SESSION 6A

PEST CONTROL IN ANNUAL TROPICAL CROPS

Proceedings 1981 British Crop Protection Conference - Pests and Diseases

INSECTICIDAL CONTROL OF CABBAGE LOOPER AND DIAMOND-BACK MOTH LARVAE ON CABBAGE IN FLORIDA, USA, USING DIFFERENT SPRAY NOZZLES AND NOZZLE ARRANGMENTS

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Summary Tests were made of spray nozzles and nozzle arrangements for controlling cabbage loopers (Trichoplusia ni) and diamond-back moth larvae (Plutella xylostella) on cabbage in Florida, USA. Insecticides were applied with different sizes of nozzles, arranged in the same manner, so that pressure and spray concentration were similar but volume differed, and with different arrangements of nozzles wherein pressure, spray concentration, and volume were similar. Marketability of cabbage was better, and was affected less, by nozzle arrangement or volume with sprays of fenvalerate, permethrin, AC 222705, and SD 47443 than with sprays of acephate, Bacillus thuringiensis var. kurstaki, or methomyl.

Resume On a mis á l'épreuve des ajutages de vaporisateurs et des arrangements d'ajutages pour régler les larves de Trichoplusia ni et de Plutella xylostella sur des chous en Floride aux Etats Unis. Les insecticides ont été appliqués de deux facon différentes: en utilisant des ajutages de dimensions différentes, arrangées pour garder une pression et une concentration de vapeur similaires, avec le volume variable, et aussi en utilisant des arrangements d'ajutages différents où la pression, la concentration de vapeur et le volume étaient similaires. Le marketing de chous s'est amélioré et a subi moins de changement dû à l'arrangement de l'ajutage ou le volume avec des vaporisateurs de fenvalerate, permethrin, AC 222705, et de SD 47443 qu'à celui dû à des vaporisateurs de l'acephate, Bacillus thuringiensis var. kurstaki, et methomyl.

INTRODUCTION

Cabbage loopers (Trichoplusia ni) and diamond-back moth larvae (Plutella xylostella) limit the production of cabbage in the southeastern USA. Growers commonly apply regular sprays to protect the crop from damage using insect control recommendations from various sources. These recommendations, however, provide little information on the application of sprays to the crop. Published insect control tests on vegetables generally describe different types of sprayers, nozzles and arrangement, volume of spray applied, and pressure.

For years, cabbage growers in Florida have used high volume and pressure, multinozzle sprayers for insect control. With increasing sprayer and maintenance costs, many growers have turned to lower capacity models with simple spray booms which are owner, dealer, or manufacturer designed and often differ from farm to farm. Recent grower problems with cabbage insect control in Northeast Florida indicate that insecticide spray coverage could be a contributing factor as experimental tests have shown better results. To test this hypothesis, various nozzle arrangements and sizes were used to apply insecticides on cabbage at the Agricultural Research Center, Hastings, Florida.

METHODS AND MATERIALS

Cabbage, cv. 'Rio Verde', was grown during the spring of 1978 and 1979 on rows 102 cm apart and elevated about 30 cm for drainage of rains, according to grower practice. Plant spacing in the row was 25 cm. A four-row tractor-drawn sprayer was used to apply the insecticides to plots four rows wide by 12 m long.

In 1978, three TeeJet 4664 diaphragm check valve nozzles were used per row, one positioned about 56 cm over the center of the row and two on 61 cm drop pipes, 102 cm apart, located on either side of the plants and directed at the underside of the leaves. Nozzle discs and cores for the four rows were hollow cone TeeJet D3-25, D2-25, D3-23, and D2-23 which delivered 468, 384, 281, and 243 l/ha, respectively, at 17.6 kg/cm^2 pressure. All insecticides were mixed with water at the 468 l/ha dosage. Treatments included B. thuringiensis var. kurstaki and methomyl, the two major registered materials used by growers on cabbage; acephate, fenvalerate, permethrin, and an untreated check.

In the 1979 test, the sprayer was equipped with 4664 nozzles and D3-25 discs and cores utilizing a different spray nozzle placement (SNP), patterned after various grower designs, for each row. SNP-1 consisted of one nozzle positioned about 56 cm over the center of the row and two nozzles on 61 cm drop pipes, 102 cm apart, located on either side of the plants and directed at the underside of the leaves. SNP-2 and 3 were similar to SNP-1 but with 30 cm and 0 cm drops, respectively. SNP-4 consisted of 2 nozzles with D4-25 discs and cores located on the boom 25 cm apart and about 56 cm over the center of the row. Each SNP was selected to deliver approximately 468 l/ha at 17.6 kg/cm^2 pressure, with the nozzles directed at the center of the plants throughout the season. Treatments included acephate, B. thuringiensis var. kurstaki, methomyl, fenvalerate, permethrin, AC 222705 (RS)-α-cyano-3-phenoxybenzyl (S)-2-(4-difluromethoxyphenyl)-3-methylbutyrate; SD 47443 (structure not available), and an untreated check. Treatments in both tests were replicated four times in a randomized complete block design with seven applications of insecticides made at weekly intervals from head initiation to harvest. Insecticide dosages tested were those which gave effective control in previous tests (Schuster et al., 1977, 1978) or were recommended for grower use. Differences between treatments were evaluated by recording caterpillar feeding damage to the head and four loose wrapper leaves of ten plants/plot at harvest by using a 1-6 rating system (Greene et al., 1969) wherein marketable plants contained no damage to the head and 5% or less to the wrapper leaves. Larval species and density were recorded at weekly intervals from untreated cabbage plots.

RESULTS

Caterpillar pressure for the tests was high, with means on untreated plants of 15.2 cabbage loopers and 7.7 diamond-back moth larvae in 1978 and 6.6 cabbage loopers and 7.7 diamond-back moth larvae in 1979, during the four weeks before harvest. Several other species caused insignificant damage.

In the 1978 trial, when insecticides were applied at the same concentration with different sizes of nozzles, cabbage damage increased with reduction of spray volume. This increase was least with the treatments of permethrin and fenvalerate where most of the cabbage was marketable, but was high with the treatments of B. thuringiensis, methomyl, and acephate (Table 1).

In the 1979 trial, the use of different spray nozzle placements showed a trend towards reduced cabbage marketability when drop pipes were reduced from 61 to 30 to 0 cm in length to two nozzles over the row and was most evident with the acephate, B. thuringiensis, and methomyl treatments (Table 2).

The tests show that spray nozzle placement and size in relation to volume are important factors in the effective use of insecticides against caterpillars on cabbage in Florida and that available insecticides are affected to different degrees by them. The synthetic pyrethroid sprays, fenvalerate, permethrin, AC 222705, and SD 47443 gave the best cabbage marketability and were least affected by differences in spray volume or SNP.

DISCUSSION

The loss of cabbage marketability when insecticides were applied at the same concentration with different sizes of nozzles was likely due to decreased coverage and amount of toxicant/plant and in the case of acephate, *B. thuringiensis*, and methomyl, limited effectiveness against large larvae which survived earlier sprays. The synthetic pyrethroids give rapid knockdown of mature larvae.

The improved marketability with the use of SNP-1 was probably due to the direction of sprays at the undersurface of the leaves where the highest numbers of cabbage looper and diamond-back moth eggs and small larvae are found. Cabbage loopers become difficult to control with increase in size and large larvae are almost impossible to control with registered insecticides in Florida.

Large amounts of *B. thuringiensis* and methomyl have been used on cabbage in Florida after head formation when the use of methamidophos is restricted. Growers using these materials should give particular consideration of efficient spray volume and nozzle placement for the most effective results.

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Table 1

Cabbage damage and marketability

following use of insecticides applied at various volumes for control of caterpillars in Florida, USA, 1978

Treatment/ formulation	Rate g ai/ 468 l/ha	Nozzle size/volume (l/ha)											
		D3-25/468			D2-25/384			D3-23/281			D2-23/243		
		$\bar{x}$ Rating[a]		Mkt.[b]	$\bar{x}$ Rating		Mkt.	$\bar{x}$ Rating		Mkt.	$\bar{x}$ Rating		Mkt.
Permethrin 25% e.c.	56	1.3a	z	100	1.9a	y	98	2.9b	x	75	2.2a	y	98
Permethrin 40% e.c.	56	1.5a	z	100	1.6a	z	100	2.0a	z	100	2.6a	y	100
Fenvalerate 30% e.c.	56	1.5a	z	100	1.6a	z	100	2.2a	y	100	2.2a	y	98
Bacillus thuringiensis[c]	560	2.4b	z	100	2.7b	z	98	3.4b	y	65	4.2b	x	20
Methomyl 90% s.p.	560	3.2c	z	70	3.2b	z	63	4.2c	y	10	4.3b	y	8
Acephate 75% s.p.	560	2.7b	z	95	3.2b	z	78	4.0c	y	30	3.8b	y	25
Check	--	6.0d	z	0	6.0c	z	0	6.0d	z	0	6.0c	z	0

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[a] 1-6 rating of damage, none to severe, at harvest and mean separation within columns and rows, respectively, by Duncan's multiple range test, 5% level. Cabbage rated 3.0 or under is marketable.

[b] Percent of cabbage with less than 5% caterpillar feeding damage in four wrapper leaves, none in the head.

[c] 16,000 IUP/mg.

Table 2

Cabbage damage and marketability following use of insecticides applied with four spray nozzle placements (SNP) for the control of caterpillars in Florida, USA, 1979

Treatment/ formulation	Rate g ai/ 468 l/ha	Nozzle placement[c] SNP-1 $\bar{x}$ Rating[a]	SNP-1 Mkt.[b]	SNP-2 $\bar{x}$ Rating	SNP-2 Mkt.	SNP-3 $\bar{x}$ Rating	SNP-3 Mkt.	SNP-4 $\bar{x}$ Rating	SNP-4 Mkt.
SD 47443 7.5% e.c.	22	1.5a z	100	1.8a z	95	1.7a z	100	1.7a z	95
Fenvalerate 30% e.c.	56	1.8a z	100	1.8a z	100	2.1ab z	90	1.9ab z	88
AC 222705 31% e.c.	56	1.5a z	100	2.0a z	90	1.5a z	98	1.6a z	95
Permethrin 40% e.c.	56	2.0ab z	90	1.9a z	90	2.0ab z	95	1.7a z	98
Acephate 75% s.p.	560	1.6a z	98	1.9a z	88	2.6bc y	80	2.5bc y	75
Bacillus thuringiensis[d] plus methomyl 90% s.p.	420 + 420	2.7bc z	85	2.9b z	68	3.0c z	70	2.8c z	63
Bacillus thuringiensis	560	2.7bc z	78	2.9b z	70	3.2c z	58	3.9d y	43
Methomyl 90% s.p.	560	2.9c z	68	4.1c y	23	4.2d y	18	4.4d y	25
Check	--	5.9d z	0	5.8d z	0	5.9e z	0	5.9e z	0

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a/ 1-6 rating of damage, none to severe, at harvest and mean separation within columns and rows, respectively, by Duncan's multiple range test, 5% level. Cabbage rated 3.0 or under is marketable.

b/ Percent of cabbage with less than 5% caterpillar feeding damage in four wrapper leaves, none in the head.

c/ SNP-1 to 4: Three TeeJet D3-25 nozzles arranged -- one over row with two on 61 cm drop pipes, one over row with two on 30 cm drop pipes, one over row with two on 0 cm drop pipes, 102 cm apart; and two TeeJet D4-25 nozzles over the row, 25 cm apart, respectively.

d/ 16,000 IUP/mg.

NOTES

Proceedings 1981 British Crop Protection Conference - Pests and Diseases

EVALUATION OF THE "TOXIC CARPET" SPRAY STRATEGY WITH CYPERMETHRIN ON COTTON

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Summary The "Toxic Carpet" spray strategy is a programme of sprays devised for cypermethrin, the intervals and dose rates of which are based not only on the day to day occurrence of pests but mainly on the rates of plant growth, vegetative expansion, the degradation of cypermethrin, and the capacity of different spray methods to effect coverage within the crop canopy. The paper presents the results of three replicated aerial trials, one in N W Mexico and two in El Salvador, in which the strategy was tested.

Superior control of Heliothis, Spodoptera and Anthonomus spp to that resulting from sprays applied "as necessary" was provided by the "Toxic Carpet" strategy at equivalent spray dose rates, but yield differences were not significant. It is suggested for future split farm tests that spraying should commence at first flowering with a series of short interval sprays and applications should be maintained, using longer intervals, until bollworm attack ceases. Under these conditions lower rates than normal would be used so the cost would be lower than average normal practice, and some or all of the specific insecticides for Spodoptera or Anthonomus control may be unnecessary.

Résumé La technique du "tapis toxique" consiste en un programme de pulverisations mis au point pour la cypermethrine, les intervalles de traitement et doses étant basés non seulement sur la date d'apparition du predateur mais aussi sur le rythme de croissance de la plante, sur l'evolution du volume de matière végétale, sur la dégradation de la cypermethrine, et sur la capacité des differentes techniques de traitement à couvrir efficacement l'ecran végétal.

Cette communication presente les resultats de trois essais par voie aérienne conduits avec répétitions, l'un au nord ouest du Mexique et deux au Salvador, pays on cette stratégie fut teste.

Un meilleur controle de Heliothis, Spodoptera et Anthonomus fut obtenu avec la technique du "tapis toxique", par rapport aux pulverisations faites classiquement, mais les differences de rendement entre les deux méthodes n'ont pas eté significatives.

Il est suggeré que, pour de futurs tests comparatifs, que les traitements commencent au debut de la floraison avce une serie d'applications rapprochées, puis plus espacées jusqu'à ce que les attaques cessent. Sous ces conditions, des doses inferieures à la normale devraient être employés, le côut de la protection, devant être inferieur, certaines pulverisations specifiques contre Spodoptera et Anthonomus pouvant egalement être éviteés.

INTRODUCTION

Strategies for cotton pest control

During the 1970's most areas of intense cotton cultivation and high Heliothis spp bollworm pressure have relied for bollworm control upon multiple applications of organophosphates. The short persistence of these products dictated a "knock down"strategy - one in which applications were made only when pests were observed - and threshold levels were devised to enable the application to be timed as precisely as possible. These products were capable only of reducing established infestations rather than of protecting the crop, and this was possible almost regardless of the standard of spray application because of the mobility of the products once within the canopy, as vapours (eg methyl parathion; Worthing, 1979) or by translaminar or systemic action (eg monocrotophos; Worthing, 1979).

The synthetic pyrethroids, however, are capable not only of killing insects directly at the time of spraying but also of maintaining protection of the crop for one to three weeks by contact action of the dry deposit (mortality, repellancy, oviposition inhibition and antifeeding) (Ruscoe, 1977; 1979; Highwood, 1979). This feature has enabled spray intervals to be extended. Their lack of mobility however demands both good spray coverage and good application timing in relation to the development stage of the pest for their maximum effect to be achieved.

The education of the cotton farming community in spray application has hence formed a major part of pyrethroid marketing campaigns. Aspects receiving attention have been aircraft nozzle calibration, swath width, spray volume, climatic limitations to spraying, and scouting to precisely determine the occurrence of economic spray thresholds.

The most serious problem affecting pyrethroid performance is that of ensuring correct timing and Morton (1979) proposed a strategy for pyrethroid use in cotton which seeks to overcome this. His basic thesis was that because pyrethroids are essentially residual materials capable of preventing pest attack, it is more rational and reliable to gear the timing and rates of application to plant growth and rates of chemical degradation than to the observed day to day abundance of pests. This would avoid the consequences of the inevitable delay that occurs on most farms between the detection of economic thresholds and spraying, even where scouting can be as frequent as in El Salvador where it is a daily operation in all fields.

A simple model incorporating chemical degradation rate, plant growth rate (both increase in height and expansion of leaves) and the ability of different types of spray equipment to effect spray penetration was the basis on which the timing and rates of application could be determined. For example, with aerial spraying a series of sprays applied from first flowering to peak flowering would be essential to establish sufficient deposit to protect parts which later on become progressively less accessible to spray as the crop increases in height and vegetative density. This would improve both the control of "escapes" in heavy infestations of Heliothis spp and of low canopy dwelling pests such as Spodoptera exigua.

It was envisaged that local information on crop growth, rainfall, temperature, etc could be incorporated into the model to produce a programme of sprays each of the optimum dose rate, which would be closely and efficiently adapted to local needs. "Toxic Carpet" was coined to describe the strategy (Morton, 1979).

The principal benefits anticipated from such a programme would be

a) More cost effective control of Heliothis bollworms.

b) Improved control of within-canopy pests (eg Heliothis "escapes" and Spodoptera exigua).

c) Ease of planning and organisation of spraying.

d) Reduction in scouting costs.

e) Improved profitability.

Attempts were made to test the strategy in large scale aerial trials, two in El Salvador (1979/80, and 1980/81) and one in Mexico (1979).

Background to the cotton crop in Central America and Mexico

The crop in El Salvador grows rapidly especially in the early season climate of daily sub-tropical rainfall. The first fruiting bodies are always shed due to excessive vegetative growth and with the plant growing to at least 2·0 m there is significant boll rot. The harvested yield comes from the middle and top crop but management of the crop is of a very high order. Average yields exceed 2,000 kg/ha (FAO, 1978) and some farms may achieve 4,000 kg/ha. In N W Mexico the crop is irrigated and grown in intense heat and radiation with no rainfall during the season. Soil salinity can be a problem but growth is generally rapid and sometimes there is excessive vegetative production. Average farm yields are somewhat higher than in El Salvador approaching 2,500 kg/ha (FAO, 1978).

METHODS AND MATERIALS

The experiment sites were commercial cotton farms chosen for the expressed full co-operation of the owner, suitable dimensions of cotton fields and homogeneity of cotton production and growth. In each case arrangements were made to ensure the full co-operation of pilots and daily availability of a spray aircraft. Treatment lists appear in Tables 1 and 3. For spraying the pilot was given the ground plan of the trial area with the particular plots for each treatment highlighted. Flagmen were present to mark the start of each swath at both ends of each plot.

The "Toxic Carpet" spray programmes were planned as follows:

El Salvador: From first flowering until peak flowering sprays applied at 5 day intervals, then two sprays at 7 day intervals and the remainder at 9 day intervals until pest attack ceases. Mexico: From first flowering until peak flowering sprays applied at 6 day intervals, thereafter at 9 day intervals until bollworm attack ceases.

Spraying of the standard "as necessary" treatments was based on a spray threshold of 20 small (< 1 cm) Heliothis larvae per 100 plants. Each treatment was supposed to be applied independently on the basis of scouting in each treatment area.

In practice, however, spraying of all three trials started later than desirable and in 1980/81 in El Salvador it was not possible to maintain the precise schedule of "Toxic Carpet" intervals:

Mexico 1979. Start 30 July, then 7, 6, 7, 5, 6, 9, 9, 9, 9 day intervals. El Salvador 1979/80. Start 15 September, then 5, 6, 9, 10, 10, 9, 10, 13, 14 day intervals. El Salvador 1980/81. Start 4 October, then 7, 9, 7, 9, 9, 8, 10, 10 day intervals.

The application of all the "as necessary" treatments in El Salvador tended to occur simultaneously after a majority of treatment plots reached the spray threshold. Hence the potential to realise underlying differences between the two strategies was diminished.

Experiment details

El Salvador 1979/80

Site: "El Sitio", Jiquilisco, El Salvador. Cotton: Stoneville 213. Experiment design: Seven treatments in four randomised blocks. Plot size: 275 m long x 100 m (4 spray swaths) wide. Spray aircraft: Grumman Agcat. Spray machinery: Six Micronair AU 3000 rotary atomisers. Assessment: Pest count and yield area 80 m x 25 m (rows) in the centre of each plot. Daily pest counts made on six plants per plot.

El Salvador 1980/81

Site: "El Sitio", Jiquilisco, El Salvador. Cotton: Cedix. Experiment design: Nine treatments in four randomised blocks. Plot size: 352 m long x 100 m (5 spray swaths) wide. Spray aircraft: Cessna Agwagon. Spray machinery: Six Micronair AU 3000 rotary atomisers. Assessment: Pest counts and yield from the central 40 m (rows) x 100 m in each plot. Daily pest counts made on six plants per plot.

Mexico 1979

Site: Hermosillo, Sonora, Mexico. Cotton: Furrow irrigated Delta Pine 213 variety. Experiment design: Seven treatments in four blocks using two randomisations alternately. Plot size: 244 m long x 96 m wide (6 swaths). Spray aircraft: Piper Pawnee. Spray machinery: Boom and nozzle at 1·72 bars applying 40 litres/ha. Assessment: Area in centre of each plot 88 m long x 32 m (2 swaths) wide. Pest counts made on 24 and later 20 plants per plot twice per week. This area was harvested. Samples of 25 leaves per plot were taken from top, middle and bottom of the plant on 20 September for cypermethrin residue analysis.

RESULTS

El Salvador 1979/80

Heliothis attacked the trial site for a month before the first experiment sprays could be applied (15 September). Subsequent pest counts accumulated over the remainder of the season showed that the "Toxic Carpet" spray strategy gave better control than spraying on an "as necessary" basis. *Heliothis* control was not only better *per se*, it was less affected by application rate than in the "as necessary" treatments (Table 1). *Heliothis* eggs may also have been less abundant.

Spodoptera exigua and other *Spodoptera* spp (*S.frugiperda*, *S.eridania*) were markedly fewer on the "Toxic Carpet" treatments (Table 1) particularly later in the

TABLE 1

Comparison of cypermethrin spray strategies on cotton in El Salvador

1979/80 Treatments(2) Total of 48 pest counts on 24 plants per treatment(5)

Spray strategy (1)	g ai/ha	No of sprays	Heliothis larvae	Heliothis eggs	S.exigua larvae	S.exigua egg masses	Other sp Spodoptera larvae	A.grandis adults	A.grandis damaged buds	Final yield kg/ha	(3) Spray costs US$/ha	(4) Profit US$/ha
AN	107	6	141	367	385	92	104	98	453	3711a	177	1323
AN	89	6	180	416	377	90	99	60	412	3767a	152	1384
AN	72	6	207	412	457	94	75	86	455	3496a	129	1239
TC	107	11	64	338	198	46	38	5	243	4042a	325	1381
TC	89	11	78	353	178	80	87	28	429	4031a	281	1418
1980/81 Treatments(2)			Total of 52 pest counts on 24 plants per treatment(5)									
AN	89	4	131b	189d	624bcd	130ab	-	65ab	402ab	2805a	102	837
AN	72	4	164ab	266a	716ab	171a	-	72a	487a	2442a	86	628
TC	89	9	32d	151d	485f	59d	-	11de	226c	2712a	230	651
TC	72	9	53c	216bd	504ef	70d	-	46bc	322b	2796a	194	740
TC	54	9	71c	241ac	587de	116ab	-	33c	402ab	2913a	158	849

(1) AN = "As necessary"; TC = "Toxic Carpet"

(2) First spray; 1979/80 15 September, 1980/81 4 October. Peak flowering; 1979/80 and 1980/81 end September

(3) Include spray aircraft costs at US\$5·5/ha per spray. Only cypermethrin (Cymbush 25 cc) sprays are costed

(4) Other costs of production of US\$800/ha, and a seed cotton price of US\$0·62/kg have been used

(5) Treatment means per column with no letter in common are significantly different (p = 0·05)

TABLE 2

Yields, and pest and damage counts per 24 plants at peaks of infestation, El Salvador

		Yield kg/ha first 2 picks		S.exigua on 17 12 79	A.grandis on 12 10 79	
Spray strategy	g ai/ha	Pick 1	Pick 1&2	larvae	adults	Damaged buds
AN	107	2200ac	3167ac	26	38	7
AN	89	2178ac	3158ac	96	10	14
AN	72	2004c	2977c	132	18	11
TC	107	2325a	3432a	12	0	0
TC	89	2397a	3476a	1	0	0

season when Spodoptera tend to be most troublesom (Table 2).

Differences in cotton yield reflected pest count differences (Tables 1 and 2). Yields from the first picks were significantly higher in "Toxic Carpet" treatments compared with "as necessary" when averaged over rates ($p = 0{\cdot}038$ for pick 1 and $p = 0{\cdot}016$ for picks 1 and 2) Table 2, though final yields were not significantly different.

El Salvador 1980/81

The trial was not started until 4 October which was at about peak flowering. The farmer had already applied three blanket sprays for bollworm control on the 6, 14 and 24 September and so unfortunately the experimental spray schedules (Table 1) started well into the most important phase of growth, flowering and Heliothis oviposition.

The "Toxic Carpet" strategy gave three to four times better ($p < 0{\cdot}01$) control of Heliothis larvae than "as necessary" sprays, and the abundance of eggs was slightly lower (significant ($p < 0{\cdot}5$) in the case of the 50 g ai/ha rate). Spodoptera exigua larvae ($p < 0{\cdot}01$) and egg masses ($p < 0{\cdot}01$) were also significantly reduced and, as with Heliothis, responded to dose rate of ai.

As in 1979/80, numbers of Anthonomus were much lower ($p < 0{\cdot}01$) at equivalent dose rates under the "Toxic Carpet" strategy and numbers of damaged buds were correspondingly reduced ($p < 0{\cdot}01$) by approximately 70% (Table 1).

Yields of seed cotton varied considerably between plots and could not be attributed to treatment or block effects (Table 1).

Mexico 1979

In spite of a very high standard of planning and local implementation of assessments and spray applications the trial produced yield variations unrelated to treatment or block effects. It is believed this was due to variable water status of the soil and to salinity. In the single "Toxic Carpet" treatment eleven sprays were applied compared with nine or ten in "as necessary" treatments (Table 3). Only one spray for Anthonomus control was necessary under the "Toxic Carpet" strategy compared with four or five in the "as necessary" strategy.

One day after spraying in tall dense cotton late in the season the "Toxic Carpet" treatment resulted in higher cypermethrin residues on leaves low in the canopy than the same rate applied in an "as necessary" programme (Table 3).

TABLE 3

Comparison of spray strategies on cotton in Mexico, 1979

Spray strategy(1)	g ai /ha(2)	No of sprays(2)	Damaged buds/24 plants(3,6)	Lower leaf residues mg/kg(4,6)	Yield(6) kg/ha	Spray costs US$/ha(5)
AN	100	9(4)	6·6a	5·4a	3277a	319
AN	81·25	10(5)	4·4a	-	3677a	318
AN	62·5	10(4)	6·5a	-	3483a	258
TC	100	11(1)	5·1a	6·5a	3816a	346
AN	-	14(12)	10·8b	-	2748b	458

(1) AN = As necessary; TC = Toxic Carpet. Spraying started 30 July.
(2) All treatments were based on cypermethrin except the last listed which was the farmers' programme of profenofos and monocrotophos. No of sprays given is for bollworm control, figures in parenthesis are methyl parathion sprays to control Anthonomus grandis.
(3) Mean of 16 counts.
(4) Cypermethrin residues on 20 September, one day after spraying both treatments for the 6th (AN) and 8th (TC) time. 100 leaves/treatment (25/plot).
(5) The cost of cypermethrin sprays and any other insecticides used, and the cost of spray aircraft.
(6) Means per column followed by the same letter are not significantly different at p = 0·05. Lower leaf residues were significantly different at p = 0·06.

DISCUSSION

The success of the "Toxic Carpet" strategy can be judged on the basis of pest control and overall cost effectiveness.

Pest control

Substantially reduced Spodoptera spp populations occurring on the El Salvador trials support the premise that better low canopy pest control can be expected from the "Toxic Carpet" due to the activity of cypermethrin deposits established by earlier sprays. Higher cypermethrin residues on lower leaves was confirmed by chemical analysis (Table 3).

Improved control of Anthonomus in all three trials is also of interest since this is a pest not normally controlled by commercial rates of the pyrethroids at their frequency of use in Latin America (Table 1). Numbers recorded on 12 October (Table 2) were following sprays of both the "as necessary" and "Toxic Carpet" treatments seven days earlier and the superiority of the "Toxic Carpet" must therefore be due to earlier sprays.

Because the "Toxic Carpet" involved more sprays, better results may be attributable to the more frequent exposure of adults to wet spray, or alternatively due to higher cypermethrin residues on the plant killing or more successfully repelling or inhibiting the oviposition of adults, as demonstrated in the laboratory for another pyrethroid (Moore, 1980). According to Gutierrez (1979), reduction in boll weevil numbers should result in a less rank cotton crop of increased productivity, shortened season and shorter height incidentally improving accessibility to spray droplets. The same is commonly said for Heliothis spp, and the earlier yield demonstrated in "Toxic Carpet" treatments in El Salvador 1979/80 supports the view.

Cost effectiveness

Appraisal of the strategy on the basis of cost/benefits is hampered by high plot to plot yield variation. However, in El Salvador in 1979/80 the "Toxic Carpet" treatments produced a 9% yield increase after two picks (significant at $p = 0{\cdot}016$) reducing to 8% after the third and final pick (not significant, $p = 0{\cdot}09$). This was 300 kg/ha seed cotton valued at US$186 which more than covers the extra cost of the "Toxic Carpet" sprays (US$129/ha).

In Mexico Heliothis was comparatively more important than in El Salvador, and the increased cost of the additional two sprays in the "Toxic Carpet" compared with the "as necessary" strategy (9 and 11 respectively) was only 22%. Four methyl parathion aliquots were needed for boll weevil control in the "as necessary" sprays compared with only one in the "Toxic Carpet", and so in fact the actual cost of the "Toxic Carpet" programme was only 9% more, US$27/ha.

These comparisons are rate for rate but the trials suggest lower rates and different intervals should be tested.

A "Toxic Carpet" spray programme can be devised for El Salvador based on the experience of these trials, local information on plant growth and climate and a general understanding of the timing of pest attack:

From first to peak flowering the speed of plant growth dictates a short interval between sprays and in C America frequent rainfall also militates against maintaining a persistent deposit at that time. It is thus logical to use lower dose rates at short intervals and in C America there is no penalty from aircraft costs because there are concurrent frequent Anthonomus sprays. A programme can thus be devised totalling 13 sprays as follows: From first flowering, five sprays at 5 day intervals, then two sprays at 7 day intervals - these all at 53·6 g cypermethrin/ha. Thereafter six sprays at 15 day intervals at 62·6 g/ha.

The average number of sprays applied "as necessary" for the control of Heliothis, Trichoplusia and Spodoptera in El Salvador is nine including perhaps four mixed with a specific insecticide for improved control of Spodoptera exigua.

Comparing active ingredient, in the average "as necessary" season 9 x 90 g/ha = 810 g/ha/season would be sprayed, whilst the "Toxic Carpet" spray programme would apply 7 x 53·6 g/ha + 6 x 62·6 g/ha = 750 g/ha/season. Additionally there should be no, or fewer, specific insecticides needed to control Spodoptera exigua, and a reduced need for additional insecticidal aliquots for Anthonomus.

It is hoped to compare this "Toxic Carpet" schedule with "as necessary" sprays on split farms in El Salvador in the near future.

CONCLUSION

At equivalent rates of active ingredient per spray, a "Toxic Carpet" spray strategy provides better and more dependable control of Heliothis spp, Spodoptera exigua and Anthonomus grandis than a programme of sprays applied "as necessary". In the Central American situation using the full label dose rate in the "Toxic Carpet" strategy would require the extra production of seed cotton of only 150-200 kg/ha to cover the extra costs.

If, as suggested, lower rates are used then costs would be no higher and in many seasons lower than spraying normal rates "as necessary". If lower rates are to be used it will be essential to start the "Toxic Carpet" on time and then to maintain the schedule. The benefits of more reliable and wider spectrum pest control, and the freedom to plan the spray schedule well in advance and according to the progress of crop growth have considerable attraction to both farmers and spray aircraft operators.

Acknowledgements

We are grateful for the assistance of the three farmers who hosted the trials and the outstanding competence of the spray pilots, in particular Edmundo Flores in Mexico who gave one of us (NM) an unforgettable taste of what it is like in the cockpit spraying a pattern of plots neatly arranged by an entomologist. The willing assistance in the field in Mexico of Ing J S Llamas and Ing O Muñoz is also appreciated.

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NOTES

AC 222,705, A BROAD-SPECTRUM PYRETHROID INSECTICIDE: PERFORMANCE IN EGYPT

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Summary AC 222,705, (*RS*)-α-cyano-3-phenoxybenzyl (*S*)-2-(4-difluoromethoxyphenyl)-3-methylbutyrate, is recommended for use in Egypt at 143 g a.i./ha as a broad-spectrum cotton insecticide. It is strongly repellent and efficacious against *Spodoptera littoralis* and controls other cotton pests, such as *Earias insulana* and *Pectinophora gossypiella*, as well. At dosages ranging from 12.5 to 100 g a.i./ha on crops such as beans, cabbage, cauliflower, clover, lettuce, peas, squash, tomatoes, and watermelons, AC 222,705 has given excellent control of pests such as *Aphis gossypii*, *Bemisia tabaci*, *Empoasca* sp., *S. littoralis*, *Tetranychus* spp., and *Thrips tabaci*. There has been no phytotoxicity.

Résumé AC 222,705, (*RS*)-α-cyano-3-phenoxybenzyl (*S*)-2-(4-difluoromethoxyphenyl)-3-methylbutyrate, est recommandé sur coton en Egypte à la dose de 143 g m.a./ha comme insecticide à large spectre d'activité. Il se montre à la fois très répulsif et très efficace contre *Spodoptera littoralis*; il se montre très efficace aussi contre d'autres parasites du coton tels *Earias insulana* ou *Pectinophora gossypiella*. Dans l'intervalle de dose 12,5 g-100 g m.a./ha sur des cultures telles haricot, chou, choufleur, trèfle, laitue, pois, courgette, tomate ou melons, AC 222,705 a presenté une excellente efficacité contre des parasites tels *Aphis gossypii*, *Bemisia tabaci*, *Empoasca* sp., *S. littoralis*, *Tetranychus* spp. ou *Thrips tabaci*. Aucune phytotoxicité n'a été enregistrée.

INTRODUCTION

AC 222,705, a highly-active pyrethroid insecticide discovered by American Cyanamid Company at its Agricultural Research Center near Princeton, New Jersey, was announced at the 1979 Brighton Conference (Whitney and Wettstein, 1979). Since then, the product has undergone extensive testing and development around the world and is now included at 60 g a.i./feddan (143 g a.i./ha) in the Egyptian list of insecticides recommended for use on cotton. The purpose of this paper is to briefly describe some of the research done with AC 222,705 in Egypt by Cyanamid Agricultural Research Station, Egypt (CARSE) and to further define the bioefficacy of this potent new pesticide.

MATERIALS AND METHODS

The physical and chemical properties of AC 222,705 [(*RS*)-α-cyano-3-phenoxybenzyl (*S*)-2-(4-difluoromethoxyphenyl)-3-methylbutyrate] have been given in an earlier paper (Whitney and Wettstein, 1979). The research described in the present paper was done with two emulsifiable concentrate formulations of AC 222,705, i.e. 30% e.c. w/v and 10% e.c. w/v. Other insecticides used in these studies were commercial products and included chlorpyrifos (48% e.c. w/v), cypermethrin (30% e.c. w/v), DC 702 (38.4% chlorpyrifos plus 2.4% diflubenzuron w.p.), deltamethrin (2.5% e.c. w/v), fenvalerate (20% e.c. w/v), mephosfolan (75% e.c. w/v), methomyl (90% s.p.), phosfolan (25% e.c. w/v), and trichlorfon (95% s.p.).

Except for one experiment, all of the research reported here was conducted by Cyanamid personnel at CARSE near Zarzoura. The exception was a 1980 field trial conducted on glandless cotton at Abis near Alexandria in cooperation with the University of Alexandria.

Aqueous dilutions of the formulated insecticides were applied either by a knapsack sprayer as high-volume sprays (480 or 960 l./ha) or by a motorized backpack mistblower as low-volume sprays (24 l./ha), simulating aerial applications.

Since natural infestations of the cotton leafworm (*Spodoptera littoralis*) are sporadic and undependable for field trials, insects from a laboratory colony (originally from Alexandria) were used to artificially infest cotton plants in the field and for laboratory bioassays of leaves taken from plants in treated field plots. The leafworm bioassays were conducted in gauze-covered glass jars utilizing 10 second-instar and 10 fourth-instar larvae in separate jars on subsamples of leaves collected at random daily from the test. The bioassay period for each set of 10 larvae was 5 days when the final mortality counts were made. There were three 5-day periods after each spray date, i.e. leaf-sampling period one=0 through 4 DAT (days after treatment), period two=5 through 9 DAT, and period three=10 through 14 DAT. Each period started with a new set of larvae. The "old" leaves were removed from the bioassay jars each day and were replaced with fresh leaves from the respective plots. Generally, each treatment was replicated four or five times in a randomized complete block design. The individual plot sizes ranged from 10.5 m^2 to 546 m^2 (depending upon the crop species and purpose of the experiment) and are recorded with the tabular data. In trials against sucking pests, counts of motile stages of mites (*Tetranychus* spp.), mite eggs, immature whiteflies (*Bemisia tabaci*), and all postembryonic stages of aphids (*Aphis gossypii*), jassids (*Empoasca* sp.), and thrips (*Thrips tabaci*) were made by examination of two areas of 2.25 cm^2 on the ventral surface of the basal part of each of 10 leaves/plot per sampling date. The posttreatment sampling intervals generally were 3, 7, 9, and 12 DAT.

