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FARMER ATTITUDES TOWARDS THE CONTROL OF APHIDS ON SUGAR BEET

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Summary A brief account is given of how farmers' perception of pests and their control affect pest control decision making. Information is presented on their perception of the threat that aphids pose to sugar beet in two counties of England, and on their estimation of the effectiveness of insecticides used on sugar beet. All the farmers interviewed had suffered aphid attacks on sugar beet at some time, and all but two had used an aphicide in the last three years. The farmers believed peach potato aphid (*Myzus persicae*) to be a more serious pest than black bean aphid (*Aphis fabae*) on sugar beet. Their appraisal of the average loss caused by peach potato aphid/virus seemed to reflect local conditions, while their perception of the worst possible loss it could cause was independent of local conditions. Farmers uniformly felt that the effectiveness of insecticides is very high, in most cases far exceeding the best results reported in trials.

INTRODUCTION

Sugar beet growers in England are faced with attacks to their crop by many invertebrate pests. Chief among these is the peach potato aphid (*Myzus persicae*), the principal vector of virus yellows. The black bean aphid (*Aphis fabae*) is also a common pest of sugar beet and in 1975, 86% of the beet acreage was treated against aphids (Dunning & Davis, 1975).

The farmer's perception of the hazard presented by pests, and his perception of the effectiveness of the control measures available, are two key factors determining pest control decision making (Norton, 1976; Mumford, 1978). It is the farmer's perception of a pest hazard, and not the actual level of attack that could occur, that causes him to consider applying an insecticide. If his concern is with the average benefit from pest control over many years he will be most influenced by his perception of the typical, or average, attack. If the short term risk of loss is of greater concern, his decision is more likely to depend on what he believes to be the worst possible loss he could suffer. Likewise, in considering the use of insecticides, it is his belief in their effectiveness, not their actual effectiveness, that will prompt him to decide for or against them. These perceptions of pest severity and insecticide efficiency are based on the farmer's own experience, as well as that of his neighbour, on contacts from the agrochemical industry, the British Sugar Corp., ADAS, and the research establishments.

This paper describes some preliminary findings of a study undertaken to gain information on what perceptions sugar beet growers hold about aphids, yield losses- and insecticides, and how these perceptions influence their pest control decisions.

METHODS

A stratified random sample of sugar beet growers in Cambridgeshire and S. Humberside was selected. Within each area ten farmers were chosen at random from each of three groups: those growing 10 ha or less of sugar beet, those growing 10 to 20 ha, and those growing over 20 ha. These thirty farmers in each of the two areas were interviewed during July and August, 1977. They were asked about their general cropping patterns, the problems of pests on sugar beet, their control practices on sugar beet, what relevant information about pest control was available to them and used, and the processes leading to their decision to apply insecticides to sugar beet. All of the interviews were conducted personally by the author, and a standard questionnaire was used as a framework. The interviews lasted from 30 min to 2 hr, though most were about 45 min in length.

RESULTS

The median response in a survey of this kind is usually the best indication of what the 'typical' farmer thinks, though the range of responses should also be considered. The median indicates the response which half the farmers are above, and half below.

The farmers were asked what pests they had experienced at any time on their sugar beet crop. All 60 reported having suffered aphid attack. Of these, 52 had peach potato aphid, 49 had black bean aphid, and 7 had aphids but did not distinguish between the two species. Next they were asked how frequently, that is, how many years in ten, they believed each pest to have been present. In the northern area the median response for peach potato aphid frequency was 6 years in 10, and for black bean aphid, 7 years. In the southern area, 70% were of the opinion that peach potato aphid occurred every year, while the median response for black bean aphid frequency was 3 years. The range of response can be seen in Fig. 1.

The farmers were then asked to estimate what percentage loss ofyield they would expect from both a typical and worst possible attack, if the aphids were left uncontrolled. All but two farmers responded to this question. The median loss estimated for peach potato aphid/virus in the northern area was in the 0-10% class for a typical attack, and in the 21-30% class for the worst possible attack (Fig. 2A.). In the southern area the median loss estimated for peach potato aphid/virus was in the 11-20% class for a typical attack, and in the 21-30% class for the worst possible attack (Fig. 2B.). The median loss estimated for black bean aphid in both areas was in the 11-20% class for the worst possible attack (Fig. 3.).

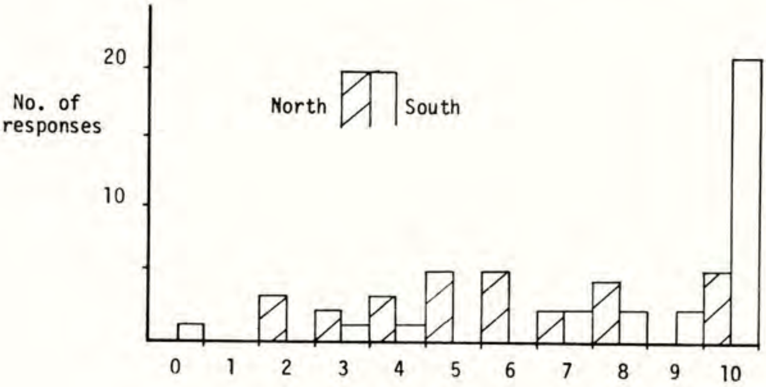
The extent of insecticide use was determined by asking the farmers what insecticides, if any, they had used on sugar beet in the last three years. All but two had used some insecticide against aphids at least once during the last three years, and all had used insecticide at least once to control some pest on sugar beet in the last five years.

The farmers were then asked to estimate the efficiency of their particular insecticide programme, in terms of the percentage yield loss prevented. A numerical estimate was given by 53 farmers, 6 stated in unquantifiable terms that they believed insecticides to be very effective, while one felt that they were not very effective. The results for those responding numerically (Fig. 4.) show that 75% believe that insecticides prevent at least 90% of the potential loss.

Fig. 1

Farmers' estimates of aphid frequency (years in 10)

A. Peach potato aphid



B. Black bean aphid

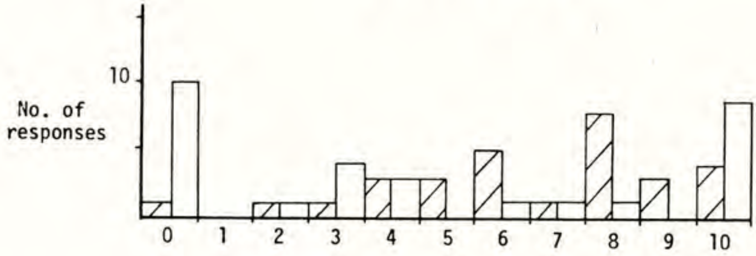
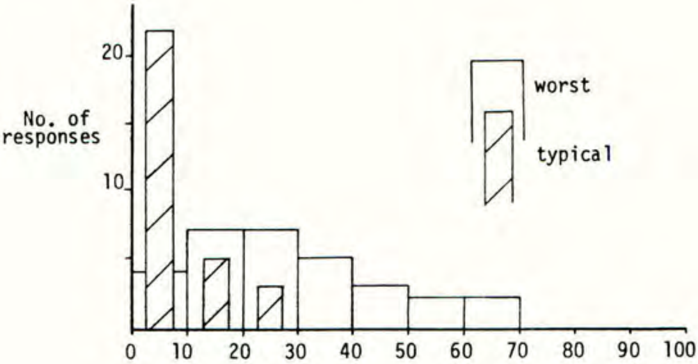


Fig. 2

Farmers' estimates of % loss from peach potato aphid/virus

A. S. Humberside



B. Cambridgeshire

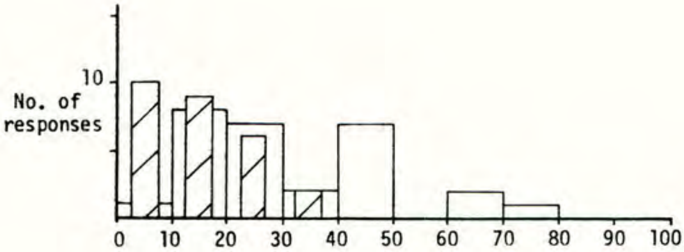
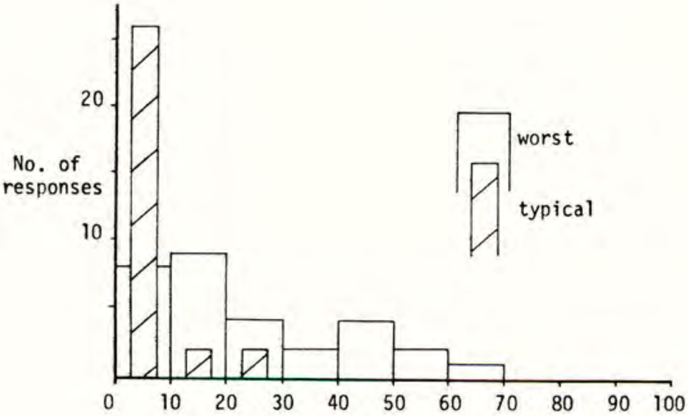


Fig. 3

Farmers' estimates of % loss from black bean aphid

A. S. Humberside



B. Cambridgeshire

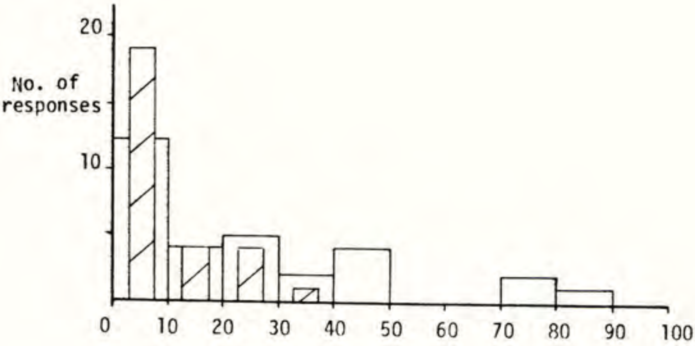
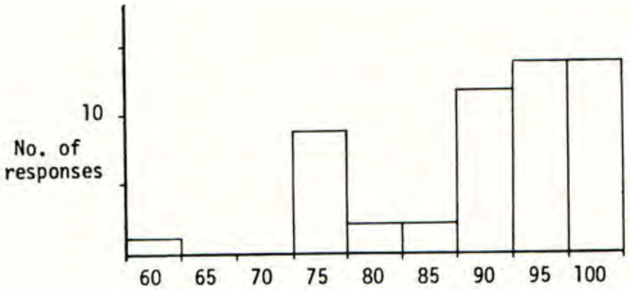


Fig. 4

Farmers' estimates of % insecticide efficiency



DISCUSSION

In deciding on a pest control programme for his farm the farmer must pose and then answer several questions. For example, how much damage will the pest do if it comes, and how often will the pest occur? What control measures are available, and how effective are they? His answers, right or wrong, will be used to decide on a pest control strategy for his farm. Clearly the accuracy of his perceptions will affect the appropriateness of the actions upon which he decides, and so should be a concern of researchers and advisors.

Average losses, due to virus yellows, can be estimated from the specific field count surveys of yellows made by British Sugar Corp. fieldmen. The average losses in these two counties from 1972-76, calculated from the yellows counts, assuming 3% loss of value per week of infection (Heathcote, 1978), were: S. Humberside, 4%; Cambridgeshire, 12%. These calculated losses are, however, after treatment. If the control measures had reduced loss by up to 40% the potential losses would still be below 10 and 20% respectively.

The median estimates given by the farmers for average losses from peach potato aphid/virus are in fact within these classes in these two regions. The farmers also perceive that peach potato aphid occurs more frequently in the south, which coincides with the fieldmen's records that virus yellows is more severe there. It appears therefore that farmers have a fairly good idea of normal losses in their own area, providing a reasonable basis for deciding on a control programme in which average outcomes are more important than the short term risk of severe loss.

When estimating the worst loss from peach potato aphid/virus, farmers in both counties gave the same median response, in the 21-30% class, though with considerable variation. This is despite the fact that the worst loss calculated for the southern area since 1948 is three times that of the northern area. There was an estimated loss of 9% in S. Humberside in 1975, and 29% in Cambridgeshire in 1974, the worst recorded years respectively, though this is after treatment. If the loss had again been reduced by about 40% due to treatment, the potential losses in the north would have been in the 11-20% class, and in the 41-50% class in the south.

It would appear therefore that the northern farmers tend to see the pest as worse than has actually occurred, and those in the south tend to see it somewhat less potentially harmful than has been recorded. For the risk averse farmer, who is motivated to use insecticides as an insurance measure, the idea of the worst possible loss is likely to be a major factor in deciding on control action. It may be that in considering the worst possible attack, the two groups are influenced by the same source. Publicity over the severe, partly controlled, epidemic in the south in 1974 may well have had more impact than local conditions, which appear to be more important in thinking about typical attacks.

The black bean aphid is considered by the farmers to be generally less serious than peach potato aphid. While it was believed to be fairly frequent in the north, the normal level of damage it caused is felt to be relatively slight on sugar beet. This is also the appraisal of researchers, who have placed priority on the study of the peach potato aphid as the more important pest.

