PERSISTENCE AND EFFECTIVENESS OF CARBOPHENOTHION, CHLORFENVINPHOS AND ETHION SEED DRESSINGS TO CONTROL WHEAT BULB FLY (LEPTOHYLEMYIA COARCTATA)

D.C. Griffiths & G.C. Scott
Rothamsted Experimental Station, Harpenden, Herts.

Summary Cappelle winter wheat seeds dressed with carbophenothion, chlorfenvinphos, ethion or fungicide alone (controls) were sown on a wheat bulb fly infested site in October, November and December. Plant samples were taken in February for extraction and estimation of insecticide, and in March for recording the biological effects of the treatments. The amounts of insecticide recovered from the seeds and roots of February samples were similar for all three sowings and were about 30% of the carbophenothion, 2% of the chlorfenvinphos and 15% of the ethion that had been applied to the seeds. Little insecticide was found inside the 'bulbs' of the plants. The biological effects of the treatments were greatest with the late sowings where the controls had twice as many damaged shoots and only half as many healthy shoots as treated plants. Yields were taken only from the early sown plots where the differences were least marked, and although all three treatments yielded more than the controls the increases were not significant.

INTRODUCTION

Techniques for chemical analysis of insecticides can be used in field experiments to help explain biological results. In our experiment, wheat seeds dressed with carbophenothion, chlorfenvinphos or ethion were sown at different times, and the degree to which they protected plants from wheat bulb fly attack was compared with the amounts of insecticide remaining in or around the plants at the time of insect attack. Carbophenothion, chlorfenvinphos and ethion were chosen because they were the best materials tested in single-row tests (Griffiths et al., 1967) or field trials (Maskell, 1967; Mathias & Roberts, 1967; Dixon, 1967) as replacements for the persistent organochlorine insecticides.

METHODS

Seeds were dressed, at dosages similar to 2 oz/bu, by mixing 400g samples of Cappelle winter wheat in closed glass bottles with 0.8g commercial powder formulations of 60% carbophenothion, 40% chlorfenvinphos or 67% ethion, all containing 1% organomercury fungicide, or with 0.8g 1% organomercury alone (Control). The seeds were sown on three dates, 13 October, 9 November and 5 December on a medium boulder clay containing 2,350,000 wheat bulb fly eggs/acre. There were 3 replicates of each treatment at each date. Plots were 10 ft long and 12 rows wide, sown at 1g seed/ft at 1 inch depth. The first two sowings were done with a V-belt drill but the soil was so wet in December that the final sowing had to be done by hand.

Eggs began to hatch in late January, and by 9 February more than half the control plants were attacked. On this date an equal number of plants were removed from each plot and stored at -20°C until used for chemical analysis. Other plants were taken 20 days later, on 1 March when the insecticides had had time to show their full effects, and were examined for live and dead larvae, and healthy and attacked shoots. All shoots over $\frac{1}{4}$" long were examined, including those visible only after reflecting the outer leaves. Yields were taken only from early sown plots because mid and late sown plots were badly trampled at sowing.

Extracts of insecticide from seeds, roots and 'bulbs' of the samples collected on 9 February, were analysed chemically. Seeds were removed from 60 plants from each plot, combined and weighed, crushed with a pestle in a mortar, extracted overnight on a rotating wheel with 15 ml mixture of hexane/acetone (2:1 v/v) and extracted again with two smaller aliquots of hexane; each extract was washed with 2% sodium sulphate, then combined and made up to 25 ml. Roots were cut off 60 plants from each plot and treated similarly to seeds, except that soil clung more to the roots than the seeds and some was left on them. 'Bulbs' were cut out from the plants after removing the outer leaves: they were combined and weighed, ground in a glass tissue grinder with 5 ml hexane/acetone (2:1 v/v) and then with two further aliquots of 2 ml hexane; each extract was washed with 2% sodium sulphate, then combined and made up to 10 ml.

All extracts were analysed by gas chromatography using an Aerograph phosphorus detector and a ⅛" x 2 ft column of 5% S.E. 30/chromosorb W and nitrogen as carrier gas.

RESULTS

Table 1 compares the numbers of healthy shoots/100 plants in March samples from treatments and controls.

Table 1.

Mean number of healthy shoots/100 plants in samples taken 1 March

Sowing Date	Control organomercury alone	Carbophenothion 2 oz/bu 60%	Chlorfenvinphos 2 oz/bu 40%	Ethion 2 oz/bu 67%
13 October	181	213	210	238
9 November	55	99	92	110
5 December	35	78	69	85

Variance ratios

Treatments vs error	8.9	0.001>P
Dates vs error	134.1	0.001>P

Standard Error ± 13 (22 d.f.)

October-sown plants were well tillered before attack but those grown from treated seeds had about 1.3 times as many healthy shoots as the controls. Later sowings had fewer healthy shoots and the differences between controls and treatments were more obvious: treated seeds sown in December gave plants with twice as many healthy shoots as the controls. An important effect of the three insecticides was to prevent larvae entering the plants. The number of damaged shoots in control plants was similar for all three sowings (Table 2) and was greater then the number of damaged shoots in plants grown from treated seeds. The differences between treatments and controls were again greatest in the December sowings, where control plants had more than twice as many damaged shoots as any of the treatments. The figures for percentage plants with live larvae were variable (Table 3) because of differences between the observers who dissected the plants but most dead larvae were found in the December sowings.

When harvested on 5 September 1967, the mean yields in lb/plot with S.E.±0.94 and 6 d.f. were carbophenothion 5.49, chlorfenvinphos 5.76, ethion 4.68 and control 4.30. Therefore all treatments increased yields but the increases were not significant.

Table 2.

Mean number of damaged shoots/100 plants in samples taken 1 March

Sowing Date	Control organomercury alone	Carbophenothion 2 oz/bu 60%	Chlorfenvinphos 2 oz/bu 40%	Ethion 2 oz/bu 67%
13 October	81	73	71	65
9 November	87	54	79	52
5 December	72	33	31	30

Variance ratios

Treatments vs error	6.98	0.01>P>0.001
Dates vs error	13.8	0.001>P

Standard Error ± 9 (22 d.f.)

Table 3.

% plants with live larvae in samples taken 1 March

Sowing Date	Control organomercury alone	Carbophenothion 2 oz/bu 60%	Chlorfenvinphos 2 oz/bu 40%	Ethion 2 oz/bu 67%
13 October	50	46	51	31
9 November	70	25	50	27
5 December	60	7	16	13

Variance ratios

Treatments vs error	9.5	0.001>P
Dates vs error	5.94	0.01>P>0.001

Standard Error ± 9 (22 d.f.)

The mean weight of seeds dressed in the laboratory was 52.8mg, so the theoretical amounts of insecticide per seed were carbophenothion 63, chlorfenvinphos 42 and ethion 70 µg/seed. However not all the insecticide stuck to the seeds and the actual amounts, measured by extraction and chromatography were 41.5, 35.5 and 61.5 µg/seed respectively. Tables 4-6 give the amounts and concentrations of insecticides recovered from plant samples taken from the plots on 9 February. Consistently less chlorfenvinphos was recovered than ethion or carbophenothion. However, the distribution of all three materials was similar: the greatest quantities of insecticide were recovered from the seeds, less from the roots plus adhering soil, and least from the 'bulbs'. The figures for µg/g seed are greater for October than for later drillings because the seeds lost weight in the soil. When expressed as µg/seed it is clear that, for each material, the amount of insecticide recovered from any one sowing was very similar to the amounts recovered from the two other sowings. Only in the extracts from 'bulbs', and from seeds dressed with carbophenothion, was there any evidence that more insecticide was in material from later than from earlier sowings.

Table 4.

Amounts and concentrations of insecticides recovered from seeds of samples taken on 9 February. Log. transformations in brackets

Sowing Date	Carbophenothion Amount µg/seed	Carbophenothion Conc. µg/g seed	Chlorfenvinphos Amount µg/seed	Chlorfenvinphos Conc. µg/g seed	Ethion Amount µg/seed	Ethion Conc. µg/g seed
13 October	8.6 (0.93)	435.0 (2.64)	0.7 (-0.15)	36.6 (1.56)	8.1 (0.90)	489.0 (2.68)
9 November	11.8 (1.07)	332.7 (2.50)	0.7 (-0.18)	17.7 (1.24)	10.0 (0.92)	283.0 (2.41)
5 December	13.1 (1.11)	262.7 (2.40)	0.8 (-0.22)	19.4 (1.10)	8.2 (0.84)	202.7 (2.16)

Variance ratios	µg/seed	Probability	µg/g seed	Probability
Treatments vs error	89.9	0.001>P	67.6	0.001>P
Dates vs error	0.09	P>0.2	6.24	0.01 = P
Standard Error transformed values	±0.12 (16 d.f.)		±0.14 (16 d.f.)	

Table 5.

Amounts and concentrations of insecticides recovered from roots of samples taken on 9 February. Log. transformations in brackets

Sowing Date	Carbophenothion Amount µg/root	Carbophenothion Conc. µg/g root	Chlorfenvinphos Amount µg/root	Chlorfenvinphos Conc. µg/g root	Ethion Amount µg/root	Ethion Conc. µg/g root
13 October	0.53 (-0.28)	2.05 (0.31)	0.05 (-1.38)	0.35 (-0.52)	1.45 (0.16)	6.09 (0.74)
9 November	0.57 (-0.43)	3.22 (0.45)	0.11 (-1.04)	2.13 (0.19)	0.22 (-0.75)	3.97 (0.58)
5 December	0.47 (-0.41)	7.81 (0.75)	0.05 (-1.32)	0.95 (-0.07)	0.83 (-0.12)	14.38 (1.10)

Variance ratios	µg/root	Probability	µg/g root	Probability
Treatments vs error	32.9	0.001>P	23.96	0.001>P
Dates vs error	1.56	P>0.2	4.55	.05>P>.01
Standard Error transformed values	±0.16 (16 d.f.)		±0.17 (16 d.f.)	

DISCUSSION

The recovery of insecticide from October-sown plants sampled on 9 February showed that all three materials persisted in the soil conditions described. The quantities recovered from each sowing differed little and were about 30% of the carbophenothion, 2% of the chlorfenvinphos and 15% of the ethion applied to the seed. Some insecticide may have moved to parts of the plant or soil not analysed and some may have decomposed: in particular, the small amounts of chlorfenvinphos detected

Table 6.

Concentrations of insecticide recovered from 'bulbs' of samples taken on 9 February

Sowing Date	Carbophenothion µg/'bulb'	Chlorfenvinphos µg/'bulb'	Ethion µg/'bulb'
13 October	0.65	not detected	0.18
9 November	0.36	0.63	0.34
5 December	1.37	1.32	4.32

Variance ratios	µg/'bulb'	Probability
Treatments vs error	3.19	0.2>P>.05
Dates vs error	15.6	0.001>P
Standard Error	± 0.502 (16 d.f.)	

may be because it is more soluble (150 ppm) than the other insecticides and so could move more easily away from the seed, or because of known metabolites (Beynon & Wright, 1967) not detected by our methods. However, compared with most organophosphates, chlorfenvinphos is reasonably stable in soil (Beynon, Davies & Elgar, 1966) and its biological effects in this trial differed little from the other insecticides.

The small differences between numbers of healthy shoots in October-sown controls and treatments can be explained because early sown plants had many tillers and were able to withstand some insect attack without chemical protection. However, the numbers of damaged shoots in the treated plants were greater in the early than in the later sowings, with which the insecticides must have worked better. This effect cannot be explained by the chemical results presented here, but requires a knowledge of amounts of insecticide in parts of the soil and plant not analysed. The apparently greater numbers of dead larvae in late-sown plants may be related to the larger amounts of insecticide found in their 'bulbs', but further work is necessary to be sure. The amounts of insecticide in the 'bulbs' were smaller than in similar experiments with γ-BHC and dieldrin (Lord et al., 1967) and indeed much of the protection given by organophosphorus seed dressings is in preventing wheat bulb fly larvae entering the plants.

All three insecticides persisted from the earliest sowings but little was found in the 'bulbs' of the plants. Yields were increased by dressing October-sown seed, but not significantly so, and experiments with large plots would be necessary to determine the commercial advantage of such treatments.

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References

BEYNON, K.I., DAVIES, L. and ELGAR, K. (1966) J. Sci. Fd Agric. 17, 167.

BEYNON, K.I. and WRIGHT, A.N. (1967) J. Sci. Fd Agric. 18, 143.

DIXON, G.M. (1967) Plant Pathology 16, 1, suppl., 10.

GRIFFITHS, D.C., SCOTT, G.C., MASKELL, F.E. and MATHIAS, P.L. (1967) Plant Pathology 16, 1, suppl., 11.

LORD, K.A., SCOTT, G.C., JEFFS, K.A., GRIFFITHS, D.C. and MASKELL, F.E. (1967) Ann. appl. Biol. (in press).

MASKELL, F.E. (1967) Plant Pathology 16, 1, suppl., 1.

MATHIAS, P.L. and ROBERTS, P.F. (1967) Plant Pathology 16, 1, suppl., 3.

ETHION FOR THE CONTROL OF WHEAT BULB FLY

by R.J. Cole & D. Soper

May & Baker Ltd., Ongar Research Station, Essex

Summary

Research programmes were arranged during 1965-67 to evaluate ethion as a seed dressing for the control of wheat bulb fly (Leptohylemia coarctata). The first season's work carried out by ourselves and the N.A.A.S., showed that the field performance of ethion was at least equivalent to standard materials and that it was non-phytotoxic to emerging wheat plants. In Autumn 1966 two replicated trials were set up by May & Baker to compare ethion with gamma -BHC (lindane) and dieldrin, and to investigate the effects of drilling depth and sowing time on the performance of these compounds. At the same time box experiments were set up to assess any possible effects of soil type on the activity of ethion.

Examination of wheat plants in Spring 1967 confirmed the contact activity of ethion against wheat bulb fly larvae before shoot entry. This material was at least as effective as dieldrin and gamma -BHC in preventing crop damage, and was particularly successful in protecting November and December drillings. Grain yield was normal from the ethion-treated plots in marked contrast to the poor yields from the controls. The value of good cultural practice in assisting field performance of the insecticides used was verified in the replicated trials, and the user trials served to show that ethion seed dressing was commercially acceptable to merchants and farmers. All the experiments, including recent N.A.A.S. trials, have demonstrated the good activity of ethion against the various levels of wheat bulb fly attack on winter wheat.

Field studies with several species have led to the conclusion that ethion-dressed seed offered no hazard to grain-eating birds.

INTRODUCTION

In early field screening trials for the control of wheat bulb fly (Leptohylemia coarctata) carried out jointly in 1964-65 by Rothamsted Experimental Station and the Entomology Department of the N.A.A.S. (Eastern Region), ethion was the most effective compound tested. The activity of ethion seed dressings against this pest was further confirmed by 1965-66 May & Baker and N.A.A.S. experiments. Our own work showed that a dose of 0.12 to 0.16% a.i. to weight of seed gave acceptable protection from attack and that a formulation containing 65 to 70% a.i. was needed to give the correct seed loading at a dressing rate of 2 to 3 oz. per bushel of wheat. The official trials demonstrated that there was no phytotoxicity to the cereal plants even when ethion was used at 0.5% a.i. to weight of seed, and that this material controlled bulb fly at least as well as dieldrin.

Because of these promising results a further series of experiments was initiated in the Autumn of 1966. Replicated trials were laid down to determine the efficacy of ethion on seed sown early, normal and late in relation to depth of drilling, and box experiments were begun in order to investigate the possible influence of soil type on insecticidal activity.

Parallel to this small-plot work, user trials were organised to check the field and dresser performance of factory-made batches of a potential commercial formulation of the seed dressing; also, a field investigation was undertaken to assess the risk to grain-eating birds of cereal seeds treated with ethion. At the same time, N.A.A.S. workers included ethion in their regional tests of candidate new materials for wheat bulb fly control.

FIELD ACTIVITY

Two replicated experiments were set up in Autumn 1966 on clay loam soils at Shingay, Cambs., after a full fallow (egg count 3½ million/acre), and at Brent Pelham, Herts, after a half-fallow (egg count 2½ million/acre). Ethion-dressed Cappelle wheat was sown at intervals one month apart beginning in October and at two different soil depths, ¾" to 1" and 2" to 2½", in comparison with the standard materials, gamma -BHC and dieldrin, and a control. All the dressings contained mercury (1% Hg) in an organically-combined form and they were applied to the seed in a commercial dry-dresser. Drilling took place with a 7-coulter small-plot machine at the rate of 2.8 bushels (176 lb) per acre. Each treatment was repeated four times and in every case was split according to the time of drilling and split again on the depth of drilling.

The damage caused by wheat bulb fly was assessed during late March at Shingay and early April at Brent Pelham by detailed examination of samples of wheat plants. A total of twenty-five plants were dug from several stations throughout each plot and taken back to the laboratory for assessing the total number of shoots, and the number of attacked shoots, per plant. Bulb fly larvae were looked for in the attacked shoots (Brent Pelham site only), dissected out, and recorded as alive or dead. The plant examination results expressed as percentage attacked plants and shoots are given in Tables 1 and 2. A visual assessment of crop vigour was made on three occasions at intervals from February onwards (Table 4), and yields were taken using a 6 ft-cut combine-harvester (Tables 1 and 2).

A statistical analysis was carried out on the counts of attacked plants using an angular transformation. The proportion of attacked plants per plot (i.e. out of 25) was expressed in degrees by means of the transformation $\phi = \sin^{-1} \sqrt{p}$ where ϕ is the angle (in degrees) and p is the proportion expressed as a percentage. Tests of significance, based on mean values of ϕ for compounds, times of drilling, and depths of drilling (interactions between these factors were not significant), are set out in Table 3.

Table 1

Effect of time and depth of drilling on the activity of ethion and standard dressings (Shingay)

Seed Dressing Per cent a.i.	Rate oz/bushel	a.i. w/w seed	Drilling Depth/Date	Per cent Attacked plants	No. of shoots per 100 plants	% attacked shoots	Yield cwt/acre*
Ethion 70%	2.4	0.16%	Shallow/ 27.10.66	39	276	15.2	33.2
Ethion 67%	1.9	0.13%		37	322	12.7	26.3
Dieldrin 60%	2	0.12%		70	224	33.9	32.1
Gamma-BHC 40%	2	0.08%		63	246	35.1	27.6
Control (Hg only)	2	(0.002% Hg)		99	166	80.1	15.1
Ethion 70%	2.4	0.16%	Deep/ 27.10.66	94	146	78.0	22.9
Ethion 67%	1.9	0.13%		93	159	68.6	21.6
Dieldrin 60%	2	0.12%		87	166	60.2	27.0
Gamma-BHC 40%	2	0.08%		81	159	65.4	23.9
Control (Hg only)	2	(0.002% Hg)		98	130	87.6	12.9
Ethion 70%	2.4	0.16%	Shallow/ 17.11.66	47	235	28.9	20.4
Ethion 67%	1.9	0.13%		21	235	9.3	30.8
Dieldrin 60%	2	0.12%		62	193	32.6	27.8
Gamma-BHC 40%	2	0.08%		43	166	27.7	23.3
Control (Hg only)	2	(0.002% Hg)		99	110	97.2	8.36
Ethion 70%	2.4	0.16%	Deep/ 17.11.66	60	162	40.7	26.1
Ethion 67%	1.9	0.13%		59	153	39.2	20.8
Dieldrin 60%	2	0.12%		68	162	41.9	26.8
Gamma-BHC 40%	2	0.08%		64	141	47.5	17.4
Control (Hg only)	2	(0.002% Hg)		98	111	93.6	6.74
Ethion 70%	2.4	0.16%	Shallow/ December	20	114	17.5	23.0
Ethion 67%	1.9	0.13%		20	124	16.1	14.7
Dieldrin 60%	2	0.12%		42	137	30.6	22.1
Gamma-BHC 40%	2	0.08%		31	142	21.8	21.2
Control (Hg only)	2	(0.002% Hg)		94	113	84.9	4.76
Ethion 70%	2.4	0.16%	Deep/ December	13	108	12.0	27.0
Ethion 67%	1.9	0.13%		27	114	23.6	19.7
Dieldrin 60%	2	0.12%		35	128	27.3	14.9
Gamma-BHC 40%	2	0.08%		43	133	32.3	21.2
Control (Hg only)	2	(0.002% Hg)		99	106	94.3	4.27

Least significant difference between yields (P = 0.01) 16.63

Table 2

Effect of time and depth of drilling on the activity of ethion and standard dressings (Brent Pelham)

Seed Dressing Per cent a.i.	Rate oz/bushel	Drilling Depth/Date	Per cent Attacked plants	No. of shoots per 100 plants	% attacked shoots	Yield cwt/acre*
Ethion 67%	1.9		37	287	18.4	27.7
Dieldrin 60%	2	Shallow/	42	300	14.6	28.4
Gamma-BHC 40%	2	27.10.66	38	250	19.2	25.1
Control (Hg only)	2		81	330	44.8	22.6
Ethion 67%	1.9		41	265	24.9	27.2
Dieldrin 60%	2	Deep/	46	289	19.7	26.7
Gamma-BHC 40%	2	27.10.66	67	252	44.0	23.6
Control (Hg only)	2		79	270	51.8	20.2
Ethion 67%	1.9		12	276	5.0	19.6
Dieldrin 60%	2	Shallow/	25	260	10.3	21.9
Gamma-BHC 40%	2	17.11.66	37	278	16.9	17.9
Control (Hg only)	2		65	230	40.4	14.7
Ethion 67%	1.9		20	255	10.1	23.7
Dieldrin 60%	2	Deep/	35	235	15.3	23.5
Gamma-BHC 40%	2	17.11.66	37	248	20.9	21.6
Control (Hg only)	2		85	210	62.3	13.5
Ethion 67%	1.9		7	257	2.7	16.9
Dieldrin 60%	2	Shallow/	18	230	7.8	16.4
Gamma-BHC 40%	2	21.12.66	26	228	13.1	7.25
Control (Hg only)	2		79	192	48.4	8.05
Ethion 67%	1.9		3	240	1.2	17.0
Dieldrin 60%	2	Deep/	25	208	12.0	19.5
Gamma-BHC 40%	2	21.12.66	24	213	11.7	12.9
Control (Hg only)	2		65	162	43.2	8.6

Least significant difference between yields (P = 0.01) 6.95

*Grain yields at 85% dry matter, based on total of two replicate plots (Table 1) and total of four replicate plots (Table 2).

Table 3

Mean percentage attacked plants (expressed in degrees)

Compounds	Shingay	Brent Pelham
ethion 70%	43.55 a	-
ethion 67%	41.32 a	23.44 a
gamma-BHC 40%	48.71 a b	37.73 b
dieldrin 60%	53.65 b	33.62 b
Control (Hg only)	91.98 c	64.29 c
Standard error of diff. between any two means.	4.34	3.12
Times of drilling		
27.10.66	68.25 a	48.53 a
17.11.66	56.71 b	39.37 b
December	42.57 c	31.40 c
S.E. of diff. between any two means.	3.51	2.77
Depths of drilling		
Shallow $\frac{3}{4}$"-1"	50.51 a	38.05 a
Deep 2"-2$\frac{1}{2}$"	61.17 b	41.48 a
S.E. of diff. between any two means.	2.98	2.68

Duncan's Multiple Range Test: Any two means with a common suffix a, b, or c, are not significantly different from one another.

N.B. No significant interaction between main factors: compounds, depth of drilling or time of drilling.

Table 4

Crop Vigour

Scored on scale 1 = no crop to 10 = normal growth. Total of four replicate plots (i.e. maximum = 40)

Seed Dressing per cent a.i.	Dressing rate oz/bushel	Drilling Depth/Date	Shingay, Cambs 17.2.67	Shingay, Cambs 28.3.67	Shingay, Cambs 24.5.67	Brent Pelham, Herts 17.2.67	Brent Pelham, Herts 28.3.67	Brent Pelham, Herts 9.5.67
Ethion 70%	2.4	Shallow/ 27.10.66	38	40	34	-	-	-
Ethion 67%	1.9		38	39	30	39	40	35
Dieldrin 60%	2		38	39	35	38	39	36
Gamma-BHC 40%	2		37	39	33	38	38	31
Control (Hg only)	2		37	36	12	39	38	27
Ethion 70%	2.4	Deep/ 27.10.66	38	40	27	-	-	-
Ethion 67%	1.9		38	38	18	38	40	33
Dieldrin 60%	2		38	40	32	38	40	35
Gamma-BHC 40%	2		38	39	26	38	39	28
Control (Hg only)	2		38	34	12	38	38	23
Ethion 70%	2.4	Shallow/ 17.11.66	37	40	29	-	-	-
Ethion 67%	1.9		39	40	29	36	40	31
Dieldrin 60%	2		37	38	24	38	39	29
Gamma-BHC 40%	2		37	39	22	36	37	23
Control (Hg only)	2		37	33	6	37	36	19
Ethion 70%	2.4	Deep/ 17.11.66	39	40	28	-	-	-
Ethion 67%	1.9		39	39	22	38	40	29
Dieldrin 60%	2		38	39	28	38	39	32
Gamma-BHC 40%	2		38	38	16	37	38	27
Control (Hg only)	2		38	34	4	37	36	17
Ethion 70%	2.4	Shallow/ December	32	40	29	-	-	-
Ethion 67%	1.9		29	33	18	27	39	21
Dieldrin 60%	2		29	37	20	25	35	18
Gamma-BHC 40%	2		32	39	26	18	34	11
Control (Hg only)	2		31	30	5	27	34	9
Ethion 70%	2.4	Deep/ December	34	40	32	-	-	-
Ethion 67%	1.9		31	39	30	30	39	24
Dieldrin 60%	2		31	38	21	33	39	23
Gamma-BHC 40%	2		33	39	26	29	36	17
Control (Hg only)	2		28	33	5	34	34	5

In the replicated experiments the relatively low percentage of attacked plants on the ethion plots (Tables 1 and 2) demonstrated the excellent activity of this insecticide against wheat bulb fly. As expected, all the control plots were heavily attacked, and the differences between the controls and the insecticide-treated plots became quite distinct as the season progressed and were reflected in the yield figures. Under similar conditions of drilling there was no difference in crop vigour between the ethion and dieldrin plots, even in May, although by this time the gamma -BHC plots were looking less satisfactory (Table 4). Statistical analysis of percentage attacked plants showed that ethion was significantly better than all other treatments at Brent Pelham and better than dieldrin at Shingay. There was no significant difference between gamma -BHC and dieldrin, or between the two doses of ethion (Table 3). At both sites early drilling gave better results than later drilling for all treatments and sowing depths; at Shingay only, shallow drilling was better than deep drilling. Interactions between the factors of drilling time, depth of sowing, and compounds were not at all significant, but the percentage attacked plants on the ethion plots drilled in December (both depths) and drilled in November (shallow depth only) was extremely low compared with the other treatments. This indicates that ethion is particularly effective in preventing attack on late drillings, probably better in this respect than dieldrin. However, when the plants on all the dieldrin plots were dissected they were found to contain few live larvae, whereas in comparison more were found in the plants from the ethion plots. This suggests a contrasting mode of action between the two materials; ethion kills mainly by contact action before larval entry and dieldrin kills the larvae after they have entered the plants. (See Table 5).

Table 5

Results of Plant Dissection (Shingay)

Seed Dressing per cent a.i.	Dressing rate (oz/bushel)	Drilling Depth/Date	Per cent Plants with living larvae	No. of larvae per 100 plants Live	Dead
Ethion 70%	2.4	Shallow/ 27.10.66	12	12	1
Ethion 67%	1.9		17	18	1
Dieldrin 60%	2		5	6	21
Gamma-BHC 40%	2		25	26	9
Control (Hg only)	2		60	83	1
Ethion 70%	2.4	Deep/ 27.10.66	32	45	9
Ethion 67%	1.9		40	43	8
Dieldrin 60%	2		8	13	6
Gamma-BHC 40%	2		37	39	5
Control (Hg only)	2		39	53	15
Ethion 70%	2.4	Shallow/ 17.11.66	8	8	0
Ethion 67%	1.9		7	7	1
Dieldrin 60%	2		0	0	0
Gamma-BHC 40%	2		20	21	0
Control (Hg only)	2		33	33	8
Ethion 70%	2.4	Deep/ 17.11.66	18	19	3
Ethion 67%	1.9		10	11	5
Dieldrin 60%	2		1	1	0
Gamma-BHC 40%	2		18	18	1
Control (Hg only)	2		31	40	5
Ethion 70%	2.4	Shallow/ December	1	1	0
Ethion 67%	1.9		2	2	0
Dieldrin 60%	2		0	0	0
Gamma-BHC 40%	2		16	16	0
Control (Hg only)	2		43	43	9
Ethion 70%	2.4	Deep/ December	2	2	0
Ethion 67%	1.9		4	4	1
Dieldrin 60%	2		0	0	1
Gamma-BHC 40%	2		16	16	1
Control (Hg only)	2		39	52	21

Table 6

N.A.A.S. Trials - Plant Examination Results

Counts from 24 x 1 ft. rows of plants per treatment		Ethion 67% 2 oz/bushel		Dieldrin 60% 2 oz/bushel		Control -org. mercury only.	
		Shingay	Thorney	Shingay	Thorney	Shingay	Thorney
Plants	Total	462	405	429	395	-	392
	Per cent damaged	14.3	40	55.3	60	100*	63
Per cent living larvae		16	68	0	40	-	97
Per cent plants with live larvae		1	23	0	22	-	54

*Underground attack.

Although both materials were satisfactory, ethion and dieldrin gave better results on the clay loam site than on the fen. Their contrasting modes of action were verified.

EFFECT OF SOIL TYPE

Since both replicated trials were being carried out on one soil type only, simply because it was impossible to find a variety of soil types with high egg counts, it was decided to set up separate box experiments to assess a possible soil/ethion interaction.

Six soils with widely differing characteristics were chosen, sieved and put in 9" x 5" x 2½" boxes which were sown with Cappelle wheat in mid-November, at a rate of 40 seeds per box, which is equivalent to about 3 bushels/acre. The seeds were dressed with mercury only (control), 60% dieldrin, or 67% ethion at a rate of 1.9 oz per bushel. In mid-January wheat bulb fly eggs were added to the boxes at a rate of 1 egg/2 plants, approximately equivalent to 850,000 eggs/acre. The eggs had been extracted from soil by the standard washing technique and stored for this purpose. Before being added each egg was examined to ensure that it was viable. The boxes were kept in outdoor frames.

Counts of damaged and undamaged shoots were made in mid-March by visual means only, and total dry weights (root + shoot) were taken in June. These results, together with a statistical analysis of the numbers of attacked shoots are given in Table 7; the transformation θ was used so as to stabilize the variation in number of shoots per box.

Factory-made batches of ethion seed dressing, suitable for use in commercial dressers, were selected and distributed to a limited number of agricultural merchants for dressing Cappelle wheat seed at their premises. Satisfactorily treated seed was supplied to collaborating farmers in each merchant area for drilling on land liable to wheat bulb fly attack. During the course of these user trials general observations were made on diverse factors involved in the handling of the commercial dressing and comments of merchants and farmers were obtained.

Plant examination counts were attempted at some sites in the user trials but were somewhat less conclusive, because of the generally low incidence of wheat bulb fly. However, the commercial acceptability of ethion seed dressing to the merchant and farmer was clearly established.

Two trials comparing potential new materials for bulb fly control were laid down recently by the N.A.A.S. (Eastern Region). Cappelle Desprez was sown at 2.7 bushels/acre. One site was in a clay loam soil at Shingay, drilled 3rd January 1967, and with a 3½ million egg count. (This trial was in fact adjacent to the May & Baker experiment); the other site was on peaty loam soil at Thorney, Isle of Ely, drilled 18th November 1966, and with a 1½ million egg count. The results of plant examination carried out in March are given in Table 6.

Table 7

Effect of soil type on the activity of ethion

Total of three replicate plots (boxes)

Soil Texture	Organic matter/ approx.pH	Seed Dressing	Total Plants	Total Shoots	Total attacked Shoots	Total dry wt. of plants (g.)
clay	low/ 7	Ethion 67%	108	126	13	45.0
		Dieldrin 60%	101	123	13	45.5
		Control (Hg only)	111	119	39	38.7
sand (podsolic)	very high/ 3.5	Ethion 67%	87	93	9	15.4
		Dieldrin 60%	86	91	12	12.7
		Control (Hg only)	78	82	20	8.9
calcareous silty clay loam	low/ 7.5	Ethion 67%	110	124	8	28.3
		Dieldrin 60%	112	117	14	27.0
		Control (Hg only)	106	108	32	28.2
gleyed silt	low/ 6.5	Ethion 67%	104	126	2	37.0
		Dieldrin 60%	106	120	12	32.5
		Control (Hg only)	105	121	31	38.0
sand	low/ 7	Ethion 67%	109	114	7	51.9
		Dieldrin 60%	109	112	19	33.3
		Control (Hg only)	107	112	42	54.8
silt	high/ 7	Ethion 67%	109	113	10	17.1
		Dieldrin 60%	107	110	11	19.3
		Control (Hg only)	108	117	36	14.7

Statistical Analysis (based on attacked shoots)

(i) Soil types were significant at 1% P; treatments were significant at 0.1% P.

(ii) Soil/treatment interactions were significant at 5% P; the following table gives the number of infested shoots (transformed*):-

Treatment	clay	podzol	chalk	gley	sand	silt
Ethion 67%	58.78	57.24	47.29	21.95	46.69	54.83
Dieldrin 60%	59.12	66.30	63.07	58.02	74.56	57.01
Hg only	105.36	90.91	99.84	92.72	113.46	103.85

L.S.D. 5% level = 6.27
1% " = 8.52
0.1% " =11.46

*Figures in table are values of θ given by

$$\theta = \frac{1}{2}\left[\sin^{-1}\sqrt{\frac{x}{n+1}} + \sin^{-1}\frac{x+1}{n+1}\right]$$

where x = no. of attacked shoots out of n shoots.

In these box experiments statistical analysis showed that interaction between soil and treatment was highly significant. Ethion was active on all six soil types but tended to show some slight reduction in activity in soils with a high organic matter and/or a high clay content. This was supported by the calculation of total dry weights, since the outstanding yields from the ethion treatments were obtained from the sands.

GERMINATION TESTS

The results of tests given in Table 8 below, showed that ethion had no adverse effects on germination:-

Table 8

(i) Per cent germination of ethion dressed seed (Cappelle) after storage

Interval (weeks) between dressing and testing	3	8	14	18	27	32	37
Untreated seed	99	96	98	96	95	97	95
Ethion dressed seed	98	96	98	97	96	93	94

(ii) Germination of four varieties of winter wheat dressed with ethion

Variety	% Germination	
	Seed dressed with ethion	Untreated Seed
Cappelle Desprez	96	99
Rothwell Perdix	96	96
Champlein	96	97
Maris Widgeon	98	99

WILDLIFE INVESTIGATION

A field study was undertaken in Autumn 1966 to investigate the effect on grain-eating birds of cereal seeds treated with ethion and mercury. The work followed as closely as possible a pattern suggested by Dr. R.K. Murton and Mr. E.N. Wright of the Ministry of Agriculture's Infestation Control Laboratory, Worplesdon. Three fields of 4, 6 and 15 acres, adjacent to woodland, were drilled in October/November to winter wheat dressed with 67% ethion seed dressing at the rate of 2 oz/bushel (0.15% ethion + .002% Hg w/w of seed). The fields were located within a $1\frac{1}{4}$ mile radius, but they were spaced well apart from each other and from other dressed cereal sites. Hides were erected before drilling, and observations were made on wild bird behaviour directly after drilling until feeding ceased. Watches were kept for a 1 to $1\frac{1}{2}$ hour period twice daily, and every two or three days roost areas in the neighbouring woodland and thickets were carefully searched.