Cotton bollworm (*Earias insulana* and *Pectinophora gossypiella*) data were obtained by random collection and dissection of 25 to 50 bolls/plot at 7 and 14 days after each spray.

Studies on the repellent effects of AC 222,705 and other insecticides against ovipositing *S. littoralis* were conducted by placing 20 moths (not sexed) and four potted flowering cotton plants in a 1.5 m^3 screen-covered cage. Except in the untreated control cages, two of the four plants per cage were previously sprayed with an aqueous dilution of the insecticide and the other two plants were sprayed with water only. The moths had a free choice to oviposit on either treated or untreated plants. Each treatment setup was tested in duplicate. Counts of egg masses were made after five days, at which time all moths were dead in control cages. Moth mortality was recorded daily.

RESULTS AND DISCUSSION

Spodoptera littoralis larvae and adults were strongly repelled by AC 222,705. In the detached-leaf bioassays, it has been noted that during the first day or two, when larvae were confined in a jar with treated leaves, the larvae avoided the leaves and did not eat until they were almost starved. The results of the free-choice oviposition tests (Table 1) show that, at practical dosage levels, AC 222,705 was more strongly repellent than the other products tested. While moth mortality was somewhat accelerated and the total egg masses found was reduced in the cages with two treated and two untreated plants compared to the cages with only untreated plants, the repellent effects of AC 222,705, deltamethrin, mephosfolan, and phosfolan were clearly shown.

Table 2 presents a summary of typical results of the *S. littoralis* bioassays of cotton leaves collected from field plots which received four consecutive sprays during June-September, 1980. These data show that in this commonly used test procedure, all of the insecticides benefited substantially from protracted exposures which more closely simulated practical field conditions. The more strongly repellent products such as AC 222,705 require relatively long exposure periods in such bioassay systems in which the larvae can avoid contact with the treated foliage until excessive hunger impels them to eat.

While in the traditional 24- to 48-hour bioassays the mortality data may give the impression that AC 222,705 is relatively weak against *S. littoralis* larvae, longer bioassay exposures (Tables 2 and 5) as well as data on unconstrained populations in the field (Tables 3 and 4) show that AC 222,705 is indeed very effective against this pest under practical conditions.

Performance of AC 222,705 against cotton bollworms has been very good, especially when compared with that of competitive products (Tables 5 and 6).

Although a number of field-plot trials against insects and mites on vegetable crops have been completed, only a few representative results can be presented here because of time and space limitations.

Results of a high-volume spray trial against aphids, jassids, and thrips on zucchini squash are summarized in Table 7. It should be noted that field trials with all insecticides against sucking insects are inherently variable; however, at 50 g a.i./ha, AC 222,705 performance was consistently equal to or better than the comparative products, i.e. fenvalerate at 100 g a.i./ha or deltamethrin at 12 g a.i./ha. Even at dosages as low as 12.5 g a.i./ha, AC 222,705 has given very respectable levels of control of these pests.

AC 222,705 when applied as a full-cover spray at 12.5-100 g a.i./ha, has shown satisfactory control of whiteflies and mites. Examples of the performance against whiteflies on six different crop species are given in Table 8. Typical activity of AC 222,705 against spider mites is recorded in Table 9. It should be noted that the comparative pyrethroids, fenvalerate and cypermethrin, were considerably less effective against the mites.

In all of the tests conducted with AC 222,705 10% e.c. and 30% e.c. on the various crop species, no signs of phytotoxicity have been shown.

CONCLUSIONS

Results from a large number of trials on a wide range of crop species grown under Egyptian conditions have shown AC 222,705 to be a highly efficacious insecticide against a broad spectrum of pests. The compound has appropriate residual activity and is significantly repellent to important pests, such as *S. littoralis*. AC 222,705 consistently showed a useful level of acaricidal activity when applied as a full-cover foliar spray. The product has shown no phytotoxicity.

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Table 1

Repellency and lethality of AC 222,705 and other insecticides to adult *Spodoptera littoralis* in free-choice cage tests with 20 moths on two treated and two untreated cotton plants in same cage
High-volume sprays (960 l./ha)

Treatment		Egg masses on treated plants (%)	Total no. egg masses/ 20 moths	Moth mortality (%) at day				
Product	g a.i./ha			1	2	3	4	5
AC 222,705 30% e.c.	54	6	4.25	50	76	93	94	100
	71	9	2.75	51	80	94	95	100
	107	0	2.25	45	60	75	96	100
	143	0	2.00	49	59	85	96	100
Fenvalerate 20% e.c.	286	40	17.50	58	80	95	100	100
Cypermethrin 30% e.c.	143	40	10.00	45	65	95	100	100
Deltamethrin 2.5% e.c.	45	7	8.00	63	98	98	100	100
Phospholan 25% e.c.	893	22	4.50	34	50	80	93	100
Mephosfolan 75% e.c.	1071	20	2.50	56	88	94	100	100
Chlorpyrifos 48% e.c.	1143	36	11.00	45	75	90	100	100
DC 702[a] w.p.	1143+71	44	12.50	23	60	95	100	100
Untreated	-	-	17.00	33	62	77	90	100

[a] 38.4% chlorpyrifos + 2.4% diflubenzuron.

Table 2

Effect of length of exposure on mortality of *S. littoralis* larvae in laboratory bioassays of cotton leaves collected daily from sprayed field plots

Treatment		Mean mortality (%)[a] at				
Product	g a.i./ha	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
AC 222,705 30% e.c.	143	56	78	86	90	92
Deltamethrin 2.5% e.c.	45	69	88	94	96	96
Cypermethrin 30% e.c.	143	77	91	96	98	99
Fenvalerate 20% e.c.	286	73	91	95	98	99
Mephosfolan 75% e.c.	1071	53	72	84	89	91
Phosfolan 25% e.c.	893	47	76	88	93	95
Chlorpyrifos 48% e.c.	1143	65	82	88	91	93
DC 702[b] w.p.	1143+71	59	78	85	90	92
Untreated	-	0.6	1.9	3.4	5.1	6.4

[a] Mean of 2nd & 4th instars, 4 HV (960 l./ha) sprays (June 27, July 6, Aug. 21, & Sept. 11, 1980), 4 reps. of 42 m^2 each, 5 samples/rep./date, 10 larvae (each instar)/sample & sampled at 0-4, 5-9, & 10-14 DAT; thus each data point represents 4800 larvae.

[b] 38.4% chlorpyrifos + 2.4% diflubenzuron.

DAT = days after treatment.

Table 3

Field performance of AC 222,705 and other pyrethroids against *Spodoptera littoralis* larvae on cotton. High-volume sprays (960 l./ha)

Treatment		Mean control of larvae (%)[a]					
		Small		Medium		Large	
Product	g a.i./ha	2 DAT	5 DAT	2 DAT	5 DAT	2 DAT	5 DAT
AC 222,705 30% e.c.	71	99.5	100	34	43	50	50
	107	100	100	53	60	57	62
	143	100	100	98	100	73	88
Fenvalerate 20% e.c.	286	100	100	69	82	58	75
Cypermethrin 30% e.c.	143	100	100	78	93	53	73
Deltamethrin 2.5% e.c.	45	100	100	100	100	73	90

[a] Mean of 2 trials (2 reps. x 42 m^2 in 1979 and 4 reps. x 42 m^2 in 1980).
Small = 1st & 2nd instar, Medium = 3rd & 4th instar, Large = 5th & 6th instar.

DAT = days after treatment.

Table 4

Field performance of AC 222,705 and other insecticides against *Spodoptera littoralis* larvae on clover. High-volume sprays (480 l./ha), Oct. 1979; 5 reps. x 25 m^2 each

Treatment		Prespray	Control (%)				
Product	g a.i./ha	counts[a]	2 DAT	5 DAT	7 DAT	9 DAT	Mean 2-9 DAT
AC 222,705 30% e.c.	36	(0.5)	91	84	82	70	80
	71	(1.6)	98	97	92	96	95
Deltamethrin 2.5% e.c.	25	(0.7)	92	93	78	88	87
Methomyl 90% s.p.	643	(0.9)	87	97	89	91	90
Trichlorfon 95% s.p.	1131	(0.8)	85	86	49	79	74
Untreated	-	(2.1)	(2.0)	(2.4)	(1.7)	(2.3)	(1.9)

[a] Mean no. larvae (all stages) per m^2 shown in parentheses in this column and across bottom row of numbers.

DAT = days after treatment.

Table 5

Performance of AC 222,705 and other insecticides against insects on glandless cotton at Alexandria. Low-volume sprays (24 l./ha) on July 29, Aug. 18, & Sept. 4, 1980; 5 reps. x 546 m^2 each

Treatment		Leafworm mortality (%)[a]			Bollworm control (%)[b]	
Product	g a.i./ha	0-4 DAT	5-9 DAT	10-14 DAT	*Earias insulana*	*Pectinophora gossypiella*
AC 222,705 30% e.c.	143	100	100	100	99	87
[AC 222,705 30% e.c. + Phosfolan 25% e.c.]	[75 893]	100	100	100	94	72
Chlorpyrifos 48% e.c.	1143	100	94	83	44	54
Untreated	-	3	3	6	(24.0)	(13.7)

[a] *Spodoptera littoralis*, 4th instar larvae, 5-day exposure in laboratory to leaves taken daily from field plots.

[b] Data based on dissection of 1,100 bolls per treatment and % control calculated by direct comparison to untreated plot populations. Numbers in parentheses are mean % infested bolls in 5 counts taken from Aug. 5-Sept. 18.

DAT = days after treatment.

Table 6

Control of cotton bollworms with AC 222,705 and other insecticides applied as high-volume sprays (960 l./ha); 4 reps. x 100 m^2 each in 1979; 4 reps. x 42 m^2 each in 1980

Treatment		Mean control (%) (7 and 14 DAT)	
Product	g a.i./ha	1979 trial	1980 trial
AC 222,705 30% e.c.	107	82	85
	143	84	96
Fenvalerate 20% e.c.	286	76	85
Cypermethrin 30% e.c.	143	84	85
Deltamethrin 2.5% e.c.	45	68	77
Mephosfolan 75% e.c.	1071	88	77
Chlorpyrifos 48% e.c.	1143	64	85
DC 702[a] w.p.	1143+71	58	77
Untreated	-	12.5% inf.	6.5% inf.

[a] 38.4% chlorpyrifos + 2.4% diflubenzuron.
DAT = days after treatment; inf. = infestation.

Table 7

Performance of AC 222,705 and other pyrethroids against aphids[a], jassids[b], and thrips[c] on zucchini squash. High-volume sprays (960 l./ha), May, 1980; 4 reps. x 24 m^2 each

Treatment		Mean control (%)[d]		
Product	g a.i./ha	Aphids	Jassids	Thrips
AC 222,705 30% e.c.	12.5	73	83	96
	25	76	87	75
	50	93	87	96
	75	91	93	93
Fenvalerate 20% e.c.	100	82	79	86
Deltamethrin 2.5% e.c.	12.5	93	70	91
Untreated	-	(0.27)	(0.10)	(0.56)

[a] *Aphis gossypii*; [b] *Empoasca* sp.; [c] *Thrips tabaci*.

[d] Based on counts made at 3, 7, 9, and 12 days after each spray. Figures in parentheses are mean numbers of pests/cm^2/count.

Table 8

Field plot trials with AC 222,705 and other insecticides against *Bemisia tabaci* in winter vegetables. High-volume sprays (480 l./ha), Oct. 1979

Treatment		Mean control (%) of whiteflies (3-12 DAT)						
Product	g a.i./ha	Peas[a]	Beans[a]	Tomatoes[b]	Lettuce[b]	Cabbage[b]	Cauliflower[b]	All crops
AC 222,705 10% e.c.	12.5	98	-	-	-	-	-	-
	25	100	94	85	64	68	78	82
	50	100	94	86	87	78	89	89
	100	100	93	95	80	-	94	92
Fenvalerate 20% e.c.	50	91	-	72	-	80	76	80
	100	-	83	-	-	-	-	83
Deltamethrin 2.5% e.c.	12.5	-	70	-	-	-	69	70
	25	-	-	-	91	68	-	80
Methomyl 90% s.p.	643	-	11	10	-	23	8	13
Untreated (Mean no. larvae/cm^2 leaf)	-	(0.13)	(0.13)	(0.11)	(0.12)	(0.18)	(0.24)	(0.15)

[a] 3 reps. x 21 m^2 each.

[b] 4 reps. x 10.5 m^2 each.

DAT = days after treatment.

Table 9

Effects of pyrethroids on *Tetranychus* sp. on watermelon foliage. High-volume sprays (960 l./ha) May 22 and June 20, 1980; mite and egg counts made before each spray and at 3, 7, 9, and 12 DAT; 4 reps. x 24 m^2 each

Treatment		Mean reduction (%) of	
Product	g a.i./ha	Mites	Mite eggs
AC 222,705 10% e.c.	12.5	85	74
	25	88	78
	50	95	85
	75	95	89
Fenvalerate 20% e.c.	100	62	48
Cypermethrin 30% e.c.	75	47	30
Untreated (Mean no./cm^2 leaf/count at 3-12 DAT)	-	(4.9)	(0.4)

DAT = days after treatment.

Proceedings 1981 British Crop Protection Conference - Pests and Diseases

THE USE OF THE 'ELECTRODYN' SPRAYER TO CONTROL PESTS OF VEGETABLES AND RICE

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Summary Recent developments in electrostatic and electrodynamic spray application herald an era of greater efficiency and reliability in the chemical control of insect pests and diseases. The ICI "Electrodyn" sprayer was primarily designed for use in cotton, where most of the current data relate to the application of pyrethroids. However, a lightweight, ultra-low volume machine which is simple to operate and places more chemical on desired targets than sprayers marketed previously, should be suited to many other crops, including vegetables and rice.

In vegetables, the prospect of reducing the frequency and hence the cost of application, and in rice, the convenience of a ULV system which facilitates correct dosing per unit area, make electrodynamic spraying particularly appealing. Data presented here illustrate the biological potential of the prototype Electrodyn sprayer; further improvements may result from modifications to the basic design and from the use of a wider range of active ingredients appropriate to vegetables and rice.

Résumé De récents développements en vaporisateur electrostatique et electrodynamique auront pour résultat une plus grande efficacité et sureté dans le controle chimique contre les insectes nuisibles et maladies. Le vaporisateur ICI "Electrodyn" a été construit préliminairement pour l'utilisation dans le coton où la plupart des données sont en relation avec l'application du pyrethroïdes. Cependant une machine, légère et ULV qui est simple à utiliser et déposant plus de produits chimiques sur les endroits desirés que des vaporisateurs déja sur le marché, serait plus convenable pour d'autres récoltes, comprenant légumes et riz.

Les avantages de la vaporisation par electrodynamique sont: dans les légumes la réduction du nombre de vaporisation, donc le coût, et dans le riz, la convenance d'un système ULV qui faciliterait le dozage exact pour chaque endroit. Les données présentées ici illustrent un potentiel biologique du vaporisateur prototype "Electrodyn", qui pourrait être amélioré des modifications du modèle original et avec l'utilisation d'une plus grande varieté de produits chimiques approprié a chaque légume et riz.

INTRODUCTION

Condemnation of conventional pesticide application on the grounds of inefficiency, operational risk and sheer drudgery has been widespread in recent years (see, for example, Walker, (1980) and Peacock, (1981). Thus, there is an impetus to develop, as quickly as possible, the discoveries in the field of electro-static and electrodynamic spraying unveiled at the British Crop Protection Conference two years ago (Arnold, 1979; Coffee, 1980a). In particular, production of narrow droplet-size spectra and controlled droplet trajectory are seen as major advances whereby the unacceptable wastage of agro-chemicals might be prevented.

One electrodynamic spraying system already commercially available in several cotton-growing countries (Morton, 1981) is the ICI "Electrodyn"† sprayer. Amongst the key features encouraging its acceptance by farmers are:

(1) No moving parts (less "wear and tear"),
(2) Ultra-low volume (0.5 l/ha or less in cotton),
(3) Ultra-low energy consumption (a set of four torch batteries lasts for up to 50 hours of spraying),
(4) Chemicals supplied in disposable combined bottle and nozzle (the "Bozzle"† container),
(5) High pesticide recovery index, including "wrap-around" on hidden crop targets,
(6) Improved operator safety (a sealed system avoids any handling of concentrate),
(7) Less dependence on wind conditions (a 'directed', not a 'drift' spray).

The consequence of these features is a potential for improved pest control in many tropical crops, a wider spectrum of pests controlled by any one active ingredient, and greater reliability and convenience in application. Evaluation and development of the hand-held Electrodyn sprayer was initially directed at insect control with pyrethroids in cotton and is reported elsewhere in this conference (Morton, 1981). The aim of this paper is to highlight preliminary research findings in two other important tropical crops, vegetables and rice, which offer some interesting contrasts in pest control requirements.

Vegetables and rice are fundamental components of most diets in the Third World and rely heavily on pesticides to protect them from insect pests and diseases. An average grain loss of 0.5 to one ton/hectare is frequently quoted due to insect attack in unprotected paddy rice though far higher damage can occasionally result from severe outbreaks of brown planthopper or from the transmission of diseases such as grassy stunt and tungro.

Where vegetables like cabbage, tomatoes and onion are intensively grown in parts of S E Asia, an array of lepidopterous defoliators can devastate crops which are not regularly treated with pesticides from germination through to harvest.

The goals of improved pesticide application in vegetables and rice can be compared as follows:-

Vegetables

(1) Less frequent and more efficient application to reduce chemical costs per season and to minimise the spread of resistance,
(2) Appropriate packages of insecticides and fungicides for the entire pest and disease complex,

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† "Electrodyn" and "Bozzle" are trade-marks of Imperial Chemical Industries Limited PLC

(3) Equipment adaptable to a wide range of growing systems (raised beds, intercropping etc),
(4) Less contamination of the soil in order to preserve ground-dwelling beneficial arthropods.

Rice

(1) Greater convenience in application through reduced volumes of diluent,
(2) Correct dosing of active ingredient per unit area to ensure maximum biological effect,
(3) Improved timeliness of spraying in relation to pest outbreaks or forecasts,
(4) Less contamination of paddy water to preserve beneficial arthropods and fish.

The extent to which the Electrodyn sprayer offers potential solutions to some of these problems is indicated by trials' results given below.

RESULTS

(1) Electrodyn Application in Vegetables

Tables 1 to 4 show results obtained in tomato, chilli, eggplant and cauliflower. The Electrodyn sprayer has generally proved superior in its control effect to medium and high-volume equipment, particularly in young crops or crops with small leaf area indices, where the potential to spray exposed soil rather than foliage is relatively great with non-charged sprays.

Table 1. Control of *Heliothis armigera* in tomato with Electrodyn and knapsack sprayer application of cypermethrin, Thailand

Sprayer	Chemical	Formulation	g ai/ha	Volume l/ha	% fruit damage/ after 5 applications
Electrodyn	Cypermethrin	6%ED	30	0.5	1.7
Knapsack	Cypermethrin	25%ED	30	700	3.8
Untreated					10.4

Table 2. Control of resistant *Spodoptera exigua* in chilli with Electrodyn and knapsack sprayer application of cypermethrin, Thailand

Sprayer	Chemical	Formulation	g ai/ha	Volume l/ha	% fruit damage/ after 5applications
Electrodyn	Cypermethrin	6% ED	45	0.75	3.9
Electrodyn	Cypermethrin	6% ED	90	1.5	1.8
Knapsack tank mixes (grower treatment)				1000	4.9

Table 3. Control of *Heliothis armigera* and *Spodoptera litura* in egg plant with Electrodyn and knapsack sprayer application of cypermethrin, Thailand

Sprayer	Chemical	Formulation	g ai/ha	Volume l/ha	% fruit damage/ after 8 applications
Electrodyn	Cypermethrin	6% ED	45	0.75	0.0
Knapsack	Cypermethrin	25% ec	45	750 - 1000	4.8
Knapsack tank mixes (grower treatment)				750 - 1000	4.6

Table 4. Control of *S.litura* and *Plutella xylostella* in cauliflower with Electrodyn and knapsack sprayer application of cypermethrin, Thailand

Sprayer	Chemical	Formulation	g ai/ha	Volume l/ha	Mean no. of cater-pillers/20 plants after 4 applications
Electrodyn	Cypermethrin	6% ED	45	0.75	8
Knapsack	Cypermethrin	25% ec	45	500 - 750	44
Untreated	-	-	-	-	292

The spraying technique and the choice of active ingredient has influenced the results but even inappropriate usage of the Electrodyn sprayer was as good as or better than conventional spraying at the same rate. In summary, the present commercial prototype seems well suited to row vegetable crops, and because drift is minimal in wind speeds normally considered acceptable for spraying, its use in intercropped and strip-cropped vegetables on small-holdings may be particularly appealing.

2) Electrodyn Application in Rice

Tables 5 to 8 illustrate that control of major pests of rice with the Electrodyn is at least equivalent to that from conventional spraying. The commercial prototype, though easy to use in paddy fields, may well require modification to improve swath-width and to increase spray penetration in dense canopies.

Table 5. Control of *Nephotettix virescens* (GLH) in rice with Electrodyn, ULVA and knapsack application of cypermethrin, Philippines

Sprayer	Chemical	Formulation	g ai/ha	Volume l/ha	Mean no. of GLH/10 sweeps after 2 applications
Electrodyn	Cypermethrin	2.5% ED	62.5	2.5	0.1
Ulva	Cypermethrin	2.5% ULV	62.5	2.5	0.4
Knapsack	Cypermethrin	25% ec	62.5	300	2.0
Untreated					29.8

Table 6. Control of *Hydrellia philippina* (whorl maggot) in rice with Electrodyn and knapsack application of cypermethrin, Philippines

Sprayer	Chemical	Formulation	g ai/ha	Volume l/ha	Mean % damage/plot after 1 application
Electrodyn	Cypermethrin	5% ED	50	1.0	3.1
Knapsack	Cypermethrin	25% ec	50	300	7.5
Untreated					15.9

Table 7. Control of *Tryporyza incertulas* (stem borer) in rice with Electrodyn and knapsack applications of cypermethrin, India

Sprayer	Chemical	Formulation	g ai/ha	Volume l/ha	Mean no. of dead hearts/8m^2 after 2 applications
Electrodyn	Cypermethrin	3% ED	37.5	1.25	18.2
Knapsack	Cypermethrin	25% ec	50	500	29.7
Broadcast	Carbofuran	3% G	750	-	8.0
Untreated					70.9

Table 8. "Knockdown" control of Nephotettix virescens (GLH), Nilaparvata lugens (BPH) and rice bug, Leptocorisa sp. in rice, Philippines

Sprayer	Chemical	Formulation	g ai/ha	Volume l/ha	Mean no. of GLH/10 sweeps Pre-spray	Mean no. of GLH/10 sweeps Post-spray 1)	Mean no. of BPH/25 hills Pre-spray	Mean no. of BPH/25 hills Post-spray	Mean no. of rice/bugs 20 sweeps Pre-spray	Mean no. of rice/bugs 20 sweeps Post-spray
Electrodyn	Cypermethrin	3% ED	25	0.84	89.8	8.0	8.4	3.2	5.8	1.8
Knapsack	Cypermethrin	5% ec	25	500	80.4	3.4	8.4	2.6	7.2	2.6

1) post-spray counts approx 24 hours after spraying

Cypermethrin has performed well in these trials, but there are probably more appropriate chemicals for certain rice pests, particularly when correct timing of application cannot be guaranteed or when local BPH-susceptible varieties of rice create a potential for pest resurgence.

DISCUSSION

The results show that the Electrodyn sprayer can be used successfully to control major pests of vegetables and rice, while offering solutions to some of the application problems outlined earlier.

Thus the Electrodyn sprayer offers many of the advantages of other ULV systems, such as convenience and care of operation, with the bonus of further reducing both volumes of diluent and rates of active ingredient in some situations. Speed of application with the Electrodyn sprayer cannot compare with techniques which drift pesticide over five or six metres (unless post-atomisation discharge is used, Coffee, 1980b), but when all field operations are considered (refilling, maintenance and repair of nozzles, replacement of batteries etc), the Electrodyn is likely to compare favourably with existing commercial hand-held sprayers.

In tropical rice and vegetables, ULV or CDA spraying is not widely practised for a variety of reasons related to cost of equipment, availability and cost of formulations and the unsuitability of drift techniques for small-holdings. Nevertheless, its potential has been demonstrated: a recent study in lowland rice (Pickin et al, 1981) suggested a saving of $8/ha in labour and chemicals for water-based CDA spraying over knapsack spraying, and in Nigerian cowpeas similar benefits are apparent for oil-based CDA (Raheja, 1976).

It should be emphasised that the prototype Electrodyn sprayer launched in cotton is the first of a range of hand-held and vehicle-mounted systems which might be geared to the specific needs of major crops, in terms of both design and the range of chemicals available in "Bozzle" containers. For example, systemic compounds for the control of established infestations of insects like lepidopterous stem-borers of rice are currently being tested.

We conclude that electrodynamic spraying is worthy of further development in vegetables and rice, on the basis of the biological evidence presented here, the convenience of ultra-low volume application, and the potential for improved compatability of pesticides with other components of integrated pest management.

Acknowledgements

We thank many colleagues in Plant Protection Division for their co-operation, and in particular Messrs: Ocampo and Selway. Mr Lino Rondon of Warner Barnes (Philippines) kindly provided some of the rice data.

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SESSION 6B

VIRUSES AND VECTOR CONTROL

Proceedings 1981 British Crop Protection Conference - Pests and Diseases

THE SIGNIFICANCE OF APHID MONITORING IN IMPROVING BARLEY YELLOW DWARF VIRUS CONTROL

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Summary Barley yellow dwarf virus is introduced into early-sown autumn cereals by winged aphids migrating from volunteer cereal plants, maize crops, and grasses. Information on aphid abundance and infectivity can be combined in an Infectivity Index but this may not provide a reliable guide to subsequent infection. A forecast of disease risk should be based on both the migrant Infectivity Index, which indicates likely primary infection, and some measure of aphid behaviour on the crop, which gives a measure of the secondary virus spread which may occur in late autumn and winter.

Résumé Le virus de la Jaunisse Nanissante de l'Orge est introduit dans les semis précoces de céréales d'automne par des pucerons ailés qui volent des repousses de céréales, des cultures de maïs, et de diverses graminées. On peut combiner des informations sur l'abondance et l'infectiosité des pucerons dans une Index d'Infectiosité, mais ceci ne donne pas nécessairement une indication sûre touchant l'infection résultante. Une prévision des risques de l'apparition de la maladie doit être basée à la fois sur l'Index d'Infectiosité des migrateurs, qui indique les chances d'infection primaire, et sur des indications du comportement des pucerons sur la culture, qui mesure la dissémination secondaire du virus qui peut avoir lieu vers la fin de l'automne et en hiver.

INTRODUCTION

Barley yellow dwarf virus (BYDV) is the cause of the most damaging virus disease of cereals in the United Kingdom (UK) and its importance is expected to increase as autumn-sown cereals, especially barley, are sown earlier; crops that emerge in early autumn may coincide with a migration of winged cereal aphids carrying BYDV. The spread of BYDV on winter-sown barley by aphid vectors can be effectively controlled by correctly timed insecticide sprays in the autumn (Plumb 1977, Horellou and Evans 1979, Kendall and Smith 1981a). However, the incidence of the disease is often spasmodic so it is desirable to know when such sprays are worthwhile.

Crops are infected initially by winged aphids migrating from volunteer cereal plants, maize crops, and grasses in September and October. Plumb, (1981) has suggested that a good indication of the risk of autumn infection by BYDV can be obtained by combining information on aerial abundance of these aphids, provided in the UK by the Rothamsted Insect Survey (Taylor, 1974), with a measure of the proportion carrying BYDV obtained by the use of indicator plants (Plumb, 1976); Plumb called this combination an Infectivity Index. However, the proportion of a crop ultimately infected with BYDV depends not only on the primary infection by winged immigrants but also on other factors, including the subsequent spread of virus within the crop during late autumn and winter by the wingless offspring of these immigrants. This secondary spread accentuates the patchy distribution of infected plants typically seen when symptoms appear in spring.

This paper shows the need, in South West England, to include measurements of secondary spread in schemes to predict the severity of disease outbreaks.

MATERIALS AND METHODS

The Rothamsted Insect Survey measures aerial abundance of aphids (Taylor, 1974). Infectivity of autumn migrants was measured daily by allowing aphids caught alive in suction traps to feed on virus-sensitive oat plants (cv. Blenda), and subsequently observing symptoms (Plumb, 1976). An Infectivity Index was calculated by multiplying the proportion of aphids infected with BYDV, averaged for the period September - January, by the total catch in the Rothamsted Insect Survey trap at Long Ashton from crop emergence until the end of January. Observations were confined to September - January because at that time winter-sown barley is at an early growth stage and most susceptible to infection and damage. Crops were sampled, at approximately 2 weekly intervals, by counting all aphids on plants in two adjacent 1m lengths of row. At least 8 such samples were selected at random on each occasion. BYDV was assessed in late April - May by counting tillers showing symptoms in $1m^2$ sample areas.

RESULTS AND DISCUSSION

Infectivity index for migrant aphids

Table 1 shows, for winter barley, migrant Infectivity Indices at Long Ashton, dates of crop emergence and the percentage of tillers with BYDV symptoms found subsequently in spring. Each year the earliest-sown crops were exposed to more virus-carrying aphids than later-sown crops. The total number of infective aphids varied from year to year, but crops emerging after the end of October were always exposed to few, if any, infective aphids, and therefore to little risk of virus infection. Correspondingly, very little BYDV was recorded at Long Ashton on crops emerging in November.

However, there was no correlation between Infectivity Index and the area of crop infected when comparisons were made from year to year. For example, for crops emerging by September 20 in 1977 and 1980 the Infectivity Indices were similar but subsequent crop infection was very different (Table 1). We believe that in South West England this is largely due to differences in the secondary spread of virus in late autumn.

Secondary spread of BYDV

The development of the aphid population in the crop both during and after invasion by migrants, and consequently much of the secondary spread of virus, is very dependent on climatic factors such as temperature and rainfall, and seems to be little affected by the numbers of migrants. In 1977 and 1980 similar numbers of migrants colonised early-sown winter barley (Fig. 1), but in 1977 the subsequent aphid population declined towards December and crop infection was $< 1\%$, whereas in 1980 aphid numbers increased in November and during December and January and virus infection was epidemic ($> 70\%$ of crop infected).

The secondary spread of virus depends on the movement of viruliferous aphids from plant to plant. Therefore, the extent of infection from each primary source in a crop should largely depend on the number of aphids and the time they are present and active on the crop. The area under an aphid population curve plotted on a physiological time-scale of accumulated day-degrees above a developmental or activity

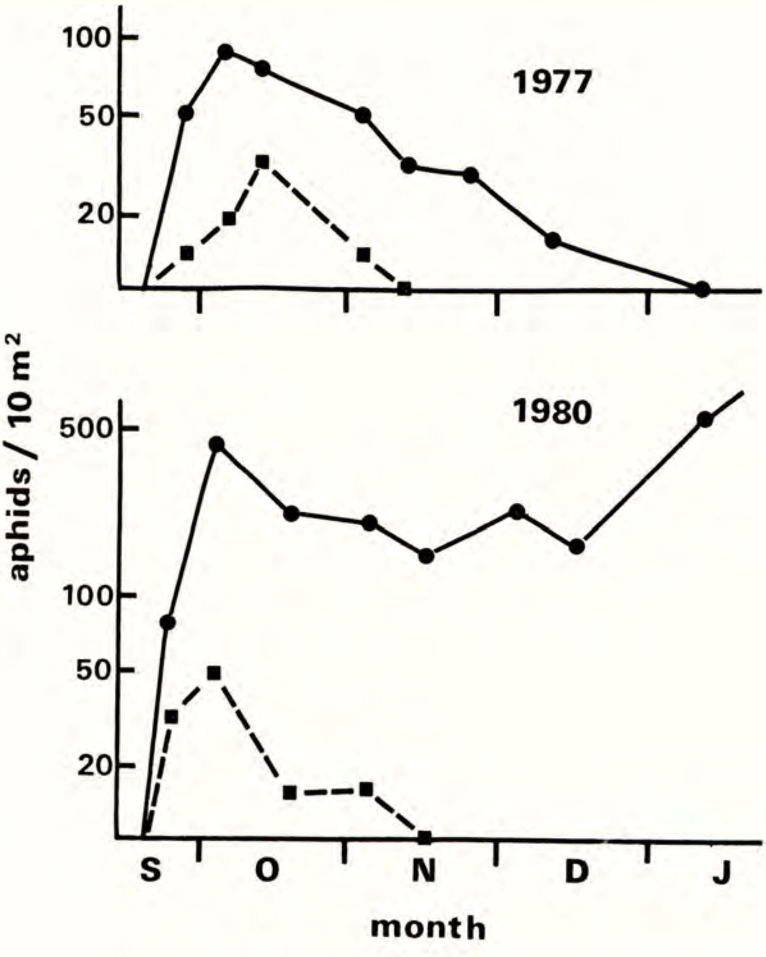

Figure 1 Aphid populations on early sown winter barley at Long Ashton in 1977 and 1980. (■ — — ■, winged migrant aphids settling on crop; ●——●, wingless aphids subsequently developing in crop)

Table 1

Migrant Infectivity Indices, crop emergence and corresponding BYDV infection (% tillers with symptoms in spring) in winter barley plots at Long Ashton Research Station

Date of crop emergence	1976	1977	1978	1979	1980
20 Sept.	16 (1.2)	399 (0.2)	225	94	425 (71.0)
5 Oct.	8	247	164 (1.3)	62 (0.3)	48 (18.0)
20 Oct.	2	58	43	10 (0.4)	18
25 Oct.	< 1	24	32 (0.1)	7	6 (7.0)
5 Nov.	< 1	< 1 (0.01)	< 1	< 1	< 1
25 Nov.	0	0	< 1	< 1 (0.01)	< 1 (0.01)

threshold, may provide an integrated measurement of this. Hence, although Plumb's migrant Infectivity Index should still provide an indication of the probable number of initial infection sources per unit area of crop, we hope to develop a predictive model of the risk of autumn infection based on regular observations of aphid numbers in crops and use this model to indicate the likelihood and extent of further virus spread after its initial introduction by winged immigrants. There is probably enough time in the autumn for such monitoring since insecticide treatment, if required, should not be applied, even to the earliest sown winter barley crops, before late-October to mid-November (Kendall and Smith 1981b).

Acknowledgements

Our thanks to Mrs S. Hazell, Miss L Mathias and Miss N. Chinn for doing much of the experimental work; and to Dr L.R. Taylor (Rothamsted Experimental Station) for making available information from the Rothamsted Insect Survey.

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Proceedings 1981 British Crop Protection Conference - Pests and Diseases

THE INFLUENCE OF RATE AND TIMING OF AUTUMN APPLIED PYRETHROID AND CARBAMATE INSECTICIDE SPRAYS ON THE CONTROL OF BARLEY YELLOW DWARF VIRUS IN ENGLISH AND FRENCH WINTER CEREALS

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Summary Barley yellow dwarf virus (BYDV) continues to be a serious problem in early-sown winter cereals in France, and the disease is becoming more frequently noted in English autumn-sown cereals. Trials in these crops in France and England in 1979 and 1980 confirmed that the pyrethroid insecticide permethrin at 40 - 50 g a.i./ha gives good control of the BYDV vector *Rhopalosiphum padi* and that equally effective control can be achieved with cypermethrin at 20 - 25 g a.i./ha. Pirimicarb gave rather poorer control. BYDV developed in 6 of 13 trials infested with aphids in the autumn. The extent of virus infection in the spring varied according to the effectiveness of aphid control in the autumn. Large increases in yield were recorded when pyrethroids where applied 7 days after the initial aphid infestation in France, and 7 - 14 days after infestation in England.

Résumé. La jaunisse nanisante de l'orge (JNO) continue de'être un problème important pour les céréales semées précocement en automne en France. Cette maladie est observée de plus en plus fréquemment dans les céréales d'automne en Angleterre. Les essais réalisés dans ces cultures tant en France qu'en Angleterre en 1979 et 1980, ont confirmé que la perméthrine (insecticide pyréthrinoide) à la dose de 40 à 50 g de m.a./ha permettait une lutte efficace contre *Rhopalopsiphum padi*, agent de transmission de la jaunisse nanisante de l'orge, et qu'un niveau équivalent d'efficacité peut être obtenu avec la Cyperméthrine, à des doses de 20 à 25 g m.a./ha. Le Pirimicarb montre une tendance à donner des niveaux d'efficacité plus bas. La jaunisse nanisante de l'orge ne s'est extériorissé que dans 6 des 13 essais présentant une infestation de pucerons a l'automne. L'importance de l'infection virale observée au printemps est fonction du niveau d'efficacité obtenu sur pucerons à l'automne. Des augmentations de rendement très importantes ont pu être obtenues lorsqu'une application de pyréthrinoides a été effectuée sept jours après l'apparition des pucerons en France et sept à quatorze jours après l'apparition des pucerons en Angleterre.

