SESSION 3C

NEW DEVELOPMENTS IN PEST AND DISEASE CONTROL IN HORTICULTURE

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VIDEO-RECORDING APHID RESPONSES TO DISCRETE DEPOSITS OF BIFENTHRIN ON CHRYSANTHEMUMS

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ABSTRACT

Adult Aphis gossypii were video-taped as they walked across the abaxial surface of chrysanthemum leaves. The leaves had been sprayed with uniformly-sized aqueous droplets of bifenthrin and a 50-fold range in quantity of a.i. required to cause hyperactivity was dependent upon the quality of the deposit (droplet size, droplets/cm^2 and concentration of a.i.). When a fluorescent tracer (Saturn Yellow GT-17N) was incorporated in the spray mixture, activity was filmed under ultra-violet illumination. The video-recordings were used to measure the time spent on, and the distance walked across, the treated surface by each aphid, while the number of contacts with spray deposits was also counted. Following exposure to the insecticide, aphids were transferred to untreated leaves, and mortality was determined 24 hours later. These data revealed that the number of contacts with deposits was positively correlated ($r > 0.67$) with the distance walked. However, none of the combinations of factors examined accounted, satisfactorily, for the subsequent mortality.

INTRODUCTION

The process of dose-transfer from spray deposits on foliage to insect surfaces, is greatly influenced by any behavioural response to the pesticide (Ford & Salt, 1987). In the extreme case of a sessile pest, such as whitefly scales (Trialeurodes vaporariorum) or mite eggs (Tetranychus urticae), diffusion of the active ingredient (a.i.) through the epicuticular waxes may be most influential in determining biological efficacy (Abdalla, 1984; Adams et al., 1987; Munthali & Wyatt, 1986). However, mobile pest stages may be irritated or repelled by the toxicant, resulting in dispersal (Iftner & Hall, 1983) and the possibility of either accelerated dose acquisition, or movement into uncontaminated / non-lethal refugia. The spread of viral diseases by aphids vectors may be affected as a result of such behaviour (Gibson et al, 1982; Rice et al, 1983).

Incorporating nigrosine dye and pesticide into large spray droplets (vmd~200μm) is a method that has been used to determine the relationship on natural and artificial surfaces between drop

density and frequency of encounter by mobile pests (Fisher & Menzies, 1973, 1976). Alternatively, the spatial relationships of droplets (vmd~100μm) and sessile pests have been established by applying oil-based formulations containing a fluorescent tracer and photographing the deposits and pests under ultra-violet and subdued white light (Abdalla, 1984). Typically, the vast majority of droplets contained in agricultural sprays are <100μm in diameter (although the vmd may be considerably greater) and the present study is directed at developing a method that allows recording of aphid movement in relation to visible deposits resulting from the impaction of aqueous spray droplets, <100μm diameter, on a leaf surface.

MATERIALS & METHODS

Uniformly sized spray droplets, containing bifenthrin 2E (FMC Corp.), were applied to the abaxial surface of square sections (6.25 cm^2) of chrysanthemum (cv."Iceberg") leaf using a droplet generator that permitted precise control over the number of droplets produced (Young, 1986). The spray mixture also contained 0.1% X-77 (Ortho) and, for video recording under ultra violet illumination, 3g/l Saturn Yellow GT-17N (Day Glo Corp.), a fluorescent tracer. The upper surface of the treated leaf was afixed to a piece of card and adult Aphis gossypii apterous virginoparae were tapped onto the lower surface from a camel hair brush. Aphid movement was recorded for up to 20 minutes after exposure to the pyrethroid deposit using the apparatus shown in Figure 1 (without the heat filters or uv light), which gave a screen magnification of x8.

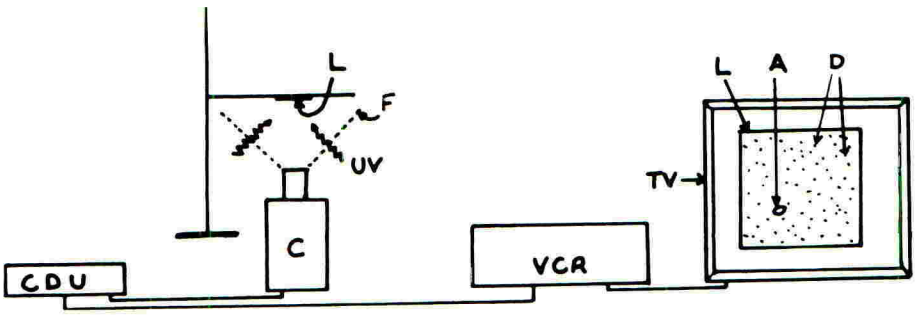

FIGURE 1. Apparatus for viewing and video-recording aphid responses to bifenthrin deposits. CDU = camera drive unit; C = video camera; L = leaf; F = heat filter; UV = ultra-violet light; VCR = video-cassette recorder; TV = television; A = aphid D = droplet deposit.

Initially, experiments were performed under normal laboratory lighting, observing 10 aphids at a time (3 replicates for each combination of droplet size, drops/cm^2 and concentration of

bifenthrin). The number of aphids that moved, that walked or dropped off the treated area, and the distance they covered were recorded, and the standardized (S) values ([x - x]/σ[n - 1]) for these parameters provided an irritancy index using the factor score coefficients derived from principal components analysis to give the transformation statement:

Index = 0.387.Smoved + 0.406.Sdistance + 0.359.Soff.

On unsprayed or water sprayed leaves, little activity was recorded and an index of ~-1 was calculated, compared with a maximum of +2 for extremely irritant deposits (Table 1). Regression analysis was applied to the index values of the aphids in each treatment. After the exposure period, aphids were transfered to untreated leaves for 24 hours to determine whether a lethal dose had been acquired.

TABLE 1. Examples of combinations of numbers of aphids moving, mean distance moved and total moving off the treated area, that correspond to irritancy indices after standardization (S).

Moved		$\bar{x}$ Distance		Off		Irritancy Index
n	S	cm	S	n	S	
27	1.12	2.36	1.53	24	2.65	+2
25	0.58	1.73	0.57	18	1.57	+1
24	0.31	1.21	-0.23	8	-0.23	0
19	-1.05	0.77	-0.90	6	-0.59	-1
20	-0.78	0.41	-1.45	0	-1.67	-1.5

Exposing one aphid at a time to deposits containing Saturn Yellow, and recording under ultra-violet illumination with subdued white light from a cold light source, the time spent on the treated surface, the distance moved and the number of deposits that were encountered were determined. As before, aphids were transferred to untreated leaves after exposure. Linear regression analysis was used to establish whether there were any relationships between these responses, while logistic regression examined any influence upon mortality.

RESULTS

The irritancy index showed a significant linear regression (r^2 > 0.75, F prob. < 0.05) for 6/10 spray treatments. Using an index of +1 as a measure of an irritating deposit, it was possible to derive figures for quantity of bifenthrin/cm^2 leaf surface area that induced hyperactivity. These data clearly show that a 50-fold increase in dose/cm2 accompanied an increase in bifenthrin from 0.0075 to 7.5g a.i./l (Table 2). Mortality amongst the exposed aphids was negligible for every treatment.

TABLE 2. Bifenthrin deposits causing an irritancy index of +1.

Conc. a.i. (g/l)	Drop diam. (μm)	r^2	F prob.	Drops/cm^2	ng/cm^2
7.5	90	0.99	0.001	8	22.9
0.075	60	0.91	0.004	117	1.0
	90	0.85	0.01	121	3.5
	120	0.93	0.03	51	3.5
0.0075	120	0.94	0.03	75	0.5
	160	0.79	0.04	29	0.5

A droplet density (40/cm^2, 80μm droplet diameter) in excess of that causing hyperactivity at high concentrations (1.9 - 7.5 ga.i./l) was used in the u-v/tracer/video studies, once it had been established that it caused some mortality. The relationships and interactions of the factors measured are given in Table 3. In all cases, the irritancy index was > 1.9.

TABLE 3. Relationships between distance (D) walked, time (T) spent on the leaf and number of contacts (C) with deposits when aphids were exposed to bifenthrin applied in 80μm drops (40/cm^2).

Parameters	Conc. ga.i./l	Eqn. of linear regression	r
D v C	7.5	y = 2.44x - 0.87	0.86
	3.8	y = 1.52x - 0.41	0.72
	1.9	y = 1.77x - 0.17	0.67
D x T v C	7.5	y = 0.32x + 2.10	0.82
	3.8	y = 0.22x + 1.57	0.74
	1.9	y = 0.15x + 2.57	0.47

There was a close correlation between the distance walked, and the number of droplets encountered. The relationship between (distance x time) and number of contacts was also close at the higher concentrations. However, much poorer correlations were apparent when relationships between these parameters and mortality (which was 60 - 70%, n = 44 - 71, for the 3 concentrations) were investigated (r^2 < 0.5).

DISCUSSION

Bifenthrin deposit quality had a profound effect upon the quantity of a.i. required to irritate A. gossypii (Table 2). Although these deposits were insufficient to kill the aphids during the experimental period, in practice, such activity would probably be sustained until a knock down and/or lethal dose had been acquired. Indeed, electrostatic application of 0.02g a.i./l bifenthrin to a chrysanthemum plot caused 95% mortality amongst ~50% aphids that dropped off the plants during 2 hours after spraying (Lindquist et al., 1988). Once irritated aphids began to walk, they did not probe the leaf, and if a similar response occurs with aphid vectors of virus diseases, this may account for a decrease in virus spread on pyrethroid treated crops (Highwood, 1979).

