarium Corm Rot	% Corms infected with Core Rot	% Corms infected with Dry Rot
0.2% Thiram Soak	68.8	5.8	7.2	10.7
Hot Water Treatment	85.3	0.0	2.3	8.6
0.1% Benomyl Soak	84.0	2.0	2.7	3.5
Control	37.0	17.0	17.7	22.8
SE	4.69	2.59	1.68	2.44

As can be seen from Table 2 there was quite a high incidence of disease in stocks (37%). All the treatments gave a significant control of the three diseases but with only one treatment and one disease (hot water treatment and Fusarium corm rot) was there a complete control. The growth of the plants in this treatment was however generally stunted and had a grassy appearance. The hot water and benomyl treatments gave a significantly better control than the thiram treatment but did not differ from each other. For the individual diseases there were no differences between treatments except as mentioned above.

DISCUSSION

Though the hot water treatment gave the best disease control the plants were generally stunted and had a grassy appearance. This, however, may have been due to the time of treatment. The best overall control with no phytotoxicity was achieved with the benomyl soak.

(c) Effect of time of benomyl and thiabendazole dip treatments on the control of Fusarium bulb rot of tulips

METHOD AND MATERIAL

In this experiment seven hundred visually healthy tulip bulbs were selected from a heavily Fusarium bulb rot infected stock of the variety Gudoshnik and after cleaning and grading were given the following treatments in lots of 100 bulbs per treatment:

1. Dipped in 1000 ppm benomyl in water for 30 minutes at 20°C within 12 hours of lifting.

2. Dipped in 1000 ppm benomyl in water for 30 minutes at 20°C for 7 days after lifting.

3. Dipped in 1000 ppm benomyl in water for 30 minutes at 20°C for 21 days after lifting.

4. Dipped in 1000 ppm thiabendazole in water for 30 minutes at 35°C within 12 hours of lifting.

5. Dipped in 1000 ppm thiabendazole in water for 30 minutes at 35°C for 7 days after lifting.

6. Dipped in 1000 ppm thiabendazole in water for 30 minutes at 35°C for 21 days after lifting.

7. Control - not dipped.

After the various treatments the bulbs were dried and kept in trays in well ventilated stores held at 18°-20°C until 26 September 1970 when a diseases assessment was made of the numbers of bulbs infected with Fusarium bulb rot "Sour". The results are given in Table 3.

Table 3

Percentage healthy bulbs at the beginning and end of the experiment

Fungicide Dip times after lifting crop	Control	12 hours		7 days		21 days	
		Benomyl	TBZ	Benomyl	TBZ	Benomyl	TBZ
Start of Expt 25.6.70	100	100	100	100	100	100	100
End 26.9.70	8	73	61	45	41	19	10

SE = 3.6

The healthy bulbs were planted in nets and grown on for phytotoxicity assessments.

Benomyl gave a significantly better control at the 12 hour dip than did the thiabendazole treatment, but there were no significant differences between the two chemicals in later treatments. The effectiveness of the control diminished rapidly with the delaying of the dip treatment so that dipping after 21 days of lifting gave similar results to the control, i.e. undipped. There were no phytoxic effects. These results compare well with those of Narcissus (Gould et al 1970) in the USA and show that for best control the sooner bulbs are dipped in benomyl after lifting the better is the Fusarium bulb rot control.

GENERAL DISCUSSION

These three experiments show the value of the benzimidazole fungicides benomyl and thiabendazole for the control of various seed, cormel and bulb borne diseases of freesia, gladiolus and tulip. All three experiments have been repeated in 1971 with similar results but due to lack of time between harvest in September and the final date of publication of this paper it was not possible to analyse and include them here.

Acknowledgements

The author wishes to thank Messrs Merck Sharp and Dohme Limited for the samples of "Tecto 60" 60% thiabendazole w.p. Messrs Fisons Co Ltd for samples of "Benlate" 50% benomyl w.p. and Mr Denis Pye for technical assistance.

References

FORSBERG, J.L. (1969). Pl. Dis. Reptr. 53, 318.

FORSBERG, J.L. (1970). Illinois St. Florist Assoc. (312) 4.

GOULD, C.J. (1967). Florists' Rev. 140 (3633), 14.

GOULD C.J. (1970). 1st Int. Sym. on Flowerbulbs, Lisse Netherlands.

GOULD, C.J. MILLER, V.L. (1970). Pl. Dis. Reptr. 54, 377.

GOULD, C.J. MILLER, V.L. (1971). Pl. Dis. Reptr. 55, 428.

HUMPHREYS-JONES, D.R. (1970). ADAS Cambridge unpublished data.

MAGIE, R.O. (1968). Proc. Florida State Hort. Soc. 81, 422.

MAGIE, R.O. (1969). Sunshine State Agr. Res. Rept. May, 11-12.

MAGIE, R.O. (1970). 1st International Sym Flowerbulbs, Lisse Netherlands.

MAGIE, R.O. (1971). Pl. Dis. Reptr. 55, 82.

PAUL, A.O. BESEMER, S. SHIBIYA, F. and NELSON, J. (1970). Pl. Fis. Reptr. 54, 689.

PRICE, D. Sylvia M. GOODENOUGH. Rep. Glasshouse Crops Res. Inst. 1970, 193.

ROOY, M. De and VINK, G.J.M. (1969). Laboratorium voor Bloembollenonderzoek, Praklykmededeling nr 29.

ROOY, M. De and VINK, G.J.M. (1970). Bloembollencultuur Sept 18, 299.

SCHENK, P.K. (1971). Dutch Bulb Forcers Clinic April 29-20 Lisse.

SCHOLTEN, G. (1970). 1st International Sym. on Flowerbulbs, Lisse Netherlands.

SMITH, P.M. Rep. Glasshouse Crops Res. Inst. 1967, 90.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

CHANGES IN ORGANO-CHLORINE USAGE ON SUGAR BEET, AND PROGRESS IN THE REPLACEMENT OF DIELDRIN SEED TREATMENT

R.A. Dunning and G.H. Winder
Broom's Barn Experimental Station, Higham, Bury St. Edmunds, Suffolk

Summary Organo-chlorine pesticides are used on sugar beet to prevent damage by pests attacking the root, stem or foliage, especially of seedlings. Only γ-BHC or DDT are now applied to soil or foliage; the acreage treated is increasing because fewer seeds per acre are sown and growers wish to protect the seedlings from pests such as millepedes (*Blaniulus* and other species), leatherjackets (*Tipula* spp.), pygmy beetle (*Atomaria linearis*) and beet flea beetle (*Chaetocnema concinna*). Trials have not been made to find alternative materials to γ-BHC and DDT for preventing damage to foliage. Currently all seed is dressed with 0.2% of dieldrin and most is pelleted; progress has been made in testing alternative materials, of which methiocarb seems the best for control of pygmy beetle, one of the major seedling pests.

INTRODUCTION

Organo-chlorine pesticides are used on sugar beet as a seed dressing, or as a spray on the soil or foliage; this usage was first reviewed in 1961 (Dunning, 1962), and later in comparison with other crops (Anon, 1964, 1969; Strickland, 1965). Dieldrin is used on all sugar-beet seed as a precautionary treatment against damage by wireworms (*Agriotes* spp.) (Dunning & Winder, 1965b) and because, in fields not known to have resident pests, it usually increases slightly the numbers of sugar-beet seedlings and plants.

Organo-chlorines and alternatives were tested in 1964, 1965 and 1968 on wireworm-infested fields, and in 1968 to 1971 on fields with millepedes (usually *Blaniulus guttulatus* or *Brachydesmus superus*), symphylids (*Scutigerella immaculata*), springtails (*Onychiurus* sp.) or pygmy beetle (*Atomaria linearis*). Because treating seed with 0.2% dieldrin does not control these latter pests well, larger amounts and alternative materials were also tested, especially by incorporation in the seed pellet. Choice of materials to test was influenced by work on millepedes in Belgium (Steyvoort, 1965) and France (Durgeat & L'Hoste, 1965), and on pygmy beetle in Ireland (Feeney, 1971) and Holland (Heijbroek, 1971).

Seedling pests cause damage irregularly in England; where damage is expected, the current recommendation is to spray the seedbed with 8-16 oz γ-BHC/acre (0.56-1.2 kg/ha) and this was used as a standard treatment in many of the trials.

Soil-inhabiting pests are considered such a threat to the establishment of seedlings in Belgium that nearly all 90,000 ha of sugar beet are treated with heptachlor, 25% overall and 75% with smaller amounts in the seed row. Similarly, of France's 400,000 ha, 25% are treated overall and 50% in the seed row with heptachlor to control mainly *Blaniulus* (Dunning, 1972). In England the use of monogerm seed sown at wide spacing and of herbicides is rapidly extending; there are few or no surplus seedlings and hence they need protecting effectively until fully established.

CURRENT USAGE

Until 1964 γ-BHC or heptachlor were recommended alternatives to dieldrin for treating seed; difficulties in formulating γ-BHC made it inefficient, or occasionally phytotoxic, and led to its abandonment; heptachlor was withdrawn by the manufacturers (Table 1).

Table 1

Sugar beet acreage and seed treatment

Year*	Acres sugar beet in England and Wales	Heptachlor treated seed		γ-BHC treated seed		Dieldrin treated seed	
		Acres	% Total	Acres	% Total	Acres	% Total
1962/63	408,400	143,000	35	61,300	15	204,200	50
1964	432,400	26,800	6	94,900	22	298,100	68
1965	445,900	Nil	0	92,000	21	338,900	77
1966	439,100	Nil	0	80,500	19	345,400	80
1967	451,900	Nil	0	8,600	2	422,200	97
1971	447,000	Nil	0	Nil	0	447,000	100

* For 1962/3 see Anon (1964), and for 1964-1967 see Anon (1969). For historical background to sugar beet seed treatment see Dunning & Winder (1965b)

Conversion factor : hectares = $\frac{\text{acres}}{2.47}$

At present all sugar-beet seed is treated with 0.2% of dieldrin, either by the seed merchant before delivery to the British Sugar Corporation or to the seed pelleting plant, or during the pelleting process. Pelleted sugar-beet seed was first used commercially in 1965 and, by 1971, 89% of the crop was precision drilled with it, in preference to 'raw' seed. Pelleted seed is almost always monogerm and, when sown at an average spacing of about 5 in (12.7 cm) in rows 20 in (50.8 cm) apart, only about 1½ lb (0.68 kg) seed equivalent to 9 lb (4.1 kg) pelleted seed is used; this applies 1/20 oz dieldrin /acre (3.5 g/ha).

Spraying the soil with 8-16 oz γ-BHC/acre (0.56-1.2 kg/ha) before final seedbed cultivations is a routine of some growers on the silt and heavy peat soils of the fenland areas of Eastern England, where soil-inhabiting pests of seedlings seem especially troublesome. There, and in other areas, 8-16 oz/acre (0.56-12 kg/ha) γ-BHC or, especially, DDT are being used increasingly to control the various stem and foliage pests that may cause seedling losses, especially beet flea beetle (*Chaetocnema concinna*), pygmy beetle, leatherjackets (*Tipula* spp.) and cutworms (*Agrotis* & *Euxoa* spp.) (Table 2).

Alternative materials have not been assessed for the control of these foliage pests, nor has the efficiency of DDT or γ-BHC against them on sugar beet ever been tested. Organophosphorus alternatives exist for the control of beet leaf miner (*Pegomya betae*) (Dunning, 1961), and are preferable because they also control early aphid infestations (Dunning & Winder, 1965), but some manufacturers continue to recommend DDT and some growers still use it for this purpose.

Table 2

Estimated acreage of sugar beet treated by soil or foliage application (England & Wales)

Year	Material			
	Aldrin	γ-BHC	DDT(1)	Dieldrin
1964	1,000	70	46,000	900
1965	0	400	14,200	0
1966	(10)	230	4,500	(10)
1967	(0)	180	5,000	(50)
1968(2)	140	2,415	23,634	0
1969	0	8,141	14,994	0
1970	0	5,757	25,922	0
1971(3)	0	11,000	65,000	8

(1) Used mainly for control of beet leaf miner in 1964 and 1965, and subsequently for flea beetle, pygmy beetle, leatherjacket and beet leaf miner; many acres probably sprayed unnecessarily in 1971 for expected rather than actual pest damage control.

(2) Soil applications not recorded accurately before 1968; in 1968 and subsequently soil application data calculated from records on a 5% sample of the total acreage.

(3) Data provisional.

EXPERIMENTAL RESULTS

Two trials on wireworm-infested sites in 1964 tested seed treatments (Dunning & Winder, 1965), and compared granular formulations of organophosphorus compounds and dieldrin applied in the seed furrow (Table 3). Diazinon and thionazin were effective at only one site, and thionazin damaged seedlings at the other but, on average, 'Bayer 38156' equalled dieldrin granules and seed dressing in lessening damage; γ-BHC sprayed on the soil before preparing the seedbed was the most consistently effective treatment.

Similar trials in 1965 tested 'Bayer 38156', dieldrin and γ-BHC seed dressings, aldrin, 'Bayer 38156' and γ-BHC sprays on the seedbed, and 'Bayer 38156', phorate and fonofos granules either in the seed furrow or in a 3 in (7.6 cm) band in the soil above the seed. None of the organophosphorus treatments were as effective as γ-BHC spray but they were sometimes more effective than dieldrin seed dressing (Dunning & Winder, 1966). Because pelleted seed was beginning to be preferred commercially, later experiments mainly tested insecticides incorporated in the pelleting material, but also seed-row treatments as the simplest means of screening compounds.

In nineteen trials throughout the country in 1968, γ-BHC or dieldrin in the inner or outer layers of the seed pellets did not differ on average in improving seedling and plant establishment (Dunning & Winder, 1969). However, seed treated with γ-BHC produced many abnormal seedlings when germinated in the laboratory and also some in the field. Pest damage occurred at two sites only - Peterborough (millepedes, and some wireworms) and Wissington (pygmy beetle) - where granules of aldicarb (18 oz a.i./acre (1.26 kg/ha)) 'Terracur' (14 (0.98)) 'Mobam' (15(1.05)) and 'Dursban' (8 (0.56)) were incorporated in the soil surface in a 5 in (12.7 cm)

Table 3

The effects of insecticide treatments on seedling and plant populations at Milton Ferry and Witchford, 1964, and also on wireworm damage at Witchford

Treatment (oz a.i. per acre)(1)	MILTON FERRY: Living seedlings(2) per yard of row, (pre-singling)		MILTON FERRY: Thousands of(3) plants per acre (post-singling)	WITCHFORD: Living seedlings(2) per yard of row, (pre-singling)		WITCHFORD: Wireworm-killed seedlings as % of total seedlings	WITCHFORD: Thousands of(3) plants per acre (post-singling)
	19 May	28 May	15 June	28 April	14 May	7 May	15 June
Control - no insecticide	15.6	16.1	33.8	8.9	5.3	13.9	17.6
Dieldrin seed dressing (0.17) 40% w/w	17.1	18.8^{+++}	34.9	11.0	9.6^{+}	6.6^{+}	29.5^{++}
Dieldrin granules (4.6) in seed furrow 5% w/w	18.0^{+}	20.3^{+++}	35.1	12.3	10.0^{+}	4.4^{++}	29.0^{++}
'Bayer 38156' granules (3.7) in seed furrow 2.5% w/w	17.9	19.2^{+++}	35.7^{++}	11.2	11.1^{++}	4.1^{++}	29.1^{++}
Diazinon granules (3.5) in seed furrow 5.0% w/w	17.7	18.7^{++}	35.6^{+}	11.2	7.6	11.1	19.3
Thionazin granules (3.5) in seed furrow 10.0% w/w	19.6^{++}	19.7^{+++}	35.4^{+}	7.8	3.8	15.4	12.5
γ-BHC spray (8.1) in seed bed 47 g.p.a.	18.9^{++}	20.0^{+++}	35.3^{+}	18.1^{+++}	18.0^{+++}	2.6^{+++}	34.1^{+++}
Least significant difference between any two treatments 5%	2.4	1.5	1.4	3.6	3.9	6.0	6.8
1%	3.2	2.0	1.9	4.9	5.2	8.1	9.2
0.1%	4.3	2.7	2.5	6.5	7.0	10.8	12.2

+, ++, +++, significantly better than control at the three levels of probability.

Conversion factors : (1) oz/acre x 70.06 = g/ha.
(2) seedlings/yard x 1.09 = seedlings/m.
(3) plants/acre x 2.47 = plants/ha.

band above dieldrin-treated seed. 'Mobam' decreased seedling and plant numbers at Peterborough whereas 'Dursban' increased them at Wissington.