The ability of insecticides to prevent loss from beet pests was perceived as being uniformly high, as seen in Fig. 4. All but one of the farmers responding with a numerical estimate of insecticide efficiency gave figures greater, and often considerably greater, than 70%. However, 71% was the greatest reduction in yellows reported by Hull & Heathcote (1967) from experiments carried out over 12 years, and the best achieved by Hills *et al* (1965) was 69%. Indeed, in a recent issue of the beet grower's journal, Dunning (1976) has stated that control better than 50% is unlikely.

Since most of the farmers leave no untreated area for comparison, they have no way of checking their belief in the efficiency of their chemicals. This is particularly important as a firm belief that insecticides are very effective is an important inducement to the farmer in adopting these chemicals.

Acknowledgements

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LOSSES CAUSED BY CUTWORMS (AGROTIS SEGETUM SCHIFF.) AND APPROACHES TO THEIR CONTROL IN DENMARK

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Summary. Losses in Denmark during three recent "cutworm years" varied from 2o - loom Dkr. Among the five most important agricultural crops, the average losses varied from 7% (potatoes) to 3o% (red beet). The efficiency of control with chemical insecticides has been unsatisfactory but watering during, and immediately after, the swarming of moths has reduced damage by up to 84%.

Six experiments in 1975-76 using *Agrotis segetum* Granulosis Virus in red beet and carrots showed 75-8o% reductions in damage. The GV was produced in laboratory-reared cutworms and applied in water solution. The GV was effective one year after application and had spread to untreated plots adjacent to treated plots. The economics of propagation of GV compare favorably with the cost of using parathion four times in each crop season.

INTRODUCTION

In Denmark, *Agrotis segetum* Schiff. is the most important species of cutworm in agricultural crops, constituting 94-99% of all specimens sampled in 1974-76, whereas *A.exclamationis* L. comprised 1-6% of the total (Jørgensen, In prep.). The economically most important host crops are potatoes, carrots, beet species, onions and leeks, but forest seedlings, strawberries, lettuce and other crops may also suffer heavy damage.

Forecasting The short period when early instar cutworm larvae feed above the soil is the crucial time for control measures to be applied. Older larvae are very difficult to control, especially now that use of the persistent chlorinated hydrocarbons, including dieldrin, is forbidden. In Denmark, the most commonly used insecticides include parathion, azinphos-methyl and other organophosphorus compounds but the results have often been unsatisfactory, even with frequent applications of spray during the growing season. To obtain maximum control with conventional insecticides, correct timing of the first larval period is therefore important. During the past lo-15 years, the Danish State Plant Pathology Institute at Lyngby has used light traps with mercury-vapour bulbs to collect adult moths from May onwards. Flight data for *A.segetum* and *A.exclamationis* have been collected each year and dates for spraying were issued according to the flight peaks. This forecasting system has, however, been inefficient because moths swarmed and laid eggs before they were attracted to the light traps. Atractions of *A.segetum* males to virgin females is now being tried in large-scale experiments to determine the beginning and peak of swarming more precisely than was possible with light traps. These co-operative experiments are being done by the Danish State Plant Pathology Institute and the Royal Veterinary and Agricultural University (Bromand *et al.*, 1977).

Losses Years with severe cutworm damage are often characterised by having dry summers, e.g. 1969, 1975 and 1976 in the last decade. Losses of five crops in these three years have been estimated as pertentages of the total harvested (Table 1), using data from Thygesen (1970), Agricultural Extension Officers and grading stations. Red beet was consistently the most susceptible crop with 20-30% losses and potatoes among the least susceptible (7-11% losses). Losses in crops other than those mentioned in Table 1, and in particular garden crops, are more difficult to estimate and have been assessed as an additional 25% of losses in the five main crops. On this basis, the total financial loss was approx. 20m Dkr in 1969, 60m in 1975 and 100m in 1976.

Table 1

Yield losses caused by cutworms in Denmark in 1969, 1975 and 1976

	Area (ha)	Yield (metric tonnes)	Value (m Dkr)	Losses		
				%	metric tonnes	m Dkr
Potatoes (for human consumption)						
1969	27.000	350.000	100	7	24.500	7
1975	20.000	400.000	400	8	32.000	32
1976	18.000	320.000	400	11	35.200	44
Carrots						
1969	1.450	40.000	30	13	5.200	4
1975	1.500	47.500	77	9	4.300	7
1976	1.400	39.300	61	30	11.800	18
Onions						
1969	1.000	13.500	20	10	1.400	2
1975	800	12.800	14	8	1.000	1
1976	850	14.900	26	10	1.500	2,5
Leeks						
1969	650	8.000	18	12	1.000	2
1975	600	8.300	20	9	800	2
1976	650	10.000	31	20	2.000	6
Red beet						
1969	300	5.000	2,5	20	1.000	0,5
1975	250	9.200	6,5	30	2.800	2
1976	250	10.400	9,5	30	3.100	3
All 5 crops						
1969	30.400	416.500	170	8,0	33.000	15,5
1975	23.150	477.800	517	8,5	41.000	44,0
1976	21.150	394.000	527	13,5	53.000	73,5

METHODS AND MATERIALS

The experiments described in this paper were done to assess the efficiency of cutworm control using Granulosis Virus (GV), relative to the control achieved in Denmark with other methods used.

Experiments in 1975 and 1976 used three different localities in Lammefjorden, N.W.Zealand, with three different types of soil: loamy sand, silt with humus, and mull. Each experiment consisted of nine lom^2 plots. Plots in four experiments were covered with netting (1-2mm^2 mesh) before adult moths started to swarm in May (Table 2).

Table 2

Details of experiments with *A.segetum* Granulosis Virus

Expt.	Year	Locality	Crop	Soil	Expt. type
1	1975	Brogaard	Red beet	Loamy sand	Covered
2	1976	"	Carrots	"	"
3	1975	"	Red beet	"	Open
4	1975	Stubberupholm	"	Silt/humus	Covered
5	1975	"	"	"	Open
6	1976	"	Carrots	"	Covered
7	1975	Ingerbyvej	Red beet	Mull	Open

Details of experiments with watering

8	1976	Lammefjord	Carrots	Silt/humus	Open
9	1976	St.Jyndevad	Potatoes	Loamy sand	Open

Crops were sown at the beginning of May with five or six rows/plot. From 28o (Expt. 1) to 5oo eggs or young larvae (Expts 2, 4 and 6) from laboratory cultures were placed in each covered plot. The eggs were placed in groups of lo, evenly spaced in each plot and attached to the basal parts of the plants. Attacksby the natural populations of moths were relied upon in the experiments with open plots.

Granulosis Virus was applied 2-4 days after eggs were placed in the covered plots. Each experiment included at least 3 replicates of each treatment: untreated (water only), Granulosis Virus and parathion applied at the recommended rate (only in Expts 1, 3, 4 and 5). The GV was produced in laboratory cultures. Dead larvae containing virus were macerated in a blender and filtered through muslin. The GV was kept in water at -2o C until used. Before application, the solution was diluted with water (25:1 vol/vol) and then applied with a spray bottle with an atomising nozzle. Each plot received o.5 l of the diluted solution. The plants were treated laterally so that the spray reached the inner parts of the plants.

Effects of treatments were evaluated from September to November, at harvest. Crops were washed and examined for cutworm hollows. Superficial (3mm deep) and deep hollows (3mm deep) were recorded separately. Hollows covering 1cm^2 of the crop surface were assessed as a single unit of damage whereas larger hollows were counted according to their surface area.

RESULTS OF AGROTIS SEGETUM GRANULOSIS VIRUS TREATMENTS

Results are summarised in Table 3 as reductions in the number of deep hollows/loo roots after treatment of plots with GV or parathion, calculated using assessments of damage on untreated plots. GV applied 2-4 days after egg release reduced damage significantly ($\underline{P}$=o.o5) in six experiments. Reductions in damage were similar in covered and open plots. Application of GV ten days after egg release gave significant ($\underline{P}$=o.o5) reductions in damage but the effect was less than that with some of the 4-day treatments. Reductions in damage on plots treated with parathion and covered with netting varied between 42-58% and on those treated with insecticide but not covered from 11-2o%.

Table 3

Reductions in cutworm damage on field plots treated with GV or parathion

Treatment	Expt.	Expt. type	% Redn. in no. deep hollows/loo roots compared with untreated plots
GV: 4 days	1	Covered	79^a
"	3	Open	67^a
"	4	Covered	79^a
"	5	Open	69^b
"	7	Open	74^b
"	6	Covered	81^b
GV: lo days	6	Covered	6o^a
Parathion: 4 days	1	Covered	58
"	3	Open	2o
"	4	Covered	42^c
"	5	Open	11^c

The suffix ^{a} denotes a statistically significant reduction ($\underline{P}$=o.o5)
The suffix ^{b} denotes a statistically significant reduction ($\underline{P}$=o.ol)
The suffix ^{c} denotes a statistically significant difference ($\underline{P}$=o.o5) compared to GV.

More detailed analyses, including the effects of GV one year after its application, are presented in Table 4. Damage in plots treated with virus in 1975 and 1976 did not differ significantly ($\underline{P}$=o.o5). In addition, no significant difference could be detected in 1976 between amounts of damage on untreated plots and those treated with GV in Experiment 2, indicating that the virus was effective one year after application and that it had spread to 'untreated' plots a few metres from the points of application.

Table 4

Assessments of cutworm damage in 3 experiments in covered plots at Lammefjord in 1975 and 1976 (Figures are means of three replicates)

Expt.	Treatment	No. deep hollows/1oo roots
1	Untreated	224
	GV	47 [a]
	Parathion	95
2	Untreated	21
	GV: 1975	19
	GV: 1976	13
6	Untreated	173
	GV: 4 days	33 [b]
	GV: 1o days	7o

The suffix [a] denotes a statistically significant difference from the number of hollows in roots from untreated plots (*P*=o.o5)

The suffix [b] denotes a statistically significant difference from the number of hollows in roots from untreated plots (*P*=o.o1)

Economics of treatment of crops with Granulosis Virus

The small-scale production of *A.segetum* virus for experimental trials indicated the necessary scale of costs that would be involved in commercial production. Lammefjorden has been selected as a market for GV and the area to be treated estimated at 1ooo ha/year, with 2oo infected cutworms/ha being needed to provide adequate control. The total costs involved in the production of the necessary number of infected larvae (2oo ooo) would be about 2oo ooo Dkr/annum. It is estimated that, whereas the cost of treatment of 1 ha with 4 applications of parathion would cost 28o Dkr, treatment with one application of the more persistent GV would cost 245 Dkr. Further development of the methods of production of the virus would probably make the product even less expensive.

RESULTS OF WATERINGS

Some potato farmers control cutworms by watering their crops (Zethner and Jørgensen, 1976) and the amount of control achieved has often been appreciable. For example, in a comparison of the effects of watering on medium-early and late potatoes, reductions in damage varied between 74-84% in the medium-early varieties and 2-90% in the late varieties, although damage on unwatered plots was usually greatest in the medium-early varieties (Table 5).

Table 5

Effect of watering on cutworms in potatoes at St. Jyndevad, S. Jutland

(Treated plots received 235mm water in 8 applications commencing 21 June and each figure represents the mean of 3 plots. Expt. 9, table 2).

Potato var.	Treatment	Damage to potato tubers	
		No. deep hollows/ 100 tubers	% Redn. in damage on treated plots compared with untr.
Medium-early:			
Bintje	Unwatered	2.08	
	Watered	0.37	82^b
Octavia	Unwatered	4.67	
	Watered	1.20	74^b
Penta	Unwatered	3.19	
	Watered	0.50	84^b
Feja	Unwatered	13.15	
	Watered	2.37	82^b
Late:			
Dianella	Unwatered	0.77	
	Watered	0.08	90^b
Amia	Unwatered	1.37	
	Watered	0.63	54
63-PH	Unwatered	0.85	
	Watered	0.83	2

The suffix b denotes a statistically significant reduction (P=0.01)

In a similar series of trials with carrots however, damage was reduced by only 39-52% when water was applied four times starting two weeks after the peak of swarming of the adult moths (Table 6). The effect of applications of water in relation to the time of peak swarming needs further investigation.

Table 6

Effect of watering on cutworms in carrots at Lammefjord, N.W. Zealand

(Treated plots received 120mm water in 4 applications commencing either 6 July or 12 July and each figure represents the mean of 2 plots Expt. 8, table 2).

Expt.	Treatment	First date of watering	Damage to carrots	
			No. deep hollows/ 100 roots	% Redn. in damage on treated plots compared with untr.
I	Unwatered		41.5	
	Watered	6 July	25.2	39.3
II	Unwatered		26.5	
	Watered	13 July	12.8	51.7

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The Danish Agricultural Experimental Stations at Roskilde and St. Jyndevad readily supplied crops from some of their experiments for examination. Finally, my warmest thanks are extended to a great number of interested growers, agricultural advisors and managers of potato grading stations, carrot washeries and food industries. The studies were financed by the Danish Agricultural Research Council (grants nos. 513-3616 and 513-5091).