The species and number of all birds visiting the sites during observation periods, and the actual duration of feeding, were recorded. Whenever possible a minimum of three peck rates (i.e. the time taken in seconds to make 12 pecks) were determined for each bird. The results for one site, which are quite typical, are given in Table 9, and show that over a three-week period there was no falling-off in peck rates, which remained fairly constant for the three species observed. However, the birds exhibited a marked preference for alternative food sources (e.g. wild oat seeds, acorns, volunteer beans) to ethion dressed seed if these were available. General behaviour was normal: there was a fluctuating population of wood pigeons, and steadier populations of pheasants and moorhens, though the numbers of the latter were quite low. Three dead birds, all wood pigeons, found during the searches, died from causes other than chemical poisoning.

Feeding on wheat seed dressed with ethion and mercury appeared to offer a negligible risk to wild birds during the Autumn period, and field studies will shortly be undertaken on winter wheat sown in January to February.

Table 9

Post-drilling observations on Feeding Times and Peck Rates for Moorhen, Pheasant, and Wood Pigeon

Area of Field: 15 acres; Date of Drilling: 3.11.66; Crop: Cappelle winter wheat;
Drilling rate: $2\frac{1}{2}$ bushels (160 lb) per acre.

Days after drilling	MOORHEN Total feeding time (bird-minutes)	MOORHEN Mean peck rate (secs/12 pecks)	PHEASANT Total feeding time (bird-minutes)	PHEASANT Mean peck rate (secs/12 pecks)	WOOD PIGEON Total feeding time (bird-minutes)	WOOD PIGEON Mean peck rate (secs/12 pecks)
4	0	-	48	-	1	-
5	0	-	28	16	1	-
6	2	-	78	15	0	-
7	30	-	498	19	198	32
8	9	-	280	21	37	-
9	20	23	FOXHUNTING IN AREA - BIRDS DISTURBED			
10	0	-	SHOOTING IN AREA - BIRDS DISTURBED			
11	0	-	426	20	25	29
12	88	-	484	19	191	31
13	20	-	374	28	7,845	29
14	40	27	1,035	24	2,115	30
15	67	-	678	18	10,135	26
16	0	-	1,179	17	2,767	17
17	50	22	110	17	0	-
18	31	18	645	16	120	20
19	40	14	331	16	3,017	28
20	34	17	190	14	0	-
21	HEAVY MIST ALL DAY - ACCURATE OBSERVATION IMPOSSIBLE					
22	33	17	459	16	39	-

CONCLUSIONS

The field experiments described in this paper confirm that early drilling of winter wheat is in itself a form of insurance against wheat bulb fly attack. If early drilling is not practicable on land subject to risk from this pest, it is essential to protect a winter wheat crop by using an insecticide seed dressing. It has been shown that ethion, applied in this way, prevents crop damage so that normal grain yield is obtained. The protection given is equivalent to dieldrin for early sowings and slightly better than dieldrin for mid- to late-season drillings.

The practical implication of the soil work, so far as ethion is concerned, is that there may be slight shortening of its insecticidal persistence in soils with high organic matter and/or high clay content. When a very heavy bulb fly attack is expected on these soils, good cultural practice (e.g. shallow drilling) becomes proportionately more important. Ethion is remarkably non-phytotoxic to wheat seed and offers little or no hazard to birds eating Autumn-sown grain.

Ethion is an organophosphorus compound which when applied as a seed dressing is a satisfactory and safer alternative to dieldrin for the control of wheat bulb fly.

Acknowledgments

We should like to acknowledge the assistance given by Mr. F.E. Maskell, N.A.A.S. Eastern Region, and also the help of many of our colleagues.

References

1. Cessac & Guillot (1967) Proc. XIXth Ghent Symposium.

2. Dixon, C.M. et al. Supp. to Jnl. Plant Path. 16, 1.

3. Griffiths, D.C. & Scott, G.C. (1965) Proc. 3rd. Brit. Insect. Fung. Conf. 190.

TRIALS WITH CARBOPHENOTHION AND N.2790 FOR WHEAT BULB FLY AND WIREWORM CONTROL IN CEREALS

W.S.Catling and I.K.Cook
The Murphy Chemical Co.Ltd., Wheathampstead

Summary

Carbophenothion (S-(p-chlorophenylthio) methyl-O-O-diethyl phosphorodithioate) and N.2790 (O-ethyl S-phenyl ethylphosphonodithioate) were evaluated for their activity against Wheat Bulb Fly in Winter Wheat and against Wireworms in Spring Cereals.

In the control of Wheat Bulb Fly carbophenothion as a 60% seed dressing was shown to be equivalent to a 60% dieldrin dressing, and N.2790 as a 60% seed dressing was found to be inferior to a dieldrin dressing. N.2790 5% granules applied at sowing time were found to be extremely efficient in the control of Wheat Bulb Fly.

Carbophenothion was found to have no activity against Wireworms in Spring Cereals, but N.2790 was shown to be active as both a 60% seed dressing and as 5% granules.

It is argued taking toxicity considerations into account, that carbophenothion is a suitable material for development as a Wheat Bulb Fly Seed Dressing and that N.2790 is suitable as a granule formulation for Wireworm control in Cereals.

INTRODUCTION

The conclusive evidence for the accumulation for organochlorine residues in wild life (Moore et al 1964), and the toxic nature of these chemicals to wild birds in particular (Cramp & Conder 1961), has led to increased pressure for further safeguards since the use of certain of the organo-chlorine pesticides was limited in 1961. Thus the use of aldrin, dieldrin and heptachlor as seed dressings on Winter Wheat was limited to that seed sown before 31st December and where a real danger from Wheat Bulb Fly existed. Their use as over all treatments and as seed dressings for the control of Wireworms in all cereals was discontinued. Gamma-BHC has proved to be an inadequate substitute to aldrin, dieldrin and heptachlor. Its use as a seed dressing is limited by phytotoxic considerations (Jameson et al 1951) and its use as an over all treatment can result in taint problems in the succeeding crop (Potter et al 1956).

With the continued importance of Wheat Bulb Fly and the problems attached to the use of gamma-BHC, it became imperative to find suitable pesticides for the efficient control of Wheat Bulb Fly and Wireworm in cereals. This paper reports the work carried out to determine the suitability of carbophenothion (S-(p-chlorophenylthio) methyl-O-O-diethyl phosphorodithioate) and N.2790 (O-ethyl S-phenyl ethylphosphonodithioate) for use as soil insecticides in cereals.

METHOD AND MATERIAL

N.2790

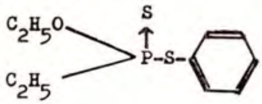
N.2790 which carries the trade name Dyfonate was first shown by Rothamsted workers (Griffiths et al 1965) to be active against Wireworms and Wheat Bulb Fly. It was subsequently demonstrated by N.A.A.S. workers (Mathias 1967) to be active as a granular formulation against Wheat Bulb Fly.

Physical and Chemical Properties of N.2790

Chemical name: O-Ethyl-S-phenyl-ethylphosphonodithioate

Empirical formula: $C_{10}H_{15}OPS_2$

Structural formula:



Molecular weight: 246.34

Physical state: Liquid

Specific gravity: 1.16 at 25/25°C

Index of Refraction: $N\frac{30}{D} = 1.5883$

Boiling point: 130°C at 0.1 mm.

Solubility: Insoluble in water. Miscible in organic solvents such as methyl isobutyl ketone, kerosene and xylene.

Formulations used

N.2790 was formulated as a 60% dry powder seed dressing containing 1% organically combined mercury. It was also formulated as a 4% granule based on fuller's earth.

Toxicology

N.2790 inhibits cholinesterase and in this respect is similar to other organophosphorous insecticides.

Table 1

Acute Toxicity

Animal	Application route	Acute LD 50 value mg./kg.
Rats	oral	16.5
Rabbits	percutaneous	35
Guinea pigs	percutaneous	278

Residue data

Samples were taken for residue analysis from two Winter Wheat trials and from one Spring Cereals trial. Only the N.2790 4% granule treatment was sampled. In the case of the winter sown trials analyses were carried out on the soil 30, 67 and 97 days after application. In the case of the Spring Cereal trial, soil samples were analysed 59 and 121 days after application, in addition a grain sample was analysed at harvest.

The residues were assessed at the Huntingdon Research Centre by extraction in benzene in the presence of sodium sulphate, cleaning up the extract on a silica gel column and determining the residue by injection on to G.L.C. with an electron capture detector. The results are given in Table 2 as mean values in parts per million and are calculated for a 90% recovery at 0.3 ppm.

Table 2

Residues found in Cereals treated with N.2790 in mg./kg.

Site I - Organic Peat Soil. Cappelle-Desprez Winter Wheat sown 3rd November, 1965

Treatment	Rate	Soil 30 days after sowing	67 days after sowing
N.2790 4% granules	50 lbs./acre	1.25	2.7
Control	-	< 0.05	< 0.1

Site II - Clay Mineral Soil - Cappelle-Desprez Winter Wheat sown 3rd November, 1965

Treatment	Rate	Soil 97 days after application
N.2790 4% granules	50 lbs./acre	0.8
Control	-	< 0.1

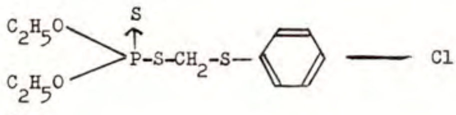
Site III - Sandy-Chalk soil. Proctor Spring Barley sown 25th April, 1966

Treatment	Rate	Soil 59 days after application	121 days after application	Grain 121 days after application
N.2790 4% granules	40 lbs./acre	2.08	< 0.1	< 0.02
Control	-	< 0.1	< 0.1	< 0.02

CARBOPHENOTHION

Carbophenothion which has the trade name Trithion was first shown by Rothamsted workers (Griffiths et al 1966) to be active against Wheat Bulb Fly.

Physical and Chemical Properties of Carbophenothion

Chemical name	S-(p-chlorophenylthio)methyl-O-O-diethyl phosphorodithioate
Empirical formula	$C_{11}H_{17}O_2Cl\ P\ S_3$
Structural formula	
Molecular weight	310
Physical state	Liquid
Specific gravity	1.265 - 1.285 at 20/20°C
Index of Refraction	$N\frac{25}{D}$ = 1.590 - 1.597
Solubility	Solubility in water is 0.34 parts per million at 20°C. Soluble in most organic solvents including petroleum, ether, benzene, toluene, xylenes, ethers, alcohols, esters, ketones, etc.

Formulations used

Carbophenothion was formulated as a 60% dry powder dressing containing 1% organically combined mercury. It was also formulated as a 60% liquid dressing to be applied with a 2% mercury liquid formulation through the Mist-O-Matic seed dressing machine.

Toxicology

Carbophenothion inhibits cholinesterase and in this respect is similar to other organophosphorous insecticides.

Table 3

Acute Toxicity

Animal	Application route	Acute LD 50 value mg./kg.
Rats	oral	56
Mice	oral	218
Poultry	oral	in excess of 316
Rabbits	percutaneous	1270

Rats and dogs confined in a near saturated atmosphere of carbophenothion during a four week period exhibited no signs of toxicity. There was no reduction in cholinesterase activity of either blood plasma or red blood cells of rats. There was a slight reduction in the plasma cholinesterase of dogs, but there was no effect on the red blood cell cholinesterase level.

Subacute feeding tests in the rat indicated that 5 ppm in the whole diet will produce no significant cholinesterase depression, while 1 ppm in the dog is a "safe" no effect level.

Acute potentiation of toxicity between carbophenothion and eight other organo phosphorous compounds failed to produce effects greater than additive in any case when the limits of experimental error were considered.

Residue data

Samples were taken for residue analysis from four sites at four different stages. Soil samples were taken from two of the sites at approximately 130 days after sowing and from the remaining two sites at 220 days after sowing. Seedling samples consisting of the seedlings and the soil attached to the roots of these seedlings were taken from two of the sites 130 days after sowing. Small green ear samples were taken from four sites prior to the commencement of heading, and for two of these sites the embryo ears were dissected from the plants and assessed for residue separately. Finally harvest samples were taken from all four sites and were assessed for straw and grain residues.

To assess the residues in the samples, they were extracted with benzene in the presence of sodium sulphate as a dehydrating agent. A portion of the extract is subjected to an oxidation procedure using an acetic acid-peroxide system which converts carbophenothion to more powerful cholinesterase inhibitors. The total residue is then determined using human blood plasma cholinesterase where enzyme inhibition is measured by a pH change under standard conditions. The residues found are given in Table 4 as mean values in parts per million and are calculated for 70% recovery.

Table 4

Residues found in Winter Wheat treated with Cabophenothion in mg./kg.

Site I - Clay Mineral Soil. Cappelle-Desprez Winter Wheat sown 22nd November, 1966

Treatment	Rate	Soil 215 days after sowing	Small greenears 215 days after sowing		Harvest 291 days after sowing	
			stalks	ears	straw	grain
60% Carbophenothion Powder Seed Dressing	2 oz./ bush.	0.03	0.08	0.00	0.00	0.00
60% Carbophenothion Liquid Seed Dressing	2 fl.oz. /bush.	0.03	0.00	0.00	0.00	0.00
Control	-	0.02	0.00	0.00	0.00	0.00

Site II - Skirt Fen Soil. Cappelle-Desprez Winter Wheat
sown 31st November,1966

Treatment	Rate	Soil 243 days after sowing	Small greenears 243 days after sowing		Harvest 297 days after sowing	
			stalks	ears	straw	grain
60% Carbophenothion Powder Seed Dressing	2 oz./ bush.	0.00	0.00	0.00	0.00	0.00
60% Carbophenothion Liquid Seed Dressing	2 fl.oz.	0.05	0.05	0.00	0.00	0.00
Control	-	0.00	0.00	0.00	0.00	0.00

Site III - Clay Mineral Soil. Cappelle-Desprez Winter Wheat
sown 1st November, 1966

Treatment	Rate	Soil 138 days after sowing	Seedlings 138 days after sowing	Small greenears 192 days after sowing	Harvest 313 days after sowing	
					straw	grain
60% Carbophenothion Powder Seed Dressing	2 oz./ bush.	0.00	2.80	2.10	0.00	0.00
60% Carbophenothion Liquid Seed Dressing	2 fl.oz. /bush.	0.00	8.50	1.40	0.00	0.00
Control	-	0.00	0.00	0.00	0.00	0.00

Site IV - Organic-Fen soil. Cappelle-Desprez Winter Wheat
sown 11th November, 1966

Treatment	Rate	Soil 119 days after sowing	Seedlings 119 days after sowing	Small greenears 175 days after sowing	Harvest 280 days after sowing	
					straw	grain
60% Carbophenothion Powder Seed Dressing	2 oz./ bush.	0.06	14.00	0.08	0.00	0.00
60% Carbophenothion Liquid Seed Dressing	2 fl.oz. /bush.	0.00	12.00	1.10	0.00	0.00
Control	-	0.00	2.10	0.00	0.00	0.00

TRIALS METHODS

The powder seed dressings were applied to the seed at 2 oz./bush. in a normal tumbler type of seed dresser. The liquid formulation was applied together with a liquid mercury formulation by a Mist-O-Matic seed dressing machine. All control seed was treated with liquid mercury.

Prior to and during the trial the germination of the treated seed was checked by standard N.I.A.B. techniques involving the use of both sand and John Innes No.1 compost.

Before sowing, the adhesion of the dressings on the seed was checked by the utilization of gas-chromatographic techniques. The actual loading found being compared with the theoretical loading.

Trial sites were found with the help of the N.A.A.S. who carried out Wheat Bulb Fly egg and Wireworm larval counts. The seed was sown with normal farm drills, plot sizes being 10 ft. wide and between 50 and 100 ft. long. Granule treatments were applied just before drilling by hand and were harrowed in. Eight treatments were normally included in a trial which was replicated in a randomized block design, there always being four replicates.

Eight Wheat Bulb Fly trials were carried out in the last two years and four of the trials are reported. The trials were assessed in February, before the egg hatch, for emergence, in order that any phytotoxic properties of the treatments could be detected. In March when egg hatch was judged to have been completed, the plots were sampled and a 100 plants/plot were examined in the laboratory for attack and for the presence of live larvae. In order to study the progress of the attack the plots were again sampled in April and 100 plants/plot were examined in the laboratory for tiller attack. In May the plots were scored visually and finally in September yields were assessed by harvesting the plots individually by combine and weighing the harvested grain.

During the last two seasons, five Wireworm trials have been carried out at sites of likely Wireworm attacks, in some cases Wireworm counts were made. Of these five trials only one proved to be of significant value. The site was in Yorkshire and had a Wireworm population of 1 million/acre.

The trial was sown in March, and in May the number of plants per ft. of row was assessed together with the number of plants damaged. In June a visual assessment of the plants was made and finally in September, yields were assessed by means of combine harvesting the plots and weighing the grain.

RESULTS

Wheat Bulb Fly - N.2790

Results prior to sowing obtained for germination and adhesion of the treatments are given in Tables 5 and 6 and show that N.2790 60% powder dressing adheres well to the seed and has no detrimental effect on germination. Other tests involving small scale applications of the dressing at rates greater than 2 oz./bush. demonstrated the safety of the 2 oz./bush. rate.

TABLE 5

N.2790 - germination results of treatments used in 1965-66 Wheat Bulb Fly Trials

Treatment	Rate	% germination Normals	% germination Abnormals
N.2790 60% powder dressing	2 oz./bush.	94.0	1.5
Dieldrin 60% powder dressing	2 oz./bush.	98.5	0.0
Control	-	95.5	1.5

TABLE 6

N.2790 - adhesion of treatments used in 1965-66 Wheat Bulb Fly Trials

Treatment	Rate	% Adhesion
N.2790 60% powder dressing	2 oz./bush.	84
Dieldrin 60% powder dressing	2 oz./bush.	62

The results for the performance of N.2790 in the control of Wheat Bulb Fly on a typical clay mineral soil are given in Table 7.

N.2790 has had no effect on emergence of the Wheat seedlings. In terms of control of Wheat Bulb Fly, the 60% seed dressing was superior to dieldrin in the March and April assessments. In the May visual assessment and in the yield assessment, dieldrin proved to be the superior treatment. The N.2790 4% granule treatment was superior to the dieldrin seed dressing at all assessments except the final harvest assessment where no significant difference could be found between it and dieldrin seed dressing.

In the same year a similar trial was carried out on an organic fen soil and again no effect was detected on emergence by the N.2790 treatments. Control of Wheat Bulb Fly by N.2790 was comparable to the clay mineral soil trial. Although we were unable to obtain yield data it was shown that the N.2790 4% granule treatment was better than the dieldrin seed dressing and that the N.2790 60% was superior to dieldrin in terms of percentage attacked plants, but inferior in terms of attacked tillers and at the visual assessment. The results from this trial are shown in Table 8.

It could therefore be concluded from these trials that N.2790 when applied as a 4% granule over all at 50 lbs./acre results in an efficient control of Wheat Bulb Fly and that this control is an improvement on a dieldrin seed dressing in that the larvae are effectively prevented from entering the plant.

Table 7

N.2790 - results from Wheat Bulb Fly trials on clay mineral soil 1965-66

Egg count	4.5 million eggs/acre
Previous crop	Full Fallow
Sowing Date	1st November, 1965
Sowing Rate	173 lbs./acre
Soil type	14.7% coarse sand, 22.7% fine sand, 54.4% American silt, 31.4% International silt, 31.2% clay, Total organic 2.9% pH 7.26

Treatment	Rate	Emergence plant/ft.row (Assessed February)	% plants damaged (Assessed March)	Angular Trans-formation	% Tiller damage (Assessed April)	Angular Trans-formation	Live Larvae /100 plants (Assessed March)	Visual assessment (max.=20) (Assessed May)	Yield cwt/acre (Assessed September)
N.2790 4% granules	50 lbs./acre	20.3	5.0	12.4	15.0	21.8	1.0	20	42.4
N.2790 60% powder dressing	2 oz./bush.	17.6	33.5	35.0	18.1	25.0	5.5	13	38.9
Dieldrin 60% powder dressing	2 oz./bush.	17.1	79.0	64.0	31.1	33.5	12.0	16	47.4
Control	-	19.2	82.5	69.0	74.4	54.8	59.5	0	16.6
L.S.D. 5%	-	2.2	-	14.2	-	9.6	7.1	-	5.6

Table 8

N.2790 - results from Wheat Bulb Fly trials on organic fen soil 1965-66

<u>Egg count</u> 4.35 million eggs/acre
<u>Previous crop</u> Main crop potatoes
<u>Sowing Date</u> 3rd November, 1965
<u>Sowing Rate</u> 168 lbs./acre
<u>Soil type</u> 15.6% coarse sand, 27.6% fine sand, 74.4% American silt, 42.4% International silt, 14.2% clay. Total organic 17.7% pH 7.10

Treatment	Rate	Emergence plant/ft.row (Assessed February)	% plants damaged (Assessed March)	Angular Trans-formation	% Tiller damage (Assessed April)	Angular Trans-formation	Live Larvae /100 plants (Assessed March)	Visual Assessment (Max.=20) (Assessed May)
N.2790 4% granules	50 lbs./acre	17.1	14.5	22.0	2.5	8.7	7.5	20
N.2790 60% powder dressing	2 oz./bush.	16.0	33.5	35.1	10.8	18.7	10.0	15
Dieldrin 60% powder dressing	2 oz./bush.	17.0	60.0	51.2	8.9	14.2	16.0	16
Control	-	19.1	56.0	48.9	46.4	42.9	30.5	5
L.S.D. 5%	-	N.S.	-	13.7	-	7.6	16.8	-

N.2790 60% seed dressing although giving some control of Wheat Bulb Fly was not as efficient as dieldrin. Initial control was found to be better than dieldrin showing that N.2790 seed dressing was preventing some larvae from entering the shoots. However, no kill of the larvae within the plant could be demonstrated and the dieldrin treatment proved to be superior in the later stages of the development of the attack.

Wheat Bulb Fly - Carbophenothion

Four trials were carried out during 1966-67 to demonstrate the efficiency of carbophenothion in the control of Wheat Bulb Fly. Egg counts were down on previous years and it was difficult to find sites with egg populations of over 1 million/acre. We report two trials carried out on clay mineral soils, the remaining two trials carried out on fen soils did not give significant differences for treatments as compared with the controls.

Prior to sowing, germination tests were carried out on the treated seed, and the tests were repeated upon storage. The results are given in Table 9.

Table 9

Carbophenothion - germination results of treatments used in 1966-67 Wheat Bulb Fly Trials

Treatment	Rate	% germination					
		No storage in soil		No storage in sand		12 weeks storage in soil	
		Normals	Abnormals	Normals	Abnormals	Normals	Abnormals
Carbophenothion 60% powder dressing	2 oz./ bush.	94.0	2.5	82.5	7.5	93.5	3.5
Carbophenothion 60% liquid dressing	2 fl.oz. /bush.	92.5	3.5	96.0	1.5	90.5	6.0
Dieldrin 60% powder dressing	2 oz./ bush.	97.5	1.5	79.0	18.5	89.0	6.0
Control	-	94.0	1.5	93.5	4.0	91.0	7.0

From the figures shown in Table 9 it can be seen that neither of the carbophenothion seed dressings presented a hazard to germination even after 12 weeks storage.

Adhesion investigations were also carried out before sowing and the results are given in Table 10.

Table 10

Carbophenothion - adhesion of treatments used in 1966-67 Wheat Bulb Fly Trials

Treatment	Rate	Adhesion
Carbophenothion 60% powder dressing	2 oz./bush.	55.5
Carbophenothion 60% liquid dressing	2 fl.oz./bush.	80.7
Dieldrin 60% powder dressing	2 oz./bush.	56.0

As would be expected very much better loading of carbophenothion was achieved with the liquid dressing. The powder dressing was not so efficient but was comparable to a standard dieldrin dressing.

Table 11

Carbophenothion - results from Wheat Bulb Fly trials on clay mineral soil 1966-67

Egg count	1.0 million eggs/acre
Previous crop	Full Fallow
Sowing Date	1st November, 1966
Sowing Rate	189 lbs./acre
Soil Type	12.8% coarse sand, 23.4% fine sand, 36.2% American silt, 24.2% International silt, 39.6% clay. Total organic 3.4% pH 6.46

Treatment	Rate	Emergence plant/ft row (Assessed February)	% plants damaged (Assessed March)	Angular Trans-formation	% Tiller damage (Assessed April)	Angular Trans-formation	Live Larvae /100 plants (Assessed March)	Visual Assessment (Max.=20) (Assessed May)	Yield cwt/acre (Assessed September)
Carbophenothion 60% powder dressing	2 oz./ bush.	20.1	19.8	26.1	9.4	17.7	4.8	20	39.6
Carbophenothion 60% liquid dressing	2 fl.oz. /bush.	17.7	29.5	32.8	10.3	18.5	10.5	18	39.6
Dieldrin 60% powder dressing	2 oz./ bush.	14.9	29.0	32.5	3.6	10.8	4.5	19	41.4
Control	-	16.9	34.5	35.9	13.3	21.4	19.2	10	32.6
L.S.D. 5%	-	N.S.	-	4.5	-	3.9	8.1	-	5.1

Table 12

Carbophenothion - results from Wheat Bulb Fly trials on clay mineral soil 1966-67

Egg count: 2.35 million eggs/acre
Previous crop: Full Fallow
Sowing Date: 22nd November, 1966
Sowing Rate: 168 lbs./acre
Soil type: 8.9% coarse sand, 25.1% fine sand, 39.9% American silt, 25.9% International silt, 39.9% clay. Total organic 4.2% pH 7.58

Treatment	Rate	Emergence plant/ft.row (Assessed February)	% plants damaged (Assessed March)	Angular Trans-formation	% Tiller damage (Assessed April)	Angular Trans-formation	Live Larvae /100 plants (Assessed March)	Visual Assessment (Max.=20) (Assessed May)	Yield cwt/acre (Assessed September)
Carbophenothion 60% powder dressing	2 oz./ bush.	12.5	14.8	22.2	2.0	8.1	3.8	12	13.2
Carbophenothion 60% liquid dressing	2 fl.oz. /bush.	11.6	18.0	23.6	3.0	10.0	3.0	12	11.6
Dieldrin 60% powder dressing	2 oz./ bush.	11.9	21.2	27.4	2.7	8.3	1.2	14	14.0
Control	-	12.2	43.8	41.4	2.7	9.8	25.2	4	9.0
L.S.D. 5%	-	N.S.	-	8.8	-	N.S.	6.1	-	3.0

The results from the first trial sown on the 1st November, 1966 on clay mineral soil with a population of 1 million eggs/acre are given in Table 11.

It will be seen that none of the treatments have had a significant effect on emergence. The initial assessment shows the increased efficiency of the carbophenothion powder dressing over the dieldrin dressing. The carbophenothion liquid dressing was equivalent in performance to the dieldrin dressing. The progress of the attack as shown in the April assessment, the May visual assessment and the final yield assessment, shows that dieldrin was superior in the protection of the tillers, but that in terms of final plant stand and in yield there were no significant differences between the three seed dressings.

The second trial of the 1966-67 season on clay mineral soil with an egg population of 2.35 million eggs/acre was sown with great difficulty due to inclement weather conditions on the 22nd November, 1966. It was found that the subsequent emergence, although even, was low, but significant differences were not found between treatments as can be seen in Table 12.

As with the first trial all the treatments significantly controlled Wheat Bulb Fly and in the early stages of attack the carbophenothion treatments were marginally superior to the dieldrin treatment. The dieldrin treatment was more effective in the later stages of the attack, and although yields were low both the dieldrin and carbophenothion powder dressing treatments were shown to result in significant increases in yield. The carbophenothion liquid treatment did not give a significant increase in yield over the control but the visual assessment score was equivalent to the carbophenothion powder dressing.

From consideration of the two trials it could be stated that carbophenothion as a 60% seed dressing was equivalent in efficiency to a 60% dieldrin dressing in the control of Wheat Bulb Fly. There was an indication that the powder formulation was marginally superior to the liquid formulation, but this was difficult to explain in terms of the adhesion data. The mode of action of carbophenothion differs from dieldrin in that control is achieved by prevention of entry and thus the material appears markedly superior, like N.2790, in the early stages of attack by Wheat Bulb Fly larvae.

WIREWORM

The results for the most successful Wireworm trial are given in Table 13. The host crop was Rika Barley and with a Wireworm population of 1 million/acre significant differences were found.

The plant count assessed in May approximately 6 weeks after sowing gave an indication of the subterranean attack and showed that the N.2790 granule treatment was giving the best control. The N.2790 and lindane powder dressings were resulting in equivalent control, and it is apparent that carbophenothion was of no effect. At this assessment damaged plant counts were also taken and it will be seen from the table that N.2790 granules and N.2790 and lindane powder dressings were giving equivalent control of seedling attacks. The visual assessment made in June confirmed the seedling attack assessment in that only the N.2790 and lindane treatments were effective. Yield data obtained in September showed that N.2790 granule treatment to be giving the best control. The N.2790 and lindane powder treatments gave improvements on yield over the control, whereas the carbophenothion powder treatment gave no improvement in yield as compared with the control.

From this trial it can be concluded that N.2790 had significant activity against Wireworm in Cereals. The 5% granules applied at 25 lbs./acre were superior to the 60% powder dressing applied at 2 oz./bush. This powder dressing was, however, equivalent to the standard 20% lindane powder dressing. Carbophenothion exhibited no activity against Wireworms.

Table 13

Wireworm Trial with N.2790 and Carbophenothion

Larval count	1 million/acre
Previous crop	Permanent pasture
Sowing Date	22nd March, 1967
Sowing Rate	140 lbs. Rika Barley/acre
Soil Type	Clay mineral soil. (Soil analysis not done).

Treatment	Rate	Plants/ft. row (Assessed May)	% Damaged plants (Assessed May)	Angular Trans-formation	Visual Assessment (Max.=20) (Assessed June)	Yield cwt/acre (Assessed September)
N.2790 60% powder dressing	2 oz./ bush.	8.4	2.8	9.5	13	34.0
Carbophenothion 60% powder dressing	2 oz./ bush.	6.0	11.5	19.4	9	31.4
N.2790 5% granules	25 lbs. /acre	8.9	2.8	8.3	15	36.4
Lindane 20% powder dressing	2 oz./ bush.	8.0	4.1	10.3	15	33.3
Control	-	7.2	10.6	18.2	11	31.3
L.S.D. 5%		2.2		6.0		5.0

DISCUSSION

From laboratory data N.2790 showed great potential as a possible seed dressing pesticide for control of both Wireworm and Wheat Bulb Fly. As well as a seed dressing it could be considered as a granular formulation for over all application and subsequent control of Wireworm and Wheat Bulb Fly.

The results reported in this paper show that in the field N.2790 as a 60% powder dressing was inferior to dieldrin in the control of Wheat Bulb Fly, but equivalent to a lindane 20% powder dressing in the control of Wireworm. It was shown that the initial control of Wheat Bulb Fly was superior to dieldrin. It has been reported (Way 1959) that dieldrin acts against Wheat Bulb Fly larvae within the plant, and hence the primary shoot is destroyed before control is achieved. It was apparent from the results that N.2790 did not kill larvae within the plant but only protected the plant from attack. The eggs of Wheat Bulb Fly hatch in February (Gough 1946) and hence any pesticide placed on Wheat seed sown in the autumn has to persist for at least three months for efficient control to be achieved. The trials reported indicate that insufficient N.2790 is persisting for efficient final control. Trials carried out by the N.A.A.S. in East Anglia (Maskell 1967) and East Midlands (Mathias et al 1967) indicate that the persistence is not sufficient. A trial carried out by the N.A.A.S. in Yorkshire (Dixon 1967) shows that when sown in January N.2790 as a seed dressing is most efficient, confirming that the inferior control in autumn sown trials is due to lack of persistence.

From consideration of the residue data given in Table 2 there is reasonable evidence to conclude that N.2790 presents no hazard in this direction. The toxicity data given in Table 3, does however, show that N.2790 would present a hazard if formulated as a seed dressing. It could be stated that an Acute LD 50 dermal for rabbits of 35 mg./kg. was a too high toxicity for consideration of N.2790 as a powder seed dressing.

Formulation of N.2790 as a granule would minimize the toxic hazards, and the results obtained for a granular formulation show that N.2790 applied at 2 lb. ai./acre at sowing time in Winter Wheat, and at 1¼ lb. ai./acre in Spring Cereals is of significant potential in the control of Wheat Bulb Fly and Wireworm respectively. N.2790 does not persist into the following season and hence the problems attached to gamma-BHC would be overcome.

Carbophenothion was first shown by Rothamsted workers (Griffiths et al 1967) in small hand sown trials to be active against Wheat Bulb Fly. Trials reported in this paper show that carbophenothion formulated as a 60% powder dressing and as a 60% liquid dressing applied at 2 oz. and 2 fl.oz./bush. respectively is of equivalent activity to dieldrin in the control of Wheat Bulb Fly.

The mode of action of carbophenothion was shown in trials to be similar to N.2790, in that the site of action was outside the plant. Thus initial protection was found to be superior to dieldrin. Unlike N.2790, carbophenothion has maintained its control and in the final stage of attack was resulting in a plant stand and yield equivalent to dieldrin. It is apparent therefore that carbophenothion has persisted long enough for good control of Wheat Bulb Fly, and consideration of the residue data given in Table 4 would support this conclusion. Trials have also been carried out by the N.A.A.S. in East Anglia, East Midlands and in Yorkshire with carbophenothion as a 60% powder dressing and the results of these trials will no doubt be reported elsewhere.

The adhesion results given in Table 6 and the germination results given in Table 5 show that carbophenothion was plausible to use as a seed dressing in that it could be adhered to the seed, and when so, was of no phytotoxic hazard.

The residue data given in Table 4 shows conclusively that carbophenothion when used as seed dressing is of no hazard in terms of residues in the mature crop. From the mode of action and the absence of residues in the developing plant it can be reasonably concluded that carbophenothion is not absorbed or translocated by the plant.

The toxicity data of carbophenothion given in Table 3 shows that it is a very much safer pesticide than N.2790, being less toxic orally than N.2790 and being very much less toxic dermally; the acute LD 50 dermal for rabbits being 1270 mg./kg. As to the toxic hazard to wild life, it is significant that the acute LD 50 oral for poultry is in excess of 316 mg./kg.

It is concluded that carbophenothion is of sufficient biological activity and of low enough mammalian and avian toxicity to warrant development as a powder and liquid seed dressing for use on Winter Wheat for the control of Wheat Bulb Fly.

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References

Cramp, S., & Condor, P.J. (1961) Rep.No.1 of the B.T.O./R.S.P.B. Committee on Toxic Chemicals.

Dixon, G.M. (1967) Plant Path. Supplement 16 10.

Gough, H.C. (1946) Bull.Ent. Res. 37 251.

Griffiths, D.C. & Scott, G.C. (1965) Proc. Brit. Insect. & Fungic . Conf. Brighton 3 190.

Griffiths, D.C. & Scott, G.C. (1966) Rep. Rothamsted Exp. Stn. for 1966 181.

Jameson, H.R., Thomas, F.J.D. & Tanner, C.C. (1951) Ann.App. Biol. 38 121.

Maskell, F.E. (1967) Plant Path. Supplement 16 1.

Mathias,P.L. & Roberts, P.F. (1967) Plant Path. Supplement 16 3.

Moore, N.W. & Walker C.H. (1964) Nature Lond. 201 1072.

Potter, C. Healey, M.J.R. & Raw. F. (1956) Bull. Ent. Res. 46 913.

Way, M.J. (1959) Ann. App. Biol. 47 783.

Notification of Pesticides. Scheme agreed between Government and Industry. M.A.F.F. January, 1960.

CHLORFENVINPHOS AS A SEED DRESSING FOR THE CONTROL OF WHEAT BULB FLY

by E.D. Heath, Shellstar Ltd., London

Summary

This paper outlines the results of three years' research and development of CHLORFENVINPHOS as a seed dressing for the control of Wheat Bulb Fly (Hylemyia coarctata)

Early trials were based on dust formulations. The reasons for changing to liquid formulations are reported in some detail. The superiority of chlorfenvinphos over dieldrin for control of Wheat Bulb Fly is illustrated.