On a heavy fen soil site in 1968, millepedes (mainly Blaniulus guttulatus) were prevalent before drilling and pygmy beetle also immigrated in April and May; plots were sown on 8th April, and on 7th May nearly 90% of the untreated seedlings showed damage from millepedes and 75% from the more harmful pygmy beetle. Pesticides, as liquid formulations, were tested in one trial and as granules in the other, both applied in the seed furrow, using seed treated with 0.2% of dieldrin. Table 4 only gives results of the effective materials. An adjacent trial showed that the dieldrin

Table 4

Seedling and plant populations after pesticide treatment with liquid or granule formulations where millepedes and pygmy beetle causing damage, Littleport, Ely, 1968

Seed-furrow treatment	Oz. a.i./acre (1)	Seedlings/yard (2) 16 May	Thousands plants/acre (3) 20 June
Control (dieldrin treated seed)	0.1	5.4	19.9
Liquids: 'Mobam'	4.0	8.2+++	25.8++
	16.0	7.5+	23.9
Methomyl	4.0	8.9+++	26.5++
	16.0	5.0	17.3
'C10015'	4.0	8.3+++	27.2++
	16.0	10.4+++	28.9++
γ-BHC	4.0	8.4+++	21.1
	16.0	9.0+++	26.7++
Least significant difference between any two treatments 5%		1.5	4.3
1%		2.1	5.7
0.1%		2.7	7.4
Control (dieldrin treated seed)	0.1	6.4	22.5
Granules: Aldicarb	3.5	8.4+	25.5
	18.2	9.4+++	29.0++
'Dursban'	3.0	7.4	26.1
	16.4	9.6+++	25.9
Methomyl	2.3	8.7++	25.7
	10.9	9.2+++	24.2
'Mobam'	4.2	8.2+	27.4+
	19.2	9.8+++	29.6++
Least significant difference between any two treatments 5%		1.6	4.2
1%		2.1	5.5
0.1%		2.7	7.1

+,++,+++, Significantly better than the respective control at the three levels of probability.

Conversion factors : (1) oz/acre x 70.06 = g/ha. (2) seedlings/yard x 1.09=seedlings/m. (3) plants/acre x 2.47 = plants/ha.

seed dressing increased seedling and plant numbers slightly; the larger amounts of aldicarb and 'Mobam' granules were especially effective in further increasing seedling and plant establishment, and 'Dursban' and methomyl granules were also effective. Of the liquid treatments, the most effective were both amounts of 'C10015', the larger amount of γ-BHC (but it caused some leaf abnormality) and the smaller amounts of 'Mobam' and methomyl; the larger amount of methomyl was phytotoxic. Of the other materials tested and not listed in Table 4, chlorfenvinphos, especially as a solution, and prophos and 'Terracur' granules at only 3-4 oz a.i./acre (0.21-0.28 kg/ha) greatly damaged the seedlings. 'C14421' and 'BTS 18 502' solutions, and pirimiphos-ethyl granules, were inactive.

In 1969, 0.5 and 2% of methomyl, 'C10015' and 'Dursban' were incorporated in the seed-pelleting material together with the standard 0.2% of dieldrin. None affected the laboratory germination of seed shortly after pelleting but the larger amounts of 'Dursban' seriously decreased it after six months storage (89 → 66%). These treatments were compared with 0.2% dieldrin seed treatment at four Fenland sites, but there was no damage from soil-inhabiting pests. The larger amount of 'Dursban' decreased mean seedling establishment by 11%, whereas the smaller amount increased it by 5%. At two of these sites, liquid formulations of the following insecticides were tested in the seed furrow at 1 and 16 oz a.i./acre (0.07 and 1.12 kg/ha); γ-BHC, aldrin, 'C10015', DDT, diazinon, 'GS 13006', heptachlor, methiocarb, methomyl and, at one of the sites only, aldicarb, 'Cytrolane', 'Dursban', fenthion and mecarbam. The larger amounts of γ-BHC and methomyl were phytotoxic at both sites and of 'Dursban', fenthion and mecarbam at the one site. Despite apparent absence of attack by pests, the smaller amount of heptachlor increased seedling numbers at one site, and the smaller amount of methiocarb increased both seedling and plant numbers at the other.

In 1970, at three sites where pygmy beetle and/or millepede damage occurred, seed pelleted with 0.2% of dieldrin was compared with 0.8% of 'Dursban', heptachlor and mecarbam, both with and without 16 oz γ-BHC/acre (1.12 kg/ha) overall in the seedbed. Dieldrin seed treatment and γ-BHC spray each increased seedling numbers, but the other seed treatments decreased them. In subsidiary trials at two of the sites, aldicarb granules at 10 oz a.i./acre (0.7 kg/ha) applied in the seed furrow were compared with similarly placed liquid formulations of γ-BHC, carbaryl, DDT, 'Dupont 1410', 'Dursban', fenitrothion, fenthion, heptachlor, mecarbam, methiocarb and propoxur at 1 and 10 oz a.i./acre (0.07 and 0.7 kg/ha). At both sites 1 oz of methiocarb increased both seedling and plant numbers and 1 oz of fenthion increased plant numbers; at one site, seedling and plant numbers were also slightly increased by 1 oz (0.07 kg) of carbaryl or heptachlor. The greater amounts of γ-BHC, fenthion and mecarbam decreased seedling and plant numbers.

In 1971, to ensure damage by pygmy beetle, sugar beet was grown again at two sites where sugar-beet seedlings were damaged by this pest in 1970; millepedes (Brachydesmus superus) were present at both sites. A trial at each site compared seed treatments (γ-BHC, carbaryl, 'C10015', dieldrin, methiocarb and propoxur) with γ-BHC seedbed spray, and another compared in-furrow treatments of granular aldicarb, 'Cytrolane', dimethoate, fonofos, mecarphon and liquid γ-BHC, carbaryl, 'C10015', DDT, diazinon, 'Dupont 1410', 'Dursban', fenitrothion, fenthion, heptachlor, methiocarb, phoxim and propoxur. Pygmy beetle damage was severe on the untreated plots or those with ineffective treatments, at one site so severe that nearly all seedlings were killed; after assesment the area was cultivated and re-sown with a further seed-treatment trial.

Preliminary analysis of results suggests that the best treatments (omitting the persistent organo-chlorines) were: 16 oz γ-BHC seed-bed spray; 0.2% γ-BHC, 0.8% methiocarb, 3.2% 'C10015' seed treatments; and seed-furrow treatments with granular mecarphon (13 oz a.i./acre (0.9 kg/ha)) or aldicarb (10 (0.7)) or solutions of methiocarb (" ") or 'Dupont 1410' (" "). At the sites where damage was less severe, plant establishment was decreased by 10 oz of γ-BHC and phoxim as solutions. To measure any harmful effects of treatments on plant growth they were also tested at two other sites where pest damage was not expected. Some results of the 1971 trials will be presented at the Conference.

DISCUSSION

Sugar-beet seedlings are attacked sporadically by many different pests, whose damage cannot be forecast. Protection of the seedling has always been desirable but is more necessary now because each year the acreage 'sown-to-a-stand' is increasing. About 60,000 seeds per acre (148,200/ha) are sown to give the desired 30,000 plants per acre (74,100/ha), assuming an average establishment of 50%; establishment can vary widely, for instance, it ranged from 24 to 71% in one series of trials (Dunning & Winder, 1971). Seedling losses cannot be tolerated and, for maximum yield, each seedling must be undamaged and grow vigorously.

Most sugar-beet seed is now pelleted and probably all soon will be, as an aid to precision seed spacing; pelleting adds to the seed about five times its weight of 'clay' and up to 25% of this material could easily be replaced by pesticide (R.D. Reid, pers. comm.). Each pelleted seed carries a more accurate and uniform amount of dieldrin than treated 'raw' seed especially when this is added during pelleting (J.F.T. Oldfield, pers. comm.).

At present all sugar-beet seed is treated with dieldrin because no alternative has yet been adequately tested and, with the fewer seeds sown, only 1/20 oz of dieldrin is applied per acre (3.5 g/ha). Dieldrin controls wireworm damage, but this pest is now rare in comparison with other soil-inhabiting pests that are not controlled well by the present amount of dieldrin applied. More dieldrin per seed may be better, as suggested by our 1971 trials, but further trials will not be done to establish the amount because alternative materials are preferred. Ideally the seed dressing should prevent damage by all seedling pests, and seed pelleting makes it possible to incorporate more than one material if necessary. Further investigations are needed, especially with the potentially effective materials 'C10015', mecarphon and methiocarb; the last is recommended by Kühe (1971). Because sugar beet is very easily damaged by chemicals, trials must also be made on pest-free sites.

The best material for applying to the seedbed is γ-BHC at 8-16 oz/acre (0.56-12 kg/ha) but this is 40-80 times more active ingredient than a 0.8% seed dressing, and it can taint subsequent crops. Mixing 1.1 lb/acre (1.25 kg/ha) of heptachlor with the pre-emergence herbicide pyrazon, and applying both in a band on the soil surface over the seed row, was effective in Belgium but less so than mixing 3.12 lb/acre (3.50 kg/ha) in the surface soil (Steyvoort, 1965). Our trials of band spraying on the soil surface were inconclusive (Dunning & Winder, 1967), probably because such treatment depends on rain leaching the active material into the soil.

Seed-furrow treatment with some liquid or granule formulations can be combined with sowing and may be the method of the future in England to give maximum benefit from minimum amounts of pesticide on those sites where seed treatment is insufficient; granular heptachlor is used in this way extensively in France at 0.22-1.2 lb a.i./ acre (0.25-1.3 kg/ha) (Bonnemaison, 1971), and alternatives are being sought.

Acknowledgements

We are most grateful for the help of the growers and the British Sugar Corporation fieldmen with the field trials, and also for technical assistance by Margaret Shields, Marie Winder and John Crane. Manufacturers kindly supplied the materials tested, and Messrs Germains (U.K.) Ltd. pelleted the seed.

Insecticides Tested

Aldicarb, aldrin, γ-BHC, carbaryl, 'Cytrolane', 'C10015', DDT, diazinon, dieldrin, 'Dursban', dimethoate, fenitrothion, fenthion, fonofos, heptachlor, mecarbam, methiocarb, methomyl, phorate, phoxim and thionazin are described in Martin (1971).

The following compounds were also tested but are not described in Martin (1971):

'Bayer 38156' : O-ethyl-S-p-tolyethylphosphonodithioate.

'BTS 18 502' (RD 18502) : Boots experimental compound.

'C14421' : Ciba experimental dithiocarbamate.

'Dupont 1410' : S-methyl 1-(dimethylcarbamoyl)-N-((methyl carbomoyl) Oxy) thioformimidate.

'GS 13006' : O.O-diethyl-s-(2-methoxy-1,3,4,-thiadiazol-5 (4H)-onyl-(4)-methyl)-dithiophosphate.

Mecarphon (MC2420) : S-(N-methoxycarbonyl-N-methylcarbomoyl methyl) dimethyl phosphorodithioate.

'Mobam' : 4-benzothienyl-N-methyl carbamate.

Pirimiphos-ethyl ('PP211') : 2-diethylamino-6-methylpyrimidin-4-yl diethyl phosphorothionate.

Prophos ('Mocap') : O-ethyl S.S.-dipropyl phosphorodithioate.

'Terracur' : 5-carboxymethyl-3-methyl-2H-1,3,5-thiadiazine-2-thione.

References

ANON, (1964) Review of the persistent organochlorine pesticides. H.M.S.O. London.

ANON, (1969) Further review of certain persistent organochlorine pesticides used in Great Britain. H.M.S.O. London.

BONNEMAISON, L. (1971) Lutte contre les enemis animaux des semis de betteraves. 34th I.I.R.B. Winter Congress, Brussels.

DUNNING, R.A. (1961) Mangold fly incidence, economic importance and control. Pl. Path., 10, 1-9.

DUNNING, R.A. (1962) Insecticides and fungicides used to control sugar beet pests and diseases. Chem. & Ind., 4, 155-158.

DUNNING, R.A. (1972) A survey of sugar beet pest and disease incidence and damage, and pesticide usage in Europe, 1970. J. int. Inst. Sugar Beet Res. (In the press.)

DUNNING, R.A. & WINDER, G.H. (1965a) The effect of insecticide applications to the sugar beet crop early in the season on aphid and yellows incidence. Pl. Path., 14, 30-36.

DUNNING, R.A. & WINDER, G.H. (1965b) Sugar beet seedling populations and protection from wireworm injury. Proc. 3rd Br. Insectic. Fungic. Conf., 85-99.

DUNNING, R.A. & WINDER, G.H. (1966) Rep. Rothamsted exp. Stn for 1965, 264-6.

DUNNING, R.A. & WINDER, G.H. (1967) Rep. Rothamsted exp. Stn for 1966, 280.

DUNNING, R.A. & WINDER, G.H. (1969) Rep. Rothamsted exp. Stn for 1968, 274.

DUNNING, R.A. & WINDER, G.H. (1971) Rep. Rothamsted exp. Stn for 1970, 250-1.

DURGEAT, L.A. & L'HOSTE, J. (1965) Field experiments to evaluate the action of chemicals on millipedes in sugar beet. Proc. 3rd Br. Insectic. Fungic. Conf., 80-4.

FEENEY, A. (1971) The control of Atomaria damage to sugar beet seedlings by seed or soil treatment with insecticides. 34th I.I.R.B. Winter Congress, Brussels.

HEIJBRÖEK, W. (1971) Minimal usage of pesticides and alternatives for organochlorines. 34th I.I.R.B. Winter Congress, Brussels.

KÜTHE, K. (1971) Neue Möglichkeiten zur Bekämpfung des Moosknopfkäfers (Atomaria linearis Steph.) Zucker, 24, 219-222.

MARTIN, H. (1971). Pesticide Manual, 2nd Edition, British Crop Protection Council.

STEYVOORT, L. VAN (1965) Control of spotted millepedes, the most important pest of sugar beet seedlings in Belgium. Proc. 3rd Br. Insectic. Fungic. Conf., 73-9.

STRICKLAND, A.H. (1965) Amounts of organochlorine insecticides used annually on agricultural, and some horticultural, crops in England and Wales. Ann. app. Biol., 55, 319-325.

Proc. 6th. Br. Insectic. Fungic. Conf. (1971)

THE REPLACEMENT OF ORGANOCHLORINE INSECTICIDES ON CEREAL AND GRASS CROPS AND FUTURE NEEDS

J. H. White

ADAS, Northern Region, Newcastle upon Tyne

Summary Changed farming systems over the last two decades have lessened the importance of pests on cereals as many are associated with break crops. Considerable progress has been made in replacing the organochlorine insecticides for wheat bulb fly control, but the inadequacy of seed dressing techniques is probably reducing the efficiency of otherwise acceptable materials. There has been little progress towards an alternative to BHC or aldrin for wireworm control. Should saddle gall midge develop as a major pest, it can probably be contained by sprays of fenitrothion. Although one organophosphorus compound is available against leatherjackets, there is need for other alternative materials. This is particularly urgent where grassland needs to be treated as no insecticide is available following the restrictions on DDT usage in 1971.

INTRODUCTION

Since the third conference in 1965, when a comparable session was held to consider substitutes for the organochlorines, there have been a number of official and unofficial reports bearing on the subject. The most important has undoubtedly been the Further Report on the Organochlorine Insecticides by the Advisory Committee on Pesticides and other Toxic Chemicals in 1969, the Wilson report, as it laid down the pattern of OC usage in the immediate future. Possibly the most helpful unofficial report was the series of papers and lesser notes which made up the supplement to Plant Pathology, Vol. 16, 1967, bringing together the results of trials on alternatives conducted since the previous supplement in 1965. There has, therefore, been a period of five years of further experimentation and development and it is my purpose to try and draw together work done during this period and assess the relative values of possible alternatives as used against pests of cereals and grass.

GENERAL CONSIDERATIONS

As has been pointed out by Gair (1967), White (1968) and others, the more intensively cereals are grown, and the more long runs of cereals occur on farms, the less important do pests appear to be. More cereal pests are encountered after grass or other break crops than after cereals. Many of these are classed as minor pests and there appears to be scant data on their economic significance.

Wheat shoot beetle (Helophorus nubilis), wheat flea beetle (Crepidodera ferruginea), grass moths (Crambidae), grass and cereal flies (Opomyza), common rustic moth (Apamea secalis) are all in this category. They appear every year, but sporadically, and seldom cause sufficient loss to justify intensive study of the pest numbers and economic damage relationship. Without this knowledge there has been little incentive for investigators to work out control measures or the damage level to justify them.

The number of pests which are recognised as of major importance on cereals is quite limited and of these a number need not enter into our discussion as organochlorine insecticides are never advocated for their control. As was pointed out at the 1st Insecticide and Fungicide Symposium Usage (White 1970), the major problems of an entomological nature are considered to be slugs, the efficient application of seed dressings, leatherjackets and cereal aphids in that order. Of these four subjects causing most widespread concern today only two, leatherjackets and seed dressings, have any immediate bearing on the present topic.