Video-recordings under u-v illumination demonstrated that A. gossypii were not repelled by bifenthrin deposits, indicating that irritancy, expressed as hyperactivity, was the nature of the behavioural response. It was evident from both the fluorescent droplet studies, and the droplet density required to cause irritancy at 7.5 g/l (Table 2), that direct contact with deposits was not necessary to initiate movement. Although bifenthrin has a very low vapour pressure (1.81×10^{-7} mmHg, 25°C), these results suggest that a very localised vapour effect (possibly enhanced by the hairiness of chrysanthemum leaves) may be responsible for the initial irritancy, which is perpetuated by the subsequent contact with spray deposits. Consequently, a sub-lethal spray deposit on the abaxial leaf surface may have a lethal effect, indirectly, if the irritancy it causes results in the pest walking onto the adaxial leaf surface which, almost inevitably, will be more heavily dosed. Clearly, an appreciation of this behaviour may help to establish application/deposition guidelines, while identifying the means by which spray distribution on a crop exerts its biological effect.

The data collected from the uv-video experiments indicates that dose acquisition was dependent upon more than simply the number, or frequency, of contacts with spray deposits. The number of "footfalls" in deposits and the transfer efficiency from plant to insect surfaces (Ford & Salt, 1987) are likely to be influential, while a local vapour effect may vary in importance with distance from deposits. These possibilities are being investigated.

In its present form, the apparatus used for this study (Figure 1) is unsuitable for the analysis of behavioural responses of large/active pests (eg. lepidopteran larvae, Myzus persicae) because the magnification that is required to elucidate deposits, of a size that is relevant to those likely to be encountered in the field, limits the field of view. However, mounting the camera on a stage, with the facility to move it in 2 or 3 dimensions, should enhance the versatility of this technique. Also, fluorescent tracers have been applied to very small pests (spider mites) to aid discrimination under u-v light.

REFERENCES

Abdalla, M. R. (1984) A biological study of the spread of pesticides from small deposits. PhD thesis, University of London.

Adams, A. J.; Abdalla, M. R.; Wyatt, I. J; Palmer, A. (1987) The relative influence of the factors which determine the spray droplet density required to control the glasshouse whitefly, Trialeurodes vaporariorum. Aspects of Applied Biology 14, 257-266.

Fisher, R. W.; Menzies, D. R. (1973) Relationship of spatial density of spray droplet to frequency of contact by European red mite (Acarina: Tetranychidae). Canadian Entomologist 105, 999-1001.

Fisher, R. W.; Menzies, D. R. (1976) Effect of spray droplet density and exposure time on the immobilization of newly hatched Oriental fruit moth larvae. Journal of Economic Entomology 69, 438-440.

Ford, M. G.; Salt, D. W. (1987) The behaviour of pesticide deposits and their transfer from plant to insect surfaces. In: "Critical Reports in Applied Chemistry" Ed. Cottrell, H. Society of Chemical Industry. Blackwells.

Gibson, R. W.; Rice, A. D.; Sawicki, R. M. (1982) Effects of the pyrethroid deltamethrin on the acquisition and inoculation of viruses by Myzus persicae. Annals of Applied Biology 100, 49-54.

Highwood, D. P. (1979) Some indirect benefits of the use of pyrethroid insecticides. Proceedings 1979 British Crop Protection Conference - Pests and Diseases. 361-369.

Iftner, D. C.; Hall, F. R. (1983) Effects of fenvalerate and permethrin on Tetranychus urticae Koch (Acari: Tetranychidae) dispersal behaviour. Environmental Entomology 12, 1782-1786.

Lindquist, R. K.; Adams, A. J.; Hall, F. R; Adams, I. H. H. (1988) Biological efficacy of bifenthrin, applied using an air-assisted electrostatic sprayer, to control aphids on chrysanthemums. Proceedings 1988 Brighton Crop Protection Conference - Pests and Diseases (this volume).

Munthali, D. C.; Wyatt, I. J. (1986) Factors affecting the biological efficiency of small pesticide droplets against Tetranychus urticae eggs. Pesticide Science 17, 155-164.

Rice, A. D.; Gibson, R. W; Stribley, M. F. (1983) Effects of deltamethrin on walking, flight and potato virus Y-transmission by pyrethroid resistant Myzus persicae. Annals of Applied Biology 102, 229-236.

Young, B. W. (1986) A device for the controlled production and placement of individual droplets. Pesticide Formulations and Application Systems 5, 13-22, ASTM/STP 915.

DEVELOPMENT OF BUPROFEZIN FOR CONTROL OF WHITEFLY TRIALEURODES VAPORARIORUM AND BEMISIA TABACI ON GLASSHOUSE CROPS IN THE NETHERLANDS AND THE UK.

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ABSTRACT

Buprofezin, is a new selective insect growth regulator for the control of the glasshouse whitefly (Trialeurodes vaporariorum) and tobacco whitefly (Bemisia tabaci). Trials in Holland and the UK have demonstrated that two sprays at 7.5 g ai/hl applied high volume will provide long-term control. When used in conjunction with the parasite Encarsia formosa, on which buprofezin has little if any effect, a single spray gave good control for 10 weeks, illustrating its potential for use in effective integrated pest control programmes. There was excellent safety over the range of important edible and ornamental crops tested.

INTRODUCTION

Control of the glasshouse whitefly (Trialeurodes vaporariorum) has become a major problem in recent years due to the widespread occurrence of strains with high levels of pesticide resistance (Wardlow et al; 1984). There has been increasing reliance upon the parasitic wasp Encarsia formosa, but achieving a satisfactory balance between parasite and pest is not easy and can be expensive. Also the low level of pest infestation necessary to maintain equilibrium is not usually acceptable on ornamental crops. The arrival of the tobacco whitefly (Bemisia tabaci), has further exacerbated the problem. B. tabaci is also very resistant to most insecticides, has many plant hosts and cannot be controlled by E. formosa.

The insect growth regulator buprofezin, 'Applaud', discovered by Nihon Nohyaku Co Ltd, Japan (Kanno et al; 1981) has shown long-term activity against T. vaporariorum (Naba et al; 1983). It has good larvicidal activity by inhibiting chitin biosynthesis and prevents the moulting process of instars 1, 2 and 3. Although adult whitefly are not controlled directly by buprofezin, the hatchability of eggs laid by treated adults is suppressed, giving long-term control (Yasui et al; 1987). An important aspect is its relative safety to the parasite E. formosa (Garrido et al; 1984) thus enabling the use of buprofezin in programmes of integrated pest control.

Since 1983 over 30 trials on 20 edible and ornamental protected crops have been conducted by ICI Holland and more than 20 trials on 30 different crops in the UK by ICI Agrochemicals since 1985. Representative results

from some of these trials will be used to illustrate insecticidal activity, selectivity and crop safety.

MATERIALS AND METHODS

Plot size and trial design depended on trial objectives. Early efficacy trials were with small plots replicated 3 or 4 times. However, it was soon found that due to the vapour effect of buprofezin (Ledieu et al; 1987) and the mobility of adults, results from small plots could be unreliable. Most later efficacy trials were of single large plots, up to 4000 m^2. Specific crop safety trials were conducted on small plots, generally containing just a few plants.

Treatments were applied high volume by hand-lance to achieve complete crop cover. Water volumes ranged from 400 to 5200 litres/ha depending on type and size of crop. Buprofezin was initially applied as a 25% wettable powder (wp), coded variously as NNI 750, PP618, NL4140 or FD4076. In 1986 this was compared with a 250 g/l suspension concentrate (SC) formulation coded JF10616 or FD4170, which superseded the wp in 1987.

Insecticidal efficacy was assessed by counting the number of live scales (larvae) or live and dead scales on a representative sample of leaves. On trials where E. formosa had been introduced, the number of live and parasitised scales were counted.

RESULTS

Control of Trialeurodes vaporariorum

Results of trials in Holland in 1983-85 show that one or two applications (10-14 day interval) of buprofezin wp at 5 to 10 g ai/hl gave excellent control of whitefly scales, and was superior to either permethrin or pirimiphos-methyl (Table 1).

TABLE 1

Control of T. vaporariorum, Holland, 1983-85.

		% Control of Scales							
		----1983----		----------1984----------					1985
Treatment	Rate g ai/hl	Beans[1] 18DAT[2]	Beans 26DAT	Aubergine 12DAT	Lettuce 12DAT2	Gherkin 12DAT2	Gerbera 12DAT	Pelargonium 7DAT2	Gerbera 21DAT2
Buprofezin WP	5.0	86	99	99	99	97	92	97	-
Buprofezin WP	7.5	-	100	98	99	98	96	98	98
Buprofezin WP	10.0	100	100	-	-	-	-	-	-
Permethrin	12.5	80	66	72	-	-	-	-	-
Pirimiphos-methyl	75.0	28	93	63	-	-	-	-	-
Untreated[3]		(1981)	(2678)	-	-	-	-	-	(2768)

1 - Spray applied to top surface of leaves only.
2 - 18DAT = assessed 18 days after treatment, DAT2 = days after treatment two. (Second treatment applied 10-14 days after the first).
3 - () Number of live scales/50 leaves.

UK trials in 1986 confirm the Dutch results where two applications at 7.5 g ai/hl provided almost total control of scales 14 days after the second spray. The suspension concentrate was at least as effective as the wettable powder (Table 2).

TABLE 2

Control of T. vaporariorum, UK, 1986.

		Whitefly/leaf 14DAT2(1)			
	Rate	Cucumber		Tomato	
Treatment	g ai/hl	Adults	Scales	Adults	Scales
Buprofezin WP	7.5	2.0	0.1	0.4	0.2
Buprofezin SC	7.5	1.1	0	0.3	0.1
Untreated		35	530	15	82

(1) - Second spray applied 14 days after the first.

Control of Bemisia tabaci.