Germination, phytotoxicity and toxicological studies, together with a wild-life survey are also reported. The safety in use of chlorfenvinphos is clearly indicated.

INTRODUCTION

The Wheat Bulb Fly (Hylemyia coarctata) can be found in an area bounded approximately by the latitudes 40°N and 65°N and stretching from Central Asia in the east to the extreme west of Europe. This includes such countries as the United Kingdom and Eire, France, Holland, Belgium, Denmark, Germany, Poland, Czechoslovakia and parts of Russia, Finland, Norway and Sweden (1).

The areas of greatest economic damage are Northern France and Eastern England and in several other countries the amount of damage caused is sufficient to warrant some control measures being taken.

Chlorinated hydrocarbon insecticides have been used extensively for the chemical control of Wheat Bulb Fly, almost entirely as seed dressings. However, due to the build-up of resistence to these compounds by some Dipterous species and also their possible effect on wild life, a search for alternative insecticides began which led to the extensive development of organo-phosphorous compounds.

Certain organo-phosphorous insecticides with a systemic action afford some measure of control when sprayed on to the growing crop in Spring, but the most outstanding control can be achieved by the use of insecticides such as chlorfenvinphos. This is applied to the soil as granules at the time of sowing winter wheat, but the cost of such a treatment is high. The most effective economic means of control, based on present values in the United Kingdom, remains the seed dressing.

GENERAL INFORMATION

Chlorfenvinphos (2-chloro-1-(2,4-dichlorophenyl) vinyl diethyl phosphate) was synthesised in 1961 and subsequently developed in the Shell Research laboratories at Modesto, California and Sittingbourne, England. The compound was reported in some detail in a paper presented at the 3rd British Insecticide and Fungicide Conference, 1965, (2) when its evaluation as a Wheat Bulb Fly insecticide had only just begun.

It is one of a group of compounds known as vinyl phosphates of which several have already become commercially successful. The spectrum of activity of chlorfenvinphos is confined largely to soil-inhabiting Dipterous larvae such as the Cabbage Root Fly (Erioischia brassicae), Carrot Fly (Psila rosae), Onion Fly (Hylemyia antigua), Bean Seed Fly (Delia cilicrura), Wheat Bulb Fly (Hylemyia coarctata) and Frit Fly (Oscinella frit).

As a soil insecticide it affords some control also of millipedes (Cylindroiulus iondinensis and Polydesmus angustus), symphilids (Scutigerella immaculata) and mushroom flies (Sciaridae). Its principal use other than as a soil insecticide is for the control of ectroparasites on livestock and in this it has gained wide acceptance in the antipodean areas of the world. Recently it has been shown also to be the most active compound for the control of Colorado beetle (Leptinotarsa decemlineata), being effective at as little as 2 oz. per acre.

It is without systemic activity and acts mainly as residual contact poison, upsetting the insect cholinesterase system. Although chlorfenvinphos has a high oral toxicity to rats, its toxicity to other mammals, particularly its low percutaneous toxicity, puts the compound in the moderately toxic category.

FIELD EVALUATION

It was a fortunate coincidence that chlorfenvinphos first became available as an experimental seed dressing in 1964 when the Ministry of Agriculture in the United Kingdom were actively engaged in finding suitable alternatives to the chlorinated hydrocarbons. This meant that numerous research workers laid down trials against Wheat Bulb Fly which included chlorfenvinphos and a large volume of data on its performance became available in a short space of time.

This paper reports on some of the many trials which have been carried out. The trials cover three seasons, namely 1964/65, 1965/66 and 1966/67, and were carried out on many soil types varying from sandy loam to heavy clay and peat. Drilling dates have ranged from October to January under a wide variety of conditions and varying intensities of Wheat Bulb Fly attack. In the majority of instances, chlorfenvinphos treatment has given the best control of Wheat Bulb Fly damage and resulted in the highest yields of wheat.

A. 1964/65 SEASON

In the autumn of 1964 an experimental chlorfenvinphos mercury dust seed dressing was included in a large number of Wheat Bulb Fly trials laid down by the N.A.A.S. and by Shell Chemical Co. Two of the Shell trials included in addition a liquid chlorfenvinphos seed dressing. Usually two standards were included, a 60% dieldrin/mercury dust and a 40% B.H.C./mercury dust. In one trial involving chlorfenvinphos liquid, an aldrin liquid seed treatment was included as the standard.

During the first weeks after emergence, field observation showed that on four of the seven sites the chlorfenvinphos treated plots were slightly behind the standard treatments in general growth and vigour. By the spring of 1965 however, it was apparent that the plots treated with chlorfenvinphos were superior to the standard treatment in all trials except one, although after the mild wet winter the level of attack was, on average, only moderate. In one trial only, dieldrin dust dressing yielded some 2½ cwts. per acre more than chlorfenvinphos dust dressing, but this was not significant.

Results of the N.A.A.S. trials have been reported elsewhere (3). Results of the two trials which included liquid chlorfenvinphos were as follows:

TRIAL 1

Soil Type:	Clay Loam
Variety:	Cappelle
Design:	Randomised Blocks, 4 repeats
Date Sown:	26th November, 1964
Date Assessed:	12th April, 1965

Treatment	% damaged plants	% damaged shoots	% plants with live larvae	Score for vigour 20 = v. good
40% Chlorfenvinphos dry S.D. @ 2 oz/bu.	28	14	12	20
40% Chlorfenvinphos dry S.D. @ 4 oz/bu.	15	10	6	18
50% Chlorfenvinphos liquid S.D. @ 2 fl.oz/bu.	31	23	17	20
50% Chlorfenvinphos liquid S.D. @ 4 fl.oz/bu.	26	12	8	17
26% aldrin liquid S.D. @ 3 fl.oz/bu.	28	21	14	13
Mercury S.D. only	34	30	24	8

(All insecticide treatments include mercury)

TABLE 1

Although the higher rates of chlorfenvinphos treatment gave the best kill of larvae and the least damaged shoots, the lower rates had a better appearance, having a denser stand and fuller growth. Egg count before drilling was 2,200,000.

TRIAL 2

Soil Type: Flinty, medium loam

Variety: Cappelle

Design: Randomised blocks, 4 repeats

Date Sown: 26th November, 1964

Date Assessed: 11th April, 1965

Treatment	% damaged plants	% damaged shoots	% plants with live larvae	Score for vigour 20 = v. good
40% Chlorfenvinphos dry S.D. @ 2 oz/bu.	32	28	16	19
40% Chlorfenvinphos dry S.D. @ 4 oz/bu.	28	28	12	18
50% Chlorfenvinphos liquid S.D. @ 2 fl.oz/bu.	33	30	19	17
50% Chlorfenvinphos liquid S.D. @ 4 fl.oz/bu.	26	16	12	15
40% BHC dry S.D. @ 2 oz/bu.	32	25	15	11
Mercury S.D. only	43	40	37	6

(All insecticide treatments include mercury)

TABLE 2

Some delay in germination was observed with chlorfenvinphos at the higher rates but this effect disappeared after 3-4 weeks. Subsequently the lower rates made better growth although not giving as good protection as the higher rates. The entire trial site was subjected to severe flooding twice during the winter. Pre-drilling egg count was 1.750,000.

B. 1965/66 SEASON

TRIAL 1

Soil Type:	Heavy clay
Variety:	Cappelle
Design:	Randomised blocks, 4 repeats
Date Sown:	4th November, 1965

Treatment	% Tillers attacked 4th April, 1966	Yield in cwt/acre 9th Sept. '66
40% chlorfenvinphos dry S.D. @ 2 oz/bu.	32.1	45.5
60% dieldrin dry S.D. @ 2 oz/bu.	41.9	42.7
40% BHC dry S.D. @ 2 oz/bu.	72.5	32.9
Mercury S.D. only	70.4	32.4
L.S.D.*		4.3

(All insecticide treatments include mercury)   (figures by courtesy, NAAS Shardlow)

TABLE 3

Some delay in germination was noticeable on the chlorfenvinphos treated plots, but this effect soon disappeared and the highest yield resulted from this treatment. In spite of a very high Wheat Bulb Fly egg count, 6,000,000 per acre, in the autumn, good growing conditions enabled all treatments to yield fairly well and damage was much lighter than would normally be expected.

This trial and three others which follow were part of a series carried out by the N.A.A.S. East-Midland Region and the N.A.A.S. Eastern Region and the author is most grateful for permission to refer to them here.

TRIAL 2

Soil Type:	Peaty Loam
Variety:	Cappelle
Design:	Randomised blocks, 4 repeats
Date Sown:	11th November, 1965

Treatments	% plants damaged 11 Mar. '66	% plants with live larvae 11 Mar. '66	Yield in cwts/acre 26 Aug. '66
40% chlorfenvinphos dry S.D. @ 2 oz/bu.	59	16	38.6
60% dieldrin dry S.D. @ 2 oz/bu.	76	20	35.9
Mercury S.D. only	97	80	0.0
L.S.D.*			7.0

(All insecticide treatments include mercury) (figures by courtesy of NAAS Cambridge)

TABLE 4

The chlorfenvinphos treatment delayed growth initially but plants recovered completely by mid-March. The Wheat Bulb Fly attack was so heavy that the control plots were a complete failure, with no yields. Egg count exceeded 2,000,000.

TRIAL 3

Soil Type:	Sandy Loam
Variety:	Champlein
Design:	Randomised blocks, 3 repeats
Date Sown:	18th October, 1965
Date Assessed:	30th March, 1966

Treatment	% damaged shoots	% plants with live larvae	Score for vigour 20 = v. good
50% chlorfenvinphos liquid S.D. @ 2 fl.oz/bu.	35	18	16
50% chlorfenvinphos liquid S.D. @ 3 fl.oz/bu.	18	8	20
40% BHC powder S.D. @ 2 oz/bu.	40	23	14
Mercury S.D. only	41	31	9

(All insecticide treatments include mercury)

TABLE 5

No differences between treatments were noted at germination or during the early stages of growth. All insecticide treatments resulted in appreciably better growth than that obtained from mercury alone from the end of February onwards. Pre-drilling egg count was 1,800,000.

C. 1966/67 SEASON

TRIAL 1

Soil Type:	Fen peat
Variety:	Cappelle
Design:	Randomised blocks, 4 repeats
Date Sown:	18th November, 1966
Date Assessed:	13th March, 1967

Treatments	% plants damaged	% plants with live larvae	Score for vigour 20 = v. good	Yield in cwt/acre Sept. '67
40% chlorfenvinphos dry S.D. @ 2 oz/bu.	31	9	20	45.7
35% chlorfenvinphos liquid S.D. @ 3 fl.oz/bu.	30	11	19	43.7
60% dieldrin dry S.D. @ 2 oz/bu.	60	22	15	38.8
Mercury S.D. only	63	54	6	22.6

(All insecticide treatments include mercury) (figures by courtesy NAAS Cambridge)

TABLE 6

Despite the slow start of the chlorfenvinphos-treated plots the very rapid growth after late February is reflected in the scores for vigour. Yield figures, which correspond well with the earlier visual scores, are gross weights as harvested, moisture content not having been determined at the time of writing. Egg count was 1,950,000.

TRIAL 2

Soil Type:	Clay Loam
Variety:	Cappelle
Design:	Randomised blocks, 4 repeats
Date Sown:	3rd January, 1967
Date Assessed:	28th March, 1967

Treatments	% plants damaged	% plants with live larvae	Score for vigour 20 = v. good
40% chlorfenvinphos dry S.D. @ 2 oz/bu.	1.6	0	20
35% chlorfenvinphos liquid S.D. @ 3 fl.oz/bu.	4.5	0	20
60% dieldrin dry S.D. @ 2 oz/bu.	55.3	0	14
Mercury S.D. only	100	underground attack	

(All insecticide treatments include mercury) (figures by courtesy NAAS Cambridge)

TABLE 7

These figures well illustrate the severity with which Wheat Bulb Fly can attack. The lateness of the sowing, coupled with a high population (egg count 3½ million) are contributory factors. The figures also show just how effective a seed-dressing can be. When sowing is as late as this, plants may be very small when the attack first starts and suffer severe damage unless protected. On the other hand the seed-dressing, after late sowing, is much more effective, having been in the ground only a few weeks before the larvae emerge.

Laboratory evaluation

Throughout the series of field trials, samples of winter wheat were dressed with various rates of dry and liquid chlorfenvinphos and subjected to germination and phytotoxicity tests in the Shell and N.I.A.B. laboratories. Table 8 below is compiled from a report by the N.I.A.B. Cambridge. The sample of Cappelle Wheat was chosen deliberately for its poor initial germination because the effect of seed-dressings is often more noticeable on such samples.

Treatment	Germination %	Phytotoxic Symptoms
40% chlorfenvinphos dry S.D. @ 2 oz/bu. (+ mercury)	63	NIL
40% chlorfenvinphos dry S.D. @ 4 oz/bu. (+ mercury)	58	NIL
50% chlorfenvinphos liquid S.D. @ 2 oz/bu. (+ mercury)	61	NIL
50% chlorfenvinphos liquid S.D. @ 4 oz/bu. (+ mercury)	46	NIL
Mercury S.D. only	62	NIL
Untreated sample	48	NIL

TABLE 8

In all cases except the high rate of chlorfenvinphos liquid, germination has been appreciably increased above that of the untreated sample, and no phytotoxic symptoms were observed on any treatment.

Table 9 shows the results of a test on Champlein winter wheat. All samples, including control, were first treated with a standard liquid mercury. The two highest rates of 5 and 6 fl.oz/bushel made the samples extremely wet and would not in any case be used in practice, but the object was to determine the level at which chlorfenvinphos was phytotoxic to wheat seed. Only at the highest rate, 6 fl.oz/bushel, was there a trace of phytotoxicity, shoots tending to be shorter and rather swollen compared with the Controls. Germination was delayed approximately three days by the two highest rates and one day by all other rates except the lowest, which was unaffected.

Treatments	Germination %	Score for vigour 10 = v. good
50% chlorfenvinphos @ 1 fl.oz/bu.	88	10
liquid seed dressing 2 fl.oz/bu.	86*	9
" " " 3 fl.oz/bu.	90*	9
" " " 4 fl.oz/bu.	86*	7
" " " 5 fl.oz/bu.	82*	6
" " " 6 fl.oz/bu.	79*	4 (T)
Control - mercury S.D. only	81	10

* germination delayed

(T) trace of phytotoxicity

TABLE 9

Seed treated in the same way as the samples in Table 9 was drilled in rod (5 metres) rows in the field and assessed after one week and after twelve weeks. The results, shown in Table 10, indicate that no long term detrimental effect is likely to result from an accidental overdose of chlorfenvinphos liquid seed dressing.

Treatment	Insecticide rate per bushel	Score after 1 week 10 = v. good	Score after 12 weeks 10 = v. good
Mercury S.D. only	0	8	9
50% chlorfenvinphos liquid S.D.	1 fl. oz	9	10
" " " "	2 fl. oz	10	9
" " " "	3 fl. oz	8	10
" " " "	4 fl. oz	8	9
" " " "	5 fl. oz	6	9
" " " "	6 fl. oz	6	9

TABLE 10

WILD LIFE STUDIES

In order to assess the safety of chlorfenvinphos seed dressings to wild life a series of laboratory studies was undertaken by Shell Research Ltd., Tunstall Laboratories. Domestic fowl were fed for up to 52 weeks and pheasants up to 12 weeks on a diet containing chlorfenvinphos at a concentration equivalent to that in dressed grain. Despite this extreme exposure there was no evidence of interference with fertility or hatchability, and chlorfenvinphos was not translocated to the eggs in detectable amounts. The only effect attributable to pesticides was a small depression of acetyl-cholinesterase.

In acute oral toxicity studies, four species of birds were studied, domestic fowl, quail, pheasant and pigeon. The results, given in Table 11, show that pheasant were least and pigeon most susceptible.

SINGLE DOSE ACUTE ORAL TOXICITY OF UNDILUTED
TECHNICAL CHLORFENVINPHOS TO BIRDS

Species	Approximate LD_{50}
White Leghorn Fowl	44 - 62.5
Japanese quail	27
Pheasant	100
Pigeon	13.8 - 16.2

TABLE 11

In addition to laboratory studies, the effect on wild life in the field was the subject of a survey conducted in the spring of 1966, after several thousand acres of winter wheat had been dressed commercially with a chlorfenvinphos dust seed dressing.

An area of southwest Lincolnshire was chosen where pheasant, partridge and pigeon were in abundance and where at least 1,870 acres of chlorfenvinphos-dressed seed was known to have been drilled. Frequent searches were made across 18 farms between drilling and full emergence of the wheat and not a single pheasant, partridge or pigeon was found dead.

Practical Considerations

In the foregoing paragraphs the biological efficiency and comparative safety of chlorfenvinphos have been illustrated. In general the use of a dust formulation has given results at least the equal of liquid formulations. However, there are other important factors in the production of a commercially satisfactory seed dressing than the points discussed so far.

The first batch of dust seed dressing which was marketed on a limited scale in 1965 produced adverse comments from seed merchants and farmers alike. The compound had not been easy to formulate and the commercial product was of low bulk density and lacked the free-flowing yet adhesive properties desirable in a good dust seed-dressing.

The results in commercial usage were caking of powder on the augers, reduction in the flow-rate of treated grain both in the seed-merchants machinery and in the farmers drill, and alteration of the bulk density of treated seed so that a hundredweight of seed after treatment overflowed a bag which it just filled when untreated.

In many premises the operators complained of the extreme dustiness of the dressing and of its pungent odour. In this respect however, blood cholinesterase tests carried out on operators before and after using chlorfenvinphos seed dressing showed no significant changes.

Attempts to improve the dust formulation were not successful in 1966 and for the autumn of that year commercial quantities of a liquid formulation were made available. This product was extremely well received and from the operators point of view is safer and more pleasant to work with. The problems of dustiness, caking and changed flow-rate of grain are all eliminated.

Conclusions

The Wheat Bulb Fly, (*Hylemyia coarctata*), occurs widely in Europe. Satisfactory control in the United Kingdom can be achieved with chlorfenvinphos seed dressings.

Although there may be some slight delay in germination and slower early growth after chlorfenvinphos seed treatment this is not a persistent effect, and in the majority of field trials, chlorfenvinphos seed dressings gave better control of Wheat Bulb Fly and higher yields of wheat than standard aldrin, dieldrin and BHC seed dressings.

Deliberate overdosing of seed treatments has shown that there is a high safety margin of tolerance by winter wheat seed and that phytotoxicity is extremely unlikely to occur in practice.

Wild life should not be affected as a result of the widespread use of chlorfenvinphos seed treatment on winter wheat.

The dust formulation of chlorfenvinphos was not commercially acceptable and has been replaced by an equally safe and efficient liquid formulation.

Acknowledgements

The author wishes to thank all those farmers who so willingly co-operated with field trials; the N.A.A.S. Regional Entomologists for their help, advice and kind permission to use some of their invaluable data; the Commonwealth Institute of Entomology and many colleagues. Also the directors of Shellstar Limited, Shell Research Limited and the Shell International Chemical Company, for permission to publish this paper.

References

1) (1960); Comm. Inst. Entom; Map 115, Series A.

2) HEATH E.D. and TROUGHT T.E. (1965); "The Insecticide Chlorfenvinphos" Proc. 3rd B.I.F. Conf.

3) DIXON G.M.; MASKELL F.E.; and MATHIAS P.L. and ROBERTS P.F. (March 1967) Supp. to Pl. Path, 16 No. 1.

SOME REMARKS AND RESULTS ON THE CONTROL OF POWDERY MILDEW IN CEREALS

by J. Kradel and E.H. Pommer
BASF Agricultural Research Station, Limburgerhof

Summary The control of powdery mildew in cereals (Erysiphe graminis, E.g.) has gained little importance despite considerable yield reductions, especially in spring barley. Some of the reasons for this are discussed in this article. Also contained is a report on several years' experimental results with the compound Cyclododecyl-2,6-dimethyl-morpholin-acetate, CDM (code number F 238 or 2380 F). In the experiments, the chemical was applied at the normal time when first mildew infection was noticed and also at the time of late hormone weed killer spraying, i.e. at the last stage of tillering/beginning of shooting.

INTRODUCTION

In Central Europe powdery mildew in cereals (Erysiphe graminis, E.G.) is regularly found in wheat and barley crops. In years with favourable climatic conditions for mildew infections, severe reductions in yield have been established. Generally spring barley in particular is affected. From various referenced in literature the following extent of yield reductions were found.

Table 1.

Yield reductions caused by Erysiphe graminis
(from references in literature)

Crop	Number of references in literature	Yield reduction %
Spring barley	8	10 - 30
Winter Barley	1	26
Spring Wheat	1	19
Winter Wheat	4	10 - 15

By applying appropriate fungicides these losses can be considerably reduced. However, until now direct control was mainly limited to plant breeders and to experimental stations. The following reasons could be mainly responsible for direct control not being widespread:

1. Heavy mildew infection is only to be expected at intervals of three to five years.

2. Until now the chemicals chiefly used such as sulphur and Dinocap have not been entirely satisfactory as their fungicidal action is not long lasting and hence repeated spraying is required. Therefore, this type of control is hardly an answer from the economical point of view.

3. Generally the mildew is not noticed before the leaves directly below the ear have become heavily infected. By this time it is already too late to use fungicides with success.

4. Due to the danger of crop damage the farmer is not prepared to drive spraying machinery over the cereals which have already shot.

METHOD AND MATERIALS

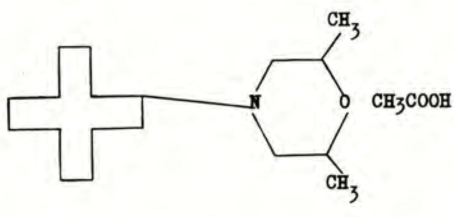
Stephan (1957) and Roeder (1967) studied the climatic conditions in Germany under which heavy mildew attack occurred causing correspondingly heavy yield reductions. This always happens when the fungus finds favourable conditions for developing - due to abnormally high temperatures from February up until April. However, providing rainfall is not excessive it plays a minor part. When the favourable conditions for the fungus do not occur before May/June the serious depressions in yield do not usually occur.

These findings are in agreement with the results of Large and other workers (1963). According to his investigations, the percentage of leaves on the total assimilation surface becomes less as the growth of the plant advances. At the end of tillering the leaves have a share of approximately 80% of the total assimilation surface. At the stage of shooting they only represent 35%. The balance of the assimilation area is supplied by the stem and ear.

In Germany, chemical weed control is carried out on approximately 60-70% of the total cereal acreage. Conditions in Denmark are similar. Therefore from different sides it was suggested to combine weed control in cereals with the control of powdery mildew.

At the time of late spraying hormone weed killers (end of tillering/beginning of shooting) it should be possible to check early infections of E.g. from which losses in yield result. At this juncture it would be ideal to have a fungicide available with an outstanding lasting effect. From internal experimental work a compound from the range of substituted Morpholine derivatives called Cyclododecyl-2,6-dimethyl-morpholinacetate became available (see picture 1).

Picture 1



Cyclododecyl-2,6-dimethyl-morpholinacetat

Reports on this compound have already been given on other occasions (K.H. Koenig and others, 1965; E.H. Pommer and others, 1967; J. Kradel and others, 1967).

The acute toxicity of this compound is relatively low (LD 50 rat peroral appr. 4.8 g/kg, mouse interperitoneal 0.6 g/kg). Although C.D.M. is somewhat of a skin irritant, it does not cause skin sensitivity.

The results of residue work and long term feeding trials are not yet available.

In the experiments conducted, an emulsifiable concentrate (E.C.) containing 50% active ingredient with the code number F 238 or 2380 F was used.

RESULTS

In glasshouse work, 2380 F has shown not only a preventative effect but also a certain eradicating effect against powdery mildew in cereals. After soil treatment a systemic action was noticed (Table 2).

Table 2

Effect against powdery mildew (Erysiphe graminis) by soil treatment (50 ml/pot)

(Greenhouse experiment with spring barley)

Product	Conc. active ingredient %	Mildew Assessment (1-9) *) 8 days after treatment	16 days after treatment
Untreated	-	9	9
Dinocap	0,0125	4	8
Sulphur	0,1	4	6
2380 F	0,025	1	1
2380 F	0,0125	1	2

*) 1 = complete control; 9 = no control

The field experiments mainly conducted in spring barley were laid out in the normal way with 3 to 4 replications. In these experiments, 2380 F was applied at a rate of 1.0 - 1.5 kg/ha active ingredient at the time of late applications of hormone weed killers (end of tillering) as well as at the first indication of mildew infection. The results are summarised in Table 3.

Table 3

Effect against powdery mildew (Erysiphe graminis) in spring barley

Treatment	Experiments conducted		Yield (absolute)	Yield over untreated	
	Number	Time	dz/ha	dz/ha	%
2380 F 1.5 kg/ha (a.i.) at first infection	29	1963-1966	47,3	5,1	12,1
2380 F 1.5 kg/ha (a.i.) at the time of late spraying hormone weed killer	30	1964-1967	42,0	6,1	16,9

The application of 2380 F led to remarkable increases in yield which were statistically significant as compared with the untreated plots.

In 1967, Germany was subject to an early and very heavy mildew infection in barley crops. In the Northern areas even a new biotype of E.g. appeared which attacked barley varieties which until then had been considered resistant. Under these conditions the success of mildew control was extremely evident (Table 4).

Table 4

Effect against powdery mildew (*Erysiphe graminis*) in spring barley 1967

3 experiments (21 varieties)

Treatment	Yield dz/ha (absolute)	Yield relative	Assessment (1-9)* infected top leaves
Untreated	30,3	100	7,6
2380F 1.0 - 1.5 kg/ha (a.i.) at the time of late spraying hormone weed killer	36,0	118,8	3,2

*) 1 = complete control; 9 = no control

The yield increases are significant.

In some experiments, countings of mildew infection at the three top leaves below the ear were made and the results confirmed the fungicidal effect of 2380 F (Table 5).

Table 5

Effect against powdery mildew with treatment of 2380 F 1,5 kg/ha (a.i.) at the time of late spraying hormone weed killer

Crop	Affected leaf area in %* (mean of the 3 top leaves) Untreated	Affected leaf area in %* (mean of the 3 top leaves) 2380F	Assessment ... weeks after treatment
Spring barley (3 experiments)	21,0	2,7	4 - 5
Winter barley (1 experiment)	19,7	8,9	5
Winter wheat (1 experiment)	23,0	10,0	8

*) assessments were made on 300 leaves per plot

In this connection, some individual observations may be of interest. In fact, by adding a non-mildew controlling fungicide to a mildew effective compound, noticeable yield increases were occasionally observed (Table 6).

Table 6

Effect against powdery mildew (Erysiphe graminis) in spring barley

(3 experiments 1966/1967)

Treatment	Yield dz/ha (absolute)	relative
mildew fungicide only	45,3	100
mildew fungicide + Thiocarbamate	48,0	106

In these experiments rust diseases (Puccinia sp.) did not appear. Similar results were found in two experiments conducted in New Zealand.

These very limited observations should not be exaggerated. Further experimental work may give an answer as to whether this was perhaps on account of eliminating other fungi on the cereal leaves or whether other causes may have been responsible.

As was found by the Plant Protection Board Muenster (Dr. Dame, 1966/67) with winter barley, the application of a contact herbicide (Active material Dinitrobutylphenylacetate) in Autumn gave a remarkable reduction of mildew infection.

In Schleswig-Holstein, spring barley grown on light sandy soils is often sprayed with copper oxychloride (2.0-3.0 kg/ha a.i.) as a preventative measure against copper deficiency. Occasionally, here also it was observed that mildew infection decreased.

In both cases, the application of these chemicals caused the older mildew infected leaves to die off earlier than normal and consequently a further spreading of the infection to the top leaves was indirectly diminished. In future experiments special attention should be paid in particular to the possible combination of contact herbicide and mildew control measurements at a later date.

DISCUSSION

In view of the promising results achieved, further large scale work on a combined weed and mildew control particularly in spring barley should be carried out.

By this method, at least the spreading of mildew over the whole plant becomes checked for a certain period of time. However, this is supposed to be satisfactory because in particular early mildew infection causes severe losses in yield. The farmer could practise this method without any additional work. Naturally this method is mainly restricted to areas where powdery mildew more frequently occurs. It has been noted from experience that this occurs mostly in regions where not only spring barley is grown but also winter barley. Here, with the autumn sown barley, the mildew causing fungus is capable of withstanding the winter. If, in addition, the climatic conditions favour the fungus there is a strong likelihood of infection building up very quickly in the spring sown barley.

In this connection, experiments should give evidence as to whether it would be useful to treat winter barley in spring for a successful retarding of the fungus' life cycle.

For those barley growing areas suffering only occasionally more or less heavy mildew attacks, a prognosis and warning system would be desirable. By regular investigation of the crop and observing exactly climatic data, it should become possible for official advisory stations to give warning to farmers in time so that from the very first infection, definite steps can be taken against powdery mildew. For larger fields and where crops have developed further, aerial spraying could be the answer.

References

AUFHAMMER, G. (1952) Landw.Forschung, 2.Sondherheft 93-103

BENADA, J. (1965) Sborn, UVTJ, Ser. Ocker.rost, Prag 1(1), 1-6; 7-14
(1966) Ref. Z.f.Pflanzenkrankheiten u.Pflanzenschutz, 73. 489

BUUS, H. Johansen (1963) Kong. Veterin.o.Landbohøgskole Arsskr. 54-63
Ref. Landw.Zentralblatt II/1965, 2334.

KOENIG, K.-H. et al Angew. Chemie, 77/1965, 327-333

KRADEL, J. et al Gartenwelt 67/1967, 185-186

KRADEL, J. et al (1967)BASF-Mitteilungen fuer den Landbau /Pflanzenschutz, Mai

LARGE, E.C. et al(1963)Plant Pathology 12, 128-130

LARGE, E.C. et al(1962)Plant Pathology 11, 47-57

POMMER, E.-H. et al (1967) XIX Internationales Symposium ueber Pflanzenschutz, Gent.

ROEDER, W. (1967) Archiv fuer Pflanzenschutz, 3 Vol., 2. 121-130

STEPHAN, S. (1957) Nachrichtenblatt Deutsch.Pflanzenschutzdienstes (Berlin) 11, 169-177

TJUBINA, L.R. Selektion u. Samenzucht (Russian) 24 (6) 1959, 52-53,
Ref. Landw. Zentralblatt II/1960, 2209.

ZWATZ, B. (1966) Der Pflanzenarzt, 19, 124-125

Authors unknown:(1956) Rapport d'activité Stations Fédérales d'Essais Agricoles. Annaires Agricole Suisse 55, 400-640.
Ref. Zeitschr. fuer Pflanzenkrankheiten und Pflanzenschutz 65/1958, 181-182.

(1954) Rep. Rothamsted Exp.Stat. Ref. Zeitschr. fuer Pflanzenkrankheiten und Pflanzenschutz 63/1956, 314.

(1955) Rep. Rothamsted Exp.Stat. Ref. Zeitschr. fuer Pflanzenkrankheiten und Pflanzenschutz, 64/1957, 125-127.

THE TREATMENT OF WOOD INFECTIONS OF GLOEOSPORIUM SPP. TO CONTROL ROTTING OF STORED APPLES

K. L. Edney
Ditton Laboratory, Larkfield, Maidstone, Kent.

Summary

The number of conidia of Gloeosporium album and Gloeosporium perennans released from infections on the wood of Cox's Orange Pippin apple trees is reduced by applying sprays of phenyl mercury compounds or dichlorophen. Suppression of sporulation by this method also reduces losses of fruit from rotting in store. Mercury compounds are more effective in reducing the viability of conidia produced after treatment. This property, together with resistance to weathering, is very desirable in an ideal spore-suppressant material.

The conidia of Gloeosporium album and Gloeosporium perennans are produced by small lesions on the wood of apple trees. They are produced throughout the year and are dispersed by rain. They form latent infections on immature fruit which do not subsequently develop to form rots until the fruit has been harvested. Infection of unpicked fruit takes place with increasing ease as the growing season progresses and in consequence protectant spraying must continue until the fruit is picked. The difficulties encountered by growers attempting to apply late sprays when the branches of trees are weighed down by fruit necessitated the development of alternative methods of control. Bryde et al (1952) established that spore production from cankers caused by Nectria galligena could be reduced by spraying during the winter, using materials previously shown to have eradicant properties. Sharples and Somers (1959) have demonstrated that 0.30% phenyl mercuric chloride reduces sporulation when applied to wood infections of G. perennans. In view of these results it seemed possible that similar treatments applied to the wood infections of Gloeosporium spp. might achieve a reduction in rotting of the fruit by restricting the production of inoculum.

The relationship between spore numbers and incidence of rotting is not a simple one. Both during the growing period and in store, the resistance of the apple is gradually declining. This means that the number of rots developing from spores released from wood infections in September is greater than from spores released in July. Thus a simple total of spores trapped over the period July - September will not necessarily provide an accurate assessment of the effectiveness of a treatment. Similarly, for a given spore load, the incidence of rotting in store at any given time depends on the rate at which ripening progresses. Storage in optimum conditions will usually reduce rotting for at least part of the storage life of the apple, providing the level of resistance at harvest is adequate.

In 1957, a number of trials were initiated to explore the possibilities of reducing spore production by Plant Protection Limited, in collaboration with workers from Long Ashton Research Station and Ditton Laboratory and with the assistance of Kirdford Growers Limited. In this and all other experimental work the variety Cox's Orange Pippin was used. P.P.Mercury was used at 0.1% mercury and treatments were applied during the dormant season to avoid phytotoxic damage. These trials met with a fair degree of success (Edney et al 1961). They were followed by further trials with the same material used at lower strengths and in some instances applied in April instead of March. These trials demonstrated that at concentrations as low as 0.025% mercury, good reductions of rotting could still be obtained (Corke et al 1965).

An additional series of trials with phenyl mercuric chloride carried out at East Malling (Burchill and Edney 1963) demonstrated clearly the relationship between rotting and spore load. As shown in Table 1, the totals of G. album spores trapped during the period July to 20 September (picking time) were directly proportional to the incidence of rotting.

Table 1.

The effect of p.m.c. applications in March 1960 on the number of spores trapped in the period July - 20 September 1960 and on the percentage of Gloeosporium rots recorded on fruit after storage for 21 weeks at 4.5°C

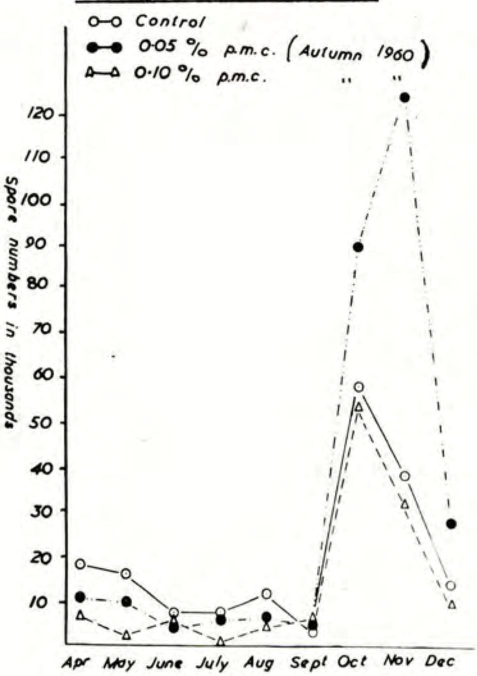
Period	No. of counts	Rainfall (in.)	Treatment 0.10% p.m.c.	 0.05% p.m.c.	 Control
				Spore catches	
July	9	3.69	4,000	36,000	53,000
August	10	4.31	13,000	12,000	22,000
1 - 20 Sept.	6	4.11	1,000	3,000	Nil
July - 20 Sept.	25	12.11	18,000	51,000	75,000
% rotting after storage			5.6	12.5	21.9

The figures for the percentage rotting for each treatment differed significantly ($P \leqslant 0.001$)

The data obtained in these trials indicated a further aspect of the consequences of applying mercuric sprays. As shown in Fig. 1 a peak of spore production takes place during the autumn under natural conditions.