The cereals sub-committee of the ADAS Experiments and Development Committee undertook in 1970 a comprehensive review of cereal crops. The report discussed all aspects of cereal growing and highlighted those areas where there was greatest probability of increasing cereal yields. Furthermore, these possible areas were given degrees of priority. Pest control was the back marker and no sense of urgency was expressed in dealing with insect problems. Only three projects were put forward as warranting further study in the immediate future. They were the cereal aphid/virus complex, the importance of free-living nematodes and saddle gall midge.

These two reviews, produced by independent groups of scientists and observers, both indicate that the insects against which the OCs have been used are not considered today to be pressing problems. Whether or not these problems will remain of relatively slight importance if and when the OCs are entirely replaced is rather conjectural.

It is proposed to deal individually with the few pests against which the organochlorines are, or have been used, or recommended in recent years.

Wheat Bulb Fly (Leptohylemyia coarctata)

The recommendation of the Cook Committee in 1964, suggesting that aldrin and dieldrin seed dressings should be considered again at the end of three years was probably responsible for intensified search for less persistent alternatives. This has been centred principally, but not entirely, on seed dressings as these are relatively easy to apply, cheap and use minimal amounts of active ingredients. Throughout these investigations there has been a tendency to use 60 per cent dieldrin seed dressing as a standard against which others are evaulated. Farmer experience and experimental work over at least 15 years suggest that this material has still to be improved on.

Unpublished data from ADAS, East Midland Region, has listed all the materials used in their trial work over the years. 116 treatments using 32 chemicals either alone or in different combinations and/or formulations have been used at 44 sites. All experimental treatments were scored and awarded points ranging from 10-0 based on their performance. Table 1, which is an extract from the data lists the relative standing of materials which are available or have been available for a period, together with the score representing the level of control achieved. Only materials which have appeared in 4 or more trials are considered.

TABLE 1

Relative values of some materials against wheat bulb fly

Treatment	No. of Trials	Total Points	Mean
60% Dieldrin SD	11	89	8.1
40% Chlorfenvinphos SD	5	40	8.0
67% Ethion SD	4	30	7.5
60% Carbophenothion SD	5	34	6.8
40% BHC SD	8	45	5.6
Dimethiate spray	8	43	5.4
Control	24	65	2.7

Evidence of the efficiency of carbophenothion has also been published by Catling and Cook (1967) and Griffiths and Scott (1967). Trought and Heath (1965) produced comprehensive data on the usefulness of chlorfenvinphos, which has been confirmed over a period of years in commercial practice and experimental work. The control of wheat bulb fly by ethion was discussed by Cole and Soper (1967). This material came on the market for a short period and was then withdrawn for commercial rather than scientific reasons, but during that short period it proved itself of value and of comparable efficiency to the other available materials.

Unfortunately all these insecticides have drawbacks and we are still awaiting the ideal solution to the wheat bulb fly problem. The long persistence of dieldrin and its possible hazard to wild life, reduced as it is by voluntary limitation of the period of use, are adverse factors. The fact that it enables some primary damage to be caused before killing the larvae within the shoot can be an unfortunate consequence in late sown crops. The principal criticism of the organophosphorus insecticides is that they do not always give protection over a sufficiently long period. They tend to be much more efficient on late sowings than early ones (Maskell 1970). In the ultimate crop response this factor is often countered by the well known fact that early drilling minimizes the effect of potentially heavy attacks. The lack of persistence of the OPs is seen particularly in late springs when attacks are delayed due to extended winter conditions. A further doubt concerning these newer seed dressings is their ability to stand up satisfactorily to attacks of more than average severity. On fields with egg populations of 3 million plus/acre crop loss is far greater than one would wish to see. A third factor relating to the OP seed dressings, though admittedly a minor one, is that they do not exert any control over wireworms should they be present, whereas the OC dressings also control this pest.

In its attributes, BHC seed dressing almost seems a bridge between dieldrin and the OPs. It is considered to cause less risk to wild life and indeed is the only material approved for spring-sown crops. Furthermore it also will control any incipient wireworm damage. Unfortunately it seems marginally less efficient than other approved seed dressings and often causes considerable phytotoxicity.

In years of particularly severe infestations the areas where wheat is at risk spread outwards from the anticipated localities. Egg sampling in late summer is not carried out as intensively in these areas and in consequence many crops can unknowingly be at risk, not having received an insecticidal seed dressing prior to drilling. Under these circumstances a spring treatment to control such attacks could be of considerable value. Three materials, dimethoate, ethoate-methyl and formothion are available for use as sprays after invasion of the crop by larvae. They are of limited value. For maximum efficiency they need to be applied immediately invasion has taken place, before attacked tillers are clearly discernable to the farmer's relatively untrained eye. The date at which spraying should take place cannot be determined by rule of thumb as there is considerable annual variation in the date of egg hatch.

Here is scope for further development relating to materials more efficient than the three in use today and a warning system for the benefit of farmers. Should this line of attack be successful, there is much to commend it. Spraying need only be applied on those fields where attacks are evident; the difficulty of prolonged effectiveness without undue risk to the environment is overcome as materials which are degraded quickly may be developed. Admittedly it would be more costly than seed dressings but to some extent this is counterbalanced by the large acreage treated unnecessarily in areas or years that do not justify treatment.

Reference has already been made to the present-day concern over the apparent inadequacies of seed dressing techniques. Lord <u>et al</u> (1967) first drew attention to the difficulty of applying uniform amounts of insecticides to seeds and the effect this might have on wheat bulb fly control. More recently, Lord <u>et al</u> (1971) have shown that dry and liquid insecticide dressings differ in their limitations. Dry dressings are more uniformly distributed between seeds than liquids, but the proportion adhering can be very variable and the amount available at the site of action can be far short of the supposed application rate. Although a much higher percentage of a liquid dressing is retained on seeds, the distribution is erratic, some seeds being grossly overloaded but others carrying little or none.

If this problem can be satisfactorily solved and the intended load of insecticide applied evenly to all seeds the degree of control of wheat bulb fly would probably be enhanced and the alternatives to OCs now available would be able to stand up more satisfactorily to conditions of extreme heavy attack.

Wireworm (<u>Agriotes spp</u>)

Before the introduction of BHC, this pest was probably responsible for more loss to growing cereal crops than any other insect. Now it is a relatively minor problem. Even after ploughing up old grass, down 20 years or more, losses are far less frequent than formerly. Although there is little evidence to support it, it is thought that the extensive use of combined BHC - organomercury seed dressings as an insurance measure over the last twenty years, and often quite unnecessarily, has had a slow but steady influence on the population levels of this beetle.

Possibly the relative unimportance of wireworm today is underlined by the limited amount of investigational work on it during recent years. Griffiths and Scott (1965) and Griffiths (1967) carried out laboratory trials using a range of OPs and carbamates. Of 31 materials provisionally tested only N-2790, now marketed as Dyfonate, showed any marked promise. Field trials by the same workers were subsequently inconclusive. Golightly <u>et al</u> (1969) carried out field trials on winter wheat using chlorfenvinphos, ethion and Dursban as seed dressings, parathion granules combine-drilled and broadcast, Dyfonate and trichloronate broadcast as granules against standards of BHC and dieldrin seed dressings and aldrin spray. Parathion granule application alone gave results comparable to the OCs. 3 lb/ac broadcast appeared marginally better than the same amount combine-drilled. Sellick and Evans (1965) had previously reported on the value of parathion as a general soil insecticide. This material in a granular formulation was marketed for a short time and then withdrawn, but it appears the only material which could replace the organochlorines for wireworm control in cereal crops until such time as new materials are available as candidate chemicals.

As the organochlorines are phased out of the market, and this will presumably occur in time, wireworms may reassert themselves as pests of importance, so every opportunity should be taken to screen the newer materials against this pest.

Leatherjackets (<u>Tipula and Nephrotoma</u> spp.)

The numbers of Tipulid larvae fluctuate considerably but appear to reach a peak at intervals of approximately five years (White 1963). Populations have been extremely low for three years and experimental work has been at a virtual standstill. Nevertheless important contributions to current control measures have been made by the Leatherjacket Working Party of the Closed Conference of Advisory Entomologists during the last period of intense activity. Trials by NAAS (Golightly 1967, White 1967, Raynor 1969) emphasize the superiority of baits over sprays, and as baits normally use half the quantity of active ingredient per acre, it is desirable that these should be used. It was due to co-operative work between NAAS Northern Region and a commercial organisation that a prepared bait formulation of BHC was marketed in the form of pellets for immediate distribution on the farm. This overcomes the principal drawback associated with baits as previously it was necessary to mix them on the barn floor immediately prior to use.

A further development in this particular field has been the introduction in 1969 of fenitrothion for leatherjacket control. NAAS entomologists were again responsible for much of the trial work demonstrating its value. Approval has only been sought for, and granted, for its use with a bran base as a bait. Experience during the development period indicated that occasionally for no known reason the spray application failed completely. Not only is the failure to control noted on a whole field basis, but in trials it has been seen that four replicates would give satisfactory control (70-90%) but on the fifth there would be no mortality. In view of this rather unpredictable pattern, fenitrothion spray is not recommended.

At present, the organochlorine insecticides available for leatherjacket control are DDT and BHC as bait or spray, aldrin spray or bait on DDT susceptible barley varieties and fenitrothion bait. Parathion granules have proved very effective (La Criox and Newbold 1968, Rayner 1969) but are not now available. There is undoubtedly a user-preference for sprays as opposed to baits. If this prejudice cannot be overcome despite the clear superiority of baits, then there is an urgent need to develop a spray as an alternative to the organochlorines.

Saddle gall midge (<u>Haplodiplosis equestris</u>)

During the last two decades this insect has caused concern on the Continent. Not only has the area over which it is a recognised pest increased, but the severity of attacks too. Spraying is recommended in Scandinavia and the lowland countries of Europe. This upsurge has coincided with the practice of growing continuous cereals or at least long runs of cereal crops.

In 1967 a survey was conducted in the Eastern counties of England (Woodville 1968) and of 79 fields examined, 37 were infested to varying degrees. A preliminary attempt at damage assessment was made on one heavily attacked field. This suggested that 55% of stems galled reduced yield by 5 cwt/ac. This survey was repeated in the two succeeding years (Woodville 1970) and demonstrated the widespread distribution of attacks in the Eastern counties. 48 per cent of the fields were affected to some degree or other, the pest being recorded in all counties of the region. Heavy attacks with severe yield reduction have also been recorded in Kesteven, Lincolnshire.

In view of the relatively recent development of this insect as a pest of some importance, its widespread distribution in the principal cereal growing areas of the country, and the limited information on crop loss/pest numbers relationship, it has been urged (White 1968) that more work be devoted to it so that its exact status can be assessed with more certainty. Damage assessment often develops alongside control measures. Judicious insecticide application can deliberately induce differential attacks, so providing in the same experiment information on the crop loss and insect numbers relationship and the relative efficiency of the insecticides used. Work along these parallel lines is currently being undertaken by several ADAS regions.

In the East Midland region there have been several trials to evaluate less persistent chemicals for control purposes. On the continent a mixture of DDT plus parathion is recommended so the 1971 trials used this treatment as a standard. Table 2 presents results of trial No 1 when sprays were applied ten days after the beginning of oviposition.

Table 2
Saddle gall midge control - Trial No 1 East Midland

	I % Stems with larvae	II Larvae per stem	I x II Index of infestation	Yield cwt/ac 85% DM
Water only	22.0	2.66	58.5	37.1
Fenitrothion	13.25	1.08	14.3	38.5
Carbaryl	24.5	1.80	44.1	38.1
DDT + parathion	14.5	1.07	15.7	38.1
LSD				1.76

(SE per plot = 3.0%)

Rates of use were:-

DDT + parathion: ½ lb 50% DDT wp (0.227 Kg) + 15 fl oz 20% parathion ec (0.426 l.)
Fenitrothion: 25 fl oz 50% ec (0.710 l.)
Carbaryl: 1¾ lb 85% wp (0.794 Kg)
Sprays applied in 30 gallon/acre (337 l/ha)

The attack was relatively light, but even so fenitrothion seems comparable to DDT + arathion whilst carbaryl does not appear very successful. In two further unreplicated trials, Table 3, the sprays were applied about 10 days after peak oviposition and here too fenitrothion gave most promising results.

Table 3

Saddle gall midge control - East Midlands

	I % Stems with larvae	II Larvae per stem	I x II Index of infestation	Yield cwt/ac 85% DM
Trial A				
Water only	45	9.17	412.6	36.2
DDT + parathion	13	0.71	9.2	37.5
Fenitrothion	19	1.35	25.6	37.9
Trial B				
Control	52	14.16	736.2	45.7
Fenitrothion	4	0.12	0.5	49.8
Pirimiphos-methyl	24	2.28	54.7	50.2

Should damage assessment trials indicate that saddle gall midge attacks justify controlling chemically, fenitrothion might well prove as useful as the continental recommendation of DDT with parathion.

Frit fly (Oscinella frit)

This pest, like wireworm, has become of reduced importance during the last twenty years. Formerly of considerable economic significance on spring oats it has now been relegated to the role of a minor pest, for the time being at least. This change has been brought about by two main factors, first the widespread replacement of oats by barley on farms concentrating on cereals, and secondly the ousting of oats by grass in the marginal areas on the realisation that in livestock areas well managed grassland has a greater productivity potential than cereals.

Although oats, the major cultivated host plant is less widely grown now, another susceptible crop, maize, is likely to be increasingly grown in the southern counties. Recently introduced varieties are most promising as replacements for traditional cereal fodder crops.

The BCPC Insecticide and Fungicide handbook recommends DDT to control frit fly on oats, but this has never been put into practice on any appreciable scale. In any case, this possible use ceased on 30 September 1971. Experimentally it was shown in the mid-fifties (Thomas 1968) that high volume parathion sprays could successfully control attacks, but this use has not been developed or approved. The high volume spraying of an OP of such toxicity is not a practice to be encouraged on farms where personnel may be inexperienced in the use of such materials. To prevent frit fly attack on maize there is an approved method which does not rely on organochlorines, the application of phorate in a granular formulation in the furrows at drilling. Placement in the zone of maximum uptake is clearly important.

There is undoubtedly a need for further work, using the newer insecticides to control frit fly, particularly as sprays to stop incipient attacks developing to serious proportions. This problem should be studied now rather than waiting till there is an upsurge in the activities of this pest.

Grassland pests

There are two particular situations in which pests can be important on grass. They are during the period of establishment and on seed crops. Immediately after germination young grasses may be subject to wireworm, leatherjacket, frit fly, etc, and are particularly susceptible to injury. These pests have been referred to earlier and any control methods of value on cereals can usually be applied here. The only insects given 3-star status in the BCPC Handbook in the section devoted to grass pests are aphids. The bird-cherry aphid (Rhopalosiphum padi) fescue aphid (Metopolophium festucae) and the apple-grass aphid (Rhopalosiphum insertum) are singled out for special mention. There are adequate agents for control among the OPs should it be necessary to apply chemical control measures.

Outside these two areas, establishment and seed crops, pests on established grass are not generally of great significance. Reference should, however, be made to two pests which are occasionally responsible for important losses. It has been shown (White and French 1968) that leatherjackets can be responsible for severe loss of productivity in leys. An estimated annual average of 100,000 acres suffering quite serious damage is suggested. Only occasionally are attacks so severe that the grass is killed out. Most of the lost grass is not appreciated. DDT has in the past been available to control leatherjackets in grassland but it is no longer available, nor is there yet a suitable alternative. Experimental work has shown that baits do not achieve the same degree of control as sprays in these circumstances and that the OPs are not comparable in efficiency to DDT for eliminating Tipulid larvae.

The second pest which occasionally causes widespread loss of grassland is antler moth. It appears sporadically and at infrequent intervals but in seasons when it is abundant it can devastate thousands of acres of hill grassland and cause severe economic hardship to hill farmers. The land which is affected is of low inherent value and there is no economic justification for insecticide application. Although it is known that DDT controlled this pest most effectively, effort expended in searching for an alternative would not be cost effective, particularly as much of the land is of difficult terrain, so increasing the cost of application.

Acknowledgements

I would like to express my grateful thanks to colleagues in ADAS for permission to use unpublished data.

References

CATLING, W S and COOK, I K (1967) Trials with carbophenothion and N2790 for wheat bulb fly and wireworm control in cereals.
Proc. 4th Brit. Insectic. Fungic. Conf., 139-155.

COLE, R J and SOPER, D (1967) Ethion for the control of wheat bulb fly. (Leptohylemyia coarctata) Ibid., 124-138.

GAIR, R (1967) Effects of intensive cropping on the pests of cereals in England and Wales. Ibid., 517-8.

GOLIGHTLY, W H (1967) Control of Tipula spp larvae. Suppl. to Pl. Path., 16, 33-35.

GOLIGHTLY, W H, MATHIAS, P L and ROBERTS, P F (1969) Chemical control of wireworms in winter wheat in the East Midlands 1966-68. Pl. Path., 18, 23-33.