INTRODUCTION

Following recognition of the increasing economic significance of barley yellow dwarf virus (BYDV) on winter barley in France (Bayon & Ayrault 1977), Horellou & Evans (1979) examined the use of the photostable pyrethroid permethrin to control the aphid vector Rhopalosiphum padi in cereal growing areas where the problem was considered to be endemic. Earlier work had indicated that the use of insecticides against this aphid vector could give some control of this persistently transmitted, circulative virus (Smith, 1963, Plumb 1973, A'Brook, 1974).

Horellou & Evans (1979) tentatively concluded that when 5% of a winter barley crop showed BYDV symptoms in the spring, yield losses would be significant and that 40 g a.i./ha of permethrin applied at the 2 - 3 leaf stage, within 7 days of aphid infestation, was the optimum rate and time for spraying, i.e. the stage when cereals are most susceptible (Watson & Mulligan, 1960). Experience suggested that only low levels of aphid infestation on the crop could be tolerated, although no particular aphid infestation could be established as a threshold for the onset of spraying.

The French trials described in this paper were carried out in 1979/80 to establish the validity of Horellou & Evans' (1979) conclusions with permethrin and to compare and contrast permethrin with the intrinsically more active pyrethroid, cypermethrin. In England, the considerable increase in the area of winter barley grown in the 1970s and the frequency of reports of BYDV infection, especially in sheltered fields near coasts or estuaries in the south, prompted us to do experiments, similar to those done in France, with permethrin, cypermethrin and pirimicarb in autumn 1979 and 1980. Since aphid monitoring had previously indicated that there is an autumn maximum for the incidence of R. padi during October (Taylor & French 1970), insecticides were applied towards the end of this month or at the beginning of November.

METHODS AND MATERIALS

The results presented are from fully replicated small plot trials. Permethrin was applied as a 25% w/v e.c., cypermethrin as a 10% w/v e.c., and pirimicarb as a 50% w/w dispersible grain. In the French trials all treatments were applied using a hand held boom and a spray volume of 500 l/ha to simulate tractor application. Treatments in the English trials were applied with similar equipment but using spray volumes of 200 - 250 l/ha.

Aphid infestations were measured by counting aphids on 100 plants/plot in the French trials and 15 - 20 plants/plot in the English trials, BYDV infection by visual scoring, and grain yields by taking standard combine cuts; all grain yields were adjusted to 85% dry matter unless stated otherwise. All the trials were on winter barley, except Suffolk 1 which was on winter wheat.

Other details are given in Table 1.

Table 1

Experimental conditions

Country	Trial Number	Area	Cultivar	Spray Date	Crop Growth at Spraying
France	103	Tours	Astrix	17 Oct '79	3 lvs
	153	Tours	Sonja	19 Oct '79	2 lvs
	104	Tours	Thibault	13 Nov '79	3 lvs
	154	Tours	Thibault	13 Nov '79	2 lvs
	111	Reims	Sonja	24 Oct '79	2 lvs
	112	Reims	Thibault	5 Nov '79	2 tills
	113	Reims	Sonja	5 Dec '79	2 tills
	14	Toulouse	Sonja	12 Nov '79	2 lvs
	15	Toulouse	Alpha	18 Oct '79	2 lvs
England	Sussex	Sussex	Sonja	29 Oct '79	3 lvs
	Suffolk 1	Suffolk	Armada	8 Nov '79	3 lvs
	Suffolk 2	Suffolk	Igri	13 Nov '80	4 lvs

RESULTS

(a) French trials 1979/80

Spraying dates ranged from 17 October - 5 December 1979. The aphids present were principally R. padi. In all but two trials, at least 33% of plants were infested at spraying, and in most untreated plots this level of infestation remained constant or increased during the next 14 - 30 days (Table 2). Since most of the crops were at the very susceptible 2 - 3 leaf stage the probability of the BYDV developing appeared to be great.

Table 2

Percentage of untreated plants infested with aphids at and after the time of autumn insecticide spraying in 9 French winter barley trials 1979.

Days Post Spray	TOURS				REIMS			TOULOUSE	
	103	153	104	154	111	112	113	14	15
0	33	36	24	36	17	43	61	66	55
2	19	14	-	-	-	-	-	60	34
14	-	31	-	-	-	30	49	60	50
21	87	29	-	-	24	41	45	-	-
30	-	-	-	-	32	34	59	-	-

However, symptoms developed in only 3 of the 9 trials (Table 3). In two trials, moderate to larger areas of infection appeared in the controls, whilst in the third less than 10% of the plants showed symptoms.

Table 3

The effects of autumn applied insecticides on the percentage of winter barley plants showing BYDV symptoms

	TOURS 103		TOULOUSE 14		TOURS 153
Assessment Date	Feb	May	Feb	May	May
Control	35.8 b	60.0 d	20.8 b	95.0 b	7.5
Permethrin 40 g a.i./ha	5.4 a	8.3 bc	0.6 a	33.3 a	0
Permethrin 2 x 40 g a.i./ha	-	-	-	-	0
Cypermethrin 15 g a.i./ha	6.4 a	10.4 c	0.6 a	30.0 a	0
Cypermethrin 20 g a.i./ha	3.7 a	3.9 ab	0.2 a	25.0 a	0
Cypermethrin 25 g a.i./ha	3.3 a	2.8 a	0 a	23.3 a	0

In this and all subsequent tables, figures in vertical columns with the same letter are not significantly different at P = 0.05.

In the three trials where BYDV developed, permethrin gave good to excellent aphid control in the 2 - 3 weeks following its application, as did cypermethrin which in Tours 103 provided better control of both aphids and virus as the rate of active ingredient was increased (Tables 3 & 4). A second application of permethrin was applied in Tours 153 as control after 2 days did not appear to be adequate, but this second spray did not improve aphid or BYDV control.

Table 4

Percentage of winter barley plants infested by aphids after spraying with insecticides in those French trials where BYDV subsequently developed

	TOURS 103		TOULOUSE 14		TOURS 153		
Days After Spraying	2	21	2	14	2	14	21
Control	19.0	87.0	60.0	60.0	14.3	30.5	28.7
Permethrin 40 g a.i./ha	2.0	10.0	0	0	2.5	1.0	0.5
Permethrin 2 x 40 g a.i./ha *	-	-	-	-	0.7	2.0	3.0
Cypermethrin 15 g a.i./ha	4.0	17.0	0	0	-	-	-
Cypermethrin 20 g a.i./ha	2.0	11.0	0	0	0.5	2.3	1.7
Cypermethrin 25 g a.i./ha	1.0	7.0	0	0	1.5	3.5	4.0

All treatments (except *) applied 7 days after aphid infestation observed.

* second treatment applied 2 days after first treatment.

Notable and significant increases in yields were achieved following all autumn insecticide treatments in the two trials where infection by BYDV was most extensive whilst there was a trend towards higher yields in the third trial (Table 5). The dose response to cypermethrin suggested by the data for aphid control and disease incidence was only evident in the yields from Tours 103.

Table 5

The effect on yield (t/ha) of insecticides applied to 3 French winter barley crops attacked by BYDV

	TOURS 103	TOULOUSE 14	TOURS 153
Control	3.23 c	2.71 b	5.94
Permethrin 40 g a.i./ha	5.44 b	4.63 a	6.27
Permethrin 2 x 40 g a.i./ha	-	-	6.45
Cypermethrin 15 g a.i./ha	5.51 b	4.83 a	-
Cypermethrin 20 g a.i./ha	5.47 b	5.07 a	6.04
Cypermethrin 25 g a.i./ha	5.95 a	4.81 a	6.19

(b) English Trials 1979/81

In three winter-sown cereal trials, aphid infestation of barley and wheat, principally by R. padi, increased during November on untreated plots (Table 6). Indeed, in the Sussex trial live aphids were observed throughout the winter. Permethrin and cypermethrin, applied 1 - 2 weeks after aphids were initially observed, gave excellent control but with pirimicarb, control was generally poorer. In a fourth trial in Sussex in autumn 1980, only 2% of the plants were infested at spraying, and three weeks later no aphids were to be found either in the control or treated plots.

Table 6

Percentage of cereal plants infested with aphids up to 4 weeks after autumn application of various insecticides.

	SUSSEX Winter barley '79		SUFFOLK 1 Winter wheat '79		SUFFOLK 2 Winter barley '80
Weeks after Spraying	1 wk	3 wk	2 wk	4 wk	2 wk
Control	37.9 a	21.9 a	49.0	82.5	10
Permethrin 50 g a.i./ha	0.4 c	0 b	0	0	0
Cypermethrin 25 g a.i./ha	1.5 c	0.7 b	-	-	0
Cypermethrin 20 g a.i./ha	-	-	0	0	0
Pirimicarb 140 g a.i./ha	8.0 b	4.2 b	0	17.3	-

Spraying dates: Sussex, Oct 29, 1979. Suffolk 1, Nov 8, 1979. Suffolk 2, Nov 13, 1980.

Pre-Spray Infestations: Sussex, 27%, Suffolk 1, 36% and Suffolk 2, 8% of plants.

By the following May and early June BYDV symptoms were evident in all three trials, and as in France, autumn insecticide treatments had significantly decreased the extent of infection. Permethrin and cypermethrin were equally effective although, as for aphid control, pirimicarb was poorer (Table 7).

Table 7

BYDV incidence in winter barley and winter wheat crops following use the previous autumn of various insecticides.

	Sussex *			Suffolk 1#	Suffolk 2*
	Winter barley			Winter Wheat	Winter barley
Month after spraying	March	April	May '80	June '80	May '81
Control	3.0	67.6 a	72.3 a	4.4 a	10
Permethrin 50 g a.i./ha	0.0	3.9 c	1.3 c	1.0 c	0.3
Cypermethrin 25 g a.i./ha	0.8	1.8 c	0.0 c	-	0.1
Cypermethrin 20 g a.i./ha	-	-	-	0.2 c	0.3
Pirimicarb 140 g a.i./ha	1.8	25.0 b	19.9 b	6.0 b	-

Spraying dates as in Table 6.

* % plants showing BYDV symptoms.
# Number of BYDV foci/plot; approximately 10% of crop area affected in control.

Yield increases were generally greatest where autumn treatment had decreased aphid numbers and virus incidence most. Plots sprayed with cypermethrin and permethrin gave similar, significant increases in yield whilst there was less response to pirimicarb in the two trials where it was tested (Table 8).

Table 8

Winter cereal yields (t/ha) following the autumn application of insecticides

	Sussex Winter barley '79	Suffolk 1 Winter wheat '79	Suffolk 2 Winter barley '81
Control	2.74 d	6.59 c	7.14 b
Permethrin 50 g a.i./ha	6.35 a	7.00 ab	8.16 a
Cypermethrin 25 g a.i./ha	6.38 a	-	8.06 a
Cypermethrin 20 g a.i./ha	-	7.20 a	8.06 a
Pirimicarb 140 g a.i./ha	5.30 b	6.63 bc	-

DISCUSSION

All the trials confirmed that permethrin at 40 - 50 g a.i./ha gives good or excellent control of autumn aphid infestations and that equally effective control can be given by cypermethrin at half these rates of active ingredient. Pirimicarb gave poorer control than the pyrethroids.

The incidence of BYDV in the six trials where it occurred, (three in France and three in England) depended on effectiveness of autumn aphid control, and generally these differences were also reflected in yields. The data confirm that very large increases in yield, up to 130%, can be achieved by the use of autumn insecticide sprays.

An optimum time for autumn spraying has not been clearly defined by the these trials. Indeed, with the large number of interacting factors that are involved, time of aphid infestation, level of aphid infestation, severity of the BYDV isolate carried by the aphid, plant growth stage and weather, it is probable that the optimum time for spraying will differ from year to year and from crop to crop.

Nevertheless, the French trials have shown that BYDV can be controlled and large yield increases obtained by monitoring the influx of aphids into winter barley crops and spraying seven days following infestation. In England, similar results were achieved with sprays applied 1 - 2 weeks after aphids were first noted in the crop. The control of BYDV and the associated increased yields (Table 9) in our trials suggest that some build-up of aphids in winter cereals can be tolerated before spraying.

Table 9

Summary of BYDV incidence and insecticide application in French and English trials 1979/81

	TOURS 103	TOULOUSE 14	TOURS 153	SUSSEX	SUFFOLK 1	SUFFOLK 2
Sowing Date	25 Oct	18 Oct	19 Oct	20 Sept	17 Sept	15 Sept
Spray Date	28 Nov	12 Nov	3 Nov	29 Oct	8 Nov	13 Nov
Growth Stage at Spraying	2 leaves	2 leaves	2 leaves	3 leaves	3 leaves	4 leaves
% Plants Infested at spraying	33	66	36	27	36	8
Max % BYDV in Control	60	95	7.5	72	4.4*	10
Max % Yield Increase following insecticide use.	84	87	8	131	10	14

* Foci/plot

Permethrin and cypermethrin are particularly suited for the control of the aphid vectors of BYDV because they are persistent on the crop and give prolonged control (Ruscoe 1977, Horellou & Evans 1979).

The experiments with BYDV and winter cereals described in this paper highlight the practical difficulties of monitoring the probable severity of the disease, and deciding upon preventive action. In France the trials were in areas where BYDV is considered endemic, yet in only two of nine winter barley crops was the disease damaging despite moderate to severe infestations of aphids at the 2 - 3 leaf stage. Similarly, with the four English experiments the disease developed in only 3 of 4 trials even though all were infested by aphids in the autumn. Variations in the presence, origin, virulence and efficiency of transmission of the virus probably accounted for these differences but these are difficult parameters for farmers to assess.

Observing and spraying aphids in the autumn in areas of risk, i.e. those known by practical experience, are likely to remain important measures of controlling BYDV in the immediate future, and Plumb (1977) and Bayon et al (1981) have attempted to define the geographical areas of high risk for BYDV in England and France respectively. Monitoring aphids field by field in the autumn is therefore essential in these areas, but unless more information on the local infectivity potential of aphid populations can be obtained and disseminated effectively to farmers in the autumn, it seems probable that there will, in some regions, be a shift towards the routine spraying of aphid-infested crops feared by Plumb (1977).

Acknowledgements

The authors wish to acknowledge Messrs G Painparay, M Gibbard, T J Gorringe, S F B Cousins and other colleagues in SOPRA and UK Department, ICI Plant Protection Division who have helped to gather, collate and analyse the information presented in this paper.

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Proceedings 1981 British Crop Protection Conference - Pests and Diseases

USE OF MINERAL OILS FOR THE CONTROL OF PLANT VIRUS DISEASES

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Summary A specially formulated mineral oil has been used for control of aphid-borne virus diseases in the USA for the past four years. Crops, and viruses, on which the oil has been used include 1) pepper, potato virus Y and tobacco etch, 2) tomato, potato virus Y and tobacco etch, 3) squash, watermelon mosaic, 4) cucumber, watermelon mosaic, 5) sweet corn, maize dwarf mosaic, and 6) potato, potato virus Y. Disease control has been good even under heavy disease pressure.

Not only is the type and formulation of oil important, the application techniques used are also significant. By optimizing all of these parameters good disease control has been obtained using oil at the relatively low concentration of 0.75%; at this concentration, injury to plants is negligible.

INTRODUCTION

Since Bradley et al (1962) first reported that oil interfered with aphid transmission of potato virus Y (PVY), many researchers have investigated the possibility of using oil sprays for control of certain aphid-borne virus diseases. It was soon established that oils work by interfering with transmission of virus (both acquisition and inoculation) and the phenomenon was shown to operate with every virus transmitted non-persistently by aphids that was tested. Vanderveken et al (1966) also demonstrated that oils reduced transmission of the semi-persistently aphid transmitted beet yellows virus. Oil has been reported not to interfere with the transmission of persistently aphid transmitted viruses such as pea enation mosaic virus (Vanderveken, 1968) and potato leafroll virus (Hein, 1971). However, Zitter and Everett (1979) have reported that oil sprays reduced spread of tomato yellows in Florida. Tomato yellows virus is closely related to potato leafroll virus and is persistently transmitted by the green peach aphid, *M. persicae* (T. Zitter, personal communication).

As a result of this evidence it might be expected that oils would be widely used for virus control. However, with the exception of limited use in Europe on seed potatoes and lilies, there has been very little commercial adoption of oil spraying; in the USA the first commercial use of oil was in 1977. There are several reasons why oils have been slow to gain commercial acceptance including 1) lack of adequate efficacy, 2) phytotoxicity, 3) lack of research effort to develop oils specifically for virus control, and 4) lack of interest by oil companies and agricultural chemical manufacturers. There has also been a general attitude of disbelief among growers that a treatment which only interfered with transmission of viruses by aphids but which did not kill the aphids or directly affect the viruses could be of real value in disease control.

This paper reports the results of four years commercial use of a mineral oil specifically designed to control plant viruses.

METHODS AND MATERIALS

Laboratory studies

Various experimental oil formulations were tested using some specialized techniques. Plants (peppers, squash and tomatoes) were grown in a glasshouse until about 15 cm high and then transferred to a screenhouse for several weeks before being used for testing. This procedure insured that plants had leaf surfaces comparable to those grown in the field.

Spraying was done with specially designed equipment. The boom, which had three nozzles, was attached to an overhead track approximately 8 m long. A variable-speed motor moved the boom up and down the track at speeds from 1-6 km/h. The speed of the boom was always adjusted so that equal volumes of spray material were applied to the plants. Plants were sprayed to the point of runoff. Thus, results with different nozzles and/or spray pressures were not associated with differences in the amount of oil applied. Spray pressures were controlled by a pressure regulator and were varied through 6.8-40.8 bar at 6.8 bar increments. From 15-25 plants were sprayed at any one time. After spraying, the plants were kept in the screenhouse overnight before they were inoculated with virus.

Viruses were inoculated by using two wingless M. persicae/plant. Source plants were always used two weeks after infection. Aphids were given access feeding periods of 1-3 min on the source plants. Two people made the aphid transfers; each person placed one aphid on each plant. After inoculation feeds of several hours the plants were sprayed with methomyl and put in the glasshouse.

The viruses used were PVY on peppers and tomatoes and watermelon mosaic virus 1 (WMV) on squash. The viruses were propagated only by aphid inoculation; PVY was maintained in pepper and tomato and WMV was maintained in squash (zucchini).

Field studies

Field trials were established when aphid flights were expected to occur. The following procedures were used.

1) Plot design After trying many designs it was found that, with one modification, the randomized block was best. The unsprayed control plots were located some distance (usually 50-75 m) from the treated plots. The juxtaposition of unsprayed and sprayed plots causes considerable bias in results. Laying the block out as pairs of plots placed at right angles to the prevailing wind was also helpful. Each plot was square and each treatment was replicated four times.

2) Plot size Because plants respond only once with systemic infections it is necessary to use rather large samples in each plot. We used 250 plants/plot for peppers and 150 plants/plot for tomato and squash.

3) Virus inoculum Using naturally occurring inoculum resulted in great variability. A border row of infector plants outside the plot area worked well but was no more satisfactory than introducing infector plants into the plots. Therefore, in these trials inoculum was provided by placing two infector plants (side by side) in the centre of each plot. The plants were generally inoculated by manual inoculation with sap from aphid-transmitted isolates of the virus.

4) Spraying technique Oil emulsions were applied using sufficient nozzles per row to give thorough coverage of the outer canopy of foliage. For small plants three nozzles per row were used. For larger plants as many as 12 nozzles per row were used. Nozzles were placed at intervals of 30 cm on the boom and drop booms were used to insure coverage of the sides of the plants. Volumes of emulsions sprayed ranged from 400-950 l/ha depending on plant size. For squash, the plants were sprayed twice weekly until they flowerd after which they were sprayed once/week. Peppers and tomatoes were sprayed once/week. A tractor speed of about 6 km/h was used. Oil was used at a concentration of 0.75%. Plants were not sprayed unless the foliage was dry. Other pesticides were applied separately from the oil.

5) Recording Plots were generally scored for virus weekly.

Oils used

Oils used in these studies were manufactured by the Sun Oil Company of Philadelphia, Pennsylvania, USA. They were all derived from the same base oil, Sunoco 7N oil hereafter referred to as CO. Sunoco 7E oil, referred to as COE, is a commercially formulated version of CO. JMS Stylet-Oil®, referred to as EO, is a specially formulated oil used for virus control.

Sunoco 7N oil (CO) is a paraffinic mineral oil with a viscosity of 14.2 cSt at 37°C (=74 SUS). It has an unsulfonated residue of no less than 92%.

RESULTS

Development of oils designed for virus control

There is good evidence that the oil which is effective in stopping transmission of virus is located on the surface of the leaf (Simons et al, 1977). This suggests that good coverage of the leaf will be essential to obtain maximum efficacy with low concentrations of oil. As aphids usually initiate their feeding probes in the grooves which separate epidermal cells, it seems likely that an oil which collected selectively in these grooves would be optimally effective.

Both viscosity and the emulsification system affect coverage. Oils with different viscosities, which have been made for use on plants, are commercially available. The most common of these have viscosities in the 60 s, 70 s, and 110 s Saybold Universal Seconds (SUS) ranges. The results of testing such a series of oils, all of which contained equal amounts of the same emulsifier, have recently been published elsewhere (Zitter and Simons, 1980). These results showed highly significant differences in the efficacy of these oils. The 70 s oil was best when one type of nozzle orifice was used but the 110 s oil was the most effective when a different orifice was used. This work confirmed that of de Wijs et al (1979) who found oils in the 70-110 s viscosity range to be the most effective.

The influence of emulsifiers on the effectiveness of oil formulations used for virus control have been little investigated. Table 1 shows data from tests using several emulsifiers which are used commercially to make oil formulations for use on plants. The emulsifiers were used at a concentration of 1.25% and the oil formulations were sprayed at a pressure of 27.2 bar using an 0.75% concentration of oil. Pepper plants were used in the trial and the test virus was PVY. There were differences in the effectiveness of the formulations even though there were no apparent differences in the appearance of the emulsions which were formed.

Apart from the oil formulation, there are also aspects of application technique which could be of importance in affecting efficacy. The two most obvious are nozzle type and its effect on emulsion droplet formation and spray pressure. The results of some of these trials have recently been published (Zitter and Simons, 1980) and some striking interactions between nozzle orifice and spray pressure were found.

Table 1

Efficacy of several oil formulations in preventing aphid inoculation of potato virus Y to pepper

Emulsifier [a]	% Infection [b]
Ninate 401 + Poe 5	36
Triton X-363M	36
T-Mulz A02	46
Span-80	48
-	66
Unsprayed	88

[a] Emulsifiers were used at a concentration of 1.25%. The oil (CO) had a viscosity of 70 s (SUS) and was sprayed at a concentration of 0.75% using a spray pressure of 27.2 bar.

[b] Based on means of 4 replications each of 25 plants.

As a result of the information on emulsifiers it appeared very likely that, through a process of trial and error, it should be possible to find a formulation of oil which would be significantly superior to existing commercial formulations. In Tables 2-5 results of some of these trials are reported.

Table 2 gives the results of laboratory tests on three formulations of a 70 s viscosity oil 1) oil without emulsifier (CO), 2) oil with emulsifier (COE), and 3) the same oil experimentally formulated for maximum effectiveness (EO). The test systems were WMV in squash and PVY in pepper. All formulations were sprayed at a pressure of 27.2 bar. The trials were done twice using three replicates of 25-30 plants for each treatment in each trial. Formulation (EO) was consistently the most effective in reducing virus infection.

Table 2

Effect of oil sprays on transmission of watermelon mosaic virus to zucchini squash and potato virus Y to pepper under laboratory conditions

	% WMV in squash		% PVY in pepper	
Treatment [c]	Trial 1[a]	Trial 2[b]	Trial 1[a]	Trial 2[b]
CO	28	36	72	59
COE	23	33	51	51
EO	16	19	35	35
Unsprayed	32	43	77	84

a/ Three replicates each of 25 plants

b/ Four replicates each of 20 plants

c/ Oils were applied at a concentration of 0.75% using a spray pressure of 27.2 bar. TX-5 nozzles were used for squash, TX-4 nozzles were used for pepper. See text for explanation of treatment code.

Table 3 gives results of laboratory tests using tomato and PVY and three experimental oil formulations. The oil (CO) was the same as used in the previously described experiments (Tables 1 & 2), but a different emulsifier was used. Emulsifier concentrations of 1.2, 2.4, and 4.8% were used. Controls consisted of the (CO) oil without emulsifier and unsprayed plants. Two nozzle orifice sizes (TX-4 and TX-5) were used and a spray pressure of 27.2 bar was utilized. Oils were sprayed at a concentration of 0.75%.

Table 3

Effect of nozzle orifice size and concentration of emulsifier on efficacy of oil sprays when used on tomatoes which were inoculated by green peach aphids with potato virus Y.

TX Nozzle		% Transmission a/		
Orifice	% Emulsifier	Trial 1	Trial 2	$\bar{x}$
4	1.2	73	65	69.0
4	2.4	53	43	48.0
4	4.8	74	65	69.5
5	1.2	65	60	62.5
5	2.4	35	50	42.5
5	4.8	44	38	41.0
Unsprayed		88	88	88.0

a/ A sample of 40 plants was used for each treatment

The TX-5 nozzles were better than TX-4 (118 plants infected out of 240 inoculated versus 150 infected of 240 inoculated, $\chi^2 = 3.80$, $P = .05$). An emulsifier concentration of 2.4% was sufficient for optimum effectiveness. In the case of the TX-4 nozzles the use of a 4.8% concentration of emulsifier appeared detrimental as compared to 2.4%, and with the TX-5 nozzles the 4.8% concentration was no better than the 2.4%.

Table 4 gives results of a field trial with WMV in squash in which the same oils as in the experiment reported in Table 2 were used (COE and EO). The oils were sprayed at two pressures, 13.6 bar and 27.2 bar using TX-5 nozzles. Twice weekly applications were made. The tractor speed was adjusted so that equal amounts of spray were applied to each treatment. Plots were 15 m long and 8 rows (10 m) wide with 160 plants in each. Four replicates were used.

The two spray pressures were used because laboratory data indicated that the higher spray pressure was more effective. Results from the field studies verified the laboratory data. Both oils were more effective when sprayed at a pressure of 27.2 bar and the EO formulation was more effective than the COE formulation.

Table 5 reports results of a field trial in which COE was compared with EO using peppers and potato virus Y. Plots were 16 m long and 10 rows (10 m) wide with 250 plants in each. Four replicates were used. Peppers were sprayed weekly using TX-4 nozzles and a spray pressure of 27.2 bar.

Laboratory data had indicated that the EO formulation would be more effective than the COE formulation. Results of the field trial confirmed this.

Table 4

Effect of oil sprays on transmission of watermelon mosaic virus in zucchini squash in the laboratory and field

Treatment [a]	Pressure (bar)	% Inf. in Laboratory	% Infection in Field [b] Apr. 28	May 4	May 11
COE	13.6	55	11	17	34
COE	27.2	28	4	11	20
EO	13.6	23	6	10	18
EO	27.2	18	5	8	11
Unsprayed		54	10	17	35

[a] Oils were applied twice weekly at a concentration of 0.75%. TX-5 nozzles were used. See text for treatment code.

[b] Each treatment had 160 plants and four replicates were used.

Table 5

Results of a field trial using oil sprays against transmission of potato virus Y in pepper

Treatment [a]	% PVY Infection on [b] December 6	December 26	January 2
COE	3	15	22
EO	1	9	12
Unsprayed	5	28	39

[a] Oils were applied weekly at a concentration of 0.75%. TX-4 nozzles were used. See text for treatment code.

[b] Each treatment had 250 plants and four replicates were used.

DISCUSSION

The use of oil for the control of viruses of vegetables in Florida has become an accepted practice by most growers in virus-prone areas. Growers who choose not to spray provide dramatic proof of the effectiveness of oil sprays because, almost invariably, their unsprayed crops become extensively infected. Without question the most surprising consequence of the widespread use of oil has been the good virus control achieved. Where oil is sprayed weekly from the time winged aphids appear, mature crops often have only a trace of infection.

Unlike other areas, phytotoxicity from oil sprays has not been a problem. This is almost certainly because of the low concentration of oil used. Field trials in which higher concentrations of oil have been used have shown that concentrations of 2.0% oil or more cause visible injury to peppers, squash and tomatoes. The same field trials showed that a concentration of 0.75% oil is the optimum for virus control which must be a reflection of the excellent coverage obtained through the use of a sophisticated application system.

However, oil sprays are not without problems. Spraying does not always start when winged aphids first appear, some growers are gamblers, and if infection reached 10% or more before spraying starts, the effectiveness of the oil can be much reduced. Another drawback is that, for maximum effectiveness, the oil must be applied separately from other pesticides. Addition of chemical formulations with potent surfactant systems of their own is detrimental to the emulsification system used in the oil and use of wettable powders in combination with oil will cause excessive nozzle wear at the 27.2 bar spray pressure used. We have found that most water soluble pesticides can be combined directly with the oil with no adverse effects on either component. Stainless steel nozzle tips are necessary because of the high spray pressure which is used.

Phytotoxicity can be a problem where certain fungicides are used in spray programmes. This is true even though the materials are sprayed separately. However, maneb can be used safely with oil although it should be sprayed separately.

It seems unlikely that oil sprays can be made significantly more effective. The choice of a 70 s viscosity oil has been confirmed by de Wijs et al (1979) in an extensive research effort. Most of the commercially available emulsifiers have been tested by the writer and the best of these is used at the optimum concentration with the currently used oil formulation. Application technology has been optimized to the point where no significant improvement would seem likely.

It would be most helpful if oil could be sprayed in direct combination with other pesticides. Work aimed at this goal needs to be done. Careful attention will need to be paid to the effect of the oil on the biological activity of the other pesticides and this will require a lot of field testing.

There are also some interesting possibilities for increasing the virus control potential of oil by combining it with other chemicals. Chemicals which affect insect behaviour, such as antifeeding compounds and repellants, could be used to advantage with oils.

The safeness and relatively low cost of oils make them ideal pesticides. There are no residue restrictions on the use of oil in the USA thus spraying can be done even during harvest. Oils have minimal impact on beneficial insect species and are therefore useful in Integrated Pest Management programmes. The current cost for oil makes it possible to spray a hectare for about $7.50 for the material. This figure is based on use of 600l/h of an 0.75% concentration of oil.

Acknowledgements

The author gratefully acknowledges the kind assistance of British Sun Oil Company in making this contribution possible.

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SESSION 7A

CEREAL PEST AND DISEASE CONTROL (II)

Proceedings 1981 British Crop Protection Conference - Pests and Diseases

CONTROL OF CEREAL INSECT PESTS WITH TRIAZOPHOS

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Summary Replicated field trials have been carried out by Hoechst UK Limited and ADAS since 1973 to investigate the control of various cereal insect pests with triazophos as a foliar spray. Applied during the egg-hatch period, 0.6 kg/ha a.i. gave good control of the important pest of cereals, wheat bulb fly (Leptohylemyia coarctata), and a grass and cereal fly (Opomyza florum). Frit fly (Oscinella frit) and leatherjackets (Tipula spp.) were effectively controlled on a range of cereal crops by 0.8 kg/ha a.i. sprayed when damage was first seen. Triazophos significantly reduced the numbers of grains attacked by both the lemon (Contarinia tritici) and orange (Sitodiplosis mosellana) blossom midges and increased yield when applied between ear emergence and flowering at 0.34 kg/ha a.i. Triazophos is thus an effective treatment for control of a wide range of important cereal pests.

Résumé Depuis 1973 de nombreux essais ont ete realises par Hoechst UK et l'ADAS afin de determiner l'interet du triazophos en applications foliaires pour lutter contre les ravageurs des cereales. La dose de 0.6 kg/ha a.i. appliquee pendant la periode de ponte, assure une bonne protection contre la mouche grise des cereales (Leptohylemyia coarctata), la mouche jaune des cereales (Opomyza florum). La dose de 0.8 kg/ha a.i. appliquee des l'apparition des premiers degats, controle l'oscinie (Oscinella frit) et les tipules (Tipula spp.) sur de nombreuses cereales. La dose de 0.34 kg/ha a.i. appliquee entre le debut de l'epiaison et la floraison, reduit de facon significative le nombre de grains attaques par les cecidomyies jaune (Contarinia tritici) et orange (Sitodiplosis mosellana) et permet correlativement des accroissements de rendement. Ces travaux demontrent l'interet du triazophos pour lutter contre un grand nombre de ravageurs sur cereales.

INTRODUCTION

Triazophos is a broad-spectrum organophosphorus insecticide and acaracide. It is a contact and stomach poison and, although non-systemic, penetrates deeply into plant tissue. It therefore tends to be rainfast and persistent.

The structure, properties and biological activity of triazophos were first reported by Vulić et al (1970). Trials have been carried out in the U.K. on pests of non-cereal crops and results have been published for red spider mite (Panonychus ulmi) on apples (Hay, 1971), pea moth (Cydia nigricana) (Biddle, 1977; 1979) and seed weevil on oilseed rape (Alford et al, 1979). Black and Hewson (1979) also gave results for control of a range of pests of fruit, vegetable and arable crops with triazophos.

In recent years new uses for the chemical have been developed and this paper reviews the trials work carried out to date with triazophos to control cereal insect pests.

METHODS AND MATERIALS

All trials were done on commercial crops of cereals. In Hoechst UK Limited trials the plot size was 2 x 7.5m with four replicates and a randomised block design. Application was made with a Van der Weij 'AZO' sprayer at a pressure of 2.5 bar and 225-300 l/ha water. Triazophos was formulated as 40% e.c. Hostathion (registered trade mark of Hoechst) and commercially available formulations of other products used were chlorpyrifos (48% e.c.), dimethoate (40% e.c.) and omethoate (57.5% e.c.). Details of other trials, and assessments of individual pests in all trials are given in the results section. In Tables 3, 4, 5 and 7 results marked *, ** or *** differ significantly from untreated controls at $P = 0.05$, 0.01 and 0.001, respectively.

RESULTS

Trials were done on a grass and cereal fly (*Opomyza florum*), wheat bulb fly (*Leptohylemyia coarctata*), frit fly (*Oscinella frit*), leatherjackets (*Tipula spp.*) and wheat blossom midges (*Sitodiplosis mosellana* and *Contarinia tritici*). Work on each pest is reported separately.

Grass and cereal fly

This pest occurs in winter wheat and is of increasing importance. Like wheat bulb fly it is a stem-borer and is responsible for producing 'deadheart' symptoms. It occurs mainly in East Anglia and is associated with early-drilled crops in a close cereal rotation.

Three trials were done by Hoechst UK Limited in each of two seasons. All sites were drilled between the 4th and 7th October. Of the 1979/80 trials, two were located in Suffolk (Nos. 1 and 2) and one in Essex (No. 3). Dates of application were 20th - 26th November (egg laying), 16th or 17th January (egg hatch) and 2nd - 17th April (first signs of damage). The 1980/81 trials were located in Essex (No. 4), Norfolk (No. 5) and Warwickshire (No. 6). Applications were made on 13th - 28th November (egg laying), 22nd - 26th January (egg hatch), 10th or 16th February (early-spring treatment in Trial Nos. 5 and 6 only) and 4th - 12th March (first signs of damage). 'Deadheart' assessments were made on five 0.5m lengths of row in each plot, two weeks after the last application. Trial No. 1 was badly affected by drought and No. 6 by poor drainage and neither was harvested. Results for both years are given in Table 1. On the untreated plots and those sprayed when 'deadhearts' were first seen, the crop was stunted and many small ears were visible.

Wheat bulb fly

This is a most serious and widespread insect pest of winter wheat. It is particularly prevalent in the east, east midlands, north east England and Scotland. Unlike the grass and cereal fly it is more common in late-sown winter wheats following crops such as peas and potatoes. It produces 'deadheart' symptoms similar to those caused by the grass and cereal fly, but they generally appear slightly earlier.

Five trials were done by Hoechst UK Limited, two in 1979 and three in 1980. In the first year the trials were located in Essex (No. 1) and Norfolk (No. 2).

Table 1

Control of a grass and cereal fly with triazophos

Treatment	Rate (kg/ha a.i.)	Timing	% reduction in 'deadhearts'						Relative yield (untreated = 100)			
			Trial numbers						Trial numbers			
			1	2	3	4	5	6	2	3	4	5
Triazophos	0.6	Egg laying	0	16	54	49	36	15	108	105	104	105
Dimethoate	0.6		0	0	0	-	-	-	106	102	-	-
Triazophos	0.6	Egg hatch	43	50	68	82	79	79	110	109	108	103
Dimethoate	0.6		0	34	0	-	-	-	110	97	-	-
Triazophos	0.6	Early spring treatment	-	-	-	-	13	23	-	-	-	98
Dimethoate	0.6		-	-	-	-	-	-	-	-	-	-
Triazophos	0.6	First signs of damage	0	5	0	45	22	0	107	100	103	100
Dimethoate	0.6		0	12	0	-	0	48	113	104	-	103
'Deadhearts'/m row and yield, t/ha, on untreated controls			28	36	41	41	23	6.2	7.66	7.12	9.70	7.37

Dates of application were 20th March and 2nd April (egg hatch) and 17th April (first signs of damage in both trials). In 1980 the trials were located in Oxfordshire (No. 3), Essex (No. 4) and Norfolk (No. 5). Applications were made on 11th - 15th February (egg hatch) and 15th February - 21st March (first signs of damage). Triazophos and chlorpyrifos were applied close to the peak of egg hatch whereas dimethoate and omethoate were sprayed when the first signs of damage appeared. Chlorpyrifos was omitted from Trial No. 4. In the 1979 trials, healthy tillers were counted and in the 1980 trials 'deadheart' assessments were made as in the grass and cereal fly trials. The results are summarised in Table 2.