Figure 1.

The effect of an autumn application of phenyl mercuric chloride on the concentration of G.album spores trapped from April to December 1961



If the action of the treatment is less effective at this time the treated lesions may produce more spores than untreated wood infections. Should this occur before harvest, fruit on such trees might receive a higher spore load than if the trees were untreated. After harvest, infections behaving in this manner might release large numbers of spores when pruning operations were in progress and this would probably result in a large number of pruning cuts becoming infected.

Little work had been done at this time on the mode of action of these sprays other than recording their effect on spore production. The twelve trees sprayed in the first experiment in 1957 with 0.1% mercury were subsequently given a similar treatment in 1958 and 1959. No evidence was obtained that these successive annual applications of mercury brought about a progressive reduction in the level of infection. Sharples (1959) found that the treatment of cankers of G. perennans with a number of formulations of phenyl mercuric chloride did not inhibit the spread of the fungus although the spore output was reduced. The possibility exists though that some eradicant action may take place where the lesions are relatively small and are located on dead or moribund tissue.

As soon as the effectiveness of the use of spore-suppressants in controlling storage rots had been established, work was continued to determine whether other less toxic materials possessed spore-suppressant properties. Screening trials, carried out mainly at Long Ashton, indicated that dichlorophen [bis-(3 chloro-6-hydroxy phenyl) methane] was sufficiently effective to warrant field trials. This material is sufficiently non-phytotoxic for use during the summer at 0.25% a.i. and accordingly, spray schedules could be employed which enabled various combinations of spring and summer applications to be tested.

Applied at 1.0% a.i. and 0.5% a.i. in May 1963, this material effectively reduced rotting, the higher strength giving the better control (Table 2). A single application in July at 0.25% a.i. was ineffective.

Table 2.

The effect of dichlorophen on rotting by Gloeosporium spp. of fruit stored at 4.5°C.

	% Rotting 16 weeks	% Rotting 19 weeks
1% Dichlorophen at pink bud (8.5.63)	13.6	12.7 *
0.5% Dichlorophen at pink bud (8.5.63)	15.8	16.1
0.25% Dichlorophen (4.7.63)	24.0	19.5
Untreated	22.8	23.8

* Significantly less than untreated ($P < 0.05$)

To obtain optimum results with summer sprays, one trial was carried out in which after the initial application, subsequent sprays were applied when spore traps affixed to treated trees indicated that the number of spores being released were increasing i.e. the effect of the treatment was declining (Burchill and Edney 1963). As demonstrated in Fig. 2, the effective life of dichlorophen as a spore-suppressant against G.album was, in this instance, approximately six weeks after application in early June and four weeks after the second application in mid-July. Table 3 indicates the numbers of spores trapped during the period of treatment and the reduction of rotting obtained.

Figure 2.

The effect of summer sprays of dichlorophen on the concentration of G. album spores trapped from July to September 1961

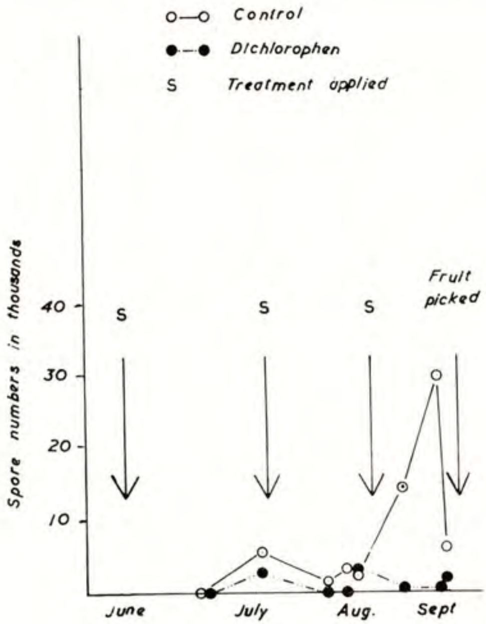


Table 3

The effect of dichlorophen applications in summer 1961 on the mean concentration of spores trapped in the period July - 11 September 1961 and on the percentage of Gloeosporium album rots recorded on fruit after storage for 16 weeks at 4.5°C.

Period	Rainfall (in.)	Treatments Dichlorophen spore catch	Control spore catch
July	2.28	3,000	6,000
August	1.12	4,000	22,500
1 - 11 September	0.91	2,500	38,600
July - 11 September	4.31	9,500	67,100
% rotting after storage		10.6	24.8

The difference in rotting was significant ($P < 0.05$)

The necessity of using three applications meant that although good control of rotting was obtained, the treatment did not eliminate the difficult task of spraying after the end of July. In view of the effectiveness of the pink-bud applications it is reasonable to speculate that if it were possible to use higher strengths without damage during July, very good control would be obtained.

In comparing the relative merits of the two types of material described, Corke (1962) has demonstrated the greater efficiency of mercury compounds in reducing the viability of conidia produced after treatment. These findings indicate that in assessing the merits of spore-suppressant materials, the total of viable spores released must be used as the criterion for assessing effectiveness. The passage of spores over bark treated with fungicide will in many instances reduce viability. The effectiveness of a fungicide will obviously be enhanced by its ability so to influence germination over a relatively long period. Thus in defining the properties necessary for an effective material, resistance to weathering and, in particular, low solubility in rain water is of the greatest importance. It may be more fruitful to try and improve the resistance to weathering of materials with good suppressant properties than to think entirely in terms of searching for new materials which may be better than those already tried. Some evidence of the usefulness of this approach has already been provided by Sharples and Somers (1959) who showed that the residue level of phenylmercuric chloride was increased when formulated in 2% linseed oil emulsion or in 5% polyvinyl acetate latex. These authors also call attention to the influence of the time of application and the weather conditions during treatment on the durability of materials. In view of the need to complete treatment before the end of July, the ideal material must remain active for 6 - 8 weeks and be able to reduce the number of viable conidia reaching the surface of the fruit to an acceptable minimum.

References

BURCHILL, R. T. & EDNEY, K. L. (1963). Ann. appl. Biol. 51, 379.

BYRDE, R. J. W., CROWDY, S. H. & ROACH, F. A. (1952). Ann. appl. Biol. 39, 581.

CORKE, A. T. K. (1962). Ann. appl. Biol. 50, 735.

CORKE, A. T. K., EDNEY, K. L. & HAMER, P. S. (1965). Ann. Rep. Long Ashton Res. Sta. for 1964, 145.

EDNEY, K. L., AUSTIN, W. G. L., CORKE, A. T. K. & HAMER, P. S. (1961). Plant Path. 10, 10.

SHARPLES, R. O. & SOMERS, E. (1959). Plant Path. 8, 8.

THE EFFECT OF GLOEOSPORIUM ON COMMERCIAL FRUIT GROWING.

By Peter S. Hamer
Horticultural Consultant: Fittleworth, Pulborough, Sussex

Summary

A study of the production of Cox's O.P. on a Kirdford farm and the losses which occurred during storage showed that Gloeosporium was the most important single cause of post harvest wastage.

The effect of Gloeosporium on farm practice is shown in the farm records over a period of 20 years, and its incidence is found to be influenced by the grower's choice of the fungicidal spray programme and storage time.

Finally consideration is given to the practical methods of reducing losses due to Gloeosporium, particularly tree hygiene, the use of fungicides and the selection of the most suitable orchards as a source of apples for storage.

INTRODUCTION

The following is a brief consideration of data supplied by a commercial grower, of the post harvest behaviour of his Cox's O.P. Crops over a period of 20 years. This data reflects the steps taken on the farm, by the grower, to help reduce post harvest wastage of his crop, and the storage treatment of his fruit in certain years.

DESCRIPTION OF DATA USED IN THIS ACCOUNT

The data on wastage states the TOTAL wastage recorded during storage and this includes factors other than rots due to Gloeosporium.

Detailed analyses of the total wastage of this farm has been carried out (Hamer 1954-1957) on a number of occasions, namely in 1954, 1955, 1956 and 1957 and again in 1965, when all the components were assessed. It was found on each occasion that rotting due to Gloeosporium accounted for at least 50% of the total wastage figure. Although the evidence considered in this account is based on total wastage, the data indicates that the considerable variation from year to year in this wastage, reflects directly the variability of rotting due to Gloeosporium.

FARM AND ITS CROP RECORDS

The total Cox's O.P. Crop from Farm I for the period 1946-1966 is given in Figure 1. The farm was purchased in 1931 and established during the period 1932-1937. In general, the acreage throughout the period 1946-1966 consisted of fully mature, cropping trees over the age of 10 years at the start of the period.

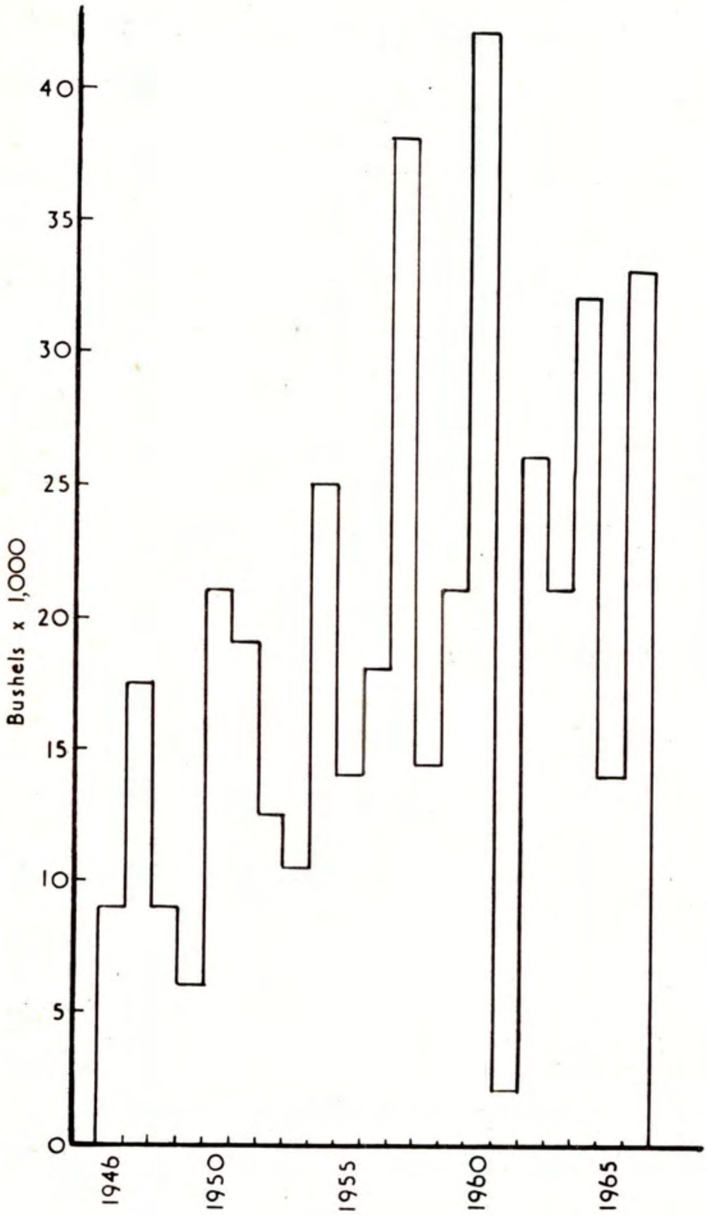
The main factor affecting regular cropping has been low temperature injury to the blossom buds in the Spring: the very low yield of 1961 being entirely due to this factor.

TOTAL WASTAGE RECORDS

Fruit wastage which rises above 10% is, under any circumstances, of serious concern to a grower. A check has been made of the levels of rotting due to Gloeosporium (Hamer 1954-1957) of each orchard of this farm, and the results of that check revealed that all the mature orchards had a high incidence of rotting due to Gloeosporium. From this it was assured that a high level of inoculum was present in those orchards. Under these circumstances it has been found that Gloeosporium rotting has been influenced by the following factors :-

FIGURE 1.

Total Crop of Cox's O.P. 1946-1966. Farm I.



(i) the maturity of the fruit at harvest (Edney 1964a)
(ii) the treatment of the fruit prior to storage (Corke et al.1965)
(iii) the length of time the fruit is stored (Edney 1964b)
(iv) the weather conditions experienced in any one year (Corke 1956)

The percentage of post-harvest wastage of Cox's O.P. of the Farm and of the Co-operative Packhouse, for the period 1946-1966, is given in Figure 2. The Packhouse record is, (in effect), an average for all the fruit sent to it by its member farms.

The farm's wastage exceeds that of the Packhouse average, with the exception of 1950 and 1956 when it was the same, and 1960 when it was lower.

A comparison of the Figures 1 and 2 shows that the wastage from the farm is greatest in years when the crop is light. This is probably due to (a) light crops, resulting from Spring frost injury, having a higher proportion of russet fruit; and (b) light cropping trees yielding fruit of poor storage quality. Both these factors appear to result in fruits which are more susceptible to Gloeosporium infection.

The wastage for the years 1946-1954, may well reflect the orchard management of those years, when the methods for the control of Gloeosporium were not yet established.

CAPTAN AND THE FARM SPRAY PROGRAMME

The history of the farm's usage of Captan is given in Table I. Captan replaced Sulphur as the Apple Scab control material in 1954: and from 1957 it became standard practice to apply late season Captan sprays to fruit intended for long storage. In 1964 and 1965, Dichlorophen was applied to the trees at the late green cluster stage to supplement the control effect of the late season Captan sprays.

It is notable that no Captan was applied to the fruit in 1961, a year of light crop and high wastage. Again it is notable that the high wastage of 1965 coincides with considerable difficulty in applying the late Captan sprays and indicated by the length of time taken to apply each of the late sprays.

THE FARM COX'S O.P. CROP STORAGE : 1955 AND 1956

A breakdown, orchard by orchard, of the fruit selected for storage in 1955 and 1956 is given in Figure 3. Each column is hatched according to the orchard of origin and the same orchard identification is used in Figure 4.

The low wastage of the years 1955, 1956 and 1957 can be related to the fact that the fruit was stored for considerably shorter periods during these years. Figure 3 shows the period of time the fruit was in store during 1955 and 1956. Although the amount of rotting on certain loads of fruit was fairly high, the bulk of the fruit was marketed before serious rotting had occurred.

Application of the late Captan sprays for the control of Gloeosporium did not begin until 1957. A comparison of the storage performance of certain orchards in 1955 and 1956 with their storage performance in 1965 and 1966, suggests that these orchards were behaving in a similar way - after virtually ten years of late Captan spray treatments.

THE FARM COX'S O. P. CROP STORAGE : 1965 AND 1966

A breakdown, orchard by orchard, of the fruit selected for storage in 1965 and 1966, is given in Figure 4. It is notable that 1965 was a year particularly prone to Gloeosporium rotting. An aspect of this year has already been instanced in the difficulty the farm experienced in applying the late Captan sprays.

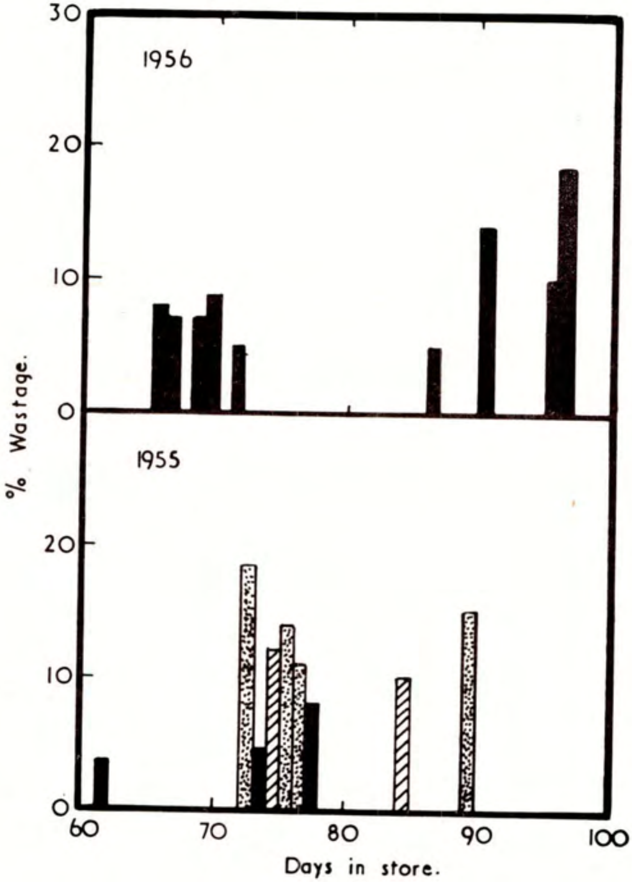


FIGURE 3

Percentage Wastage of Fruit from different orchards 1955-56

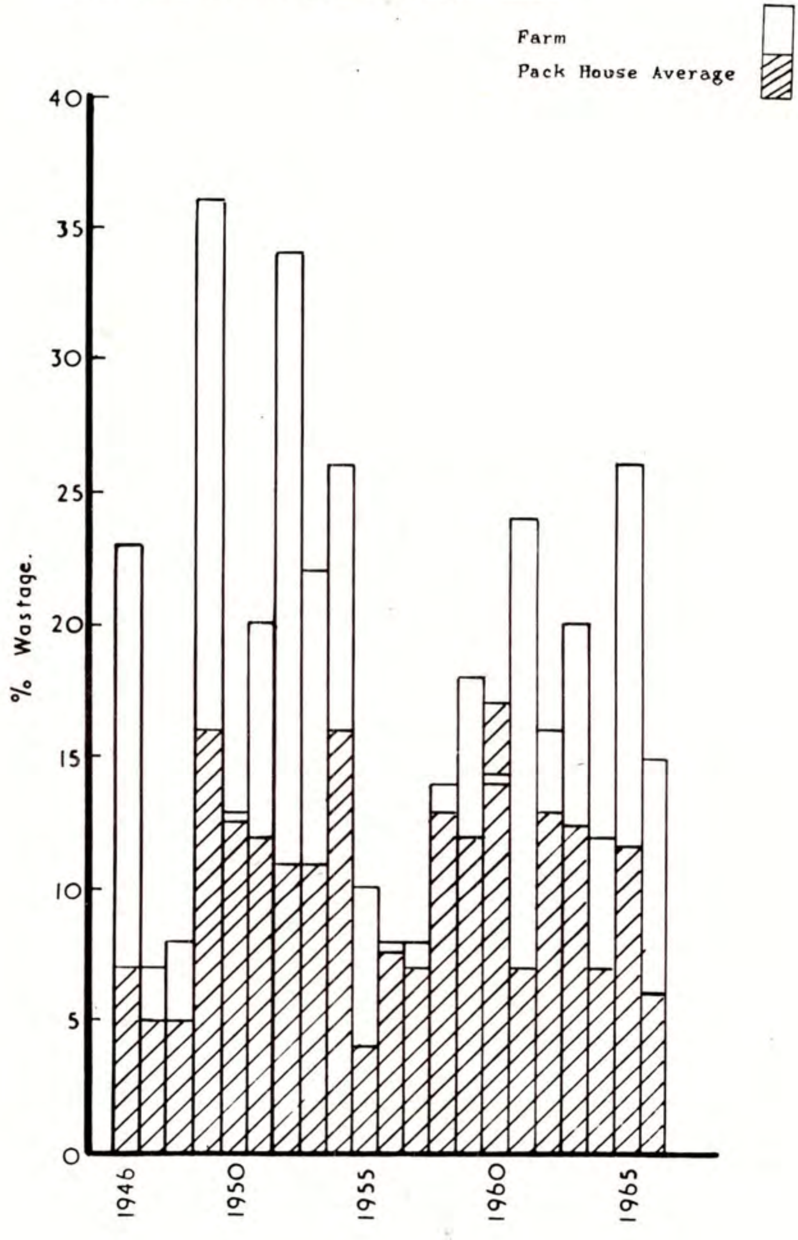
TABLE 1.

History of use of Captan on Farm (I) Orchards

Year	Captan applied for "Scab" control: dates of :- Start	Finish	Days Interval Between 8 Sprays	Captan applied for Gloeosporium control. Dates of Application	Dichlorophen for Gloeosporium control. Date of application
1954	8/3/	3/7/	14	-	-
1955	14/4/	27/7/	14	-	-
1956	24/4/	10/7/	14	-	-
1957	26/3/	22/7/	14	12/8/ : 5/9/ :	-
1958	7/4/	16/6/	10	4/7/ : 16/8: 12/9	-
1959	27/3/	7/7	7	12/8/ : 5/9/ :	-
1960	2/4/	17/6/	7	22/7/ : 17/8 : 6/9 :	-
1961	25/3/	19/6/	7	- - -	6/3/
1962	16/4/	18/6/	7	16/7/ : 7/8/ : 28/8: 14/9/	-
1963	15/4/	15/7/	7	29/7/ : 19/8/: 9/9/	-
1964	12/4/	29/6/	7	29/7/ : 10/8/: 31/8/	27/4/
1965	14/4/	14/6/	10	19-27/9/ : 9-17/8/! 31/8/ - 2/9/! 16/9/	26/4/
1966	23/3	15/7/	10	25/7 : 8/8/ : 22/8/	-

FIGURE 2.

Total Cox O.P. Wastage 1946-1966 Farm I



The wastage from each load of fruit in store is represented by a column hatched according to its orchard of origin. It will be noted that the orchards which did not receive any late Captan sprays yielded the highest amounts of wastage. Figures 3 and 4 also indicate (i) the variability of rotting occurring in any one orchard, and (ii) that there is a reduction in amounts of rotting during the period 130-175 days as compared with the period 60-100 days. A possible explanation of this latter point is that fruit going into Scrubbed Controlled Atmosphere storage was the first picked, and that this form of storage results in better maturity control of the fruit than does the C.A. storage.

Another factor which is illustrated in Figures 3 and 4, is that there is an appreciable rise in the rate of rotting from the time the store is opened until all the fruit is graded. The arrows shown with the storage descriptions indicate the opening and finishing of these stores. It takes up to 7-10 days to grade out a 100 ton store, and 15-20 days to grade out a 200 ton store. During these periods the ungraded fruit remains in store under temperature controlled conditions only.

The year 1966 proved much less prone than 1965 to rotting by Gloeosporium. It is again notable that the fruit which did not receive both the Dichlorophen and the late Captan sprays yielded the highest amounts of wastage. Again the tendency for rotting to increase between opening a store and finishing the grading of the fruit is illustrated.

The two years 1965 and 1966 show the considerable differences which can be experienced, year by year, of rotting due to Gloeosporium.

PRACTICAL METHODS OF CONTROLLING GLOEOSPORIUM

It will be appreciated from the evidence submitted that Gloeosporium is a serious cause of the loss of stored fruits. Rotten fruits are a direct loss to the revenue of the farm. Rotten fruits which have received the benefit of a season's cultural practises and post harvest storage facilities add to this loss factor. In this case the grower is a member of a co-operative packhouse. Rotten fruits accumulated at a packhouse have to be disposed of, at an added cost to the grower. The presence of large amounts of rot fruit going over the grader, slow down the grading process considerably, and so penalises other users of the grading facilities.

The need to extend the marketing of Cox's O.P. ensures that this variety is stored. The longer fruit is stored the greater is the risk of rot losses due to Gloeosporium. The surest way to reduce storage losses is to market the fruit as soon as possible after harvest.

Four main lines of attack are available, at the present time, to the apple grower who finds it necessary to control Gloeosporium - and many growers who do not wish to run the risk of Gloeosporium losses come into this category (Hamer 1962). These are :-

(i.) Keeping dead and moribund tissues on the apple tree to a minimum - by pruning them out.

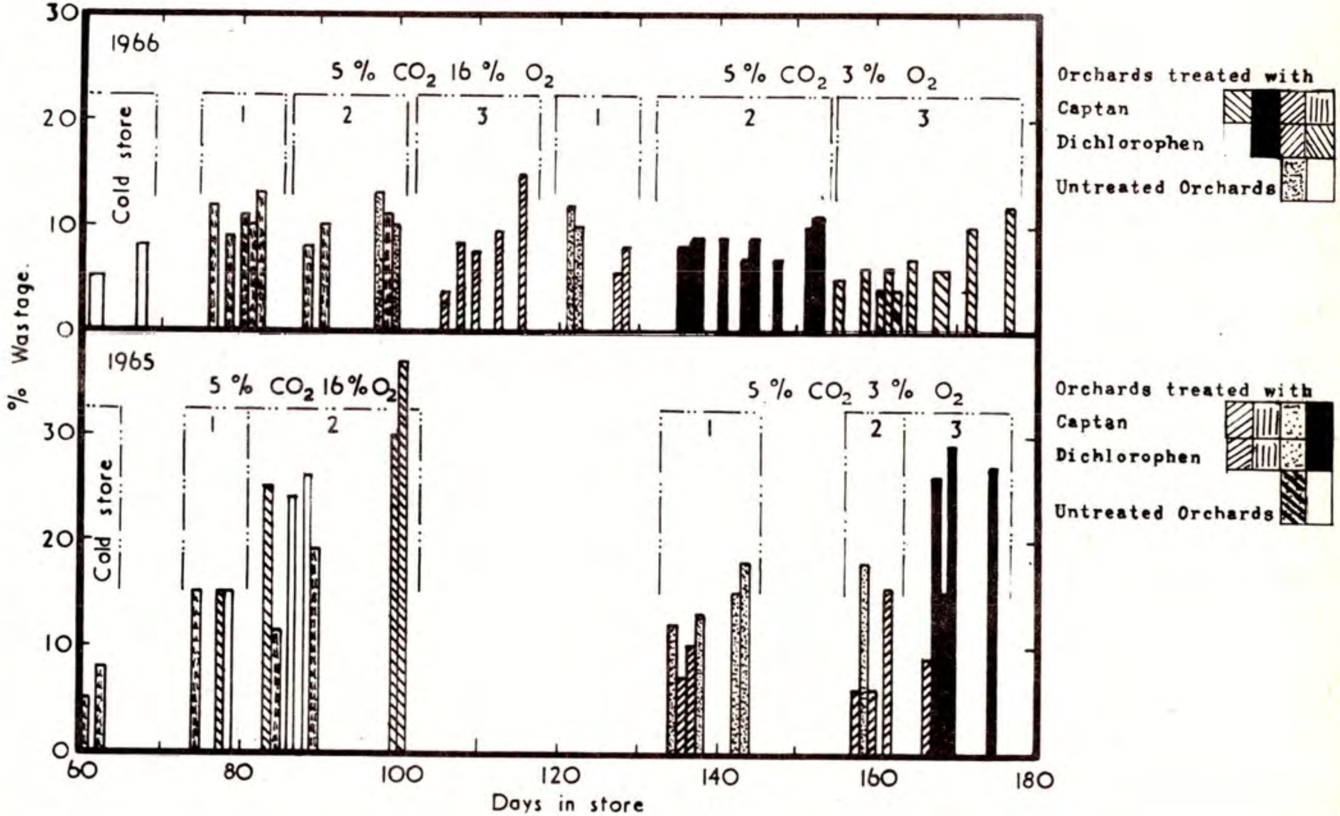
(ii.) Suppressing the fungus on the wood of the tree by using chemical sprays during the dormant stages (e.g. Mercury materials) or Dichlorophen up to the pink bud stage.

(iii) Protecting the surface of the fruit with a layer of fungicide until the fruit is harvested.

(iv.) Selecting the earliest picked fruits from the least susceptible orchards for storage, and storing under scrubbed atmosphere storage conditions.

FIGURE 4.

Percentage Wastage of Fruit from different orchards 1965-66



CONCLUSIONS

1. A consideration of cropping data of Cox's O.P. over a period of 20 years indicates a variable cropping propensity, year by year, which is consistently conditioned by Spring frosts.

2. A consideration of rotting experienced year by year from Cox's O.P. in store, over a period of 20 years shows:-
   (a) some indication of an overall reduction of rotting due to Gloeosporium since the introduction of the late Captan sprays.
   (b) a correlation between light crop years and increased amounts of wastage.
   (c) a marked tendency, in certain years for the Gloeosporium rotting to increase when the late Captan sprays are either withheld or applied under difficult weather conditions.

3. A consideration of the detailed orchard selection of fruits for various forms of storage in the years 1965 and 1966 shows :-
   (a) That fruit which has not received any late Captan sprays yields the highest amounts of Gloeosporium rotting.
   (b) That considerable variation in the amounts of wastage can be experienced within an orchard.
   (c) That there is a tendency for rotting to increase between the time a store is opened and the last fruits graded.
   (d) That different years give markedly different storage wastage results, orchard by orchard, and irrespective of the type of storage used.

4. A consideration of the detailed orchard selection of fruits from various forms of storage in the years 1955 and 1956 shows that under a "No late Captan sprays" programme, the orchard losses are very similar to those experienced ten years later. Captan does not appear to have any carry over effect from year to year.

Acknowledgments

The author wishes to thank Mr. P. Mursell of Dounhurst Farm, Wisborough Green, Sussex, and Messrs. Kirdford Growers Ltd., of Kirdford, Sussex, for much of data reviewed in this account.

References

Corke, A.T.K. (1956) J. hort. Sci. 31, 272.
Corke, A.J.K., Edney, K.L. and Hamer, P.S. (1965) Ann. Rep. Long Ashton Res. Sta. for 1964, 145.
Edney, K.L. (1964 a) Ann. appl. Biol. 53, 119.
Edney, K.L. (1964 b) Ann. appl. Biol. 54, 327
Hamer, P.S. (1954-1957) Unpublished reports prepared for Co-operative Packhouse.
Hamer, P.S. (1962) Grower 58 734, 738 and 782

APPLE SCAB CONTROL IN NORTHERN IRELAND BY ERADICANT AND PROTECTANT SPRAYING

J. Cartwright
Ministry of Agriculture for N. Ireland, Horticultural Centre, Loughgall

Summary

Eradicant spray programmes based on organo-mercurial compounds applied in relation to apple scab infection data gave inconsistent control. Infection data based on hours of leaf wetness, temperature and relative spore counts from an artificial orchard floor was effective in assessing definite infection periods but was not sufficiently flexible to deal with doubtful infection periods. The lack of precision associated with doubtful periods coupled with the need to apply organo-mercury sprays immediately after infection can leave serious gaps in the spray programme.

Protectant spray programmes based on organic compounds with good fungicidal properties gave good scab control. These sprays were applied every ten days with reductions to seven days during periods of severe or continuous infection, also during periods of rapid leaf expansion.

INTRODUCTION

There are approximately 5,000 acres of Bramley's Seedling orchard in County Armagh, Northern Ireland and the majority of these trees are at least forty years old. Apple scab (Venturia inaequalis) became a problem in N. Ireland in 1924 (Muskett 1926). Early spray programmes were based on copper sulphate and lime and these remained effective for twenty to twenty five years. With advancing years and under the N. Ireland climatic conditions an increasing amount of phytotoxicity occurred with these sprays. Spray programmes based on the eradicant properties of organo-mercury compounds replaced the copper sprays. The effective use of these eradicant sprays required them to be applied in relation to known infection periods. Programmes based on Mills Period infection criteria (Mills and La Plante 1954) while an improvement on haphazard spraying still left serious gaps. Additional information derived from daily, relative ascospore release from an infected artificial orchard floor improved the Mills Period criteria and led to the introduction of an Apple Scab Observation Service. (Anon 1959, 1960, 1961, 1962, Cartwright 1963, 1964, 1965, 1966, 1966a). During the period of ascospore discharge, March to June, daily assessments were made of hours of leaf wetness, and temperature from four weather stations, also counts of discharged ascospores. Two major problems remained, doubtful infection periods and the practical difficulty of applying eradicant sprays within a limited period of time after infection had been assessed to have occurred.

Post harvest, pre leaf fall sprays and orchard floor treatments with organo-mercury compounds D.N.O.C., Tar oil and sulphate of ammonia reduced the spore potential but not sufficiently to enable reductions to be made in the spraying programme during the period of ascospore discharge in the following year (Anon 1959).

Protectant spray programmes based on Captan led to increased infestation by red spider (Willis 1955) and although good scab control was obtained this material was not used extensively in N. Ireland. The relatively recent introduction of effective organic protectant fungicides has led to comparison experiments on materials and spray programmes.

METHOD AND MATERIALS

Eradicant spray programmes were based on infection information supplied by the Apple Scab Observation Service. At late pink bud the eradicant sprays were replaced by protectant sprays.

Protectant spray programmes were applied at ten day intervals which were shortened to seven days during periods of severe or continuous scab infection or during periods of rapid leaf expansion.

All spray programmes commenced at bud burst. The site was a five acre orchard of mature Bramley's Seedling using a randomised block design with three replicates. Treatment plots consisted of three rows of approximately six trees. Two different trees were left unsprayed each year. The sprays were applied by triple nozzle, broom headed, hand lances at a pump pressure of 300 p.s.i. All sprays were applied to the point of run off. The method of scab assessment was that described by Cartwright 1964.

Fungicide treatments 1966

1.	Dinitro-rhodane-benzene	45% Wettable powder	2½ lb/100 gal 1¾ lb/100 gal	Pre blossom Post blossom
2.	DAC 2787 Tetrachloroisophtalonitrile	75% Wettable powder	1½ lb/100 gal	Pre and Post blossom
3.	Mancozeb/Zineb complex	78% Wettable powder	2 lb/100 gal	Pre and Post blossom
4.	Dodine	20% Liquid	1¼ pt/100 gal 1 pt/100 gal	Pre blossom Post blossom
5.	Dodine	65% Wettable powder	½ lb/100 gal	Pre and Post blossom
6.	Phenyl Mercury Nitrate Dodine	2.5% Wettable powder 65% Wettable powder	2 lb/100 gal ½ gal/100 gal	Pre blossom Post blossom
7.	Dicarboxyimide	50% Wettable powder	¾ lb/100 gal	Pre and Post blossom
8.	Dithianon	60% Col.	¾ pt/100 gal ½ pt/100 gal	Pre blossom Post blossom

Table 1.

Infection Periods 1966++

Date	Time	Av. Temp.	Curative spraying period	Date issued
25.3.66	1400 hrs	43°F	120 hrs	26.3.66
31.3.66	1400 "	39°F	120 "	1.4.66+
9.4.66	0100 "	46°F	88 "	9.4.66
18.4.66	2200 "	40°F	120 "	19.4.66
5.5.66	1800 "	50°F	64 "	6.5.66

+ Severe Infection Period
++ Doubtful periods were disregarded

Table 2.

Spray Calendar 1966

Treatments

Date	1	2	3	4	5	6	7	8
28.3.66	x	x		x	x	x	x	x
29.3.66			x					
7.4.66		x	x	x	x		x	x
13.4.66						x		
18.4.66		x	x	x	x		x	x
20.4.66						x		
28.4.66	x	x	x	x	x		x	x
9.5.66	x	x	x	x	x	x	x	x
18.5.66	x	x	x	x	x		x	x
1.6.66	x	x	x	x	x	x	x	x
16.6.66	x	x	x	x				
17.6.66					x	x	x	x
1.7.66	x	x	x	x	x	x	x	x
18.7.66	x	x	x	x	x	x	x	x

Table 3.