GRIFFITHS, D C and SCOTT, G C (1965) Some tests on organophosphorus and carbamate insecticides for the control of wireworm and wheat bulb fly.
Proc. 3rd Brit. Insectic. Fungic. Conf., 190-193.

GRIFFITHS, D C and SCOTT G C (1967) Persistence and effectiveness of carbophenothion and ethion seed dressings to control wheat bulb fly (Leptohylemyia coarctata)
Proc. 4th Brit. Insectic. Fungic. Conf., 118-123.

GRIFFITHS, D C (1969) Some laboratory tests of feeding deterrents and baits against wireworms (Agricotes spp)
Proc. 5th Brit. Insectic. Fungic. Conf., 398-404.

LA CROIX, E A S and NEWBOLD, J W (1968) Autumn treatment against leatherjackets. Pl. Path., 17, 78-82.

LORD, K A, SCOTT, G C, JEFFS, K A, GRIFFITHS, D C and MASKELL, F E (1967) Persistence and distribution of insecticidal seed-dressings for control of wheat bulb fly, Leptohylemyia coarctata.
Ann. Appl. Biol., 60, 173-180.

LORD, K A, JEFFS, K A and TUPPEN, R J (1971) Retention and distribution of dry powder and liquid formulations of insecticides and fungicides on commercially dressed cereal seed. Pestic. Sci., 2, 49-55.

MASKELL, F E (1970) Further seed-dressing trials against wheat bulb fly (Leptohylemyia coarctata) in East Anglia, 1966-68. Pl. Path., 19, 42-46.

RAYNER, J M (1969) Chemical control of leatherjackets (larvae of Tipula spp), in spring cereals with special reference to alternatives to persistent organochlorine insecticides. Proc. 5th Brit. Insectic. Fungic. Conf., 71-77.

THOMAS, J D (1958) Control of frit fly by chemical means. Ann. Appl. Biol., 46, 497-501.

TROUGHT, T E T and HEATH, E D (1965) The insecticide chlorfenvinphos. Proc. 3rd Brit. Insectic. Fungic. Conf., 248-264.

WHITE, J H (1963) Observations on leatherjacket populations, assessment, forecasting and control measures. Proc. 2nd Brit. Insectic. Fungic. Conf., 51-58.

WHITE, J H (1967) The use of organochlorine insecticides and possible alternatives against leatherjackets. Pl. Path. 16, 83-88.

WHITE, J H (1968) Integrated pest control. J. Appl. Ecol., 5, 489-516.

WHITE, J H (1970) First Review of Insecticide and Fungicide Usage B.C.P.C. 17-19.

WHITE, J H and FRENCH, N (1968) Leatherjacket damage to grassland. J. Bri. Grassld. Soc., 23, 326-329.

WILSON, A (1969) Further review of certain persistent organochlorine pesticides used in Great Britain. H.M.S.O., London.

WOODVILLE, H C (1968) Saddle gall midge survey on barley 1967. Pl. Path., 17, 64-66.

WOODVILLE, H C (1970) Results of a three year survey on saddle gall midge (Haplodiplosis equestris) on spring barley. Pl. Path., 19, 141-145.

PEST CONTROL IN VEGETABLES: SOME FURTHER LIMITATIONS IN INSECTICIDES FOR CABBAGE ROOT FLY AND CARROT FLY CONTROL

G.A. Wheatley
National Vegetable Research Station, Wellesbourne, Warwick

Summary A better understanding of the limitations of present insecticides is needed so that they can be used to best advantage. A method is described for applying continuous, logarithmically-increasing rates of insecticide granules for cabbage root fly control. On mechanically transplanted summer cauliflowers, root damage was enhanced by low rates of fonofos, diazinon or chlormephos applied as post-planting surface bands, probably because they adversely affected populations of natural enemies of the pest. A chlorfenvinphos surface band showed no tendency to enhance damage, nor did this occur when any of the insecticides were applied by a subsurface placement method at planting. Some of the chemicals may have subtle effects on plant growth which prevent the maximum potential yield being obtained. For carrot fly control, a bow-wave application of phorate protected a late-March sowing of carrots longer than a late-May sowing. It controlled carrot fly more effectively within the shelter zone of a tall hedge than in more exposed positions away from the hedge.

INTRODUCTION

In the U.K., it has become more difficult in recent years to achieve acceptable levels of control of a number of the more important pests of vegetables than was the case ten years ago (Gair, 1971, Wright, 1971). There are several contributory reasons for this. We have much still to learn about the best ways of using the new generation of insecticides that has largely surplanted the organochlorine compounds. The standards of pest control needed to guarantee high quality produce for sophisticated market outlets have also increased, setting targets for pest control which, in some instances, are clearly not attainable, nor are likely to be, by conventional methods. This is particularly so with soil-inhabiting pest of vegetables, and ways of improving the performance of the methods used for their control are now urgently needed.

A correct diagnosis is the first important step in attempting any cure. Watts (1970) has concluded that pest control systems fall within the category, of so-called 'counterintuitive' processes, in the language of the systems analyst. Characteristically, such processes are complexes of interacting variables and feed-back loops often indicating corrective actions which will be ineffective, or even produce effects opposite to those intended. These occur in even the most elementary pest control situations and further improvements in methods of pest control must depend on our ability to pin-point the principal factor(s) limiting success and so identify the best approaches for corrective action in each situation.

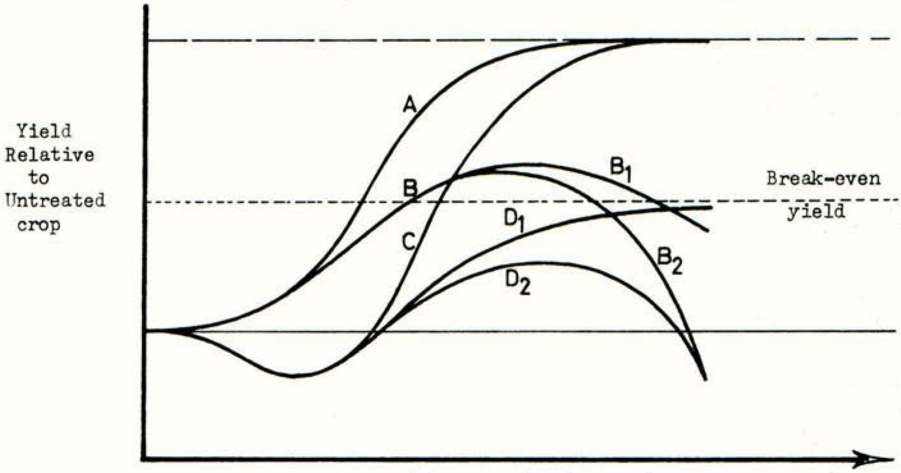
Not unnaturally, there is a strong tendency to blame the present problems on the inadequacies of the new generation of chemicals. They do not have the innate capacity for single applications to protect crops throughout their growing season but the very characteristic, persistence, which so favoured the performance of the organochlorine compounds, was at the same time one of the principal reasons for their downfall. Furthermore, concern with pesticides residues in the produce was minimal during the era of 'successful' usage of the organochlorine compounds; that is no longer the case and residues in the crop would today almost certainly make their use, for instance, for controlling carrot fly attack on crops for canning, quite unacceptable. Some of the more stable organophosphorus compounds such as chlorfenvinphos or fonofos are perhaps one-half to one-fifth as persistent in soil as gamma-BHC, one of the least persistent of the commoner organochlorines. There is very little margin, therefore, to develop compounds of greater stability than some of those now being used. It is difficult to visualise more persistent compounds being released for general agricultural use in the future and, certainly, there would seem to be no question of compounds of comparable persistence to DDT or dieldrin being developed. We must conclude, therefore, that seeking greater stability in chemicals to prolong the protection of our crops from pest attack is unlikely to be an acceptable cure for present problems.

Since there is no reason to doubt the inherent potency of the present generation of chemicals, we are left with two approaches to alleviate the problems until more permanent solutions are found. Firstly, we must again begin to apply the knowledge that we already have of pest ecology to avoid agroecosystems that are liable to enhance pest populations or make control methods less effective. Secondly, we must use the insecticides now available within their limitations and to best advantage. It can be just as important to know what <u>not</u> to do as to know what <u>can</u> be done. This argument is illustrated by examples taken from the results of recent experiments on the chemical control of cabbage root fly and carrot fly. The first of these shows some of the complicating factors involved in the relationships between chemicals, methods for their application, cabbage root fly control and the yield of transplanted summer cauliflowers. The second reveals a new variable in the performance of insecticides againt carrot fly on main-crop carrots, namely the possible influence of shelter, and the third shows how the duration of effectiveness of an insecticide can vary with sowing date.

<u>Cabbage root fly</u> (<u>Erioischia brassicae</u>) <u>control</u>: Trials with insecticides for cabbage root fly control were undertaken by the A.D.A.S. Brassica Pests Working Party (Rolfe, 1969) between 1968 and 1970. Attempts to summarise the results have been frustrated by the complications revealed. Root damage was not always related to the amounts of insecticides applied and increases in yield seemed to occur more commonly with some insecticides or application methods than with others. Of even greater importance, yields lower than those recorded on untreated plots occurred too frequently to be dismissed as the extremes of normal error expectations and only relatively large increases in crop yields were statistically significant, even though moderate increases often occurred logically and consistently in relation to the treatments applied. Complications such as those modelled in Fig. 1 seemed to be operating. This diagram shows the expected relationships between crop yield and the dose of chemical applied, according to whether or not the chemical is selective and/or phytotoxic. A non-selective insecticide present at concentrations that are too low to control the cabbage root fly can enhance attack by reducing populations of its natural enemies, particularly predatory beetles, (Coaker, 1966). Acute phytotoxicity is also well recognised as a hazard of applying certain present-day insecticides at sensitive stages of plant growth. However, some chemicals may also have more subtle effects on plant growth rate and any adverse effects would interact to limit the benefits accruing from root fly control.

In Fig. 1, 'A' portrays the ideal relationship; the chemical is selective and does not affect plant growth in the 'useful' range of dose. By increasing the dose until the pest is adequately controlled, the crop can attain its maximum potential yield. The relationships in curves 'B1' or 'B2' would occur if the chemical was selective but tended to restrict plant growth rate to varying degrees. There would be an optimum dose above or below which the yield would tend to decline and the maximum potential yield may never be obtained. A non-selective chemical not affecting plant growth (curve 'C') would result in a suppressed yield at low doses, but it would then increase rapidly to the maximum as the dose increased. In practice, results would be variable if the recommended dose was within the narrow range where the curve increases to the maximum. A non-selective chemical that also affected plant growth (curves D1 or D2) would cause the yield to oscillate at or near the level for an untreated crop. Benefits from treatment would then be minimal, if any, and a break-

Fig. 1
Expected effects on yield of
increasing the dose of insecticide



even yield may not be obtained even though the pest is well-controlled at the higher doses. The experimental results summarised below illustrate some of these points.

Carrot fly (Psila rosae) Control: On maincrop and late carrots, the control of late attacks by the carrot fly is still an unsolved problem. A complete or permanent solution seems unlikely to be obtained with the present-day types of insecticides, but it should be possible to get better results more consistently in practice if their limitations were more fully understood. Different compounds decline in effectiveness at different rates during the late summer and autumn and some seem to be better applied in one way than in another (Wheatley, 1969; Mowat, 1969). Row spacing can also affect their performance. Whereas the efficiency of broadcast applications of disulfoton for instance, are not much affected by row-width, bow-wave applications tend to be progressively less effective at wider row spacings if the amount per unit length of row, contrasting with the requirements for controlling carrot-willow aphid (Cavariella aegopodii) (Wheatley & Wright, 1970). Factors determining the uptake of residues during the period of exponential growth of carrots may also influence the effectiveness of an insecticidal treatment (Suett, 1971). Nor can levels of control be much improved simply by increasing the application rates beyond those now recommended, and there is a real risk of impairing germination and/or seedling vigour by so doing.

In the spring, carrots may be sown and treated by the 'bow-wave' methods from March until June, a period when soil temperatures increase rapidly. Degradation of the insecticides in soil is negligible while soil temperatures are below 6-7°C (Wheatley, et al, 1971) and so the duration of effectiveness of 'bow-wave' treatments should vary according to sowing date. This was explored in an experiment on a loamy-peat soil in 1970. In 1969, an experiment was done to determine whether the effectiveness of a 'bow-wave' application of phorate depended on the carrot cultivar being grown. Significant effects of cultivars were not demonstrated, but the insecticidal performance from this type of application was apparently affected by proximity to a tall hedge. Results from these two experiments are summarised.

MATERIALS AND METHODS

The following commercially-available granular formulations of insecticides were used:-

Common Name	Formulation	% a.i.
aldicarb	Temik	10
chlorfenvinphos	Birlane	10
chlormephos	(MC 2188; Murphy Chemical Co.)	5
diazinon	Basudin 5	5
disulfoton	Disyston NF	7.5
fonofos	Dyfonate	10
phorate	Thimet Phorate	10

Cabbage root fly control on summer cauliflowers, 1970 Cauliflowers, cv. Finney's 110, were transplanted into a sandy-loam soil at Wellesbourne on 12 May using a Super Prefer twin-unit planter. The plants were spaced at 18 in (46 cm) intervals in rows 24 in (61 cm) apart over the experimental area comprising 32 rows each of 80 plants with two additional rows at either sides as guards. The end two plants in each row were guards and were not included in calculations of the results. Large numbers of cabbage root fly eggs were being laid on the plants within a few hours of transplanting.

The granular formulations of chlorfenvinphos, chlormephos, diazinon and fonofos were applied at continuous logarithmically-increasing rates, either as a pre-planting sub-surface band or as a post-planting surface band. The sub-surface band was applied while planting by delivering the granules through a 2-3 in (5-8 cm)-wide coulter set to a depth of 2-3 in (5-8 cm) below the soil surface about 6 in (15 cm) infront of and exactly in line with the planter share, according to specifications developed by A.D.A.S. Entomologists in the Yorkshire/Lancashire Region (J.R. Kelly, pers. comm.). The post-planting treatments were applied about 16-18 h after transplanting. The methods of application were confined to main-plots arranged as a 2 x 2 Latin square, each main-plot being 16 rows wide x 31-32 plants long. Within each main-plot, the four insecticides were applied in randomised order to plots each 4 rows wide x 31-32 plants long. Untreated plants were restricted to strips 5-10 plants wide across the ends of the rows (plots) and the centre of the planted area. In one pair of main-plots the application rates increased towards the centre of the experiment, in the other they increased towards the outside.

The insecticide granules were delivered from a twin V-belt applicator mounted on and geared to, the planter. The logarithmic application rates were achieved by loading pre-weighed amounts of granules into an exponentially-shaped trough and then tilting the trough to place the granules along the V-belt. The application rate was varied 16-fold in treating 30 plants, the starting and finishing rates being held constant to treat an additional plant at either end. Diazinon was applied at from 0.63 to 10 oz a.i./1000 yd row (1 oz/1000 yd = 32 g/1000m = 4.8 mg/ 15 cm / plant) and the other compounds at from 0.45 to 7.2 oz a.i./1000 yd. The beginning and end of the granule bands were marked by observing the fall of coarse pumice granules added at each end of the load on the V-belts. Delivery was to within about ± 9 in (22cm) of the desired marks and visual inspection showed that the density of granules in the surface bands increased regularly on the ground along the rows.

The cauliflowers were cut at 2-3 day intervals from 7 to 22 July and the diameters of the curds measured to the nearest cm, recording the exact position of each. Root damage indices (RDI) (Wright, 1953; Rolfe, 1969) were assessed on 23-27 July. Only 4 plants were available for each dose-position on each plot and so running means of 3 dose-positions were calculated to damp-out the variability. The 'untreated' levels of curd diameter and root damage were assumed to follow linear trends along the length of each treated plot between the levels recorded on untreated plants at either end, and the effects on root damage and curd diameter were calculated for each plant position along the dose range. Effects on root damage were expressed as '% Reduction in RDI', a measure of treatment efficiency largely independent of infestation level. The effects on yield were calculated as the differences in the mean diameters of treated and untreated curds exceeding 5 cm.

Carrot Fly Control: The same methods were used as described previously (Wheatley, 1969). The experiments were done on a loamy-peat soil at Mepal, Cambridgeshire, applying the insecticide granules by the bow-wave method while drilling the seed. The treatment effects were assessed by recording the percentage of unattacked carrots and then calculating the percentage reductions in carrot fly attack.