Results of two trials in Holland show that B. tabaci is also controlled by buprofezin, when a single spray at 7.5 g ai/hl gave approximately 80% control (Tables 3 and 4).

TABLE 3

Control of B tabaci on Poinsettia (single spray) Holland, 1987.

		Whitefly Scales					
	Rate	% Hatched		% Unhatched		Total No.	
Treatment	g ai/hl	12DAT	19DAT	12DAT	19DAT	12DAT	19DAT
Buprofezin SC	7.5	9	19	91	81	212	190
Untreated		41	81	59	19	245	257

TABLE 4

Control of B. tabaci on Poinsettia, Holland, 1987.

Treatment	Rate g ai/ha	Whitefly Scales 15DAT % Hatched	% Unhatched	% Dead	Total No
Buprofezin SC	7.5	21	2	77	3119
Untreated		85	9	6	784

Effect on Encarsia formosa.

Results of UK trials in 1986 (Table 5) and in Holland 1987 (Table 6) show that on sites where E. formosa had been introduced prior to treatment, parasitisation of whitefly scales continued after buprofezin application. The number of parasitised scales was reduced on some trials but this was always associated with, and as a consequence of, a high mortality of treated scales, thus leaving few live scales to be parasitised.

In the Dutch trial, teflubenzuron reduced parasitisation without giving adequate whitefly control.

TABLE 5

Effect of buprofezin on E. formosa, UK, 1986.

Treatment	Rate g ai/hl	No. Parasitised Whitefly Scales Per Leaf Tomatoes 14DAT2	Cucumbers 14DAT2	Cucumbers 7DAT2	Cucumbers 14DAT2
Buprofezin	7.5	2.7	8.5	20.0 (2.9)	8.5 (0.1)
Untreated		1.0	10.7	3.4 (500)	114.3 (530)

() Number of live whitefly scales.

TABLE 6

Effect of buprofezin on E. formosa in Aubergine, Holland, 1987.

Treatment	Rate g ai/hl	Whitefly Scales 10DAT % Parasitised	% Alive	% Dead	% Hatched
Buprofezin SC	7.5	20	2	76	2
Buprofezin WP	7.5	16	2	80	2
Teflubenzuron	22.5	22	1	15	62
Untreated		34	1	5	60

In further Dutch trials in 1987 (Table 7), where a single spray of buprofezin was applied following the introduction of E. formosa, control of whitefly after 70-74 days was at the 95-97% level, while the proportion of scales being parasitised was still increasing (70-78%).

TABLE 7

Effect of buprofezin* on E. formosa in Tomatoes, Holland, 1987.

Assessment	% Parasitised	Whitefly Scales % Alive	% Dead	% Hatched
Trial 410				
Zone 1**				
Pre-treatment	21	53	0	26
12DAT	51	4	11	34
Zone 2				
Pre-treatment	1	98	0	1
18DAT	37	1	52	10
Zone 3				
74DAT	70	5	1	24
Trial 416				
Zone 1				
Pre-treatment	48	11	0	41
12DAT	54	1	2	43
Zone 2				
Pre-treatment	12	87	0	1
19DAT	66	1	31	2
Zone 3				
70DAT	78	3	0	19

* Buprofezin applied as a single spray at 7.5 g ai/hl.

** Zone 1 is the part of the tomato plant most heavily infested at the time of treatment (lower part of the plant). The pre-treatment assessment shows the level of parasitisation, indicating whether or not the system is in equilibrium.
Zone 2 is the top part of the plant (whitefly larvae present but not pupated and not yet visibly parasitised).
Zone 3 is new growth after treatment which in time becomes infested and can be assessed for the level of parasitisation and equilibrium.

Crop Safety

No crop damage was evident with buprofezin on any of the glasshouse vegetable crops treated, including tomatoes, aubergines, lettuce and the most sensitive crop - cucumber. Excellent crop safety was also demonstrated on all but six of over forty ornamental species treated. Phytotoxicity on these six house pot plants was shown as slight leaf scorch and recovered 14 days after treatment.

DISCUSSION

The results of over 50 trials conducted over the period 1983-87 in the Netherlands and UK demonstrate that buprofezin provides a high level of control of glasshouse whitefly T. vaporariorum. Its selectivity towards beneficial insects such as the whitefly parasite E. formosa and the red spider predator Phytoseiulus persimilis (data not presented) enables its use in programmes of integrated control. This is particularly important due to the difficulties of achieving equilibrium between pest and parasite, especially during the winter months, and because of the tendency of whitefly to become highly resistant to insecticides in a short time.

Buprofezin also gave good control of the tobacco whitefly B. tabaci. This is a new and potentially even more important pest of glasshouse crops. It appears to be very resistant to nearly all existing insecticides, has a large range of host crops and is not controlled by E. formosa.

Many glasshouse crops such as cucumbers are highly sensitive to spray chemicals and crop damage to ornamentals can reduce their market value. Buprofezin showed excellent crop safety on all crops treated, with the exception of transient slight leaf scorch on six pot plant species.

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REFERENCES

Wardlow, L. R., Lewis, G. A., Jackson, A.W. (1984). Pesticide resistance in the glasshoue whitefly (Trialeurodes vaporariorum [Westw.]). Research and Development in Agriculture 2, 87-88.

Kanno, H., Ikeda, K., Asai, T., Maekawa, S. (1981) 2-tert-Butylimino-3-isopropyl-5-phenyl-per-hydro-1,3,5-thiadiazin-4-one (NNI 750). A new insecticide. Proceedings 1981 British Crop Protection Conference - Pests and Diseases 1 56-69.

Naba, K., Nakazawa, K., Hayashi, H. (1983) Long-term effects of buprofezin spray in controlling the greenhouse whitefly, Trialeurodes vaporariorum (Westwood), in vinylhouse tomato. Applied Entomology and Zoology 18 (2), 284-286.

Yasui, M., Fukada M., Maekawa, S (1987) Effects of Buprofezin on Reproduction of the Greenhouse Whitefly, Trialeurodes vaporariorum (Westwood) (Homoptera : Aleyrodidae) Applied Entomology and Zoology 22 (3), 266-271.

Garrido, A., Beitia, F., Gruenholz, P. (1984) Effects of PP618 on Immature Stages of Encarsia formosa and Cales noacki (Hymenoptera : Aphelinidae). Proceedings 1984 British Crop Protection Conference - Pests and Diseases 1 305-310.

Ledieu, M. S., Helyer, N. L., Yalgin, E. (in preparation). The potential of buprofezin for control of greenhouse whitefly (Trialeurodes vaporariorum) (Westw.).

APPLICATION OF ABAMECTIN FOR *Frankliniella occidentalis* CONTROL IN GLASSHOUSES

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ABSTRACT

Abamectin was efficacious for western flower thrips feeding on terminals, mature buds, and flowers at both the 0.012 and 0.024 g a.i./litre rates. The standard methomyl, at 0.6 g a.i./litre, was also efficacious for thrips in these growth stages. The population was insufficient on tight buds to determine efficacy.

INTRODUCTION

Even though thrips feed on most tissue of vascular plants, on ornamentals they are separated into two groups: foliage feeding and flower feeding thrips. Thrips have become a severe problem on ornamentals in the last few years. The foliage feeding and flower feeding species have become more prevalent since 1980 (Oetting 1986a). One species, the western flower thrips (*Frankliniella occidentalis* Pergande) has become very difficult to control with the present insecticides. A miticide/insecticide abamectin has demonstrated activity for the control of thrips (Oetting 1986b). Abamectin is a mixture of a minimum of 80% avermectin B1a and a maximum of 20% avermectin B1b (Dybas and Green 1984). Mortality of adult and immature *Echinothrips americanus* Morgan was significantly increased (approximately 90%) when thrips were placed on abamectin treated leaves within 24 hr after application (Oetting 1987). The efficacy decreased with increased time after application. Abamectin has also demonstrated efficacy on other pests of ornamentals [e.g. leafminers (Leibee 1988, Schuster and Taylor 1988) and spider mites (Mizell et al. 1986)].

The purpose of this study was to investigate abamectin efficacy for western flower thrips at different growth stages of chrysanthemums. Observations were made of efficacy against thrips when abamectin was applied to growing tips, buds, and flowers to determine the growth stage where the best control can be achieved.

MATERIALS AND METHODS

This study was conducted at the Georgia Agricultural Experiment Station, Griffin, Georgia, USA during 1987-1988. The primary insecticide evaluated in the experiments was abamectin, a mixture of avermectins containing $\geq$ 80% avermectin B1a (5-O-demethyl avermectin A1a) and $\leq$ 20% avermectin B1b (5-O-demethyl-25-de(1-methylpropyl)-25-(1-methylethyl)avermectin A1a). The avermectins are macrocyclic lactones derived from a soil microorganism, *Streptomyctes avermitilis*. The mode of action is the disruption of the nervous system by stimulating the release of gamma-aminobutyric acid, an inhibitory neurotransmitter (Putter *et al.* 1981). Abamectin is formulated as a 2% emulsifiable concentrate and was applied as a foliar spray at 0.012 and 0.024 g a.i./litre. Methomyl 2L was also used as a standard treatment

at 0.6 g a.i./litre. These treatments were compared to a water check. All treatments were applied as a full coverage foliar spray with a compressed air sprayer utilizing a 8003 nozzle. Treatments were applied to blocks of four chrysanthemum plants (cultivar Manatee Iceberg) and were replicated four times. Treatments were isolated by cages so thrips could not move between treatments. Chrysanthemums were grown on raised benches in a glasshouse infested with *F. occidentalis* prior to treatment.

Efficacy was evaluated by removing five flowers from each treatment block at 7 day intervals and placing the flowers in Berlese funnels for seven days for thrips extraction. The thrips were collected in ethanol and the adults and immatures counted. The species of the adults was determined and at least 95% of the specimens were *F. occidentalis*.