Table 2

Comparison of treatments for wheat bulb fly control

Treatment	Rate (kg/ha a.i.)	Healthy tiller count (untreated = 100)		% reduction in 'deadhearts'			Crop yield (untreated = 100)		
		Trial numbers		Trial numbers			Trial numbers		
		1	2	3	4	5	2	3	4
Triazophos	0.6	120	130	78	38	70	106	108	100
Chlorpyrifos	0.75	110	121	84	-	87	109	106	-
Dimethoate	0.7	108	123	65	2	37	111	105	103
Omethoate	0.5	100	126	85	36	57	105	106	102
'Deadhearts' or tillers/m row and yield, t/ha, on untreated control		68	73	7.9	22	3.0	5.29	5.38	7.41

In an ADAS, Eastern Region trial (Maskell, pers. comm.) triazophos (0.6 kg/ha a.i.) was applied at egg hatch on 7th February, 1980. Assessments were made on 24th March and the following results obtained (Table 3).

Table 3

Control of wheat bulb fly with triazophos

Treatment	% attacked shoots	% living larvae	% plants with live larvae	Grain yield t/ha
Triazophos	21 ***	88	34 **	4.87 **
Untreated control	41	91	55	4.06

Frit fly

Although frit fly is best known for its damage to late-sown spring oats it can also cause serious losses in winter wheat particularly after a grass ley crop. Like the two previous pests, it bores into the central shoot causing typical 'deadheart' symptoms.

Trials in spring oats were done by ADAS in Herefordshire (Rayner, pers. comm; Anon, 1976a). In each of three years an application of triazophos (0.8 kg/ha a.i.) was made in 220 l/ha water between the 19th and 24th May when the crop plants had 2-3 leaves. Plots were 10m x 10m with four replicates. Counts of fritted and undamaged shoots were made on ten 30cm lengths of row per plot four to six weeks after application. Results for the triazophos treatments are given in Table 4.

Table 4

Control of frit fly in spring oats in Herefordshire with triazophos

Treatment	% fritted shoots 1974	1975	1976
Triazophos	0.7 ***	1.4 **	21 ***
Untreated control	6.4	7.6	51

Trials to control frit fly in spring oats have also been done in Scotland (Shaw, 1981). There were four trials, two in both 1979 and 1980, and application of triazophos (0.84 kg/ha a.i. in 337 l/ha water) took place between the 4th and 11th June at the 2-3 leaf stage of the crop. Assessments of seedling damage were made 2 to 3½ weeks later on four 30cm lengths of row/plot and are given together with yields in Table 5. At the Strathdon site, gross d.m. was assessed; at the remaining sites grain yield was recorded.

Table 5

Control of frit fly in spring oats in north Scotland with triazophos

Treatment	Craibstone		Strathdon		Kintore		Midmar	
				% damage				
Triazophos	11.5 ***		2.6 ***		2.5 ***		1.1 ***	
Untreated control	49.2		54.6		76.6		11.6	
				yield (t/ha)				
Triazophos	4.50 **		6.79 **		3.09 ***		2.20	
Untreated control	3.62		5.30		2.18		2.21	
				Plant and tiller counts				
	Plants	Tillers	Plants	Tillers	Plants	Tillers	Plants	Tillers
Triazophos	421	717	261	187	346	66	252	119
Untreated control	518	1115	237	342	260	270	280	175

In a further trial done by Hoechst UK Limited, triazophos at 0.8 kg/ha a.i. was applied to winter wheat cv. Maris Hobbit on 6th February 1978 when the crop was beginning to tiller. Assessments of living and dead larvae were made on 3rd June by sampling 25 plants in each of four replicate plots. On the triazophos plots the mean number of living and dead larvae was 10.3 and 67.0, respectively. The corresponding numbers on the untreated control plots were 51.5 and 18.0. The percentage of dead larvae was, therefore, 86.7 for the triazophos treatment compared with 25.9 on the untreated control.

Leatherjackets

Damage is caused by larvae of the crane fly which feed on young cereal plants at or just below ground level. Spring cereals are most commonly attacked but winter crops are also affected.

Extensive trials to control leatherjackets in cereals have been done by ADAS (Rayner, 1975 and pers. comm; Anon, 1976b; Anon, 1977, Anon, 1978b). Results obtained at very low temperatures when the pest was inactive have been disregarded but the remaining twenty-two trials in which triazophos was included are given in Table 6.

Table 6

Control of leatherjackets in cereals with triazophos

Location	Crop	Treatment date	Leatherjacket population ('000/ha)		Assessment date	% control with triazophos
			Pre-treatment	Untreated control†		
Devon	Spring barley	1.5.73	1450	837	21.5.73	100
Bute	Spring barley	3.4.75	1235	371	24.4.75	50
Renfrewshire	Spring barley	18.4.75	1112	1081	5.5.75	63
Northumberland	Winter barley	7.3.75	1235	324	5.5.75	81
Gwynedd	Spring barley	28.4.75	700	1328	14.5.75	96
Dyfed	Winter oats	7.1.75	7886	2194	28.1.75	96
Glamorgan	Winter wheat	7.1.75	1897	1170	29.1.75	19
Avon	Spring barley	14.5.75	1077	185	4.6.75	11
Newcastle	Spring barley	29.4.76	1589	906	29.4.76	85
Northumberland	Spring barley	27.4.76	1102	750	27.4.76	75
Herefs-Worcs.	Winter wheat	31.3.76	1313	447	22.4.76	79
Glamorgan	Winter wheat	11.2.76	4640	1166	2.3.76	41
Dyfed	Spring barley	6.4.76	560	1372	20.4.76	85
Hampshire	Winter wheat	25.2.76	2250	2774	18.3.76	77
Dumfries	Spring barley	9.4.76	647	437	30.4.76	81
Clwyd	Spring oats	30.4.76	800	500	14.5.76	75
Powys	Spring barley	16.5.77	1280	655	26.5.77	88
Gloucestershire	Spring barley	3.5.77	370	180	17.5.77	100
Northumberland	Spring barley	28.4.77	1021	638	13.5.77	64
Northumberland	Spring barley	4.4.77	1900	950	10.5.77	41
Co. Durham	Spring barley	3.5.78	790	562	24.5.78	98
Co. Durham	Spring barley	9.5.78	1625	1087	26.5.78	95

† At assessment

Wheat blossom midges

These pests have become more important in recent years particularly in the north of England. Larvae of the lemon blossom midge (C. tritici) feed in large numbers on the grain ovary so that the flower becomes sterile, whereas larvae of the orange blossom midge (S. mosellana) are usually found singly in each attacked flower where their feeding can lead to shrivelled grain.

In a trial done by ADAS (Oakley, pers. comm.) on winter wheat (cv. Maris Huntsman) a range of chemical treatments including triazophos (0.34 kg/ha a.i.) was applied on 30th June 1977. The plots were sampled on 26th July and ten heads per plot were dissected and the number of grains attacked by each species and the number of larvae attacking each grain were recorded. Yields were taken on 11th September and the results obtained with triazophos are shown in Table 7.

Table 7

Control of wheat blossom midges with triazophos

Treatment	Numbers/head				Yield
	Attacked grains		Larvae		t/ha
	Orange	Lemon	Orange	Lemon	
Triazophos	1.3 ***	3.5 *	2.1 ***	28.0	5.59 **
Untreated control	4.6	5.8	8.0	57.0	4.92

DISCUSSION

In the grass and cereal fly trials, time of application was critical for control to be obtained. In both 1979 and 1980 triazophos applied at egg hatch in mid-late January was the most effective treatment (Table 1). Reduction in 'deadhearts' was less if application was delayed until February or when damage was first visible in March or April. This is possibly because the pest normally only attacks the main shoot and does not migrate from tiller to tiller and damage has already occurred if application is delayed until this time. In some trials an application to coincide with egg laying gave reasonable results. This may be due to kill of adult females, preventing further egg laying, an ovicidal effect of the chemical or control of the larvae by persistence of the chemical through to January. Dimethoate had little effect no matter when it was applied. Good control of the grass and cereal fly with triazophos has also been reported by Short (1981).

An application of triazophos at egg hatch was also effective in reducing the percentage of 'deadhearts' caused by wheat bulb fly (Tables 2 and 3). In Table 2 some damage was visible when triazophos was applied at trial No. 4 and this is probably the reason for the poor results.

Frit fly in spring oats was well controlled with 0.8 kg/ha a.i. triazophos applied at the first signs of crop damage in trials in Herefordshire (Table 4) and Scotland (Table 5). In the former, triazophos gave very good control in all three years and tended to be more effective than fenitrothion or pirimiphos-methyl (Anon, 1976a). In Scotland, significant reductions in seedling damage resulted in very high yield responses. However, damage to the untreated controls tended to result in secondary tillering which increased the tiller count. At the recommended rate of 0.8 kg/ha a.i. triazophos was also reported to be an effective treatment in controlling frit fly in spring oats in Wales and winter wheat in ADAS East Midland Region (Anon, 1978a).

Under a wide range of crops and soil types triazophos gave effective control of leatherjackets (Table 6). On average, 73% control was obtained. Occasional results were poor and these were generally associated with lower than recommended rates of application, low populations or sites where pre-emergence applications were made (Bute, Avon).

Limited trials data (Table 7) indicate that triazophos will also control wheat blossom midges and this and the other uses described have been confirmed by commercial application.

Acknowledgements

The authors wish to thank the many farmers who kindly provided trial sites, and their colleagues within the Technical Department of Hoechst UK Limited for carrying out the field work. They also thank J.N.Oakley and F.E.Maskell of ADAS, M.W.Shaw of the North of Scotland College of Agriculture and J.M.Rayner for permission to include their trials results.

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DAMAGE ASSESSMENT AND CHEMICAL CONTROL OF A GRASS AND CEREAL FLY (Opomyza florum)

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Summary Attacks by O. florum were monitored in several crops of winter wheat in 1979/80 and 1980/81. Early sowing favoured oviposition and subsequent attacks were more severe than in crops sown later. Direct drilling appeared to decrease egg populations and tiller attack. However, yields in 1980 tended to be larger in crops that had suffered greater damage, probably because the agronomic benefits of early sowing outweighed the loss of tillers. Six trials were done to try to determine the best chemical treatment and application times. Yield increases, of up to 17%, were obtained in four trials but no outstanding treatment emerged. Treatments applied up to four weeks after egg hatch were more effective than those applied later. The pest status of O. florum is still unresolved.

INTRODUCTION

A grass and cereal fly, Opomyza florum, has been recorded as a pest of cereals, particularly winter wheat, throughout much of Europe (Balachowsky and Mesnil, 1936; Thomas, 1933; Slope, 1957; Pavlyuchuk, 1969; Kuznetsova, 1969; Latteur, 1974).

Eggs are laid in the soil during November around the bases of the host plants, within about 3 cm of the plant (Thomas, 1933) and no deeper than 3 cm (Pavlyuchuk, 1969). In the UK egg hatch occurs in March or early April (Slope, 1957) and larvae enter tillers by crawling up the outside then down between the outer leaves to the base of the tiller. They cut into the growing point and central shoot, producing a characteristic circular or spiral incision (Balachowsky and Mesnil, 1935), and spend the three larval stages feeding in the central shoot. Unlike wheat bulb fly, O. florum does not migrate to other tillers in its larval stages. Pupation occurs in about May, either in the attacked tiller or under the leaf sheath of an adjacent tiller (Pavlyuchuk, 1969). The attack causes the 'deadheart' symptom typical of dipterous stem borers. Adult flies emerge in June and live until November, frequenting shady places such as hedgerows and woodlands (Thomas, 1933; Pavlyuchuk, 1969). Vickerman (1977) rarely found adults in crops other than winter wheat when he sampled crops and hedgerows during June.

Descriptions of all stages are given by Balachowsky and Mesnil (1935), and of larval stages by Nye (1958); Thomas (1933) describes eggs and larval stages.

O. florum larvae have been found in small numbers in winter wheat crops attacked by wheat bulb fly in ADAS Eastern Region for many years (F E Maskell, pers comm). The incidence of the pest increased markedly in 1979 in winter wheat crops and remained high enough to cause concern in 1980 and 1981. No methods of chemical control were available and there was little information about the pest status of the species or whether or not it was responsible for loss of yield. In order to provide advice for farmers, therefore, chemical control trials against O. florum were done in 1980 and 1981 and observations were made of its incidence and importance in Eastern Region.

METHODS AND MATERIALS

1. Damage assessment and incidence of O. florum

Oviposition in several wheat crops in 1980 and 1981 was assessed during December and January. Ten or 20 soil samples were taken per field using a 10 cm diameter soil sampler. Cores were taken to a depth of 5 - 8 cm and within, rather than between, the rows of plants. Sampling stations were chosen away from headlands and at random across each field. Soil cores were stored at about 2°C before being washed through a Fenwick can (Fenwick, 1940) and eggs were retained on a 250 mm sieve. Eggs were examined and counted using a low power binocular microscope after allowing them to dry.

Larval attacks were assessed in the laboratory by dissecting tillers or counting 'deadhearts'. Samples of tillers were taken in each field as grab samples or as 10 0.5 m lengths of row across the field.

Where a crop was followed through to harvest, estimates of the yield were made using the ADAS sample harvest technique (Baldwin, 1968) or a combine harvester.

In addition to the field studies, information about the general incidence of O. florum in Eastern Region was extracted from records of samples sent to the ADAS Plant Clinic at Cambridge.

2. Chemical control

Six trials were done in commercial crops of winter wheat during 1980 and 1981 to test the efficacies of various insecticides and to determine the optimum timing for insecticidal applications in late winter/early spring. A range of wheat cultivars was included in the trials and all crops were sown before mid-October. Details of treatments are given in Table 1.

Each treatment was replicated 4 - 5 times in a randomised block design. Plots were 3 x 8 m in 1980 and 9 x 5 m in 1981. Sprays were applied by knapsack or wheelbarrow-mounted sprayers in 200 l/ha. A knapsack blower applicator was used to apply fonofos granules.

Larval damage was assessed when treatments were applied. Post-treatment tiller attack assessments were not made for all treatments at East Raynham and Snettisham because of lack of time and manpower.

Estimates of ear numbers were made at all sites except Heveningham Site 2 where the crop became badly lodged. At Heveningham Site 1, ears were counted in three one-metre lengths of row per plot. At the other sites full and poorly developed small ears were counted in five 0.2 m^2 quadrats per plot. Subjective growth scores of the trials at East Raynham and Norton were made on 21 May 1981.

Table 1

Chemical control trials - treatments

Site	Chemicals, rates (g a.i./ha), application dates
Heveningham Site 1	chlorfenvinphos (700) on 6 Mar or 26 Mar chlorpyrifos (720) on 6 Mar or 26 Mar
Heveningham Site 2	pirimiphos-methyl, triazophos, omethoate, dimethoate (900, 600, 640 and 640 respectively) on 26 Mar
Grantchester	triazophos (600) on 27 Jan, 12 Feb, 24 Feb, 12 Mar or 27 Mar
Norton	triazophos (600) on 28 Jan, 13 Feb, 26 Feb, 12 Mar or 27 Mar
Snettisham	fonofos, chlorfenvinphos, chlorpyrifos, cypermethrin, triazophos, omethoate, dimethoate, carbosulfan, chlormequat (1400, 902, 720, 30, 600, 644, 680, 500, 2.3 1 product/ha) on 29 Jan, except fonofos, 21 Oct 1980 and chlormequat, Nov 13 1980. Omethoate also applied on 31 Mar
East Raynham	as Snettisham except quinalphos (438) applied instead of carbosulfan. Fonofos applied 24 Oct 1980

All trials included untreated controls.

RESULTS

1. Damage assessment and incidence of O. florum

In 1980, larval invasion of tillers began in late February/early March but 'deadhearts' did not become noticeable until the beginning of April. Larvae tended to attack secondary rather than primary tillers. In 1981, the attack began in late January and 'deadhearts' were first seen in late February.

In 1980, 32% of samples containing O. florum received by the Plant Clinic came from Norfolk, 29% from Cambridgeshire, 19% from Essex, 16% from Suffolk and 3% from Bedfordshire. A mean of 20.4 ± 4.6% of tillers were attacked, calculated from field estimates or examinations in the laboratory. A similar level of attack occured in 1981 (19.7 ± 4.8% of tillers) but the incidence was slightly more widespread. Twenty five per cent came from Norfolk, 20% from Hertfordshire, 15% each from Cambridgeshire and Suffolk, 10% each from Northamptonshire (not included in Eastern Region in 1980) and Essex, and 5% from Bedfordshire. All commonly grown cultivars of winter wheat suffered damage and there were a few reports of attacks in winter barley crops.

In both years there was a clear relationship between the sowing date of a crop and the severity of attack of O. florum, illustrated by assessments made at the Norfolk Agricultural Station in 1980 (Table 2). In the autumn of 1980, the relationship between oviposition and drilling date was observed in cultivation trials at Terrington Experimental Husbandry Farm, where the effects of different methods of cultivation as well as drilling date were studied. The assessment (Table 2) showed that the earlier drilled plots had larger egg populations although those of the earliest drilled plots had fewer eggs than plots drilled nine days later. There were also differences within each drilling date depending upon whether the soil was ploughed or cultivated. This link between cultivation method and O. florum was also seen in similar trials elsewhere where 14% of tillers were attacked in plots that had been direct drilled but 36 and 35% in plots drilled at the same time had been ploughed or tine-cultivated respectively.

Table 2

Effect of sowing date upon attack by O. florum

a) Terrington EHF, 1980

Sowing date	Egg populations (millions/ha) Ploughed	Egg populations (millions/ha) Cultivated
6 Sept	7.34	1.47
15 Sept	8.18	2.31
25 Sept	4.51	2.62
6 Oct	1.36	1.57

b) Norfolk Agricultural Station, 1980

Sowing date	% tillers attacked
2 Oct	34
2 Oct	44
9 Oct	26
15 Oct	18
30 Oct	2

Studies of the effects of O. florum upon yield were inconclusive. The eight crops monitored from oviposition to yield in 1979/80 showed a trend to a higher yield following a heavier attack. The mean number of eggs sampled was 8.97 millions/ha and a mean of 26.5% of tillers or 1.35 tillers per plant were invaded. Mean yield was 8.77 t/ha. The percentage of tillers attacked and the number of eggs laid were positively correlated with yield, $r = 0.74$ and 0.75 respectively ($0.05 > p > 0.01$).

Twelve fields were examined in 1980/81. Mean egg number was 7.67 millions/ha, and the mean level of attack, 27.9% of tillers or 1.03 tillers per plant. There was a positive correlation between egg number and percentage of tillers attacked, $r = 0.34$ ($p < 0.001$).

Four sites which were used for experiments in 1981 were sampled for eggs in late 1980/early 1981 (Table 3). From samples taken at two-weekly intervals from untreated areas of each site, estimates were made of the percentage and number of tillers attacked per plant at the peak, and the total number of tillers per plant at that time (Table 4).

Table 3

Egg populations of O.florum 1980/81

Date sampled	Eggs (millions/ha)	
	Grantchester	Norton
December 1980	4.94	14.82
	Snettisham	East Raynham
21 October 1980	0.31	0.62
13 November 1980	6.11	13.71
28 November 1980	4.82	19.64
8 January 1981	10.72	17.29

Table 5

Results of chemical control of *O. florum*, 1980

Site	Treatment	% tillers attacked (transformed)	No. attacked tillers/plant	No. healthy tillers/plant	% larval mortality	Yield (t/ha)
Heveningham 1	untreated	25.1	1.42	4.68	11.0	*9.27^{a}
	early chlorfenvinphos	29.1	1.47	4.44	34.9	9.63^{c}
	late chlorfenvinphos	23.4	1.74	4.56	5.5	9.31^{ab}
	early chlorpyrifos	20.8	1.23	4.58	6.9	9.43^{abc}
	late chlorpyrifos	23.8	1.26	4.25	18.7	9.56^{c}
	SE	± 0.8	± 0.06	±0.23	± 2.3	±0.07
Heveningham 2	untreated	30.2	1.25	4.10	17.2	9.02
	pirimiphos-methyl	28.7	1.64	3.73	11.5	10.37
	triazophos	25.0	1.70	4.15	7.5	10.16
	omethoate	21.4	1.26	3.78	28.0	9.96
	dimethoate	23.6	1.26	4.53	15.9	9.78
	SE	± 0.8	±0.07	±0.11	± 1.7	± 0.35

* treatments significantly different at $0.05>p>0.02$

Results sharing the same letter (a, b, c, d) in each column are not significantly different ($p = 0.05$)

Table 4

Peak attacks by O. florum larvae 1981

Site	Peak date	% tillers attacked	No. attacked tillers/plant	Total no. tillers/plant
Grantchester	27 February	20.4	0.60	2.94
Norton	26 March	37.1	0.92	2.48
Snettisham	31 March	30.5	1.16	3.60
East Raynham	20 March	43.8	0.98	2.24

2. Chemical control

1980 Heveningham, Sites 1 and 2

Assessments of attack levels, larval mortality and yield for each treatment are given in Table 5. There were no significant differences between treatments for any parameter measured except in yield at Heveningham Site 1, where chlorfenvinphos applied at the beginning of the attack and chlorpyrifos applied at 'deadheart' stage gave small but significant increases over the control. Chlorfenvinphos at egg hatch and omethoate at 'deadheart' gave relatively high rates of larval mortality. In all treatments large numbers of tillers per plant survived the attack by O. florum. Egg populations, sampled in December 1979, were relatively large, with 11.6 and 19.5 millions/ha at Sites 1 and 2 respectively. There were no significant differences between treatments in number of ears per metre row at Heveningham Site 1.

1981 Spray timing - Grantchester and Norton

Details of results are given in Tables 6 and 7.

Table 6

Spray timing - Grantchester 1981

Treatment	No. attacked tillers/plant	No. healthy tillers/plant	% tillers attacked (transformed)	Small ears/ sample	Yield t/ha	1000 grain wt (g)
		21 April	21 April			
Late Jan	0.41^{a}	2.54	20.7^{a}	64.4	9.35^{ab}	47.4
Mid Feb	0.61^{ab}	2.62	25.3^{ab}	58.4	9.51^{b}	47.7
Late Feb	0.84^{bc}	2.49	29.9^{bc}	71.8	9.53^{b}	48.4
Mid Mar	0.96^{cd}	3.06	29.3^{bc}	66.4	9.09^{a}	46.7
Late Mar	1.09^{cd}	2.72	32.4^{c}	75.6	9.39^{a}	46.9
Untreated	1.23^{d}	3.45	30.9^{c}	67.8	9.10^{a}	48.3
Significance level	***	NS	***	NS	*	NS

Table 7

Spray timing - Norton 1981

Treatment	No. attacked tillers/plant 1 May	No. healthy tillers/plant 1 May	% tillers attacked (transformed)	Small ears/ sample	Growth score	Yield t/ha	1000 grain wt (gm)
Late Jan	1.02^{a}	3.16	29.2	53.8	40	7.86^{ab}	47.7
Mid Feb	1.11^{a}	2.77	32.3	59.8	33	7.92^{a}	48.0
Late Feb	1.34^{ab}	2.68	35.3	58.6	26	7.50^{abc}	46.3
Mid Mar	2.01^{c}	3.84	36.2	59.0	23	7.45^{bc}	46.0
Late Mar	1.66^{bc}	3.68	33.9	64.8	18	7.36^{cd}	46.3
Untreated	1.45^{ab}	3.21	34.5	59.2	17	6.95^{d}	45.3
Significance level	**	NS	NS	NS	-	***	NS

At both sites the number of tillers attacked where treatment was applied early was significantly less than in the untreated controls although there were no differences between treatments in the number of tillers surviving the attack, or subsequently in numbers of full or small ears. At Grantchester, early applications significantly reduced the percentage of tillers invaded but not at Norton. Significant increases in yield were given at both sites by the earlier applications although the earliest timing, at the beginning of tiller invasion, was not as effective as application two or four weeks later.

The number of small ears at Grantchester was positively correlated with the previous percentage of tillers attacked ($r = 0.43$, $0.05 > p > 0.01$) suggesting that the number of small ears could be used as a index of the severity of attack.

1981 Screening of chemicals - Snettisham and East Raynham

Details of results are given in Table 8.

Take-all (Gaeumannomyces graminis var tritici) developed in the trial at East Raynham and affected all plots to a greater or lesser extent. All insecticidal treatments tested at Snettisham significantly increased yield above that of the control although there were no significant differences between these treatments with the exception of triazophos, which gave a slightly smaller increase. The largest yield was given by dimethoate. The growth regulator chlormequat did not significantly affect yield. There were no significant differences in 1000 grain weights at either site but there was a tendency for larger yields to be associated with heavier grain.

The number of full ears at each site did not differ between treatments. The number of small ears did differ but, at Snettisham, did not seem to be related to final yields. There was a significant negative correlation ($r = -0.47$, $0.01 > p > 0.001$) between the number of small ears and the growth score at East Raynham.

Table 8

Screening trials - Snettisham, East Raynham, 1981

Treatment	Snettisham			East Raynham			
	Small ears/ sample	Yield (t/ha)	1000 grain wt (g)	Small ears/ sample	Yield (t/ha)	1000 grain wt (g)	Growth score (max. 40)
fonofos	47.5^{a}	9.31^{ab}	53.9	79.3^{ab}	8.10	47.4	12
chlorfenvinphos	52.3^{ab}	9.54^{ab}	52.6	78.0^{ab}	8.07	47.9	26
chlorpyrifos	49.8^{a}	9.23^{ab}	53.0	64.5^{a}	7.44	46.0	25
cypermethrin	48.0^{a}	9.47^{ab}	52.4	75.8^{ab}	8.70	47.0	27
triazophos	50.8^{a}	9.09^{bc}	52.8	68.8^{a}	7.39	48.0	34
omethoate	56.3^{abc}	9.42^{ab}	52.5	75.3^{ab}	7.53	45.5	27
dimethoate	65.0^{b}	9.67^{a}	53.7	92.8^{bc}	6.86	43.6	12
quinalphos	-	-	-	89.5^{bc}	7.66	48.3	28
carbosulfan	54.5^{ab}	9.20^{ab}	51.9	-	-	-	-
triazophos, 29 Jan + omethoate, 31 Mar	52.8^{ab}	9.46^{ab}	53.4	60.8^{a}	8.22	46.8	28
fonofos, Oct 1980 + triazophos, 29 Jan + omethoate, 31 Mar	56.3^{a}	9.54^{ab}	52.3	68.0^{a}	7.49	44.9	30
chlormequat	69.3^{bc}	8.58^{cd}	53.4	116.3^{d}	7.41	46.5	14
untreated	60.3^{abc}	8.27^{d}	51.4	105.0^{cd}	7.44	45.4	16
Significance level	*	***	NS	***	NS	NS	-

DISCUSSION

Two questions were raised at the beginning of these investigations; (i) is O.florum an economically damaging pest of winter wheat in the UK, and (ii) what are the best methods of control, if required? Neither question has been completely answered.

There is little doubt that substantial numbers of tillers in a crop can be killed by O. florum but it is less certain what the effect of an attack is upon final yield. The link between sowing date and severity of attack has been noted by several authors (Thomas, 1933; Slope, 1957; Pavlyuchuk, 1969 and Kuznetsova, 1969) although the influence of sowing date and cultivation method on oviposition had not previously been recorded. The preference of O. florum for earlier sown crops makes it difficult to separate the effects on yield of tiller loss from those of the agronomic effects of sowing date. Slope (1957) states that the gain in yield obtained by sowing in September in 1956 outweighed any loss caused by O. florum and similar effects are suggested by the results of the survey of attacked crops in 1979/80, when attack by O. florum was associated with increased yields. However, in the USSR, earlier sowings which were severely attacked by O. florum gave lower yields than crops sown later, which suffered less damage (Kuznetsova, 1969).

The yield responses obtained in the trials described in this paper and by Smith and Hewson (1981) suggest that O. florum can reduce yield of early sown wheat, and the increases in the two timing trials were associated with reduction of damage following chemical treatment. Sanders (1981) studied compensation by wheat plants attacked by O. florum and found that grain weight and number of grains per ear was reduced, mainly because of the loss of older tillers and their replacement by late-developing, smaller tillers. Little is known about the ability of a crop to compensate for a given level of tiller attack, a response which would vary between seasons and crops anyway. Evidence of the economic effect of O. florum upon winter wheat crops is still inconclusive.

Until the relationship between tiller damage and yield is elucidated there is little point in forecasting the level of damage from egg samples. However, it should be possible to develop a forecasting technique and a start has been made by ADAS (Makin, unpublished).

The results of the chemical screening trial at Snettisham did not pinpoint one outstanding insecticide and more work is needed to determine which are the best treatments. In 1981 there was a period of about four weeks from the beginning of larval invasion of tillers when the insecticide used was effective. There is no method for predicting the start of egg hatch of O. florum but in both years egg hatch of wheat bulb fly started about three or four weeks before that of O. florum (F. E. Maskell, pers. comm.) and it may be possible to use this relationship as a guide to timing insecticide applications against O. florum.

Acknowledgements

It is a pleasure to thank the farmers who allowed me to sample their crops, and my ADAS colleagues for their help and encouragement.

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EXPERIMENTAL SEED TREATMENTS FOR THE CONTROL OF WHEAT BULB FLY AND SLUGS

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Summary Of twelve experimental pyrethroid seed treatments tested for control of wheat bulb fly (*Delia coarctata*) in small plots of winter wheat, permethrin, cypermethrin and NRDC 170 were the most effective. Permethrin performance was improved by the addition of a sticker, methyl cellulose, or a surfactant, methyl benzoate. Permethrin remained effective at rates as low as 0.00625% a.i./wt of seed in peaty loam but not in clay loam soils. However its effectiveness was greatly diminished by deep sowing. Yields from eleven ADAS trials showed that permethrin was at least as effective as chlorfenvinphos. Of twelve other materials tested in small plots, microencapsulated ethyl parathion and microencapsulated fonofos gave good results.

In laboratory tests to examine experimental seed treatments for controlling slugs (*Deroceras reticulatum*) in winter wheat, effective compounds related to ioxynil or nereistoxin are described.

Résumé De douze pyréthroïdes testées pour le contrôle de la mouche grise du blé (*Delia coarctata*) par le traitement des semences en petites parcelles de blé d'hiver, la perméthrine, la cyperméthrine et le NRDC 170 se sont avérés les plus efficaces. L'efficacité de la perméthrine est accrue par l'addition d'un adhésif, le methyl cellulose, ou d'un agent tensio-actif, le methyl benzoate. La perméthrine demeure active à des doses aussi faibles que 0.00625% de matière active par poids de graine dans un limon tourbeux mais non dans les limons argileux. Cependant son efficacité est grandement dimunée par les semis profonds. Les rendements obtenus dans onzes essais effectués par l'ADAS (Agricultural Development and Advisory Service) montrent que la perméthrine est au moins aussi efficace que le chlorfenvinphos. De douzes autres produits examinés en petites parcelles, l'ethyl parathion et le fonofos microencapsulés ont donné de bons résultats.

Dans des essais au laboratoire entrepris pour tester le contrôle des limaces (*Deroceras reticulatum*) dans le blé d'hiver par le traitement des semences, on decrit des substances efficaces apparentées au ioxynil ou au nereistoxin.

INTRODUCTION

Approved seed treatments for controlling wheat bulb fly (*Delia coarctata*) in Britain are γHCH, chlorfenvinphos and carbophenothion. These have been available for over nine years, but are not entirely satisfactory (Griffiths *et al*, 1975; Griffiths, 1978). As a result, use of foliar and soil treatments has increased and eight chemicals are now approved for this use. Current methods of controlling slugs (*Deroceras reticulatum*) depend entirely on soil applications of pelleted baits formulated with methiocarb or metaldehyde. Seed treatments, however, are generally cheaper than soil applications and since the pesticide is confined to the small area where it is needed, have less effect on other soil organisms. Therefore, the search for new seed treatments to control wheat bulb fly and slugs has continued. This paper reviews tests done over the past six years to examine new chemicals and formulations.

METHODS AND MATERIALS

Wheat Bulb Fly

Most materials were formulated from technical products with talc to give 20% powders. Exceptions were bioallethrin, bioneopynamin, kadethrin and carbosulfan (10% powders), and the following products: cloethocarb (50% powder), permethrin treatments after 1976 (25% powder), synergised permethrin (3% liquid), microencapsulated ethyl parathion (24% liquid), microencapsulated fonofos (48% liquid Dyfonate 4S) and chlorfenvinphos (32% Birlane liquid seed treatment). Crude polygodial was extracted from plants of *Polygonum hydropiper*. Powders were stuck to seeds with 3% methyl cellulose by mixing in a beaker (treatments before 1977) or in a small Rotostat. Liquid treatments were applied directly to seeds without sticker in the Rotostat. These methods ensure greater than 90% retention of chemical on the seed (Bardner, 1960; Jeffs, personal communication). Chemicals not identified by common names in Tables 2 and 3 are:

GD 880 2-(n-octylamino)-2-methyl-1-propanol
NRDC 169 (RS)-α-cyano-3-phenoxybenzyl (1R,*trans*)-3-(2,2-difluorovinyl)-2,2-dimethylcyclopropanecarboxylate
NRDC 170 (RS)-α-cyano-3-phenoxybenzyl (1R,*cis*)-3-(2,2-difluorovinyl)-2,2-dimethylcyclopropanecarboxylate
NRDC 181 (RS)-α-cyano-3-phenoxybenzyl(RS)-2-(4-chlorophenyl)-2-cyclopropylacetate

All seed was pre-treated with liquid organomercury fungicide.

The seed treatments were tested for effectiveness against wheat bulb fly attack in small plot field experiments; the methods used were similar to those described by Griffiths *et al* (1975). Site details, seed varieties, dates of sowing and sampling are given in Table 1

Slugs

Twenty compounds related to ioxynil and eleven compounds related to nereistoxin were examined in the laboratory to test their effectiveness in preventing slug damage to winter wheat seeds and effect on germination. The methods were described by Scott *et al* (1977).

TABLE 1

Wheat bulb fly seed treatment trials - site details

Year	Site	Soil type	Egg count (millions/ha)	Seed cultivar	Sowing date	Plant sample date
1975-6	Nocton	Sandy Clay Loam	2.5	Maris Huntsman	5.11.75	17.3.76
1975-6	Whittlesey	Peaty Loam	4.9	Champlein	12.11.75	8.3.76
1977-8	Bingham	Clay Loam	14.8	Maris Hobbit	1.11.77	17.3.78
1977-8	Whittlesey	Peaty Loam	6.1	Cappelle	11.11.77	29.3.78
1978-9	Much Hadham	Clay Loam	4.0	Maris Huntsman	2.11.78	3.4.79
1978-9	Whittlesey	Peaty Loam	6.2	Maris Huntsman	7.11.78	26.3.79
1979-80	Steeple Gidding	Clay Loam	4.2	Flanders	3.10.79	14.3.80
1979-80	Whittlesey	Peaty Loam	3.9	Flanders	28.11.79	3.3.80
1980-81	Gt. Barton	Sandy Clay Loam	6.3	Flanders	6.11.80	20.3.81

RESULTS

Wheat Bulb Fly

Materials other than pyrethroids

Visual scoring of plants soon after emergence (Table 2) showed that of the new materials tested, thiocyclam at 0.2%a.i./wt of seed and quinalphos at 0.1% were phytotoxic in both soil types. Most treatments decreased the percentage of plants with live larvae compared with the controls, but only two, microencapsulated ethyl parathion and microencapsulated fonofos, were as effective as the standard chlorfenvinphos treatment. In 1975-6, chlorfenvinphos at 0.2% (twice the recommended rate) delayed germination, but the plants recovered and were well protected from wheat bulb fly attack.

TABLE 2

Wheat bulb fly seed treatment trials - materials other than pyrethroids

Year	Material	Rate (% ai/ wt of seed)	Visual score at emergence		% Plants with live larvae	
			Clay loam	Peaty loam	Clay loam	Peaty loam
1975-6	Chlorfenvinphos	0.2	5	0	14.0	18.3
	Diflubenzuron	0.2	33	38	49.0	24.3
	GD 880	0.2	32	32	38.5	32.5
	Tazimcarb	0.2	27	33	45.0	30.0
	Thiocyclam	0.2	6	8	47.3	32.5
	Control		35	36	54.5	36.3
	SED				5.1	6.1
1978-9	Chlorfenvinphos	0.1	38	32	9.0	11.3
	Capsaicine	0.1	38	32	47.9	56.4
	Capsicum-Oleoresin	0.1	39	30	53.8	52.9
	Polygodial	0.1	37	31	64.6	42.2
	Quinalphos	0.1	10	8	30.8	12.3
	Control		38	31	62.6	60.6
	SED				6.8	6.2
1979-80	Chlorfenvinphos	0.1	18*	19	23.8	31.1
	Fonofos (m.e.)	0.2	13*	24	21.1	9.4
	Control		25*	30	61.6	65.9
	SED				10.0	9.8
1980-1	Chlorfenvinphos	0.1	24	-	39.0	-
	Cloethocarb	0.4	28	-	45.9	-
	Carbosulfan	0.2	29	-	49.9	-
	Ethyl Parathion (m.e.)	0.2	27	-	29.9	-
	Control		29	-	56.8	-
	SED				10.1	

* Low scores resulting from slug damage

Pyrethroids

Of the pyrethroids tested (Table 3), cypermethrin, fenpropathrin, fenvalerate and NRDC 170 gave good results but were not consistently better than permethrin in suppressing wheat bulb fly attack. The other pyrethroids, except bioallethrin, were reasonably effective compared with controls, but cismethrin and bioneopynamin at 0.2% were phytotoxic.