In the 1969 experiment, cultivars representing five of the main carrot-types were sown in twin rows 6 in (15 cm) apart at 71 cm (28 in) centres on 4 June. The plots were each 18 ft (5.5 m) of twin row arranged in three randomised blocks parallel to each other and to a 9-12 ft (3-4 m)-high hedge, with the carrot rows at right angles to the headland. The block nearest to the hedge was separated from it by about 16 ft (5 m) of uncropped headland and further 8 ft (2.5 m) wide uncropped strips separated the three blocks of plots from each other. The blocks occupied positions 16 to 34, 43 to 61 and 69 to 87 ft (5-10.5, 13-18.5 and 21-26.5 m approximately) west of the hedge, which extended about 300 and 500 ft (90 and 150 m) south and north of the edges of the experiment. Two plots of each cultivar were sown in each block, one being treated with phorate at 2.5 lb a.i./ac (2.8 kg/ha). Carrots were harvested on 2 December from 4 ft (1.2 m) of twin row on each plot.

For the 1970 experiment, carrots, cv Amsterdam 5558, were sown and treated, and sampled on the dates shown in Table 3. The five insecticides were each applied at two rates and their relative performances estimated graphically. The rates selected for each insecticide were, with the exception of disulfoton, intended to ensure similar levels of effectiveness on the basis of previous results. The rates of disulfoton applied were lower than intended because of a misunderstanding about the identity of the formulation used which was 7.5% a.i. and not 10% as initially believed. The time that control exceeded 90% reduction of attack and the degree of control 20 weeks after treatment were estimated graphically from the calculated efficiencies at each sampling date.

RESULTS

None of the cabbage root fly treatments fully-controlled the pest until harvest (Table 1). The subsurface applications of the insecticides reduced root damage by a maximum of about 50 to 80%, fonofos being the most, and diazinon the least, effective at 2.3 oz a.i./1000 yd row (c. 10 mg a.i./plant). For a 70% reduction in RDI, the minimum probably acceptable in practice, the order of effectiveness was fonofos > chlormephos > chlorfenvinphos ≫ diazinon. Within the dose-ranges explored, none of the insecticides caused an increase in root damage when applied sub-surface, but chlorfenvinphos was the only compound which did not enhance root damage when used as a surface band. Fonofos increased the root damage by 10-12% at rates up to about 1.5 oz a.i./1000 yd; both diazinon and chlormephos increased the RDI by more than 30% as compared with that of untreated plants.

Although the effects of the treatments on the mean diameters of the cauliflower curds (Fig. 2) were small (± < 2 cm) they represented considerable differences in absolute yields. A difference of ± 0.5 cm is equivalent to about ± 17 and 50 crates/ac (c. 40 and 120 crates/ha) for 3 in and 5 in (715 and 12.5 cm) diameter curds respectively. Although both chlorfenvinphos and fonofos gave some increase in curd diameter at low doses, curd-size did not increase progressively with increasing dose. In the field the plants seemed to be just as well-developed at the 'low-dose' ends of the treated strips where appreciable root fly damage was present on the roots at harvest, as at the 'high-dose' ends where damage was minimal throughout. In contrast,

Fig. 2

The effects on the mean diameter of cauliflower curds of application rate and method of applying insecticides for cabbage root fly control

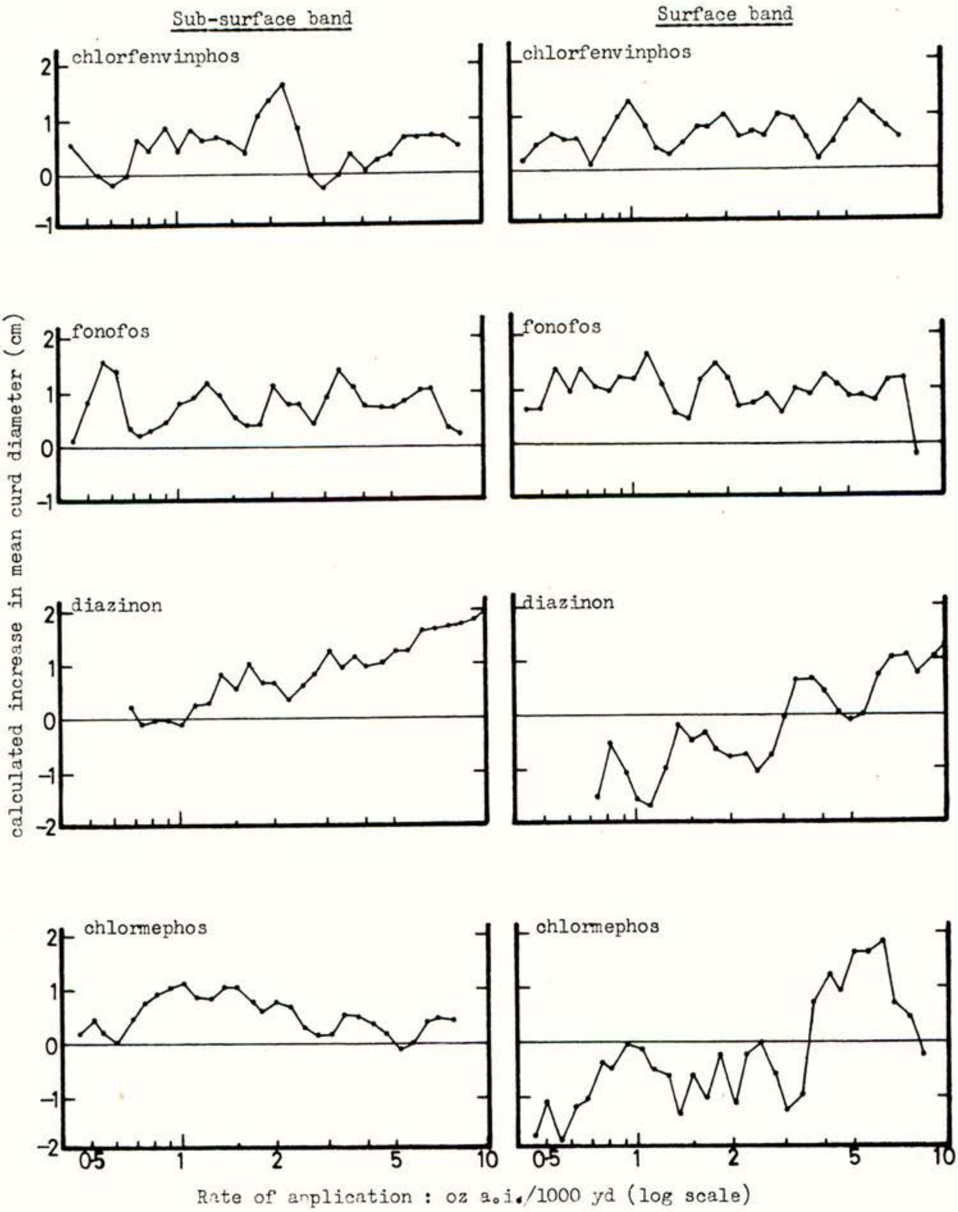


Table 1

Effects of insecticide and method of application on the control of cabbage root fly damage to summer cauliflowers, 1971

	% Reduction in RDI by 2.3 oz a.i./1000 yd*	oz a.i./1000 yd for 70% Reduction in RDI	Highest rate enhancing damage (oz a.i./1000 yd)
Sub-surface placement			
chlorfenvinphos	65	3.3	no effect(<0.45)
fonofos	78	1.9	no effect(<0.45)
diazinon	50	>10	no effect(<0.63)
chlormephos	70	2.3	no effect(<0.45)
Post-planting surface band			
chlorfenvinphos	67	2.0	no effect(<0.45)
fonofos	55	4.0	1.5
diazinon	15	10	1.8
chlormephos	(-25)	≫7.5	5.0

* 2.3 oz a.i./1000 yd is the recommended rate for chlorfenvinphos

increasing the application rate of diazinon applied by either method, resulted in a steady increase in curd diameter along the treated strips, from less than to more than the diameters of the curds from untreated plants, again agreeing with observations on plant growth in the field. The greatest improvement in curd diameter (<+2 cm increase) was given by diazinon applied sub-surface at the relatively high rate of about 10 oz a.i./1000 yd, although it barely reduced the RDI by 70%. As a surface band treatment, diazinon did not increase curd diameter until the rate applied exceeded about 3.0 oz a.i./1000 yd, compared with 1 oz/1000 yd by the sub-surface method. Of the chemicals tested, chlormephos was most affected by the method of application. Applied sub-surface, it gave a good control of the pest but only increased curd size by about 1 cm, followed by a progressive decline when the application rate exceeded about 1 oz a.i./1000 yd (5 mg a.i./plant), indicating possible phytotoxicity. As a surface band treatment, the application of this chemical could only be described as a 'disaster' for much of the dose range explored. Rates less than about 3.5 oz a.i./1000 yd so enhanced the attack that many plants were killed. From 3.5 to about 6 oz a.i./1000 yd the curd diameter increased rapidly, but there was a sharp decrease at the highest doses indicating possible acute phytotoxicity.

Table 2

Change in the effectiveness of phorate applied by the bow-wave method to control carrot fly at different distances from a hedge

Distance from hedge		*% Attacked roots		% Reduction in carrot fly attack ‡
ft	m	Treated	Untreated	
16 - 34	5 - 10.5	6.8	59.2	92
43 - 61	13 - 18.5	17.7	58.0	77
69 - 87	21 - 26.5	25.9	52.4	60

* means of 5 plots

‡ see Wheatley (1969); differences significant (P = 0.01)

Table 3

1970 Experiment: sampling dates and the infestation levels on untreated carrots

Sowing dates	Sampling: Dates	Sampling: Weeks	Infestation on untreated carrots (% attacked)
26 March	30 July, 7 Oct.	18,27	44, 45
15 April	30 July, 7 Oct., 15 Dec.	15,25,35	49, 56, 48
28 May	8 Oct., 15 Dec., 12 Jan.	19,29,33	47, 71, 69

Table 4

The effect of sowing date on the furation of effectiveness of insecticides applied by bow-wave to control carrot fly on carrots in a loamy-peat soil in 1970

		Duration of 90% reduction in attack (weeks)			% reduction in attack 20 weeks after sowing		
		Sowing date			Sowing date		
Insecticide	(lb/ac)	26 March	15 April	28 May*	26 March	15 April	28 May
fonofos	(1 & 3)	21	15	<10	94	69	27
chlorfenvinphos	(1.33 & 4)	19	15	<10	84	71	29
aldicarb	(1 & 3)	19	15	<10	83	61	10
phorate	(0.83 & 2.5)	18	13	< 5	85	62	70
disulfoton	(1 & 3)	16	11	<10	60	56	42

* = Values extrapolated; doubtful if attack ever reduced by>90%
1 lb/ac = 1.12 kg/ha

Carrot fly control: Any differences in the performance of the treatment on the different cultivars in the 1969 experiment were too small to be statistically significant and so the results for the five treated and five untreated plots in each block were each pooled to derive the means given in Table 2. The block-to-block differences in the % attacked roots indicated a slight decline in the infestation with increasing distance from the hedge, although less than expected (Wright & Ashby, 1946). However, the percentage of attacked roots on the treated plots increased with increasing distance from the hedge, indicating that the treatment became less effective away from the hedge, as seen in the calculated % reductions in attack. The trend from 92 to 60% reduction corresponded to a fall in effectiveness equivalent to at least a three-fold reduction in dose available, as estimated from previous dose/response curves.

The results of the 1970 experiment show (Table 3 and 4) that the later the sowing date the shorter the period of adequate protection (more than 90% reduction in attack). The earliest-sown carrots were protected for 18-20 weeks, those sown in mid-April for about 13-15 weeks and those sown in late May probably never for longer than 10 weeks (estimated by extrapolation). The rates of application selected seemed to bear-out the predictions of relative effectiveness estimated from previous results, so that all of the compounds tested (excluding disulfoton) performed similarly at the rates used. However, phorate was clearly the most effective on the final sowing date. Its performance seemed least affected by the sowing date, declining from 85 to 70% reduction in attack, equivalent to perhaps a halving of the dose.

DISCUSSION

The results from the cabbage root fly experiment emphasize that neither insecticides or methods of application are interchangeable if the effects of treatments on yield, and presumably profitability, are the main consideration. Fonofos, diazinon and chlormephos applied as surface bands led to enhanced root damage at low doses probably by adversely affecting the natural enemies of cabbage root fly without providing compensatory reductions in the attack. Chlorfenvinphos is clearly a relatively selective insecticide which is not very toxic to the more important species of predatory beetles responsible for natural control of this pest (Mowat & Coaker, 1967). The subsurface method of application apparently completely masked the non-selectivity of the other insecticides which was very evident when they remained on the soil surface. Neither diazinon or chlormephos would be reliable if used as surface bands, since the margin between success and failure would be small and subject to changes in weather or soil conditions. Yield could be substantially reduced if either were applied in this way at too low a rate or inefficiently. Conventional spot applications of diazinon probably avoid this effect because much more chemical is applied per plant than with the continuous band where more than two-thirds is wasted in inter-plant spaces. The spot application would also minimise any adverse effects against the natural enemies (Wright, et al, 1960).

The destruction of the natural enemies of cabbage root fly was reasoned to be a prime factor contributing to the development of organochlorine-resistant populations in the early 1960's. Now we see the possibility that the same phenomenon may be the cause of some of the present difficulties in controlling this pest, even on a relatively short-term crop such as the summer cauliflower. Any adverse effects of insecticides on the natural enemies of the cabbage root fly may be even more important with a longer-term crop such as Brussels sprouts in which a high level of control of the first generation attack is probably necessary in order to limit attacks by subsequent generations.

Despite appreciable root damage, the plants treated with the relatively high doses of diazinon yielded the largest curds in the experiment. Chlorfenvinphos and fonofos did not achieve similar increases, although they gave better root fly control. Either diazinon slightly stimulated curd development or it was progressively suppressed by the higher doses of chlorfenvinphos and fonofos. The decline in curd diameter associated with the higher rates of chlormephos applied sub-surface indicates a subtle phytotoxicity. These effects seem to warrant further investigations.

This experiment vindicated in part the implications suggested in Fig. 1. Chlorfenvinphos and fonofos applied sub-surface, seemed to follow a B1 type relationship; fonofos as a surface band was a D1 effect; diazinon may have resulted in a form of curve C; and chlormephos seemed to follow a B2-type curve when applied sub-surface and a D2 curve as a surface band. The actual effects are likely to be even more complicated than suggested by Fig. 1.

Coaker & Finch (1965) and Coaker (1969) have shown repeatedly that serious reductions in the yield of summer cauliflowers can usually be prevented if the crop is well-protected from root fly damage during the first few weeks after planting out. Wheatley & Coaker (1969) suggested that this was the means whereby relatively low doses of diazinon applied as liquid drenches around the plants gave a major increase in yield which was only gradually improved by increasing doses. This latter characteristic of diazinon was confirmed in the experiment reported here but it clearly does not apply to all insecticides.

The reduced effectiveness of phorate against carrot fly in more exposed positions in a field has several implications if it is subsequently confirmed by further experiments. It could explain why so much damage is found on carrots towards the centres of large fields where attacks should be relatively slight (Wright & Ashby, 1946). Experiments on carrot fly control are usually done in sheltered situations likely to favour high levels of attack and this may exaggerate the efficiencies of the present insecticides in practice as indicated in small-scale trials. There are several reasons why the insecticides may be less effective in exposed situations, but there is no evidence yet to indicate which factors are most important, for instance volatilisation, soil 'blowing', differences in moisture status and so on.

The changing effectiveness of phorate applied at different sowing dates was such that not even the carrots sown late in May were adequately protected when the attack by the second generation of the pest began in August. The result implies that, when necessary, it will be safer to apply supplementary mid-season treatments in relation to the time of appearance of the second generation of flies during August rather than to delay the treatments on later-sown crops in peat soils, relying on good protection until September by the insecticide applied at sowing time. This is supported by direct evidence from other experiments done both by N.V.R.S. and A.D.A.S. Eastern Regional Entomologists (R. Gair, pers. comm.) in 1970, showing that supplementary mid-season treatments of either sprays or granules reduced late damage most effectively when they were applied during August, rather than later in the season.

Clearly, there is still a good deal yet to be learned about how best to deploy our chemical resources against this pest.

Acknowledgements

I wish to acknowledge the valuable technical assistance of Mr. F.K. Niendorf and Mr. A.J. Wright and also to thank the firms who kindly supplied the chemicals used in the experiments.

References

COAKER, T.H. (1966) The effects of soil insecticides on the predators and parasites of the cabbage root fly (Erioischia brassicae (Bouché)) and on the subsequent damage caused by the pest. Ann.appl.Biol., 57, 397-407.

COAKER, T.H. (1969) New approaches to cabbage root fly control. Proc. 5th Br. Insectic. Fungic. Conf., 3, 704-710.

COAKER, T.H. & FINCH, S. (1965). The control of cabbage root fly on edible brassicae. Pl. Path., 14, Suppl., 4-6.