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Notes

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APPLICATION OF INSECTICIDES TO PEAT BLOCKS FOR THE CONTROL OF PESTS OF CABBAGE AND LETTUCE

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Summary Summer cabbages grown in peat blocks established better and matured earlier than transplanted plants. By mixing insecticides with the peat before the blocks were made, yields in some trials were improved, damage from cabbage root fly was reduced and residues were not detectable at harvest. At rates of either 0.425 or 0.850 g a.i./kg of 'dry' peat most of the chemicals and formulations tested caused only slight or temporary damage when mixed into the peat before the blocks were made; granule formulations applied to the surface of the blocks four weeks after sowing also caused little damage, but emulsifiable concentrate formulations were phytotoxic.

In unreplicated plots, cabbage root fly damage on plants treated with from a quarter to four times the 'normal' rate of chlorfenvinphos decreased as the dose increased, and isazaphos from half to four times the normal rate eliminated damage at all but the lowest rate. Plants in blocks planted 25 or 50mm below soil level established faster, matured slightly earlier and, in 1977, out-yielded plants in blocks planted more superficially, though they suffered slightly more root fly damage.

In a preliminary trial on lettuce, systemic insecticides mixed into the peat before sowing at rates from 5-60 mg a.i./plant gave complete control of leaf aphids for five weeks but slight infestations developed after seven weeks, particularly at the lowest rates. Non-systemic insecticides were ineffective.

INTRODUCTION

Seedlings are commonly raised in peat blocks for transplanting later. Glasshouse lettuce is raised almost entirely in peat blocks and appreciable areas of outdoor lettuce, early brassicas, courgettes, tomatoes and peppers are raised in the same way.

If crop protection chemicals mixed into the peat before the blocks were made, or applied after sowing were effective without having undesirable effects on the growth of plants, presenting a hazard to operators or leaving excessive residues in harvested crops, this would provide a simple, and economic, method of pest and disease control.

Bevan (1966) mixed insecticides into peat blocks for the control of carrot fly on self-blanching celery, Wyatt (1975) showed that thorough mixing of insecticides into the compost and casing gave good control of mushroom pests and Humphreys-Jones (*pers comm*) controlled *Pythium* and *Rhizoctonia* species on celery and ornamentals by mixing fungicides into naturally infested compost. Graham (*pers comm*) incorporated various insecticides into peat blocks to control cabbage root fly on cauliflowers but at present chlorpyrifos is the only chemical cleared for this use on leaf brassicas.

MATERIALS AND METHODS

Levington Blocking Compost was used in all experiments and a hand-blocking machine was used in 1976 to make blocks approximately 5 x 4 x 4 cm. In 1977 the volume of each block was 10% larger.

Depending on the dryness of the compost, between 700-900 ml of water were added to each kg of compost to produce a slurry from which the blocks were made. Liquid and powder formulations of insecticides were added to this water before mixing but granular formulations were mixed into the dry compost.

Cabbage Trials

The "standard" rate of 0.425 mg a.i./kg "dry" compost was derived from the spot application rate of 0.017 g a.i./plant recommended for chlorfenvinphos. Using the smaller machine 1 kg of "dry" compost produced 25 blocks so that 25 x 0.017 g a.i. were applied per kg peat. Although larger blocks were made in 1977 the same concentration of insecticide per kg of peat was retained, so that the dose per plant was increased by 10%. In all experiments 0.66 g thiophanate-methyl a.i./kg "dry" compost was used to control club root.

Eight trials or observations were carried out on summer cabbages, cv Derby Day between 1976-77. In 1976, 9 different insecticides or formulations were compared, each mixed into the compost before blocking and in 1977 the 6 most promising chemicals were applied either when blocks were made or 4-5 weeks after sowing. (Table 1)

The effects of varying concentration of chlorfenvinphos (1976) or isazaphos (1977) on yield and cabbage root fly were studied in unreplicated plots. A further trial (1976) or observation (1977) was done to study the effect of the depth of planting the blocks on control of cabbage root fly. Details of the treatments are shown in Tables 2 and 3.

Seed was sown within 2 days of making the blocks which were then maintained at a minimum night temperature of 13°C for 7 days and for a further 30 days at 10°C after which they were 'hardened off' in a cold frame before planting. Plants were assessed for vigour and harvested as they reached maturity. Plant samples were retained for residue analysis in 1976 and after harvest all roots were examined for damage using the Root Damage Index (RDI) (Wright, 1953). Cabbage root fly laying was monitored at each site each year. Site details are given in Table 4.

Lettuce Trial

In a preliminary trial on lettuce cv Unrivaled, 8 formulated insecticides at each of 5 rates, 5-60 mg a.i./plant were used (Table 6.). Because of difficulties with germination 3 sowings were necessary, the final one using pre-germinated seed, was made 13 days after blocking.

RESULTS

Cabbage Trials

Phytotoxicity: In 1976 thiophanate methyl affected seedling growth very slightly compared with those in untreated compost, but the plants soon recovered. Carbofuran granules and BTS 34778 were extremely phytotoxic. Isazaphos at 0.850 g a.i./kg but not at 0.425 g a.i. retarded growth and produced slight cupping of the leaves, though plants recovered and in 1976 gave the heaviest yield; at 1.700 g a.i. the symptoms were more extreme and at 3.400 g a.i. the seedlings were killed. Triazophos e.c. retarded growth slightly in 1976 though the plants recovered before they were planted out and in 1977 no adverse effects were seen. Chlorfenvinphos granules at 0.425 and 0.850 g a.i. were very slightly phytotoxic though at 1.700 g a.i. they caused cupping of the leaves.

Chlorfenvinphos e.c. was not phytotoxic in 1976 though in 1977 it checked growth slightly. Chlorpyrifos granules had a slight effect in 1976 but in 1977 the seedlings grew slowly and unevenly. Usually symptoms were most obvious after 3-4 weeks and frequently they had almost disappeared by the time the plants were hardened-off.

Chlorfenvinphos and triazophos e.c. formulations watered onto the plants 5 weeks after sowing were very phytotoxic though triazophos-treated plants recovered. Most of the granule treatments applied at this time had little effect on growth. Half the intended rate of chlorpyrifos was used because there was not enough room for the full rate on the blocks.

Cabbage Root Fly Damage: Treatments in 1977 appeared to be more effective than those used in 1976 (Table 1). Though planted by hand at the same depth much damage occurred at the base of the stems below ground level but above the surface of the block in 1976 which did not happen in 1977. This damage was included when assessing the RDI but though substantial, it did not appear to affect growth severely and there was little correlation between cabbage root fly damage and yields.

In 1976 the least damage occurred on isazaphos-treated plants followed by the spot application of chlorfenvinphos and chlorpyrifos granules mixed into the blocks. Appreciable amounts of damage occurred in all other treatments though apart from isofenphos gran at Kingsbridge and triazophos e.c. at both sites, there was more damage on untreated plants.

In 1977 isazaphos (0.425 rate) and chlorpyrifos granules were the best block-applied treatments though all were effective. Inexplicably an appreciable amount of damage occurred in one replicate where isazaphos was used at 0.850 g a.i./kg.

In the log dose plots in 1976 the RDIs increased from nil to 87 as the rate of chlorfenvinphos decreased and in 1977 all except the lowest rate of isazaphos (0.212 g a.i.) prevented damage compared with an RDI of 40 on the untreated controls (Table 2).

The amount of damage in the planting depth trials in both years increased as the blocks were planted more deeply (Table 3); in 1976 this occurred on treated and untreated plots but to the untreated plants only in 1977 where chlorfenvinphos and isazaphos eliminated damage almost completely.

Yields: Plants raised in peat blocks matured faster and gave heavier yields than transplanted plants in both years (Table 1). In 1976 all insecticides mixed into peat blocks increased yields compared with those from untreated blocks but isazaphos was better than other treatments. At Kingsbridge where the cabbage root fly attack was heavier and where the crop was irrigated three times, the transplanted plants treated with chlorfenvinphos granules as a spot treatment out-yielded the untreated plants raised in blocks. At Starcross where the attack was lighter and the crop irrigated only once there was little difference between the plants in untreated blocks and transplanted ones treated with a spot application of chlorfenvinphos (Table 1).

In 1977 differences between block-raised plants were smaller or somewhat inconsistent between sites (Table 1) though they again out-yielded the transplanted plants. Plants grown in untreated blocks grew as well as those in treated blocks at both sites, though chlorpyrifos granules, particularly when applied before sowing, tended to delay maturity.

In the unreplicated log does experiments plants treated with varying rates of chlorfenvinphos gave rather anomolous results, though all were better than the untreated plants. In 1977 plants treated with from half to four times the normal rate of isazaphos grew well and gave a similar yield to the untreated plants (Table 2).

Both years plants set with the tops of the blocks 25 mm below the soil surface matured earlier and produced a greater total yield than plants in the blocks planted at soil level (Table 3). In 1977 blocks were also planted at 50 mm and those treated with carbofuran or chlorfenvinphos grew better than the equivalent treated plants at 0 or 25 mm. The untreated plants at 50 mm matured earlier but gave a smaller total yield.

Residues: Insecticide residues were not detected at harvest after any of the treatments used in the screening trials in 1976.

Lettuce Experiments

Phytotoxicity: The three highest rates of chlorpyrifos and the two highest rates of dimethoate damaged lettuce seedlings badly but plants treated at lower rates or with the other insecticides grew well enough to be planted.

Control of Aphids: Seven weeks after sowing plants treated with systemic insecticides at all rates were completely free from aphids but nearly all the untreated plants, or those treated with non-systemic insecticides were infested with leaf aphids (mainly Nasonovia ribisnigri and some Myzus persicae) (Table 5).

Two weeks later very low populations had developed on all plots with possibly larger populations on plots treated with smallest rates of ethiofencarb, disulfoton and phorate.

DISCUSSION

Yields of cabbage were improved when insecticides were incorporated into the blocks in 1976 even though control was apparently poor, while the reverse occurred in 1977.

Although different operators scored the plants for damage in the two years the difference is more likely to be seasonal. In 1976 the plants were sown later, hardened off for a shorter time, planted into drier soil in hotter weather and the attack of cabbage root fly began sooner after planting than in 1977 (Table 4). Even though appreciable damage occurred in the untreated plants in 1977 they were possibly sufficiently well established to tolerate damage. The higher soil moisture levels in 1977 may also have increased the efficiency of the insecticides, particularly in soil around the stem immediately above the block. Isazaphos is likely to be effective in dry conditions because it is partly systemic.

Mixing insecticides into peat blocks appears to be a simple and inexpensive method of cabbage root fly control on cabbage and possibly aphids on lettuce. Further work is necessary to assess the hazards to operators handling treated blocks, residue levels in the crops and to determine the minimum levels necessary to give economic control.

Aphid populations on the lettuce trial declined towards the end of the experiment partly as a result of predators and parasites, many of which would have been killed by sprays of non-selective insecticides. Fewer predatory beetles may have been killed in the cabbage experiments where insecticides were confined in peat blocks. This technique may, therefore, have certain environmental advantages as well as being a simple and effective technique for growers.