TABLE 3

Wheat bulb fly seed treatment trials - pyrethroids

Year	Material	Rate (% ai/ wt of seed)	Visual score at emergence (Max. 40)		% Plants with live larvae	
			Clay loam	Peaty loam	Clay loam	Peaty loam
1975-6	Permethrin	0.2	33	38	2.5	8.0
	Cypermethrin	0.2	28	31	3.0	19.3
	Fenpropathrin	0.2	29	34	6.0	20.3
	Fenvalerate	0.2	32	37	9.5	14.3
	Control		35	36	54.5	36.3
	SED				5.1	6.1
1975-6	Permethrin	0.2	-	38	-	1.5
	Deltamethrin	0.2	-	38	-	12.8
	Control		-	37	-	32.5
	SED					6.7
1977-8	Permethrin	0.1	29	36	32.0	39.7
	NRDC 169	0.1	24	34	50.3	52.6
	NRDC 170	0.1	29	34	47.5	30.0
	NRDC 181	0.1	32	33	55.6	50.0
	Control		22	35	61.4	76.0
	SED				7.7	12.1
1980-1	Permethrin	0.2	34	-	28.9	-
	Bioallethrin	0.2	22	-	57.2	-
	Bioneopynamin	0.2	15	-	47.2	-
	Cismethrin	0.2	9	-	31.1	-
	Kadethrin	0.2	24	-	37.8	-
	Control		29	-	56.8	-
	SED				10.1	

Permethrin

Tables 4 and 5 summarise some of the results from the more intensive study of this chemical and compare its effectiveness with the standard commercial treatment, chlorfenvinphos. In the 1977-8 small plot trial, permethrin was less effective at the lower rates in the clay loam soil than in the peaty loam soil. Permethrin at 0.00625% was still as effective as chlorfenvinphos at 0.1% at the peaty loam site. A similar effect occurred the following year when synergised permethrin at 0.00625% was most effective in the peaty loam soil but relatively ineffective in the clay loam. Sticker and surfactant improved the performance of permethrin in both soil types. The 1979-80 small plot trials compared shallow-sown (about 2cm depth) with deep sown (about 8cm depth) treatments. The effectiveness of permethrin, but not of chlorfenvinphos, was greatly diminished by deep sowing.

TABLE 4

Wheat bulb fly seed treatment trials - permethrin

Year	Treatment	Rate (% ai/ wt of seed)	% Plants with live larvae Clay loam	Peaty loam
	Permethrin	0.00625	57.5	52.5
	Permethrin	0.0125	47.8	40.0
1977-8	Permethrin	0.1	32.0	39.7
	Chlorfenvinphos	0.1	38.2	53.0
	Control		61.4	76.0
	SED		7.7	12.1
	Permethrin, no sticker	0.1	19.9	7.95
	Permethrin + sticker+	0.1	11.7	1.7
	Permethrin + surfactant++	0.1	10.9	0.35
1978-9	Permethrin + synergist+++	0.00625	32.4	4.5
	Chlorfenvinphos	0.1	9.0	11.3
	Control		62.6	60.6
	SED		6.8	6.2
	Permethrin, shallow	0.1	3.2	33.8
	Permethrin, deep	0.1	33.4	75.9
	Chlorfenvinphos, Shallow	0.1	23.8	31.1
1979-80	Chlorfenvinphos, Deep	0.1	29.4	28.2
	Control, shallow		61.6	65.9
	Control, deep		56.4	71.2
	SED		10.0	9.8

\+ = methyl cellulose
++ = methyl benzoate
+++ = piperonyl butoxide

Table 5 summarises yields from ADAS large plot trials that included seed treatments of permethrin and chlorfenvinphos. Yields from permethrin treatments were generally similar to those from the chlorfenvinphos treatment. The best response to permethrin gave a 78.3% increase in yield compared with control. Synergised permethrin produced yields up to 40% higher than controls.

TABLE 5

Wheat bulb fly seed treatment trials (ADAS) - yields

Year	Material	Rate (% ai/ wt of seed)	Yields (t/ha) ADAS Region					
			Eastern		East Midland		Yorks & Lancs	
			*CL	PL	CL	PL	CL	Mean
1975	Permethrin	0.2		5.51	6.12		7.42	6.4
	Chlorfenvinphos	0.1		6.24	5.89		6.16	6.1
	Control			5.40	4.25		4.62	4.8
	S.E.			0.16	0.14		0.11	
1976	Permethrin	0.1		4.59	3.46		7.05	5.0
	Chlorfenvinphos	0.1		4.91	3.28		6.33	4.8
	Control			4.49	3.07		5.94	4.5
	S.E.			0.08	0.12		0.20	
1977	Permethrin	0.1					6.58	6.6
	Chlorfenvinphos	0.1					6.88	6.9
	Control						6.45	6.5
	S.E.						0.20	
1978	Permethrin	0.025		4.99	8.72		4.65	6.1
	Chlorfenvinphos	0.1		5.08	8.56		5.33	6.3
	Control			4.79	8.66		4.51	6.0
	S.E.			0.06	0.11		0.40	
1979	Permethrin	0.1	5.79		5.76	3.99	8.61	6.0
	Syn. Permethrin	0.01	5.39		5.81	3.34	8.29	5.7
	Chlorfenvinphos	0.1	5.66		5.41	3.91	7.56	5.6
	Control		4.41		4.89	2.51	4.83	4.2
	S.E.		0.10		0.31	0.16	0.25	
1980	Syn. Permethrin	0.012	5.31					5.3
	Syn. Permethrin	0.024	5.66					5.7
	Chlorfenvinphos	0.1	5.56					5.6
	Control		4.06					4.1
	S.E.		0.18					

* CL = Clay Loam
PL = Peaty Loam

Slugs

Table 6 shows the results of the best non-phytotoxic treatments compared with thiocyclam and ioxynil. Of the materials related to nereistoxin, SAN 329 and cartap were at least as effective as thiocyclam in preventing slug damage, but were much less harmful to the seeds. Many materials related to ioxynil protected seeds from damage by slugs but were phytotoxic (full results not published here). M & B 10903 did not have a serious effect on germination, but many seeds were damaged in the slug test. However, the extent of hollowing in the damaged seeds was less than in the controls, so protection may be more effective in field conditions where slugs have a choice of food.

TABLE 6

Slug seed treatment tests

Material	Rate (% ai wt of seed)	Slug test Numbers of seeds damaged (as % of control) 3 days	10 days	Germination test Numbers of seeds germinated (as % of control) 8 days	14 days
Thiocyclam	0.2	0	30	49	51
SAN 329+	0.2	0	10	97	99
Cartap	0.2	0	20	70	89
Ioxynil	0.2	0	10	8	21
M & B 10903++	0.2	71	80	76	79

\+ SAN 329 = 5-dimethylamino-1,2,3-trithiane-1,5-naphthyl disufonate

++ M&B 10903 = 3,5-Diiodo-4-hydroxybenzoic acid

DISCUSSION

Microencapsulated formulations of ethyl parathion and fonofos were the only non-phytotoxic materials, other than pyrethroids, that were as effective at decreasing wheat bulb fly attack as the standard commercial treatment, chlorfenvinphos, suggesting the potential of these and other microencapsulated chemicals.

Of the twelve pyrethroids tested, permethrin was consistently the most effective; it was still active at low rates, particularly when synergised with piperonyl butoxide, in the peaty loam soils. Permethrin acts by preventing larvae from entering the plants and may affect their movement or feeding behaviour (Griffiths, 1977). The failure of deeply sown permethrin treated seeds to decrease attack was discussed by Gatehouse et al (1981), who suggested that in deep sowings only a small amount of permethrin moves to the outer tissues of the bulb, where the larva enters the plant, and the large residue around the seed itself is too far from the bulb to have any direct effect. The sticker or surfactant added to permethrin in the trials reported here, may have increased the amounts of permethrin in the bulb tissues and thus improved its performance.

Yields of permethrin-treated plants in ADAS large plot trials compare favourably with those from chlorfenvinphos. Permethrin is more expensive than the currently available seed treatments, but formulations improved with synergists and surfactants are potentially valuable.

Of 80 compounds tested in the laboratory as seed treatments for controlling slugs in winter wheat, none was suitable as a killing agent. However, a group of chemicals related to nereistoxin and another group related to ioxynil protect seeds by preventing slugs from feeding. The two best nereistoxin materials which cause minimum phytotoxic symptoms, cartap and SAN 329, are currently being tested in field trials. All the ioxynil relatives with good activity against slugs were toxic to germinating seeds. M & B 10903 gave only moderate protection from slug damage in laboratory tests but since this material did not seriously affect germination and even promotes plant growth (Wilkins *et al* 1976), it is also being investigated in field trials.

Acknowledgements

I thank F.E. Maskell, J. Oakley and P.F. Roberts for permission to include yield results from ADAS trials.

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Proceedings 1981 British Crop Protection Conference - Pests and Diseases

THE EFFECTS OF GROWTH STAGE IN CEREALS ON YIELD REDUCTIONS CAUSED BY APHIDS

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Summary Experiments with the aphids Sitobion avenae and Metopolophium dirhodum on wheat and barley respectively, compared the effects of similar numbers of aphids at different plant growth stages. This was in contrast to earlier work where the growth stage and aphid population levels both varied. The two growth periods tested in the laboratory (S. avenae on spring wheat cv. Sappo) were (Zadoks scale): 61 to 75 and 75 to 91 (Feekes scale: 10.5.1 to 11.1 and 11.1 to 11.3). The aphid indices per stem were c.1300 in each case (index = cumulative units, where one unit = one fourth-instar or adult aphid or three of earlier instars). Grain weight reductions were twice as great in the early infestation as in the late. In the field, S. avenae populations on winter wheat (cv. Maris Widgeon) at indices of c.170 per stem in each case developed during the periods G.S. 47 to 69 and 69 to 73. Percentage yield reductions relative to the control were 34% and 13%, respectively.

Three M. dirhodum populations on spring barley (cv. Triumph) at indices of 376, 394 and 194 per stem developed during the periods G.S. 30 to 61, 55 to 75 and 71 to 80, respectively. Yield was reduced significantly in the first two treatments (by 16% and 11%, respectively) but not in the third. Five possible reasons for these reduced effects in late populations are considered. The results suggested that late cereal aphid populations (beyond G.S. 73-75) either do not reduce yield with respect to control or do not reduce yields further than populations ending at G.S. 73-75.

Résumé Les expériences avec les aphis Sitobion avenae et Metopolophium dirhodum respectivement chez le blé et chez l'orge comparaient less effets des aphis à nombre semblable aux différentes phases de croissance végétale. Ceci faisaient contraste avec les essais antérieures où la phase de croissance et la population des aphis différaient toutes les deux. On eprouvaient au laboratoire (S. avenae chez le blé de printemps cv. Sappo) les deux périodes de croissance (échelle de Zadok): 61 à 75 et 75 à 91. Chacun les indices d'aphis compte c.1300 par tige (index = unités cumulatives, ou une seule unité = une quatrième etage ou un aphis adulte ou trois d'étages antérieures). Les réductions en poids des grains étaient deux fois plus grandes chez l'invasion précoce chez l'invasion tarde. Au champ, les populations de S. avenae sur le blé d'hiver (cv. Maris Widgeon) aux indices de c.170 par tige developpaient toutes les deux pendant les périodes des étages de croissance 47 a 69 et 69 a 73. Les réductions pourcentage du rendement par rapport au témoin atteignaient 34% et 13% respectivement.

Les trois populations de M. dirhodum sur l'orge de printemps (cv. Triumph) aux indices de 376, 394 et 194 par tige développaient pendent les étages de croissance 30 a 61, 55 a 75 et 71 a 80, respectivement. Le rendement se réduisait significativement par suite des deux premiers traitements (par 16% et 11% respectivement) mais pas au troisième. On considère cinq causes possibles de ces effets diminués chez les tardes populations. Les résultats suggéraient ou que les populations tardes des aphis cérélaiers (au-delà de l'étage de croissance 73-75) ne réduisent pas le rendement quant au témoin, ou qu'elles ne réduisent pas significativement le rendement plus que les populations qui se terminent à l'étage de croissance 73-75.

INTRODUCTION

The current advice of the United Kingdom Agricultural Development and Advisory Service to growers of winter wheat is to spray against cereal aphids if there are five or more aphids per ear at flowering and the numbers have increased a few days later (George and Gair, 1979). However, supplementary advice may sometimes be needed: for instance, delays in the provision of aircraft for contract spraying may require a decision to be made after flowering. Also, significant aphid infestations can begin before or after the above growth stage and preliminary experiments have indicated that such populations may also reduce yield. Losses per unit aphid (see Summary) declined with increasing growth stage in these experiments, however, and often were not large enough overall to have repaid the costs of insecticide application (George and Gair, 1979; Wratten, et al, 1981). This reduction in the effect per unit burden in late populations could be due to any combination of three factors: higher population densities, increased length of colonization, and plant growth stage. These factors, however, could not be separated as all three changed simultaneously. The use of field cages makes possible the comparison of similar aphid densities at different plant growth stages by manipulating aphid numbers by varying the times of infestation and insecticide application. This paper presents results of three such experiments concerning plant growth stage and aphid effects: a preliminary experiment on Sitobion avenae on spring wheat in a growth room, followed by field-cage experiments on S. avenae on winter wheat and Metopolophium dirhodum on spring barley.

METHODS AND MATERIALS

All references to plant growth stage (G.S.) in this paper are those of Zadoks et al (1974) followed, in parentheses, by those of Feekes (Large, 1954).

Growth room investigation: S. avenae on spring wheat

Plants (cv. Sappo) were grown singly in 15 cm diam. pots of John Innes Compost No. 2 in a growth room (19°C with a six degree range; 16 h daylength). Tillers were removed as they appeared, leaving only the main stem, facilitating aphid counting. Fifteen plants were allocated randomly to each of the following treatments:

Control: no aphid infestation

Treatment 1: infestation from G.S. 61 (10.5.1) to G.S. 75 (11.1)

Treatment 2: infestation from G.S. 75 (11.1) to G.S. 91 (11.3)

Plant positions were randomized in the growth room and re-randomized weekly.

Twenty S. avenae (from a virus-free laboratory culture) were placed on the soil at the stem base and the number and size class of the aphids (Wratten, et al. 1979) were recorded twice weekly. Infestation levels were adjusted by addition or removal of aphids as required and a cumulative index was calculated for each plant (Wratten et al. 1979). Apteriform fourth instar aphids were collected and weighed from each infestation to enable correction of the indices for aphid weight differences. The infestations were terminated by spraying with pyrethrum, the late ones being terminated when the mean cumulative index plant was approximately equal to that of the early infestation. Ears were harvested at G.S. 93 (11.4) and grain number and mean grain weight were recorded for each ear.

Field investigation 1: S. avenae on winter wheat

On June 5 1979 2m x 2m x 2m field cages (see Wratten et al., 1979) were erected on 20m x 2m plots of winter wheat (cv. Maris Widgeon) at the trial grounds of the National Institute of Agricultural Botany at the Hampshire College of Agriculture, Sparsholt. The wheat was sprayed with pyrethrum to kill any aphids already on the plot, although none was found during plant searching. Three cages were allocated randomly to each of the following treatments:

Control: no aphid infestation

Treatment 1: infestation from G.S. 47 (10) to G.S. 69 (10.5.3)

Treatment 2: infestation from G.S. 69 (10.5.3) to G.S. 73 (11.1)

In each cage 50 main stem ears bearing 19 or 20 spikelets were selected randomly and labelled. Virus-free aphids on leaves from the culture plants were placed on the crop canopy. Aphids were counted, populations adjusted and cumulative indices calculated as described above. Labelled ears were harvested on August 29 at G.S. 93 (11.4), dried at 40°C to zero water content and grain number and mean grain weight were recorded for each ear. Adult apterous aphids were collected from unlabelled plants in each cage and were weighed to enable corrections to be made to the cumulative indices, if necessary. On four occasions before harvest, the number of green leaves on ten randomly-selected main stems per cage was recorded.

Field investigation 2: M. dirhodum on spring barley

On May 18 1981, 16 cylindrical cages each enclosing 0.2 m^2 (c.90 tillers) and covered with Tygan mesh were erected at 2m intervals in a field of spring barley (cv. Triumph) (G.S. 28 (4-5). This was done at Bridget's Experimental Husbandry Farm (M.A.F.F.), near Winchester, Hampshire. The caged barley and surrounding areas were sprayed with pyrethrum and four cages allocated randomly to each of the following treatments:

Control: no aphid infestation

Treatment 1: infestation from G.S. 30 (6) to 61 (10.5.2)

Treatment 2: infestation from G.S. 55 (10.2) to 75 (11.1)

Treatment 3: infestation from G.S. 71 (10.5.4) to 80 (11.2)

Clonal, virus-free M. dirhodum were introduced as appropriate and in each cage aphids were counted and their feeding position recorded twice-weekly. Aphid indices were calculated as before. Plants were harvested on August 13 (G.S. 93 (11.4)) and the ears were dried at 35°C for 4 h.

RESULTS

Growth room investigation: S. avenae on spring wheat

The mean cumulative aphid indices for the two infestation periods did not differ significantly ($p > 0.05$; Table 1),

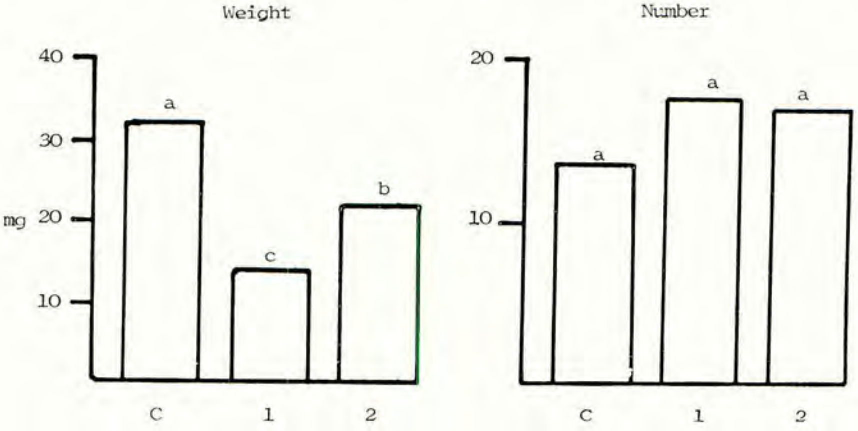
Table 1

Size of growth room S. avenae infestation and weight of fourth-instar apteriform aphids

	Control	Infestation at G.S. 61 to 75	Infestation at G.S. 75 - 91	5% LSD
Size of infestation (Aphid unit days)	125	1430	1250	217
Weight of 4th instar aphids (mg)	-	0.99	1.02	0.10

nor did the weight of fourth-instar aphids from these infestations ($p > 0.05$, Table 1). Mean weight per grain was significantly lower ($p < 0.01$) in the early infestation than in the late and both infestations significantly reduced mean weight per grain compared with the control. Grain number was unaffected (Fig. 1).

Fig. 1. Effect of S. avenae on grain weight and number (lab.)



Field infestation 1: S. avenae on winter wheat

The size of the early aphid infestation and adult aphid weight did not differ significantly from those of the later population ($p > 0.05$).

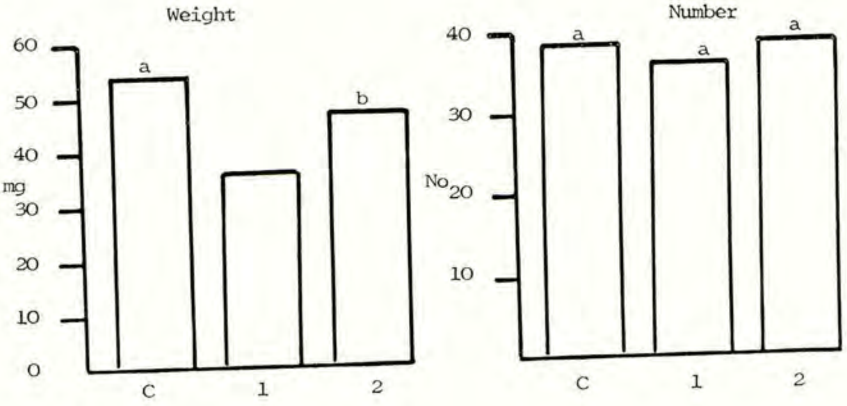
Table 2

Size of field cage S. avenae infestations and weight of adult aphids

	Control	Infestation at G.S. 47 - 69	Infestation at G.S. 69 - 73	5% LSD
Size of infestation (Aphid unit days)	0	166	174	29
Weight of adult aphids (mg)	-	1.31	1.16	0.41

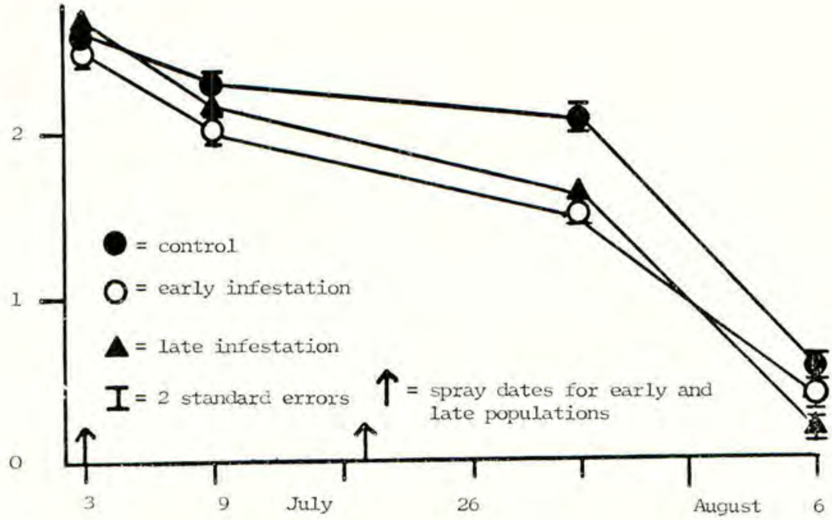
Both populations significantly reduced mean weight per grain ($p < 0.01$) and this was significantly lower in the early infestation than in the late one ($p < 0.01$). Percentage grain weight reductions were: early 34%; late 13%. Grain number was unaffected (Fig. 2).

Fig. 2. Effect of S. avenae on grain weight and number (field)



The senescence of main stem leaves was accelerated slightly by aphid infestation and this acceleration occurred earlier in the early infestation than in the late one (Fig. 3).

Fig. 3. No. of green leaves per main stem



Field investigation 2: M. dirhodum on spring barley

In treatments 1 and 2, the mean cumulative aphid indices/stem were 376 and 394 respectively, which did not differ significantly ($p > 0.05$) and the duration of each population was 36 days. In treatment 3, populations reached a mean index of only 194/tiller because of the lateness of the infestation and the consequent approaching ripeness of the crop; this infestation was at a significantly lower level than that in the first two treatments and lasted for 25 days ($p < 0.05$).

Grain number was unaffected by all treatments but mean weight per grain was significantly lower than the control in treatment 1 (by 16%) and in treatment 2 (by 11%). The apparent 4% yield reduction with respect to the control in treatment 3 was not significant; if the yield loss in this treatment is doubled (to allow for the aphid index being half that in treatments 1 and 2) and assuming a pro-rata effect by the 200 extra aphid units, it just reaches significance ($p < 0.05$) with a projected yield reduction of 8%.

DISCUSSION

Results from the preliminary growth room experiment suggested that, after heading, an early infestation of S. avenae might cause more damage than a later one of the same size. The field investigations confirmed this for S. avenae and for M. dirhodum. This growth stage difference in aphid effects has several possible explanations, which are not mutally exclusive. 1) The increased duration of the development of sooty moulds and yeasts on the leaves in the growth room and early field infestations could have reduced photosynthetic rate through a reduction in light energy reaching the chloroplasts. 2) There may have been an irreversible increase in the rate of respiration of the attacked plants, as was noticed by Kloft (1960) when plants were attacked by *Myzus ascalonicus*. 3) Infestation during the period of fertilization and initial development of the grain may be particularly damaging. However, grain number was unaffected in all experiments, as in the open-field results obtained by (e.g.) Kolbe and Linke, 1974; Latteur, 1970; in the growth room, aphid populations were largely post-fertilization but the pattern of results was similar (i.e. a greater effect by early populations). 4) Late infestations of cereal aphids (after G.S. 70 (10.5.4) on cereal ears show a reduced individual fecundity and survival (Watt, 1979) and their feeding rate may also decline during this period, although the latter has not been investigated. It could, however, reduce the effect per aphid unit in the later infestations. 5) Aphids feeding early in the grains' development could have a residual effect on photosynthesis which persists after the population decline or artificial removal by insecticide. One such residual effect could be accelerated senescence which can occur in leaves either after the population has been removed (Fig. 3) or in organs remote from the aphid feeding site (Wratten, 1975). Another such effect could be one caused by honeydew accumulation (R. Rabbinge, personal communication).

The cages used in the field experiments have already been shown to have no significant effect on the mean weight per grain of cereals (Wratten, *et al.* 1979) so it is valid to consider the above results in the light of commercial farming. George and Gair (1979) calculated, on the basis of 1977 figures, that the cost of a single spray against cereal aphids on winter wheat is equivalent to between 2.6% and 6% of the yield, depending on the method of insecticide application. On the basis of these calculations, both populations of *S. avenae* in the field experiment would have repaid spraying costs but it should be noted that the later of the two ended at G.S. 73 (11.1); this population did not persist as long as those reported by Wratten *et al.* (1979) and Lee *et al.* (1981), where spraying beyond G.S. 73 (11.1) would not have repaid costs, as little further damage would be done. The results for *M. dirhodum* on barley support those of *S. avenae* on wheat.

In general, the results of Wratten *et al.* (1979), Lee *et al.* (1981) and those presented here support the view of George and Gair (1979), and indicate that late populations of cereal aphids (i.e. beyond G.S. 73 to 75 (11.1) reduce yields less than populations ending at G.S. 73-75 (11.1).

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SESSION 7B

NEW APPROACHES TO THE CONTROL OF SOIL-BORNE PESTS AND DISEASES

Proceedings 1981 British Crop Protection Conference - Pests and Diseases

POSSIBILITIES FOR BIOLOGICAL AND INTEGRATED CONTROL OF WHITE ROT DISEASE OF ALLIUM

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Summary Species of Allium were shown to vary in their capacity to stimulate germination of sclerotia of Sclerotium cepivorum but no differences in stimulatory capacity have been found amongst onion cultivars. Constituents of artificial onion flavouring were tested for their ability to stimulate sclerotial germination, diallyl disulphide being the most effective. Field experiments with artificial onion flavouring suggest that under suitable conditions 95% of the sclerotial population can be eliminated. Germination of sclerotia occurred in the presence of seed treated with iprodione but mycelial growth from sclerotia was considerably reduced. Concentrations of iprodione which reduced mycelial growth from sclerotia also caused a greater percentage of those germinating to form secondary sclerotia. Despite this, iprodione treatment seems, at present, to be the most likely method of reducing sclerotial populations in the field.

INTRODUCTION

Sclerotium cepivorum, the cause of white rot disease in onion and other Allium crops, is a widespread and troublesome fungus. The total area of infested land in Egypt, Australia, Netherlands and the United Kingdom is around 12 000, 5300, 3400 and 700 ha respectively (Georgy personal communication; Merriman et al, 1980).

Primary infections of white rot arise from sclerotia, which can survive in field soil for at least 10 y (Coley-Smith, 1979). When germination occurs the sclerotial reserves are depleted totally and the sclerotia are left as broken hollow shells. Occasionally a small percentage of sclerotia, usually $<1\%$, form secondary sclerotia. The germination of sclerotia, triggered specifically by members of the genus Allium (Coley-Smith, 1960; Coley-Smith & Holt, 1966), results from the fact that the roots of members of the genus exude non-volatile alkyl- and alkenyl-cysteine sulphoxides (Coley-Smith & Cooke, 1971) which the soil microflora metabolises to yield volatile sulphides (Coley-Smith &King, 1969; King & Coley-Smith, 1969). These trigger germination. The sulphoxides are also flavour and odour precursors and Freeman & Whenham (1975) grouped Allium spp. in three categories according to whether (1) S-1-propenyl-, (2) S-2-propenyl-(allyl) or (3) S-methyl-L-cysteine sulphoxide was the principal flavour precursor. Allium spp., (Freeman & Whenham, 1975) and even onion cultivars (Schwimmer & Weston, 1961), vary in flavour and odour intensity, as well as in type.

Several types of biological control, based upon the specific nature of the relationship between sclerotia of S. cepivorum and Allium spp. seem possible. The following three are being investigated by us and other workers:

(1) Disease escape resulting from the low capacity of species or cultivars to stimulate germination of sclerotia.

(2) Use of artificial stimulants which cause sclerotia to germinate in the absence of an Allium crop.
(3) Use of fungicides which allow sclerotia to germinate but which prevent or reduce infection, thereby lowering the sclerotial population.

This paper presents some results obtained in a study of these possibilities.

METHODS AND MATERIALS

Sclerotia of S. cepivorum used were of two types: Culture sclerotia of isolate J11 (A.T.C.C.11793) grown in perlite-maizemeal and field conditioned (Coley-Smith & King, 1969) and field sclerotia collected from diseased onion bulbs grown on a plot naturally infested with S. cepivorum at the University of Hull Botanic Garden.

Stimulation experiments used a method based on the nylon strip-soil-germination tube method described previously (Coley-Smith & Holt, 1966). Five chitted Allium seeds were placed just below the soil surface around the periphery of each tube close to the nylon and a sixth seed was placed in the centre. With Allium carinatum var. pulchellum 12 seeds per tube were used instead of six. Seeds of all the group 3 species and of Allium moly were chitted at 1°C in moist sand until the radicles were just visible. All other species were chitted on moist filter paper at 15°C. Five tubes, each containing 20 sclerotia, were used for each species. The tubes were incubated in a growth room at 14°C and with a 16 h photoperiod for 3 months or until all the seedlings had been killed. Seed used in stimulation experiments was obtained from commercial sources or from plants grown at the University of Hull Botanic Garden. Seeds of Allium fistulosum, A. tuberosum and A. vavilovii were kindly provided by Dr.G.D.McCollum, USDA, Vegetable Laboratory, Horticultural Science Institute, Beltsville, Maryland, USA.

Suspensions of artificial onion flavouring (commodity code C7713; Bush Boake Allen Ltd.) were made by shaking with water. 2.5-ml aliquots of each suspension were injected directly on to bags of sclerotia in the field using a small syringe. Six replicate bags of sclerotia were used for each treatment. Sclerotia were recovered by wet sieving (Coley-Smith & Javed, 1970). Soil tube experiments with artificial onion flavouring and with its components were done as described previously (Coley-Smith & King, 1969) except that 1 ml of each water suspension was added to each tube three times weekly and tubes were incubated at 14°C.

Sclerotium survival experiments were made with field sclerotia using a nylon bag method (Coley-Smith & Javed, 1970). Each bag contained 50 sclerotia and a small quantity of sand and there were 6 replicates of each treatment. Bags were buried 10 cm below the soil surface in plots at the University of Hull Botanic Garden.

Field experiments by Entwistle & Munasinghe (1980) suggest that the fungicide iprodione, which has given good control of white rot in salad onions, functions mainly by reducing root infection and by suppressing the spread of mycelium between plants. Evidence was also obtained that sclerotia may germinate in the presence of iprodione and from this Entwistle & Munasinghe concluded that repeated use of the fungicide should lead to a progressive reduction in populations of sclerotia in infested soils. In order to discover more about the mode of action of iprodione several experiments were done with treated seed. Seeds (cv Rijnsburger Balstora), treated with 125 g iprodione (Rovral; 50% w.p.)/kg seed, were provided by Elsoms Seeds Ltd, Spalding, Lincs. Tube experiments with garlic extract and with iprodione in garlic extract were also done. Extracts of garlic were made as described by Coley-Smith & Holt (1966). Iprodione suspensions in garlic extract were made by adding the formulation direct to the extract.

RESULTS

Variation in stimulatory capacity in *Allium* spp. and cultivars

Effects of some *Allium* spp. on the germination of sclerotia are shown in Table 1.

Table 1

Germination of sclerotia (J11) in the presence of seedlings of *Allium* spp.

Species	Flavour and odour group*	Principal -cysteine sulphoxide flavour precursor	% germination of sclerotia ± S.E.
A. cepa cv. Robusta	1	S-1-propenyl-	64 ± 14.2
A. porrum cv. Thor	1	S-1-propenyl-	51 ± 17.6
A. fistulosum cv. Long white bunching	1	S-1-propenyl-	65 ± 13.3
A. vavilovii	1	S-1-propenyl-	76 ± 14.4
A. tuberosum	2	S-2-propenyl-	58 ± 11.8
A. roseum	2	S-2-propenyl-	86 ± 20.6
A. moly	2	S-2-propenyl-	80 ± 18.4
A. carinatum var. *pulchellum*	3	S-methyl-	32 ± 14.2
A. stipitatum	3	S-methyl-	4 ± 3.8
A. aflatunense	3	S-methyl-	0
A. cristophii	3	S-methyl-	0
A. karataviense	3	S-methyl-	0

* Freeman & Whenham (1975)

All species in groups 1 and 2 gave high levels of sclerotial germination. Group 3 spp. varied greatly in stimulatory capacity and results obtained so far indicate that those with moderate levels of stimulatory capacity contain relatively large quantities of the 1-propenyl radical as well as the methyl. Group 3 spp. with little or no stimulatory activity possess little or no 1-propenyl radical.

Differences in stimulatory capacity amongst species in groups 1 and 2 were not detected when using only five replicate tubes for each species. In later experiments using more replicates, differences amongst Group 1 spp., notably between onion and leek were detected. However, these differences were much smaller than amongst group 3 spp. No evidence has been obtained to indicate that the stimulatory capacity of onion cultivars differs.

Use of artificial stimulants of sclerotium germination

All the components of artificial onion flavouring were tested in laboratory soil-tube experiments to discover which were the most efficient in stimulating germination of sclerotia. Results are given in Table 2.

Table 2

Germination (% ± S.E.) of sclerotia (J11) in the presence of constituents of artificial onion flavouring (C7713)

Concentration	Diallyl disulphide	Di-isopropyl disulphide	Di-n-propyl disulphide*	Allyl isothiocyanate	Allyl alcohol
0.1 mg/l	18 ± 6.0	4 ± 6.5	3 ± 2.4	7 ± 6.0	0
1.0 mg/l	56 ± 9.7	3 ± 4.0	10 ± 6.3	18 ± 6.8	4 ± 4.9
10.0 mg/l	74 ± 16.6	3 ± 2.4	22 ± 7.5	66 ± 14.4	0
100.0 mg/l	83 ± 10.8	11 ± 10.7	50 ± 12.2	61 ± 18.0	2 ± 2.4

* Not a constituent of C7713 but included as a control

The results confirm that diallyl disulphide is the most effective constituent of the artificial onion flavouring (Coley-Smith & King, 1969). Two surprising features of the experiments were the ineffectiveness of di-isopropyl disulphide and the effectiveness of allyl isothiocyanate. The latter is not a natural component of Allium spp. but is present in certain crucifers (Cole, 1976). GLC analysis of allyl isothiocyanate showed that the material contained only traces of impurities.

In field experiments carried out over a two year period, the effects of artificial onion flavouring varied according to the time of year at which it was applied. Best results were obtained from early April treatments. Applications made during July or October gave poorer results. Following an April treatment, germination of sclerotia continued for at least 6 weeks (Fig.1) but, after 12 weeks, no sclerotia were recovered in a germinating condition and only 4% of the original number were still viable. No secondary sclerotia were observed in any experiments with artificial onion flavouring or diallyl disulphide.

Effect of iprodione on germination of sclerotia and seedling infection

The pattern of behaviour which was often, though not always, observed was that sclerotium germination during the first few weeks was higher with iprodione treated than with untreated seed (Fig.2). The reason for this appears to be that iprodione is sometimes slightly phytotoxic to onion seedlings and this phytotoxicity may cause a greater release of stimulant from roots. Little infection of roots was observed with iprodione-treated seeds and after a few weeks obvious growth of seedlings ceased. Cessation of seedling growth was accompanied usually by cessation of sclerotium germination. With untreated onion seeds, root infection occurred readily and sclerotium germination continued usually until higher levels were attained than with iprodione-treated seed.

The restriction of mycelial growth from germinating sclerotia was very obvious in tubes with iprodione-treated seed. About 10% of sclerotia which germinated formed mature secondary sclerotia which were smaller than the parent sclerotia but had complete rinds. In view of this, experiments were done with different concentrations of iprodione in garlic extract added to tubes containing sclerotia. The results of an experiment of this type are shown in Table 3.