GAIR, R (1971) Organochlorine alternatives - a review of the present position in the U.K. Proc. 6th Br. Insectic. Fungic. Conf., 1,

MOWAT, D.J. & COAKER, T.H. (1967) The toxicity of some soil insecticides to carabid predators of the cabbage root fly (Erioischia Brassicae (Bouché)). Ann.appl. Biol., 59, 349-354.

ROLFE, S.W.H. (1969) Co-ordinated insecticide evaluation for cabbage root fly control. Proc. 5th Br. Insectic. Fungic. Conf., 1, 238-243.

SUETT, D.L. (1971) Persistence and degradation of chlorfenvinphos, diazinon, fonofos and phorate in soils and their uptake by carrots. Pestic. Sci., 2, 105-112.

WATTS, K.E.F. (1970) The systems point of view in pest management. In: Concepts of pest management. North Carolina State University, 71-79.

WHEATLEY, G.A. (1969) The problem of carrot fly control on carrots. Proc. 5th Br. Insectic. Fungic. Conf., 1, 248-254.

WHEATLEY, G.A. & COAKER, T.H. (1970) Pest control objectives in relation to changing practices in agricultural crop production. S.C.I. Monogr. No. 36, 42-55.

WHEATLEY, G.A. & WRIGHT, D.W. (1970) Studies of methods of applying insecticides for controlling carrot fly and carrot-willow aphid. Proc. 7th Int. Congr. Pl. Prot., 397-399.

WHEATLEY, G.A., SUETT, D.L. & HARDMAN, J.A. (1971) Some factors influencing the persistence of chlorfenvinphos in soil. Proc. 2nd IUPAC Int. Congr. Pesticide Chemistry, (in the press).

WRIGHT, D.W. (1953) The assessment of damage caused to some brassica crops by cabbage root fly. Ann.appl.Biol., 40, 607-611.

WRIGHT, D.W. (1971) Report of the Director. Rep. natn. Veg. Res. Stn for 1970, 12-13

WRIGHT, D.W. & ASHBY, D.G. (1946). Bionomics of carrot fly (Psila rosae F.) I. The infestation and sampling of carrot crops. Ann.appl.Biol., 33, 69-77.

WRIGHT, D.W., HUGHES, R.D. & WORRAL, J. (1960). The effect of certain predators on the number of cabbage root fly (Erioischia Brassicae (Bouché)) and the subsequent damage caused by the pest. Ann. appl. Biol., 48, 756-763.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

ALTERNATIVES TO DDT FOR THE CONTROL OF BLOSSOM BEETLE ON SPRING SOWN OIL-SEED RAPE

H. J. Gould

Agricultural Development and Advisory Service, Coley Park, Reading

Summary In a series of trials to investigate the efficiency of alternative pesticides to DDT, sprays of gamma-BHC applied at the green bud and yellow bud stages gave consistently good control of adult blossom beetles. A number of other pesticides including azinphos-methyl, malathion, monocrotophos, iodofenphos, phosalone and carbaryl gave results equivalent to or better than DDT. Fenitrothion caused extensive leaf necrosis. Endosulfan and phosalone (6.6 oz a.i. /ac) gave more variable initial control of adult beetles but all the pesticides tested, including endosulfan, gave a significant reduction of subsequent pod loss.

INTRODUCTION

In recent years between 10,000 and 15,000 acres (4,000-6,000 ha) of oil-seed rape have been grown annually in the United Kingdom. In South East England, where about half the acreage is grown, the crop is almost invariably heavily infested by the blossom beetle (*Meligethes aeneus*). The adult beetles cause extensive damage to the flower buds, reducing the pod set. There is conflicting evidence on the importance of larvae, Hoffman (1952) and Jary and Carpenter (1948) suggested that they feed mainly on pollen without causing extensive bud damage but Winfield (1961) recorded severe 'tip drop' as a result of larval damage to the apical buds and the rachis of the raceme on mustard.

Surveys of pod loss in 1966-1968 confirmed that blossom beetle is an important pest of spring sown oil-seed rape. The survey results, based on samples of ten upper, middle and lower racemes per field, are shown in Table 1.

Table 1

Surveys of blossom beetle damage to oil-seed rape in South East England

Year	No. of fields	Blind stalks Mean %	(Range)	No of fields sprayed O-Cs	O-Ps
1966	23	19	(2-37)	15	1
1967	49	10	(1-36)	11	21
1968	41	19	(2-59)	13	21

Before the development of effective pesticides, various mechanical methods were considered for controlling blossom beetle on brassica seed crops including mechanically operated sweep nets and a combination of greased paper and carpet beaters. Potter and Perkins (1946) and Jary and Carpenter (1948) found that DDT dusts gave a satisfactory control of blossom beetle, and in 1957 surveys by Winfield and Gough (1959) confirmed that DDT was being used on 80% of the mustard seed crops surveyed in East Anglia.

In trials during 1958 and 1959, Winfield (1961), showed that two carefully timed sprays of dieldrin gave an economic control of both blossom beetle and seed weevil (<u>Ceutorynchus assimilis</u>) and suggested that this pesticide was more suitable than DDT which was ineffective against seed weevil.

In 1964, the 'Advisory Committee on Poisonous Substances used in Agriculture and Food Storage' (Anon 1964) recommended certain restrictions on the use of dieldrin in agriculture, including its use on brassica seed crops. The 1966 survey in South East England (Table 1) showed that the majority of treated fields were then being sprayed with DDT, or gamma-BHC. In 1969, a report by the "Advisory Committee on pesticides and Other Toxic Chemicals" (Anon 1969) recommended that DDT should not be used on brassica seed crops after October 1971.

In anticipation of this report, a series of field trials were carried out to assess the efficiency of a number of pesticides as alternatives to DDT for the control of blossom beetle on oil-seed rape.

METHOD AND MATERIALS

Blossom beetle adults are very active and Winfield (1961) outlined the problems associated with the use of small plots in insecticide trials. Sprayed plots may be reinfested fairly quickly, and, if several days elapse between spraying and sampling, misleading results may be obtained. In addition the initial population on the small control areas may decline following dispersal into the treated plots. Large plots are therefore essential when pod set or yield loss is used to assess treatment effects. However, relatively small plots (20yd x 20yd) (18m x 18m) were used successfully to obtain preliminary data on the relative efficiency of DDT and alternative pesticides for the control of adult blossom beetles when population assessments were made 24-48 hours after spraying. Details of the plot sizes are given in Tables 3 and 5. Whenever possible, large plots were also used for further evaluation of the insecticides.

Details of the insecticides used, and their rates of application, are shown in Table 2. The treatments were replicated between sites and also within sites in many of the trials.

In each trial, the insecticides were applied at the early green bud stage, followed when necessary, by a second spray at the yellow bud stage. A portable sprayer was used to spray the small plots and a tractor mounted sprayer for the large plots. All sprays were applied in 30 gal of water/acre (333l/ha).

Table 2

Insecticide formulations and rates of applications

Insecticide	Rate/ac. in 30 gal water (333l/ha)		
DDT	5 pt	15% e.c.	(15 oz a.i.)
Malathion	30 fl oz	60% e.c.	(18 oz a.i.)
Fenitrothion	20 fl oz	50% e.c.	(10 oz a.i.)
Phosalone	20 fl oz	33% e.c.	(6.6 oz a.i.)
Phosalone	30 fl oz	33% e.c.	(10 oz a.i.)
Gamma-BHC	5 fl oz	80% col.	(4 oz a.i.)
Azinphos-methyl	30 fl oz	22% e.c.	(6.6 oz a.i.)
Azinphos-methyl	26 oz	25% w.p.	(6.5 oz a.i.)
Endosulfan	30 fl oz	20% e.c.	(6 oz a.i.)
Endosulfan	20 fl oz	35% e.c.	(7 oz a.i.)
Endosulfan	20 oz	35% w.p.	(7 oz a.i.)
Monocrotophos	32 fl oz	20% e.c.	(6.4 oz a.i.)
Carbaryl	1.5 lb	50% w.p.	(12 oz a.i.)
Iodofenphos	4 pt	20% e.c.	(16 oz a.i.)

(16 oz/ac = 1.1 kg/ha)

Estimates of the blossom beetle population were made on random samples of 20-50 plants/plot one or two days after spraying. Each plant was shaken over an open tin measuring 12in x 11in x 2in (30.5cm x 28cm x 15cm) and the number of blossom beetles recorded (Winfield 1961). The counts were made only in favourable weather conditions and never when the crops were wet. In one trial, samples of buds were dissected and the number of larvae present was recorded.

The effects of blossom beetle damage can be estimated by counting blind stalks or the number of set pods on the rape raceme. Winfield (1961) showed that reliable estimates of damage on mustard could be obtained by examining samples of upper, middle and lower racemes and this method was used in these trials. However plants may partly compensate for bud damage by producing more buds, or by an increase in the size of the seed (Winfield 1961) and the results given for pod loss may be an over-estimate of the true effect on yield. As many of the observations were made on small plots, no yield data were obtained.

RESULTS

Ground Spraying
1967 trials

Preliminary screening trials were done at six sites on the variety Nilla. Details of the sites, spraying dates and the control of adult pollen beetle, assessed 24 hours after spraying are given in Table 3.

Table 3

1967 trials - percentage reduction of adult beetle population 24 hours after spraying

Site	1		2	3		4		5		6	Mean
Plot size(yd)	20 x 20		20 x 120	20 x 20		20 x 20		20 x 20		20 x 20	
Plot size(m)	18 x 18		18 x 109	18 x 18		18 x 18		18 x 18		18 x 18	
Spray	1	2	1	1	2	1	2	1	2	1	
Spraying dates	7/6	12/6	18/6	2/6	12/6	20/6	25/6	1/6	9/6	18/6	
Treatments											
Malathion	80	92	97	95	69	81	91	79	87	70	84
Fenitrothion	80	86		96	77	85	91	100	89	96	89
Azinphos-methyl	90	92	97	95	69	93	91	94	99	93	91
Phosalone	74	75		77	62	87	89	92	93	80	81
Monocrotophos	85	89		99	100	96	93			99	94
Gamma-BHC	79	99	99	99	100	99	91			100	96
Endosulfan (6 oz a.i.)	35	39		58	45	57	67	77	72	59	56
Carbaryl	84	91	86			73	84				83
DDT	87	90	87	85	78	86	80			83	84
Beetles/24 plants on unsprayed plots	74	82	118	81	30	85	55	48	54	45	

S.E. treatment mean ± 2.6 (64 d.f.)

Before harvest, samples of ten upper, middle and lower racemes were collected from each plot at Sites 1, 2, 3, 4 and 5 and the number of pods and blind stalks was determined. The results are shown in Table 4.

Table 4

1967 trials - Mean number of pods and percentage blind stalks on samples of ten upper, middle and lower racemes per plot

Sites	1		2		3		4		5		Means *	
Treatments	Pods set	% blind stalks	Pods set	% blind stalks	Pods set	% blind stalks	Pods set	% blind stalks	Pods set	% blind stalks	Pods set	% blind stalks
Malathion	38	14	20	35	29	15	29	9	32	5	32	13
Fenitrothion	24	17			32	11	27	10	38	2	28	13
Azinphos-methyl	27	17	28	35	27	16	37	9	42	3	30	14
Phosalone	30	14			29	14	29	12			29	13
Monocrotophos	32	7			28	15	29	11			30	11
Gamma-BHC	36	7	34	28	40	6	40	7			39	7
Endosulfan	30	14			28	22	28	12			29	16
Carbaryl	27	19	29	39			39	13	38	3	33	16
DDT	29	7	27	37	29	15	35	11			31	11
Unsprayed	17	33	14	56	23	33	22	20	28	7	21	29

S.E. treatment mean ± 1.9(17d.f.)

(* Means and SE for sites 1, 3 and 4 only)

All treatments, except endosulfan, gave a good initial control of adult blossom beetles. Gamma-BHC, azinphos-methyl, fenitrothion and monocrotophos gave a significantly ($p = 0.05$) better control than DDT. Fenitrothion caused general and often severe necrotic spotting on the leaves and phosalone caused some leaf chlorosis at two sites.

None of the treatments gave a high degree of control of bud damage and subsequent pod loss (Table 4) but at all the sites some damage had occurred before the green bud sprays were applied. Although the rape surrounding the experimental plots was also sprayed, at four of the sites, the plots were quickly reinfested after the first spray and a yellow bud spray was also applied. Gamma-BHC gave the best results with significantly ($p = 0.05$) more pods than any of the other treatments. All treatments, including endosulfan, gave similar results to DDT and had significantly more pods than the controls ($p = 0.05$). These results suggest that endosulfan may require longer to obtain maximum control of adult beetles than the other pesticides and its full effects may not have been detected in the assessments of adult beetles made 24 hours after spraying. On average, two sprays before flowering reduced the number of blind stalks by 60%. At site 2, where only one spray at the green bud stage was used, the damage was reduced by about 45%.

In all these trials the small plot size may have reduced the effect of the treatments and better results might be expected on a field scale.

<u>1968 and 1969 trials</u>

Further trials were done in 1968 on the variety Nilla. Different formulations of azinphos-methyl and endosulfan were compared and iodofenphos was also included in the treatments at two of the sites. Estimates of the control of adult beetles were made two days after spraying. Details of the plot sizes, spraying dates and the control obtained are given in Table 5.

Table 5

1968 trials - Percentage reduction of adult blossom beetle 48 hours after spraying

Site	1		2		3	4	5	6	Mean
Plot size (yd)	20 x 60		20 x 60		20 x 20	20 x 20	20 x 40	20 x 20	
Plot size (m)	18 x 55		18 x 55		18 x 18	18 x 18	18 x 36	18 x 18	
No of replicates	3		2		1	1	4	1	
Spray	1	2	1	2	1	1	1	2*	
Spraying dates	7/7	16/6	7/6	16/6	5/6	18/6	14/6	10/6	
Treatments									
Malathion	65	96	68	99	80				81
Azinphos-methyl e.c.	83	99	84	100	82		82	80	87
Azinphos-methyl w.p.					95		87	92	91
Endosulfan e.c. (7 oz a.i.)					40	88	40	40	52
Endosulfan w.p.					60	88	63	70	70
Phosalone						100	98	64	82
Iodofenphos	79	99	72	99					87
Gamma-BHC					97	100		100	99
DDT					87	86		80	84
Beetles/25 plants on unsprayed plots	260	211	140	60	107	40	46	50	

(*Assessments made only after second spray at Site 6: first spray applied 1 June)

On 28 June, at Site 5, samples of ten, main raceme bud bundles per plot were dissected and the number of larvae recorded. The results are shown in Table 6.

Table 6

1968 Site 5 - Mean number of larvae/10 bud bundles

Treatment	Azinphos-methyl e.c.	Azinphos-methyl w.p.	Endosulfan e.c.	Endosulfan w.p.	Unsprayed
Larvae	19	11	28	22	109

In early August, samples of ten upper, middle and lower racemes were collected from each plot at sites 1, 2, 3 and 6 and the numbers of pods set, and blind stalks were recorded. The results are given in Table 7.

Table 7

1968 - Mean number of pods and percentage blind stalks on samples of ten upper middle and lower racemes

Sites / Treatments	1 Pods set	1 % blind stalks	2 Pods set	2 % blind stalks	3 Pods set	3 % blind stalks	6 Pods set	6 % blind stalks
Malathion	23	25	27	20	24	27		
Azinphbs-methyl e.c.	29	17	30	8	27	23	28	10
Azinphos-methyl w.p.					30	19	38	6
Endosulfan e.c.					22	37	31	18
Endosulfan w.p.					27	28	33	14
Phosalone							30	16
Iodofenphos	31	16	32	12				
Gamma-BHC					27	25	31	17
DDT					28	22	28	19
Control	18	44	16	34	17	58	23	29
SE treatment mean	± 4.3(16 d.f.)		± 3.8 (16 d.f.)					

The results were similar to those obtained in 1967. Gamma-BHC, used at 3 sites, again gave a consistently good initial control of adult blossom beetle (Table 5). Iodofenphos, malathion, azinphos-methyl and phosalone gave results equal to or better than DDT.

Endosulfan again gave a lower initial kill of adult beetles than the other pesticides, assessed two days after spraying and the wettable powder formulations of both endosulfan and azinphos-methyl were better than the emulsifiable concentrates.

All treatments including endosulfan, increased the number of pods set (Table 7). On average, two sprays again reduced the number of blind stalks by about 60% (Range 35-80%).

In 1969, a series of trials was done to compare phosalone at 6.6 oz a.i./ac, the standard commercial recommendation, with the 10 oz a.i. rate used in the earlier trials. Single sprays were applied to large unreplicated strips at the yellow-bud stage only, and the control of adult blossom beetle was assessed 24 hours after spraying to reduce the effect of reinfestation. The results are given in Table 8.