Acknowledgements

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Table 1

Effect of insecticides mixed into peat blocks on yield of marketable cabbage and on control of cabbage root fly damage

1976 Screening Trials - Kingsbridge and Starcross

Treatments	Weight of Marketable Cabbage - kg 1st Cut K'bridge	SX	Total K'bridge	SX	RDI K'bridge	SX
Plants in Peat Blocks (0.425g a.i./kg peat)						
+Isazaphos gran	16.67	8.17	18.83	11.92	9.6	2.4
Chlorfenvinphos gran	12.17	6.00	13.83	9.00	43.6	47.4
Isofenphos gran	13.25	7.67	15.50	9.50	63.3	57.3
Chlorpyrifos gran	10.83	5.83	14.25	7.93	24.2	30.5
Chlorfenvinphos e.c.	11.33	5.56	16.00	9.25	44.1	42.6
Chlorfenvinphos w.p.	10.17	6.50	13.75	10.25	52.5	49.4
Triazophos e.c.	13.25	4.50	16.58	8.25	59.8	70.5
Untreated control	3.17	3.50	5.92	7.42	73.0	59.3
Transplanted Plants						
*Chlorfenvinphos gran 0.017g	1.75	5.33	9.17	7.67	23.9	9.7
Untreated control	0.17	2.83	4.67	7.50	58.3	69.6
SED ±	3.585	1.47	2.943	1.35	6.51	7.77
1977 Screening Trials - Kingsbridge and Starcross						
Plants in Peat Blocks (0.425g a.i./kg peat)						
Chlorfenvinphos gran-sowing	18.33	9.53	23.40	10.60	1.3	11.3
Chlorfenvinphos gran-later	15.73	6.10	22.67	9.43	0.2	13.0
Isazaphos gran-sowing	17.77	7.00	22.47	10.56	1.0	1.8
Isazaphos gran-later	15.03	7.00	22.60	10.63	0.9	1.4
+Isazaphos gran-sowing	15.50	7.93	21.92	10.00	1.0	8.1
Carbofuran gran-later	17.47	7.77	21.43	11.13	5.5	7.5
Chlorpyrifos gran-sowing	12.73	5.50	20.83	9.83	3.0	0.7
Chlorpyrifos gran-later	18.00	4.63	22.80	8.76	1.1	0.0
Chlorfenvinphos e.c. sowing	18.90	8.10	23.00	10.56	3.2	16.3
Triazophos e.c. sowing	15.20	7.43	22.20	11.26	9.3	13.9
Triazophos e.c. later	18.97	5.27	24.17	9.83	8.7	2.3
Untreated control	17.47	5.47	24.70	9.96	41.5	35.8
Transplanted Plants						
*Chlorfenvinphos gran 0.017g	5.03	1.33	15.07	8.63	0	1.8
*Carbofuran gran 0.02g	5.50	1.60	13.40	7.57	0.3	7.5
Untreated control	4.47	1.80	11.70	7.53	35.4	38.9
SED ±	2.83	1.84	2.56	NS	-	-

* Spot application - rates a.i. per plant

\+ 0.850 g a.i./kg dry peat

gran = granules; e.c. = emulsifiable concentrate; w.p. = wettable powder

Table 2

The effect of concentration of two insecticides on growth of cabbage and on the control of cabbage root fly

Treatment	Rate (g a.i./kg "dry" peat)	Weight of Marketable cabbage - kg 1st cut	Total	RDI
1976 Trial				
Chlorfenvinphos	1.700	-	17.0	0
Chlorfenvinphos	0.850	-	8.0	3
Chlorfenvinphos	0.425	-	14.0	29
Chlorfenvinphos	0.212	-	8.0	53
Chlorfenvinphos	0.106	-	9.0	64
Untreated control	-	-	3.2	37
1977 Trial				
Isazaphos	1.700	15.0	18.4	0
Isazaphos	0.850	12.3	19.9	0
Isazaphos	0.425	12.0	19.0	0
Isazaphos	0.212	7.8	17.1	6.3
Untreated control	-	9.4	18.3	39.6

Table 3

Effect of planting depth on growth of cabbage and on the control of cabbage root fly

Treatments	Depth of planting	Weight of Marketable cabbage - kg 1st cut	Total	RDI
1976 Trial (0.425 g a.i./kg peat)				
Chlorfenvinphos - In block	0 mm*	6.17	15.58	7.5
	25 mm	6.67	14.25	16.2
Chlorfenvinphos - Surface of block	0 mm*	1.33	13.42	6.6
	25 mm	3.67	13.0	9.7
Untreated control	0 mm*	2.25	11.25	27.2
	25 mm	3.17	11.67	34.1
SED ±	-	2.126	2.057	3.19
1977 Trial - Unreplicated				
Chlorfenvinphos - In block	0 mm*	0.2	3.6	0
	25 mm	1.4	10.1	6.1
	50 mm	5.1	11.6	0
Isazaphos - In block	0 mm*	0.2	2.0	0
	25 mm	1.7	10.5	0
	50 mm	8.8	13.4	0
Untreated control	0 mm*	3.7	11.2	15.4
	25 mm	5.3	15.5	53.9
	50 mm	6.0	9.1	57.0

* Soil surface

Table 4

Site details for experiments on the control of pests of cabbage and lettuce

	Plants per plot	Replicates	Sowing date	Planting date	1st cut	Final cut	Cabbage root fly data: Peak egg laying	Cabbage root fly data: Maximum eggs/plant/week
Cabbage Trials								
1976								
Screening - Kingsbridge	30	3	11 March	27 April	29 June	12 July	12-18 May	59
Starcross	15	3		29 April	23 June	8 July	7-14 May	24
Depth of planting	28	3		30 April	28 June	22 July		
Log dose	30	1		30 April	26 July	26 July		
1977								
Screening - Kingsbridge	30	3	28 Feb	25 April	22 June	29 July	25-31 May	13
Starcross	15	3		22 April	20 June	4 July	7-13 June	10
Depth of planting	30	1		27 April	20 June	27 June		
Log dose	30	1		22 April	20 June	27 June		
Lettuce Trial					Aphid Assessments			
Preliminary trial	10	3	9 June	5 July	15 July	28 July		3-4 August

Table 5

Control of leaf aphids on lettuce in peat blocks

Treatment	Rate (mg a.i. /plant)	No of infested plants per plot (10 plants)			Harvest weight/ plant-g
		15 July	28 July	3-4 August	
Ethiofencarb 10% g	60	0	3.0	0	85.9
	40	0	3.0	0	70.0
	20	0	3.7	1	90.0
	10	0	2.3	0.3	131.7
	5	0	4.0	1.3	140.0
Disulfoton 10% g	60	0	2.7	0	143.3
	40	0	2.0	0.3	110.0
	20	0	1.7	0	123.3
	10	0	2.0	0.3	100.0
	5	0	4.7	0	133.5
Phorate 10% g	60	0	2.3	0.3	111.7
	40	0	2.3	0.3	96.7
	20	0	2.3	0	103.3
	10	0	6.0	2.0	120.0
	5	0	6.7	1.7	116.7
Demeton-S-methyl 58% e.c.	60	0	5.3	0.3	120.0
	40	0	1.7	0.3	133.3
	20	0	2.0	0	111.7
	10	0	3.0	0	103.3
	5	0	3.3	1.7	158.3
Dimethoate 40% e.c.	20	0	1.3	0.7	76.6
	10	0	2.0	0	106.6
	5	0	1.3	1.0	143.3
Chlorpyrifos 5% g	10	8.7	8.7	4.7	103.3
	5	10.0	9.7	4.7	96.6
Diazinon 5% g	60	7.7	8.7	2.3	100.0
	40	7.3	8.0	2.0	88.4
	20	9.3	6.7	2.0	106.7
	10	8.7	8.0	1.3	116.7
	5	9.3	7.7	3.3	140.0
Diazinon 40% w.p.	60	8.7	9.0	1.7	116.7
	40	7.7	8.7	1.7	83.3
	20	10.0	8.3	6.7	101.7
	10	7.3	8.7	1.3	113.3
	5	9.0	7.7	1.7	103.3
Untreated control (Mean of 3)	-	8.9	8.8	2.3	111.1

Notes

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CONTROL OF POWDERY MILDEW (ERYSIPHE CRUCIFERARUM) ON BRUSSELS SPROUTS

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Summary Three years of replicated field trials were carried out to evaluate fungicides and two methods of application, using drop-leg and overhead plot sprayers for control of powdery mildew (*Erysiphe cruciferarum*) on brussels sprouts. All fungicides gave some control of the disease but the best control was achieved with dinocap and fluotrimazole. Application with a drop-leg sprayer seemed to give better results than overhead spraying. Overall yield was not affected by the disease or any of the treatments, and the main effect of the disease was to cause blemishing of the buttons. For the most effective control of powdery mildew, application should be made at an early stage of disease development. Under conditions of rapid development of infection, subsequent applications may be necessary at fortnightly intervals.

INTRODUCTION

Powdery mildew, (*Erysiphe cruciferarum*), commonly attacks Brassicae (Dixon, G.R., 1974) and the incidence in brussels sprout acreages has been causing concern in recent years. In 1975 and 1976 infections were severe in Cambridgeshire and Bedfordshire and the disease has been reported in sprouts for processing in other areas. Cross infection from rape, swedes and turnips may occur since they also are prone to powdery mildew attack. (Dixon, G.R., 1977).

Conditions favouring powdery mildew are initially periods of drought stress followed by moisture. It is first noticed as a mass of white mycelia occurring in spots on the upper leaf surface, which coalesce covering the leaf. The mildew may then spread and penetrate the buttons.

Although powdery mildew affects foliage and buttons, it is the quality of the buttons, rather than yield depression, which suffers most. Under the EEC grading system, blemishes with mildew result in downgrading of sprouts for fresh market. Processors may reject crops where the disease is severe, since extra hand trimming is necessary to remove affected leaves and, where penetration occurs, the produce fails to reach the required standard. Mechanical stripping or trimming machines will not remove defective outer leaves.

Trials investigating ways of controlling powdery mildew with fungicide sprays were carried out by PGRO from 1974-76 under contract to MAFF. Different methods of application were also studied, since it was considered essential when using a protectant to obtain good coverage of the lower leaves where initial infection occurs.

METHODS AND MATERIALS

In 1975 a replicated experiment with a randomised block layout was carried out in a brussel sprout crop grown for freezing. The effectiveness of fungicides was compared (Table 1) and one material, dinocap, was applied by a drop-leg spray rig, as well as by a conventional overhead sprayer. Water was applied to untreated control plots. Treatments were applied in 560 l/ha of water at intervals of approximately fourteen days. Sprays were applied with either a Van der Weij (overhead) plot sprayer fitted with Birchmeier cone nozzles at a pressure of 2.5 kg/cm^2, or a drop-leg sprayer with a boom consisting of two rigid pendant lances and an overhead section fitted with ceramic tipped 'T-jet' fan nozzles and operating at 2.5 kg/cm^2 pressure. The experiment was at Shefford, Bedfordshire and used F_1 hybrid cv. Rampart at 50 x 50 cm plant spacing. Plots were three rows wide and 5 metres long, and the middle row was assessed and harvested. Applications started on 26th August when 5% of the lower leaves were infected. Five applications were made during the season as the severity of the disease increased.

In 1976 fungicide treatments were applied at two sites, and first applications of all materials tested (Tables 2 & 3) were made with overhead or drop-leg sprays, when the latter passed through the crop without difficulty. Subsequent applications were made with the overhead sprayer. Experiment 2, at Elsworth, Cambridgeshire, used cv. Lunet grown at 50 x 71 cm and the first treatments were applied when there was 10% infected area on the lower leaves. At Mogerhanger, Bedfordshire (experiment 3), with cv. Rampart grown at 50 x 76 cm. spacing, first applications were made at a stage when there was 6% mildew infection on the lower leaves.

Assessments for powdery mildew were made using the NIAB key, on a random sample of 5 plants from the centre rows of each plot, before each spray application. Results were recorded as % infected area of upper surface of lower leaves, and upper surface of uppermost, fully expanded leaves. Five buttons from lower, middle and upper portions of the stem of five plants were also assessed. The centre row from each plot was harvested and assessed for mildew. Stems were stripped using a Jamafa sprout stripper, and buttons examined for mildew penetration. Plot produce was weighed and buttons graded for size.

RESULTS

Yields of sprout buttons in experiments 1 and 2 are shown in Tables 1 & 2 respectively. No statistically significant differences (P = 0.05) were found between yields of any of the treatments.

The results of assessments for powdery mildew in 1975 in experiment 1 are the mean of four replicates (Table 1). The disease developed on control plots up to 22nd September, but all treatments reduced the level of infection. Rainfall then reduced the amount of leaf infection. However, by harvest on 24th November, it had spread on control plots to give 26% infection on lower buttons and penetrated below 8 leaves, and on middle buttons infection was 8% and penetration below 3 leaves. Cold weather turned the mycelium growth on the buttons black, causing further disfigurement. Treatments prevented the disease developing on the buttons up to 6th November, but infection then increased although penetration into the buttons did not occur. The quality defects on the buttons were not removed by the stripping machine.

Application of dinocap with a drop-leg sprayer gave slightly better control than with the overhead sprayer, probably because the reservoir of infection on lower leaves was reduced at an early stage. However difficulties in operating the drop-leg sprayer in a dense crop were experienced during late applications.

Table 1

Experiment 1. Assessments of powdery mildew (*Erysiphe cruciferarum*) & Total Yield of Brussels sprouts

Percentage area infected, mean of 20 plants (NIAB key)

Fungicide	Rate kg a.i./ha	10 Sept. Leaves % Lower	22 Sept. Leaves % Lower	22 Sept. Leaves % Upper	20 Oct. Leaves % Lower	20 Oct. Leaves % Upper	20 Oct. Buttons % Lower	24 Nov. Buttons % Lower	24 Nov. Buttons % Middle	24 Nov. Buttons % Upper	Total yield tonnes/ha
Dinocap (drop-leg)	0.56	1	3	0	1	0	0	1	0	0	16.7
"	0.56	3	6	1	5	3	0	5	2	0	10.6
" + Actipron oil	0.56+5.6 1	3	6	1	7	3	0	5	1	0	11.4
Fluotrimazole	0.09	4	10	1	6	2	0	6	0	0	9.7
"	0.18	3	9	1	4	1	0	5	0	0	12.7
Tradimefon	0.24	4	12	2	6	1	0	8	2	0	11.9
Pyrazophos	0.3	3	11	2	6	3	0	7	2	0	12.3
Tridemorph	0.53	5	17	3	11	4	0	10	3	0	10.3
"	1.06	3	10	2	7	2	0	8	2	0	11.9
" + carbendazim	0.26+0.15	3	12	3	11	5	5	8	2	0	12.0
Binapacryl	1.0	4	14	2	13	7	0	12	4	0	12.8
Ditalimfos	0.5	4	16	4	10	4	0	13	3	0	12.3
Water control	-	6	41	10	30	10	28	26	8	0	13.2
Significance @ P = 0.05											N.S.
S.E. as % of gen. mean											22.2

Application dates 26 August, 10 September, 22 September, 7 October & 23 October.