Experiment 1

This experiment was conducted to determine the effect of foliar application of abamectin against thrips on terminal growth. The terminals were actively growing and approximately two weeks before bud formation. Only one application was made since repeat applications would not be on the same foliage because of continued growth.

Experiment 2

The activity of abamectin was determined against thrips on new buds 0.5-1.0 cm diam. The buds were tight without any petal color showing. Three applications of the treatments were made at seven day intervals.

Experiment 3

This experiment was to determine the efficacy of foliar sprays against thrips on buds which had just opened sufficiently to show color. The color was showing but the petals were still flat and had not extended upward when the experiment was initiated. At the conclusion of the experiment the buds had petals extending upward. Three applications of the treatments were made at seven day intervals.

Experiment 4

The last experiment was conducted to determine if abamectin effectively reduced thrips in the open flower. The petals were not fully extended at the beginning of the experiment. At the conclusion of the experiment the flowers were fully open. Three applications of the treatments were made at seven day intervals.

RESULTS

The data obtained in the above experiments indicate that abamection was efficacious when applied as a foliar spray to four different stages of plant development. In the first experiment the population of thrips was reduced from approximately 5 adults and 40 immatures per five tips to less than one adult thrips in all chemical treatments. There were less than 3 immature thrips in the high rate and less than one immature thrips per five tips in the low rate abamectin. The methomyl treatments had 3 thrips per five tips. The water check had 2.5 adult and 51.3 immature thrips per five tips at 7 days post treatment.

In experiment two the thrips populations in the tight bud stage were lower. The populations were not large enough for significant mean separation (Table 1).

TABLE 1

Insecticide efficacy for *F. occidentalis* on tight bud chrysanthemums. Treatments applied on day 0, 7, and 14. (I=immatures, A=adults)[a].

Treatment (g a.i./litre)	Mean thrips/5 buds					
	7 day		14 day		21 day	
	I	A	I	A	I	A
Abamectin (0.024)	1.0 a	2.0 a	1.3 a	0.8 a	0 a	3.0 a
Abamectin (0.012)	2.0 a	1.0 a	1.5 a	0.5 a	0.5 a	0 a
Methomyl (0.6)	1.3 a	1.3 a	2.5 a	0.5 a	0.3 a	0.3 a
Water check	1.5 a	1.0 a	1.3 a	0.5 a	0.3 a	0 a

[a] Means followed by the same letter are not significantly different (Duncan's Multiple Range Test, P>0.05).

In experiment 3 the population of thrips was larger and significant control was achieved with all chemical treatments (Table 2). The populations of immatures were greater than for adults in the water checks.

TABLE 2

Insecticide efficacy for *F. occidentalis* on buds showing color. Treatments applied on day 0, 7, and 14. (I=immatures, A=adults)[a].

Treatment (g a.i./litre)	Mean thrips/5 buds					
	7 day		14 day		21 day	
	I	A	I	A	I	A
Abamectin (0.024)	1.8 a	0.5 a	2.3 a	0 a	0.5 a	0.3 a
Abamectin (0.012)	1.8 a	0 a	1.8 a	0.5 a	0 a	0.3 a
Methomyl (0.6)	3.3 a	1.5 a	2.8 a	1.3 a	0 a	0 a
Water check	22.0 b	9.8 b	13.5 b	7.3 b	7.3 b	2.3 b

[a] Means followed by the same letter are not significantly different (Duncan's Multiple Range Test, P>0.05).

In the flowering chrysanthemums, experiment 4, the populations of adults and immature thrips were higher and more equal than observed on buds (Table 3). All chemical treatments were efficacious for thrips but were not significantly different. The populations of thrips in water checks were about 50% of that observed on untreated flowers on uncaged plants in the glasshouse at 14 days post treatment.

TABLE 3

Insecticide efficacy for *F. occidentalis* on chrysanthemum flowers. Treatments applied on day 0, 7, and 14. (I=immatures, A=adults)[a].

Treatment (g a.i./litre)	Mean thrips/5 buds					
	7 day		14 day		21 day	
	I	A	I	A	I	A
Abamectin (0.024)	2.8 a	0.5 a	1.8 a	0.5 a	1.5 a	0 a
Abamectin (0.012)	1.0 a	0.8 a	0.8 a	0.5 a	0.5 a	0.8 a
Methomyl (0.6)	2.5 a	0.5 a	4.3 a	0 a	5.3 a	6.5ab
Water check	32.3 b	26.3 b	31.0 b	20.3 b	22.8 b	9.8 b

[a] Means followed by the same letter are not significantly different (Duncan's Multiple Range Test, P>0.05).

DISCUSSION

All treatments of abamectin and methomyl significantly reduced thrips populations as compared to water checks. None of the chemical treatments completely eliminated thrips populations. The populations were the lowest in the tight bud stage and this would be the developmental stage where the thrips could most easily be controlled. Application at this time would prevent flower damage as a result of thrips feeding and possible phytotoxicity as a result of chemical application to flower petals. However, no phytotoxicity was observed from the treatments tested. All flowers on the chemical treated plants were free of thrips injury. The water checks were heavily damaged in the experiments on buds showing color and open flowers.

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REFERENCES

Dybas, R. A., and A. S. J. Green (1984) Avermectins: their chemistry and pesticide activity. *Proceedings British Crop Protection Conference - Pests and Diseases* 1984: 947-954.

Leibee, G. L. (1988) Toxicity of abamectin to *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae). *Journal Economic Entomology* 81(2): 738-740.

Mizell, R. F. III, D. E. Schiffhauer, and J. L. Taylor (1986) Mortality of *Tetranychus urticae* Koch (Acari: Tetranychiidae) from abamectin residues: effects of host plant, light, and surfactants. *Journal Entomological Science* 21(4): 329-337.

Oetting, R. D. (1986a) Biology of thrips on greenhouse crops. *Society American Florist Proceedings Second Conference on Insect and Disease Management on Ornamentals*: 28-30.

Oetting, R. D. (1986b) Insecticide efficacy against western flower thrips, Georgia, 1985. *Insecticide and Acaracide Tests* 11: 196.

Oetting, R. D. (1987) Laboratory evaluation of the toxicity and residual activity of abamectin to *Echinothrips americanus*. *Journal Agricultural Entomology* 4(4): 321-326.

Putter, I., J. G. MacConnell, F. A. Preiser, A. A. Haidri, S. S. Ristich, and R. A. Dybas (1981) Avermectin: novel insecticides, acaricides and nematicides from a soil microorganism. *Experientia* 37: 963-964.

Schuster, D. J. and J. L. Taylor (1988) Longevity and oviposition of adult *Liriomyza trifolii* (Diptera: Agromyzidae) exposed to abamectin the the laboratory. *Journal Economic Entomology* 81(1); 106-109.

BIOLOGICAL EFFICACY OF BIFENTHRIN, APPLIED USING AN AIR-ASSISTED ELECTROSTATIC SPRAYER, TO CONTROL *APHIS GOSSYPII* GLOVER (HOMOPTERA: APHIDIDAE) ON POTTED CHRYSANTHEMUMS

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ABSTRACT

A hand held sprayer, producing an electrostatically charged air-atomized spray, was used to apply low-volume (30ℓ/ha) of aqueous sprays containing bifenthrin and fluorescent tracer to potted chrysanthemums. At each treatment rate, spray distribution on ab-and adaxial leaf surfaces was assessed on each of 4 plants within each plot by examining leaves under UV light using a binocular microscope. Overall, deposition was quite good on adaxial leaf surfaces, regardless of plant position in the plot. However, abaxial surface deposition generally was lower on plants near the center of the plots.

Aphid (*Aphis gossypii* Glover) mortality was more closely related to application rate rather than plant position. More than half of the aphids dropped off plants and were found on circular acrylic discs coated with a sticky material. In experiments using non-sticky acrylic discs, more than 95% of these aphids subsequently died. On plants, most of the dead aphids were found on adaxial leaf surfaces.

INTRODUCTION

The use of electrostatic sprays to improve pesticide efficiency on horticultural crops has been researched for more than a decade. Results of such studies, particularly as they relate to insect and mite control, have been mixed. Although deposition of pesticide and/or tracer materials on abaxial leaf surfaces is generally improved by using charged sprays, improvements in pest control may not occur. One of the primary factors causing relatively poor pest control has been attributed to poor canopy penetration (Cayley *et al.*, 1984). The use of air-assistance, combined with electrostatic charging of spray droplets, has resulted in improved foliage canopy penetration and subsequent pest control (Adams and Palmer, 1986; Abdelbagi and Adams, 1987; Lindquist *et al.*, 1986).

We report here results of experiments utilizing a hand-held air-assisted electrostatic sprayer (Simmons and Lehtinen, 1988) to apply the pyrethroid insecticide, bifenthrin, for *A. gossypii* control on potted chrysanthemums.

MATERIALS AND METHODS

Insect Culture

Adult virginoparae of *Aphis gossypii* (Glover) were collected from a natural infestation on glasshouse grown chrysanthemums (cv. 'Iceberg') during the spring of 1987. These insects were used to establish a laboratory culture which was maintained in a controlled environment cabinet (18 hours light: 6 hours darkness; 30°C) on potted chrysanthemum plants.

Bioassay

A camel's hair brush was used to transfer 20 adult apterous aphids onto the adaxial surface of leaves 4 and 12 of each of 20 chrysanthemum plants to be treated at each rate of bifenthrin 24 hours before the insecticide was applied. Leaves were numbered from the top to the base of each plant. Just prior to spraying, the leaves were examined and any aphids on the adaxial surface were placed on the abaxial surface. After spraying, an acrylic disc (25cm diam) was placed around the base of each plant and a thin layer of "Sticky Stuff"® (Olsen Products Inc., Medina OH) was painted on it to trap any insects that fell off the plant. The location and fate of the aphids was determined 24 hours after spray application by examining each leaf and the stem from every plant sampled, and the disc.