Apple Scab Infection 1966+

Treatment	Leaves Per cent scab 21.6.66	Leaves Per cent scab 3.8.66	Apples on tree per cent scab 8.9.66
1	0.95	4.7	33.3
2	0.0	0.03	1.9
3	1.7	2.6	11.1
4	1.3	3.0	8.3
5	0.97	1.2	2.8
6	8.2	10.3	21.8
7	0.1	9.7	6.3
8	0.1	0.1	1.7
L.S.D. P = 0.05	3.9	5.2	9.2
Unsprayed	7.3	8.8	69.2

+ Mean of three replicates except for unsprayed trees

Fungicide treatments 1967

1.	Dodine	65% Wettable powder	½ lb/100 gal	Pre and Post blossom
2.	Dithianon	60% Col.	½ pt/100 gal	Pre and Post blossom
3.	DAC 2787 Tetrachloroisophtalonitrile	75% Wettable powder	1 lb/100 gal	Pre and Post blossom
4.	M2452 o,o-Diethyl phthalinido phosphozothioate	50% Wettable powder	1 lb/100 gal	Pre and Post blossom
5.	Mancozeb/Zineb complex	78% Wettable powder	2 lb/100 gal	Pre and Post blossom
6.	Dithianon	60% Col.	[illegible] pt/100 gal	Pre and Post blossom

7.	E.L. 200	Liquid	$1\frac{3}{4}$ pt/100 gal	Pre and Post blossom
8.	Dodine	20% Liquid	$1\frac{1}{4}$ pt/100 gal	Pre and Post blossom
9.	Dinitro-rhodane-benzene	45% Wettable powder	$2\frac{1}{2}$ lb/100 gal $1\frac{3}{4}$ lb/100 gal	Pre blossom Post blossom

Table 4.

Infection Periods 1967

Date	Time	Av. Temp	Curative spraying period	Date issued
22.3.67	0100 hrs	46°F	88 hrs	23.3.67+
25.3.67	1900 "	37°F	120 "	26.3.67
1.4.67	2200 "	44°F	104 "	2.4.67
19.4.67	1900 "	46°F	88 "	20.4.67++
20.4.67	1800 "	46°F	88 "	21.4.67+
23.4.67	2200 "	46°F	88 "	24.4.67+
3.5.67	1700 "	44°F	104 "	10.5.67
9.5.67	1900 "	52°F	55 "	10.5.67
13.5.67	1800 "	46°F	88 "	14.5.67
16.5.67	1900 "	46°F	88 "	17.5.67

+ Severe infection periods
++ Very severe infection periods

Table 5.

Spray Calendar 1967
Treatments

Date	1	2	3	4	5	6	7	8	9
22.3.67	x	x	x	x	x				
23.3.67						x	x	x	x
31.3.67	x	x	x	x	x	x	x	x	x
10.4.67	x	x	x	x	x	x	x	x	x
18.4.67	x	x	x	x	x	x	x	x	x
25.4.67	x	x	x	x	x	x	x	x	x
4.5.67	x	x	x	x	x	x	x		
5.5.67								x	x
15.5.67	x	x	x	x	x	x	x	x	
16.5.67									x
24.5.67	x	x	x	x	x	x	x	x	x
6.6.67	x	x	x	x	x	x	x	x	x
19.6.67	x	x	x	x	x	x	x	x	x
21.6.67									x
4.7.67	x	x	x	x	x	x	x	x	x

Table 6.

Apple Scab Infection 1967+

Treatment	Leaves Per cent scab 12.6.67	Leaves Per cent scab 9.8.67	Apples on tree per cent scab 4.9.67
1	0.07	0.43	1.10
2	0.10	0.20	1.13
3	0.03	0.13	1.87
4	0.67	6.13	19.47
5	0.07	2.53	2.93
6	0.07	0.10	1.63
7	0.13	1.77	2.60
8	0.00	0.10	2.20
9	0.43	1.23	5.20
L.S.D. P = 0.05	0.27	2.25	7.18
Unsprayed	14.9	74.2	85.0

+ Mean of three replicates except for unsprayed trees

DISCUSSION

Weather records over a period of seven years have shown that scab infection information was relevant throughout the orchard area of N. Ireland. As a general guide the Scab Observation Service gave growers a day to day assessment of scab infection and indicated when protectant programmes should have been shortened to seven day intervals.

Protectant spray programmes based on a ten day interval with modifications to reduce to seven days during periods of severe or continuous infection or during periods of rapid leaf development have given excellent results over a four year period with dithianon and dodine and over a two year period with DAC 2787 and a Mancozeb/Zineb complex.

Eradicant spray programmes based on infection period data failed to control infection in 1965 and, as seen in the results, also failed in 1966.

The limitation of eradicant spraying with organo-mercury compounds, which in themselves are excellent eradicants, is that they must be applied within a relatively short time of infection having occurred. This is not always possible in the season of ascospore discharge when generally the conditions for infection, in the form of discontinuous rain, are also the conditions which make precision timing of sprays difficult. As the orchard area increases the difficulty of spraying within a given period of time also increases.

More than four or five sprays of phenyl mercury nitrate as eradicant sprays under N. Ireland conditions on mature Bramley's Seedling can cause hardening of the leaves.

REFERENCES

ANON (1960) Loughgall Ann. Rep. (1959)

ANON (1961) Loughgall Ann. Rep. (1960)

ANON (1962) Loughgall Ann. Rep. (1961)

ANON (1963) Loughgall Ann. Rep. (1962)

CARTWRIGHT, J. (1964) Loughgall Ann. Rep. (1963 59-64)

CARTWRIGHT, J. (1965) Loughgall Ann. Rep. (1964 48-54)

CARTWRIGHT, J. (1966) Loughgall Ann. Rep. (1965 86-90)
(1966a) Proc. Irish Crop Protection Conf. 181-186
CARTWRIGHT, J. (1967) Loughgall Ann. Rep. (1966 1-3)
MILLS, L.D. and LaPLANT, A.A. (1954) Cornell Ext. Bull. No. 711
MUSKETT, A.E. (1926) Govt. of N.Ireland, Min. of Agric. Leaflet 33
WILLIS, R.J. (1956) The Res. and Exp. Rec. of the Min. of Agric. N. Ireland, Vol. V. 1955

THE ROLE OF ERADICANTS IN THE CONTROL OF BLACK CURRANT DISEASES

A. T. K. Corke
Long Ashton Research Station, University of Bristol

Summary

The use of eradicant sprays during the winter seldom leads to the permanent elimination of a disease from a crop. It has been shown experimentally that there are many chemicals capable of completely inhibiting the release of viable spores from treated tissues. Nevertheless, little progress is usually made towards the eradication of a disease by the use of such chemicals in the field, even when the crop is repeatedly sprayed.

Whether or not eradicant sprays have a part to play in the control of a disease depends largely on the effect of the fungus on the host plant, and how the fungus survives the winter. Among black currant diseases, those which overwinter on the fallen leaves present a much easier target for eradication than those which infect the shoots.

It appears that the sudden increase in the severity of certain black currant diseases in recent years may have been associated with the sweeping changes which have taken place in horticultural practice. The chemicals formerly used in routine spray programmes have, therefore, been re-examined to determine their effect on these diseases. The efficiency of insecticidal winter washes in reducing the overwintering fungal inoculum has been demonstrated, and a large number of closely related materials has been screened in laboratory trials against Botrytis cinerea isolated from black currant fruit.

There can be little doubt that the most effective way to eliminate most plant diseases is to remove all infected parts of the host plants and destroy them. For a number of reasons such treatment may be impracticable, or may not give the results expected. Recourse is then made to the use of chemicals.

Before turning to the part which eradicant chemicals may be able to play in the control of the economically important diseases of black currants, it is necessary to consider what constitutes an eradicant. The fungicides in common use are separated, for convenience, into groups based broadly on their mode of action. Such an arrangement is misleading. Chemicals described as protectants can usually be shown to protect plants against fungal infection so long as sufficient active deposit remains on the surface, but those described as eradicants seldom achieve more than a temporary reduction in the level of the disease against which they are used.

Byrde (1961) defined eradicant fungicides as 'compounds applied externally to the host to kill a fungal pathogen already present on or within it' and, in reviewing the previous work done on this subject, he pointed out that 'fungicidal performance was generally assessed on the basis of reduction of spore inoculum rather than on viability of the mycelium', which may be buried deep in the tissues. In the present context, therefore, materials which are known to have a measurable effect only on sporulation are referred to as spore suppressants, while the remaining materials covered by the definition given, i.e. those which can be shown to affect permanently the viability of the mycelium of the fungus on or within the host tissues, following external application, are described as eradicants. Only compounds such as these can be regarded as truly eradicant, since experience has shown that even where sporulation is effectively suppressed for a considerable period, only a limited reduction, if any, in the overall level of infection is achieved, unless the mycelium is destroyed (Byrde and Corke, 1954; Corke A. T. K. et al., 1965).

Logically, a completely successful programme of protective spraying carried out during an entire growing season should lead to the eradication of a disease, provided that no primary infections are initiated in the following year by spores from outside sources. Considerable success has been achieved in this direction with leaf spot (Pseudopeziza ribis) and American gooseberry mildew (Sphaerotheca mors-uvae) on black currants (Corke, 1966a ; Corke and Jordan, 1967) but the difficulties involved in trying to obtain an adequate control of most diseases by protective spraying alone have long been recognised (e.g. Keitt and Palmiter, 1937), and some winter treatment is usually needed in addition. Although the use of sprays to reduce the level of overwintering fungal inoculum is generally restricted to the dormant season, the situation frequently demands that the period of spraying is extended into the late autumn or the early spring (e.g. Burchill, 1966; Byrde, R. J. W. et al., 1965; Corke, 1960; Moore and Bennett, 1960). At these times such sprays are often also partly protective, and they then merge with the protectant spray programme for the spring and summer.

Whether or not it is possible to eliminate a disease by winter spraying only, depends largely on the depth of penetration of the fungus into the host tissues, and on the way in which the fungus survives the winter. A fungus which is entirely dependent on fallen leaves for its survival until the following year clearly presents a much easier target for eradication during the dormant season than one which infects the shoots. However, it has proved to be extremely difficult to obtain satisfactory results in the field, even by treating overwintering black currant leaves, on the ground, with chemicals known to inhibit completely the discharge of viable spores from infected leaves treated in the laboratory (Corke, 1960). The unsatisfactory performance of promising materials when dead leaves are sprayed on the ground can most readily be attributed to the poor cover obtained, compared with that achieved by dipping individual leaves in test solutions in the laboratory.

A possible solution to the problem of getting adequate cover might be to spray the bushes immediately before leaf-fall (Corke, 1955); provided that no damage is done to the buds, it is unlikely that any harm will be done to the bushes by promoting defoliation at this stage. Also, it is clear that, if the normal development of the overwintering stage of a fungus can at least be interrupted by treatment at this time of year, a significant reduction in the primary inoculum in the following year should result. The use of less toxic, or non-toxic materials before leaf-fall, as alternatives to the accepted eradicants and spore suppressants has, therefore, recently been studied on apples and black currants (e.g. Burchill, R. T. et al., 1965; Corke, 1960 and 1967b).

It may also be advantageous to use a winter spray as late as possible before bud burst. This may either be because the material must be used during the dormant season and has a relatively short active life, or because the fungal pathogen passes through a particularly vulnerable stage at this time of year. Treatment just before bud burst has been found to be essential with all spore suppressants tested so far against bitter rot (Gloeosporium perennans) on apples (Corke, 1967a), in order to extend the effect as far into the growing season as possible: a spray of dinitro-o-cresol applied at this time has been found to be effective in the control of mildew (Podosphaera leucotricha) on apple (Moore, M. H. et al., 1962; Waugh, 1960), against gooseberry mildew on gooseberries (Junker, 1953) and on black currants (Corke and Jordan, 1966). Apple mildew is thought to overwinter solely in the buds (Burchill, 1960), but the extent to which this is true of mildew on gooseberry is a matter of controversy (e.g. Porreye, 1963 ; Preece, 1965). It is clear, however, that on black currants bud infection plays a very small part in the perennation of the mildew fungus (Jordan, 1967). The penetrative power of petroleum oil, which is usually used to carry DNOC, enables the spray to reach the mildew fungus in opening apple buds and reduce the level of inoculum which gives rise to the primary infections; from the previous summer until this time, the fungus within the buds has been protected against the action of fungicidal sprays. The effect of late dormant sprays on mildew on black currants is more direct: in this case, the maturing perithecia appear to become increasingly susceptible to damage.

At the present time the economically important diseases of black currant bushes grown in this country are leaf spot (P. ribis), mildew (S. mors-uvae) and grey mould (Botrytis cinerea). Each fungus has a life-cycle differing in important respects from that of the others, and the measures adopted for the control of each disease must, therefore, meet a different set of conditions. It is not surprising that a spray programme, which can afford black currant bushes an equal degree of protection against all three diseases, has not yet been found. The leaf spot fungus is virtually restricted to the leaves of the black currant, causing a progressive reduction in the area of active leaf and leading to premature defoliation. While the evidence available suggests that some defoliation can take place without any effect on the bush, extensive defoliation before harvest can cause shrivelling of the berries and the death of the tips of young shoots (Corke and Wilson, 1964), as well as a heavy loss of crop in the following year. American gooseberry mildew infection of the leaves causes an even greater loss of efficiency than leaf spot, stopping shoot extension and leading to the death of the tips; it also reduces the numbers of flowers formed in the developing buds, causing a severe reduction in crop in the following season. This fungus also invades the leaf petioles and young stems, where it develops a thick felt of mycelium in which the overwintering perithecia are buried. With the recent spread of mildew into black currant plantations, the number of shoots with dead tips, and of young shoots killed, particularly in the centre of the bushes, has increased markedly. Simultaneously, the incidence of Botrytis on the flowers and fruit has increased, and heavy losses have occurred. Although the fungus causes obvious damage only to flowers and fruit, it readily invades moribund tissue, and the presence of large numbers of dead shoots provides a greater potential inoculum, with a better chance of survival, than when the fungus was dependent on mummified fruit and plant debris alone. The development of sclerotia on infected shoots, from which conidiophores arise in the spring, makes this a much more difficult fungus to attempt to control by winter spraying than the two previously mentioned.

Among the sweeping changes in horticultural practice in black currant plantations, which have taken place in recent years, the substitution of new insecticides for the traditional winter wash and lime sulphur programme was the most likely to enable the sudden invasion by mildew to develop unhindered (Corke, 1966c). Significantly, lime sulphur applied in the spring has long been the basis of control measures against this fungus on gooseberries; the abandonment of this spray in particular, would thus have left the young black currant foliage unprotected against mildew infection at the most critical time of the year. Considering that severe losses of crop through infection by Botrytis have simultaneously become more common, and that adequate protection of the flowers and fruit is extremely difficult to achieve, the effectiveness of standard winter washes in preventing sporulation from infected wood after treatment has been examined (Corke, 1966b). The results of preliminary experiments with 13 formulations of DNOC and tar and petroleum oils indicated that the growth of Botrytis mycelium from infected wood could be reduced by at least 25 per cent by treatment with any one of the materials tested. Several mixtures of two, and of all three, materials gave complete inhibition of growth for two or more weeks, and in one case all attempts to recover viable mycelium of the fungus failed, in spite of extensive weathering and culturing. However, since the infected wood used in these tests was found to be very variable, further work was carried out in culture (cf. Crowdy, 1948).

The fungicidal properties of coal tar distillates have received little attention in the past, but tar preparations have been used extensively in rubber plantations to control diseases, in particular the tapping panel mouldy rot (Ceratostomella fimbriata). Large differences in the effectiveness of tested materials led Coles and Byrde (1954) to examine the fungicidal activity of the constituents of tar. The phenols were found to be largely responsible for determining the efficiency of the product, the type of phenol present being as important as the concentration, and about 25 per cent of the more active phenols was suggested as the minimum content needed in the formulated product to achieve a reasonable degree of efficiency in the field (Coles, G. V. et al., 1955).

In further tests to determine the fungicidal activity of materials against Botrytis, therefore, a wide range of phenolic compounds has been included, both in their pure form, and as constituents of proprietary products: standard winter washes and several fungicides have also been tested. Each material, suitably formulated, was incorporated in agar poured into four Petri dishes which were then inoculated with discs cut from a 7-day-old culture of Botrytis isolated from black currant. The cultures were incubated at 25°C, and the diameter of the colonies measured along predetermined lines after 48 and 96 hr. to give a measure of the rate of growth of the fungus in the presence of the material at a known concentration.

It is possible here only to summarise the results obtained so far, but it is clear that they are in general agreement with those of Coles and others (1955) in indicating that the phenols are a very actively fungicidal group of compounds, and that they vary widely in their toxicity. Under the conditions of the test, very few of the 57 materials used at 150 p.p.m. failed to restrict markedly the growth of Botrytis mycelium, while 21 completely inhibited growth. The effective materials included chemically pure phenolic compounds, a variety of proprietary winter washes, two fungicides of a phenolic nature, a high boiling tar acid and a coal tar product. Only the strongly phenolic materials, the chlorinated phenols in particular, continued to inhibit growth following progressive dilution to less than 50 p.p.m. The emulsifiers used in the formulation of the materials caused a slight inhibition of growth in all tests, giving a mean reduction of about 20 per cent compared with the control cultures, but not exceeding 30 per cent.

In these latest laboratory experiments it was found that, while some insecticidal washes have no anti-fungal activity, a few are quite as effective in preventing growth of the fungus, when in contact with it, as some conventional fungicides at the same concentration. Also, a number of compounds closely related to the active components of the insecticidal washes are active in preventing growth at very low concentrations. The aim, therefore, is to formulate a wash which, by substitution or the addition of active constituents, is as effective as a fungicide as it is as an insecticide. The main difficulty in the use of a wash in the field is penetration of the infected shoots, so that the material can be brought into intimate contact with the fungus. Fortunately, since the Botrytis-infected shoots are dead, materials are more readily absorbed than would be the case with living shoots, and earlier experiments indicated that this could be facilitated by the use of petroleum oil. In contrast, penetration of the overwintering mildew and leaf spot fruit bodies should present less difficulty, and there is thus good reason to hope that it may be possible to achieve an adequate control of the diseases and many of the pests of black currants by means of an eradicant winter wash.

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References

BURCHILL, R. T. (1960) J. Hort. Sci., 35, 66.

BURCHILL, R. T., HUTTON, K. E., CROSSE, J. E. & GARRETT, C. M. E. (1965) Nature, 205, 520.

BURCHILL, R. T. (1966) Rep. E. Malling Res. Sta. (1965), 148.

BYRDE, R. J. W. & CORKE, A. T. K. (1954) Ann. Rep. Long Ashton Res. Sta. (1953), 159.

BYRDE, R. J. W. (1961) Recent Advances in Botany (9th. Int. Bot. Cong. 1959), 461.

BYRDE, R. J. W., EVANS, S. G. & RENNISON, R. W. (1965) Pl. Path. 14, 143.

COLES, G. V. & BYRDE, R. J. W. (1954) Ann. Rep. Long Ashton Res. Sta. (1953), 109.

COLES, G. V., MARTIN, J. T. & BYRDE, R. J. W. (1955) Ann. Rep. Long Ashton Res. Sta. (1954), 74.

CORKE, A. T. K. (1955) J. hort. Sci., 30, 197.

CORKE, A. T. K. (1960) Ann. Rep. Long Ashton Res. Sta. (1959), 118.

CORKE, A. T. K. & WILSON, D. (1964) Ann. Rep. Long Ashton Res. Sta. (1963), 71.

CORKE, A. T. K., EDNEY, K. L. & HAMER, P. S. (1965) Ann. Rep. Long Ashton Res. Sta. (1964), 145.

CORKE, A. T. K. (1966a) Exp. hort., 15, 71.

CORKE, A. T. K. (1966b) Proc. Brit. Insecticide and Fungicide Conf., (1965), 150.

CORKE, A. T. K. (1966c) Proc. Brit. Insecticide and Fungicide Conf., (1965), 336.

CORKE, A. T. K. & JORDAN, V. W. L. (1966) Ann. Rep. Long Ashton Res. Sta. (1965), 184.

CORKE, A. T. K. (1967a) Ann. appl. Biol. (In press)

CORKE, A. T. K. & JORDAN, V. W. L. (1967) Unpublished results.

CORKE, A. T. K. (1967b) Unpublished results.

CROWDY, S. H. (1948) Ann. Rep. Long Ashton Res. Sta. (1947), 158.

JORDAN, V. W. L. (1967) M.Sc. Thesis, University of London.

JUNKER, H. (1953) Pflanzenschutz, 5, 7.

KEITT, G. W. & PALMITER, D. H. (1937) J. agric. Res., 55, 397.

MOORE, M. H. & BENNETT, M. (1960) Rep. E. Malling Res. Sta. (1959), 85.

MOORE, M. H., BENNETT, M. & BURCHILL, R. T. (1962) Rep. E. Malling Res. Sta. (1961), 97.

PORREYE, W. (1963) Agricultura, 11, 145.

PREECE, T. F. (1965) Pl. Path., 14, 83.

WAUGH, N. (1960) Ann. Rep. Long Ashton Res. Sta. (1959), 115.

FUNGICIDAL "STUMP" TREATMENTS FOR THE CONTROL OF AMERICAN GOOSEBERRY MILDEW ON BLACK CURRANTS

P. Wiggell, B.Sc.,
National Agricultural Advisory Service
Area Laboratory, Evesham, Worcs.,

Summary

Trials at Luddington and Stockbridge House Experimental Horticulture Stations on black currant bushes cut down for harvesting by machine, showed that the fungicidal "stump" treatments of 10% lime sulphur and 6% tar oil applied soon after harvest to a 3 ft band of soil along the cut-down bush rows followed by quinomethionate sprays to the regrowth, increased survival and vigour of treated bushes and gave a reduction in the level of American gooseberry mildew on the foliage in late summer/early sutumn. Additional foliage sprays in the following year, when black currant bushes are in the growing phase, of quinomethionate, dinocap, or 1% lime sulphur + wetter, applied to bushes which had received the "stump" treatments, gave a dramatic increase in survival and vigour of bushes and a marked reduction in the level of mildew.

INTRODUCTION

American gooseberry mildew (Sphaerotheca mors-uvae), has become the major disease threat to black currant growing. The disease was first reported on gooseberries in Kent and Worcestershire in 1906 and on red and black currants in 1907 and 1908 respectively. The disease, since 1906, has been generally troublesome on gooseberries but, until 1960, was only occasionally seen on black currants. The disease is now established in all the main black currant areas and is likely to limit the production of black currants when harvested by machine.

The recent increase in the level of the disease may, to a certain extent, be due to:-

1. the replacement of winter wash (aphid control) and lime sulphur (gall mite control)by newer insecticides

2. the widespread use of dithiocarbamate fungicides (e.g.: zineb, zineb-mancozeb) for the control of leaf spot (Pseudopeziza ribis). Selectivity among diseases is such that a perfectly good fungicide, while controlling one disease very well, will allow another to develop, as with the rapid spread of apple mildew following the use of captan by itself

3. the chemical control of weeds which has resulted in an increase in the survival of dead leaves on the plantation floor over the winter

4. the production of soft, vigorously growing foliage which is susceptible to infection by mildew. Irrigation, combined with the higher levels of nitrogenous fertilisers, predisposes to soft growth. In addition, bushes cut down for mechanical harvesting produce a flush of succulent foliage in the late summer and again during the growing phase in the following year.

The post-war demand for black currants for juice extraction and the long-term contracts made to growers to supply fruit for this purpose increased interest in the black currant crop. A substantial part of the cost of production is that incurred in picking. The hand-picking of black currants, supervision of pickers, weighing of fruit into containers and transport in the field, cost approximately £40 a ton. An improvement in harvesting methods by reducing this cost could make a major contribution to increased profitability.

The first attempts to mechanise picking involved:-

(a) Harvesting from the standing bush

This method has the advantage of annual cropping and requires little change in existing growing methods. The machines developed at present consist of hand-held reciprocating 'guns' which are used to shake the fruit from the branches into a hopper placed beneath the bush. The machines produced so far have not proved to be very successful. Any picking, however, by this method should not remove too many leaves, Corke and Wilson (1963).

(b) Cutting down the bush either partly or completely for harvesting

With this method the cut shoots are fed into a static or mobile machine for picking. Picking is more rapid but involves radical changes in cultural methods. Further development towards a combine harvester is feasible.

Trials at Luddington Experimental Horticulture Station are mainly concerned with the techniques of growing bushes for harvesting by method (b) because machine development has been more successful for this purpose.

The most promising method has been to cut down the bushes completely for picking so facilitating mechanical or combine harvesting. The yield from these bushes in the cropping season has been similar to that from the conventionally picked bush. By cropping only once in two years, however, the yield is equivalent to about half that from conventional bushes. Closer bush spacing may compensate for loss of crop, otherwise the grower will have to increase his acreage of black currants.

Providing the biennial cropping method is successful an aspect still to be resolved is the system of growing the bushes.

Two possible mthods are the alternate row system and the bed system. At the present interim stage a row spacing of 4½ ft is suggested as the most adaptable, with a bush spacing within the row of 2 to 4 ft depending on variety. The advantages of the 4½ ft row spacing are that it provides for either (a) alternate row system, (b) modification to a bed system by removing every sixth row to give five row beds provided with 9 ft tractor alleyways, or (c) return to conventional 9 ft planting distance by removing each alternate row.

METHOD AND MATERIALS

Jordan (1966, 1967) has established that, contrary to the experience of Salmon (1914) with perithecia of American gooseberry mildew on gooseberries, perithecia produced on leaves and shoots of black currant bushes persist throughout the winter and that ascospores developing the following spring are capable of initiating primary infections. Ascospore maturation is reached at about the time of full blossom each season and once first infections have been established rapid secondary spread by conidia takes place.

When black currant bushes are cut down completely for mechanical picking the "stumps" of the bushes remain enveloped in a layer of fallen leaf debris. During late July, August and September vegetative growth develops from axillary buds low down in the crown of the stools. This growth is readily infected by the mildew fungus with subsequent death of a proportion of stools, unless eradicant and protectant fungicidal measures are adopted.

At Luddington and Stockbridge House Experimental Horticulture Stations dramatic effects have been seen on the incidence of mildew and bush survival and vigour when "stump" and foliage treatments were applied post-harvest to black currant bushes cut down for harvesting by machine.

Luddington Experimental Horticulture Station

An observation was commenced at Luddington Experimental Horticulture Station in 1965 on the black currant cultivar Wellington XXX cut down for machine harvesting on 13th and 14th July. Fungicidal "stump" treatments were applied on 22nd July to a 3 ft band of soil along the cut-down bush rows. In addition, foliage sprays to the regrowth of quinomethionate at 2 oz a.i. ($\frac{1}{2}$ lb 25% w.p.)/100 gal (H.V.) were applied on 22nd August and 22nd September to some of the plots.

The treatments used are given in the following table:-

Table I

Post-harvest treatments to "stumps" and regrowth

	Treatments	
Treatment Code	Post-harvest "stump" treatment Applied 22nd July 1965	Foliage treatment Applied 22nd August and 22nd September 1965
10% LS/0	10% lime sulphur + 4 fl.oz 60% succinate wetter	no treatment
10% LS/M	10% lime sulphur + 4 fl.oz 60% succinate wetter	quinomethionate 2 oz a.i. /100 gal (H.V.)
0/M	no treatment	quinomethionate 2 oz a.i. /100 gal (H.V.)
6% T/0	6% tar oil	no treatment
6% T/M	6% tar oil	quinomethionate 2 oz a.i. /100 gal (H.V.)
2% LS/1% LS	2% lime sulphur + 4 fl.oz 60% succinate wetter	1% lime sulphur + 4 fl.oz 60% succinate wetter
0/1% LS	no treatment	1% lime sulphur + 4 fl.oz 60% succinate wetter
0/0	no treatment	no treatment

RESULTS

Results from the treatments given in Table I are presented below:-

Table II

Effect of treatments on bush vigour and disease control

Assessments made on 13th September 1965

Treatment Code	Mean height bush/inches	Mean number shoots/bush	Mean number shoots over 6" high/bush	Mean mildew infection category (0 to 5) leaves	shoots
10% LS/0	9	22	14	3.5	3.5
10% LS/M	16	34	28	1.0	0.5
0/M	8	24	9	3.5	4.0
6% T/0	8	26	10	3.5	4.0
6% T/M	15	33	24	1.0	0.5
2% LS/1% LS	12	19	14	2.5	1.5
0/1% LS	5	26	0	2.0	2.0
0/0	4	22	1	5.0	5.0

Note that assessments given in the table were made before the application on 22nd September 1965.
Mildew assessments were made using a provisional Key and are not related to subsequent assessments using Key 21 (see Table III).

Quite dramatic control of mildew was given by the combined 10% LS/M and 6% T/M treatments. "Stump" treatments and foliage treatments when applied separately failed to give adequate control of the disease. The differences in vigour of new growth produced from the cut-down bushes reflect the degree of mildew control obtained by treatments applied to the stumps and foliage in the late summer.

In 1966 each treatment plot was split, one half received quinomethionate at 4 oz a.i. (1 lb 25% w.p.)/100 gal (H.V.) from 12th May 1966, repeated at three week intervals until the end of August. The other half of each treatment plot was left unsprayed during 1966.

Results are given in Table III:-

Table III

Cumulative effects of treatments on control of mildew

1965 Treatment	Treatments (1966): 4 oz a.i. quinomethionate/ 100 gal — Mean Mildew Index on leaves 7th July	4 oz a.i. quinomethionate/ 100 gal — % infected shoots 11th Oct	Untreated — Mean Mildew Index on leaves 7th July	Untreated — % infected shoots 11th Oct
10% LS/0	1.0	29.6	5.0	100
10% LS/M	1.0	31.4	5.0	100
0/M	2.0	40.7	5.0	100
6% T/0	1.7	28.7	5.0	100
6% T/M	2.0	32.6	5.0	100
2% LS/1% LS	2.0	32.6	5.0	100
0/1% LS	2.0	41.2	5.0	100
0/0	1.7	31.7	5.0	100

Assessed using Key No.21 Part II prepared by the Disease Assessment Committee of the National Agricultural Advisory Service Conference of Advisory Plant Pathologists. (Assessment 5.0 indicates that more than 50% of the leaves showed mildew infection on more than half their leaf surface).

The differences in the incidence of mildew on the current years extension growth in 1966, reflect the effectiveness of quinomethionate applied when mildew was first observed (11th May) and repeated at three week intervals until the end of August.

A late attack of leaf spot developed by the second week of October 1966 and caused premature defoliation (95% leaf spot infection) of the unsprayed bushes. At this time bushes which had received quinomethionate showed only 5% to 10% leaf spot infection.

A comparable trial, carried out on Wellington XXX during 1966 and 1967, gave similar results.

Stockbridge House Experimental Horticulture Station

METHOD AND MATERIALS

A trial on the cultivar Malvern Cross was commenced in 1966. Bushes were grown at a spacing of $4\frac{1}{2}$ ft row width by $2\frac{1}{2}$ ft apart in the rows on the alternate bed system, whereby alternate blocks in a plantation are cut down for machine harvesting. Half the bushes in the experiment are cut down and cropped in any one year.

The treatments which were replicated four times are given in Table IV:-

Table IV

Post-harvest "stump" and foliage treatments for control of American gooseberry mildew

Treatments

Foliage treatment (1966 and 1967)	Post-harvest "stump" treatment (Aug/Sept 1966)
Dinocap 4 oz a.i./100 gal	6% tar oil plus quinomethionate 2 oz a.i./100 gal
1% lime sulphur + wetter	10% lime sulphur plus quinomethionate 2 oz a.i./100 gal
Untreated	Untreated

In 1966 foliage sprays were applied before harvest on 27th May (at the end of flowering) and repeated on 21st June and 12th July.

Post-harvest treatments in 1966 were applied to cut-down bushes and the surrounding ground immediately after harvest and followed three weeks later by an application of quinomethionate to the regrowth. Good initial protection against mildew was obtained.

In 1967 the first foliage spray was applied on 25th May (early green fruit) and repeated on 13th June and 4th July.

The three "stump" treatments were applied to cut-down bushes which had received each of the pre-harvest 1966 foliage treatments. In 1967 foliage sprays were repeated to the same plots which had received the 1966 foliage treatments.

By the time fruit picking was completed in late July 1966, mildew infection on untreated plots was considerably heavier than that on sprayed bushes. The difference was emphasised by a severe frost on 3rd November which killed the regrowth on the more severely mildewed bushes in untreated plots while the leaves on the sprayed bushes remained green.

RESULTS

Results from the treatments given in Table IV are presented below:-

Table V

Percentage loss of stools due to mildew - June 1967

Post-harvest "stump" treatments (August to September 1966)	Foliage treatments (1966 and 1967): Dinocap	Lime sulphur	Untreated
6% tar oil + quinomethionate	14.6	4.1	41.0
10% lime sulphur + quinomethionate	16.6	10.4	20.8
Untreated	66.6	10.4	66.8

Percentage loss refers to dead bushes or bushes which have produced **only** one or two weak shoots.

Plots which did not receive a "stump"and foliage treatment showed heavy loss of stools as did plots which only received dinocap foliage spray in both years. Lime sulphur applied alone as a foliage spray or in combination with the "stump" treatments gave good control of mildew and low loss of stools. Dinocap foliage sprays, in combination with post-harvest "stump" treatments, also gave good disease control with a slightly higher loss of stools.

DISCUSSION

The experiments carried out at Luddington and Stockbridge House Experimental Horticulture Stations on black currant bushes cut down for machine harvesting have shown that "stump" treatments, either alone or in combination with foliage sprays of quinomethionate applied to the regrowth, provide an effective, cheap and easy method of controlling mildew in late summer and early autumn.

Bushes in their growing phase, under experimental conditions at Luddington Experimental Horticulture Station, require at least six applications of quinomethionate to give good control of mildew. At Stockbridge House Experimental Horticulture Station mildew appears later in the season and is most troublesome after picking at the end of July, through August and September. The number of sprays needed for adequate protection of bushes in their growing phase against mildew infection has yet to be finally determined at this centre.

Providing the disease is effectively controlled in the black currant growing phase then it is possible that no further spraying for mildew need be applied before harvest in the cropping year. It should be appreciated that under experimental conditions sprayed plots are always exposed to mildew infection from untreated control bushes and also from other nearby experimental plantings. Commercially, under a complete bed system of black currant growing for harvesting by machine, it might be possible to reduce the number of foliage sprays to bushes in their growing phase.

The precise reason for the effect on bush survival, vigour and disease control by the 10% lime sulphur and 6% tar oil treatments is not clear. The success with both these "stump" treatments may possibly be due to killing out, by direct contact, mildew infection on leaf debris trapped amongst stumps through which the vegetative regrowth passes. Alternatively, the tar oil may kill out mildewed vegetative buds which may be present low down in the crown of the stool. It is also possible that a drenching "stump" spray of 10% lime sulphur affords protection to the vegetative regrowth by release of sulphur vapour in addition to killing-out, by direct contact, mildewed vegetative buds in the crown. None of these explanations are supported by the findings of Jordan (1966) who showed that although mycelium was detected in the tissue of dormant buds there was no evidence that such mycelium gave rise to infections in the spring. Jordan (1966) also found that persistent mycelium (as found on heavily infected fallen leaves or shoots) was unable to initiate infections on young leaves when maintained under suitable conditions.

These observations are of a preliminary nature only but the results have been so clear-cut in the autumn of 1965 and 1966 that the most promising "stump" treatment, 10% lime sulphur, has become a standard application to bushes cut down for mechanical harvesting in trials at Luddington Experimental Horticulture Station.

Observations at Stockbridge House Experimental Horticulture Station suggest that severely mildewed vegetative regrowth is more susceptible to low temperature injury than is healthy or slightly mildewed foliage.

Acknowledgements

Appreciation is expressed to National Agricultural Advisory Service colleagues at Luddington Experimental Horticulture Station, in particular J. Ingram, and Stockbridge House Experimental Horticulture Station. I am indebted to H. J. Wilcox who supplied the results from the trial done at Stockbridge House E.H.S.

References

Corke, A. T. K. and Wilson, D. (1963) Rep. Long Ashton Res. Sta. for 1963, 71.

Jordan, V. W. L. (1966) Rep. Long Ashton Res. Sta. for 1965, 178.