Table 2

Experiment 2. Assessments of powdery mildew (*Erysiphe cruciferarum*) & Total Yield of Brussels sprouts

Fungicide	Rate kg a.i. /ha	3 Sept method of application	Percentage area infected, mean of 15 plants (NIAB key) & application												Total yield tonnes /ha.
			17 Sept.		17 Sept method of application	4 Oct.				4 Oct. method of application	27 Oct.				
			Leaves %			Leaves %		Buttons %			Buttons %			No. leaves penetrated on lower buttons	
			Lower	Upper		Lower	Upper	Lower	Middle		Lower	Middle	Upper		
Dinocap	0.56	DL	4.1	1.1	-	6.7	1	1.7	0	-	15.0	5	0	3	10.0
"	"	DL	4.3	1.7	OH	1.7	0	0	0	-	5.0	0	0	2	11.2
"	"	DL	2.8	trace	OH	2.7	trace	1.7	0	OH	8.3	0	0	2	9.1
"	"	OH	5.6	1.0	OH	5.7	0.5	0	0	OH	15.0	1.7	0	3	11.0
Fluotrimazole	0.09	DL	2.7	0.7	OH	1.7	trace	0	0	OH	1.7	0	0	2	11.7
"	"	OH	3.5	trace	OH	3.0	0.9	0	0	OH	4.3	0	0	2	10.2
Triadimefon	0.06	OH	4.0	1.0	-	4.3	0.5	3.3	0	-	14.7	3.3	0	3	9.9
"	"	DL	3.7	1.8	OH	2.3	0	0	0	OH	5.0	1.7	0	2	9.3
"	"	OH	2.3	0.7	OH	3.7	0.6	0	0	OH	13.3	3.3	0	3	9.4
Pyrazophos	0.3	OH	6.3	2.3	-	9.0	1.3	5	0	-	28.3	3.3	0	6	11.0
"	"	DL	7.7	1.9	OH	6.0	0.8	3.3	0	OH	20.0	5.0	0	4	9.0
"	"	OH	8.7	1.3	OH	9.0	0.8	1.7	0	OH	18.3	3.3	0	4	9.4
Tridemorph + Carbendazim	0.53 + 0.15	OH	8.0	2.3	-	11.3	1.5	5	0	-	20.0	15.0	trace	6	10.2
"	"	DL	8.0	2.0	OH	7.7	1.3	1.7	0	OH	17.5	7.5	0	4	10.0
"	"	OH	7.0	1.9	OH	10.0	0.8	3.3	0	OH	22.5	7.5	0	4	10.2
Control (water)		-	25	10	-	43.0	4.3	31.7	11.7	-	75.0	62.5	15	10	9.4
Significance @ P = 0.05															NSD
SE as % of gen. mean															18.6

Key: DL = drop-leg spray
OH = overhead spray

Table 3

Experiment 3. Assessments of powdery mildew (*Erysiphe cruciferarum*)

Fungicide	Rate kg a.i./ha	6 Sept. method of application	Percentage area of infection, mean of 15 plants (NIAB key) & application										
			17 Sept.		27 Sept.			27 Sept.	4 Nov.				
			Leaves %		Leaves %		Buttons %	method of application	Leaves %		Buttons %		
			Lower	Upper	Lower	Upper	Lower		Lower	Upper	Lower	Middle	Upper
Dinocap	0.56	DL	2.6	trace	2.0	1.0	0	-	8.3	1.8	0	0	0
"	"	DL	2.0	"	5.6	1.0	0	OH	7.0	trace	0	0	0
"	"	DL	3.5	1.0	6.7	1.8	0	OH	6.6	0	0	0	0
"	"	OH	4.3	1.0	5.0	1.0	0	OH	8.0	1.6	0	0	0
Fluotrimazole	0.09	DL	3.1	trace	2.0	1.0	0	OH	5.0	0	0	0	0
"	"	OH	2.0	"	5.3	1.4	0	OH	6.3	trace	0	0	0
Triadimefon	0.06	OH	3.3	1.0	4.3	1.5	0	-	14.0	1.6	trace	0	0
"	"	DL	4.9	1.0	7.0	2.6	0	OH	9.0	trace	0	0	0
"	"	OH	2.1	trace	7.3	1.7	0	OH	11.3	0	0	0	0
Pyrazophos	0.3	OH	6.3	3.3	9.0	3.1	0	-	15.6	4.3	6.3	0	0
"		DL	5.6	2.0	9.0	2.3	0	OH	12.0	1.8	1.6	0	0
"		DL	5.6	2.0	9.0	2.3	0	OH	12.0	1.8	1.6	0	0
Tridemorph + Carbendazim	0.53 + 0.15	OH	7.3	2.0	10.7	6.1	0	-	13.0	4.3	9.0	trace	0
"	"	DL	5.3	1.8	9.3	2.7	0	OH	14.0	2.0	7.3	0	0
"	"	OH	6.0	2.0	8.7	2.7	0	OH	15.6	4.0	7.3	0	0
Control (water)		-	14.3	5.6	37.3	15.3	5	-	39.3	15.6	15.0	5	0

Key: DL = drop-leg spray
OH = overhead spray

Control with systemic fungicides was not very good in 1975 when plant growth was extremely slow. The most effective fungicides were dinocap and fluotrimazole. The addition of Actipron oil to dinocap did not noticeably improve its performance.

Assessments for powdery mildew in 1976 in experiment 2 are the means of three replicates (Table 2). Before the first application of fungicides on 3rd September, 10% of the lower leaf and 5% of the upper leaf area was infected. No disease was apparent on the buttons at that time. The disease spread rapidly on control plots until heavy rain began on 24th September and infection on the upper leaves was reduced. Mildew remained on the lower leaves and spread to lower button where the infection area was 31.7% on control plots by 4th October. By harvest the quality of the buttons had deteriorated, and on all plots lower buttons became overmature and were spoiled by invasion of saprophytic organisms including Botrytis spp. On the untreated plots the infection on lower buttons was 75.0% and had penetrated below the tenth leaf. The defects were not removed by the stripping machine.

In 1976, all fungicide treatments gave some control of powdery mildew and drop-leg application of dinocap and fluotrimazole gave better control than overhead sprays. One drop-leg and two overhead sprays of fluotrimazole reduced infection to 1.7% on lower buttons and 0% on middle buttons at harvest, compared with three overhead sprays when infection was 14.7% on lower buttons and 3.3% on those from the middle of the stem. One application of dinocap seemed insufficient, but three gave no better control than two. Triadimefon was the next best treatment, pyrazophos and the tridemorph + carbendazim mixture were the least effective treatments.

Similar trends occurred in experiment 3 (Table 3) but mildew did not develop rapidly on the untreated plots. Only two spray applications were made. By 4th November, 15% of the area on the lower buttons were blemished. All treatments gave some control, but dinocap and fluotrimazole performed best. Triadimefon also gave good results. Drop-leg application gave better control and reduced infection on the lower leaves compared with overhead sprays.

DISCUSSION

Results showed no indication that overall yields were affected by the disease, or by any of the treatments. The main effect of powdery mildew is to cause blemishing of the sprout buttons, and the penetration of mildew on lower buttons from control plots in the experiments would have resulted in their rejection by the processor.

Application of materials with a drop-leg sprayer was slightly more effective than overhead sprays, because improved cover on the lower leaves apparently cleared up the reservoir of infection. This could be particularly important with a protectant type of material. In the past there has been resistance to the commercial use of drop-leg sprayers, particularly in high-density, close-row sprout crop for processing since they have a tendency to cause damage and ride on top of the crop. Recently developed sprayers, where heavy metal legs trail the ground, may overcome this.

All fungicide treatments gave some control of powdery mildew. Fungicides with some systemic action, such as triadimefon, pyrazophos, tridemorph + carbendazim, binapacryl and ditalimfos, did not generally perform as well as protectants and it is doubtful whether their use could be recommended in a sprout crop, since in some seasons translocation may be too slow to deal with mildew efficiently. The best control was achieved with fluotrimazole or dinocap. Both materials are protectants (although fluotrimazole has some systemic action in the leaf) and therefore it is necessary for sprays to be applied as soon as the disease is noticed. This was demonstrated where better control was achieved with dinocap in experiment 3, where application was made earlier when infection was at a lower level than in experiment experiment 2.

Since development of infection is dependent on weather conditions, frequent inspection of commercial crops is necessary, and, if initial applications have not controlled the disease a further application should be made after fourteen days and afterwards as necessary.

Acknowledgements

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Notes

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CONTROL OF CAULIFLOWER DOWNY MILDEW (PERONOSPORA PARASITICA) WITH SYSTEMIC FUNGICIDES

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Summary Systemic fungicides were tested for control of downy mildew in early summer cauliflower raised under polythene. In 1975/76, prothiocarb, incorporated in soil at 7 and 14 g a.i./m^2 and applied as eight foliar sprays at 1 g a.i./10 m^2 was compared with eight dichlofluanid sprays at 1 g a.i./10 m^2 in a polythene walk-in tunnel. In 1976/77 prothiocarb and LS74-783 applied in soil at 5, 10 and 20 g a.i./m^2 and as three foliar sprays were compared with eight dichlofluanid sprays in a walk-in tunnel and in low tunnels. Natural infection was relied on in all experiments.

In all trials, incorporation of the systemic fungicides in soil gave excellent control of mildew with no evidence of phytotoxicity. All rates of prothiocarb and the highest rate of LS 74-783 gave good results but the lower rates of LS 74-783 were less effective. Eight foliar applications of prothiocarb also gave very good control, but relatively poor control was obtained with three applications of the systemics or eight applications of dichlofluanid.

INTRODUCTION

Downy mildew (Peronospora parasitica) is a serious problem in cauliflower seedlings raised under glass or polythene during the winter period. Following the work of Whitwell and Griffin (1967) and Channon et al (1970) dichlofluanid has been recommended for control of this disease. It was found to be particularly effective in controlling mildew on the cotyledons but was unreliable in protecting the true leaves. This method of control therefore has the disadvantages of requiring eight or more foliar sprays and of being relatively ineffective against a late attack of mildew.

The advent of systemic fungicides active against phycomycetes has opened up new possibilities for control. Royle (1975) found some of these compounds to be effective in controlling downy mildew of hops. Baines (1975) reported on the use of prothiocarb for control of downy mildew in early summer cauliflower seedlings raised in peat blocks or in a loam-based compost in pots. Useful control was obtained when prothiocarb was applied as a programme of at least three sprays or incorporated in the compost.

The purpose of the work described here was to test the applicability of the new systemic compounds for the control of downy mildew in cauliflower sown directly in the soil in polythene walk-in tunnels and low tunnels.

METHODS AND MATERIALS

Two systemic fungicides were tested, prothiocarb only in 1975/76, and prothiocarb and LS 74-783 (Aliette) in 1976/77. Dichlofluanid was included as a standard in all experiments and eight foliar applications were made. All foliar sprays were at the rate of 1 g a.i. in 1 l water/10 m^2. For soil incorporation, fungicides were sprayed on the soil surface in 1 l water/m^2 and raked in just before seeding. The cauliflower cv. Focus was used in all trials. Individual plots consisted of 2 rows of plants 1 m long and 0.2 m apart, and there were three replicates. Natural infection was relied on.

In 1975/76, prothiocarb at 7 and 14 g a.i./m^2 was incorporated in the soil in a walk-in polythene tunnel and the seed was sown on 4th December. Commencing at seedling emergence on 5th January, eight foliar sprays of prothiocarb and dichlofluanid were applied. Following the onset of mildew, disease assessments were made on 27 February and 23rd March.

In 1976/77, two experiments were done, one in a walk-in tunnel and the other in low tunnels (or cloches). In both experiments, prothiocarb and LS 74-783, each at 5, 10 and 20 g a.i./m^2 were incorporated in the soil before sowing. They were also tested as three foliar sprays applied at emergence and at 12 and 26 days after emergence.

In the low tunnels, seed was sown on 17th December and foliar applications commenced at emergence on 29th January. Disease assessments were made on 13th and 25th April.

In the walk-in tunnel, pre-germinated seed was sown on 7th January and the first foliar applications were made on 15th January. Disease was assessed on 28th March and 13th April.

RESULTS

In 1976, mildew became evident by mid February and increased in prevalence and severity over the following six weeks. Disease assessments were made on 27th February and 23rd March (Table 1).