Experiments were also conducted in which the acrylic discs were not coated with sticky material. The aphids that fell off the plants onto the discs were transferred to untreated chrysanthemum leaves in petri dishes and mortality was assessed after 24 hours. The time after treatment that individual aphids dropped off plants was recorded, and the results were tabulated in relation to application rate and plant location.

Spray Application

A hand-held version of an air-atomizing, electrostatic ENS nozzle (Parker Hannifin Corp., Cleveland OH) was used to apply the spray to a plot of 48 potted chrysanthemums (20-25 cm tall) arranged on a bench with a plot width of 150cm (i.e., 8 pots at 20cm inter-plant spacing). The spray was directed into the crop canopy, horizontally, with the nozzle approximately 15cm from the nearest plant, operating at a flow-rate of 70-80 mls/min, an air pressure of 139kPa and a walking speed of 0.6 m/sec. The cloud current of the charged spray was 4-5μA. Previous experiments (Adams *et al*. 1989) had shown that spray distribution was best with this technique because of the relatively narrow (30°) spray cone produced by the ENS nozzle.

A spray mixture containing bifenthrin (FMC Corp., Princeton NJ; recommended rate 45 - 227g a.i./ha), 3g/l Saturn Yellow GT-17N (Day-Glo Corp., Cleveland OH) and 0.1% X-77 (Ortho) was applied to the experimental plot. Bifenthrin rates of 0.02, 0.2 and 2.0g a.i./l were

used, which equalled 0.6, 6 and 60g ai/ha, respectively, at the flow rate and walking speeds used. There were 5 replicates at each application rate. Four pre-infested plants were treated in each replicate, with one placed in each of the rows across one half of the plot. The remaining 44 plants were left in place to minimize variation in canopy structure between replicates. After the location and fate of the aphids had been established, the leaves were observed under a binocular microscope using ultra-violet illumination to reveal the spray deposits. Two areas ($1cm^2$) of each leaf surface were assigned to one of 6 droplet density categories from poor to excellent coverage. Unsprayed plants, infested with *A. gossypii*, were used as checks for aphid distribution and mortality.

RESULTS AND DISCUSSION

Typical fluorescent deposition after application is shown in Figure 1. All rates yielded similar deposition data. On plants nearest the nozzle (position 1), adaxial coverage was lowest on the apical leaves, probably because of the narrow (30^0) spray angle. However, the upward airstream and narrow spray cone was probably responsible for the particularly good abaxial coverage at the top of the plant. Conversely, from leaf 6 downwards, abaxial coverage at position 1 declined sharply. Coverage became surface dependent, rather than height dependent, the further the spray travelled into the canopy. On position 4, coverage on a single leaf was representative of the entire plant. The biological consequences of this uniformity might be poor control of some pests, since abaxial coverage ratings were quite low. The poor abaxial surface was not reflected in efficacy against *A. gossypii*, perhaps because of the "irritation" properties of bifenthrin. Aphid mortality was generally related to application rate (Table 1). Aphid mortality on plants treated with the lowest rate (0.02 g/l) was always lower than on plants treated with the two higher rates. Between 27 and 42% of the aphids were found on the leaves. Most of the dead aphids were on adaxial leaf surfaces,

TABLE 1

Combined *Aphis gossyppii* mortality on chrysanthemum plants and sticky discs after application of bifenthrin using an electrostatic sprayer.

Application Rate	Percent mortality at each plant position[a/]			
	1	2	3	4
2.0 g/l	98	99	99	97
0.2g/l	96	96	97	94
0.02g/l	78	74	73	70
Untreated	17			

[a/] Means of 5 replications; mortality assessed after 24 h.

but this ratio was lower on plants treated with the 0.02 g/l rate (Table 2). There was very little effect on plant position at any application rate. Nearly all the aphids (>97%) that dropped onto the sticky acrylic discs were dead.

TABLE 2.

Proportion of *Aphis gossypii* remaining on treated plants found on adaxial and abaxial leaf surfaces, and their corresponding mortality.

Application rate	Leaf surface	Plant Position [a] 1		2		3		4	
		% F	% D	% F	% D	% F	% D	% F	% D
2.0 g/l	adaxial	100	93	96	100	93	100	94	97
	abaxial	0	-	4	100	7	100	6	0
0.2 g/l	adaxial	98	89	66	96	90	97	85	82
	abaxial	2	100	34	8	10	50	15	67
0.02 g/l	adaxial	80	43	52	64	56	61	37	81
	abaxial	20	22	48	8	44	4	63	3

[a] Means of 5 replications; F = aphids found; D = aphids dead.

In subsequent experiments, when aphids were removed from non-sticky discs and transferred to untreated chrysanthemum leaves, mortality in all cases was >95%. This demonstrated that the "drop off" response was not merely knock down from which the insects would recover.

These experiments demonstrated that the electrostatic ENS nozzle deposited sufficient pesticide on plants within a chrysanthemum plot to provide good to excellent efficacy against *A. gossypii* at application rates below those listed on the pesticide label. Fluorescent deposition ratings on leaf surfaces were not always good indicators of subsequent biological effects because of the pesticide's characteristics of causing the aphids to move from abaxial to adaxial leaf surfaces. The "knock-down" effect of bifenthrin also resulted in virtually complete aphid mortality.

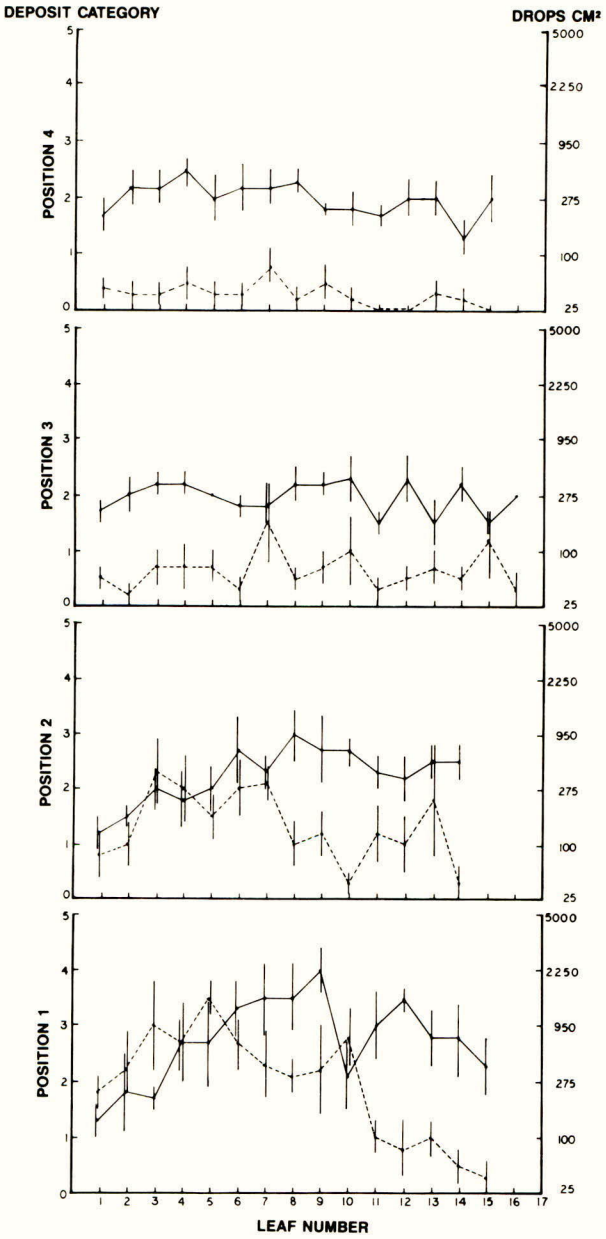

Figure 1. Deposition ratings on adaxial(——) and abaxial(----) surfaces of each leaf at each position across the plot. Each point is the mean of 5 replicates.

REFERENCES

Abdelbagi, H. A.; Adams, A. J. (1987) Influence of droplet size, air-assistance and electrostatic charge upon the distribution of ultra-low-volume sprays on tomatoes. Crop Protection 6(4):226-233.

Adams, A. J.; Hall, F. R.; Rolph, I. A. (1989) Application, distribution and efficacy of electrostatically charged sprays on chrysanthemums. Pesticide Formulations and Application Systems: 9th Volume, ASTM STP 980. (In press).

Adams, A. J.; Palmer, A. (1986) Deposition patterns of small droplets applied to a tomato crop using the Ulvafan and two prototype electrostatic sprayers. Crop Protection 5, 358-364.

Cayley, G. R.; Etheridge, P.; Griffiths, D. C.; Phillips, F. T.; Pye, B. J.; Scott, G. C. (1984) A review of the performance of electrostatically charged rotary atomisers on different crops. Annals of Applied Biology 105, 379-386.

Lindquist, R. K.; Crowther, M.; McShane, A.; Reichard, D. C.; Hall, F. R. (1986) Spray chamber evaluation of charged, uncharged and hydraulic sprays for deposition and efficacy against *Tetranychus urticae*. Proceedings 1986 BCPC - Pests and Diseases, 243-249.

Simmons, H. C.; Lehtinen, J. R. (1988) "Characteristics of an Electrostatically Charged Air-Atomized Spray for Pesticide Application," *Pesticide Formulations and Application Systems: Seventh Volume, ASTM STP 968*, G. B. Beestman and D. I. B. VanderHooven, Eds., American Society for Testing and Materials, Philadelphia, pp. 116-132.