Jordan, V. W. L. (1967) Rep. Long Ashton Res. Sta. for 1966, 180.

Rep. Luddington Exptl. Hort. Sta. for 1965.

Salmon, E. S. (1914) Jl. S-east agric. Coll. Wye 22, 403.

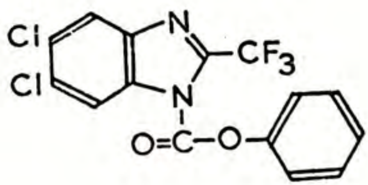
CONTROL OF FRUIT TREE SPIDER MITES WITH NC 5016

(5,6-dichloro-1-phenoxycarbonyl-2-trifluoromethyl benzimidazole)

by: Q.A. Geering, J.A. Bond, & A.J. Jones
Chesterford Park Research Station

The compound NC 5016 is a substituted trifluoromethyl benzimidazole, of the following structure. A common name has been applied for.

NC 5016 (FIG. 1)



(5,6-dichloro-1-phenoxycarbonyl-2-trifluoromethyl benzimidazole)

Initial screening tests showed significant activity against all stages of T.cinnabarinus and killed strains of T.urticae exhibiting resistance to dimethoate, phenkapton, chlorobenzilate and dicofol. No systemic activity has been noted.

In field tests, the compound has shown activity against a wide range of phytophagous mite species, viz: Panonychus ulmi; P.citri; Tetranychus urticae; T.cinnabarinus; Aceria sheldoni; Oligonychus coffeae; Hemitarsonemus latus; and Calacarus and Brevipalpus spp. - the latter on tea.

It is a crystalline solid material with a melting point of 103°C. It is highly lipophilic. The acute oral toxicities to vertebrates show a wide range from 28 mg/kg in the rabbit, to 1600 mg/kg in the mouse. The figure for the rat is 280 mg/kg and for the hen is 50 mg/kg. In a 90-day dietary feeding trial with rats, no significant abnormalities occurred at and below 50 ppm. The acute dermal toxicity figure for the rat was greater than 400 mg/kg when a 24-hour contact period was used. On the basis of these figures, therefore, the compound is considered to have a moderately high oral and low dermal toxicity. The full toxicological study and residue programme is in progress.

Both specific and general accounts have recently been published on this material (1), (2), (3). The intention here is to report field results obtained on apples for control of several species of mites, in a number of territories, during the past 18 months.

CONTROL OF T.CINNABARINUS AND T.URTICAE.

The first field trial was conducted in South Africa on a population of *T.cinnabarinus* showing a high degree of resistance to dimethoate and other phosphates - (Fig. 2). Following a single spray application, a good level of control (based on counts of infested leaves) was obtained at 0.03% a.i. After 14 days the population declined naturally and no further persistency data against this species were obtained.

Trials were conducted against *T.urticae* on apples in the Orange district of New South Wales, in early 1967. Mite build-up only occurred in January, abnormally late. A single spray sufficed for the remainder of the season and was applied on January 19th. Good control of mites up to February 24th (36 days) was obtained on a population reported to be highly resistant to phosphates and tetradifon (Fig. 3).

CONTROL OF P.ULMI.

The first field trial against this mite was conducted in England in Suffolk in the summer of 1966. The population exhibited phosphate resistance. Two sprays at 100 gal./acre were applied, the first at 80% petal-fall and the second two weeks later. At 0.05% control persisted for 40 days, after which time the population on this treatment showed a slight increase (Fig. 4). However, towards the end of the season the counts of active stages per leaf were:

Control 77; dimethoate (0.04%) 45; dicofol (0.04%) 27;
NC 5016 (0.025%) 28; NC 5016 (0.05%) 16.

The differences in mite counts were strikingly reflected in the colour differences of the leaves.

More extensive testing against *P.ulmi* has been completed during the current season in the northern hemisphere. Research trials have assessed various dosages and timings of sprays to achieve summer control of infestations. In England, after a cold wet spring, mite populations built up slowly, but eventually the populations during August again exceeded 60 motile stages per leaf on unsprayed trees at some sites.

In these research experiments replicated single tree plots were used, and results have shown:-

(a) Single sprays of NC 5016 against *P.ulmi* eggs at dormant stage in February, or at "½ inch green" in March, gave no control of the mite.

(b) Sprays of NC 5016 at petal-fall and three weeks later indicated best control at 0.05% a.i., in comparison with lower dosages down to 0.03%. There is, however, no steep dose response. Under these experimental conditions with re-invasion from controls, persistence was between 30 and 50 days.

Similar research scale trials have been carried out by Bassi and Cavallazzi in N. Italy, where plots were of three trees (5 replicates). When NC 5016 was applied on 3rd and 25th May, at dosages of 0.02% a.i., 0.04% a.i. and 0.06% a.i., all gave good mite control to mid-July. The performance of 0.04% is shown in Fig. 6, and that of all three concentrations is shown in Fig. 7. Best control of the summer build-up required 0.06% and was applied as a single spray on July 21st. The high level of resistance to the dicofol and dinocap mixture is illustrated in Fig. 7. The possible need for two sprays for control of the rapidly increasing summer populations is indicated in Fig. 6. Better results could be expected by spraying in early July.

During 1967, a limited number of grower trials, each of $\frac{1}{2}$-1 acre in size, was organised in England. Initially, the first spray was intended to be applied at 80% petal-fall. However, hatching of mites was very variable and the time of first spray varied from 19th May to 14th June. The second spray was applied 3-4 weeks later.

The dosage in these trials was 2.0 lb. of 20% WP per acre, which was applied at the growers' usual volume of water per acre, which varied from 30-200 gallons. The actual % concentration of active ingredient thus ranged from 0.02% - 0.13% a.i. There were no untreated control blocks but an adjacent equal area was treated with the grower's normal standard materials, which are listed in Fig. 8. This also shows the performance of NC 5016 and standards where the trials are grouped according to either a mean low (<3 mites) or a mean high (>12 mites) initial count per leaf.

Satisfactory fruit finish has been obtained, and no evidence of phytotoxicity observed on apples in these grower trials. In the United Kingdom the product appears, after extensive testing to be compatible with almost all products, commonly used in fruit growing, except emulsions of oil.

Concerning other crops, safety levels require further evaluation in individual territories, for example in South Africa conditions have thrown up problems which are being looked into. But the material can be expected to find uses on pears and hops, whilst in contrast vines are too sensitive.

The residue position is under close investigation and current data suggest that a safety interval of between 25-40 days may prove justifiable.

Resistance studies are in progress. At present there is no known cross-resistance to any other group of acaricides and attempts to select for resistance to NC 5016 under laboratory selection pressure have proved negative after 20 generations.

During the past two years, therefore, NC 5016 has proved to be an effective and promising new type of acaricide for use on top fruit, initially for use on apples.

ACKNOWLEDGEMENTS.

We gratefully acknowledge the assistance of growers and other collaborators, which has enabled extensive work to be done on this new and interesting acaricide.

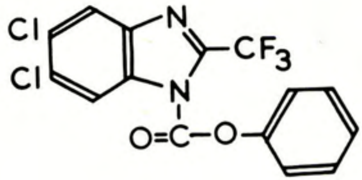
REFERENCES

1. Saggers, D.T., Clark, M.L. - 1967
"Trifluoromethyl-benzimidazoles - A new family of Acaricides" - Nature 215 (5098) pp. 275-276

2. Geering, Q.A. - 1966.
"Fenoflurazole - A new structure for Mite Control". Bull. Ent. Soc. America Vol. 12 No. 3 p. 305.

3. Geering, Q.A., Bond, J.A., Jones, A.J.
"Field results with a new acaricide, 5,6-dichloro-1-phenoxycarbonyl-2-trifluoromethyl benzimidazole". Proceedings of The International Congress of Acarology, Nottingham, 1967.

FIG. 1



5,6-Dichloro-1-phenoxycarbonyl-2-trifluoromethylbenzimidazole

FIG. 2

CONTROL OF T. TELARIUS ON APPLE (T. cinnabarinus)

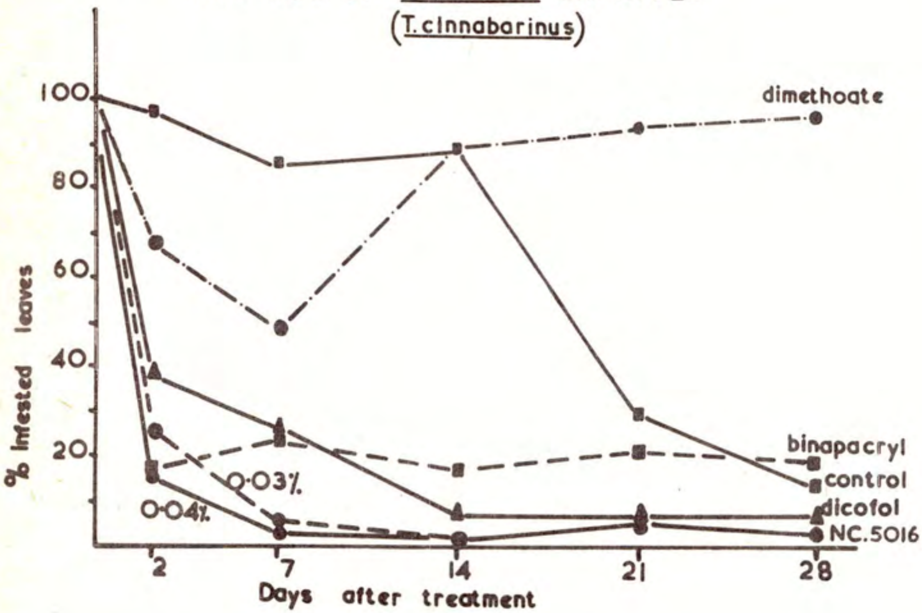


FIG. 3.

Control of *T. urticae* on Apples, 1967
Orange District N.S.W. Australia

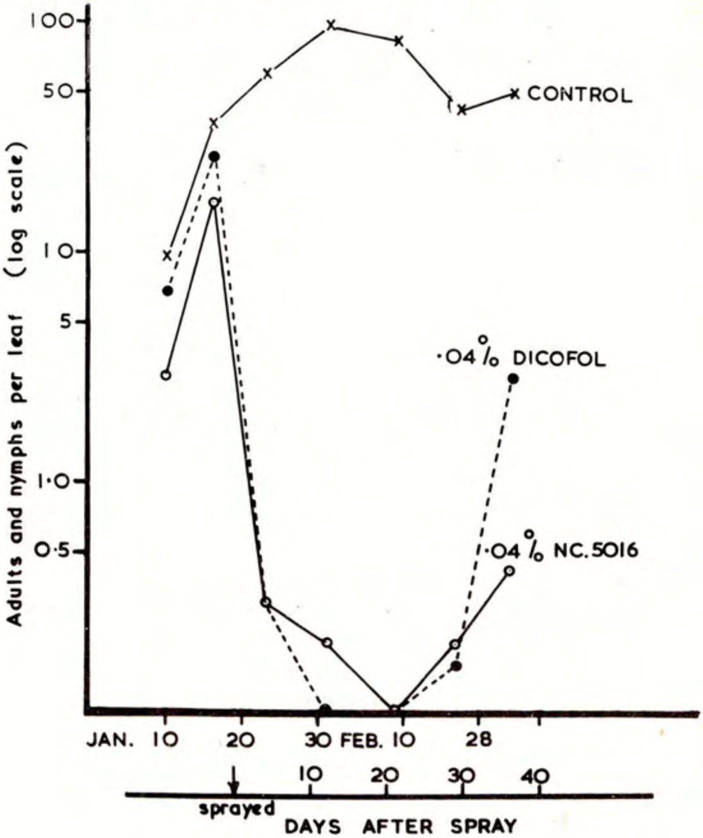


FIG. 4

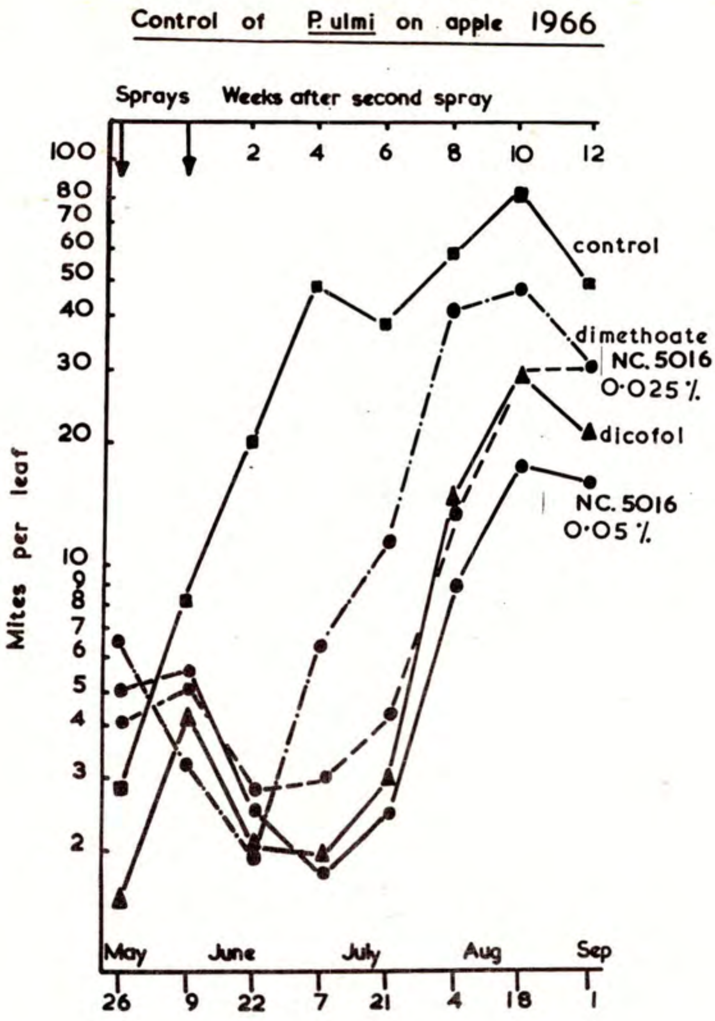

Control of P. ulmi on apple 1966
Sprays
Weeks after second spray
2
4
6
8
10
12
100
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
Mites per leaf
control
dimethoate
NC. 5016
0·025 %
dicofol
NC. 5016
0·05 %
May
June
July
Aug
Sep
26
9
22
7
21
4
18
1

FIG. 5.

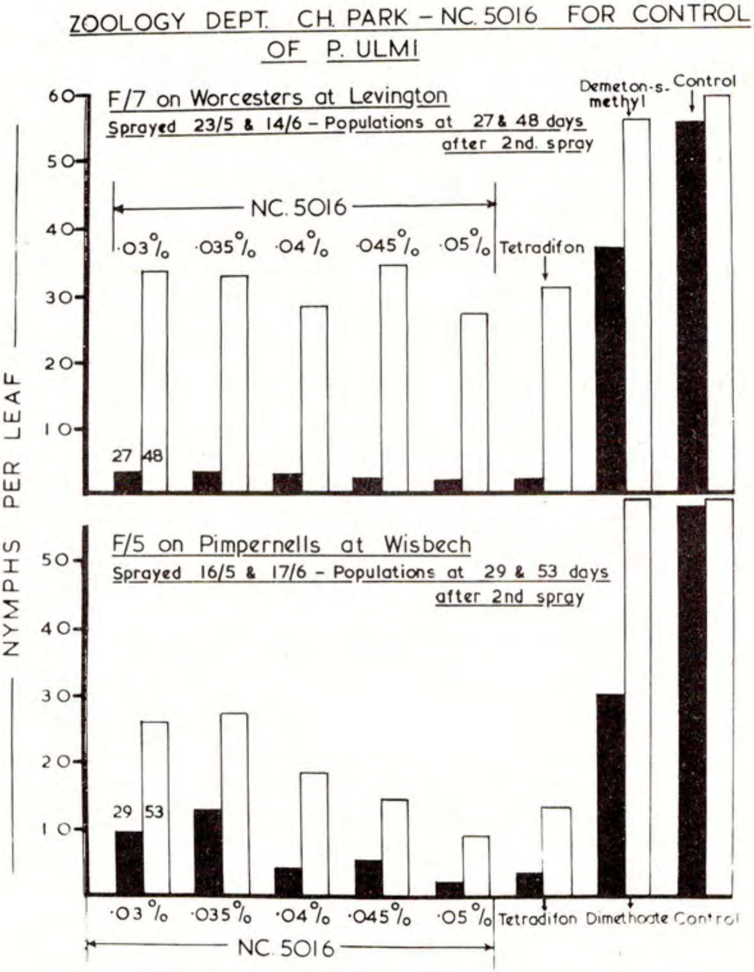

ZOOLOGY DEPT. CH. PARK – NC. 5016 FOR CONTROL OF P. ULMI
F/7 on Worcesters at Levington
Sprayed 23/5 & 14/6 – Populations at 27 & 48 days after 2nd. spray
NC. 5016
·03% ·035% ·04% ·045% ·05%
Tetradifon
Demeton-s-methyl
Control
27 48
F/5 on Pimpernells at Wisbech
Sprayed 16/5 & 17/6 – Populations at 29 & 53 days after 2nd spray
29 53
NYMPHS PER LEAF
·03% ·035% ·04% ·045% ·05% Tetradifon Dimethoate Control
NC. 5016

FIG. 6.

CONTROL OF P. ULMI ON APPLES
Bologna, Italy-1967

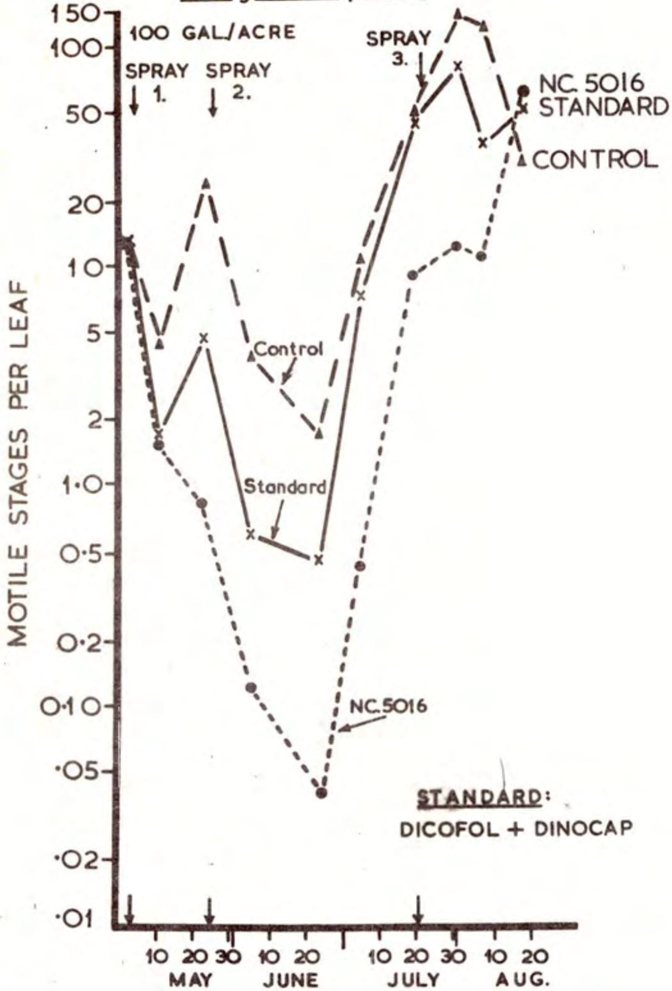


FIG. 7.

CONTROL OF P. ULMI ON APPLES – Bologna, Italy–1967

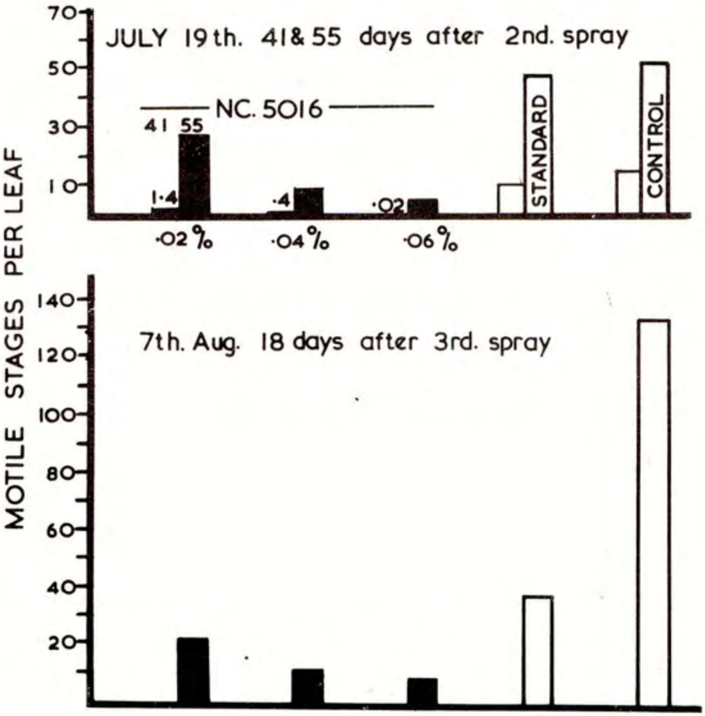
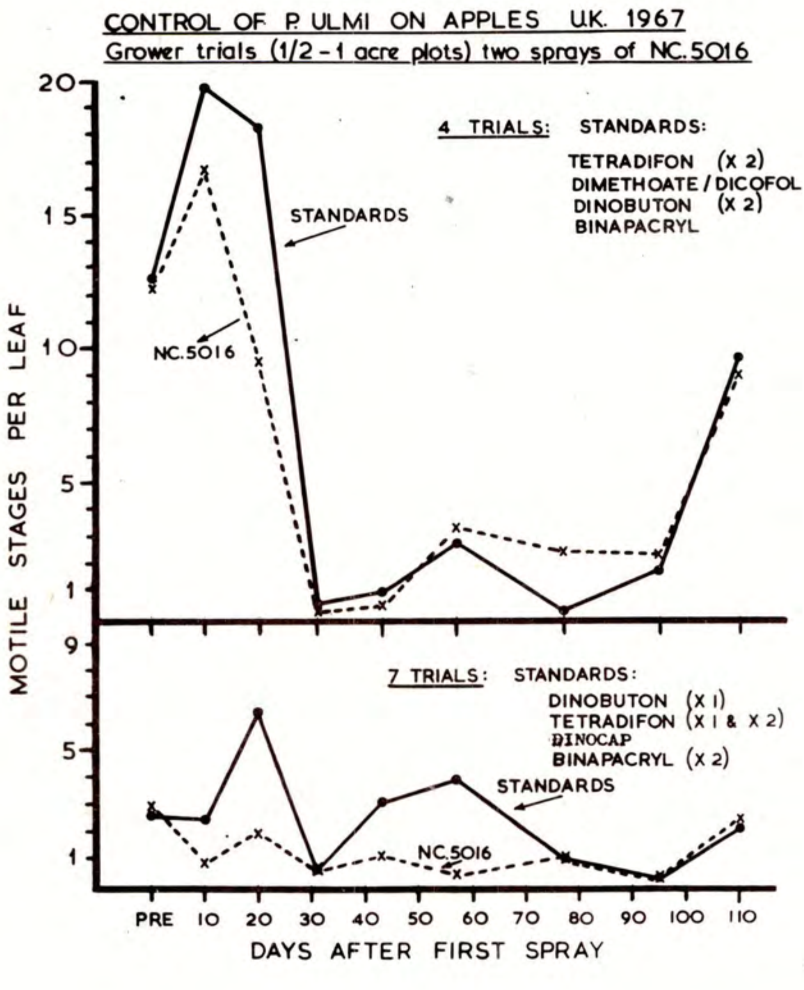


FIG. 8.



CONTROL OF P. ULMI ON APPLES U.K. 1967
Grower trials (1/2 - 1 acre plots) two sprays of NC.5016
4 TRIALS: STANDARDS:
TETRADIFON (X 2)
DIMETHOATE / DICOFOL
DINOBUTON (X 2)
BINAPACRYL
STANDARDS
NC.5016
7 TRIALS: STANDARDS:
DINOBUTON (X 1)
TETRADIFON (X 1 & X 2)
DINOCAP
BINAPACRYL (X 2)
STANDARDS
NC.5016
MOTILE STAGES PER LEAF
20
15
10
5
1
9
5
1
PRE
10
20
30
40
50
60
70
80
90
100
110
DAYS AFTER FIRST SPRAY

PEST CONTROL IN RELATION TO PROCESSING AND PREPACKAGING

P. W. Carden
National Agricultural Advisory Service, Olantigh Road, Wye
ASHFORD, Kent

Summary The impact on the grower of the processors' requirements for uniform, pest free, unblemished produce is discussed, with reference to problems met in practice.

Pests which reduce plant populations, delay maturity or stunt growth make it difficult to meet the processors' requirements. Tolerances for contamination with pests or their by-products, stray insects, pest damage or insecticide residues are very low, making a high standard of pest control necessary. This in turn leads to a very liberal use of insecticides which, with other recent developments in agriculture, may encourage the development of further problems.

Ways of achieving more economical use of insecticides are discussed, including the avoidance of routine treatments whenever possible and further development of sorting and grading techniques at the processing plant.

Mr. Bundy has discussed the significance of pest and disease damage in the production and marketing of vegetables and has shown why produce of high quality is required. I am going to look more closely at some of the problems of pest control involved in meeting the processors' requirements, with reference to particular problems met with in practice and then make some more general comments on the use of insecticides.

The processor has to plan a schedule of deliveries of produce to keep his plant working continuously without gaps or surpluses. This schedule must be based on forecasts of yields and dates of maturity. The first essential object for both processor and grower is to ensure that there is a full crop to harvest so that the forecast of yields can be fulfilled. This means taking steps to control those pests which may destroy part or all of the crop. Soil pests that may reduce plant populations are of importance here and control measures may be advisable against, for example, wireworms (Agriotes spp) on many crops, or bean seed fly (Delia cilicrura and D. trichodactyla) on runner beans. These measures usually have to be used as a routine unless forecasting of attacks is possible.

Any pest that speeds up or delays maturity of the crop, such as cabbage root fly (Erioischia brassicae) on cauliflowers, will tend to upset the schedule of deliveries for the processor and make harvesting more difficult for the grower. The ideal situation for the grower is where the whole crop can be cut on one occasion so that he can then clear the ground and plant something else.

The requirement for a uniform product also means that any pest that reduces the vigour of a plant without killing it may reduce the quality of the product out of all proportion to the actual loss of weight. For example, in addition to preventing many cauliflower plants from producing heads cabbage root fly causes considerable variation in the size of head so that even a fairly light attack can be important.

Other pests which reduce the value of the crop more by upsetting the uniformity of the product than by their direct effect on yield are those which transmit virus diseases that slow down growth, such as the willow-carrot aphid (Cavariella aegopodii) which transmits carrot motley dwarf virus. In occasional years when this aphid is numerous and there are adequate sources of the virus in the spring, the infection of early carrots may approach 100 per cent, with complete crop failure sometimes occurring. The aphids, which also cause considerable direct damage to the crop, are fairly easily controlled with systemic insecticides, but they will frequently pass on the virus to healthy plants before they die.

The second main object for the grower is to prevent contamination of the crop by insects and other pests. It has been said that every maggot or caterpillar in a tin or packet of frozen vegetables represents a lost customer. With the competition that exists in this trade the processors cannot afford to lose even a fraction of one per cent of their customers and therefore they allow very low tolerances for foreign bodies or damaged produce. On the other hand, most insecticidal treatments are only 80-90 per cent efficient and this just is not good enough under these circumstances. Species causing trouble in this way may be recognised pests of the crop in question or they may be other organisms which come into their own as pests specifically because the crop is to be processed. Contamination of the crop may be direct, by the bodies of one stage or another of the pest, or indirect, by by-products of the pest such as cast skins, honeydew or frass. In either case control measures must be applied in good time, or frequently as a preventive measure before the pest appears. Above all, the control given must be extremely efficient.

Examples of direct contamination of the crop are cabbage root fly maggots in Brussels sprout buttons, pea moth (Laspeyresia nigricana) and mangold fly (Pegomyia hyoscyami) in spinach. Mr. Coaker and Mr. Ensor will be dealing with the first of these in the next paper. For pea moth we have materials which will control most of the maggots but to be fully effective they must be applied at the right time - to kill the newly hatched larvae before they enter the pods. In the pea growing areas of East Anglia the pea moth spray warning scheme run by the National Agricultural Advisory Service, which is based on detection of the beginning of egg laying, has considerably improved the timing and efficiency of these sprays against pea moth although there is still room for further improvement. For mangold fly on spinach, where the larvae as well as the leaf mines may be troublesome during processing, treatment must be timed to coincide with egg-laying and in addition a non-toxic insecticide or one that breaks down in a day or so, such as trichlorphon or malathion, must often be used when egg-laying takes place within a few days of harvesting.

The contamination of crops with by-products of a pest can be equally serious. The aphids are particularly notorious in this respect, notably the cabbage aphid (Brevicoryne brassicae) on brussels sprouts, which fouls the product with cast skins, parasitised aphids and indirectly with the predators attracted by the colonies. Once again any control measure for the pest must be preventive - once aphids have colonised the sprouts there will be cast skins and corpses present even if the crop is treated effectively, and to the housewife a dead aphid is almost as objectionable as a live one. Systemic insecticides have proved invaluable in dealing with this pest and particularly certain of the granular materials with their relatively long persistence. However it has shown how inefficient some of our spraying has been in the past; in a dry summer when the crop stops growing there is insufficient movement of sap to carry the systemic materials round the plant with the result that many aphids not hit directly by the spray can survive. Unless irrigation is available really efficient spraying or granule application is necessary to keep the developing sprouts clean in drought years.

Pea aphids may also merit treatment because of the honeydew they deposit on the plant even when their numbers do not justify treatment in terms of direct effect on yield. The honeydew attracts fungal infections such as Botrytis and moulds and if the amount is serious it can hinder the functioning of the machinery handling the peas.

Particular problems are raised for the grower by some pests or stray insects that turn up in the harvested product in occasional seasons only, for example silver Y moth caterpillars in peas. The silver Y caterpillars are only noticeable perhaps one year in six when there has been a major invasion of the adult moths from the continent. In this occasional year the larvae, which probably feed on weeds rather than on the actual crop, may be very numerous and can cause trouble at the pea viner, or odd larvae of suitable size may go through the processing with the peas and turn up in the finished article to the embarrassment of the firm concerned. Although the last serious outbreak of silver Y moth caused problems in 1966 we hope to be in a position to give advance warning of the next serious outbreak. Light traps are operated in several areas to enable us to follow the activity of adult codling moth (Cydia pomonella) and other species, and catches of silver Y moth are now being recorded. In the event of abnormal numbers of this species being caught we will be able to issue a warning to growers to look out for the caterpillars in crops where they would be a nuisance.

Other, even less predictable, problems may occur such as a crop of spinach for canning which was rejected because of the presence of small, unidentified flies. It was suggested that their larvae had been feeding on the pea haulm that was ploughed in before the spinach was sown. The only practical answer to this type of sporadic problem, which can easily get out of hand before it is noticed, appears to be continual vigilance on the part of the grower. Unfortunately with the ever-increasing pressure on management from other directions it becomes more and more difficult to maintain this vigilance. Advisers, processors' fieldmen and the pesticide industry's representatives can also help after the first case of trouble has been spotted, by warning growers to be on the lookout for the same problem elsewhere.

In addition to direct contamination of the harvested crop by the pest or its by-products the damage caused by the pest may be equally important, as for example, carrot fly (Psila rosae) damage on carrots or parsnips. Here again the very low tolerance for damage is the main difficulty. In addition the processors and pre-packers, and therefore the growers, want to lift carrots continuously for up to ten months of the year. This is achieved by a succession of sowings from February to July, but even so protection of the roots of certain sowings is required for up to six or seven months. I am going into more detail on the control of carrot fly on carrots and parsnips than may seem justified in this particular paper because of the interest in the problem which does not seem to be covered elsewhere in this session.

Carrot fly may be controlled either by treatments directed at the adults at the time of egg laying, or by soil treatments directed at the larvae. The dieldrin soil treatment developed at the National Vegetable Research Station gave an unusually high degree of control for an insecticidal treatment and its withdrawal left a serious gap in our crop protection defences. However, considerable progress has now been made in filling this gap, at least on mineral soils.

The protection of early carrots, which are to be lifted before the second generation carrot fly attack in August and September, presents few difficulties because the time between drilling and the first generation attack is relatively short. For carrots to be lifted from September onwards, a granular formulation of chlorfenvinphos, diazinon, disulfoton or phorate, or a chlorfenvinphos spray worked into the soil, may be used on mineral soils. Disulfoton and phorate have the additional advantage of controlling the willow-carrot aphid for some weeks. On peat soils, where adsorption of insecticides on the organic matter reduces their effectiveness, either diazinon or phorate are recommended, but it is doubtful whether they persist long enough to protect all drillings throughout the attack. The processors' requirements for size and uniformity of carrot affect the method of application of the granular materials. Carrots may be grown in the traditional rows, or in order to obtain as many carrots as possible in a particular size range (which may be quite narrow), they may be grown on the "bed system" devised by Dr. Bleasdale at the National Vegetable Research Station. The granular materials may be applied to carrots grown in rows by drilling by the "bow wave" technique - that is to deliver the granules from a suitable applicator onto the soil just in front of the seed coulter, so that the seed is drilled through the granules. This gives enough mixing into the soil to cover the granules and to avoid any adverse effect on germination. However, if the carrots are being grown on the bed system it is necessary to broadcast the granules onto the beds or the whole area and cultivate them into the soil during preparation of the seed bed.

For this method a rather higher rate of application must be used, although this may be limited by the need to avoid the risk of toxic residues left on the crop at harvest time.

Foliar sprays have so far not been very effective against carrot fly, partly because of the period of activity of the adults which lasts for several weeks, as the second generation is more protracted than the first. This means that a relatively long period of protection of the crop is required and therefore several applications of insecticide. Little work has been done in this country so far with the newer insecticides used in this way although some have been tried by the National Agricultural Advisory Service in the Fens this year. It is hoped that the results will be available in time for the conference.

Another type of problem arises from the fact that crops for processing naturally tend to be grown within easy reach of the processing plants. This results in some degree of concentration of particular crops in certain localities where the soil and climate are suitable for these crops. Thus ideal conditions are provided for pests or diseases to build up over the years. There is some evidence that this has happened with pea moth (Laspeyresia nigricana) and pea root eelworm (Heterodera göttingiana).

Having laid down very strict standards for freedom of produce from pests or pest damage the processors very properly, add equally strict standards for freedom from residues of insecticides. So the grower has to attempt a high levelof pest control while keeping within the restrictions in force on the use of poisonous substances in agriculture laid down by the Ministry of Agriculture and in addition the residue tolerances of the processors. These will frequently prevent him from using what is otherwise the most suitable insecticide, or time of application, for a pest that attacks near to the harvesting date for the crop.

So we have the situation where the growers are expected to grow produce to a very high standard of uniformity, with freedom from pests, pest damage and residues. The need for these high standards inevitably leads to the use of numerous applications of insecticides including a great deal of routine use or "insurance" applications in case pests appear. I think it is fair to say that in fact we are using insecticides too freely in certain areas and that we are inevitably building up more problems for ourselves by way of resistance of pests to insecticides or of upsurges of minor pests or previously harmless species, making more and more insecticidal use necessary. We already have several examples of this such as resistance to the organochlorine compounds in cabbage root fly, carrot fly and probably inbean seed fly. I think it is significant that these and some other new problems have generally appeared on farms where insecticide applications have been heavy over a period of years. If you think that I am painting too black a picture I suggest that you ponder on the position we would be in if resistance to the organophosphorus materials became widespread in two or three main aphid pests. There have already been signs of this happening in a number of localised populations as for example a strain of the Peach and Potato aphid (Myzus persicae) on sugarbeet stecklings in southern Sweden.