Table 1

The effect of fungicidal treatments on incidence and severity of downy mildew of cauliflower and on plant stand, 1975/76

Fungicidal treatment		Rate of application	Mildew incidence (%)		Disease severity Index[1]		Plant stand (control = 100)
			Feb 27	Mar 23	Feb 27	Mar 23	Mar 23
Untreated control			44	100	1.9	2.8	100
Foliar sprays	Dichlofluanid	1 g/10m^2	18	85	1.1	2.3	124
	Prothiocarb	1 g/10m^2	0	26	0.0	1.1	131
Soil treatment	Prothiocarb	7 g/m^2	0	17	0.0	0.7	133
	Prothiocarb	14 g/m^2	0	10	0.0	0.6	129
LSD 5%			20.5	17.6	1.29	0.68	19.5

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[1] Based on scale: 0 = No disease; 5 = Very severe disease

Dichlofluanid gave some control at first but became less effective as the disease progressed. Good control was obtained at all stages with prothiocarb at both rates of soil treatment and as foliar sprays. All fungicidal treatments improved the final stand of plants.

In 1977, the onset of disease was relatively late in both experiments, especially in the low tunnels. Assessments of disease severity were made about one week after onset and again about 2 weeks later (Table 2).

Table 2

The effect of fungicidal treatments on severity of downy mildew of cauliflower, 1976/77

Fungicidal treatment		Rate of application	Disease severity Index[1]			
			Walk-in tunnels		Low tunnels	
			March 28	April 13	April 13	April 25
Untreated control			2.4	3.7	2.0	3.0
Foliar sprays	Dichlofluanid	8 @ 1 g/10 m^2	1.4	2.8	1.6	2.3
	LS 74-783	3 @ 1 g/10 m^2	1.7	1.9	1.7	1.9
	Prothiocarb	3 @ 1 g/10 m^2	1.6	2.1	1.5	1.7
Soil treatment	LS 74-783	5 g/m^2	1.2	2.6	1.0	2.0
	LS 74-783	10 g/m^2	0.7	1.8	0.3	1.2
	LS 74-783	20 g/m^2	0.0	0.8	0.0	0.6
	Prothiocarb	5 g/m^2	0.6	1.4	0.2	1.0
	Prothiocarb	10 g/m^2	0.2	1.1	0.0	0.9
	Prothiocarb	20 g/m^2	0.0	0.5	0.0	0.7
LSD 5%			0.72	0.76	0.78	0.56

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[1] Based on scale: 0 = No disease; 5 = Very severe disease

The results were similar in both experiments. All foliar treatments gave equally poor disease control though at the second assessments dichlofluanid tended to be less effective than the others. When incorporated in soil, prothiocarb at all three rates of application and LS 74-783 at the highest rate gave good disease control at both dates of assessment. The lowest rate of LS 74-783 gave poor control and the intermediate rate gave variable results.

DISCUSSION

The results obtained with prothiocarb and LS 74-783 offer a number of advances over current recommendations for control of cauliflower downy mildew. The improvement in disease control, especially of infection occurring late in the propagation period, is obviously welcome.

With regard to application methods, soil application compares favourably with foliar sprays. A small number of foliar applications does not give adequate control while a programme of frequent sprays retains the high labour disadvantage. Soil treatment offers the advantage of a single operation giving good disease control over a relatively long period. It is particularly advantageous for low tunnels where foliar applications are very troublesome.

While results suggest that LS 74-783 must be applied at a relatively high rate, it would seem that prothiocarb may be effective at rates lower than those tested. Further work is obviously necessary to examine the effects of different rates of application on degree and duration of disease control. At this stage, it may be more beneficial to establish principles and methods in relation to the use of these new systemic fungicides than to critically compare one fungicide with another. Many of the early compounds have already been replaced by related chemicals and in some instances clearance for use on food crops has yet to be obtained.

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EVALUATION OF NEW SYSTEMIC FUNGICIDES AGAINST LETTUCE DOWNY MILDEW

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Summary The systemic fungicide CGA 38140 (Ciba-Geigy) gave excellent control of downy mildew (Bremia lactucae) on protected lettuce, incorporated in peat blocking compost and applied as a drench to the block at rates equivalent to 72-75g a.i./m^3 of compost. Good control was also given by fortnightly HV foliar sprays of LS74-783 (May & Baker) at 3.0g a.i./l. CGA 38140 and LS74-783 gave better control of downy mildew than fortnightly foliar sprays of zineb plus thiram, the standard treatment. Foliar sprays of DPX-3217 (Du Pont) plus mancozeb also controlled downy mildew but were less effective than the standard treatment.

INTRODUCTION

The most important fungal diseases of protected lettuce in the United Kingdom are downy mildew (Bremia lactucae) and grey mould (Botrytis cinerea), each of which has been estimated to cause a national annual yield loss of between 1 and 3% (Fletcher, 1973). For many years control of these diseases has depended on maintaining a good cover of protectant fungicide (usually a dithiocarbamate) on the leaves, a slow growing crop often requiring as many as 10 or more foliar sprays. In recent years concern has increased in the UK about levels of dithiocarbamate residue on lettuce (Hatfull, 1976) and several European countries have imposed a limit of 3 ppm dithiocarbamate residue (Casanova and Dubroca, 1973; Steurbaut et al, 1973). To consistently achieve such low residues, post-planting control programmes would need to be restricted to one or two foliar applications leaving 4 to 6 weeks between the last application and harvest, and would not give adequate commercial control of downy mildew under 'high risk' situations in the UK. The lettuce industry, therefore, urgently needs new fungicides to be more effective against downy mildew than the dithiocarbamates with fewer post-planting applications.

In the last few years several new compounds have shown considerable promise against B. lactucae (Fletcher, 1976; Bertrand et al, 1977; Crute and Norwood, 1977; Crute et al, 1977; Schwinn et al, 1977) and against other members of the Peronosporales (Bertrand et al, 1977; Royle, 1977; Schwinn et al, 1977; Serres and Carraro, 1976; Smith, 1977; Wiertsema and Wissink, 1977) but none is yet commercially available in the UK for use on lettuce. This paper describes trials in 1976-77 in which 3 new systemic fungicides were tested against lettuce downy mildew and discusses the implications of the findings on the future strategy of disease control programmes.

METHODS AND MATERIALS

Fungicides

The experimental fungicides used were: (1) A5430 (50% CGA 38140); methyl N-(2,6-dimethyl-phenyl)-N-furoyl-(2)-alaninate; 50% w.p., Ciba-Geigy Agrochemicals. (2) EXP 1659 (80% LS74-783); aluminium ethyl phosphite; 80% w.p. and also known as Aliette, May & Baker Ltd. (3) DPX-3217; 2-cyano-n-(ethylaminocarbamyl)-2-(ethyoxyimino)-acetamide; 80% w.p., E.I. Du Pont de Nemours & Co. Other fungicides used were commercially available formulations. HV sprays were applied to run-off with knapsack sprayers, dust formulations with a Kyoritsu Duster and fogs with a Pulsfog model K 10. The fogging mixture was in the proportion of 112.5g product (w.p. formulations of zineb and thiram) to 1l of VK 2 Fogging Solution (ethyl glycol, methanol and distilled water). Apart from thiram in the standard treatment, no fungicides were applied to control B.cinerea in experiments 1 and 3. Details of fungicide applications are shown in Table 1.

Table 1

Some details of fungicide applications

Experiment number	Fungicide(s)	Method and rate of application	Intervals between applications (days)	Total number of applications	Interval between last application and harvest (days)
1	CGA 38140	Block inc. $75g/m^3$ + Foliar spray 0.3g/l	- 14	1 2	35
1*	CGA 38140	Foliar spray 0.3g/l	14	4	35
1*	DPX-3217 + mancozeb	Foliar spray 0.2g/l Foliar spray 0.8g/l	14	6	14
1*	LS74-783	Foliar spray 3.0g/l	14	5	28
1*	LS74-783	Foliar spray 3.0g/l	14	6	14
1*	Zineb + thiram	Foliar spray 1.4g/l Foliar spray 3.2g/l	14	6	14
2	CGA 38140 + iprodione	Drench 0.005g/block + Foliar spray 0.3g/l Foliar spray 0.25g/l	- - 20	1 1 2	27
2	Zineb + thiram **	Foliar spray 1.4g/l Foliar spray 3.2g/l	14	3	16
3	CGA 38140	Block inc. $20g/m^3$	-	1	76
3	CGA 38140	Block inc. $20g/m^3$ + Drench 0.01g/block	- -	1 1	51

* Pre-planting foliar sprays applied at weekly intervals from 50% seedling emergence.

** Fog and dust applications were at equivalent amounts of active ingredient and at the same frequency.

inc. is incorporation.

Details of experiments

Lettuce were raised from pelleted seed sown in peat blocks (4.3 x 4.3 x 5.0 cm).

Experiment 1, Ellbridge EHS The crop (cv. Amanda Plus) was grown in a single polythene structure. Heating was applied from 2 February to ensure a minimum day temperature of 15°C to encourage downy mildew and to give frost protection. The randomized block design comprised 6 replicates of the 6 treatments. Thirty-six of the 44 plants/plot were assessed at harvest. An unsprayed double guard row was positioned between each plot. A young lettuce plant infected with B. lactucae was introduced into each guard row on 19 January, 48 days after planting. Downy mildew developed steadily on these unsprayed lettuce and % plants and % basal area affected were respectively 90 and 50 at the first cut and 100 and 70 at the second cut. The date of the first cut (2 March) was determined by the minimum harvesting intervals for the various fungicides, and the second cut was done 7 days later.

CGA 38140 was suspended in the water used to wet the blocking compost.

Experiment 2, Fairfield EHS This trial, in 6 unheated polythene tunnels, had 3 replicates of the 4 treatments and 2 treated plots/tunnel. There were 630 plants (cv. Ostinata)/plot of which 68 (2 complete rows) were cut for assessments on 4 May. Across the centre of each tunnel was an untreated area of 250 plants. Ten lettuce seedlings infected with B. lactucae were placed in the centre of each of the untreated areas on 18 March, 8 days after planting.

CGA 38140 was applied as a drench to the blocks 9 days after sowing. In the thiram plus zineb dust and fog treatments, the amount of a.i. applied/plot was approximately the same as in the HV foliar spray treatment.

Experiment 3, Lawnswood, Leeds This experiment was in an unheated polythene tunnel. There were 4 replicates of the 2 treatments and 92 plants (cv. Plevanos)/plot, of which 23 (one complete row) were assessed. Forty-eight of the 240 untreated plants across the centre were inoculated with a spore suspension of B. lactucae on 14 April, 10 days after planting. The first cut was taken on 25 May when the crop would have been harvested under normal commercial conditions, and the second on 2 June.

CGA 38140 was suspended in the water used to wet the compost. A second application (50 ml drench/block) was made in 4 of the plots immediately after planting to give 0.01g CGA 38140/block. The total amount of a.i. applied was equivalent to 72g a.i./m^3.

Disease assessment

The % leaf area affected by B. lactucae was assessed using the key of Dixon and Doodson (1971) and the % basal area affected using the key of Dixon et al, (1973).

Stem infection with B. cinerea was expressed as an index (0 to 100) calculated as shown:

$$\frac{1\text{ (no. in category 1)} + 2\text{ (no. in category 2)} + 3\text{ (no. in category 3)}}{\text{total no. lettuce in all categories}} \times \frac{100}{3}$$

where category 0 is no infection; category 1 is lesion not girdling stem, marketable after slight trimming; category 2 is lesion girdling stem, marketable after severe trimming and category 3 is lesion girdling stem plus extensive rotting, unmarketable.

RESULTS

Experiment 1, Ellbridge EHS

HV foliar sprays of LS74-783 (applied up to 2 weeks before harvest) and CGA 38140 incorporated into the blocking compost plus two foliar sprays gave the best control of downy mildew and were significantly ($P = 0.05$) better than the zineb + thiram standard at the second cut (Table 2). Foliar sprays of LS74-783 and DPX-3217 + mancozeb, stopping 28 and 14 days before the first cut gave little or no improvement over the standard. Fortnightly foliar sprays of CGA 38140 stopping 5 weeks before harvest gave the worst control.

Table 2

Results of downy mildew assessments - Experiment 1

Treatment*	First cut		Second cut		Trimmed head weight(g)‡
	% Plants infected	% basal area affected	% Plants infected	% basal area affected	
CGA 38140 - block inc. + foliar sprays	4.1^{a}	0.1^{a}	39.5^{a}	4.0^{ab}	113.0^{b}
CGA 38140	80.9^{d}	9.7^{b}	98.7^{c}	30.1^{e}	102.4^{ab}
DPX-3217 + mancozeb	52.1^{cd}	4.5^{ab}	90.7^{b}	19.6^{d}	125.0^{c}
LS74-783 (4 weeks)**	38.9^{bc}	0.9^{a}	78.2^{bc}	11.0^{bc}	98.2^{a}
LS74-783 (2 weeks)**	14.6^{ab}	0.3^{a}	32.5^{a}	1.7^{a}	101.4^{ab}
Zineb + thiram	26.5^{abc}	2.4^{ab}	68.0^{ab}	13.7^{cd}	129.2^{c}
SE	±10.4	±2.0	±9.6	±2.4	±4.3

* HV foliar sprays unless stated.