THE POTENTIAL OF CYROMAZINE FOR MUSHROOM PEST CONTROL

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ABSTRACT

When drenched on to the casing layer of a mushroom crop at a rate of 1.0 g a.i/m^2, cyromazine gave good control of Lycoriella auripila larvae - both in terms of numbers of larvae found in the casing and the percentage of sporophores tunnelled by larvae. The level of control was superior to that achieved by diflubenzuron, the standard control measure for L.auripila. Cyromazine did not exert any degree of control over two cecid pests, Heteropeza pygmaea and Mycophila speyeri. Diazinon, the standard control measure for H.pygmaea and M.speyeri, gave a useful level of control of these two species but at the expense of a 14% loss in total yield due to phytotoxicity. There was no apparent phytotoxicity due to the cyromazine treatment.

INTRODUCTION

In the UK 500 commercial mushroom growers produce 120,000 tonnes of mushrooms annually with a farm-gate value of 150 million, making it the most valuable single protected crop and accounting for more than 50% of the value of the protected crops industry. Within the industry approximately 2-3 million/annum is being spent in efforts to control mushroom pests but, despite this, produce to the value of 5-6 million/annum is lost due to pest attacks.

At present, larval pest control mainly relies on two chemicals: diflubenzuron for the control of the mushroom sciarid, Lycoriella auripila; and diazinon for the control of the mushroom phorid, Megaselia halterata, and the mushroom cecids, Heteropeza pygmaea and Mycophila spp. (Fletcher et al, 1986). From the mushroom growers point of view, this is an unsatisfactory situation. Resistance to organophosphorus insecticides, such as diazinon, by L.auripila is widespread (White and Gribben, 1988) and any further resistance, by any pest species to either of the standard insecticides, will cause severe problems for the grower.

It is against this background, therefore, that cyromazine has been developed for mushroom pest control. It is an insect growth regulator which is highly active against dipterous larvae, including species which have developed resistance to conventional insecticides (Schlapfer et al, 1986). This paper reports on the effectiveness of cyromazine for the control of L.auripila, H.pygmaea and M.speyeri, compared to that achieved by diflubenzuron and diazinon, and the comparative phytotoxicity of these treatments, to the mushroom crop.

METHODS

Culture

Mushrooms were grown on straw-based compost (Randle,1974) in 91x61 cm

wooden trays, each constituting a plot within the experimental layout. After pasteurization, the compost (35 kg/tray) was inoculated with a commercial wheat grain spawn of the cultivated mushroom, Agaricus bisporus. After the two week spawn-running period the trays were covered with a 4-5 cm thick 'casing' mixture (consisting of equal weights of peat and crushed chalk) at a rate of 14 kg/tray. Three weeks later the first mushrooms were picked and cropping continued for 31 days.

Infestation techniques

The mushroom sciarid

Numerous adult L.auripila were released into the spawn-running room, two days after spawning, to initiate an infestation. Although it was not possible to exert any degree of control over where the females laid their eggs, experience with numerous previous experiments has shown that egg-laying is fairly uniform over a crop.

The mushroom cecids

20 small H.pygmaea larvae or 20 1st instar M.speyeri larvae were placed into separate 5 ml glass tubes containing water (12 tubes/species). The contents of a tube were then sprinkled evenly over the surface of the relevant trays of compost 11 days after spawning (two days before the casing was added).

Treatments

The 24 trays in the experiment were arranged in two rows, each consisting of three stacks of four trays. There were six treatments with four replicates/treatment - one replicate being in each of the four 'layers' of the stacks. The replicates were randomised within each 'layer'. The treatments are described in Table 1.

TABLE 1

Treatment details

Code	Chemical	Rate (a.i.)	Where used	Pest type *
A	Cyromazine	1.0 g/m^2	Casing	L.a. H.p.
B	Cyromazine	1.0 g/m^2	Casing	L.a. M.s.
C	Diazinon	30 ppm	Compost	H.p.
	Diflubenzuron	30 ppm	Casing	L.a.
D	Diazinon	30 ppm	Compost	M.s.
	Diflubenzuron	30 ppm	Casing	L.a.
E	None - Control	-	-	L.a. H.p.
F	None - Control	-	-	L.a. M.s.

* Pest species that the crop was infested with and/or of most significance in relation to the treatment. L.a., Lycoriella auripila; H.p., Heteropeza pygmaea; M.s., Mycophila speyeri.

The diazinon treatment (granular formulation) was applied to the compost at spawning while the diflubenzuron and cyromazine treatments (wettable powder formulations) were applied, respectively, to the casing materials during mixing and as a surface drench to the casing layer (in 2 l

water/m^2) immediately after casing.

Population and damage assessment

Two criteria were used for assessing insecticidal efficacy.

Firstly, the larval population densities, in the casing layer, of the three pest species were assessed on five occasions - 12, 20, 29, 47 and 61 days after chemical treatment of the casing - the first sample being before the first mushrooms were picked and subsequent samples occurring during the cropping period. 125 g samples of casing (each consisting of several sub-samples) were taken from each tray and mist-extracted, as described by Wyatt (1963), to determine larval densities.

Secondly, an assessment was made of the amount of damage to the picked sporophores, in terms of either larval burrowing by L.auripila or surface spoilage due to H.pygmaea and M.speyeri larvae. For each tray, the number of clean and damaged/spoiled mushrooms, and total weights, were recorded daily.

Analysis of data

Mushrooms grow in fairly distinct 'flushes ' at 7-14 day intervals, this interval depending on several cultural factors as well as any possible treatment effects. A fixed time-interval assessment of the data was, therefore, inappropriate. To determine the extent of the flushes, on which the analysis of the data was to be based, the yield data from each tray was subjected to moving average analysis as described by Wyatt (1977). Thus for each flush the yield, number, weight/mushroom and mean date could be determined.

RESULTS

Effects on L.auripila

Larval samples

From Table 2(a) it can be seen that, taking all sciarid instars into account, neither cyromazine nor the reference chemical, diflubenzuron, appear to exert any degree of control over the larval sciarid population. However, since both chemicals only affect the moulting process, the presence of 1st instar larvae within a sample does not necessarily indicate lack of control. When the 1st instar data are ignored, reductions in larval numbers of 72% and 24% due to cyromazine and diflubenzuron, respectively, are produced at day 61.

Spoilage to sporophores

Table 3(a) shows the effect of cyromazine and diflubenzuron on the percentage of mushrooms burrowed by sciarid larvae. Cyromazine protects the sporophores from damage to a greater degree than diflubenzuron. In the third flush, 4.5 and 6.9 times as many mushrooms are damaged in the diflubenzuron and control treatments, repectively, compared with the cyromazine treatment.

Effects on H.pygmaea and M.speyeri

Larval samples

From Table 2(c & d) it can be seen that cyromazine had no reducing

TABLE 2

The effect of cyromazine and diflubenzuron/diazinon on the number of larvae extracted from casing samples (mean no./125g sample): (a) Lycoriella auripila (all instars); (b) Lycoriella auripila (minus 1st instar); (c) Heteropeza pygmaea; (d) Mycophila speyeri.

	Treatment	Days from casing treatment 12	20	29	47	61
(a)						
	Control	0.25	3.0	2.5	11.25	39.0
	Cyromazine	0	2.5	3.75	7.75	40.0
	Diflubenzuron/diaz	0.25	7.75	3.0	6.5	42.0
(b)						
	Control	0	1.75	2.25	2.0	26.75
	Cyromazine	0	0.5	2.5	2.0	7.5
	Diflubenzuron/diaz	0.25	3.5	2.25	2.0	20.25
(c)						
	Control	1.5	1.5	121.0	118.5	550.0
	Cyromazine	0	51.5	33.0	355.5	1000.0
	Diflubenzuron/diaz	0	0	28.5	174.5	119.0
(d)						
	Control	8.0	88.0	262.5	329.0	174.5
	Cyromazine	20.0	86.5	391.5	690.5	243.5
	Diflubenzuron/diaz	4.0	2.5	176.0	74.0	47.5

TABLE 3

The effect of cyromazine and diflubenzuron/diazinon on the number of mushrooms in each flush (percentages shown in brackets) infested with larvae of: (a) Lycoriella auripila; (b) Heteropeza pygmaea; (c) Mycophila speyeri.

	Treatment	Flush number 1	2	3
(a)				
	Control	0	3.4 (0.88)	13.8 (4.04)
	Cyromazine	0	1.7 (0.41)	2.0 (0.65)
	Diflubenzuron/diaz	0	4.3 (1.30)	9.0 (3.89)
(b)				
	Control	0	0	102.2 (30.0)
	Cyromazine	0	0	113.7 (36.1)
	Diflubenzuron/diaz	0	0	19.0 (8.2)
(c)				
	Control	0	231.7 (60.5)	246.0 (72.2)
	Cyromazine	1.78 (0.6)	288.6 (70.3)	217.7 (69.1)
	Diflubenzuron/diaz	0	66.4 (20.1)	114.8 (49.5)

effect on either H.pygmaea or M.speyeri: producing about 1.8 or 1.7 times the control numbers and 4.5 or 4.7 times the diazinon numbers (means of all samples), respectively.

Spoilage to sporophores

The lack of control of cecid larvae by cyromazine is also indicated by the number and percentage of sporophores spoiled by their presence (Table 3(b & c)). With H.pygmaea and M.speyeri, 6.0 and 2.8 times as many mushrooms, respectively, were spoiled in the cyromazine treatment compared with the diazinon treatment (values averaged over all flushes). Because M.speyeri reproduce faster than H.pygmaea and are orange rather than white, spoilage is more easily noticed and occurs earlier with this pest.