We know that all agriculture and horticulture upsets the balance of nature but we must not forget that this imbalance becomes more and more severe with recent developments in other directions such as removal of hedgerows, reclamation of wasteland and the very widespread use of herbicides. These changes all increase the pressure on the innumerable parasites and predators which help to maintain the stability of animal communities. There are many examples in the literature of population explosions of pests following over-simplification of the environment, whether by monoculture, removal of natural flora, or the use of insecticides. These problems of the future will make the growing of crops of high quality more difficult, and therefore more expensive, which will affect all of us whether we are insecticide manufacturers, processors, growers or consumers.

Growers are always willing to point out that the processors pay the lowest price possible for their produce, but the fact remains that there is an element in this price to cover the cost of pest control. If the cost of controlling pests rises, the price for the crop will have to be adjusted accordingly or the growers may have to tell the processors to look elsewhere for their raw material, so it is in the interest of all parties to keep down the costs of measures against pests.

What can we do to minimise the problems of the future? Firstly, we must keep a continual watch to ensure that insecticides are being used as effectively as possible. The insecticide industry is particularly anxious to help in this respect. All of us must realise that it is always wrong to use an insecticide unnecessarily and we must look very critically at the use of routine "insurance" treatments. This may not be in line with current "managerial" thinking because it may be easier to treat a crop than to keep looking for the arrival of pests, but if these treatments lead to the appearance of new problems, as they may well do, it would have proved cheaper in terms of managerial time to keep a look out for trouble in the first place rather than to treat unnecessarily. One place where there might be room for improvement is in the recommendations for pest control made by the processors for use on crops being grown on contract. I suggest that they ask themselves - is each routine treatment really justified and is it necessary on ALL drillings of a particular crop, or are only certain drillings liable to attack? At Cambridge some years ago we were able to reduce routine treatments of celery against carrot fly in the fens, with substantial savings to the growers, when we found that 50-65 per cent of the crop was planted out after egg laying by carrot fly had finished so that treatment of these later crops was unnecessary. It may well be that experimental work is needed before some of these questions can be answered and if so this is work that should be done.

In addition to the forecasting and spray warning schemes already in operation I am sure there are other pests for which such schemes could be developed to reduce the amount of routine treatment and improve the efficiency of those control measures that are still necessary.

I think that this approach to the efficient use of insecticides would come under the heading of integrated control and other ways of integrating control measures must be looked for. I am afraid that beyond avoiding the use of chemicals where possible, there is not much scope for biological control on crops for processing, because of the low tolerance for pest damage.

Another approach which could reduce the importance of many pest problems in the field is the further development of mechanical and electronic sorting and grading techniques at the processing plant. I am quite sure the firms are very much aware of the advantages of this approach because of the incentive of the shortage and cost of labour, but improvements in this direction would give substantial advantages in the field in addition to those in the factory if standards for freedom from foreign bodies and damaged produce could be eased.

To sum up - the high standard of produce required by the processors and prepackers can be met only by very considerable usage of insecticides. Chemical control at this level is likely to encourage the development of even more difficult problems and every effort should be made to make the most efficient use of insecticides and to avoid unnecessary use whenever possible. It is in all our interests - manufacturers, processors, growers and consumers - to avoid or combat pest attack by cultural or other methods as well as insecticides and where possible to introduce improved methods of grading produce.

CONTROL OF CABBAGE ROOT FLY ATTACK ON BRUSSELS SPROUT BUTTONS

T.H. Coaker
National Vegetable Research Station, Wellesbourne, Warwick

H.L. Ensor
Unilever Research Laboratory, Colworth House, Sharnbrook, Bedford

Summary The occurrence of dipterous larvae in the axillary buds (buttons) of Brussels sprouts was investigated in 1963-66. At Wellesbourne the most severe infestations occurred on early crops harvested in August in which up to 10 percent of the buttons were damaged by cabbage root fly larvae. Most of the damaged buttons were on the lower part of the stem and were present on only a small proportion of the plants. Laboratory and field tests of insecticides showed that trichlorphon gave up to 88 percent control. The principles involved in the insecticidal control method are discussed.

INTRODUCTION

With the increasing demand for high quality Brussels sprouts by processors, the control of dipterous larvae in the axillary buds (buttons) has become economically important. The principal species involved are the cabbage root fly (*Erioischia brassicae* (Bouché)) and the bean seed fly (*Delia cilicrura* (Rond)). Eggs are laid between, or in, the folds of the outer bud leaves. They may be found as soon as the leaves have expanded away from the young buds and throughout the later button development. On hatching, the larvae tunnel into the buttons and feed on the inner leaves. Larvae that complete their development before harvest move outwards to pupate in the soil, leaving obvious exit holes in the sprouts, but younger larvae remain hidden within the buttons. Secondary rotting of damaged material is frequently present (Coaker, 1966).

The cabbage root fly is more abundant than the bean seed fly on both early and late crops but the damage caused by both species has been combined in the results which are discussed. Two other flies, *Pegohylemyia fugax* (Meigen) and *Muscina assimilis* (Fall) are also found but principally in association with damaged or decaying buttons.

Development of the infestation

The numbers of cabbage root fly eggs and larvae on the early variety Jade Cross and the later variety Cambridge Special were recorded each year from 1963 to 1966. In each year, eggs were found on the early crop within 10 days of the young leaves expanding away from the buds. Maximum egg laying on this crop was reached within the following 20-30 days. More eggs (10/plant) were laid on the early crops in 1963 than on similar crops in the other years (3-5/plant). This was possibly due to the prolonged sunny conditions favourable for egg laying during June and July in that year, coinciding with the oviposition period for second generation flies (Miles, 1953).

Larval infestation reached a peak 15-20 days after maximum egg numbers were recorded and many of these larvae had left the buttons to pupate by the time the crops were harvested in mid to late August. At Wellesbourne the attack on early crops damaged up to 12 percent of the buttons. However in late crops, harvested in October, a maximum of 0.5 percent were damaged. This was not typical of some other late crops grown elsewhere in other localities where the infestation was higher than at Wellesbourne.

Distribution of eggs and larvae on the crop

No consistent differences were found between the number of eggs laid on plants grown at 18 in x 18 in spacing and on plants grown at 36 in x 36 in. However, there was a relationship between the number of eggs laid and the bud position. The lower buttons were preferred oviposition sites and 60 percent of the total eggs laid on Jade Cross plants were on the lower 20 buttons and 90 percent on the lower 40 buttons. On average 15 percent of the buttons contained eggs, about half of these containing one egg and the remainder 2-12 eggs. The larvae recorded were similarly distributed but only about 12 percent of the buttons were affected suggesting a failure of eggs to develop due to predators or physical causes.

Insecticide control

As the eggs are protected by leaves it was considered that insecticides with translaminal as well as contact activity would be advantageous. Of the insecticides tested in the laboratory for effectiveness against eggs and larvae, trichlorphon, diazinon and azinphos-methyl were selected for field trials. Three sprays of 0.1% trichlorphon, applied to run off, at 14 day intervals and commencing 5 weeks before harvest gave the best results. This treatment reduced the number of damaged sprouts by 60 percent but this was not considered satisfactory for practical use. Comparisons of different spray programmes showed that better control was achieved by increasing the number of trichlorphon sprays and reducing the intervals. This could be due to the short active life of the insecticide and to the rapid development of the buds. The best results were obtained from four sprays of 0.1% trichlorphon applied at weekly intervals starting 28 days before harvest. This period of insecticidal cover is equivalent to the time taken for the completion of egg and larvae development.

Spray cover

As trichlorphon acts as a contact toxicant it is essential to obtain a good spray cover over all the buttons, particularly those on the lower part of the stem. This was achieved by using a tractor mounted sprayer applying the spray from a boom carrying one hollow cone nozzle above each row and semi-rigid drop arms between the rows, each arm carrying two nozzles set 6-9 in above the ground which sprayed the plants from either side as they passed between the rows. As the plants become mature the leaves bend downwards and are liable to protect the lower buttons from the spray. This was overcome by siting the lower nozzles on short right-angled arms behind the end of each lance. The vertical lances then pulled the leaves forward exposing the buttons to the spray from the trailing nozzles.

Comparisons of two types of commercially available nozzles, used in the overhead and drop lance positions, are shown in Table 1. Sprays were applied at three stages of crop growth of Jade Cross grown in 18 in rows.

Table 1.

Spray cover scores on the top, middle and bottom sprouts using different nozzles

Sprays applied (weeks pre-harvest)	Cone nozzle Top	Middle	Bottom	Mean	Fan nozzle Top	Middle	Bottom	Mean
5	2.7	2.7	1.0	2.1	2.4	1.8	0.2	1.5
3	2.8	2.9	2.4	2.7	2.3	2.8	2.1	2.4
2	2.9	2.7	1.9	2.4	3.0	2.4	1.9	2.4
				2.4				2.1

Score:- 0 = No droplets
3 = Complete cover

Spray:- 50 gal/acre at 60 p.s.i. and 2 m.p.h.

The results showed that cone nozzles provided a spray cover that equalled or exceeded the cover from fan nozzles and that cone nozzles minimised the effect of the time of application on spray cover.

The results of four trials done on crops in East Anglia to test the commercial reproducibility of the plot results are given in Table 2.

Table 2.

Control of cabbage root fly larvae in commercial crops grown on four sites in East Anglia

(Trichlorphon at 1 lb a.i./acre)

Treatment	Date	Control (%) Site/1	2	3	4	Mean	Mean % sprouts with larvae (x) Log (AX + B)	Sampled Site	Date
1 spray	- - 20/9	36	0	100	0	34	1.199	1	24/9
2 sprays	- 6/9 20/9	95	6	100	100	75	0.397	2	7/10
3 sprays	19/8 6/9 20/9	100	69	87	15	68	0.626	3	6/10
0 spray (% sprouts with larvae)		(0.40)	(0.35)	(0.23)	(0.60)		1.420	4	27/9
Sig. diff. (P = 0.05)							0.210		

A = 100 B = 1

The two and three spray treatment gave about 70 percent control of the larvae thus agreeing well with the plot trial results, but there was poor reproducibility between sites, probably due to the low level of infestation.

DISCUSSION

The most active oviposition period is in June and July but eggs are laid up to early November. Therefore Brussels sprout crops that reach maturity between August and late November are liable to attack. It is more likely that early crops will suffer the heaviest attacks and this agrees with commercial experience. Infestation of later crops may be sufficiently severe to warrant control treatments particularly if quality sprouts are desired. The distribution pattern of larvae on the plants indicates clearly the need for effective cover of the lower sprouts by the spray. This operation is best done by using the longer, more rigid lances which hold the nozzles at the correct height and also expose the sprouts by moving obstructing leaves.

Trichlorphon at 1.0 lb a.i./acre in 50-100 gallons of water per acre has now been used commercially for three years. The current recommendations specifies three, weekly applications, commencing 28 days before harvest. Although this has resulted in a substantial reduction in the proportion of infested sprouts there is still a need for improved control measures. This could possibly be obtained by the use of heavier and more elaborate spraying equipment to give better spray penetration. There is also a place for an insecticide with a longer persistence than that of trichlorphon although frequent spraying might still be necessary to protect freshly exposed leaf surfaces on the button.

References

COAKER, T.H. (1966) Ann. appl. Biol., 59, 339.

MILES, M. (1953) Agriculture, Lond., 60, 87.

CONTROL OF CARROT FLY ON CELERY

by W. J. Bevan
National Agricultural Advisory Service, Leeds

In England and Wales over 5,000 acres of celery are grown for market and processing. Most of the acreage is in the Fens of the Eastern counties but approximately 1,000 acres are grown on the moss lands of South West Lancashire. The peat soils are naturally acid and overlay raw peat, many feet deep.

About 80% of the acreage in Lancashire is main crop celery - mostly white types with some late or resistant Pink. These are grown in rows about 5 ft 6 in apart with plants 7 in apart within the row giving about 14,000 plants per acre. Early in the season lettuce is inter-cropped with the celery. The self-blanching type is grown on beds 18 in apart, 4 rows 12 in apart on each bed and the plants 10 in apart within the row, giving some 45,000 plants per acre.

There are two generations of carrot fly in Lancashire. The first generation of flies start emerging towards the end of May, somewhat later than in the southern half of England. Flies are usually active in large numbers in June and most of July. Second generation flies appear in late August and September, usually in relatively small numbers.

In Lancashire planting starts in May and continues into June, so that crops are being attacked in the period of early growth. The carrot fly larvae feed in the roots and crown of the celery plant. The bases of the outside leaves may also be mined. Attacked plants are stunted and show yellowing of the leaves. All types of celery may fail due to attack but the self-blanching types are the most susceptible to damage, then the dwarf white types, followed by the white main crop types and the least susceptible is the late or resistant Pink.

Control

Thomas and Bevan (1956) showed that Gamma BHC, aldrin and dieldrin gave good control of carrot fly on celery and these materials have been used until the last few years. Gamma BHC is still being used as a dip treatment by some growers. Adequate control is achieved when a dip containing 5% a.i. is used. Dip treatments are relatively cheap but, in some seasons, can cause check to the seedlings, the severity being directly related to the dryness of conditions at and following planting. An oil free liquid formulation is used and this causes somewhat less check than other formulations under similar conditions. In 1964, a survey showed that 75% of the growers were using such dips.

Several organophosphorus compounds have been tested in the field over the years and this paper summarises the work carried out in South West Lancashire.

In the early 1960's it was found that diazinon, ethion, phosphamidon, fenchlorphos and mecarbam used as drenches would control carrot fly on celery (Bevan 1964). Granule formulations of diazinon, disulfoton and phorate were shown to be effective against this pest on carrots at Wellesbourne (Wright 1965).

Granule formulations of chlorfenvinphos, diazinon and mecarbam at 2.0 lb a.i. and disulfoton at 1.0 lb a.i./acre were found to be effective in controlling heavy attacks of carrot fly (Bevan 1966). One of the main aims of the trials in recent years has been to find an effective and practical method of application.

A Horstine Farmery applicator was mounted on the celery planter and the granules delivered into the planting furrow as the seedlings were being planted. The granule delivery tube was placed in a position which caused some granules to be trapped in the vicinity of the root system as the press wheels closed the furrow. This method was found to be effective in a trial with self-blanching celery in 1965.

Table 1.

Application of granules by applicator mounted on mechanical planter 1965

Insecticide formulation	Active ingredient in lb per 30,000 plants	Wt. (lb) of 10 plants per plot
5% mecarbam granules	2.0	12.6
5% diazinon granules	2.0	14.3
10% chlorfenvinphos granules	2.0	13.3
No treatment	Nil	0.8

In 1966 a similar trial was carried out with self-blanching celery using the same materials and also disulfoton granules. Granules were applied in two ways - (i) in to the furrow as in 1965 and (ii) in a 3 in wide band on the soil surface in front of the share of the planter and the seedlings planted through this band. (Bow wave technique).

There was no replication of treatments, plots were 30 yards long. There were two untreated plots.

Table 2.

Application of granules by applicator mounted on mechanical planter 1966

Self-blanching celery

Insecticide formulation and method of application	Active ingredient in lb per 30,000 plants	Wt. (lb)of 10 plants per plot
5% diazinon granules - furrow	2.0	19.8
5% diazinon granules - bow wave	2.0	7.5
4% mecarbam granules - furrow	2.0	14.0
4% mecarbam granules - bow wave	2.0	3.9
10% chlorfenvinphos granules - furrow	2.0	15.3
10% chlorfenvinphos granules - bow wave	2.0	7.9
7.5% disulfoton granules - furrow	2.0	15.8
7.5% disulfoton granules - bow wave	2.0	14.3
No treatment	Nil	1.9
No treatment	Nil	2.8

All four insecticide granules applied as furrow treatments gave good control but only disulfoton appeared to give a reasonable degree of control as a bow wave treatment.

When a planter share moves through the soil and a band of granules on the soil surface, there is a considerable sideways movement of granules and soil, the deeper the furrow the greater the movement. It is likely that soil conditions will affect the amount of movement of the granules. In this trial some granules were found 10 in away from the transplanted seedlings and relatively few in the immediate vicinity of the roots, this was in marked contrast to the position of granules applied in to the furrow.

In 1967, trials were designed to investigate further the methods of placement of granules using Horstine Farmery applicators mounted on a mechanical planter. Granule formulations of chlorfenvinphos, mecarbam, disulfoton and phorate were used at 2.0 lb a.i./45,000 plants.

Four methods of application were tried; (i) granules delivered directly into the furrow as the seedlings were planted, (ii) granules delivered on the soil surface after planting, (iii) granules applied into the soil at a depth of 3 in using a coulter with the delivery tube attached in front of and in direct line with the planter share; and (iv) granules applied into the soil at a depth of 6 in using a coulter with the delivery tube attached in front of the planter and in direct line with the planter share.

Table 3.

Application of granules by applicator mounted on mechanical planter 1967

Self-blanching celery

Mean Wt. (lb) of 10 plants per plot

Insecticide	Furrow	Surface	Soil-3 in	Soil-6 in	Mean
Chlorfenvinphos	13.2	11.2	16.1	13.2	13.4
Disulfoton	13.4	12.5	15.8	12.2	13.5
Mecarbam	15.2	12.4	16.3	13.6	14.3
Phorate	13.7	13.8	14.3	12.6	13.6
Mean	13.9	12.5	15.6	12.9	
No treatment	10.5	10.5	10.5	10.5	

Insecticides applied at 2.0 lb a.i./45,000 plants per acre.

Although only a light attack occurred in this trial there are indications that all insecticides gave:- (i) reasonably good control when placed into the furrow when the seedlings were being planted; (ii) less effective control when applied on the surface following planting; (iii) very good control when placed into the soil at a depth of 3 in and (iv) only fairly good control when placed in the soil at a depth of 6 in.

Observations in the field, using "traced granules" and Ultra Violet light equipment, indicate that a greater concentration of granules occur in the soil around the seedling's root system when granules are applied in front of the planter into the soil at a depth of 3 in than with any of the other methods of application. When applied into the planting furrow some granules fall to the bottom of the furrow and some are trapped in the soil immediately around the roots. When granules are applied at a depth of 6 in, none are brought into the area immediately around the seedling's root system.

In another trial carried out in 1967, using Late Pink Celery, the granule treatments were applied into the soil at a depth of 3 in using a Horstine Farmery Microband applicator mounted on a wheel barrow frame. The seedlings were planted with a mechanical planter into the bands of treated soil.

Chlorfenvinphos, disulfoton, phorate, mecarbam and ethyl ethoate granules were used at the rate of 1.0 lb a.i./14,000 plants (approximately an acre of maincrop celery).

Table 4.

Granules applied at a depth of 3 in - maincrop celery, 1967

Insecticide	Active ingredient in lb per 45,000 plants	Mean Wt. (lb) of 10 plants	Percentage plants damaged	
			Light	Heavy
Granules				
Chlorfenvinphos	1.0	18.0	0	0
Disulfoton	1.0	17.1	0	0
Phorate	1.0	15.8	2.5	0
Mecarbam	1.6	15.9	0	0
Mecarbam	1.0	15.9	0	0
Ethyl Ethoate	1.0	6.7	17.5	80
No treatment	Nil	4.4	0	100
L.S.D. (P = 0.05)		4.5		
(P = 0.01)		6.0		
(P = 0.001)		8.0		

Ethyl ethoate was relatively inefficient against carrot fly larvae. Chlorfenvinphos, disulfoton, phorate and mecarbam treatments appeared to be equally efficient.

Control of carrot fly in self-blanching celery grown from seedlings in soil blocks

Small acreages of self-blanching celery are grown for the early market and the seedlings are pricked out into soil blocks or boxes of soil under glass. The seedlings together with the soil around the roots are hand planted. It is convenient for any treatment for carrot fly control to be applied to the soil into which the seedlings are pricked out or to the seedlings within a few days of planting in the field.

Experiments on the incorporation of insecticide into the potting soil used for making soil blocks showed that mecarbam used at 4.0 lb and 2.0 lb a.i./50,000 plants was phytotoxic. Diazinon and fenchlorphos, were not phytotoxic and both gave good control of carrot fly. (Bevan 1966).

The easiest method of treatment is for an insecticidal drench to be applied to the seedlings and soil prior to planting out. In 1966 and 1967 drenches of mecarbam, chlorfenvinphos, diazinon, trichlorphon and ethyl ethoate were compared with aldrin and dieldrin on the self-blanching variety - Lathom. Each drench was applied at 0.5 fl ozs per plant two days prior to planting out in the field. Only a very light attack occurred in the trial in 1966 and the weights of plants receiving the insecticidal treatments were not significantly different from the untreated, apart from those treated with trichlorphon which was phytotoxic. This treatment caused an 18% loss in yield compared with the untreated plants.

In the 1967 trial a heavy attack occurred, trichlorphon was not used and none of the treatments were phytotoxic.

Table 5.

Insecticide applied to self-blanching celery in soil blocks, 1967

Insecticide	Active ingredient in lb per 50,000 plants	Mean Wt (lb) of 10 plants	Percentage plants damaged	
			Light	Heavy
Aldrin (e.c.)	1.6	4.2	56	0
Chlorfenvinphos (e.c.)	2.0	7.3	0	0
Diazinon (w.p.)	2.0	7.6	0	0
Mecarbam (e.c.)	1.0	7.4	0	0
Ethyl ethoate (e.c.)	2.0	2.8	0	100
No treatment	Nil	0.7	0	100
L.S.D. P = 0.05		2.24		
P = 0.01		3.07		
P = 0.001		4.24		

There was no evidence in this trial of phytotoxicity but mecarbam was used at 1.0 lb a.i./50,000 plants and the seedlings were a few weeks old with a well established root system in the soil blocks when the treatment was applied.

The yields in this trial were relatively low - this was due to late planting, no nitrogen top dressing and very wet soil conditions.

The mecarbam, chlorfenvinphos and diazinon treatments gave good control, ethyl ethoate little or no control and aldrin gave relatively poor control, 56% of the plants showed light damage due to carrot fly attack, and a loss in yield of about 40% compared with the best treatment. Bevan (1964) using a similar rate of aldrin on dwarf white celery plants, 0.5 lb a.i. on about 14,000 plants, obtained inadequate control and a similar decrease in yield compared with aldrin at the 4.0 lb.a.i. rate. At present there would appear to be no firm evidence of organochlorine resistant strains of carrot fly on this holding, since aldrin at 2.0 lb a.i./14,000 plants (maincrop) and gamma BHC dip gave good control in another trial on this same holding in 1967.

References

THOMAS, J.D., and BEVAN, W.J. (1956) Investigations into the control of carrot fly on celery. Pl. Path., 5, 115-9

BEVAN, W.J. (1964) Control of carrot fly in celery. Expl. Hort. No.11, 51-8

WRIGHT, D.W. (1965) Alternatives to organochlorine insecticides for the control of carrot fly and cabbage root fly. Ann. Appl. Biol. 55, No.2, 337-340.

BEVAN, W.J. (1966) Control of carrot fly on celery with notes on other pests. Pl. Path. 15, 101-108.

LABORATORY METHODS FOR THE STUDY OF DOWNY MILDEW DISEASES

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

Summary Peronospora parasitica and Bremia lactucae were cultured on detached cabbage and lettuce cotyledons respectively, incubated in moist plastic boxes.

Detached cabbage cotyledons were used in laboratory protectant and eradicant tests of fungicides. The most successful protectants were captafol ("Difolatan"), "Daconil 2787", dichlofluanid, dichlone, propineb (mezineb), thiram and captan. None of the chemicals eradicated infection when applied after the fungus had penetrated the host (5 hours), though a maneb-nickel sulphate fungicide did prevent spread of the pathogen in the tissues.

Using detached cotyledons, three races of Bremia (W.1, W.2, W.3) were identified. Race W.1 was unstable and could give rise to race W.2.

INTRODUCTION

The downy mildews form an important group of diseases caused by fungi which are obligate parasites and which require high humidity for infection and sporulation. Study of these diseases in the field can be difficult since natural inoculum levels may be very variable and weather conditions unpredictable. The use of laboratory methods of investigation under controlled conditions is, therefore, particularly advantageous.

In studies at the National Vegetable Research Station, Wellesbourne, methods have been developed of experimenting with the causal fungi of two downy mildews using detached cotyledons. These methods have been used in tests of fungicides against Peronospora parasitica on brassicas and in studies of races of Bremia lactucae on lettuce.

CULTURING THE FUNGI

In view of the obligate nature of the fungi, cultures had to be maintained on living host tissue. Although satisfactory development and sporulation of both Peronospora and Bremia occurred on young cabbage and lettuce plants in humid chambers, difficulties of space were encountered, particularly when a number of separate cultures had to be maintained. It was found that both for maintenance and experimental purposes rapid infection and dense sporulation could be obtained on seedling cotyledons.

On some occasions, seed was sown direct on a double thickness of moist filter paper in plastic boxes ($9 \times 5\frac{1}{2} \times 3\frac{1}{2}$ in) and the seedlings were inoculated 7-10 days later by spraying them with a spore suspension of the pathogen. On other occasions, cotyledons detached from 10-14 day old cabbage or lettuce seedlings were placed on moist filter paper in smaller plastic boxes ($4\frac{7}{8} \times 3\frac{1}{8} \times \frac{7}{8}$ in) and inoculated by spraying them with or dipping them in the spore suspension. Although single cotyledons, particularly of cabbage, could be handled satisfactorily in this way, it was found that with lettuces, cutting off the seedling near the base of the stem and using the paired cotyledons laid on edge, reduced the rate of degeneration and gave sporulation on both surfaces. Where quantitative inoculation was required, 0.01 ml drops of spore suspension (containing a known number of spores) were applied to the cotyledons by a standardised capillary micro-pipette. Constant stirring of the spore suspension was essential to maintain the uniformity of the inoculum during the inoculation of an experiment. Incubation was normally at 15°C, in constant temperature cabinets under 12 hours artificial illumination per day.

In studies on Peronospora, development of the mildew and degeneration of the cotyledons were directly affected by the incubation temperature (in the range 5-20°C). At 5°C, infection and degeneration were slow, while at 20°C both were rapid. At 10-15°C the effects were intermediate. Light was essential for satisfactory survival of the cotyledons.

FUNGICIDE TESTS AGAINST PERONOSPORA PARASITICA

Using detached cabbage cotyledons (var. Primo) as a bioassay substrate, methods have been devised for examining two properties of fungicides, viz. (a) the protectant properties, where the chemicals were applied to the cotyledons before the latter were inoculated with the pathogen, and (b) the eradicant properties, where the cotyledons were inoculated, and the fungicides were applied after the fungus had penetrated the tissues of the cotyledon. Although not as precise as tests based on spore germination responses on glass slides, the methods gave reasonably standard results and had the advantage of involving both partners in the host-parasite combination.

Protectant tests

The fungicides, which in most of the present work were proprietary wettable powders, were prepared at one or more concentrations. 2 ml of each fungicide preparation were applied by a microsprayer to the upper surfaces of the cotyledons on 14 cabbage seedlings (10-14 day old) cut off at soil level and held in a wire rack. Following spraying, the fungicide was allowed to dry overnight, the seedlings being kept turgid by placing the rack on a dish of water in which the cut ends of the stems were immersed. A plastic cover was also placed over the seedlings to aid the maintenance of turgidity. On the following day the cotyledons were cut off the seedlings in each rack and the best 24 were placed on moist filter paper in 3 or 4 plastic boxes (measuring $3\frac{1}{8}$ x $1\frac{7}{8}$ x $\frac{7}{8}$ in). Each cotyledon was then inoculated with a 0.01 ml drop of spore suspension, containing approx. 1000 conidia of P. parasitica, and the boxes were incubated in randomised blocks in wire trays in the illuminated constant temperature cabinet at 15°C. Assessment of the numbers of cotyledons bearing spores was made after 8 days.

Using zineb (wettable powder containing 75% active ingredient) as a standard, a range of fungicides was compared at concentrations of 0.1, 0.05 and 0.025% a.i. Examples of some protectant tests are shown in Table 1.

Table 1.

Protectant tests of some proprietary fungicides

Exp. No.	Test chemical	% cotyledons bearing spores			
		% a.i. of test chemical			
		0.1	0.05	0.025	0
1.	Captafol ("Difolatan") (80% a.i.)	0	0	0	100
2.	Dichlofluanid (50% a.i.)	4	4	0	100
3.	Dodine (65% a.i.)	0	4	58	100
4.	Chloranil (48% a.i.)	0	17	67	100
5.	Quinomethionate (oxythioquinox) (25% a.i.)	100	100	100	100
*	Zineb (75% a.i.)	13	55	83	

* average of the 5 experiments

The results show that most of the fungicides at 0.1% a.i. gave marked reductions in mildew. At 0.025%, however, the test chemicals ranged in effectiveness from those such as captafol and dichlofluanid, which were highly fungicidal, through dodine and chloranil, which were much less active, to zineb and quinomethionate, which were ineffective against the disease.

Since it appeared that at a concentration of 0.025% a.i., the fungicides could be separated into groups showing high, medium or low levels of toxicity to P. parasitica, most of the materials tested at the three concentrations above, plus some from other sources of supply, were re-tested at the above single concentration. The results were broadly the same as those in the previous tests, and by accumulation of the results it was possible to group the fungicides according to their protectant activity against P. parasitica (Table 2).

Table 2.

Protectant activity (at 0.025% a.i.) against P. parasitica

Protectant activity	Fungicide
High	Captafol, captan, "Daconil 2787" (tetrachloroisophthalonitrile), dichlofluanid, dichlone, propineb (mezineb), thiram
Medium	Calomel, dodine, "Bradosol" (domiphen bromide)ø, mancozeb, maneb, maneb-copper oxychloride*, maneb-nickel sulphate*, "Polyram" (zinc activated polyethylene thiuram disulphide)
Low	Chloranil, copper oxychloride+, dinocap, quinomethionate, quintozene, zineb

* tested at 0.025% maneb
\+ tested at 0.025% Cu
ø phytotoxic

Eradicant tests

For tests of eradicant action, the cotyledons were cut off 10-14 day old cabbage seedlings and placed on moist filter paper in plastic boxes (6 cotyledons per box) similar to those used for the protectant tests. Each cotyledon was inoculated with a drop of spore suspension by capillary pipette and incubated at 15°C for 5 hours (to allow the fungus to penetrate the tissues). For each fungicide treatment, 24 cotyledons were then removed from 4 boxes and pinned to a fibreboard platform, sprayed with 2 ml of the test chemical and returned to the plastic boxes. After a further 8 days incubation at 15°C, the number of cotyledons bearing spores and the intensity of sporulation on them was assessed on the following scale:

0 = nil

1 = trace

2 = dense on less than $\frac{1}{4}$ of cotyledon surface

3 = dense on $\frac{1}{4}$-$\frac{1}{2}$ of cotyledon surface

4 = dense on more than $\frac{1}{2}$ of cotyledon surface

The 5 hour interval between inoculation and spraying with fungicide was chosen as a result of an experiment in which it was shown that little infection occurred if cotyledons were sprayed with 0.2% zineb, either 1 or 2 hours after inoculation, but that much infection occurred if spraying was delayed for a longer period. It was presumed, therefore, that zineb had no penetrant or eradicant effect, and that 3 hours after inoculation the fungus had penetrated the tissues of the host and would be inaccessible to a purely surface acting fungicide.

Using a concentration of chemical (0.2% a.i.) which would be expected to kill the fungus on the surface of cotyledons, most of the fungicides which showed good or moderate activity with no phytotoxicity in the protectant tests were examined for eradicant action. None of the materials eradicated the disease from the infected cotyledons. There was some evidence, however, that a fungicide containing maneb with nickel sulphate did reduce the amount of disease when applied 5 hours after inoculation (Table 3).

Table 3.

Effect of spraying a maneb-nickel sulphate fungicide on cotyledons 5 hours after inoculation

Material sprayed	% cotyledons bearing spores	Mean sporulation grade per infected cotyledon (max. 4)
Water	92	4.0
Maneb-nickel sulphate*	71	2.1

* tested at 0.2% maneb

Although some reduction in the number of cotyledons bearing spores occurred, the major reduction was in the intensity of sporulation. Subsequent studies have shown that the nickel sulphate was largely responsible for the reduction in infection, for though it did not eradicate the fungus it penetrated the host and prevented the fungus spreading to previously uninvaded tissue.

Conclusions

The results of the protectant and eradicant tests on detached cabbage cotyledons suggest why mildew on brassicas is difficult to control, for not only does the fungus penetrate very rapidly (in less than 3 hours at 15°C) but once it is inside the host, there are no fungicides which can enter the tissues and eliminate it. It is apparent that frequent spraying and efficient surface coverage of the host foliage are required if protectants such as captafol or dichlofluanid are to have any hope of success. It is possible that a similar situation may exist with many of the other downy mildew diseases.

RACES OF BREMIA LACTUCAE

The use of detached lettuce cotyledons has revealed the existence of at least 3 races of *Bremia lactucae* at Wellesbourne:-

Race W.1 Capable of attacking many commercial varieties including Proeftuins Blackpool, but incapable of infecting the two varieties Avondefiance and Avoncrisp (and a breeding line No. 61025) bred at the N.V.R.S. for mildew resistance.

Race W.2 Capable of attacking all the varieties susceptible to race W.1 (including Proeftuins Blackpool), plus Avondefiance and line No. 61025, but not Avoncrisp.

Race W.3 Capable of attacking some of the varieties susceptible to races W.1 and W.2 (but not Proeftuins Blackpool), plus Avondefiance, Avoncrisp and line No. 61025.

Using detached cotyledons it has further been possible to demonstrate that race W.2 arises from race W.1, possibly by mutation. Single conidia of *Bremia* taken from a cotyledon culture of race W.1 were placed on separate cotyledons of the variety Proeftuins Blackpool, and incubated on moist filter paper in specimen tubes until sporulation appeared. Multispore sub-cultures were then taken to cotyledons of

Proeftuins Blackpool and the breeding line No. 61025. Those cultures which infected Proeftuins Blackpool, but failed to attack line No. 61025, were confirmed as true cultures of race W.1 originating from single spores. These were sub-cultured by multispore transfers at approx. weekly intervals to further cotyledons of Proeftuins Blackpool. At intervals, in addition to the routine sub-cultures to Proeftuins Blackpool, inoculations were made to line No. 61025 to test for the presence of race W.2. Out of 10 single spore isolates initially identified as race W.1, 9 had changed within 20 weeks and contained some race W.2 spores.

Conclusions

The results of this work indicate that detached cotyledons provided satisfactory test vehicles for race identification. It is further apparent that race W.1 was relatively unstable, and changed to race W.2 quite readily. Since no host specific to race W.1 has so far been found, the contamination of race W.1 cultures with race W.2 spores is a constant feature. By the continued use of detached cotyledons it is hoped to be able to determine whether similar changes, from race W.1 to W.3, race W.2 to W.3, or vice versa can also occur.

Acknowledgments

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CHEMICAL CONTROL OF DOWNY MILDEW IN SEEDLING CAULIFLOWER

J. D. Whitwell
Kirton Experimental Horticulture Station, Kirton, Boston, Lincs.
G. W. Griffin
Plant Pathology Department, NAAS Regional Sub-Centre, Starcross, Devon

Summary

Seedlings of the early summer cauliflower variety Snowball A.H.291 were sprayed with five different fungicides on eight occasions between seedling emergence and the fully expanded two-true leaf stage.

Two of the chemicals, dichlofluanid and propineb, reduced the level of early mildew infection and increased the size and dry weight of the plants. The survival of seedlings was better in the plots treated with these two fungicides, and when the young plants were counted at transplanting time, the increase in numbers of plantable plants over the mean control was 62% and 41% for dichlofluanid and propineb respectively.