** Intervals between last application and first cut.

‡ Mean of first and second cuts.

Means were subjected to Duncan's Multiple Range Test. Means with the same letter in the suffix are not significantly different at the 5% level.

Experiment 2, Fairfield EHS

None of the treatments gave an acceptable commercial control of B. lactucae (Table 3) and > 80% of plants were unmarketable from the plots treated fortnightly with zineb + thiram. CGA 38140 at 0.005g/block also failed to contain the disease but did reduce infection on the inner younger leaves; consequently the majority of plants were marketable.

Two applications of iprodione controlled grey mould as well as 3 applications of zineb + thiram.

Table 3

Results of disease assessments - Experiment 2

	Bremia lactucae			Botrytis cinerea		
Treatment	% plants infected	No. affected leaves/plant	% basal area affected	Stem lesion index	Untrimmed head weight (g)	% marketable plants
*Untreated control	100.0	12.2	59.9	38.2	n.r.	0.0
Zineb + thiram (foliar spray)	89.2	6.1	7.0	7.5	242.2	13.3
Zineb + thiram (fog)	98.6	6.8	6.6	12.1	243.8	6.7
Zineb + thiram (dust)	99.3	7.3	8.7	13.0	223.3	10.0
CGA 38140 (block drench and foliar spray) + iprodione (foliar spray)	94.4	6.0	11.9	5.3	249.5	97.1
SE	±4.6	±1.0	±2.0		±4.6	

* Figures not included in the statistical analysis

Experiment 3, Lawnswood, Leeds

CGA 38140, as a block incorporation plus planting drench, gave outstanding control of downy mildew (Table 4). Although 69% of lettuce were infected, lesions were small and restricted to the basal leaves, and sporulation of B. lactucae was sparse. Infected leaves were mostly removed by the normal trimming process and the weight loss after trimming was small.

Table 4

Downy mildew assessments for CGA 38140 treatments - Experiment 3

Variate	Untreated	Block inc. (A)	Block inc. + drench		Significance	
			1st cut (B)	2nd cut (C)	A vs B	B vs C
% plants infected	100.0	100.0	68.7	100.0	$P < 0.001$	$P < 0.001$
No. affected leaves/plant	11.5	9.4	1.3	8.9	$P < 0.001$	$P < 0.001$
% area affected/leaf	43.3	20.6	6.4	10.3	$P < 0.001$	$P < 0.05$
Untrimmed weight (g)	194.2	260.2	264.8	329.8	n.s.	n.s.
Trimmed weight (g)	92.1	157.3	204.9	195.7	$P < 0.01$	n.s.
% weight loss with trimming	52.6	39.6	22.5	40.9	$P < 0.001$	$P < 0.001$
% unmarketable with *B.cinerea*	25.0	5.4	9.7	0.0	-	-
% unmarketable with *B.lactucae*	75.0	4.2	0.0	0.6	-	-

The single block incorporation of 20g CGA 38140/m^3 failed to give an acceptable commercial control of downy mildew. Nevertheless, as in Experiment 2, the disease was restricted to the basal leaves and after severe trimming > 90% of plants were marketable.

A second cut was taken of plants which received the 2 applications of CGA 38140. The extra 8 days led to a considerable breakdown in control of downy mildew (Table 4). However, there was a 25% weight increase of plants in this period.

DISCUSSION

The experiments demonstrated that CGA 38140 and LS74-783 were effective against *B. lactucae* and gave better control than the commercially available protectant fungicides. The results with DPX-3217 plus mancozeb were less encouraging. Our findings agree with those of Crute *et al* (1977) and Crute and Norwood (1977) who reported that CGA 38140 and LS74-783 were active against *B. lactucae* when applied as foliar sprays, root drenches or block incorporations, whereas DPX-3217 was phytotoxic to lettuce roots at low concentrations and effective as a foliar spray only at relatively high concentrations. There are no reports of phytotoxicity from applications of CGA 38140 or from foliar sprays of LS74-783 but Crute *et al* (1977) reported phytotoxicity with LS74-783 incorporated into peat blocks at concentrations which gave good control of downy mildew.

The poor control of downy mildew at Fairfield EHS demonstrates the limitations of dithiocarbamates as fortnightly sprays when infection pressure is severe.

Foliar sprays of LS74-783 were more persistent than the standard treatment (zineb + thiram) and gave reasonable protection up to 4 weeks after treatment at Ellbridge EHS. In the same experiment, CGA 38140 incorporated into the blocking compost at $75g/m^3$ plus the 2 foliar sprays gave good protection against B. lactucae for 18 weeks in a slow-growing crop. At Lawnswood, CGA 38140 at 0.01 g/block gave good protection against downy mildew for 7 weeks in relatively rapid-growing lettuce. The infection pressures to which these crops were subjected were much greater than would normally be encountered on commercial holdings.

Incorporation into peat blocks of a systemic fungicide with curative and protective properties against B. lactucae for the life of the lettuce crop could revolutionize downy mildew control. Application to the blocking compost would be easy and inexpensive and the reduction or omission of post-planting sprays would significantly cut growing costs. It would still be necessary to apply post-planting foliar sprays against B. cinerea which, however, is easier to control than downy mildew and requires less frequent fungicide applications.

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THE IMPORTANCE OF CRITICAL TIMING OF SPRAY APPLICATIONS IN THE CONTROL OF PEA MOTH (CYDIA NIGRICANA F.) AND FIELD TESTS WITH INSECTICIDES

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Summary Experiments in commercial crops of dry-harvest peas cv. Maro for control of pea moth (Cydia nigricana F.) showed that treatments applied at the full flower stage, before the first spray date recommended by the ADAS/PGRO warning, or after the second recommended spray date, gave much poorer control of damage than the two sprays made on the recommended dates. Sprays on the second of the recommended dates were more effective than those made only at the first, indicating deficiencies in the egg count method of forecasting attacks. Field evaluation of insecticides showed that sprays of permethrin and the mixture of triazophos plus dimethoate gave a much better reduction of damaged produce than either chlorpyrifos or etrimphos.

INTRODUCTION

Pea moth (Cydia nigricana F.) is still the most damaging pest of peas in the U.K., and is particularly serious on dry-harvest peas. Vining peas and green peas for fresh market picking are usually harvested before the main annual attack develops, though only small amounts of damage to vining peas can cause the crop to be rejected by processors.

For some years the control of pea moth has been timed by means of a system of forecasting, carried out jointly by PGRO and ADAS. This is based on the detection of moth eggs (Gould and Legowsky, 1964) laid in pea crops growing in previously infested areas, beginning with the earliest, in the southern part of Essex, and then progressively more northerly areas. On the basis of egg development, a date coinciding with peak larval hatch is calculated to obtain that on which the first of the two sprays necessary to achieve maximum reduction of damage in dried peas should be applied, the second spray being made about 10 days later (Biddle, 1976).

A more efficient method of forecasting, currently being developed by Rothamsted Experimental Station in conjunction with PGRO and ADAS, is now at an advanced stage; this is based on catches of male moths in pheromone-baited sticky traps, to indicate peak adult flights and subsequent egg laying periods (Greenway et al., 1976).

It had become obvious, from enquiries received each season by the PGRO advisory department, that many growers wished to spray crops as a precautionary measure at the full flowering stage, irrespective of whether or not a warning had been issued. In addition, there were those who tended to treat crops which had passed the susceptible growth stage, much later than the warning had advised. The importance of accuracy in the timing of spray applications was the subject of a series of experiments carried out by PGRO in 1974 and 1975 and described below. In addition, field evaluation of some of the newer insecticides was carried out in trials during 1975 and 1976.

METHODS AND MATERIALS

Timing experiments Spray treatments were carried out on four occasions at each site, single and double applications being made as detailed below. The four occasions occurred throughout the time of flowering to full pod set, which included the two spray dates recommended on the basis of the ADAS/PGRO warning. The work was carried out in dry-harvest peas cv. Maro, in commercial crops grown on farms which had had a history of moth damage. Two experimental sites were chosen in 1974, at Buckworth (Cambridgeshire) and Nassington (Northants), and in 1975 the site at Buckworth was chosen again.

Each experiment was fully replicated and randomized, with individual plots measuring 2m x 5m. Sprays of azinphos-methyl with demeton-S-methyl sulphone as Gusathion MS, were made at 0.36 kg a.i./ha using a Van der Weij plot sprayer at 2.1 kg/cm^2 pressure in 560 l. water/ha.

In each experiment the target was to apply treatments which consisted of the following spray regimes:-

1. A single application made at full flower about 1 week before the first spray date recommended by the warning.
2. Two single applications made on each of the warning dates.
3. A single spray made on the first warning date.
4. A single spray made on the second warning date.
5. A single spray applied 7 days after the second date.
6. A single spray applied on the date of the first warning and a second spray made 7 days after the second warning date.

The degree of control achieved was assessed after hand shelling all the pods from 25 plants selected from each plot at harvest time and counting damaged and undamaged seeds.

Insecticide evaluation The second part of the work involved the field evaluation of four insecticides which were included in a series of three experiments in 1975 and 1976. The layout of the experiments was similar to the ones previously described, but in 1976 the two trial sites were at Deeping St. Nicholas (Lincolnshire) and Walpole Highway (Cambridgeshire). The rates of chemicals used in all experiments are shown in Table 2. Applications of each material were made on the two dates specified by the spray warnings and the results were compared with untreated control plots.

RESULTS

Timing experiments Because of variable weather conditions, the timing of spray applications achieved were slightly different from those planned but were thought to be not significantly so. The details appear in Table 1, with the results showing the mean control of damage achieved at each site in both years. A mean control level of all three trials is given in the last column.

Although differences in spray timings occurred between experiments, the overall results show that treatments applied before the first spray warning, even though the plants were at the full flowering stage, or after the second spray date, gave poorer control than the two sprays timed according to the warnings. There was

Table 1

Control of pea moth damage with different spray timings

Stage:	Full flower	1st spray warning (1974) (+ 2 days 1975)	2nd spray warning (1974) (+ 4 days 1975)	Late spray (+ 5 days 1974) (+ 3 days 1975)	1974				1975		Mean % Control
					Site 1		Site 2				
					% Damage	% Control	% Damage	% Control	% Damage	% Control	
Sprays applied (*)	*				4.7	0	1.7	50	1.06	49	33
		*	*		1.4	65	1.0	71	0.98	50	62
		*			3.9	2.5	1.9	44	1.42	32	33.7
			*		1.0	75	1.0	71	1.31	36	60.7
				*	2.6	35	2.4	29	0.54	63	42.3
		*		*	3.3	17.5	2.2	35	0.57	63	38.5
	LSD at P = 0.05				n.s.		n.s.		0.8		
	CV%								74.2		

Table 2

Control of pea moth damage - insecticide evaluation

		1975		1976				
				Site 1		Site 2		
Material	Rate kg a.i./ha	% Damage	% Control	% Damage	% Control	% Damage	% Control	Mean % Control
Triazophos + dimethoate	0.34 + 0.17	0.57	63	0.1	96	1.3	67	75.3
Chlorpyrifos E.C.	0.5	0.82	59	1.0	58	3.2	18	45.0
"	0.75	0.97	52					52.0
"	1.0			1.1	54	2.6	33	43.5
Etrimphos	0.3	1.49	31					31.0
"	0.5			1.2	50	2.3	41	45.5
"	0.7			0.8	67	1.5	62	64.5
Permethrin	0.03			0.4	83	0.6	85	84.0
"	0.05			0.3	86	1.6	59	72.0
"	0.50	0	100					100
Untreated	-	2.23	0	2.4	0	3.9	0	0
CV% @ P = 0.05		74.2		12.6		41.6		
LSD		0.8		n.s.		1.9		

an indication that the second warning spray is more important than the first, but best control is achieved when both sprays have been carried out.

Insecticide evaluation The results are given in Table 2. In all experiments the level of moth damage was low, ranging from 2.2 to 3.9% on the untreated plots, and the variability in the trials was such that statistical significance was not always achieved. In all experiments the mixture of triazophos plus dimethoate gave satisfactory levels of control. Etrimphos was most effective at the highest rate of application, but the overall control was not very satisfactory. Chlorpyrifos gave disappointing results at all sites; permethrin was used in 1975 at a high rate and complete control was achieved. However, the pyrethroid has a very high level of activity, so in 1976 the rate of application was reduced to 0.05 kg a.i./ha. The results gave an overall control level comparable to triazophos plus dimethoate.

DISCUSSION

Female pea moths lay their eggs in crops from the time of full flowering onwards to full pod set. It is essential to apply insecticides to the crop to coincide with maximum egg hatch, a second spray being necessary to control larvae from eggs laid later. Rainfall occuring at the time of spraying advised according to the warning delayed spray applications although, from the results, control was not seriously affected, possibly indicating that the weather also delayed larval hatching.