Fig. 1 The effect of artificial onion flavouring (5%) on survival and germination of field sclerotia of *S. cepivorum*

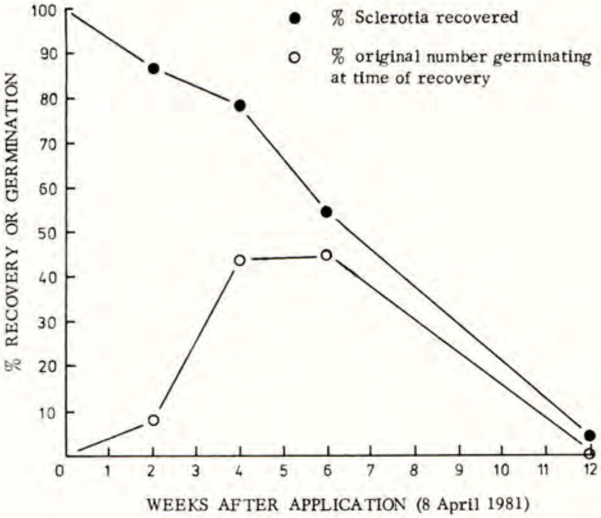

Fig. 2 Germination of sclerotia of *S. cepivorum* (J11) in soil tubes in the presence of seedlings of Rijnsburger Balstora

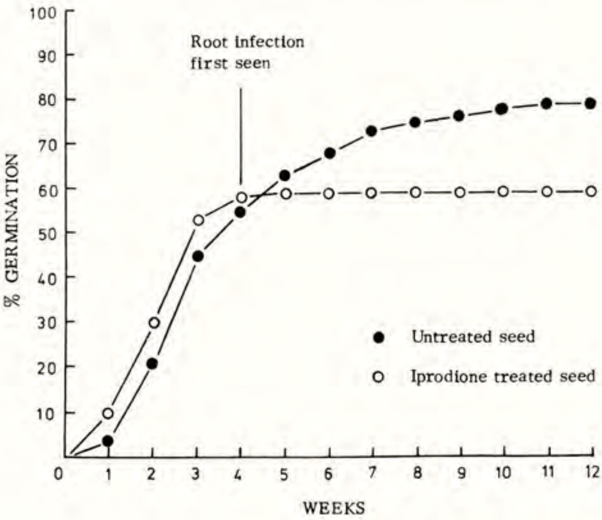

Table 3

Germination (% ± S.E.) of sclerotia (J11) in the presence of iprodione in garlic extract

Concentration (g/l) of iprodione in garlic extract	Germination of sclerotia	Whether reduction in mycelial growth	% germinating sclerotia forming secondary sclerotia
0	44 ± 10.2	-	0
0.001	47 ± 10.4	-	0
0.01	48 ± 14.6	+	10
0.1	26 ± 8.6	+	9

Concentrations of iprodione which reduced mycelial growth from germinating sclerotia also caused the diversion of the sclerotial reserves into the production of secondary sclerotia. Concentrations of iprodione of 0.1 g/l and above usually reduced sclerotium germination.

DISCUSSION

The results of this investigation have demonstrated clearly considerable variation in the capacity of different Allium spp. to stimulate germination of sclerotia of S. cepivorum. High methyl species had little or no activity and this supports previous results (Coley-Smith & King, 1969) in which suspensions of methyl sulphides had little effect. An interesting feature of this work is that lack of stimulatory activity does not necessarily indicate that such spp. are resistant to infection. Experiments have been undertaken with non-stimulatory spp. in which germination of sclerotia was triggered with garlic extract. These experiments have already shown that A. aflatunense and A. cristophii, which are devoid of stimulatory activity, are nevertheless readily infected. Differences in stimulatory capacity have not yet been found amongst onion cultivars but, even if they do exist, they are likely to be much smaller than those between species. The existence of onion cultivars with a reduced capacity to stimulate germination therefore seems unlikely but investigations into this possibility are continuing.

Control of white rot disease by treatment of infested soils with materials which stimulate germination of sclerotia appears to offer a much greater chance of success. The results obtained in this investigation were similar to those obtained by other workers (Merriman & Sutherland, 1978; Merriman et al, 1981; Entwistle et al, 1981). Amongst a number of materials which have been tested diallyl disulphide gave the highest levels of germination of sclerotia and further experiments would probably best be confined to this material. Field experiments have shown that, under appropriate conditions, 95% or so of the sclerotial population could be eliminated and future research should be directed to achieving these high levels in practice. Severe levels of infestation with sclerotia of S. cepivorum are known to occur in several countries. Crowe et al, (1980) reported levels of up to 1300 sclerotia/kg soil in the USA and, according to Georgy (personal communication), levels of 1000 sclerotia/kg soil are common in Egypt. Even a 95% reduction in the sclerotial population in such severely infested soils would leave a residual population of 50 sclerotia/kg soil and results obtained by Crowe et al, (1980) suggest that this would give severe disease outbreaks. It is possible however that the residual population occurring after treatment with artificial stimulants would consist of individuals least responsive to stimulation and therefore least likely to cause infections. This is a feature of such treatments which has not yet been examined.

Seed treatment with iprodione, followed by stem base sprays with the same material, as used by Entwistle & Munasinghe (1980, 1981) seems to offer the best possibility so far of reducing field populations of sclerotia without the disadvantage of having to leave fields fallow. The level of disease control would have to be very high in order to prevent replenishment of sclerotial populations from infected plants. In any case some attention should be paid to the fact that sclerotia which germinate in the presence of iprodione produce secondary sclerotia relatively frequently. It is not yet known whether these small secondary sclerotia survive for very long or whether they can infect roots. Now that the mode of action of iprodione has been established, a search should be made amongst existing fungicides for materials with similar or perhaps even greater effects. It is also interesting to speculate that, in the presence of fungicides such as iprodione which reduce mycelial growth more than sclerotium germination, onion cultivars with a very high level of stimulatory activity might be more effective in reducing field populations of sclerotia than those with a low level of stimulatory activity.

Acknowledgements

We thank Mrs. C.M.Mitchell, Mrs.J.Wheeler-Osman, V.Swetez and L.Bielby for technical assistance.

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Proceedings 1981 British Crop Protection Conference - Pests and Diseases

CONTROL OF SOIL-INHABITING ARTHROPODS WITH NEOAPLECTANA CARPOCAPSAE

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Summary Aqueous suspensions of the entomophilic nematode, Neoaplectana carpocapsae were applied to rows of sugar beet in small plots. The nematode was mass-reared in the laboratory on wax moth larvae (Galleria mellonella). Nematode infections persisted up to several weeks. They decreased populations of some soil-inhabiting arthropods and particularly those of some Collembola and many species of Coleoptera. Significant decreases in attack by pygmy mangold beetle (Atomaria linearis), mangold flea beetle (Chaetocnema concinna) and onychiurid springtails were observed.

INTRODUCTION

The possibilities of using entomophilic nematodes of the genus Neoaplectana to control pests have been considered by several workers since Glaser et al (1942) published their work on N. glaseri. The species that has shown most promise is N. carpocapsae (DD 136) but, although the results of laboratory tests have been very promising against a wide variety of arthropods, the results of field trials have often been disappointing (Webster, 1980). There are more than fourteen species of Neoaplectana, each with many strains, and together they have a very wide host range. Arthropods susceptible in laboratory tests include Hoplocampa testudinea (Hymenoptera, Tenthredinidae), Otiorrhyncus sulcatus (Coleoptera, Curculionidae) and Phyllobius oblongus (Coleoptera, Curculionidae). In field trials, Psylliodes chrysocephala (Coleoptera, Chrysomelidae), Agrotis segetum (Lepidoptera, Noctuidae), Sciapteron tabaniformis (Lepidoptera, Sesiidae) and Scutigerella immaculata (Symphyla, Scutigerellidae) have been controlled by Neoaplectana.

There have been few studies to investigate the potential of Neoaplectana in control of soil-inhabiting pests. The studies reported here are part of a collaborative investigation by the 'Integrated Control of Soil Pests Working Group' of the International Organization for Biological Control of Noxious Pests and Diseases (I.O.B.C.). Coordinated experiments were done in Wageningen, the Netherlands (W. Heijbroek and W.R. Simons), Zurich, Switzerland (V. Delucchi and A. Rahay) and England (C.A. Edwards, A.R. Dunning and J. Oswald), as part of a programme aimed at integrated control of sugar beet pests.

METHODS AND MATERIALS

Supplies of N. carpocapsae for field application were obtained by rearing them in larvae of the greater wax moth, Galleria mellonella (Thompson and Cantwell, 1964; Dutky et al, 1962). The nematode acts by infecting arthropods with a pathogenic bacterium.

Figure 1 Persistence of *Neoaplectana* infectivity in soil - 1977

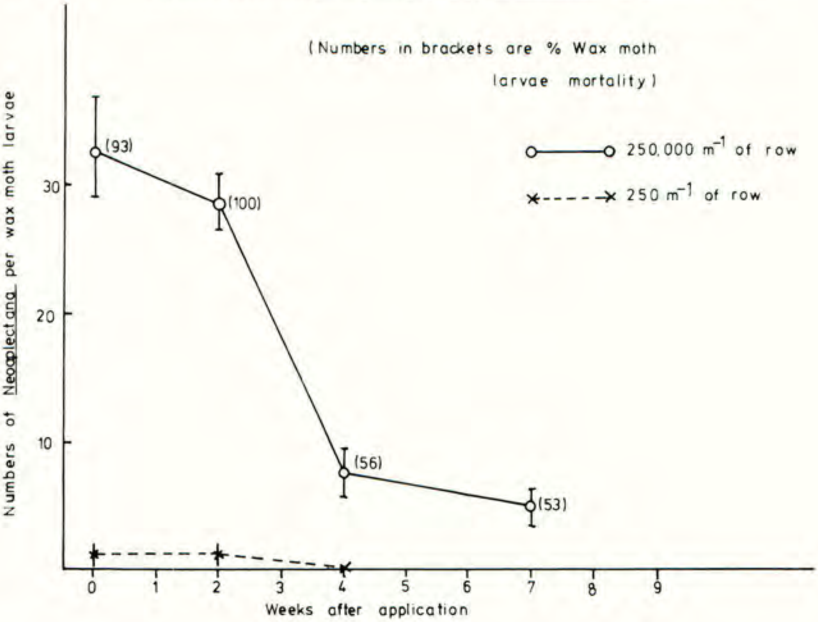
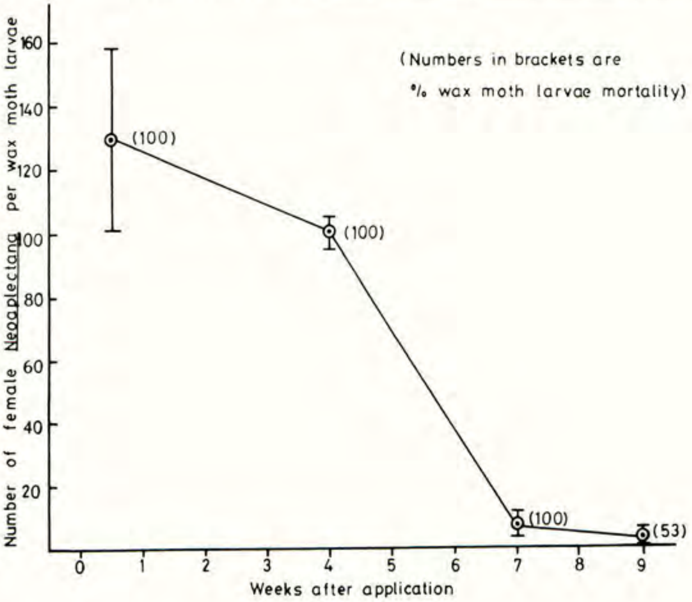


Figure 2 Persistence of *Neoaplectana* infectivity in soil - 1978



To build up numbers of N. carpocapsae, 20 anaesthetized final instar wax moth larvae were placed in a petri dish on filter paper and a nematode suspension containing about 2000 active infective stage Neoaplectana larvae added. These were left at 24°C for 10 days. Nematodes were harvested by collecting through a nylon gauze filter into very dilute formaldehyde (1 part in 1000 parts distilled water). The suspension was adjusted to about 100,000 nematodes per ml by counting on a grid and stored at 5°C until used.

Field tests were done in plots of sugar beet 10m long and 5 rows wide. The centre three rows only were treated at drilling with nematodes at three rates: (i) 250 000/m row, (ii) 2 500/m row, (iii) 250/m row. To apply them, a suitable dilution to provide about 250 ml of suspension/m row was dripped on to the row from a large enclosed plastic funnel. Control plots were treated with water only.

The arthropod populations were assessed in each plot using two 7cm x 13cm deep pitfall traps sampled weekly for larger arthropods and by taking four soil samples at the seedling, 2-4 leaf and 4-6 leaf stages in 1977 and at the 2-8 and 10 leaf stage in 1978, with a 5cm diameter 15cm deep soil auger to assess populations of smaller arthropods. Arthropods were extracted from soil cores in modified high gradient Tullgren funnels.

The persistence of nematode activity was assessed by a bioassay method which involved taking 500g of soil from between the plants with a 2.5cm auger. This was done immediately after application, at the seedling stage and at the 4-6 leaf stage, approximately 4 and 7 weeks after application of nematodes. To assess nematode activity, the Bedding trap technique was used (Bedding, 1976). This involved placing 500g of soil firmly on to 10 wax moth larvae in a large jar with a lid to prevent escapes. The jar was kept at 25°C for six days. The larvae were then removed from the soil and mortality was assessed. Additional information was obtained by dissecting the larvae and counting the adult nematodes inside.

These trials were repeated in 1977 and 1978.

RESULTS

The numbers of soil-inhabiting arthropods extracted from soil samples in the two experiments are summarised in Table 1. Differences in numbers between the treatments were not great, with the possible exception of those of Coleoptera.

The persistence of infectivity of Neoaplectana in soil is shown in Figs. 1 and 2. Clearly, the nematode remained active in the soil for several weeks after application.

The numbers of pygmy mangold beetles (Atomaria linearis) caught in pitfall traps in 1978 are given in Fig. 3, those of mangold flea beetle (Chaetocnema concinna) in Fig. 4 and the populations of onychiurid springtails extracted from soil samples in 1978 are summarized in Fig. 5. These decreases in numbers were the only ones of any economic significance.

DISCUSSION

Although the two field trials effectively screened the relative susceptibility of different groups of soil-inhabiting arthropods to infection by Neoaplectana, the plots were small and the numbers of soil samples and pitfall traps limited, so it was difficult to assess the effects of the nematodes on individual species of arthropods. However, it was clear that the greatest effects were on certain soil-dwelling Collembola and a number of species of Coleoptera. These two groups include the most

Figure 3 Effect of *Neoaplectana* treat ments on numbers of *Atomaria lineatus*

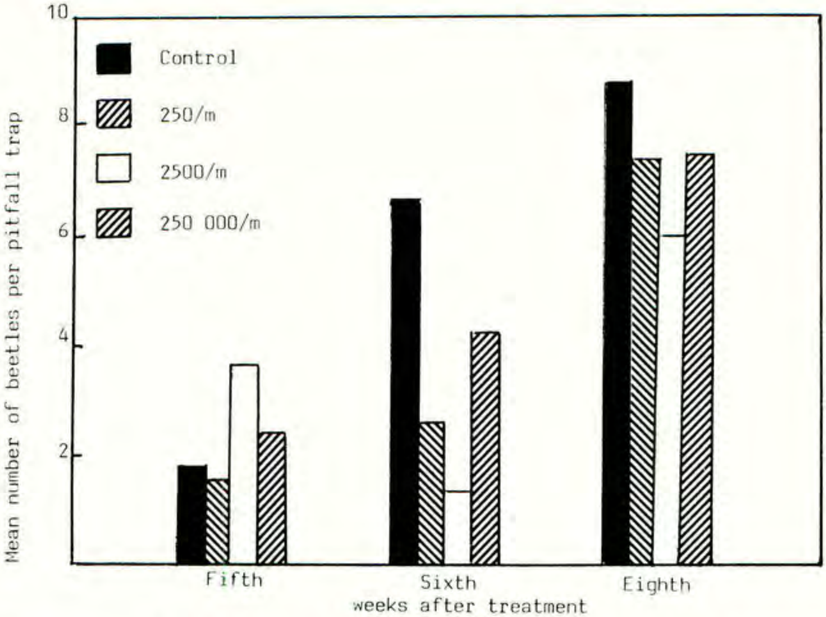


Figure 4 Effect of *Neoaplectana* treatments on numbers of *Chaetocnema concinna*

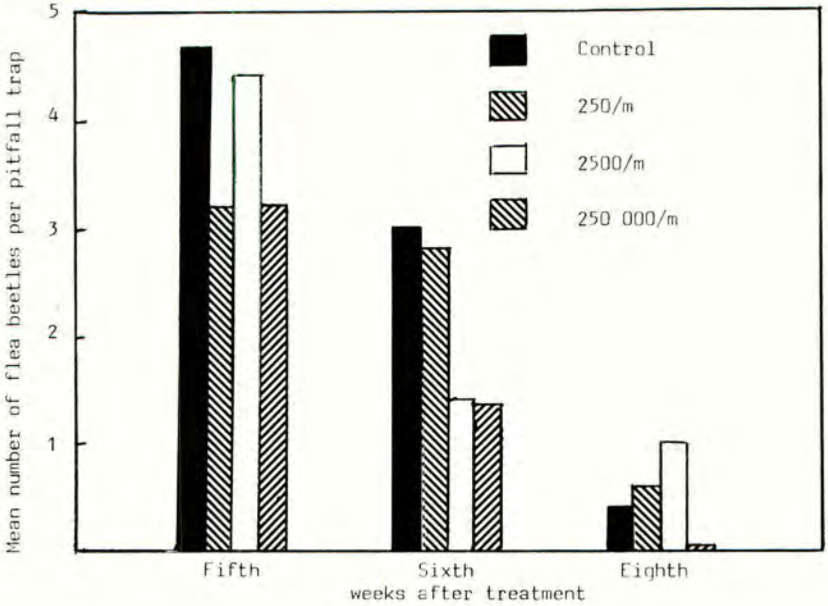


Figure 5 Effects of Neoaplectana treatment upon Onychiurus populations

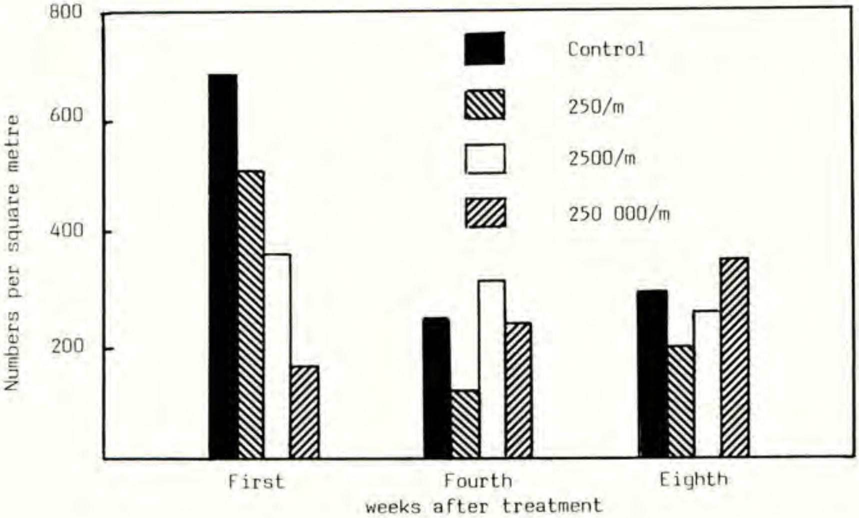


Figure 6 Effect of Neoaplectana treatments on populations of soil-inhabiting arthropods

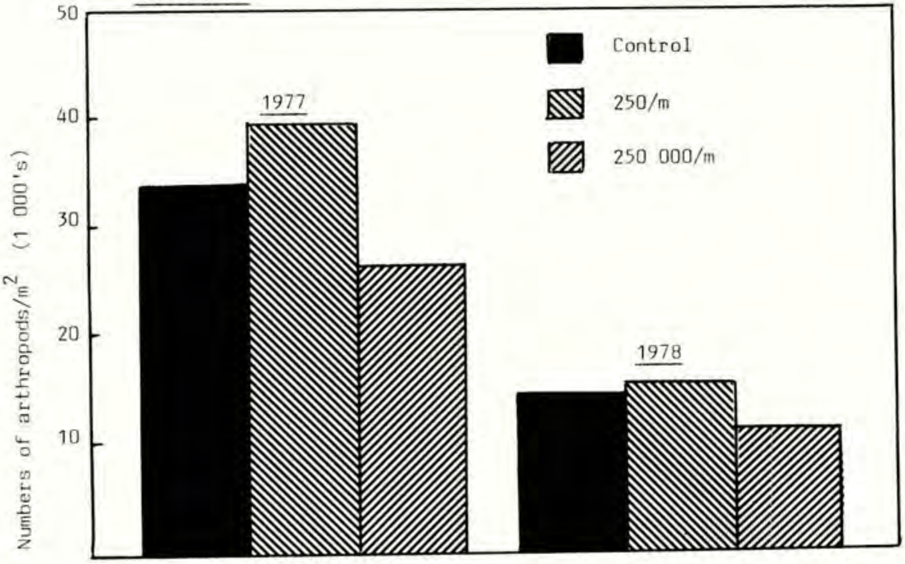


Table 1

Effects of *Neoaplectana* inoculation on soil arthropod populations (No/m^2)

Group/Year	Dose (No/m)			Significance
	Control	2500	250 000	
1977				
Acarina	15699	18862	12289	N.S.
Collembola	16890	19521	12904	N.S.
Coleoptera	698	123	205	$P = 0.05$
Diptera	822	1192	904	N.S.
1978				
Acarina	2668	1816	1611	$P = 0.05$
Collembola	8640	9205	7104	$P = 0.01$
Coleoptera	1676	2482	1513	N.S.
Diptera	403	625	492	N.S.

important seedling pests of sugar beet, i.e. pygmy mangold beetle, mangold flea beetle and the springtail, *Onychiurus armatus*. Populations of these pests varied greatly from year to year but, in 1978 for the beetles and 1977 and 1978 for the springtails, they were numerous enough to demonstrate that *Neoaplectana* could decrease their numbers, although the data were inadequate to assess the optimum level of treatment with the nematode (Figs. 3, 4, 5 and 6).

In corresponding field trials in Switzerland, organized by Professor Delucchi, the effects of the nematode on these pests were very much greater than in those reported here. In 1977, about 90% control of *Atomaria linearis* was obtained, and the overall effects on many soil-inhabiting arthropods were much more drastic.

The nematode certainly has potential for pest control, because it may be mass reared readily in large numbers, stored for months in aerated diluted formalin at 4°C, applied easily as an aqueous spray, is unharmed by most pesticides (Webster, 1980) and migrates readily in soil.

However, we still need to know much more about the different species and strains of *Neoaplectana*, the optimal environmental conditions, interactions with soil factors, optimal doses and susceptibility of different species of pests.

The nematode is being produced commercially in France. This may stimulate further work on its potential as a biological control agent.

Acknowledgements

Thanks are due to Dr. A. Dunning and Mr. A. Thornhill who collaborated in the experiments, provided experimental sites and did some sampling, and to Mr. John Bater who did much of the identification of arthropods. The planning of the work was with Dr. W. Heijbroek and Dr. V. Delucchi.

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Proceedings 1981 British Crop Protection Conference - Pests and Diseases

THE USE OF IPRODIONE FOR CONTROL OF RHIZOCTONIA BOTTOM ROT OF LETTUCE

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Summary Application of iprodione dust (0.5 and 1.0 g a.i./m^2) or quintozene dust (7.0 g a.i./m^2) to the soil, pre-planting, gave good control of bottom rot of lettuce caused by Rhizoctonia solani. At a dose of 0.5 g a.i./m^2, iprodione dust gave a degree of control similar to that of quintozene. Increasing the dose to 1.0 g a.i./m^2 did not give significantly better control.

Where the soil treatments were supplemented by fortnightly sprays of iprodione at 0.25 kg a.i./ha, control of bottom rot was increased significantly. The effect of the post-planting iprodione sprays was irrespective of previous soil treatment and, where applied alone, the sprays gave control equivalent to quintozene applied pre-planting. This provided a new approach to control of Rhizoctonia bottom rot which had been based on incorporation of quintozene into the soil. The most effective treatments for control of lettuce bottom rot included iprodione or quintozene applied pre-planting and supplemented by fortnightly sprays of iprodione.

INTRODUCTION

Lettuce bottom rot caused by Rhizoctonia solani is one of the most damaging diseases of the protected lettuce crop in the United Kingdom. In most cases, the disease is not apparent until the crop is harvested when the underside of the lettuce can be seen. The root of the plant remains healthy but a light brown rot develops around the base of the lower leaves and spreads up them. Often , light brown flecking can be seen on the midribs of affected leaves. The rot is often invaded by secondary bacteria giving it a slimy appearance. The base of the plant is covered commonly with a webbing of R. solani mycelium, visible to the naked eye.

When the disease is very severe, it progresses into the heart leaves, stunts plants and can be seen from above. The rapid rotting in the later stages of the disease may be due to a complex of R. solani and other secondary rotting organisms (Pieczarka and Lorbeer, 1975). Occasionally, dark brown sclerotia form in the infected tissues in the later stages of the disease.

The disease can make lettuce plants completely unmarketable due to extensive rotting but, even with smaller infections, extra trimming of the lower leaves makes cutting and packing more difficult and can reduce the lettuce head weights significantly. Lettuce bottom rot differs greatly from the damping-off caused by R. solani (Abdel-Salam, 1933) which is now fairly uncommon.

Holmes and Knapman (1963) described the effectiveness of quintozene dust applied to the soil pre-planting in controlling lettuce bottom rot. This became the standard method of controlling the disease and is now widely used. Initial experiments showed that iprodione was active against R. solani and that it could be useful in controlling lettuce bottom rot. Further experiments done in 1980/81 to investigate methods of application, placement and doses are reported here. Effects on bottom rot of fortnightly applications of HV sprays of iprodione, the standard treatment for control of *Botrytis cinerea* in lettuce, were also investigated and are reported in this paper.

METHODS AND MATERIALS

Two formulations of iprodione were investigated, a 50% a.i. w.p. (Rovral) and a 1.25% a.i. dust (Rovral dust). The dust was used as a pre-planting soil treatment at 0.5 or 1.0 g a.i./m^2, with and without incorporation, and the w.p. was used as a HV spray, pre- and post-planting at 0.25 kg a.i./ha. In the earlier experiments, several doses of iprodione were tested in order to determine the optimum rate of each method of application. In all trials, quintozene (P.C.N.B.; 20% a.i. dust) was included as the standard treatment.

Several trials were done in 1980/81 in commercial glasshouses where bottom rot had caused problems in recent crops and at Stockbridge House EHS, where high levels of *R. solani* in soil were encouraged by growing successive untreated crops. Most trials used a plot size of approximately 4.5 m^2, equivalent to about 100 plants. A randomized block design was used in all trials with at least 4 replicates of each treatment and of untreated plots.

Split-plots were used in most trials, allowing investigation of possible interactions between pre-planting soil treatments applied on the day prior to planting and post-planting 'foliar' sprays. This was particularly important because the standard method of controlling *B. cinerea* in protected lettuce at this time was by means of HV sprays of iprodione (0.25 kg a.i./ha) applied fortnightly. All pre- and post-planting sprays were applied at 1000 l/ha.

At harvest, 20 plants were selected from the centre of each plot and bottom rot was assessed visually, using a 0 to 3 scale: 0 - No obvious disease; 1 - Slight disease, little or no extra trimming necessary; 2 - Moderate disease requiring extra trimming and resulting in a reduced head weight but leaving a marketable lettuce; 3 - Severe disease leaving an unmarketable lettuce after trimming. A *Rhizoctonia* index (0 to 100) was calculated for each plot:

$$\textit{Rhizoctonia}\ \text{index} = \frac{1\ (\text{No. plants in category 1}) + 2\ (\text{No. in 2}) + 3\ (\text{No. in 3})}{\text{No. lettuce assessed}} \times \frac{100}{3}$$

Head weights of lettuce were recorded. Damage caused by other diseases, including *B. cinerea*, was also recorded although, in most trials, levels were very low.

RESULTS

Detailed data are presented from two sites, at Hesketh Bank (1980) and Snaith (1981), to illustrate the effects of the various treatments under conditions of high and low incidence of lettuce bottom rot.

Table 1 shows the results of a trial where bottom rot was severe. The plots without soil and foliar treatments gave a mean disease index of 93.8; in effect very few lettuce from these plots were marketable. The post-planting sprays of iprodione significantly reduced the level of disease in all cases, irrespective of the pre-planting soil treatments. Of the soil treatments without post-planting sprays, only iprodione dust applied to the soil surface at 0.5 and 1.0 g a.i./m^2 and quintozene applied at 7.0 g a.i./m^2 reduced the disease index significantly ($\underline{P} = 0.05$). Where post-planting sprays of iprodione were applied, only quintozene gave a further significant reduction in the disease index.

Table 1

The effect of pre-planting soil treatments and a post-planting spray programme on the severity of Rhizoctonia bottom rot at harvest (Hesketh Bank, 1980)*

Pre-Planting Soil Treatment			Rhizoctonia Index	
Fungicide/Formulation	Dose (g a.i./m^2)	Method of Application	No treatment post-planting	Iprodione sprays post-planting
Untreated	-	-	93.8^{d}	66.3^{b}
Quintozene dust	7.0	raked in	65.9^{ab}	27.9^{a}
Iprodione dust	0.5	surface	72.5^{abc}	53.8^{b}
Iprodione dust	0.5	raked in	79.6^{abcd}	55.8^{b}
Iprodione dust	1.0	surface	60.9^{a}	49.6^{b}
Iprodione dust	1.0	raked in	85.0^{cd}	55.4^{b}
Iprodione w.p.	0.5	spray	80.4^{abcd}	50.0^{b}
Iprodione w.p.	1.0	spray	83.8^{bcd}	50.0^{b}

*Treatment indices having any letter common in the suffix within each column do not differ significantly (*P* = 0.05).

In the absence of post-planting sprays, incorporation of iprodione dust applied at 1.0 g a.i./m^2 by raking reduced the level of disease control when compared with a surface application. At a similar dose, the pre-planting iprodione spray treatment gave worse disease control than the equivalent dust treatment applied to the surface without subsequent incorporation. There was no significant difference in control given by the two doses of iprodione dust applied by either of the two methods in the absence of foliar sprays.

Effects of treatments on lettuce head weights, given in Table 2, show trends similar to those of the disease indices. Where post-planting sprays of iprodione were applied, there were no significant differences between any soil treatments.

Table 2

The effects of pre-planting soil treatments and a post-planting spray programme on lettuce head weights at harvest (Hesketh Bank, 1980)*

Pre-Planting Soil Treatment			Head Weights (g)	
Fungicide/Formulation	Dose (g a.i./m^2)	Method of Application	No treatment post-planting	Iprodione sprays post-planting
Untreated	-	-	92.7^{a}	154.7^{a}
Quintozene dust	7.0	raked in	165.7^{b}	197.5^{a}
Iprodione dust	0.5	surface	136.2^{ab}	172.5^{a}
Iprodione dust	0.5	raked in	122.0^{ab}	162.2^{a}
Iprodione dust	1.0	surface	161.0^{b}	170.0^{a}
Iprodione dust	1.0	raked in	100.2^{a}	161.0^{a}
Iprodione w.p.	0.5	spray	130.0^{ab}	191.0^{a}
Iprodione w.p.	1.0	spray	125.5^{ab}	174.5^{a}

* Treatment indices having any letter common in the suffix within each column do not differ significantly (*P* = 0.05).

Where no sprays were applied post-planting, iprodione dust applied at 1.0 g a.i./m^2 to the soil surface without subsequent incorporation and quintozene applied at 7.0 g a.i./m^2 gave lettuce head weights which were significantly heavier than those achieved by all other treatments.

Table 3 shows the results from a site where disease indidence was much lower,

Table 3

The effect of pre-planting soil treatments and a post-planting spray programme on severity of Rhizoctonia bottom rot at harvest (Snaith, 1981)*

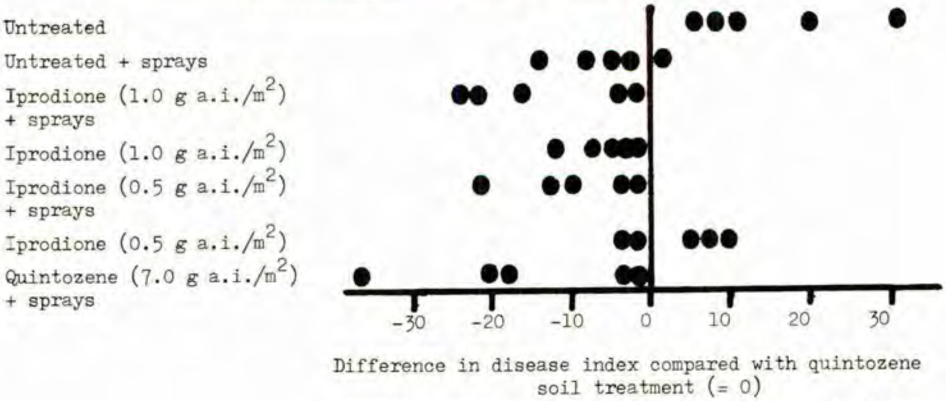
Pre-Planting Soil Treatment			Rhizoctonia Index	
Fungicide/Formulation	Dose (g a.i./m^2)	Method of Application	No treatment post-planting	Iprodione sprays post-planting
Untreated	-	-	34.2^b	0.8^a
Quintozene dust	7.0	raked in	23.8^{ab}	1.3^a
Iprodione dust	0.5	surface	32.5^b	0.0^a
Iprodione dust	1.0	surface	18.8^a	1.47^a

* Treatment indices having any letter common in the suffix within each column do not differ significantly (P = 0.05)

the completely untreated plots giving a mean disease index of 34.2. This figure is equivalent to approximately 90% marketable heads in this trial. As in the previous trial, the post-planting spray programme significantly reduced disease levels, irrespective of soil treatments, and gave very low disease indices, equivalent to 100% marketability of lettuce heads. Where no post-planting sprays were applied, only the 1.0 g a.i./m^2 dose of iprodione applied to the soil surface without subsequent incorporation gave an index significantly lower than that obtained for plants from untreated plots.

Effects of treatments on disease levels at 5 trial sites in Yorkshire and Lancashire are summarized in Fig. 1. For each trial, the disease index for the

Fig 1. Summary of data from 5 trials on protected lettuce using pre-planting dust and post-planting spray treatments with iprodione showing the effect of treatments on disease indices, compared with quintozene soil treatment alone (represented as zero on the horizontal axis)



(Symbols within each horizontal row represent single site results) quintozene-alone treatment is represented as zero and the increase or decrease in disease index achieved by each treatment is plotted accordingly. Where iprodione sprays supplemented soil treatments, there was generally an improvement in disease control. A marked increase in disease control was seen when post-planting sprays alone were compared with the totally untreated plots. The disease control with only post-planting sprays compared well with that achieved by soil treatment with quintozene alone. All treatments which included soil treatment and post-planting sprays were better than the standard quintozene alone. Effects of iprodione dust applied alone at 0.5 g a.i./m^2 were not significantly different from those of the standard quintozene treatment.

DISCUSSION

A striking feature of the results obtained in these trials was the effectiveness of post-planting sprays of iprodione in reducing infection on lettuce by R. solani, irrespective of pre-planting soil treatments. This is of particular note because many growers apply iprodione fortnightly to control B. cinerea. Its effectiveness in controlling Rhizoctonia had apparently gone unnoticed for some while. When a spray programme starts 4-5 days after planting, the lettuce plants do not provide a very large target area for spray deposit and it is inevitable that much of the first and, perhaps, subsequent sprays is deposited on the soil surface. It must be assumed that it is the application of iprodione to the soil surface which has an effect on disease levels. This assumption is supported by limited trials work showing that single HV sprays of iprodione, applied pre- or immediately post-planting, had a significant effect on the incidence of Rhizoctonia bottom rot. Application of pre- and post-planting HV fungicidal sprays is a new approach to the control of Rhizoctonia bottom rot of protected lettuce as control of this disease has been based previously on pre-planting incorporation of fungicidal dust into the soil surface. Although application of iprodione to control both Rhizoctonia and Botrytis on lettuce at first appears to be highly desirable, its use may have to be accompanied by caution in the light of experiences with the development of resistance to fungicides by some fungi.

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NOTES

Proceedings 1981 British Crop Protection Conference - Pests and Diseases

THE PERFORMANCE AGAINST CARROT FLY AND UPTAKE BY CARROTS OF CARBOFURAN AND PHORATE INCORPORATED AS GRANULAR FORMULATIONS IN GELS USED FOR DRILLING PRE-GERMINATED CARROT SEED

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Summary Gels containing pre-germinated carrot seed and granular formulations of carbofuran or phorate were drilled to give doses of 2.5, 5.0 or 10 mg a.i./15 cm row in a sandy loam or a black fen soil.

Six weeks after drilling, the numbers of carrot seedlings, in which the mean concentration of total carbofuran residues 4 weeks after treatment with the highest dose was 31 mg/kg, were not reduced by the insecticide. A similar dose of phorate produced residues of approximately 1 g/kg in similar-age seedlings and reduced plant stands on both soil types significantly.