INTRODUCTION

Downy mildew (Peronospora parasitica) is a perennial problem in seedling cauliflower production in the Holland division of Lincolnshire, especially in the Autumn sown crop which overwinters under glass for planting out in the Spring. When the disease appears in very young seedlings (on the cotyledons) the plants may die, but if the plants have developed two-true leaves before they are infected, they are usually strong enough to survive quite severe attacks. Plant raisers have learned to tolerate mildew symptoms on the older plants are are often unaware of the seedling losses that can occur after early infection.

Methods and materials currently used by growers to combat this disease are ineffective, and preliminary work indicated that if protectant sprays were to be of use in the control of this disease, they should be applied from initial germination and repeated at close intervals during the very susceptible early stages of growth.

METHOD AND MATERIALS

The soil border of a north-south orientated unit of twenty double span dutch light frames was dug over, steam sterilized and flooded during the first three weeks of September, 1966, and thiram-soak treated seeds of the early summer cauliflower variety Snowball A.H. 291 were sown in the centre sixteen double spans on 27th September. The seed was drilled directly into the frame border using a "Snild" precision drill, set to space one seed every inch in rows three inches apart. The two double span frames situated north and south of the experimental area were used as guard plots. All the frames and glass were washed down initially with 20% formalin solution.

Five different spray materials and three controls, unsprayed, water alone and water plus wetter, were replicated four times in a randomized block design, each plot being half a double span dutch light in area (approximately $1\frac{1}{4}$ yd^2). The fungicides used are given in Table I.

Table I

Fungicides	Rate
"Daconil 2787" (tetrachloroisophthalonitrile)	3 lb 75% w.p./100 gal
Captafol	3 lb 85% w.p./100 gal
Dichlofluanid	1½lb 50% w.p./100 gal
Zineb	3 lb 70% w.p./100 gal
Propineb	3 lb 70% w.p./100 gal

A 50% succinate wetting agent was added to each of the spray materials at a rate equivalent to 4 fl oz/100 gal.

The sprays were first applied at 20% emergence (day 0) on 3rd October, and then on days 3, 7, 11, 18, 25, 32 and 39, the last spray being applied when the second true leaf was fully unrolled (11th November). The rate used on the first three dates was 100 gal per acre and on the last five dates, 200 gal per acre.

An Oxford Precision sprayer was used to apply the materials and spray drift to adjacent plots was prevented by the use of a portable screen.

OBSERVATIONS

The mildew assessment records were taken from the middle four rows in the plots, the outer three rows on each side of the frames being discarded. A population count was made after emergence and, in March, the number of plants suitable for planting out was also recorded. Disease assessments were made at two stages: (1) when the cotyledons were fully expanded. (2) when the second true leaf had expanded. At each assessment, the plants in four 1' lengths of row were cut off at soil level and the presence or absence of mildew sporulation on the leaves recorded.

After the second disease assessment, leaf lengths and dry weights of the sampled plants were also recorded.

RESULTS

Table II

Disease assessments

% infected plants (angles)
(actual percentages are given in brackets)

No.	Treatment	17 Oct.	14 &15 Nov.
1	"Daconil 2787"	17.6 (9.6)	71.6 (88.3)
2	Captafol	11.5 (4.2)	64.7 (80.9)
3	Dichlofluanid	10.3 (4.6)	55.4 (67.2)
4	Zineb	18.4 (10.1)	71.1 (85.8)
5	Propineb	12.7 (5.3)	69.5 (87.3)
6	Control (unsprayed)	25.6 (20.4)	75.9 (91.6)
7	Control water and wetter	20.5 (12.5)	77.2 (93.2)
8	Control water only	26.4 (22.2)	70.8 (88.8)
Least significant difference			
P = 0.05		8.9	11.1
P = 0.01		12.1	15.1

On the first assessment date, captafol, dichlofluanid and propineb reduced the percentage infected plants when compared with the mean control. The other two materials gave less control.

By 14th November, disease levels were much higher and at this assessment only dichlofluanid showed clear signs of controlling the disease.

At the second disease assessment, obvious growth differences were apparent between the treatments and an attempt to measure these differences was made using the plants which had been assessed for mildew. Individual samples had been bulked after disease assessment, giving only one sample per plot. The largest and smallest plants were selected from each bulked sample and the length of the first true leaf from node to apex was recorded. Dry weights of each sample were also taken.

Table III

Plant size and dry weight (table of means)

No.	Treatment	Average length of first true leaf (mm)	Dry weight of tops (gm)
1	"Daconil 2787"	46.6	1.57
2	Captafol	51.9	2.05
3	Dichlofluanid	60.0	2.36
4	Zineb	53.1	1.93
5	Propineb	57.1	2.21
6	Control (unsprayed)	43.0	1.24
7	Control water and wetter	46.0	1.42
8	Control water only	47.4	1.31
Least significant difference			
P = 0.05		10.2	0.60
P = 0.01		13.8	0.82

Plants treated with dichlofluanid and propineb were markedly larger than the mean control, but plants from the captafol and zineb plots showed only a marginal increase in size. A similar pattern emerged from the dry weight records. Differences within the group were not detectable.

Sample stand counts were taken on 14th October, 1966, after all the seedlings had germinated, and on 10th March when the plants were ready for transplanting, an assessment was made of the total number of plantable plants per plot.

TABLE IV

Plant Populations (means)

No.	Treatment	Plant stand 14.10.66. (per 20' run of row)	Plant stand 10.3.67. (per whole plot)
1	"Daconil 2787"	283	168
2	Captafol	288	167
3	Dichlofluanid	275	248
4	Zineb	273	190
5	Propineb	288	217
6	Control (unsprayed)	300	174
7	Control water and wetter	260	141
8	Control water only	297	145
Least significant difference			
$P = 0.05$		39	38
$P = 0.01$		53	52

There were no large differences between treatments on 14th October, but when counts were made on 10th March, dichlofluanid and propineb treated plots yielded significantly higher numbers of plantable plants than the untreated plots. This may be related to the low incidence of mildew on the first assessment date, (Table II). However, captafol, which also had a low percentage mildew infection on that date gave a relatively low count of plantable plants.

The results show that dichlofluanid and to a lesser extent, propineb, can protect the young plants from infection, and it is likely that by this means a larger and more vigorous plant is produced. This is not necessarily an advantage however, as unpublished preliminary work suggests that plants covering a wide size range at planting out show no difference at harvest, either of quality or total yield.

The most significant result obtained was the increase in population of plants and this in economic terms is a substantial return from the investment of spray materials and time.

It should be emphasized that these are the results from one year's trial, and it will be necessary to continue this work through several seasons, preferably including a more severe winter than has been experienced of late. Important also is the fact that the trial was on direct sown plants that were not pricked off. Many growers are still using the method of broadcasting seed and pricking out at the cotyledon stage, when the disease is most troublesome. It remains to be seen whether a protectant spray programme as described here, will be of benefit under these conditions.

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COMPARING COSTS AND EFFICIENCY OF FUNGICIDES FOR THE CONTROL OF GREY MOULD IN LETTUCE

C. L. J. Ryan
National Agricultural Advisory Service, Jersey, C.I.

Summary

Trials on grey mould control in spring maturing frame lettuce were carried out for three years. In two years reduction in disease from 12% to under 2% was obtained using seedling sprays of dichlofluanid, thiram or thiram + zineb. Three sprays were applied at approximately fortnightly intervals from the first true leaf stage and at least one of these was given after transplanting. PCNB soil treatments did not control grey mould but gave the highest yield in one year, and a PCNB spray treatment increased mildew susceptibility in another year. Low disease incidence was correlated with high yields with dichlofluanid but not with thiram or thiram + zineb. In the two years when grey mould occurred all the plant spray treatments were financially beneficial but the PCNB soil treatment was uneconomic in one year. All fungicides retarded maturity by up to two days.

INTRODUCTION

Grey mould (Botrytis cinerea) is a serious disease of lettuce which occurs throughout the world and causes death of plants at any stage of growth or seriously affects the quality of marketable heads. Botrytis is essentially a fungus which invades damaged or dead plant tissue before infecting the living plant and any factors causing physical damage or an increase in physiological susceptibility of a plant predispose it to infection by the fungus. Losses by the disease depend therefore on seasonal weather, soil conditions, methods of growing, control measures applied and varietal susceptibility.

In the West Midlands where this work was carried out lettuce is the major winter crop under cold glass. Losses from grey mould in such unheated crops are often 5 to 10% and 25% losses noted by N.A.A.S. advisers are not uncommon.

In the early work on the control of this disease Brown (1935) found that a pentachloronitrobenzene (P.C.N.B.) dust applied to seedlings of spring maturing outdoor lettuce before planting out gave good results. Further work on this compound and on tetrachloronitrobenzene derivatives was continued by Smieton and Brown (1940), Brown and Montgomery (1948), Last (1952) and Brook and Chesters (1958). Their work showed that treating frame raised seedlings with these compounds before planting out controlled Botrytis and Rhizoctonia solani in the frame bed and resulted in an improved final stand in the field, but phytotoxicity was noted and delay in maturity occurred. Work at Efford and Stockbridge House Experimental Horticulture Stations between 1958 and 1961 demonstrated the usefulness of PCNB and Dicloran soil treatments for grey mould control. Commercial experience with these compounds produced variable results. Following up work by Powlesland and Brown (1954), who noted the promise of thiram for Botrytis control, Way and Keyworth (1959) showed the efficacy of this material when used on outdoor lettuce in the seedling stage and on frame lettuce after planting out.

Several workers have noted that grey mould is liable to occur when lettuce seedlings have reached a certain stage of development; usually when the cotyledons and lower leaves are dying, (Brooks 1908). This may occur if seedlings are crowded before transplanting, when Botrytis can invade the stem through these moribund leaves which remain on the plant, as lettuce leaves do not absciss. Physical damage at transplanting may also predispose plants to fungal attack and it has been shown that the larger the seedlings at transplanting the more susceptible they are to grey mould. Smieton and Brown (1940) and Brown and Montgomery (1948) had noted that a single dusting of seedlings before transplanting gave a good final stand in the field. Way and Keyworth (1959) noted in one experiment that one pre-planting thiram spray also gave a significantly better final stand. Pre-planting sprays were not used in their frame lettuce experiments but in one trial two post-planting thiram sprays gave as good disease control as four. Delay in plant maturity was noted where several applications were given.

Noting the occasional success of one pre-planting treatment for outdoor lettuce and the effect of as few as two post-planting sprays in frame lettuce for the control of grey mould, this work was started in cold house lettuce to study the efficiency of a limited number of fungicidal sprays. The aim was to protect the plants during the pre- and post-planting period when leaf senescence begins and physical damage is most likely to occur. Preliminary observations made in the West Midlands in cold house spring lettuce crops by Dr. A. G. Walker and Miss E. R. Schofield (personal communication), showed that sprays of thiram applied pre- and post-planting could give good disease control. Continuation of this work was reported by Ryan (1965). The work described in this paper was instigated to test the limited spray technique fully, to assess the merits of fungicides in use for the control of lettuce diseases in comparison with alternative chemicals and to study their effects on other diseases, crop yield and maturity.

Although many experiments have been carried out on grey mould control in lettuce very few workers have compared the effects of treatments in terms of crop quality and financial returns; which are the factors of importance to a grower. Chemicals giving the same level of grey mould control may not give the same crop yield because of phytotoxicity or other factors, such as the control of other diseases.

The results of three years' work at Luddington Experimental Horticulture Station on spring maturing frame grown lettuce are described here. The years 1965, 1966 and 1967 mentioned in the text refer to the year of harvest.

MATERIALS AND METHODS

Recommendations for the control of grey mould in frame lettuce include the regular use of thiram or captan sprays or dusts and the incorporation of PCNB into the soil pre-planting to control soil-borne inoculum of Botrytis and Rhizoctonia solani. PCNB controls seedling attacks by Rhizoctonia which may predispose them to subsequent attack by Botrytis. Dicloran is also used as a pre-planting soil treatment but this does not control Rhizoctonia, (Holmes and Knapman 1963).

New Materials

In 1964 a new fungicide dichlofluanid which showed outstanding promise for the control of Botrytis rot of strawberries (Muller 1964) was made available for trials and this material was included in all three years. Later a dust formulation of dichlofluanid became available and was included in 1967 together with a wettable powder PCNB which had given good control of lettuce grey mould in Australia (Ballantyne 1964).

Layout

The trials were carried out in double span Dutch light frames with 18 double lights per frame. Each frame comprised one block and treatments were replicated in three blocks in 1965 and 1966 and in four in 1967. Plot sizes in the three years were the areas covered by two, three and four lights respectively. Plants were spaced at 9 in by 7½ in giving 24 plants per light.

The variety May Princess was used in all three years together with Kwiek in 1965 and Profos in 1966.

Treatments

In 1965 and 1966

(1) No fungicidal treatment
(2) Quintozene (P.C.N.B.) at 121 lb a.i. (605 lb 20% dust)/acre
(3) Thiram at 3.2 lb a.i. (4 lb 80% w.p./100 gal)/acre (H.V.)
(4) Zineb at 1.3 lb a.i. (2 lb 65% w.p./100 gal)/acre (H.V.)
(5) Thiram at 3.2 lb a.i. + zineb at 1.3 lb a.i./acre (H.V.)
(6) Dichlofluanid at 1 lb a.i. (2 lb 50% w.p./100 gal)/acre (H.V.)

In 1967, in addition to treatments 1, 3, 5 and 6 above

(7) Quintozene (P.C.N.B.) at 2.0 lb a.i. (4 lb 50% w.p./100 gal)/acre (H.V.)
(8) Thiram at 3 lb a.i. (20 lb 15% dust)/acre
(9) Dichlofluanid at 3 lb a.i. (20 lb 15% dust)/acre
(10) Dicloran 12 lb a.i. (300 lb 4% dust)/acre

Cost of treatments

Experience at Luddington E.H.S. and elsewhere has shown that the time needed for one spraying or dusting operation for 1/10 acre of glass is approximately one hour. Assuming a labour charge of 6/6d. per hour, the total charge for three applications is £1. This is also the cost of applying and raking-in dusts to the soil prior to planting out.

The costs of materials per 1/10 acre are: PCNB dust £8; dicloran £4; thiram 3 sprays £0.6, 3 dusts £0.6; dichlofluanid 3 sprays £0.6, 3 dusts £1.4; zineb 3 sprays £0.2. These costs of sprays and dusts are approximate because of very small quantities involved in seed box applications.

Methods

Seed was sown in J.I.P.1 compost in seed boxes in an unheated structure on 24th November, 1964, 28th October, 1965, and 18th November, 1966.

The seedlings were sprayed or dusted three times at fortnightly intervals. The first application was made approximately five weeks after sowing when the seedlings were developing the first true leaf. The seedlings were planted after the first or second treatment when conditions were suitable and received at least one application in the frames. Before the final application plots were gapped up where losses caused by slugs had occurred.

Times of applications:

1st To seedlings in the boxes 4 weeks after sowing in 1965 and 5 weeks after in 1966 and 1967.

2nd To seedlings in the boxes 6 weeks after sowing in 1965 and to transplanted seedlings 7 and 8 weeks after sowing in 1966 and 1967 respectively.

3rd To plants in the frames 9, 9 and 10 weeks after sowing in the three years 1965 to 1967 respectively.

The plants were sprayed to run off with a pressurized knapsack sprayer or dusted with a small bellows type hand duster.

RESULTS

Records of disease incidence were made throughout the growing periods and infected plants were left in situ.

Yield data were obtained by cutting and grading the lettuce as recommended in the M.A.F.F. Marketing Guide Number 33. Guard rows were left uncut around each plot. In 1965 all the lettuce were cut on 10th May but in 1966 and 1967 cuts were made on three dates, 27/4, 2/5 and 6/5 in 1966 and on 24/4, 27/4 and 1/5 in 1967.

A composite figure of nominal number of crates per treatment is used in presenting the results and this is based on the number of crates of the different grades. The results for the two different varieties are combined in 1965 and 1966 as effects of the treatments were the same on each variety.

In calculating the gross returns the figure of 16/- per crate is used. This was the overall average return per crate over the four years 1964 to 1967 during the cutting period, end of April to early May, when most unheated lettuce is cut in the West Midlands. The gross return per lettuce over the same period was 7d. The results are presented in Tables 1, 2 and 3, where the plot values are shown converted into 1/10 acre values.

Table 1.

Yields and Gross Market Returns

Treatment	1965		1966	
	Nominal Number Crates/Treatment	£ Gross 1/10 acre	Nominal Number Crates/Treatment	£ Gross 1/10 acre
Control	1.1	165.0	1.30	178.9
PCMB dust	1.6	240.0	1.28	176.1
Thiram	1.3	195.0	1.37	188.5
Thiram + Zineb	1.2	180.0	1.32	181.6
Zineb	1.2	180.0	1.43	196.8
Dichlofluanid	1.5	225.0	1.62	222.9
Sig. diff. (P = 0.05)	0.38		0.17	

Table 2.

Plant losses due to Botrytis and calculated financial loss

Treatments	1965			1966		
	Plants Lost		£ Lost	Plants Lost		£ Lost
	per plot	per 1/10 acre	per 1/10 acre	per plot	per 1/10 acre	per 1/10 acre
Control	3.67	691	20.16	7.0	903	26.34
PCMB dust	2.50	471	13.74	6.17	796	23.21
Thiram	0.50	94	2.75	1.0	129	3.76
Thiram + Zineb	0.20	38	1.10	2.0	258	7.53
Zineb	2.02	381	11.10	4.33	559	14.41
Dichlofluanid	0.50	94	2.75	0.67	86	2.52
Sig. diff. (P = 0.05)	2.92			3.43		

Table 3.

1967

Treatments	Yields and Gross Returns		Plant Losses and Financial Loss		
	Nominal Number Crates/Treatment	£ Gross 1/10 acre	Plants lost		£ lost Per 1/10 acre
			Per Plot	Per 1/10 acre	
Control	1.98	242.8	0.75	71	2.07
PCNB spray	1.80	220.8	0.25	24	0.7
Thiram	1.77	217.0	0.0	0	0
Thiram dust	1.92	235.5	0.5	48	1.4
Thiram + Zineb	1.69	207.2	0.5	48	1.4
Dichlofluanid	1.81	221.9	0.0	0	0
Dichlofluanid dust	2.03	248.9	0.5	48	1.4
Dicloran	1.98	242.8	0.75	71	2.07
Sig. diff. (P = 0.05)	0.44		0.87		

Yield - The yield of lettuce in 1965 and 1966 from all spray treatments was higher than the untreated control.

In 1965 dichlofluanid and PCNB treatments gave significantly higher yields than the untreated control and the PCNB was significantly better than the thiram and thiram + zineb treatments.

In 1966 the yield from the dichlofluanid treatment was significantly better than all others and in 1967 only the dichlofluanid dust treatment gave a higher yield than the control, but there were no significant treatment differences.

Grey Mould Control - In 1965 and 1966 all the spray treatments resulted in fewer plant losses than in the control or PCNB treatments.

In 1965 thiram, thiram + zineb and dichlofluanid gave significantly fewer plant losses than in the untreated.

In 1966 thiram, thiram + zineb and dichlofluanid gave significantly better disease control than the PCNB or control and dichlofluanid was also significantly better than zineb.

In 1967 there were no significant differences between treatments. The correlation of yield with plant loss is discussed below.

DISEASE OBSERVATIONS

Grey Mould

No diseased seedlings were seen before planting out. Botrytis was the main cause of plant death in the frames with Rhizoctonia infecting a few of those plants which died earliest. In all three years diseased plants were first noted approximately seven weeks after planting. In 1967 plant losses were very few but in 1965 and 1966 the disease levels were much higher and very similar with approximately 12% total loss in the controls, 10% in the PCNB, 5% in the zineb and less than 2% in all other treatments (Fig. 1 and 2).

Fig. 3 shows a great similarity in the mean weekly temperature patterns in 1965 and 1966 with low temperature periods occurring approximately six weeks after planting out. In 1967 the temperature pattern was quite different during the early post-planting period. The lower temperatures in the first two seasons may have caused increased plant susceptibility to attack by grey mould particularly in plants not having received a fungicidal spray treatment. Severe grey mould in untreated lettuce was noted by Smieton and Brown (1940) following after frost. Grass minimum temperatures were higher during 1967 than in the other two years during the first few weeks after planting out.

Downy Mildew

Downy Mildew (Bremia lactucae) was noted one week before cutting in 1966 and 1967.

In 1966 infected plants were scattered in the frames and disease assessments made during cutting showed no difference in the mildew level between treatments.

In 1967 those plots which received the PCNB spray had more mildewed plants and more severely infected plants than any other treatment (Table 4). When PCNB dust with a lime filler was used on seedlings by Smieton and Brown they noted more mildew than on seedlings treated with PCNB with a talc filler. Further work is needed on this PCNB w.p. formulation to determine whether it increases susceptibility to mildew as any new material for grey mould control would be of little value if it increased mildew susceptibility.

Table 4.

1967

Treatment	No. Mildewed as % total	Mean Mildew Grade
Control	9.1	0.135
Thiram	8.0	0.097
Thiram + zineb	5.9	0.071
Dichlofluanid spray	4.2	0.046
PCNB spray	29.9	0.565
Thiram dust	10.6	0.161
Dichlofluanid dust	10.6	0.131
Dicloran	3.4	0.043
Sig. diff (P = 0.05)	13.1	0.258

Disease assessment grades were made using the N.A.A.S. Plant Pathologists Key No. 12.

Bacterial Rot

Sliminess was noted on the lowest leaves of many lettuce at cutting in 1965. A Pseudomonas sp. was associated with this disorder which was least in the PCNB plots.

EFFECT OF TREATMENTS ON MATURITY

In 1967 plot yields were little affected by plant losses and yields at the first cut were lower for all fungicidal treatments but on the second cut 3 days later several of the treatments yielded more than the control. Although there was no significant difference in final yields the thiram and thiram + zineb sprays gave the lowest final yields and had significantly lower yields at the first cut suggesting a delay in maturity of about two days.

In 1966 even though plant losses were reduced by spray treatments, the control yield at the first cut was higher than that from the PCNB, thiram and thiram + zineb treatments. The evidence suggests that all treatments retarded maturity with thiram being the most and dichlofluanid the least damaging.

DISCUSSION

In these trials the object in grey mould control was to cover the cotyledons and first true leaves with a protective fungicidal material to prevent Botrytis colonising those leaves which wither first and to protect the seedlings during transplanting when damage may occur. It was hoped to study the effect of these seedling sprays on infection by Rhizoctonia but the PCNB soil treatments showed that soil inoculum of Rhizoctonia was at a low level and unimportant in initiating attack by Botrytis. These PCNB treatments gave poor control of grey mould which suggests that most infection occurred through moribund leaves. The plant sprays of thiram, thiram + zineb and dichlofluanid gave good control with less than 2% plant loss in all three years. These results show effectiveness of seedling sprays for grey mould control. Zineb, which was included in the trial as a mildew control standard, was not so effective in direct grey mould control as the other materials nor by indirect control of Botrytis colonising leaves damaged by mildew, as mildew did not appear until late in the trials.

It is of interest to note the similarity in disease and temperature patterns in 1965 and 1966. It would be of interest to study the effect of fungicidal applications based on temperature data to give protection when low temperature injury is likely to occur. In these trials the plants were probably covered by fungicidal deposits when low temperatures were experienced. Non phytotoxic materials are necessary for application to small plants in cold weather as it is under these conditions that a check to the plants is greatest (Smieton and Brown 1940). Phytotoxicity was not noticed in any of these trials but delay in maturity of about two days was the maximum noted which is of no practical importance.

With many crops, plant loss directly affects marketable yield but this is not borne out with the lettuce as can be seen by comparing Tables 1 and 2. For instance in 1965 and 1966 losses were highest in the control and PCNB treatments, but although control yields were low in both years, the PCNB treatment gave the highest yield in 1965. This high yield is difficult to explain although there was least waste in this treatment because of less sliminess of the lower leaves and it is possible that compensatory growth because of fewer maturing plants resulted in the larger lettuce obtained. Comparison of figures for other treatments shows that only with dichlofluanid is there a high yield and low plant loss and this material appears most promising for grey mould control.

If the costs of treatments (labour and materials) are compared with market returns all the treatment costs were more than justified by increased returns except when PCNB was used in 1966. If, however, costs of treatments are compared with value of plants lost by disease, which is a technique commonly used, the use of PCNB (costing £9 per 1/10 acre) cannot be justified in either year but all other treatments show good returns. This latter method of disease control comparison may therefore give a false picture because of the effect of materials on other disorders not under consideration. The effect on gross market returns is the most important criterion and in future work on new materials for disease control in lettuce this should be an important consideration. More work is needed on the comparison of dusts and sprays and of possible disadvantages of new materials such as increasing susceptibility to other diseases as occured when a PCNB spray was used in 1967.

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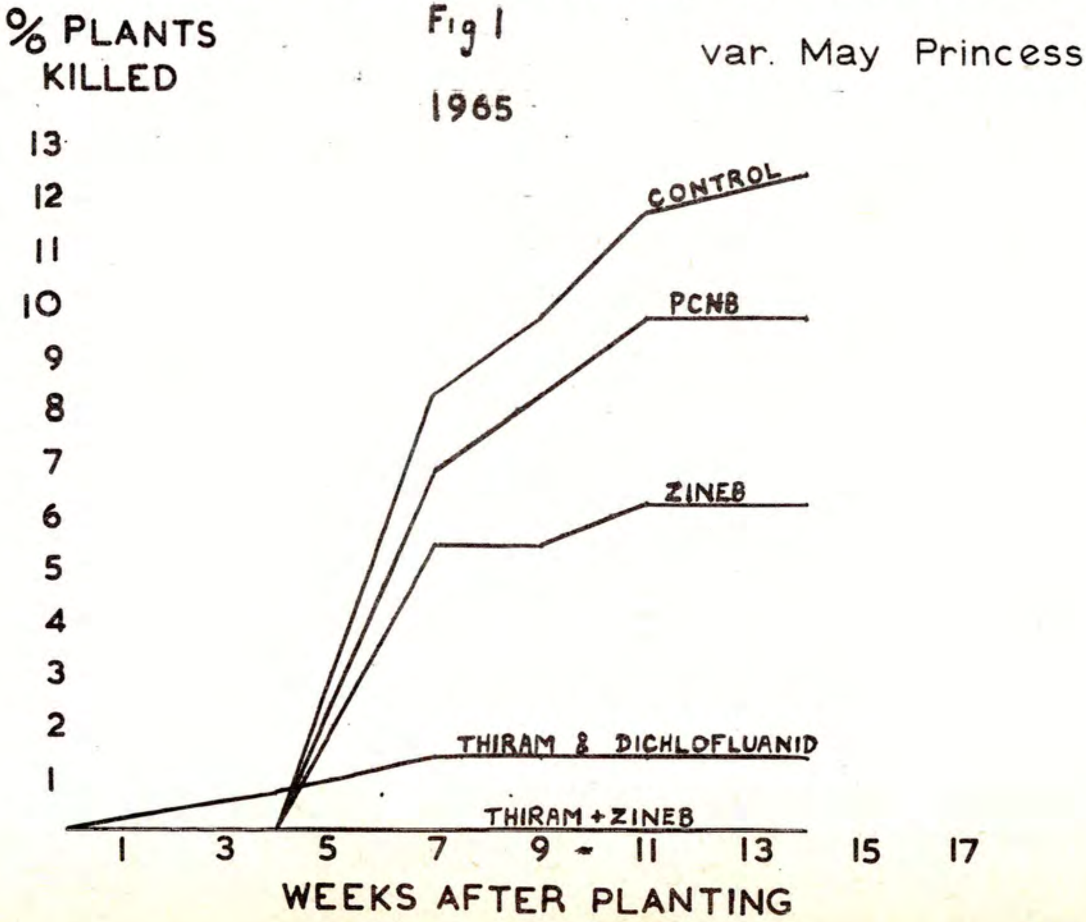
References

Ballantyne, Barbara (1964) Agric. Gaz. N.S.W. 75, 1048
Brooks, F. T. (1908) Ann. Bot., Lond., 22, 479
Brook, M. and Chesters, G. G. C. (1958) Ann. appl. Biol. 46, 159
Brown, W. (1935) J. Pomol. 13, 247
Brown, W. and Montgomery, N (1948) Ann. appl. Biol. 35, 161
Holmes, T. D. and Knapman, J. (1963) Plant Path. 12, 147
Last, F. T. (1952) Ann. appl. Biol. 39, 557
Muller, H. W. K. (1964) Erwerbsobstbau 6, 67
Powlesland, R. and Brown, W. (1954) Ann. appl. Biol. 41, 461
Ryan, C. L. J. Results of Horticultural Experiments 1965 N.A.A.S. West Midland Region
Reps. Efford Exp. Hort. Sta. 1959-1961
Reps. Stockbridge House Exp. Hort. Sta. 1960-1961
Smieton, M. J. and Brown, W. (1940) Ann. appl. Biol. 27, 489
Way, J. M. and Keyworth, W. G. (1959) Ann. appl. Biol. 47, 685

LETTUCE PLANTS KILLED BY BOTRYTIS



LETTUCE PLANTS KILLED BY BOTRYTIS

Fig 2

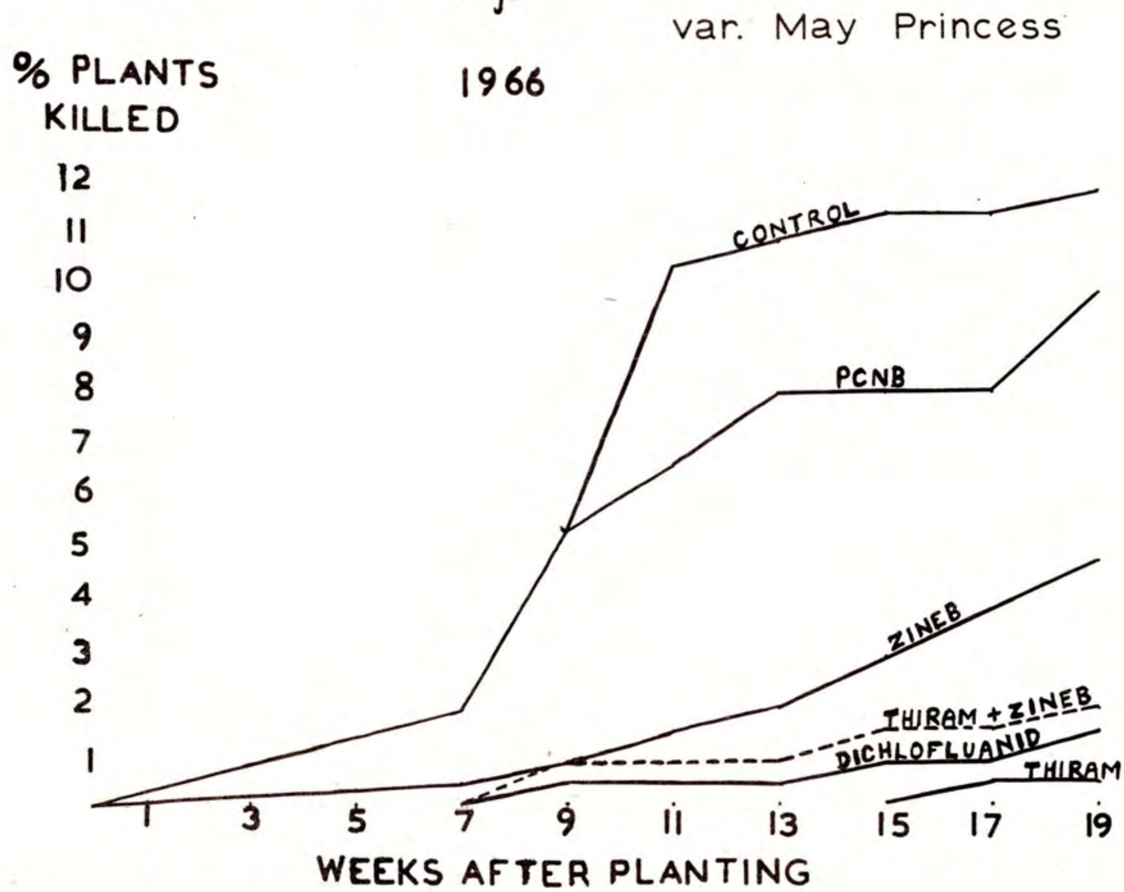
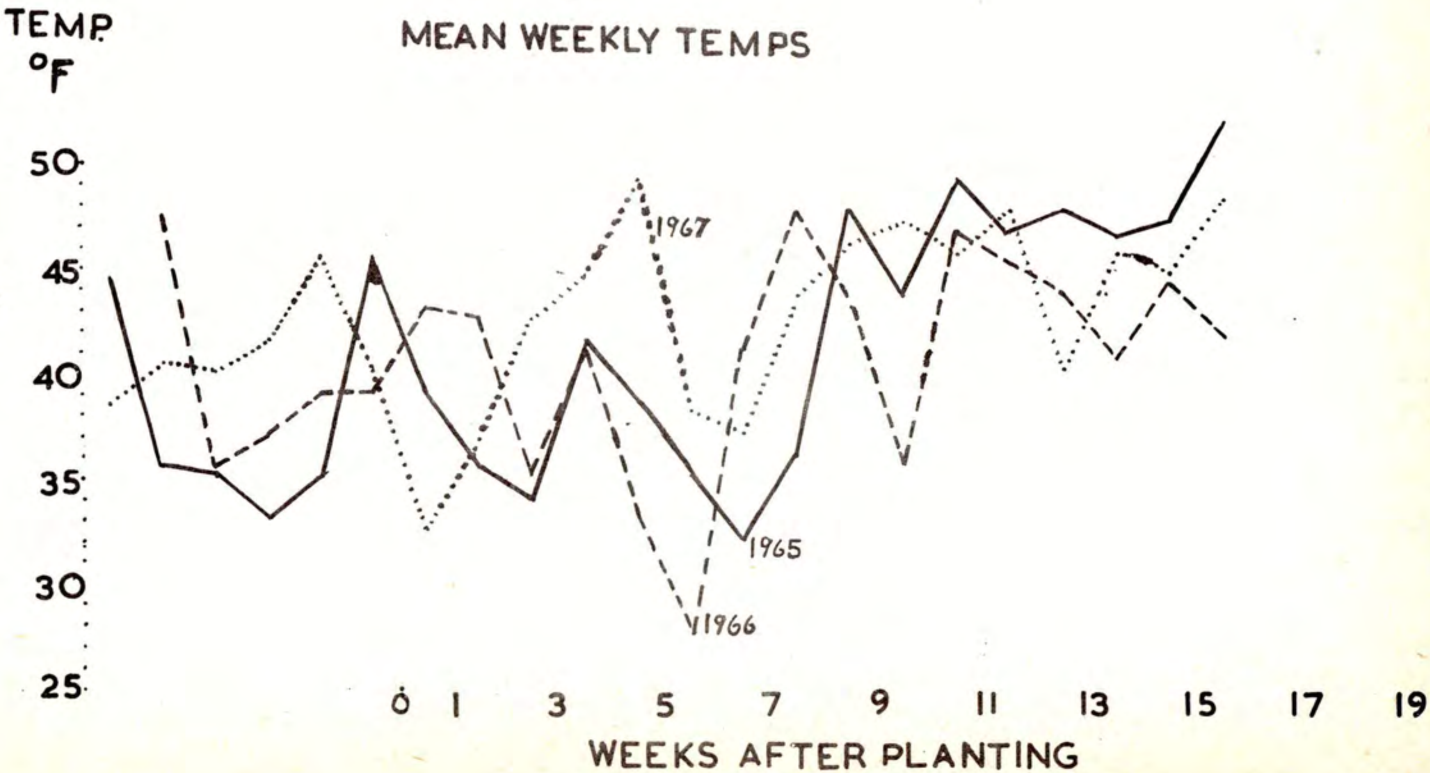


Fig 3



TEMP.
°F
MEAN WEEKLY TEMPS
50
45
40
35
30
25
1967
1965
1966
0
1
3
5
7
9
11
13
15
17
19
WEEKS AFTER PLANTING