There is a tendency for growers to spray peas at full flower, before the warning has been issued. The results clearly show that materials applied at a stage before moth activity has begun will not be persistent enough to achieve effective control later on, when the eggs hatch.

The reason why one spray made at the second warning stage was as effective as two sprays made at both warning stages is not clear, although one of the disadvantages with the egg forecasting scheme is that inaccuracies can occur when field samples are drawn for plant examination. The pheromone traps currently being developed should provide a more efficient forecasting method. The value of spraying to a forecasting system has been well demonstrated.

The evaluation of new insecticides is an important part of the PGRO moth control programme and results to date have shown that the mixture of triazophos and dimethoate is a useful combination for reduction of pea moth damage and aphid control. The synthetic pyrethrum material also shows good activity at very low dose rates. As it is common practice to add an aphicide when spraying against pea moth, work is progressing with mixtures of permethrin and aphicides.

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THE USE OF IPRODIONE FOR THE CONTROL OF BOTRYTIS IN GLASSHOUSE TOMATOES AND LETTUCE

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Summary Three seasons' trials have been carried out with iprodione* for the control of Botrytis cinerea on glasshouse tomatoes and protected lettuce in the U.K.

High volume treatments at 0.05% w/v a.i. were extrememly effective on Botrytis stem and leaf lesions of tomatoes, although 'ghost-spotting' manifestation of the disease was not directly controlled. At half this concentration (0.025%) the disease was much reduced on lettuce.

On both crops, the effectiveness of iprodione in growing environments where benzimidazole-tolerant strains of Botrytis were present or suspected, was confirmed.

Disease control improved the yield of marketable produce.

Résumé L'iprodione a été évalué pendant trois ans dans le Royaume - Uni pour la lutte contre le Botrytis cinerea sur les tomates cultivées en serres et les laitues cultivées soit sous cloches.

Les traitements à haut-volume comportant 0,05% p/v m.a. se sont montrés très efficaces contre les tâches de la pourriture grise sur les tiges et les feuilles de tomates, bien que l'efficacité ait été moins bonne sur les petites tâches des fruits 'ghost spotting'. A la moitié de la dose, 0,025% m.a., la maladie était beaucoup plus réduite sur la laitue.

Pour les 2 cultures, l'efficacité de l'iprodione s'est confirmée sur le Botrytis dans les cas ou la présence des souches insensibles aux fongicides benzimidazole était soit constatée, soit presumée.

La lutte contre cette maladie a augmentée les rendements pour le marché des cultures concernées.

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* B.S.I. common name for 3-(3,5-dichlorophenyl)-N-isopropyl-2,4-dioxoimidazolidine-1-carboxamide.

INTRODUCTION

The biological properties of iprodione, previously coded 26,019 RP, have been outlined by Burgaud *et al* (1975). Potential for the use of this new fungicide for the control of *Botrytis cinerea* on glasshouse crops including tomatoes and lettuce was suggested.

This paper is a digest of the considerable development work which has been carried out in these two crops during the period 1974-76.

METHODS AND MATERIALS

All work described in this paper was carried out using a 50% w.p. formulation of iprodione, now marketed as 'Rovral'*.

On lettuce four small-plot replicated experiments were carried out during 1974-76, and 11 user trials were undertaken in 1975/76. The small plots were a minimum size of 1.5 x 2m (approx. 50 plants), replicated 4 times in most cases. Applications were made with a knapsack sprayer using about 1,000 l. of water per ha. On commercial holdings, blocks of lettuce comprised of at least 1,000 plants were treated by the grower using a variety of application equipment.

The small-plot tomato trials were carried out on plots of 8-12 plants, replicated 4 times, again using a knapsack sprayer. Spraying commenced when the first truss had formed, about 2,000 l. of water per ha being applied. This volume increased as the season progressed in order thoroughly to wet the plants. By this means each plant received a maximum of 8 applications through the season. In twelve grower trials, blocks of at least 500 tomato plants were treated using a variety of high-volume equipment.

Lettuce crops were inspected regularly and *Botrytis*-infected plants were recorded. Tomatoes were assessed for *Botrytis* lesions, ghost-spotting, and spray deposit levels at the conclusion of the spray programme.

RESULTS

Table 1

Control of *B. cinerea* on glasshouse lettuce - replicated trials 1974

Site: Writtle, Essex
Var.: Ostinata
Sown: 20.2.74; transplanted 17.3.74; harvested 3.5.74
Treatment dates - 20.3, 2.4, 17.4 (all post-transplant)

MATERIAL	DOSE % a.i.	% BOTRYTIS INFECTED PLANTS	MEAN LETTUCE WT (g)	% MARKETABLE
Iprodione	(0.025	2.2 abc	223	95
	(0.05	2.0 ab	230	92
Thiophanate-methyl	0.10	10.5 c**	215	85
Dicloran/thiram programme		2.4 abc	230	93
Untreated	-	6.1 bc	218	85

Treatments having the same suffix letter do not differ significantly from each other at 5% (Duncan's multiple range test).

** MBC-resistant strains of *B. cinerea* present.

* Trade Mark of May & Baker Ltd.

Table 2

Control of B. cinerea on glasshouse lettuce - replicated trial 1974/5

Site: Writtle, Essex
Var.: Amanda plus
Sown: 22.9.74; transplanted 10.10.74; harvested Jan. 1975
Treatment dates - 27.9, 4.10 (prop. house); 14.10; 28.10; 11.11*; 26.11

MATERIAL	DOSE % a.i.	% BOTRYTIS INFECTED PLANTS	MEAN LETTUCE WT (g)	% MARKETABLE
Iprodione	(0.025	0.9 a	98.5	89
	(0.05	0 a	102.0	95
Thiophanate-methyl	0.05	1.5 a	103.0	94
Zineb + Thiram	0.14 + 0.32	1.3 a	91.3	92
Untreated	-	8.7 b	92.7	85

* N.B. Additional treatments on standards only.

Treatments having the same suffix letter do not differ significantly from each other at 5% (Duncan's multiple range test).

Table 3

Control of B. cinerea on glasshouse lettuce - replicated trial 1975/6

Site: Writtle, Essex
Var.: Miranda
Sown: 31.12.75; transplanted 18.2.76; harvested 26.4.76
Treatment dates - 5.1, 19.1, 2.2 (prop. house); 23.2, 8.3, 22.3

MATERIAL	DOSE % a.i.	% BOTRYTIS INFECTED PLANTS	MEAN LETTUCE WT (g)
Iprodione	0.025	1.9 a	209
Benomyl	0.025	7.3* b	223
Thiram	0.32	2.9 a	204
Untreated	-	7.1 b	177

Zineb (at 0.14% a.i.) added to each Botrytis treatment

* MBC-resistant strains of B. cinerea present

Treatments having the same suffix letter do not differ significantly from each other at 5% (Duncan's multiple range test).

Table 4

Control of *B. cinerea* on glasshouse lettuce - User trials 1975/6

(a) Farrington, Lancs.

Var.: Miranda
Sown: 20.12.75; transplanted 4.2.76; harvested 14.4.76
Treatment dates - 28.1 (prop. house); 9.2, 25.2, 10.3, 24.3

MATERIAL	DOSE % a.i.	NUMBER PLANTS/TRMT.	PERCENT PLANTS MARKETABLE (at 1.4.76)
Iprodione	0.025	1000	99.9
Benomyl	0.025	5000	98.7

Mancozeb/zineb added to both treatments

(b) Little Witley, Worcs.

Var.: Miranda
Sown: 2.2.76; transplanted 1.3.76; harvested 30.4.76
Treatment dates - 14.2 (thiram to all plants - prop. house);
19.3, 6.4, 20.4

MATERIAL	DOSE % a.i.	NUMBER PLANTS/TRMT.	PERCENT PLANTS MARKETABLE* (at 1.4.76)
Iprodione	0.025	4000	95
Thiram	0.32	6000	90

Both treatments included zineb at 0.14% a.i.

* Precludes both obviously infected and 'missing' plants

Table 5

Control of B. cinerea on glasshouse tomatoes - replicated trial 1974

(a) Writtle, Essex.

Var.: Eurocross BB
Regime: Polythene house, unheated.
Spray dates: 12.6, 28.6, 7.7, 26.7, 9.8, 23.8, 6.9. 20.9.74
Picking from 1.8 - 7.11
Disease assessment: 8.10.74

MATERIAL	DOSE % a.i.	NUMBER BOTRYTIS LESIONS/16 PLANTS		% FRUIT GHOST SPOTTED	MEAN YIELD CLEAN FRUIT/PLANT (kg)
		STEMS	FRUIT TRUSSES		
Iprodione	0.05	1.6	0 a	32.9 b	2.6 b
Thiophanate-methyl + wetter	0.1	6.4*	9.6* bc	33.3 b	2.0 c
Dichlofluanid	0.05	1.6	4.8 ab	11.6 a	3.4 a
Untreated	-	6.4	9.6 c	41.3 b	2.1 bc

* MBC-resistant strains of Botrytis suspected.

(b) Brentwood, Essex.

Var.: Sonato
Regime: Heated glass
Spray dates: 30.7, 13.8, 27.8, 10.9, 25.9, 9.10, 23.10, 6.11.74
Picking dates: 18.9 - 18.12
Disease assessment: 13.11.74

MATERIAL	DOSE % a.i.	NUMBER BOTRYTIS LESIONS/16 PLANTS			MEAN YIELD CLEAN FRUIT/PLANT (kg)
		LEAVES	STEMS	FRUIT TRUSSES	
Iprodione	0.05	35 abc	15 a	20 a	3.2 ab
Thiophanate-methyl + wetter	0.1	41 bc	18 a	39 a	2.7 c
Dichlofluanid	0.05	24 ab	24 a	30 a	3.0 ab
Untreated	-	49 c	50 b	65 b	2.8 bc

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

Table 6

Control of *B. cinerea* on glasshouse tomatoes - user trials 1975

SITE	VARIETY	STAGE AT DISEASE ASSESSMENT			NO. BOTRYTIS LEAF LESIONS/50 PLANTS	
		NO. FRUITING TRUSSES	NO. PREVIOUS SPRAY APPLNS.	DAYS AFTER LAST TRMT.	Iprodione	Standard+
Ipswich, Suffolk.	Adagio	11	4 (6)*	20 (7)*	18	172
Fareham, Hants.	Sonato	20+	1	70	4	50
Rustington, Sussex.	Grenadier	16	5	7	11	31
Colchester, Essex.	Sonato	10-12	2	22	0	9

+ Standard at Ipswich and
Colchester - benomyl
" " Fareham - dichlofluanid
" " Rustington - chlorothalonil

* Figures in brackets are those for standard treatment.

Table 7

Yield results from tomato user trial 1976

Site: Ipswich, Suffolk.
Var.: Adagio

TREATMENT	WT. MARKETABLE FRUIT (kg)	TOTAL YIELD (t/ha)	YIELD/PLANT (kg)	WT. ROTTEN FRUIT (kg)
Iprodione	10,260	170	5.13	31.8
Benomyl	9,856	163	4.93	68.2

DISCUSSION

Lettuce

The three small-plot replicated experiments (Tables 1-3) showed that, under moderate disease pressure, iprodione provided a control of *Botrytis* at least equal to that of the standard treatment based upon thiram and, in one experiment (Table 1), 0.05% iprodione performed significantly ($P = 0.05$) better than the standard. In two experiments (Tables 1 and 3) where benzimidazole fungicides were relatively ineffective, due to the presence of resistant strains of *B. cinerea*, iprodione gave satisfactory control.

Since there was little difference in efficacy between 0.05% and 0.025% in the replicated work - this has also been verified by A.D.A.S. (Powell et al, 1974) - the lower rate was chosen for the eleven grower trials on grounds of cost and the desire to minimize chemical residue levels.

At two user sites where significant disease occurred, the effectiveness of iprodione was again confirmed (Table 4). In all the trials there was no crop damage and yields from all treatments were satisfactory.

Tomatoes

In two replicated trials (Table 5), a regular spray programme of iprodione applied at 0.05% (high volume) significantly reduced the incidence of Botrytis affecting the stems and fruit. As with lettuce, control of benzimidazole-tolerant strains of the disease was achieved.

'Ghost-spotting' control by iprodione and thiophanate-methyl was equivalent, but dichlofluanid was superior to both these treatments in controlling this aspect of Botrytis. Though not significant, there was a trend for iprodione to be superior to dichlofluanid in reducing general fruit infection.

When used on a large-scale iprodione gave excellent control of leaf lesions compared to standard programmes (Table 6), and sporulation from stem lesions was markedly reduced. The amount of chemical deposit on fruit was similar to that with dichlofluanid and therefore assessed as acceptable.

Yield results from the two replicated trials (Table 5) were advantageous to iprodione and this was also demonstrated at one user site (Table 7).

Because regular high-volume spraying of tomatoes involves a high labour cost, development work is being undertaken with a formulation of iprodione suitable for use in thermal-fogging equipment, and satisfactory results are now being achieved.

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