Table 8

1969 trials - Percentage reduction of adult blossom beetle after single sprays at yellow-bud

Site	1	2	3	4	5
Plot size (yd)	20 x 100	20 x 100	10 x 100	10 x 100	20 x 20
Plot size (m)	18 x 91	18 x 91	9 x 91	9 x 91	18 x 18
Spraying date	13/6	13/6	21/6	4/7	4/6
Treatments					
Azinphos-methyl					96
DDT	96				87
Gamma-BHC		80			99
Phosalone (10 oz a.i.)	84	73	89	93	75
Phosalone (6.6 oz a.i.)		61	66	86	60
Beetles/25 plants on unsprayed plots	220	115	125	80	113

Although the data cannot be analysed statistically, the 6.6 oz a.i./ac. rate of phosalone gave a consistently lower control of adult blossom beetle than the 10 oz rate and more frequent spraying would probably be required to maintain effective control during bud development.

Aerial Spraying

In 1969, some information on the efficiency of aerial spraying was obtained at one site, where five adjoining fields of heavily infested spring rape were treated in different ways. Sprays were applied to four of the fields on 14 June. One day after spraying, the number of blossom beetles was recorded on 80 plants/field. Details of the sprays applied and the results, are shown in Table 9.

Table 9

Comparison of aerial and ground application of gamma-BHC and malathion

Treatment	Blossom beetle on 80 plants	
	Total	% plants infested
Gamma-BHC 1 pt 10% e.c./5gpa (56l/ha) - aerial	1	1.5
Gamma-BHC 1 pt 10% e.c./30gpa - ground	1	1.5
Malathion 30 fl oz 60% e.c./5gpa - aerial	5	5
Malathion 30 fl oz 60% e.c./30 gpa - ground	6	6
Control	994	97

These results confirm that aerial sprays of gamma-BHC or malathion can give a good initial control of adult blossom beetle.

DISCUSSION

In these trials, gamma-BHC gave the most consistent control of adult blossom beetles and all the organophosphorus insecticides tested were at least as effective as DDT and often gave better results. Fenitrothion, caused extensive leaf necrosis. The reduction in bud damage, and subsequent pod loss, obtained with two sprays was often relatively poor but this may be related to the very early migration of blossom beetle into the crop during the rosette stage which occurred at several sites and the rapid and persistent reinfestation of the small plots used in some of the trials.

The longer persistence of DDT compared with some of the alternative pesticides would not appear to be an important advantage on spring sown oil-seed rape which makes very rapid extension growth during bud development. Two sprays of a contact pesticide, cannot maintain a complete cover of toxic deposit on the new growth over this period.

The alternative pesticides tested, other than the formulation of gamma-BHC used, are more expensive than DDT but they all have some activity against seed weevil which is not controlled by DDT (Winfield 1961). Because of the risk of taint, gamma-BHC cannot be used on fields to be cropped with potatoes within 18 months.

Bees are not important as pollinators of oil-seed rape but they are strongly attracted to the crop during flowering. Although blossom beetle control should be completed before the crop is in flower, there may be some risk to bees from the yellow-bud sprays as some early flowers are usually open. Several of the alternative pesticides are more toxic to bees than DDT. Duval (1969) reported DDT, endosulfan and phosalone as moderately hazardous to bees. Azinphos-methyl, carbaryl, dieldrin, fenitrothion, gamma-BHC and malathion were classed as hazardous. Needham and Stevenson (1968) showed that endosulfan killed very few bees when used on flowering rape while malathion and azinphos-methyl killed large numbers. Although there is insufficient field evidence in the UK, unpublished results (Twinn pers.comm.) also suggest that phosalone is less toxic to bees, agreeing with Duval's grouping.

Gamma-BHC, azinphos-methyl, malathion, phosalone and endosulfan are now in commercial use on oil-seed rape in the UK.

Acknowledgments

I wish to thank CIBA Agrochemicals Ltd and May and Baker Ltd for their co-operation with some of the trials in 1968 and '69.

References

Anon, (1964) Review of the Persistent Organochlorine Pesticides, Ministry of Agriculture Fisheries and Food, H.M.S.O. London 1964.

Anon, (1969) Further Review of Certain Persistent Organochlorine Pesticides Used in Great Britain, Department of Education and Science, H.M.S.O. London 1969.

Duval, C.T. (1969) Pesticides and the Honey Bee. P.A.N.S. 15, 321-324.

Hoffman, A. (1952) A Propos de Ceutorhynchus assimilis Payk. Rev. Path. Vég. et d'ent; Agric. de France 31 175-178.

Jary, S.G. and Carpenter, K. (1948) Insect pests of brassica seed crops in Romney Marsh, Kent. Ann. appl. Biol., 35, 134.

Needham, P.H. and Stevenson, J.H. (1968) Poisoning of honey bees on oil-seed rape. Rep. Rothamstead Exp. Stn. for 1967, 175-176.

Potter, C and Perkins, J.F. (1946) Control of brassica pests by DDT. Agriculture, 53, 109-113.

Winfield, A.L. and Gough, H.C. (1959) Pests of mustard seed crops. Agriculture, 65, 554-558.

Winfield, A.L. (1961) Field observations on the control of blossom beetles (Meligethes aeneus F.) and cabbage seed weevils (Ceutorhynchus assimilis Payk.) on mustard seed crops in East Anglia. Ann. appl. Biol., 49, 539-555.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

CARBARYL, A BROAD SPECTRUM SUBSTITUTE FOR D.D.T.

C. Sinclair
Duphar-Midox Limited, Smarden, Kent
J.H. Bryant
Murphy Chemical Co. Ltd., Wheathampstead, Herts

Summary Numerous replicated and grower trials to investigate the use of Carbaryl for the control of codling (Laspeyresia pomonella), tortrix (Archips spp), and winter moths (Operophtera brumata), and capsid bug (Plesiocoris rugicollis) in apples, and pea moth (Laspeyresia nigricana) in peas, have been made in S.E. England over the last decade. Comparisons with D.D.T. and D.D.T./B.H.C. formulations have shown that Carbaryl is either equal or superior in the prevention of damage caused by these pests. Dosage rates were also compared for the control of these and other D.D.T. susceptible pests. Yields of apples were not assessed, but pea yields were shown to be unaffected by treatment, and tasting-panel tests on Carbaryl treated peas showed no detectable taint or off-flavour.

INTRODUCTION

The current decline of the widespread use of D.D.T. has necessitated the use of alternatives such as Carbaryl which, although not effective against the same spectrum of pests controlled by D.D.T., is equally widespread in activity. Among the pests controlled by Carbaryl are codling moth (Laspeyresia pomonella), tortrix moth (Archips spp), winter moth (Operophtera brumata), and capsid bug (Plesiocoris rugicollis) in apples and pears, and pea moth (Laspeyresia nigricana) in peas. These uses of Carbaryl have been granted Approval under the Ministry of Agriculture Approvals Scheme, and the supporting biological data in comparison with D.D.T. are presented in this paper.

Other uses of Carbaryl not presented here are for the control of earwigs (Forficula auricularia), earthworms (Lumbricus spp), flea beetle (Longitarsus parvulus), chafer beetle (Melolontha melolontha), leaf hopper (Typhlocyba spp), cutworm (Agrotis spp), moth and butterfly larvae (Lepidoptera), thrips (Thrips spp), white fly (Aleyrodes proletella), leatherjacket (Tipula spp), weevil (Anthonomus pomorum), sucker (Psylla spp), twig cutter (Rhynchites coeruleus), fruit rynchites (Caenorhinus aequatus), sawfly (Hoplocampa testudinea), fruit miner (Lyonetia clerkella), silver Y moth (Plusia gamma), pea midge (Contarinia pisi), pea weevil (Sitona spp), and as a thinner in apples. Carbaryl has been cleared for use on apples, pears, blackcurrants, gooseberries, raspberries, strawberries (pre-blossom), peas, brassicae, lettuce and tomatoes.

Some of the original work on Carbaryl has been reviewed by Dicker (1965) in U.K. and by Haynes et al (1957) in U.S.

METHOD AND MATERIALS

Trials were conducted on peas and apples over 6 years mainly in Essex and Kent. Carbaryl was applied as a 50% w.p. (apples) or an 85% w.p. (peas) at a range of rates, and D.D.T. as a 50% w.p., a 50% paste, a 15% emulsion or a B.H.C./D.D.T. emulsion or w.p. on apples, and a 25% emulsion on peas. Yield assessments and taint tests were made on peas. Further details of the trials are presented in Table 1.

Table 1

Details of trials

Pest	No. of trials	No. of applns.	Timing of Application	No. of reps/trt	D.D.T. formulation	D.D.T. lb/ac a.i.	Carbaryl lb/ac a.i.
Codling	12	1	Bud burst	1-12	BHC/DDT emul.	0.5/1.0	0.5; 1.0; 2.0
"	5	3	June - July	12	Wp; Paste	1.5: 2.0	1.5
Tortrix	4	2	Bud burst/ green bud	20-40	BHC/DDT emul.	0.5/1.0	1.5
"	7	3	June - July	12	Wp; Paste	1.5; 2.0	1.5
"	5	3	June - July	1	Emul; Paste	2.5; 2.5	1.9
"	1	5	Bud burst - End July	1	Emul	1.5 - 2.5	1.9
"	1	1	End April	1	BHC/DDT wp.	0.5/1.0	1.5
Winter	2	2	Bud burst/ green bud	6-20	BHC/DDT emul.	0.5/1.0	1.5
"	1	1	End April	1	BHC/DDT wp.	0.5/1.0	1.5
Capsid	1	1	End April	1	BHC/DDT wp.	0.5/1.0	1.5
Pea moth	6	1	Beg. July	4	Emul.	2.0	1.0; 1.5; 2.0
" "	6	2	Mid June/ Beg. July	6	Emul.	2.0	1.5; 2.0; 2.5; 3.0

Note: 1 lb/ac = 1.1 kg/ha.

RESULTS

Table 2

Percentage infested fruit or blossom trusses, and percentage control of pea mo
and yields in relation to treatment

Pest	Sample size/ treatment	Untreated	D.D.T. Paste	D.D.T. Others	Carbaryl			
			(rates and formula-tions as in Table 1)		(rates as in Table			
Codling	150-300, or 8x200 apples	11.8	-	5.3	14.2	4.6	2.1	
"	10 x 100 apples	5.6	1.1	1.0	0.6			
Tortrix	10 x 20-40 blossom trusses 10x12 shoots	4.9	-	1.6	1.6			
"	10 x 100 apples	10.1	2.9	3.9	2.1			
"	10 x 100 apples	-	6.1	5.4	4.2			
"	10 x 100 apples	-	-	10.4	1.1			
"	150 buds	-	(Pre-5	Post-1)	(Pre-6		Post-	
Winter	100 x 6-20 trusses	22.9	-	1.9	4.8			
"	150 buds	-	(Pre-16	Post-3)	(Pre-18		Post-	
Capsid	150 buds	-	(Pre-53	Post-0)	(Pre-29		Post-	
Pea moth	8 pods/20x4 plants	-	-	56.7	68.3	80.0	81.7	
" "	All pods/3x5x6 "	-	-	58.0	81.0	87.0	90.0	9
" "	Yield pods, oz/15 plants/repl.	15.8*		14.3	15.8	16.0	15.2	1

Pre-no. = no. of infested buds before application
Post-no. = no. of infested buds after application
* L.S.D. (5%) ± 2.4, for pea yields.
Carbaryl at 1.5 and 3.0 lb/ac a.i. caused no taint or off-flavour in peas.

DISCUSSION

The results presented here, together with many years commercial experience, have shown that on peas and apples Carbaryl applied at 1½ lb/ac a.i. gave a satisfactory control of pea, codling, tortrix and winter moths and apple capsid. This rate was shown to be equal or, in most cases, superior to the standard rate D.D.T. used for the control of these pests. Increased rates applied to small pl have caused neither phytotoxicity to apples or peas, nor yield depression or tai of peas.

Other results (Anon. 1961) have shown that Carbaryl and D.D.T. gave 90% and control respectively of tortrix moth on apple, and 89% and 50% control respective of pea moth. (Ensor, personal communication).

The results presented show that Carbaryl can therefore be regarded as an acceptable and superior biologically active substitute for D.D.T. The other uses of Carbaryl listed cover a wide field of crops and pests such that more time is needed to provide sufficient data for Approval and future publication.

Acknowledgements

Thanks are due to The Fruit and Vegetable Preservation Research Association, Chipping Campden, Glos., who undertook the taint tests, and to growers who kindly participated in trials.

References

Anon (1961) Rep. E. Malling Res. Sta. for 1960, 31.

DICKER, G.H.L. (1965) Proc. 3rd Br. Insectic. Fungic. Conf., 269 - 275.

HAYNES, H.L., LAMBRECH, J.A. and MOOREFIELD H.H. (1957) Contr. Boyce Thompson Inst., 18, 507 - 513.

Proc. 6th Br. Insectic. Fungic. Conf. (1971)

FENITROTHION - ITS PLACE IN U.K. AGRICULTURE

G. N. Price and D. M. Weighton
The Boots Company Ltd., Lenton Research Station, Nottingham

Summary Fenitrothion is a broad spectrum organophosphorus insecticide of low toxicity to warm blooded animals. It has proved particularly successful when applied at a rate of 0.05% a.i. against a wide range of insects attacking top and soft fruit as an alternative to DDT. These include aphids, winter moths, tortricids, capsids, codling moths and sawflies. In agricultural crops it has been shown to be effective against leatherjackets in cereal crops when applied in a bran bait and it has shown promise against pests of peas such as the pea moth and the pea and bean weevil. It is extremely effective in bulk grain stores where it has in many instances given 100% control of grain pests for periods of up to 7 weeks and where it has shown much greater persistence than malathion when applied to absorptive surfaces such as asbestos, brick and concrete. It is compatible with most chemicals with which it is likely to be applied and residues on fruit crops are minimal after approximately 2 weeks.

INTRODUCTION

Fenitrothion was introduced in 1959 by the Sumitomo Chemical Company and independently by Farbenfabriken Bayer AG. Interest in fenitrothion was aroused following indications that the Government was likely to further restrict the use of the organochlorine compounds especially DDT.

Work by the National Agricultural Advisory Service, now the Agricultural Development and Advisory Service, (Gould, French & Vernon 1967) during the period 1964-1967 showed that fenitrothion had a wide spectrum of activity on many of the pests of top fruit controlled by DDT. The species controlled included tortrix and winter moth caterpillar, apple sucker (Psylla mali), apple grass aphid (Rhopalosiphum insertum), apple blossom weevil (Anthonomus pomorum) and apple capsid (Lygocoris pabulinus). In addition Golightly (1967) showed that fenitrothion gave good control of leatherjackets (Tipula spp) when incorporated with a bait.

Having reviewed the relevant technical information, trials were initiated in 1968 with a view to evaluating its potential on a wide range of insect species.

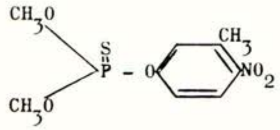
METHOD AND MATERIALS

Field trials included both the randomised block method and farm reliability trials where the grower was asked to include the material in his normal spray programme on a 1-2 acre block. These trials sites were chosen to cover as wide an area as possible of the main crop types.

The material used was a 50% w/v emulsifiable concentrate. Particular care was taken to find adjuvants which were non-phytotoxic. The following description of the technical material was provided by the Sumitomo Chemical Company.

a) Chemical Properties

Chemical name: 0;0-dimethyl-0-(4-nitro-m-toly) phosphorothioate
Chemical structure:



Molecular formula: $C_9H_{12}O_5NPS$

Molecular weight: 277.24

b) Physical Properties

Appearance: Brownish yellow liquid
Vapour Pressure: 5.4×10^{-5} mm Hg
Solubility: Soluble in most organic solvents but of low solubility in aliphatic hydrocarbons. Insoluble in water.

Stability: Isomerizes readily on distillation. Hydrolyzed by alkali.

The relatively low mammalian toxicity is well known; data provided by the Sumitomo Chemical Company show an acute oral toxocity, the LD50 varying from 400 to over 1,000 mg/kg, depending on species and an acute dermal toxicity, LD50 250-400 mg/kg. Skin and eye irritation in rabbits caused by undiluted material is only mild to moderate, but the material is as toxic as parathion to fish.

The compound has been cleared for use under the Pesticides Safety Precautions Scheme.