With 10.0 mg a.i./15 cm row, carbofuran and phorate reduced the numbers of carrot fly larvae by 71 and 46% respectively 24 weeks after drilling in the fen soil and by 94 and 99.7% after 26 weeks in the sandy loam. In the sandy loam, the mean concentration of total carbofuran residues in carrots treated with the highest dose was 0.21 mg/kg. A similar dose of phorate at the same site produced a mean total residue of 0.72 mg/kg in carrot roots.

INTRODUCTION

Advantages of drilling pre-germinated seed of some vegetable crops, including carrots, in gel carriers include earlier seedling emergence and crop yield, as well as the production of plant stands more predictable than those given by field-sown, dry seed (Currah et al, 1973, 1974). The technique also offers the opportunity to investigate the inclusion in the gels of nutrients, nitrogen-fixing bacteria and pesticides, thus providing a 'packaged' environment for the seedlings (Currah et al, 1974; Salter, 1978 a,b). Although the performance against white rot (*Sclerotium cepivorum*) of the fungicide iprodione, incorporated in the gel used with salad onions, has been described recently (Entwistle & Munasinghe, 1981), the behaviour of other pesticides, including insecticides, with this or other crops has not been reported.

In the U.K., granular formulations of some carbamate and organophosphorus insecticides, including carbofuran and phorate, are often applied to the soil at drilling to protect carrots against first, and sometimes also second and third, generation carrot fly (*Psila rosae*) (Anonymous, 1973). Experiments were done in 1979 to evaluate the performance of granular formulations of carbofuran, phorate and one other insecticide (Thompson et al, 1980) incorporated in two gels containing pre-germinated carrot seed and drilled in a sandy loam and a black fen soil. The results obtained with carbofuran and phorate are summarised in this paper.

METHODS AND MATERIALS

Sites and designs of the experiments Two field sites were used. At NVRS, Wellesbourne the sandy loam received a base fertiliser application of 100 kg N, 231 kg P_2O_5 and 231 kg K_2O/ha. At Methwold, Norfolk a black fen soil with a base application of 0 kg N, 53 kg P_2O_5 and 105 kg K_2O was used. Similar experiment designs were used at both sites and, at each site, the two gels used as carriers were confined to separate, adjacent experiments. In each experiment, insecticide treatments were assigned to single row plots in each of three, fully-randomised blocks. Each block also included three 'control' plots drilled with gel without insecticide. Plots, drilled on 11 June (NVRS) and 20 June (Methwold) with a hand-operated fluid drill (Lickorish & Darby , 1976), were 5 m long and 25 cm (NVRS) or 30 cm (Methwold) apart. Weeds were controlled initially with a pre-emergence application of 0.74 kg linuron (Du Pont Linuron 50 Weedkiller; 50% w.p.)/ha. This was supplemented at Methwold with two post-emergence applications, each of 3.3 kg pentanochlor and 1.7 kg chlorpropham (Herbon Brown; 30% pentanochlor, 15% chlorpropham)/ha. Neither experiment was irrigated.

Seed and gels Carrot seed, cv. Royal Chantenay Red Cored, was germinated for 48h at 20±1°C to give a maximum radicle length of 3mm. The gels used for drilling comprised either 8 g Polymer DP 433 (Hercules Powder Co. Ltd) or 20 g Laponite (Laporte Industries Ltd)/l water. Seeds were incorporated into gels, either 3-4 h (NVRS) or 6-7 h (Methwold) before drilling, to give 2000 seeds/l gel. Gels were extruded during drilling at 20 ml/m row.

Assessments of biological performance of insecticides To investigate possible phytotoxicity of insecticides to carrots, the numbers of plants in a 2.5-m sample of row in all plots were recorded 6 weeks after drilling.

At harvest on 6 December (Methwold) and 13 December (NVRS), 24 and 26 weeks after drilling respectively, all carrots were washed and graded for the presence or absence of carrot fly damage. The numbers of roots in each category were recorded and the % undamaged carrots given by each treatment was derived for statistical analysis. Data on % undamaged carrots were also used to estimate the efficiency of the insecticide treatments (Wheatley, 1973, 1974) as % reductions in numbers of carrot fly larvae on plots treated with insecticide (Wheatley, 1969 a,b).

Assessments of insecticide residues in seedling and mature carrots Insecticide residues were analysed in entire seedlings and mature roots sampled 4 and 26 weeks respectively after drilling at NVRS. Analytical procedures for phorate were essentially as described by Suett (1971) and carbofuran residues were determined by modifying the method of Mollhoff (1975). The modifications included clean-up of mature carrot extracts on deactivated Florisil (3% H_2O) and direct injection of sample extracts in methanol on to silane-treated glass wool without the addition of sodium hydroxide. This did not reduce the efficiency of trans-esterification. Extraction efficiencies, assessed by fortifying untreated samples with parent insecticides and degradation products at 0.01 and 0.1 mg/kg (Suett, 1971), exceeded 95% and so the results were not corrected.

RESULTS

Biological performance of insecticides At both sites, plant stands and levels of carrot fly damage on 'control' plots drilled with gels containing no insecticide were similar in the two adjacent experiments using different gels. Therefore, for each site, data obtained with the two gels were analysed together. There were no interactions between insecticides and gels on either the stands of carrot plants or the % undamaged carrots ($P>0.05$). The estimated effects of the insecticides on the numbers of carrot fly larvae were also similar with both gels. Therefore the data in Tables 1 and 2 are presented as means over gel types.

On the sandy loam at NVRS, the numbers of carrot plants 6 weeks after drilling were reduced significantly only by phorate at 5.0 and 10.0 mg a.i./15 cm row ($\underline{P}<0.05$ and 0.01, respectively) (Table 1). On black fen soil at Methwold, only the largest dose of phorate (10 mg a.i./15 cm row) reduced the numbers of plants significantly ($\underline{P}<0.05$).

Table 1

Plant stands of carrot 6 weeks after plots were drilled with gels containing pre-germinated seed and granular formulations of carbofuran or phorate

Insecticide	Dose (mg a.i./15 cm row)	Mean no. plants/ 2.5 m row
NVRS (sandy loam)		
Untreated	-	34
Carbofuran	2.5	26
	5.0	30
	10.0	27
Phorate	2.5	22
	5.0	20
	10.0	17
L.S.D. $\underline{P} = 0.05$ (48 D.F.)		12.3
$\underline{P} = 0.01$ (48 D.F.)		16.4
Methwold (black fen soil)		
Untreated	-	54
Carbofuran	2.5	50
	5.0	54
	10.0	45
Phorate	2.5	53
	5.0	43
	10.0	35
L.S.D. $\underline{P} = 0.05$ (48 D.F.)		12.4
$\underline{P} = 0.01$ (48 D.F.)		16.6

Although carrots were not protected completely against carrot fly at either site (Table 2), all doses tested at both sites increased the % undamaged carrots significantly ($\underline{P}<0.01$). The largest dose of phorate produced 99.9% undamaged carrots on sandy loam at NVRS and approximately 40% on the black fen soil at Methwold. A similar dose of carbofuran produced 89% undamaged carrots at NVRS and 62% at Methwold.

The estimated % reduction in relative numbers of larvae on treated and untreated plots is a derived parameter which can be used to compare effects of insecticide treatments on carrot fly in separate experiments (Wheatley, 1969 a,b). The estimated % reductions following the use at Methwold of carbofuran and phorate at 10 mg a.i./15 cm row were 71.4 and 45.5% respectively, comparable estimates for NVRS being 93.6 and 99.7%. Thus both carbofuran and phorate reduced the larval populations more in the sandy loam than in the black fen soil. Although, with similar doses, carbofuran was superior to phorate on the black fen soil, phorate was the more efficient (Wheatley, 1973, 1974) on the sandy loam at NVRS.

Table 2

Percentages (arc-sine transformation) of the total numbers of carrots undamaged by carrot fly and estimated effects of insecticides on numbers of carrot fly larvae in plots drilled with gels containing pre-germinated seed and granular formulations of carbofuran or phorate

Treatment		Mean % undamaged carrots (arc-sine transformation)	Mean estimated % red^n^ in relative no. larvae from untreated
Insecticide	Dose (mg a.i./15 cm row)		
NVRS (sandy loam)			
Untreated	-	13	-
Carbofuran	2.5	44	69.7
	5.0	54	81.5
	10.0	71	93.6
Phorate	2.5	68	93.6
	5.0	71	95.3
	10.0	88	99.7
L.S.D. P = 0.05 (48 D.F.)		8.5	
P = 0.01 (48 D.F.)		11.3	
Methwold (black fen soil)			
Untreated	-	23	-
Carbofuran	2.5	37	39.4
	5.0	43	55.7
	10.0	52	71.4
Phorate	2.5	32	26.8
	5.0	34	30.7
	10.0	39	45.5
L.S.D. P = 0.05 (48 D.F.)		5.7	
P = 0.01 (48 D.F.)		7.6	

Insecticide residues in seedlings and mature carrots Insecticide residue concentrations detected in carrots grown at NVRS are shown in Table 3 as means of those from three replicated plots. Total carbofuran residues comprise carbofuran and 3-hydroxycarbofuran, the latter being determined as both free and bound (glycoside) residues. Total phorate residues comprise phorate, phorate sulphoxide and phorate sulphone.

The residue concentrations in the seedlings and roots of mature carrots were generally proportionate to the applied dose, with no consistently significant differences ($P>0.05$) between the gels on either sampling occasion. Four weeks after drilling, the residue concentrations were greatest in the phorate-treated seedlings but, by harvest they had declined substantially. They were smallest in the carbofuran-treated carrots and those treated with the greatest dose contained only 0.21 mg/kg at harvest, less than the proposed FAO/WHO tolerance of 0.5 mg/kg (Anonymous, 1977). However, in the same experiment, the highest dose of phorate produced a mean residue of 0.72 mg/kg in mature carrots grown from seed drilled in

Laponite gel.

Table 3

Concentrations of total carbofuran and phorate residues in 4-week seedlings and roots of 26-week mature carrots from plots drilled in sandy loam at NVRS with gels containing pre-germinated seed and granular formulations of insecticides

Treatment		Mean insecticide conc$^{\underline{n}}$ (mg/kg)±S.D.			
Insecticide	Dose (mg a.i./15 cm row)	Polymer DP 433 gel		Laponite gel	
		Seedling carrots	Mature carrots	Seedling carrots	Mature carrots
Carbofuran	2.5	15.8±6.6	-	15.8±4.8	-
	5.0	16.5±4.4	-	17.4±2.8	-
	10.0	18.2±2.1	0.15±0.04	30.6±6.1	0.21±0.05
Phorate	2.5	292±68	0.15±0.02	503±94	0.15±0.01
	5.0	548±115	0.22±0.07	804±78	0.36±0.05
	10.0	994±196	0.46±0.15	911±126	0.72±0.09

DISCUSSION

The gels, one based on a natural hydrocolloid (Polymer DP 433) and the other on a mineral colloid (Laponite), presented an alien environment to the insecticides as the granular formulations tested were designed for direct placement in soil only. Although the two gels had no significant differential effects on the performance of the two insecticides, there were marked differences in the uptake by the plants of the insecticides from the gels. For example, the concentrations of residues of carbofuran in carrot seedlings were significantly smaller than those of phorate at a similar stage. These differences may have been caused by dissimilar rates of release of the a.i.'s from the respective granule bases followed by similar rates of uptake by the seedlings. Alternatively, they may have been due to differential rates of uptake of phorate and carbofuran by the pre-germinated seeds - a process determined to some extent by such factors as the lipoid/water partition coefficients of the insecticides and their metabolites (Suett, 1975). As treatment of soil with the commercially recommended dose of phorate during drilling of dry carrot seed is sometimes phytotoxic (Wheatley & Thompson, 1981), it is probably not surprising that the stands of plants in plots treated with the highest dose of this insecticide in sandy loam were reduced significantly. Although the total phorate residues, which were almost 1g/kg in surviving seedlings, were diluted subsequently as the carrots grew (Suett, 1971, 1974), the concentration of residues in mature roots was nevertheless more than that detected previously in maincrop carrots raised from dry seed in sandy loam following conventional bow-wave soil treatment with the commercially recommended dose of phorate (Suett, 1974).

Even slight amounts of carrot fly damage can reduce the value of a crop and, consequently, very high levels of control are demanded. It is instructive to compare the performance of the two insecticides evaluated in the experiments described in this paper with the specifications proposed by Wheatley & Thompson (1981) for treatments to control carrot fly on early, maincrop and late carrots. In their analysis of the performance of granular formulations of insecticides applied to carrots at drilling, they remarked on the discrepancy, which increased considerably as carrot harvest was delayed, between the observed and required efficiency of treatments, measured in terms of their effects on pest populations (Wheatley, 1973, 1974; Thompson & Wheatley, 1977). Even with early crops, the observed efficiency of the best conventional soil treatments was expected to be only about 86%, in contrast to the 94% required; on late crops, respective figures were 51 and 98%.

The failure of either insecticide to achieve more than 71% efficiency on the black fen soil was due probably to the strong adsorptive property of that soil which rendered a high proportion of the applied insecticide doses unavailable to the target organisms (Edwards, 1966; Guth et al, 1977). Although the incorporation of higher doses in the gels may achieve a greater reduction in the population of carrot fly larvae, and thus a greater proportion of undamaged carrots, it may however also increase the risk of undesirable phytotoxicity and unacceptable insecticide residues in harvested carrots. In contrast, on the sandy loam, the performance of carbofuran and phorate, especially with the highest dose tested, satisfied the requirements specified by Wheatley & Thompson (1981). It is likely that the degree of carrot fly control could be increased even further by the mid-season application of foliar insecticide treatments (Anonymous, 1973), although the use of these is limited by the undesirable accompanying increase in concentrations of insecticide residues in harvested roots (Suett, 1974, 1975, 1981).

The results reported in this paper support the concept of the incorporation of an insecticide into the gel used for drilling pre-germinated seed to control carrot fly on carrots grown in mineral soil. Further studies are needed on the behaviour and performance of other insecticide formulations incorporated alone, and with other pesticides, in gels, to explore more widely the potential of the method.

Acknowledgements

We thank Mrs C.E. Padbury and Mrs M.A. Simpson for assistance with the analyses of insecticide residues in carrots, Mr G.E.L. Morris for advice on the statistical analysis of some of the data and also those agrochemical companies which supplied the insecticides used in the experiments.

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CONTROL OF TWO SOIL-BORNE DISEASES OF TRANSPLANTED VEGETABLES BY INCORPORATION OF FUNGICIDES IN PEAT BLOCKS

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Summary The control of white rot and club root in transplanted onions and brassicas respectively by the inclusion of fungicides in the peat blocks was investigated. Iprodione, incorporated in the blocking compost (200 g a.i./m^3) or applied as a pre-transplanting drench (5 g a.i./m^2) gave good control of white rot. However, season-long control was not obtained consistently. For control of club root, benomyl was ineffective. Calomel incorporated in potting compost at 500 g a.i./m^3, though slightly phytotoxic to some brassica species, gave early season control of club root in cabbage.

Résumé On a examiné le contrôle possible du Sclerotium et de la hernie dans les oignons transplanté et brassicas grâce à l'utilisation de fongicides à l'intérieur des blocs de transplantation. L'iprodione incorporé au sein du terreau (200 g i.a./m^3) ou appliqué en aspersion avant transplantation (5 g i.a./m^2) s'est révélé efficace pour le contrôle du Sclerotium. Les résultats en ce qui concerne le contrôle efficace tout au long de la saison ne se sont cependant pas révélés efficaces de façon régulière. Le benomyl n'a pas été efficace pour le contrôle de la hernie. Du calomel incorporé dans le terreau de transplantation à dose de 500 g i.a./m^3, s'est révélé légèrement toxique sur certaines espèces de plantes mais efficace pour le contrôle de la hernie du choux en début de saison.

INTRODUCTION

Club root of brassicas (Plasmodiophora brassicae) and white rot of onions (Sclerotium cepivorum) are probably the most serious diseases of outdoor vegetables in the British Isles. Club root is particularly difficult to control, though the dipping of bare-rooted transplants in a preparation of pure calomel or of thiophanate methyl or benomyl has proved beneficial (Buczacki, 1973). There has been considerable improvement in the control of white rot with the use of iprodione as a seed treatment and as a basal spray (Entwistle and Munasinghe, 1980). The aim in all cases is to place a substantial quantity of fungicide in the root zone as a protectant. The recent developments in the use of peat blocks to raise seedlings for transplanting appear to offer a promising vehicle for transport of fungicides, as has been demonstrated for insecticides (Saynor and Davies, 1977). This paper reports on results obtained by the inclusion of fungicides in peat blocks.

METHODS AND MATERIALS

White rot trials were carried out in 1980 and 1981 with the onion cultivars Hyduro and Hyper respectively. Each year, the blocking compost consisted of moss peat and fen peat mixed 70 : 30 on a volume basis. The block size was 37 mm with 4 seeds sown per block. Blocking and sowing was done in late February, and transplanting in mid April in a naturally infested field. In 1980, iprodione (Rovral; 50% a.i.) was applied as a drench to the blocks just before transplanting. In 1981, incorporation of the fungicide in the blocking compost and application as a drench were tested. The doses are indicated in the tables of results. In the field, each plot consisted of 36 peat blocks and there were at least four replicates of each treatment. The incidence of white rot was recorded from May onwards and, in 1980, yields were taken in early September.

Club root trials were carried out in 1981 only. The blocking compost was moss peat and blocks were 43 mm. Cabbage cv. Derby Day, cauliflower cv. Nevada and Chinese cabbage cv. Michihili were sown in mid April and were planted out in mid May in soil naturally infested with club root. The fungicides calomel (pure product) and benomyl (Benlate; 50 % a.i.) were either incorporated in the blocking compost at 500 g a.i./m^3 or applied as a drench at 25 g a.i./4 l/m^2 before transplanting. Individual plots in the field consisted of 40 plants with six replicates of each treatment. Harvesting of plants and recording of club root was carried out in late June and in mid August.

RESULTS

White rot

The 1980 results are shown in Tables 1 and 2. None of the treatments was phytotoxic. Overground symptoms of white rot became apparent in mid May and visual assessments were made in late May and late June.

Table 1

Effect of iprodione applied as a drench (4 l/m^2) to peat blocks just prior to transplanting onions into white rot-infested field plots, 1980

Dose of iprodione (g a.i./m^2)	Estimates of white rot (% infection)		Harvested plants	
	Late May	Late June	Survival (%)	Yield (kg/plot)
0	35	68	38	5.4
1	16	37	73	9.9
2.5	20	23	68	10.5
5.0	7	16	86	14.6
10.0	4	17	81	13.2
20.0	6	12	89	14.2
LSD 5%	8.4	11.7	18.3	3.1

When plants were harvested in early September, the incidence of white rot on surviving plants was low; only % survival and yield were recorded. All doses of iprodione significantly reduced the incidence of white rot and increased plant survival and yield (Table 1). Doses of 5 g a.i./m^2 and higher gave better disease control and yields than 1 g a.i./m^2. Survival was not affected by dose. Table 2 indicates that, within the range of 1 to 8 l/m^2, the volume of the drench did not affect disease control or plant survival, though 4 and 8 l gave significantly higher yields than 1 l/m^2.

Table 2

Effect of different volumes used to drench peat blocks with iprodione (5 g a.i./m^2) just prior to transplanting into white rot-infested field plots (1980)

Volume of drench (l/m^2)	Estimates of white rot (% infection)		Harvested plants	
	Late May	Late June	Survival (%)	Yield (kg/plot)
0	29	56	41	6.8
1	12	26	78	11.2
2	8	19	83	12.0
4	13	23	90	14.6
8	7	20	87	14.0
LSD 5%	6.6	9.3	14.9	2.4

The 1981 results can be seen in Table 3.

Table 3

Effects of iprodione (a) incorporated into peat blocks, (b) applied as a drench, and (c) incorporated and applied as a drench (1981)

Treatment	Estimates of white rot (% infection)		
	Mid May	Late June	Late July
(a) Incorporated (g a.i./m^3 peat)			
200	3	8	69
100	7	12	94
50	4	11	78
25	7	19	87
(b) Applied as drench (g a.i./m^2 blocks)			
8	2	5	56
4	4	11	55
2	5	16	68
1	2	13	82
(c) Incorporation (g/m^3) + drench (g/m^2)			
200 + 4	2	4	51
100 + 4	0	7	46
50 + 4	7	11	72
25 + 4	2	9	75
Control (untreated)	24	53	96
LSD 5%	8.7	13.3	29.6

As in the previous year, the disease became evident during May. All treatments were equally effective in reducing the levels of white rot up to the end of June. The incidence of disease increased rapidly during July to almost 100% in untreated plots. In late July, only the highest two doses of the drench treatments and the highest two of the combined treatments gave significant disease control.

Club root

At the doses of incorporation used, benomyl was phytotoxic, causing severe stunting in cauliflower, moderate in cabbage and slight in Chinese cabbage; calomel was moderately toxic to cauliflower and slight to cabbage. The drench treatments were not phytotoxic. In the field, half of each plot was harvested in late June and the remainder in mid August and the incidence of club root is shown in Table 4.

Table 4

Effect on club root of calomel and benomyl incorporated into peat blocks or applied as a drench (4 l/m^2) just prior to transplanting cabbage cv. Derby Day, cauliflower cv. Nevada and Chinese cabbage cv. Michihili into club root infested field plots in 1981

	Club root infection (%)					
	Late June			Mid August		
	D.D.	N.	M.	D.D.	N.	M.
Incorporated (500 g a.i./m^3)						
Calomel	2	45	80	55	78	95
Benomyl	70	72	90	70	90	97
Applied as drench (25 g a.i./m^2)						
Calomel	55	57	82	55	86	97
Benomyl	47	75	97	57	97	100
Control (untreated)	84	97	98	81	95	97
LSD 5%	15.6	28.3	20.4	27.9	18.5	5.4

At the first harvest, incorporated calomel gave almost complete control of club root in cabbage and significant control in cauliflower. As a drench, calomel gave significant control in cabbage and cauliflower. Benomyl gave significant control only when applied as a drench on cabbage. None of the treatments had a significant effect on club root in Chinese cabbage at either harvest, or in any species at the second harvest.

DISCUSSION

The inclusion of fungicides in peat blocks has shown little promise in control of club root and has obvious limitations in the control of white rot. However, even in the case of club root, such inclusion may be warranted since alternative methods are not readily available. With relatively resistant species and a lower soil infestation, a lower dose of calomel may give a useful reduction or delay in infection without being phytotoxic.

While iprodione included in the peat blocks did not give season-long control of white rot in both years, it is probably a useful insurance against early attack in transplanted onions. Where inoculum potential is high, it may be desirable to follow up with a basal spray of iprodione later in the season. The results suggest that the drench method of application is at least as effective as incorporation and probably ensures a more even distribution of the fungicide.

Acknowledgements

Thanks are due to Messrs J. C. Cassidy, P. Marren and J. Tarpey for advice and assistance.

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Proceedings 1981 British Crop Protection Conference - Pests and Diseases

EFFECTS ON CARROT FLY LARVAE AND GROWTH OF CELERY OF SOME INSECTICIDE FORMULATIONS APPLIED TO PEAT BLOCKS USED FOR RAISING PLANTS

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Summary Granular formulations of insecticides were applied to peat blocks at a target dose of 20 mg a.i./block to control carrot fly on celery. Emulsifiable concentrate and w.p. formulations were applied to give target doses of 10 mg a.i./block. A granular formulation of fonofos gave outstanding control of the pest. Granules containing disulfoton, phorate or chlorfenvinphos were also effective, but less so than fonofos. Of the insecticides applied as liquids, only chlorfenvinphos protected the crop from attack. Chlorpyrifos was highly phytotoxic whenever it was used. Plants were severely damaged when chlorfenvinphos liquid was applied in a heated glasshouse, but were unaffected when treated in cool conditions. Analyses of residues of carbofuran, chlorfenvinphos, chlorpyrifos, diazinon, disulfoton, fonofos, iodofenphos, omethoate, phorate, pirimiphos-methyl and triazophos detected in mature plants are given and the convenience and safety of several methods of insecticide application are discussed.

INTRODUCTION

In Britain, commercially grown celery requires routine insecticidal treatment to prevent damage to petioles and roots by the larvae of carrot fly (Psila rosae) (Bevan, 1966; Anon. 1979). Most celery seedlings are raised under glass and many are now grown-on in peat blocks for subsequent transplanting in the field.

Reduced infestations of some insect pests on brassicas and lettuce following incorporation of insecticides in peat blocks have been reported (Saynor and Davies, 1977; Thompson and Percivall, 1978) and Bevan (1966) showed that some insecticides reduced carrot fly damage to celery when applied in this way. However, in the UK, no insecticide has yet received commercial clearance under the MAFF Pesticide Safety Precautions Scheme for use on block-raised celery. Some currently available insecticides, incorporated into peat blocks, may protect celery from carrot fly. This method of application could also decrease the amount of insecticide applied to the crop in comparison with that used in conventional soil treatments. Seventeen insecticide formulations were therefore evaluated in 1978-80. Trials were done to evaluate the phytotoxicity and effectiveness against carrot fly of the insecticides applied by several methods to block-raised celery seedlings. Results obtained are summarised in this paper and the convenience of the various methods for plant-raisers and growers is also considered. The potential of block-treatment for control of carrot fly on celery is discussed.

MATERIALS AND METHODS

For all trials, Fisons blocking peat was moistened in a Horti-tool mixer and 3.5 cm^3 blocks were made with a Horti-tool bulk-blocking machine. Celery seedlings were transplanted into the blocks which were maintained under glass until planted out 25 cm apart with 30 cm between rows in peat soils at four sites in Cambridgeshire. All trials included plants grown in blocks without insecticide treatment for assessment of insecticide performance.

Trials 1-3 (1978). The peat blocks were hand-planted at two sites: Mepal and Feltwell. Treatments were replicated in three randomised blocks and each plot consisted of one row of 20 plants.

For trial 1, granular formulations of seven insecticides were mixed into dry peat, prior to blocking, to give a target dose of 20 mg a.i./block. Insecticides evaluated were carbofuran (Yaltox; 5% a.i.), chlorfenvinphos (Birlane Granules; 10% a.i.), chlorpyrifos (Dursban 5G; 5% a.i.), diazinon (Basudin 5G; 5% a.i.), disulfoton (Disyston FE-10; 10% a.i.), fonofos (Dyfonate Granules; 10% a.i.) and phorate (Campbells Phorate; 10% a.i.). For trial 2, the same formulations were applied on to the top of the peat blocks immediately prior to planting-out to give a target dose of 20 mg a.i./block. In addition to the formulations used in trial 1, triazophos (Hostathion Granules; 10% a.i.) was included. In trial 3, the trays of peat blocks were sprayed with the nine insecticide formulations immediately prior to planting-out to give a target dose of 10 mg a.i. in 3 ml water/block. Insecticides evaluated were e.c. formulations of chlorfenvinphos (Birlane 24; 24% a.i.), chlorpyrifos (Dursban 48E; 48% a.i.), etrimphos (Ekamet; 50% a.i.), omethoate (Folimat; 57.5% a.i.), pirimiphos-methyl (Blex; 50% a.i.) and triazophos (Hostathion; 40% a.i.) and w.p. formulations of bendicocarb (Garvox 80W; 80% a.i.), diazinon (Basudin 40 WP; 40% a.i.) and iodofenphos (Elocril 50 WP; 50% a.i.).

Trial 4 (1979). The nine most promising treatments from the previous year were applied to give target doses similar to those used before. Insecticide formulations evaluated, all described previously, included granular formulations of chlorfenvinphos, diazinon, disulfoton, fonofos, phorate and triazophos, e.c. formulations of chlorfenvinphos and triazophos and a w.p. formulation of diazinon. The treated peat blocks were planted out at two sites: Barway and Soham. Treatments were replicated three times in a randomised block design. Plots, each containing 340 plants in five rows, were planted out by farm staff in tractor-drawn, custom-built, enclosed planting machines, each fitted with 10 Accord planter units. The staff were asked to comment on any odours detected from the treated blocks during planting.

Trials 5 and 6 (1980). For trial 5, 59,500 plants in 350 trays were sprayed 4-5 days before planting with the e.c. formulation of chlorfenvinphos to give a target dose of 10 mg a.i./block. Trays of treated plants were maintained in a glasshouse until 8,500 blocks were planted out in 0.3 ha at Barway using a planting machine as described for trial 4.

For trial 6, 350 plants were treated as in trial 5. Another 680 plants were immersed for 20 s in an aqueous emulsion of chlorfenvinphos containing enough a.i. to give a target dose of 10 mg a.i./block. These plants were maintained in a glasshouse or cold frame (Table 4) until they were hand-planted at Mepal in unreplicated plots of 80 plants arranged in two rows.

Biological assessments. In all trials, plants were inspected at intervals during the growing season for phytotoxicity. Symptoms were recorded and, where necessary, plants were measured. For trials 1-3, the 20 plants in each plot were harvested when mature and weighed. The numbers of plants with carrot fly damage were counted. For trial 4, 25 plants from each plot were weighed and assessed for carrot fly damage. In trials 5 and 6, 10 plants from each of 5 randomly selected lengths of row for each treatment were measured, weighed and assessed for carrot fly damage.

Assessments of insecticide residues. For trials 1-3, 20 plants were selected at random from each treatment and were submitted to ADAS Pesticides Residues Unit, Cambridge for analysis. For trial 4, the insecticides which had shown most activity against carrot fly in trials 1-3 and the granular formulation of triazophos which had the highest residue in trial 2 were retested.

The extractant used for chlorfenvinphos was a 50/50 acetone/hexane mixture with alumina clean-up. Chlorpyrifos, disulfoton, fonofos, phorate and triazophos were extracted in chloroform/methanol, evaporated to dryness and then taken up in hexane, with Florisil clean-up. Diazinon was extracted in ethyl acetate with Florisil clean-up. Iodofenphos, omethoate and pirimiphos-methyl were extracted in methanol, partitioned with dichloromethane, evaporated to dryness and taken up in hexane with Florisil clean-up. All analyses were by gas liquid chromatography using a phosphorus detector.

Residues of carbofuran were extracted with acetonitrile. The extracts were then washed with sodium chloride solution and petroleum ether and the carbofuran residues were partitioned into dichloromethane. The extracts were further purified by coagulation with ammonium chloride and phosphoric acid. Carbofuran was derivatised with dinitrofluorobenzene and residues determined by gas liquid chromatography, using a column of 4% SE30 + 6% QF1 on Gas Chrom Q and electron capture detection.

RESULTS

Phytotoxicity and yields. In all trials, chlorpyrifos was phytotoxic with all methods of application. All celery seedlings died when transplanted into blocks containing chlorpyrifos (Table 1). When chlorpyrifos was applied to peat blocks immediately prior to planting-out, many plants were killed and the growth of others was retarded. A few survivors grew to marketable size and quality (Tables 2 and 3).

Table 1

Effect on plant yield and carrot fly damage of granular formulations of insecticides incorporated in peat blocks used for raising celery: Trial 1 (1978)

Insecticide	Mean plant yield (kg/plot)		Mean % damaged roots
	Mepal	Feltwell	Feltwell
Untreated	20.5	16.8	68.9
Carbofuran	22.8	16.9	23.6*
Chlorfenvinphos	29.4	27.9	22.7**
Chlorpyrifos	0.0***	0.0***	-
Diazinon	27.3	23.0	56.1
Disulfoton	31.1	25.3	11.7***
Fonofos	29.4	29.6	9.4***
Phorate	29.3	26.9	19.4**
SED between any two treatments (≠ = after log transformation of % values)	± 2.30	± 2.41	± 5.37≠

*, **, *** values significantly different from untreated at P = 0.05, 0.01 and 0.001 respectively.

Table 2

Effects on plant yield and carrot fly damage of granular formulations of insecticides applied to the top of peat blocks used for raising celery: Trial 2 (1978)

Insecticide	Mean plant yield (kg/plot)		Mean % damaged roots
	Mepal	Feltwell	Feltwell
Untreated	21.8	27.0	77.7
Carbofuran	21.0	21.0	46.1*
Chlorfenvinphos	26.7	23.1	17.3**
Chlorpyrifos	11.2*	13.7***	33.8*
Diazinon	21.6	21.5	69.5
Disulfoton	23.8	24.6	18.0**
Fonofos	20.7	24.9	11.3***
Phorate	24.4	22.0	22.8**
Triazophos	27.2	25.7	60.2
SED between any two treatments (⌿ = after log transformation of % values)	± 2.21	± 1.91	± 7.14⌿

*, **, *** values significantly different from untreated at P = 0.05, 0.01 and 0.001 respectively

Table 3

Effects on plant yield and carrot fly damage of insecticides sprayed on to peat blocks containing celery plants: Trial 3 (1978)

Insecticide/Formulation	Mean plant yield (kg/plot)		Mean % damaged roots
	Mepal	Feltwell	Feltwell
Untreated	19.7	19.5	82.6
Emulsifiable concentrate			
Chlorfenvinphos	26.2	23.0	26.3*
Chlorpyrifos	9.3**	10.8**	51.9
Etrimphos	22.6	20.8	64.8
Omethoate	23.0	22.9	78.9
Pirimiphos-methyl	24.3	22.3	88.9
Triazophos	27.1	20.8	54.2
Wettable powder			
Bendiocarb	20.7	14.9	61.5
Diazinon	25.6	21.3	69.3
Iodofenphos	27.8	23.4	82.6
SED between any two treatments (⌿ = after log transformation of % values)	± 1.87	± 2.06	± 8.95⌿

*, **, values significantly different from untreated at P = 0.05 and 0.01 respectively

In 1979, none of the treatments was phytotoxic but mean yields of treated plants at Barway and Soham were not significantly different from those of plants grown in untreated peat blocks (P = 0.05). In 1980 (trials 5 and 6), plants sprayed with chlorfenvinphos developed overall chlorosis and necrotic growing points and the youngest leaves became distorted. They subsequently grew poorly (Table 4). Plants treated in the open did not develop phytotoxic symptoms and grew normally. Immersion of seedlings in the aqueous chlorfenvinphos emulsion produced transient chlorosis after which the plants established well (Table 4).

Yields were good at all sites except in trial 6 where late planting and inadequate irrigation retarded plant growth (Table 4).

Table 4

Types of treatment with chlorfevninphos e.c. and locations of peat blocks, with the height and yield of celery plants produced: Trials 5 and 6 (1980)

Treatment	Locations		Mean plant height (cm)	Mean yield (kg/10 plants)
	Treated	Maintained		
Trial 5				
Untreated	-	Glasshouse	62.4	16.8
Sprayed	Glasshouse	Glasshouse	49.7	12.6
Trial 6				
Untreated	-	Coldframe	24.5	3.4
Sprayed	Glasshouse	Coldframe	21.0	2.8
Sprayed	Open	Coldframe	28.5	5.1
Immersed	Open	Coldframe	29.5	5.0
Untreated	-	Glasshouse	26.0	3.9
Sprayed	Glasshouse	Glasshouse	22.0	3.1
Sprayed	Open	Glasshouse	26.7	4.6
Immersed	Open	Glasshouse	27.7	4.6

Control of carrot fly. A severe carrot fly attack developed at Feltwell only, in autumn 1978, with second generation carrot fly larvae tunnelling and discolouring the outer petioles. The granular formulation of fonofos consistently gave outstanding control when incorporated into blocks or applied over the top (Tables 1 and 2). Granules containing disulfoton, phorate or chlorfenvinphos were also effective when applied by either method, but less so than fonofos. Carbofuran gave some control; granules containing triazophos or diazinon were almost ineffective. Of the liquid formulations tested at Feltwell, only chlorfenvinphos protected the plants significantly from attack (Table 3).

A few plants in trial 4 at Soham were lightly attacked by carrot fly in 1979 but the incidence of damage was too low to justify statistical tests. No carrot fly damage was detected in any other trials.

Insecticide residues. Residues detected in mature celery from trials 1-4 in 1978/79 (Table 5) were generally within the Recommended International Maximum Limits (Codex) set for these insecticides or, where such limits have not yet been set, for similar chemicals.

Table 5

Concentrations of insecticide residues (mg/kg) in mature celery plants following treatment of peat blocks used for raising plants: Trials 1-4 (1978-9)

Insecticide/Formulation	Insecticide conc$^{\underline{n}}$ (mg/kg)			
	Trial 1	Trial 2	Trial 3	Trial 4
Granules				
Carbofuran	ND	0.001	-	-
Chlorfenvinphos	0.020	0.200	-	0.070
Chlorpyrifos	-	0.025	-	-
Diazinon	0.015	0.130	-	-
Disulfoton*	ND	0.010	-	0.030
Fonofos	0.160	0.050	-	0.040
Phorate*	0.015	0.040	-	-
Triazophos	-	0.500	-	0.580
Emulsifiable concentrate				
Chlorfenvinphos	-	-	0.080	0.060
Chlorpyrifos	-	-	0.015	-
Omethoate	-	-	0.020	-
Pirimiphos-methyl	-	-	0.004	-
Triazophos	-	-	0.025	-
Wettable powder				
Diazinon	-	-	0.020	-
Iodofenphos	-	-	ND	-

* = Total metabolites including sulphoxide and sulphone
ND = not detected at detection limits of 0.001-0.004 mg/kg

DISCUSSION

Carrot fly damage to celery usually commences soon after planting. However, the severe infestation at Feltwell in 1978 developed at least 14 weeks after the insecticides were applied to the peat blocks used for raising the plants. None of the treatments suppressed the attack entirely but the lack of complete control of this late generation attack by treatments applied at or before transplanting was not unexpected.