Cropping effects

The effects of cyromazine on mushroom cropping compared to the diflubenzuron/diazinon treatments are shown in Fig.1. The total yield in the control and cyromazine treatments are virtually identical. However, there was a 14% reduction in total yield in the diflubenzuron/diazinon treatment (Fig.1(b)). The total number of mushrooms produced by the cyromazine treatment was only 4% less than the control, with a consequent 3% increase in mushroom size. In addition to the 14% reduction in total yield in the diflubenzuron/diazinon treatment, mostly from the first flush, there was a 28% reduction in total numbers. Since the reduction in numbers was greater than the reduction in yield, a 19% increase in size was produced.

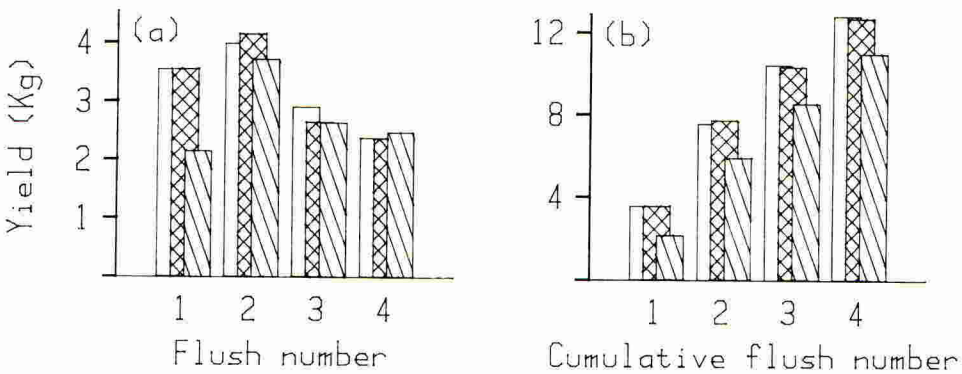

FIGURE 1. The effect of cyromazine ▨ and diflubenzuron/diazinon ▤ on mushroom cropping compared to the control □ : (a) individual flushes; (b) cumulative flushes.

In the individual flushes, cyromazine produced a yield reduction only in the third flush, while the diflubenzuron/diazinon treatment caused yield reductions in all flushes but the fourth - a 40% reduction occurring in the first flush (Fig.1(a)).

CONCLUSIONS

In this test, which was subject to high population densities of all three pest species , cyromazine gave acceptable control of L.auripila larvae

- expressed as either casing extractions or sporophore damage - and superior control to that achieved by diflubenzuron.

In direct contrast, cyromazine exerts no degree of control over the population increase of either cecid species, either in the casing layer or on the sporophores. In fact, higher populations are found in the cyromazine treatments than in any other treatment. The diflubenzuron/diazinon treatment, on the other hand, does exert a useful degree of control, using both criteria, over both species. In this double treatment, it is only the diazinon component which is effective against the cecidomyid larvae, since diflubenzuron has been shown to be ineffective against these larvae (White,1977).

The degree of control excercised by diazinon in the diflubenzuron/diazinon treatment must, however, be balanced against the apparent losses in yield due to its phytotoxic action. The diazinon component of this double treatment is the most likely cause of the reductions, since it has been shown to cause reductions in yield (Wyatt,1977) while, at the commercial rate, diflubenzuron has not (White,1986). If this experiment had been a commercial crop, however, the losses due to phytotoxic action would have been more than made up for by the reduction in spoilage.

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REFERENCES

Fletcher, J.T.; White, P.F.; Gaze, R.H. (1986) Mushrooms: Pest and Disease Control. Newcastle upon Tyne: Intercept Ltd.

Randle, P.E. (1974) Mushroom - Agaricus bisporus (Lange)Singe: Compost. Report of the Glasshouse Crops Research Institute for 1973, 82-84.

Schlapfer, T.; Cotti, T.; Moore,J.L. (1986) Cyromazine, a new insect growth regulator for leafminer control. Proceedings 1986 British Crop Protection Conference - Pests and Diseases 1, 123-128.

White, P.F. (1977) Sublethal effects of four pesticides on paedogenetic larvae of the Cecidomyiidae. Entomologia experimentalis et applicata 22, 43-52.

White, P.F. (1986) The effect of bendiocarb and diflubenzuron on mushroom cropping . Annals of Applied Biology 108, 11-20.

White, P.F.; Gribben, D. (1988) Variation in resistance to diazinon by the mushroom sciarid Lycoriella auripila. Mushroom Science XII (in press).

Wyatt, I.J. (1963) An apparatus for the extraction of dipterous larvae from mushroom compost. Report of the Glasshouse Crops Research Institute for 1962, 109-110.

Wyatt, I.J. (1977) Principles of insecticide action on mushroom cropping: incorporation into compost. Annals of Applied Biology 85, 375-388.

MEASURES FOR IMPROVING SOIL FUMIGATION

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ABSTRACT

Chemical soil disinfestation may be improved by changing routine application methods allowing lower active ingredient concentration or shorter fumigation periods, often resulting in decreased soil and plant residue hazards. Laboratory experiments have shown that depth penetration of methyl bromide (MB) in soil is enhanced by the application of admixtures with 1,2-dichloroethane (DCE) and 1,1,1-trichloroethane (TCE) allowing lower dosage (50 - 20 % of the usual dose), especially when combined with ameliorated mulching. Four types of plastic films have been tested for gas-tightness versus MB, DCE and TCE. The less lower volatile methyl isothiocyanate has been studied with plastic mulching as well as with polymer spray mulching, the latter showing promising results in view of large outdoor application.

INTRODUCTION

Intensive outdoor or protected cropping, coupled with restricted crop rotation, frequently requires regular soil disinfestation to sustain economic yields. The most widely used and most effective fumigant for this purpose is methyl bromide (MB). This compound has been the subject of many discussions from the toxicological viewpoint. MB is hazardous to apply and bromide residues may accumulate in crops and soil. Although recent toxicological data on MB and bromide (Duafala, 1986; Sangster *et al.*, 1986) are less condemning this application, any improvement in techniques which increase efficiency of disinfestation and allow lower doses to be used are worthy of investigation.

Factors determining efficacy are : concentration (C) and contact time (t) expressed as the C x t product, diffusion rate and adsorption phenomena, all of which are influenced by temperature. For methyl isothiocyanate (M.I.T.) generators the conversion rate into M.I.T. in soil is another important factor. The average concentration maintained during the necessary contact period depends for all soil sterilants on the method of sealing, which is determined by the volatility of the active chemical.

Fumigant movement by diffusion in soil is influenced by the pore volume, moisture content, adsorbing materials and temperature. However diffusion may be enhanced by using mixtures. Good plastic sheet tarps are necessary for MB. M.I.T.-producers, often used outdoors, are sometimes only sealed by moistening the upper soil layer or by rolling the surface. Polymer

sprays developed for their soil stabilizing effects may also serve as effective seals after fumigation.

EXPERIMENTAL DATA

Enhanced MB diffusion in soil using admixed compounds

Preliminary research using methyl chloride as the co-fumigant has been reported (Vam Wambeke *et al.*, 1983). For reasons of toxicology and handling difficulties alternatives to methyl chloride were investigated.

MB, 1,2-dichloroethane (DCE) and 1,1,1-trichloroethane (TCE) were applied to 30 cm columns light sandy loam soil (52 % pore volume; 49 % of the water holding capacity) at dosages equimolar to 50 g MB/m^2. Effluent gas was transported with air flowing at 20 ml/min and analyzed by electron capture glc. Table 1 summarizes the gas concentrations as a function of time elapsed after application.

TABLE 1

Concentrations (mg/l effluent air) of methyl bromide (MB), 1,2-dicloroethane (DCE) and 1,1,1-trichloroethane (TCE) after diffusion through a 30 cm soil column applied separately or combinations.

Time (h)	Separate application			Combined application MB + DCE		MB + TCE	
	MB	DCE	TCE	MB	DCE	MB	TCE
1	15.7	n.d.*	7.6	31.2	n.d.	43.6	2.5
2	23.7	0.8	36.0	88.8	1.1	190.0	60.6
3	24.6	2.5	48.8	88.0	4.8	116.0	78.0
4	18.9	8.4	25.0	47.0	16.1	51.2	42.5
7	18.1	8.6	19.0	34.8	16.8	44.1	39.5
8	16.4	8.5	15.0	30.4	18.5	38.0	33.3
10	13.1	8.0	10.0	18.0	14.8	27.8	25.3
12	10.5	7.5	7.5	10.5	12.4	20.4	19.7
14	8.1	7.1	5.5	6.8	10.9	14.7	15.2
24	0.9	5.0	1.0	0.9	6.7	1.6	4.0
30	0.9	3.9	0.6	n.d.	5.3	1.0	1.8
48	0.2	1.9	n.d.	n.d.	2.1	0.1	0.1

*n.d. = not detected

These data show greater MB transport through soil columns when combined with DCE or TCE. Although the peak concentrations of MB were maintained no longer than with MB only, the overall concentration remained higher during the following hours. Analysis for bromide in soil at the end of the diffusion monitoring showed about half of the bromide residues in the combined treatments compared to those from MB alone. This indicates a lower adsorption of MB to soil. Combined application for the given soil type appears to

improve downward distribution of MB. Analysis for adsorbed MB at the same sampling depths showed negligible concentrations (i.e. mostly < 1 mg/kg soil). DCE and TCE were found at levels upto 9 and 1 mg/kg soil respectivel.