RESULTS

Pests of top fruit

Detailed trials and an extensive series of farm reliability trials confirmed the findings of Gould, French & Vernon (1967) that fenitrothion gave effective control of the main pre-blossom pests of apples. (Table 1)

Table 1

Comparison of fenitrothion with phosalone and DDT/demeton-methyl for the control of pre-blossom pests of apples

Treatment	No. of aphids/caterpillars/25 trusses/tree							
	1st assessment (+ 7 days)				2nd assessment (+ 21 days)			
	Aphids	Caterpillars*			Aphids	Caterpillars		
		damaged trusses	live	dead		damaged trusses	live	dead
Site I - Thurgarton, Notts. (9 trees/plot x 4 reps: treated May 7)								
Fenitrothion 0.06%	0	0.9	0.1	0.2	2.4	0.3	0.1	0
Phosalone 0.02%	70.0	1.6	1.3	0.1	24.6	0.4	0	0
DDT/demeton-methyl 0.1%/0.006%	13.7	2.7	1.7	0.1	64.5	1.1	0.5	0
Control	34.5	1.3	0.8	0	26.3	0.4	0.2	0
Site II - Southwell, Notts. (2 trees/plot x 5 reps: treated May 5)								
Fenitrothion 0.06%	0	0.5	0.2	1.0	0.2	1.0	0.2	0
Phosalone 0.02%	39.2	6.0	1.8	3.0	126.0	1.2	0.5	0
DDT/demeton-methyl 0.1%/0.006%	4.0	3.0	1.0	1.0	-	-	-	-
Control	65.0	10.0	7.5	-	45.0	5.0	2.5	0

* mainly tortricids

All growers in the farm reliability trials expressed satisfaction with the product. Although infestations were light, fenitrothion, in all cases, gave results comparable to or better than the standard insecticide treatments.

Trials against codling moth have also proved successful. Because of the sporadic appearance of this pest in the U.K., field trials are often inconclusive and a combined field/laboratory method was adopted. Apple trees were sprayed and the apples were brought into the laboratory at regular intervals when insecticidal activity was determined by confining 1st instar larvae to the apple surface. (Table 2)

Table 2

Comparison of fenitrothion with carbaryl and azinphos methyl for the control of codling moth

Treatment	Percentage mortality (days after treatment)			
	3	7	14	21
Fenitrothion 0.1%	100	100	100	80
Fenitrothion 0.05%	100	100	80	40
Carbaryl 0.1%	100	100	100	80
Azinphos methyl 0.035%	100	100	100	80
Control	30*	20	20	30

Variety: Cox's Orange Pippin
Trial Layout: 1 tree/plot x 2 reps
* caused by handling larvae

Randomised field trials and a series of grower reliability trials confirmed the laboratory findings.

Although it is not an effective acaricide, fenitrothion has a beneficial suppressant effect on the fruit tree red spider mite (*Panonychus ulmi*) when applied to control post-blossom pests provided the population is not a resistant one. (Table 3)

Table 3

Comparison of fenitrothion with phenkapton and tetradifon for the control of fruit tree red spider mite on apples

Treatment	Average number of mites per leaf														
	Pre-spray			Post-spray											
	May 29			June 12			July 3			July 31			Aug 27		
	A	N/L	E*	A	N/L	E	A	N/L	E	A	N/L	A	A	N/L	E
Fenitrothion 0.1%	0	32.3	0	0.2	6.4	0.2	0.2	2.4	2.6	1.7	1.0	5.1	14.0	11.4	11.7
Fenitrothion 0.05%	0	26.6	0	0	2.9	0.1	0	1.5	1.2	2.0	2.0	6.3	17.6	16.0	15.4
Phenkapton 0.02%	0	36.8	0	0	0.5	0	0	0.5	1.1	0.1	0	0.1	1.3	1.3	1.3
Tetradifon 0.0125%	0	28.6	0	0	7.5	0	0	1.4	2.5	0	0.1	0	4.0	1.6	1.1
Control	0	29.0	0.3	0.3	28.2	10.9	3.7	2.5	53.5	9.3	6.5	15.4	Uncountable		

Variety: Worcester Pearmain
Trial Layout: 2 trees/plot x 4 reps
Assessment: 50 leaves/tree - mites removed by leaf brushing
* A = adults, N/L = nymphs/larvae, E = eggs

Pests of soft fruit

Trials were carried out in co-operation with Cyanamid of Great Britain and the Scottish Horticultural Research Institute on soft fruits against strawberry tortrix moth (*Acleris comariana*), raspberry beetle (*Byturus tomentosus*), blackcurrant and gooseberry sawfly (*Pteronidea ribesii*) and capsid (*Lygocoris pabulinus*). Satisfactory control was obtained in all cases. (Table 4)

Table 4

Comparison of fenitrothion with azinphos methyl, DDT and malathion against various soft fruit pests

Pest	No. trials	Standard	% control with standard	% control with fenitrothion
Strawberry tortrix	5*	azinphos methyl	75-80%	75-95%
Raspberry beetle	5**	azinphos methyl	50%	85%
Blackcurrant/				
Gooseberry	2	DDT/malathion	90%	90%
sawfly and capsid	3*	azinphos methyl	100%	100%
	1	Untreated	0%	50%

Fenitrothion applied at currently recommended rates ($\frac{3}{4}$-$1\frac{1}{2}$ pt/acre - 1-2 l/ha)
* J. J. B. Caldicott 1970
** C. E. Taylor 1971

Arable Crops

Cereal and grass: Golightly (1967) established that fenitrothion was effective against leatherjackets (*Tipula spp*) particularly when incorporated in a bran bait; this has been confirmed in grower trials throughout the country.

Peas: A small trial on pea and bean weevil on beans (Table 5) showed promise and the Pea Growing Research Organisation carried out work on the main pea pests (King 1971). (Table 6)

Table 5

Comparison of fenitrothion with DDT for the control of pea and bean weevil

Leaf No.+	Untreated Pre-spray No. of notches per leaf*	Untreated Post-spray No. of notches per leaf (total less no. of pre-spray notches)	Fenitrothion 10 fl oz a.i. per acre (0.7 l/ha)	Fenitrothion 12.5 fl oz a.i. per acre	DDT 10 fl oz a.i./acre
1	6.2	21.7 (15.5)	11.2 (5.0)	9.7 (3.5)	9.6 (3.4)
2	5.7	17.8 (12.2)	8.9 (3.2)	9.6 (3.9)	9.5 (3.9)
3	4.7	12.6 (7.9)	10.1 (5.3)	7.9 (3.2)	9.1 (4.4)
4	4.2	9.5 (5.3)	6.8 (2.5)	5.5 (1.2)	6.5 (2.3)
5	3.5	7.2 (3.7)	4.9 (1.5)	6.4 (3.0)	5.2 (1.8)
6	3.0	7.3 (4.3)	3.3 (0.3)	3.2 (0.2)	2.8 (0)
Total		48.6	17.7	14.8	15.7
Mean		8.1	2.9	2.4	2.6
Control		0	64.2	70.4	68.0

+ = 6 leaves per plant, 10 plants per plot
* = notches - damage caused by weevils feeding

Table 6

Comparison of fenitrothion with DDT, azinphos methyl, dimethoate, carbaryl and dioxydemeton-S-methyl for the control of pea pests

Pest	No. of trials	Standards	Control with fenitrothion
Pea and bean weevil (*Sitona* spp)	1	DDT	Equal to standard
Cabbage Linseed thrip (*Thrips angusticeps*)	1	Dimethoate azinphos methyl dioxydemeton-S-methyl	Better than azinphos methyl equal to dimethoate and dioxydemeton-S-methyl
Pea midge (*Contarinia pisi*)	2	DDT azinphos methyl dioxydemeton-S-methyl	Better than dioxydemeton-S-methyl, equal to DDT azinphos methyl
Pea Moth (*Laspeyresia nigricana*)	2	DDT carbaryl azinphos methyl dioxydemeton-S-methyl	Better than DDT, equal to others

Trial Layout: Randomised block
Fenitrothion applied at 0.63 lb a.i./ac (0.75 kg/ha) in 50 gal water, other insecticides at recommended rates.

In trials on peas Cyanamid found fenitrothion to be as effective as demeton-methyl for the control of the pea aphid (Acyrthosiphon pisum). Fenitrothion is therefore equal to or better than the standard insecticides for the control of the main pea pests.

Brassicas: Although fenitrothion is effective against cabbage white butterfly (Pieris rapae) and diamond back moth (Plutella maculipennis), phytotoxicity is a problem on brassica crops and therefore fenitrothion cannot be recommended.

Grain Stores

Work by Green & Tyler, (1966) showed that fenitrothion gave good results when used as a grain store spray. In 1970 an experiment was set up to compare the persistence of fenitrothion with that of malathion grain store spray when applied to surfaces commonly found in grain stores. Fenitrothion (50% EC) was tested at two rates, 8 fl oz per 1,000 ft^2 (0.25 l/100 m^2) and 4 fl oz per 1,000 ft^2; malathion (25% DP) was used at the normal recommended rate, 10 oz/1,000 ft^2 (300 g/100 m^2).

The six types of surface used in the test were brick, asbestos, galvanised steel, concrete, paper liner and wood. Each surface was disc shaped and 9 cm in diameter; after treatment and between assays the discs were stored in a constant temperature room.

Assays were carried out on four important grain store pests, these were:-

Saw toothed grain beetle - (Oryzaephilus surinamensis)
Grain weevil - (Sitophilus granarius)
Rust red grain beetle - (Cryptolestes ferrugineus)
Rust red flour beetle - (Tribolium castaneum)

At each assay 20 adults of each species were confined on the treated surfaces. A few wheat grains were included for food and after four days the percentage mortality was assessed. Assays were made at 1, 14, 28, 49 and 63 day intervals follwing application. (Table 7)

Table 7a

Comparison of fenitrothion with malathion when used in stores of different surfaces for the control of grain store pests

Percentage Mortality

Interval in days

	1		14		28		49		63	
Fenitrothion (50% EC) 4 fl oz	Os+	Sg	Os	Sg	Os	Sg	Os	Sg	Os	Sg
Asbestos	100	100	100	100	100	100	100	50	65	5
Brick	100	100	100	100	100	100	100	70	90	55
Concrete	100	100	100	100	100	100	75	75	100	50
Metal*	100	100	100	100	100	100	100	100	100	100
Fenitrothion (50% EC) 8 fl oz										
Asbestos	100	100	100	100	100	100	100	90	90	65
Brick	100	100	100	100	100	100	100	100	100	100
Concrete	100	100	100	100	100	100	100	100	100	75
Metal*	100	100	100	100	100	100	100	100	100	100
Malathion (25% DP) 10 oz										
Asbestos	100	100	100	5	100	15	100	5	80	0
Brick	100	15	40	0	0	0	0	0	0	0
Concrete	100	100	65	5	10	0	0	0	0	0
Metal*	100	100	100	100	100	100	100	100	100	100
Untreated										
Asbestos	25	10	25	0	5	0	15	0	0	10
Brick	0	0	0	0	5	0	0	0	0	0
Concrete	0	0	0	0	0	0	0	0	0	0
Metal*	15	10	25	0	25	5	10	0	0	0

+ Os = *Oryzaephilus surinamensis* Sg = *Sitophilus granarius*
* = similar results obtained on wood and paper liner

Table 7b

Percentage Mortality

Interval in days

Fenitrothion (50% EC) 4 fl oz	1		14		28		49		63	
	Cf	Tc	Cf	Tc	Cf	Tc	Cf	Tc	Cf	Tc
Asbestos	100	100	100	100	100	100	100	85	80	15
Brick	100	100	100	100	100	100	100	100	90	90
Concrete	100	100	100	100	100	100	100	85	100	100
Metal*	100	100	100	100	100	100	100	100	100	100
Fenitrothion (50% EC) 8 fl oz										
Asbestos	100	100	100	100	100	100	100	100	100	85
Brick	100	100	100	100	100	100	100	100	100	100
Concrete	100	100	100	100	100	100	100	100	100	50
Metal*	100	100	100	100	100	100	100	100	100	100
Malathion (25% DP) 10 oz										
Asbestos	100	100	90	30	100	5	100	15	90	0
Brick	100	55	20	0	0	0	0	0	0	0
Concrete	100	100	75	0	10	5	0	0	0	0
Metal*	100	100	100	100	100	100	100	100	100	100
Untreated										
Asbestos	5	10	5	5	0	5	15	5	0	0
Brick	0	0	0	0	5	0	0	0	0	0
Concrete	0	0	0	0	0	0	0	0	0	0
Metal*	0	0	25	5	25	15	10	0	0	0

Cf = *Cryptolestes ferrugineus*
Tc = *Triboluim castaneum*

* similar results obtained on wood and paper liner

On asbestos, all treatments gave control of saw toothed grain beetle and rust red grain beetle for 9 weeks when malathion and the low rate of fenitrothion gave a reduced kill. Malathion gave poor control of grain weevil and rust red flour beetle.

On brick, malathion gave poor control of all species; fenitrothion at the low rate showed a reduction in activity by the 7th week, but the high rate treatment gave good activity for up to 9 weeks.

On concrete, malathion showed a marked loss of activity by the 14th day but fenitrothion at low rate maintained activity until about the 7th week. On metal, wood and paper liner, all treatments gave good control throughout the period of the test.

An extensive series of grower trials carried out during the winter of 1970-71 showed that activity was maintained under 'field' conditions.

Residues

Residue data on all crop species has been obtained. The results show that fenitrothion is of low persistence, most crops having residues below 0.1 ppm 14 days or so after treatment. The results shown in Table 8 illustrate the typical decay rate of fenitrothion on apples.

Table 8

Decay of fenitrothion on apples, variety Cox's Orange Pippin

	Blank		Treated sample	
Day	Inside pulp ppm	Outside ppm	Inside pulp ppm	Outside ppm
0	ND	ND	ND	ND
3	0.16	0.07	0.17	0.79
6	0.09	0.02	0.11	0.41
10	0.07	0.02	0.06	0.16
13	0.09	0.01	0.09	0.31
17	0.06	0.01	0.07	0.06
24	ND	0.01	ND	0.03
38	0.04	0.01	0.05	0.01

ND = Not Done
Treated with fenitrothion 50% miscible oil at 0.05% a.i.

Fruit crops have been submitted to the Fruit and Vegetable Preservation Research Association for taint testing. No taints have been detected.

Crop Safety

Phytotoxicity has not been a problem except as stated in the case of brassicas where damage was obtained at all rates used and hence fenitrothion cannot be recommended for use on brassicas. It is safe on all other crops tested when used at the recommended rate.

On top fruit, mixtures of chemicals are often applied. Fenitrothion is compatible with most of the fungicides and acaracides with which it is likely to be mixed in the spray tank, but it is recommended that it should be mixed with not more than one other material when applied as pre-blossom treatment and not more than two others for post-blossom treatments.

DISCUSSION

The work of the N.A.A.S. in the period 1964-67 demonstrated that fenitrothion controlled a wide range of pests for the control of which the organochlorine compounds especially DDT were recommended. Fenitrothion appeared to be a very useful substitute being a material of low mammalian toxicity and relatively short persistence compared to the organochlorines. It also has the advantage of being a broad spectrum compound.

Trial work has since confirmed most of the early findings and new uses are still being discovered. On top fruit 1 pt/ac (1.4 l/ha) of the 50% material applied at green cluster effectively controls all of the pre-blossom pests and two applications of $1\frac{1}{2}$ pt/ac (2 l/ha) in summer control the post-blossom pests. In addition, where a non organophosphate resistant mite population occurs, fenitrothion will give a useful suppression of the population. On soft fruit such as strawberries, raspberries gooseberries and blackcurrants it will control most of the common pests.

In arable crops it controls leatherjackets when mixed with bran and applied as a bait and it has shown promise for the control of pea and bean weevil, pea moth and pea midge on peas and beans. Phytotoxic effects, however, prevent its use in brassica crops.

As a grain store spray it has shown a marked improvement in persistence over malathion when applied to the absorptive type of surfaces such as concrete commonly used in the construction of grain storage silos and barns.

Fenitrothion EC is compatible with most of the chemicals with which it is likely to be mixed as a spray and is non-phytotoxic on all the crops for which it is recommended.

Residue work has shown that on fruit it is of relatively short persistence, residues normally being less than about 0.1 ppm after 2-3 weeks. It does not taint fruit. Because of its low toxicity, short persistence and wide spectrum it has proved a suitable substitute for DDT and is now established in U.K. agriculture.

Acknowledgements

The authors wish to thank their colleagues at Lenton Research Station and Boots Farm Sales for their assistance and the farmers who co-operated in the trials; also Cyanamid of Great Britain Ltd. and the Pea Growing Research Organisation who have allowed access to their trial data.

References

CALDICOTT, J. J. B. (1970) Personal communication

GOULD, H. J., FRENCH M., and VERNON J. D. R. (1967) Alternatives to DDT for the control of pre-blossom pests on apples. Plant Path. 16, 37-42

GOLIGHTLY, W. H. (1967) Control of Tipula spp. Larvae. Plant Path. 16, 33-35

GREEN, A. A. and TYLER P. S. (1966) A field comparison of malathion, dichlorvos and fenitrothion for the control of *Oryzaephilus surinamensis* (L) (Coleoptera, Silvanidae) infesting stored barley. Jour. Stored Products Res. 1, 273-283

KING, J. M. (1971) Personal communication

SUMITOMO CHEMICAL COMPANY Technical Data

TAYLOR, C. E. (1971) Personal communication