Results from the trials described in this paper indicate that carrot fly damage to celery can be reduced by some insecticide formulations applied to peat blocks. Incorporation of granular formulations into dry peat prior to blocking is a convenient method which distributes granules relatively uniformly among the blocks (Suett and Padbury, 1978). However, as the insecticides are applied some weeks before the crop is planted out, the insecticides may lose some efficacy before carrot fly attacks develop. Furthermore, the blocks are maintained in glasshouses where high temperatures may accelerate decomposition of insecticides and production of odours. In trial 4, nursery and farm staff found these odours unacceptable and this method of treatment was therefore discontinued after 1978.

The placement of granules on top of blocks, immediately prior to planting out, has several advantages over incorporation. For example, treatments applied when seedlings were established in the blocks were generally less phytotoxic than those applied to younger plants. Decomposition or leaching of insecticides are unlikely to be extensive before carrot fly attacks begin. Because blocks may be treated either when they leave the nursery or after arrival at the farm, the difficulty with odours in glasshouses does not arise. However, odours are stronger in the planting machine, the granules are distributed less evenly between the blocks and some may be dislodged when blocks are handled for planting. A further problem in development work with block-raised plants is that standard block sizes or shapes have not yet been established for any crop. A treatment that is satisfactory in a block of one size may prove ineffective in a larger block and phytotoxic in a smaller one. For these reasons, evaluation of granules was discontinued after 1979 in favour of sprays applied to the trays of blocks before planting out.

Field staff did not object to the smell of the spray formulations and application was quick and convenient. The phytotoxicity of chlorfenvinphos in 1980, caused probably by high temperatures in the glasshouse where the insecticide was applied, was disappointing since this treatment was applied on four previous occasions in trials 3 and 4 with no observable symptoms of phytotoxicity and with good yields. Further evaluation of this method and also of the tray-immersion technique is needed. The latter technique could provide the basis for a crop protection system implemented at the propagating nursery. Palleted trays of celery plants might be driven through a tank of insecticide prior to loading onto trailers for delivery to the farm. This method would eliminate the risk of phytotoxicity in high temperatures and of insecticidal contamination of glasshouse soils used for the growing of other crops. However, the persistence, disposal and safety of the large volumes of insecticide needed for this type of treatment would have to be investigated in detail.

Acknowledgements

I thank R. Gair for helpful criticism at all stages and M. Arber of Whittlesey for the use of block-making and plant-raising facilities.

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NOTES

SESSION 8A

PEST AND DISEASE CONTROL IN FIELD CROPS (II)

Proceedings 1981 British Crop Protection Conference - Pests and Diseases

DISEASES OF WINTER OILSEED RAPE AND THEIR CONTROL, EAST AND SOUTH-EAST ENGLAND, 1977-81

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Summary Surveys showed that stem canker (Leptosphaeria maculans) was widespread and often severe in 1977 and 1978. Since 1978 this disease has been less of a problem following the introduction of more resistant cultivars. In field trials a range of fungicides were inconsistent in controlling stem canker, while autumn, spring and autumn + spring sprays of benomyl (0.55 kg a.i./ha) failed to produce an economic yield response. Dark leaf and pod spot (Alternaria brassicae) has increased since 1978. Leaf infection was shown to be more common in early (i.e. August) sown crops. Petal fall sprays of iprodione (0.50 kg a.i./ha) were very effective in protecting pods against Alternaria. At severely infected sites this led to a delay in senescence and yield increases of up to 22%.

Résumé Les études effectuées ont démontré que les taches brunes (Leptosphaeria maculans) étaient répandues et souvent d'une importance grave en 1977 et 1978. Depuis 1978, cette maladie constitue un problème de moindre importance par suite de l'introduction de cultivars plus résistants. Lors des essais sur le terrain, toute une gamme de fongicides s'est avérée inefficace pour la lutte contre les taches brunes, tandis que des traitements par pulvérisation du bénomyl en automne, au printemps, et en automne et puis au printemps (0.55 kg de p.a./ha) n'ont pas abouti à un rendement rentable compte tenu du coût des traitements. L'incidence de l'alternariose (Alternaria brassicae) a augmenté depuis 1978. L'infection foliaire s'est révélée plus sévère chez les cultures de semis précoce, c'est-à-dire celles semées en août. Les traitements par pulvérisation d'iprodione réalisés à l'époque de la chute des pétales (0.50 kg de p.a./ha) protégeaient les cosses très efficacement contre Alternaria. Aux sites où l'infection était sévère, ces traitements provoquaient un ralentissement de la sénescence et des augmentations de rendement s'élevant jusqu'à 22%.

INTRODUCTION

A.D.A.S. have monitored crops of winter oilseed rape (Brassica napus L spp. oleifera) for diseases since 1976. Early surveys in East and South-east England (Cook and Evans, 1978, Gladders and Musa, 1979) indicated the importance of stem canker (Leptosphaeria maculans, asexual stage Phoma lingam). This paper describes (a) further survey work in these areas between 1977 and 1981, a period when the area of oilseed rape grown in England and Wales increased from 24,500 ha to an estimated 120,000 ha (Anon, 1978-1981), and (b) field trials designed to attempt fungicidal control of stem canker and dark leaf and pod spot (Alternaria brassicae).

METHODS AND MATERIALS

Disease surveys

Crops of winter oilseed rape in East and South-east England were visited; 25 (E, 1978-81; S.E., 1981) or 50 plants were collected at random from each for disease assessment. The total number of crops surveyed each season ranged between 49 and 67. Crops were sampled at (a) green bud (G.S. 3.1-3.3) or early flowering (G.S.4.1) and (b) pod-ripening - harvest (G.S. 5.3-5.5). Growth stages were identified using the key suggested by Harper and Berkenkamp (1975). The incidence and severity of diseases were determined on a whole plant basis using the following keys:

leaf diseases - 0 - no infection, I - scattered lesions, 10% or less leaf and bract infection, 2 - >10-25%, 3 - >25-50%, 4 - >50-75% and 5 - >75%;
stem diseases - severity of canker on the stem base (lower 15 cm) was assessed as 0 - no infection, I - slight, lesion(s) encircling less than half the stem, 2 - moderate, lesion(s) encircling at least half the stem, 3 - severe, lesion(s) girdling the stem;
pod diseases - 0 - no infection, I - 1% or less pod and stem area infection, 2 - >1-5%, 3 - >5-10%, 4 - >10-25%, 5 - >25%.

Disease severity was expressed as a mean disease index (M.D.I.) for each crop.

Fungicide trials

i) fungicide comparison - a wide range of fungicides were evaluated for control of stem canker (1978-80). These included benomyl (0.55 kg a.i./ha), captafol (1.75 kg a.i./ha), imazalil (200 ml a.i./ha), iprodione (0.50 kg a.i./ha), thiabendazole (0.56kg a.i./ha), triadimefon + carbendazim (0.125 + 0.25 kg a.i./ha) and vinclozolin (1.00 kg a.i./ha). Sprays were applied by knapsack sprayer (667 l.water/ha) in November and again in late March - early April (except at Site 1, sprayed 6 March and 30 April).

ii) fungicide timing - autumn (November, G.S. 2.4-2.6), spring (March, G.S. 3.1-3.3) and autumn + spring sprays of benomyl (0.55 kg a.i./ha) were assessed for their effect on stem canker and yield. Sprays were applied by knapsack sprayer (500 l.water/ha).

iii) fungicides for control of *Alternaria* - sprays of iprodione 0.50 kg a.i./ha) were applied at or up to 7 days after 95% petal fall. Iprodione was applied either by tractor mounted hydraulic equipment or by knapsack sprayer (330 l.water/ha). In 1980 a 50% w.p. was used, in 1981 this was replaced by a 25% e.c. formulation.

Detailed assessment of pod infection was carried out using a method devised by Humpherson-Jones (pers. comm.). A single raceme was collected from the top, middle and bottom of the crop canopy at each of 10 sites/plot. Stripped pods from each height were kept separate, and 100/ sampling height assessed. The area of each pod blackened by *Alternaria* was allocated a rating:- 0 - healthy (a), I - <10% blackened (b), 2 - >10-25% (c), 3 - >25-50% (d), 4 - >50% (e). A disease severity index was calculated using the formula

$$\text{D.S.I.} = \frac{b + 2c + 3d + 4e}{4\,(a + b + c + d + e)}$$

All fungicide trials were of a randomised block design (4 replicates/treatment). Plots were swathed or direct combined as per farm practice.

RESULTS

The incidence of diseases at the green bud stage and at pod ripening/harvest is illustrated in Fig.1. Downy mildew (*Peronospora parasitica*) was widespread in the spring most seasons. Light leaf spot (*Pseudopeziza brassicae*, asexual stage *Cylindrosporium concentricum*) was more erratic in its occurrence. Although this disease was of generally low incidence in 1980 it caused concern when high levels of infection were recorded in four crops of cv. Jet Neuf. Primor and Rapora suffered from severe stem canker in 1977 and 1978. Levels of infection declined following the introduction of the more resistant Jet Neuf and Rafal (Table 1).

Table 1

Incidence and severity of *Phoma* stem canker at pod ripening/harvest, East (E) and South-east (SE) England, 1977/81

Harvest year	Main cultivars	Mean % plants infected E.	 S.E.	Mean disease index E.	 S.E.
1977	Primor/Rapora	76	87	1.56	1.80
1978	Primor/Rapora	73	86	1.61	1.66
1979	Jet Neuf/Quinta	38	10	0.53	0.13
1980	Jet Neuf/Rafal	45	22	0.30	0.29
1981	Jet Neuf/Rafal	32	12	0.36	0.15

Alternaria dark leaf and pod spot first became a problem in the South-east in 1979. Unlike stem canker the incidence of *Alternaria* leaf spot was no higher in crops near to the previous years rape stubble than in those distant from it. Higher levels of infection were recorded however, in the earlier sown crops (Table 2). Severity of pod infection was not related to sowing date.

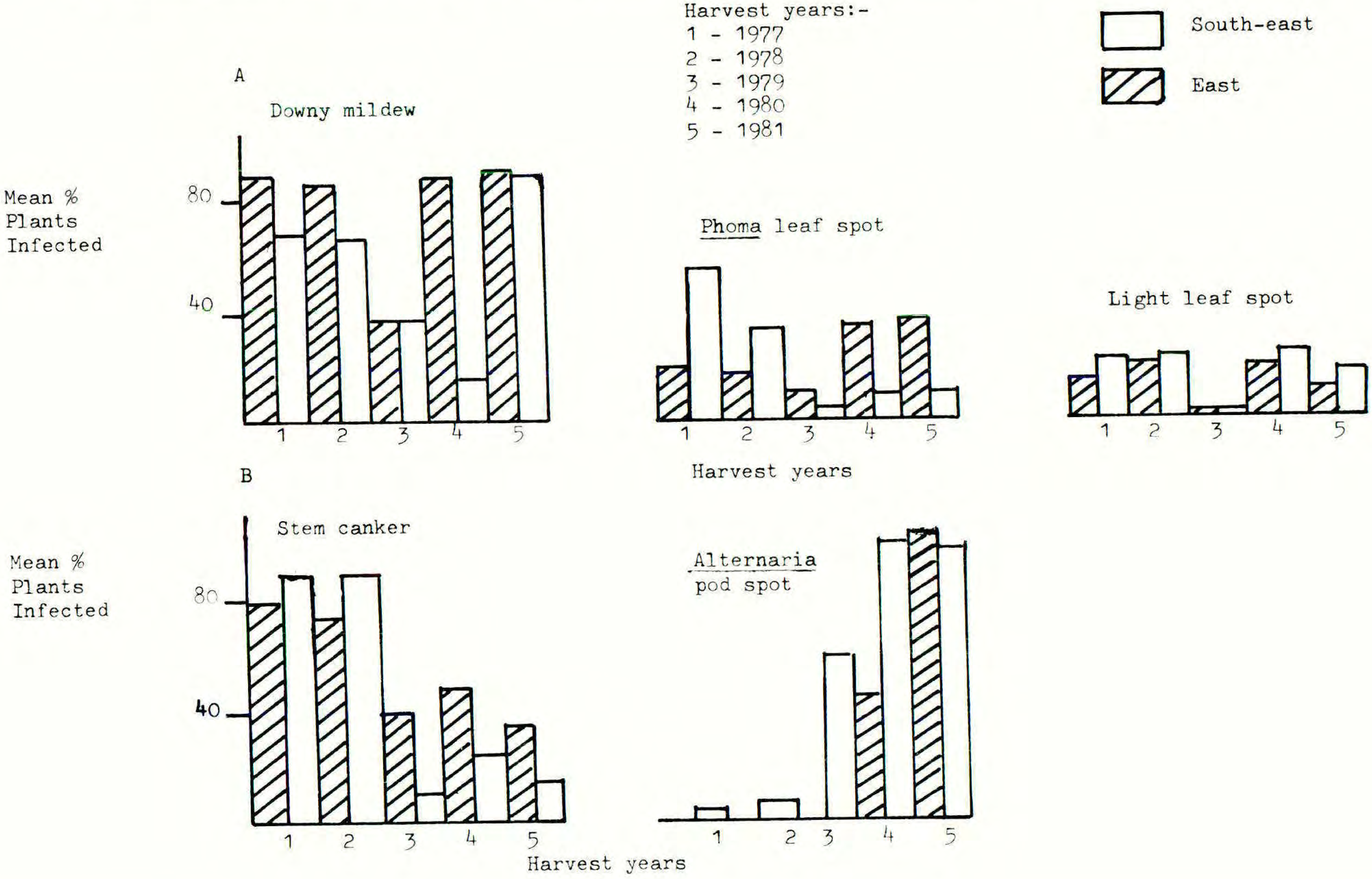
Table 2

Influence of sowing date on the incidence of *Alternaria* leaf spot at green bud, East (E) and South-east (SE) England 1980/81

	Mean % plants infected			
	1980		1981	
Sowing date	E.	S.E.	E.	S.E.
Before 21 Aug.	-	-	75.3	42.4
21-31 Aug	56.4	49.3	56.3	53.3
After 31 Aug.	21.2	18.4	39.3	30.8

Fig. 1

The incidence of diseases at green bud/early flowering (A) and at pod-ripening/harvest (B), 1977-81



Low levels of stem rot (Sclerotinia sclerotiorum) infection were present in the South-east in 1979 and 1980 but club root (Plasmodiophora brassicae) was not a problem in surveyed crops.

The effect of fungicides on Phoma leaf spot and stem canker is shown in Table 3.

Table 3

Effect of fungicides on the incidence of Phoma leaf spot (L) and stem canker (S) of winter oilseed rape, 1978/80

	1		2	3		4	
Cultivar (Primor-P Jet Neuf-JN)	1978-79			1979-80			
	P		P	JN		JN	
	% Plants infected:-						
Treatment	L.	S.	S.	L.	S.	L.	S.
Benomyl	41.3	17.3	2.7	37.0	25.4	37.0	10.7
Captafol	38.7	12.0	6.7	60.0	18.7	33.0	20.0
Imazalil	50.7	22.7	0	50.0	16.0	60.0	4.0
Iprodione	38.7	8.0	5.3	43.0	18.7	57.0	16.0
Thiabendazole	22.7	28.0	1.3	60.0	16.0	37.0	9.3
Triadimefon + carbendazim	41.3	2.7	5.3	57.0	16.0	30.0	21.3
Vinclozolin	25.3	8.0	2.7	40.0	18.7	37.0	16.0
Untreated	21.7	28.0	10.7	47.0	28.0	23.0	24.0
S.E.	± 6.07	± 7.03	±2.19	±7.01	±4.38	±8.33	±6.81

At Site 2 Phoma incidence was low but most fungicides reduced levels of stem canker; this did not occur elsewhere. Observations on other foliar diseases indicated that benomyl gave the best control of light leaf spot while iprodione, imazalil and vinclozolin were most effective against Alternaria.

In seven trials sprays of benomyl at different timings had little effect on low levels of stem canker or on yield (Table 4) of cvs. Primor and Jet Neuf.

Table 4

Effect of benomyl on yield (t/ha) of winter oilseed rape 1978-80

Treatment	Yield (t/ha)
Benomyl:-	
autumn (Oct/Dec)	2.66
spring (Mar/Apr)	2.65
autumn + spring	2.75
untreated	2.62

In 1981 a single spray of iprodione applied at 95% petal fall gave a very effective and persistent control of Alternaria pod spot (Table 5).

Table 5

Effect of a petal fall spray of iprodione on the control of Alternaria pod spot of winter oilseed rape (cv. Jet Neuf) 1981

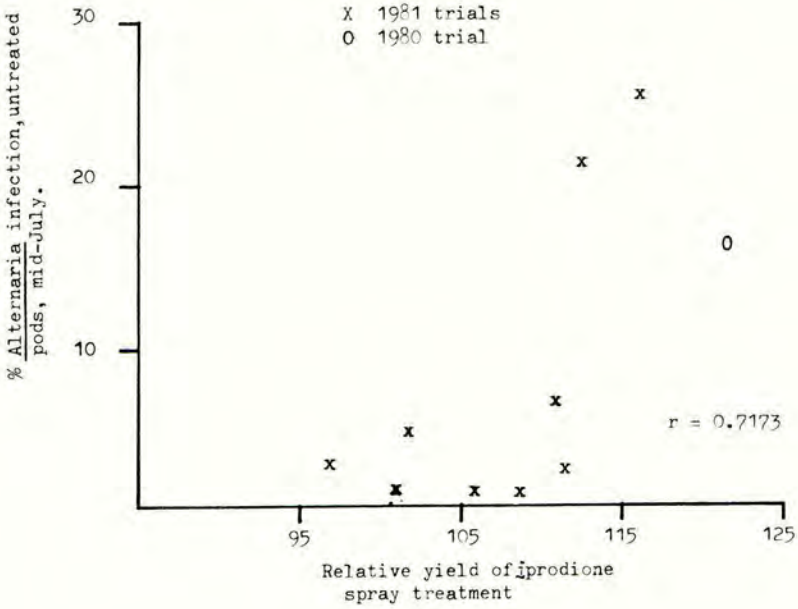
Treatment	Disease severity index top pods	 middle pods	 bottom pods
Untreated	0.24	0.30	0.31
Iprodione	0.08 **	0.13 **	0.13 **

Assessments on 6 July (36 days after spraying)
Significantly greater than untreated at P = 0.01**

Disease control at this and other severely infected sites tended to increase yield (**Fig.** 2) although responses were only significantly greater (P=0.05) than the control in two trials. Fungicide treatment had an inconsistent effect on oil content of harvested seed.

Fig. 2

Effect of controlling Alternaria pod spot on relative yield (untreated = 100), 1980-81



DISCUSSION

Survey work confirmed that stem canker was widespread in East and South-east England and that the more resistant cultivars Jet Neuf and Rafal provided useful control.

In fungicide trials only low levels of stem canker were recorded on cv. Primor during 1978-79. This occurred because dry weather in October 1978 reduced the release of ascospores of L.maculans (Gladders and Musa, 1979). Nevertheless at one site a number of fungicides reduced incidence of the disease at harvest. In 1979-80 trials on cv. Jet Neuf sprays gave little control of Phoma leaf spot and only imazalil at one site significantly reduced stem canker. Further trials with benomyl confirmed the findings of Brown et al in Australia that sprays of this fungicide are relatively ineffective in controlling stem canker on oilseed rape.

With the continued reliance on genetic resistance it is as well to remember that present cultivars are not immune to stem canker. Within days of cutting a crop mycelium spreads from often superficial cankers, perithecia soon developing on colonised tissues. To minimise carry-over of Phoma in this way and to reduce the risk of new strains developing rape stubble should be ploughed under as soon as is practicable after harvest and certainly before emergence of the next seasons autumn sown crop.

The survey results confirm that Alternaria dark leaf and pod spot has become a major problem since 1979. Currently grown cultivars are very susceptible and build-up appears to be favoured by earlier sowing. Humpherson - Jones and Maude (1981) achieved good control of Alternaria brassicicola on seed crops of Brassica oleracea with sprays of iprodione. In A.D.A.S. trials single sprays of the same fungicide applied at 95% petal fall effectively controlled P.brassicae in 1981. In South-east trials levels of P.brassicae were significantly less on iprodione treated than on untreated pods 5 weeks after spraying. Similar control is reported by Cox et al (1981). Control at severely infected sites increased yield by 11-22%. It is likely that at some sites yield figures underestimate the benefits of Alternaria control as plots were harvested when the untreated were ripe but the sprayed not yet at that stage. Differential harvesting is planned for 1981-82 trials.

In the South-east survey 40% of crops had been sprayed with iprodione in 1981. Sprays were applied over a period of a month (1-29 June). Levels of infection in mid-July were significantly less in crops sprayed at petal fall, 1-7 June (M.D.I. - 0.78) than in those treated later (M.D.I. - 2.41). Trials work should be continued on the timing of sprays for control of Alternaria on oilseed rape. Future experiments should take into account the possibility that two sprays may be necessary to obtain acceptable control in some seasons.

Acknowledgements

We wish to thank all the farmers who co-operated in the disease surveys and provided sites for field trials. We are indebted to A.D.A.S. colleagues for their assistance in this work, particularly Messrs. P Bowerman, P B Harris, J H Hawkins and Dr J M L Davies for permission to include their unpublished results in this paper. We are also grateful to Dr F M Humpherson-Jones for useful discussion of assessment methods for Alternaria.

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Proceedings 1981 British Crop Protection Conference - Pests and Diseases

THE CONTROL OF ALTERNARIA BRASSICAE AND SCLEROTINIA SCLEROTIORUM ON OILSEED RAPE WITH IPRODIONE

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Summary A single spray application of iprodione at 0.5 kg ai/ha, as either a wettable powder or flowable formulation made at the early pod stage prevented premature pod shatter caused by Alternaria brassicae in winter oilseed rape. Trials involved both small plot replicated and larger farmer applied plots in U.K. and France. Control was obtained with MV sprays and with volumes as low as 22 l/ha applied by aircraft. The superiority of the flowable formulation of iprodione, compared with a wettable powder, was generally demonstrated. Seed yield was increased up to 20% in treated crops and disease presence on harvested seed reduced. Little effect on oil content of treated seed was found.

Independently-organised trials have indicated that iprodione is also highly effective against Sclerotinia sclerotiorum in addition to its proven activity against Botrytis cinerea.

Résumé Au stade de la formation des jeunes siliques, une pulvérisation d'iprodione à la dose de 0.5 kg m.a./ha, soit en poudre mouillable, soit en crème fluide, a bien empéché l'éclatement des siliques du colza d'hiver provoqué par Alternaria brassicae. Les essais ont été réalisés dans le Royaume Uni et en France, tant sur petites parcelles répliquées, que sur grandes parcelles où les applications étaient faites par les fermiers. Des pulvérisations à moyen et bas volumes, la dose étant réduite à 22 l/ha en application aérienne, ont donné de bons résultats. Ceux obtenus avec la crème fluide se situaient, d'une facon générale, au-dessus de ceux obtenus avec la poudre mouillable. Les traitements ont, à la fois, augmenté les rendements jusqu'à 20% et réduit la contamination des semences par A. brassicae. La teneur en huile des semences n'a pas été affectée.

Des essais indépendants ont montré que l'iprodione, en plus de son activité bien établie contre Botrytis cinerea, est aussi tres efficace contre Sclerotinia sclerotiorum.

INTRODUCTION

Dark leaf spot, Alternaria brassicae has become a serious problem in brassica seed production crops in the U.K. Although the primary cause of the symptoms in the past has been due to the related A. brassicicola, all experimental cabbage seed crops at the National Vegetable Research Station (N.V.R.S.) in 1980 were found to be infected with A. brassicae. Increase in incidence of this disease was attributed to the presence of diseased oilseed rape crops growing nearby (Humpherson-Jones et al 1981).

Recent surveys of diseases of winter oilseed rape in the U.K. indicate an increase in the incidence of A. brassicae in Southern England during the past two years (Evans & Gladders 1981). This fungus is already highly significant on oilseed rape in France where it is said to produce serious yield losses, (Messeliere 1981).

Although the seed-borne phase causes little effect on seedling emergence (Richardson 1970), the disease can be transmitted from seed to seedling. Infection can later spread to leaves and stems and during flowering, lesions can be found on the pedicels and developing seed pods. Pod infection can result in premature ripening and shedding of seed.

In vitro tests using iprodione (as 26,019 RP) originally confirmed a high degree of toxicity to A. brassicae (Maude 1976) whilst later work using seed dressings confirmed activity against A. brassicicola (Maude and Humpherson-Jones 1980b) and showed additionally an excellent control of A. brassicae and Phoma lingam (Humpherson-Jones et al 1980). Later field evidence (Maude et al 1981) confirmed the effect on Alternaria and Phoma. As a result of the N.V.R.S. work iprodione is now used commercially as a seed treatment in brassica crops, including oilseed rape, in the U.K.

In an attempt to control pod infection of A. brassicicola on Brassica oleracea seed crops Humpherson-Jones and Maude (in press) showed that three HV sprays of iprodione at 0.5 kg a.i./ha applied from green pod stage reduced seed infection, increased yields and improved germination. Further work (Humpherson-Jones et al 1981) achieved similar results using VLV (c. 50 l/ha) to simulate volumes applied by aircraft and also demonstrated superiority of a flowable formulation of iprodione (Exp.1861), compared with the wettable powder.

In Northern France, during 1979-80, the Centre Technique Interprofessionel des Oléaginoux Métropolitains obtained good control of both Alternaria and Sclerotinia on oilseed rape using sprays of iprodione at 0.375 - 0.750 kg a.i./ha (Messeliere 1981).

In the U.K. Evans (pers. comm.) obtained significant yield increases in oilseed rape during 1980 when iprodione was used with phosalone insecticide as a single spray treatment at petal fall.

The trials described in this paper were carried out in England and France during 1981. They consist of both small plot replicated and large unreplicated farmer trials involving both land and aerially-applied spray treatments, comparing two formulations of iprodione with and without phosalone insecticide.

METHODS AND MATERIALS

a) Small plot trials

Plot size was 3m x 5m with 4 replicates. Treatments in the U.K. were applied with a motorised small plot sprayer using 6 No. 8003 'Tee' jets. Spray volume was 360 l/ha at 2 bars pressure. Applications in France were made using a knapsack sprayer. All crops involved the cultivar Jet Neuf, and treatments were applied at 90-100% petal fall with, in some cases, a second application made 3 weeks later.

b) Farm scale trials

Single spray treatments were applied by farms to commercial crops of winter oilseed rape cv. Jet Neuf, at timings ranging from 70-90% petal fall, when young pods were forming. Application was either by high clearance tractor-mounted sprayers at volumes ranging from 200-400 l/ha or by fixed wing aircraft at 20-50 l/ha. Tractor sprayed plots were 1-2 ha whilst aerial treatments were 2-4 ha in extent.

Treatments compared were -

(1) Iprodione 500g a.i./ha as 25% flowable (Exp.1861)

(2) as (1), plus 700g a.i./ha phosalone as 35% e.c. 'Zolone'

(3) Iprodione 500g a.i./ha as 50% w.p. ('Rovral') plus 700g a.i./ha phosalone as 35% e.c.

(4) Untreated

Assessments

a) U.K. trials

Single racemes were sampled from three 'zones' - top, middle and bottom - of plants in 20 positions at random throughout the treated areas. In the case of laid crops (caused by late snow) these 'zones' refer to heights of approx. 1.0, 0.5 and 0.1m respectively above the soil surface. The racemes were stripped of pods and a sub-sample of 200 pods assessed.

Assessments 14 days post spray were done on Alternaria presence or absence basis - including pedicel infections. Pods assessed (4-5 week post-spray) and just prior to desiccation or swathing were graded using the following key (Humpherson-Jones - unpublished):

0 =	healthy	a
Tr =	trace (unlikely to cause crop loss)	
1 =	up to 10% of pod area blackened	b
2 =	10-25% " " " "	c
3 =	25-50% " " " "	d
4 =	> 50% " " " "	e

A disease severity index was calculated using the formula: $\frac{b + 2c + 3d + 4e}{4\,(a+b+c+d+e)}$

The incidence of internal seed infection on harvested samples was determined by the method described by Maude and Humpherson-Jones 1980a.

b) French trials

20 primary and 20 secondary racemes were taken at random per treatment and 50 pods from each examined for presence of disease. Categories used were clean, 1-5 lesions, 6-10 lesions, more than 10 lesions per pod and dehisced pods. Data obtained was expressed according to the disease severity index given above.

RESULTS

TABLE 1

Control of A. brassicae. Small plot replicated trials - U.K. 1981

Disease severity index (pods examined from middle of canopy)

	No. sprays	Ongar 29*	Faversham 28*	Dover 24*	Dover 3*	Micheldever 29*	Micheldever 8*	Andover 46*	Andover 25*	Basingstoke 34*	Basingstoke 13*
Iprodione wp 500g a.i./ha	1	0.04	0.09	0.04	-	0.22	-	0.23	-	0.10	-
" " " "	2	-	-	-	0.07	-	0.05	-	0.13	-	0.05
" flowable " "	1	0.02	0.03	0.03	-	0.02	-	0.15	-	0.01	-
" " " "	2	-	-	-	0.04	-	0.03	-	0.08	-	0.00
Untreated	-	0.46	0.90	0.31		0.40		0.31		0.34	
*No. days after last spray	LSD (5%)	0.196	0.134	0.119		0.156		0.125		0.083	

TABLE 2

Control of A. brassicae. Large plot trials - U.K. 1981

Disease severity index (pods from various zones)

Location	No. days post spray	Spray vol. (l/ha)	Untreated Top	Untreated Middle	Untreated Bottom	Mean	Iprodione 50% w.p. + phosalone Top	Middle	Bottom	Mean	Iprodione flowable Top	Middle	Bottom	Mean	Iprodione flowable + phosalone Top	Middle	Bottom	Mean
Burford,	+ 40	275	0.25	0.46	0.80	0.50	0.05	0.13	0.17	0.13	0.12	0.17	0.22	0.17	0.05	0.15	0.28	0.16
Oxon.	+ 52		0.03	0.48	0.68	0.59	0.02	0.13	0.20	0.12	0.11	0.22	0.26	0.20	0.02	0.13	0.18	0.11
Fairford,	+ 33	470	0.36	0.64	0.84	0.61	0.01	0.02	0.01	0.01	0.0	0.06	0.11	0.06	0.0	0.09	0.13	0.07
Glos.	+ 44		0.50	0.68	0.80	0.66	0.06	0.17	0.14	0.12	0.14	0.20	0.14	0.16	0.01	0.23	0.13	0.12
Cricklade,	+ 42	22	0.30	0.46	0.58	0.45	0.0	0.05	0.14	0.06	0.01	0.06	0.15	0.07	0.07	0.19	0.37	0.21
Wilts.		55					-	-	-	-	0.0	0.01	0.08	0.03	0.02	0.17	0.18	0.12
	+ 53	22	0.26	0.51	0.57	0.45	0.0	0.08	0.15	0.08	0.01	0.09	0.10	0.07	0.07	0.19	0.33	0.20
		55					-	-	-	-	0.0	0.02	0.12	0.05	0.04	0.16	0.17	0.12

TABLE 3

Control of A. brassicae in France
Replicated trials 1981

Treatment	Dose g a.i./ha	Chartres Disease severity index (T + 37)	Chartres Relative yield 8% moisture	Amiens Disease severity index (T + 55)	Amiens Relative yield 8% moisture	Lyon Disease severity index (T + 47)
Iprodione wp	750	0.28	105ab	0.46	116ab	0.25
"	500	0.45	106ab	0.49	119ab	0.25
"	375	0.42	100bc	-	-	-
Iprodione flowable	750	0.28	112a	0.40	122a	0.13
	500	0.30	105ab	0.47	116ab	0.18
"	375	0.42	98bc	-	-	-
Vinclozolin wp	750	0.52	94cd	0.52	108bc	0.33
Untreated	-	0.56	100bc 2.5 T/ha	0.65	100c 1.0 T/ha	0.36

Values with the same letter are not significantly different at P = 0.05

TABLE 4

Seed infection with A. brassicae. Large plot trials 1981

Data from N.V.R.S.

Location	Spray vol. (l/ha)	% seeds internally infected Untreated	Iprodione 50% w.p. + phosalone	Iprodione flowable	Iprodione flowable + phosalone
Burford, Oxon.	275	17.0	not sampled	2.5	0.0
Fairford, Glos.	470	13.0	1.5	1.5	5.5
Cricklade, Wilts.	22	7.5	1.0	4.5	1.0
	55		-	2.5	3.0

TABLE 5

Control of Sclerotinia sclerotiorum in oilseed rape
Canada 1978 and Germany 1980

Canada: Experiments carried out by Agriculture Canada Saskatoon and the University of Saskatoon (Dueck and Morrall 1978)

Germany: Experiments carried out by Hoechst Germany

Treatment	Dose rate g a.i./ha	Crop growth stage	% Disease control Canada (mean of 2 trials)	Germany
Iprodione wp	1000	Early pod	82 a	-
"	750	Full flower	-	66
"	750	End of flowering	-	81
"	500	Early pod	66 b	-
Vinclozolin	1000	Early pod	85 a	-
Untreated	-	-	0 c	-
			*Disease index 17.75	42.5% Diseased plants

* Percent of maximum amount of disease possible based on percent of plants infected and degree of infection.

DISCUSSION

In France, where A. brassicae has been noted on oilseed rape, early work was carried out on the epidemiology and control, although at this time a really effective fungicide was unavailable (Louvet & Billotte 1964); however, the recent availability of iprodione, and its reported effects against A. brassicae, have renewed interest in controlling the disease in brassica crops.

An aspect of particular interest in these trials was to compare the 50% wettable powder formulation of iprodione with the newer flowable. The latter has shown greater efficiency in N.V.R.S. work (Humpherson-Jones et al 1981). This superiority of the flowable formulation can be seen in the small plot trials in U.K. (Table 1) and in France (Table 3), but is not clearly demonstrated in the U.K. large plot trials (Table 2). This may reflect the different weather patterns prevailing at the time: the small plot trials were conducted in the S. East of England, whereas large plot trials were carried out in the West.

A single pod spray appears to have held the disease in check in all sites for the remainder of the life of the crop in 1981, but it should be borne in mind that a repeat spray may be necessary in situations where the disease is particularly favoured. In the small plot work (Table 1) a repeat spray has reduced disease in most cases, but further work is needed on the economics of this approach.

In the reported trials, improved control of pod infection could probably have been achieved by an earlier treatment. In the event, treatments were delayed to coincide with the correct stage of application of the insecticide (90% petal fall). Toxicity tests with the iprodione formulations have indicated that sprays applied over the flowering period present no hazards to pollinating bees.

Control was achieved at spray volumes as low as 22 l/ha, and no differences in the effect on disease noted where the fungicide was used alone, or with the insecticide. In these trials minimal insect damage was found on untreated plots.

Due to the relative unsuitability of other potential fungicides for the control of Alternaria (Humpherson-Jones et al 1980) such compounds were rarely included for comparative purposes.

As was the case with the ADAS trials (Evans & Gladders 1981), problems were encountered in obtaining yields, due to the premature senescence of crop in the untreated areas. Thus, harvesting carried out when untreated plots are at an optimal stage of maturity will be too early for treated plots whereas, waiting until the latter are ready will again cause bias due to greater shedding of seed in untreated areas. It will thus be necessary in future to harvest differentially, when treated or untreated crops reach maturity. In these trials, treated plots yielded substantially more seed than untreated ones, the greatest increase being 20%, which corresponds with increases obtained in the trials of Evans and Gladders (1981) and in previous work carried out at Bridgets Experimental Husbandry Farm during 1980 (Evans - pers. comm.). Although Degenhardt et al (1974) showed that in spring rape in Canada oil content of one variety was significantly reduced where plants were infected with Alternaria, no differences were found in these trials.

Laboratory tests on untreated seed taken from farm trials show clearly high levels of internal infection of A. brassicae (Table 4) and that this infection has been **markedly** reduced by the iprodione treatments.

The known activity of iprodione against Botrytis cinerea, more prevalent on damaged crops of oilseed rape, was also noted in the trials.

Results obtained from areas where rape growing has been long established (Table 5) demonstrate that iprodione is also effective against Sclerotinia sclerotiorum, however, much more work needs to be done to define more precisely the optimal timing for spray treatments.

The current registration position regarding the use of iprodione on oilseed rape in the U.K., is that seed dressings or foliar sprays of the wettable powder formulation are fully cleared and an application is being sought for a similar status for the flowable formulation for spray treatments. Farm reaction to the widespread use of wettable powder has been very encouraging and appears to confirm the outcome of these detailed trials.

Acknowledgements

The authors wish to acknowledge the assistance of Messrs. Fieldcare Oilseeds, United Oilseeds Ltd., Kenneth Wilson, Wilmotts & West Midland Farmers for locating suitable trial sites in the U.K. and to the farmers for their participation. Advice on assessment techniques and data on seed infections provided by Dr. F.M. Humpherson-Jones of the National Vegetable Research Station is particularly acknowledged, together with useful discussions with ADAS personnel.

Thanks are also due to colleagues within the Group for their help in obtaining the results presented.

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