Diffusion of MB and co-fumigants through plastic sheets

MB, DCE and TCE were applied at a dosage corresponding with 50 g MB per m^2 of testing plastic film separating two ground glass chambers. The lower chamber only contained the fumigant tested. The upper chamber was provided with 2 ports through which an air stream (20 ml/min.) passed. Effluent gasses were collected in two serial mounted ice cooled wash bottles filled with acetone. The plastics tested were : Low density polyethylene (LDPE), Eurofilm Plus, Saranex and Waloplast Combi XX, all of 40 µm thickness, except Saranex which was 38 µm. Results are shown in tables 2, 3 and 4.

TABLE 2

Methyl bromide (MB) diffusion through different plastic films (329 mg MB applied; 5 h period).

Plastic	Quantity absorbed in acetone (mg)	Time maximum was reached (h : min)	Concentration (mg/l effluent)
LDPE	103.7	0 : 30	25.8
Eurofilm	57.6	0 : 30	23.4
Saranex	0.46	4 : 00	0.16
Waloplast	0.19	3 : 30	0.01

TABLE 3

1,2-Dichloroethane (DCE) diffusion through different plastic films (409 mg DCE applied; 3 h period).

Plastic	Quantity absorbed in acetone (mg)	Time maximum was reached (h : min)	Concentration (mg/l effluent)
LDPE	66.0	1 : 45	51.4
Eurofilm	103.0	1 : 20	48.5
Saranex	46.0	2 : 00	31.1
Waloplast	51.0	1 : 30	58.1

Saranex and Waloplast, both showed excellent barrier properties to MB but were not as gastight to DCE and TCE. About 3/4 of the MB applied was lost through LDPE, formerly the most widely used sealant, within 5 h. This indicates that reductions in MB dose could be possible if Saranex or Waloplast tarps were used rather than LDPE, and still ameliorated when combined with co-fumigants. Eurofilm has already been shown to be a usefull compromise of price and sealing quality (Van Wambeke, 1984).

Soil sealants and methyl isothiocyanate (M.I.T.) losses

Soils treated with M.I.T. generators such as metham-sodium and dazomet are less subject to rapid losses of sterilant by diffusion than MB treated

TABLE 4

1,1,1- Trichloroethane (TCE) diffusion through different plastic films (552 mg TCE applied; 3 h period).

Plastic	Quantity absorbed in acetone (mg)	Time maximum was reached (h : min)	Concentration (mg/l effluent)
LDPE	164.5	1 : 30	82.8
Eurofilm	171.5	1 : 30	92.6
Saranex	51.0	1 : 15	9.5
Waloplast	96.0	2 : 30	27.6

soils. However, earlier reports (Alphey, 1980; Bochow & Mende, 1981) on alternatives to plastic sheets for sealing soil treated with 1,3-dichloropropene or dazomet showed that LDPE and Eurofilm reduced losses of M.I.T. from soil to half those in the absence of sealant over a 2 h period. Waloplast Combi XX film was found to be very gastight to M.I.T. (Van Wambeke and Vanachter, 1986). The possibilities of replacing plastic film seals with polymer sprays for field disinfestation were investigated in the laboratory.Experiments were performed by mixing dazomet with a clay soil (25.3 % sand, 54.7 % silt, 20.0 % clay) (top layer 2 mm sieve), at a dose equivalent to 80 g/m^2. Commercial soil stabilizers were applied to soil after incorporating dazomet at label recommended rates. Air samples withdrawn from the upper closed chamber of the apparatus were analysed by nitrogen phosphorous detector glc. Results are shown in table 5.

TABLE 5

M.I.T.- diffusion experiments through different polymer mulches (room temperature)

Experiment	Polymer treatments (trade name)	Application (dose;prod./ water ratio)	Different M.I.T. concn (µg/l) time (h) 4	8	24
A	polyvinyl acetate (Curasol AE)	- 100 g/m²; 1/40	140	370	730
		- water	370	580	800
		- no mulching	380	630	800
B	polyvinyl propionate (Agrofix)	- 120 g/m²; 1/4	250		
		- no mulching	480		
C	polyacrylamide (Alcosorb)	- 1000 g/m² in upper 3 cm layer followed by moistening	150	380	590
		- no mulching	440	540	610
D	modified diphenyl methane diisocyanate - toluene diisocyanate (SS 336)	- 1 l/m²; 12 %	450	500	570
		- no mulching	800	780	740

All polymer sprays tested reduced losses of M.I.T. from soil. The results of experiment A show that this is probably not due to water applied with the polymer. However the effect of these seals declined steadily between 4 and 24 hours except with SS 336. Indirect control on the sealing effect, by M.I.T. residue estimation in water/ethyl acetate soil extract according to a glc procedure of Smelt and Leistra (1974), showed higher M.I.T. concentrations with sealants. Illustrative data for two polymers are given in table 6 also taking the influence of atmospherical moisture into account. It has been shown that a dry atmosphere could enhance the sealant capacity of these polymers (Van Wambeke, unpublished data).

TABLE 6

M.I.T. residues extracted from bare and polymer spray mulched soil.

Polymer	time (h)	M.I.T. concn (µg/l soil) dry atmosphere	moist atmosphere
polyvinyl acetate	6.0	360	320
control	6.0	190	150
polyvinyl propionate	2.5	370	250
control	2.5	280	150

Due to rather high experimental temperatures and a high soil moisture content, the residues found are low, meeting the results for comparable conditions in the experiments reported by Neumann *et al.* (1983).

Soil extracts reveal higher M.I.T. residues from soil with polymer spray than from soil without. Comparative tests with other soil types have shown that polymer effect is strongly clay and humidity dependent. Dryer atmosphere and lower temperatures between some limits favour sealing properties. Product/water ratio at the application time depends of the compound itself; polyvinyl acetate at 1/40 is much better than at 1/10 (Van Wambeke, unpublished data).

CONCLUSIONS

It was found that in soil columns methyl bromide movement can become considerably enhanced in the presence of fumigants. This may increase the effectiveness of MB and permit lower doses to be used in the field. The results with plastic sealants also suggest reduced MB doses may be possible with alternatives to the polythenes widely used in commerce. Sealing soil with polymer sprays after treatment with less readily volatilizing compounds such as M.I.T. may be as effective as LDPE and other semi-permeable plastics. This offers the prospect of simultaneous application of sealant with the fumigant or its generator, with the advantages of soil stabilization and avoidance of the need to remove plastic sheets after fumigation.

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REFERENCES

Alphey, T.J.W. (1980). The efficacy of fumigation of nematode-infested soil following different methods of soil sealing. Plant Pathology 29, 131-135.

Bochow, H.; Mende, G. (1981). Neue Möglichkeiten zur Bodenabdeckung beim grossflächigen Einsatz chemische Bodenentseuchungsmittel. Arch. Phytopathol. u. Pflanzenschutz 17 (2), 127-137.

Duafala, T. (1986). Methyl bromide and the E.P.A. Demands, reactions and results. Summaries FAO-INRA European Workshop on Methyl bromide, Avignon (France).

Neumann, U.; Will, H.; Gröner, H. (1983). Soil fumigation with Basamid Granular, including new experimental results. Acta Horticulturae 152, 171-178.

Sangster, B.; Blom, J.L.; Baas, C.; Loeber, J.G.; Rauws, A.G. (1986). Sodium bromide in human volunteers. Summaries FAO-INRA European Workshop on methyl bromide, Avignon (France).

Smelt, J.H.; Leistra, M. (1974). Conversion of metham-sodium to MIT and basic data on the behaviour of MIT in soil. Pesticide Science 5, 401-407.

Van Wambeke, E. (1984). Efficiency increase of methyl bromide soil fumigation by admixture with methyl chloride or ameliorated tarps. Acta Horticulturae 152, 137-145.

Van Wambeke, E.; Vanachter, A. (1986). Report on Section III of I.W.O.N.L.-Committee for Research on Vegetable Crops, 4-6.

Van Wambeke, E.; Vanachter, A.; Van Assche, C. (1983). Methods to increase the performance of methyl bromide soil disinfestation. Proceedings 10th International Congress of Plant Protection 2, 568.

ABAMECTIN, NOVEL NATURALLY-DERIVED INSECTICIDE/ACARICIDE FOR INTEGRAL KEY PEST CONTROLS ON PEARS AND TOMATOES

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ABSTRACT

Abamectin, a macrocyclic lactone natural product, produced by the soil microorganism Streptomyces avermitilis has shown high biological efficacy under laboratory and field conditions throughout the world for the control of resistant and susceptible pest strains, including pear psylla (Psylla pyri and P. pyricola), Tetranychid mites (Panonychus ulmi, Tetranychus spp.) and Eriophyid mites (Epitrimerus pyri) on pears, and leafminer complex (Liriomyza spp.), tomato pinworm (Keiferia lycopersici), and mite complexes (Tetranychus spp. and Aculops lycopersici) on tomatoes. Trial results to date show that abamectin at 13.5-27.0 g ai/ha plus 0.25% of agricultural mineral oil on pears and at 10-22 g ai/ha on tomatoes provides excellent control of these pests without phytotoxicity. Abamectin has been also shown not to disrupt the beneficial arthopods of pears or tomatoes, making it suitable for Integrated Pest Management Programs.

INTRODUCTION

Abamectin is a new class of natural product acaricide/insecticide that is being presently developed worldwide for the control of important crop pests (Dybas, 1983). Pear Psylla and pear mites (P. ulmi, Tetranychus spp., and E. pyri) are important pests on pears throughout the world. Liriomyza spp., in particular L. trifolii, K. lycopersici, and mite complexes (Tetranychus spp. and A. lycopersici) are also important pests on tomatoes around the world and resistance is becoming a serious problem in several growing areas. The data discussed below are a brief summary of the field evaluation results of abamectin against these important pests.

MATERIALS AND METHODS

Field evaluations against pear pests

In trial 001-87-0119, abamectin at 26.3 g ai/ha + 0.25% Superior 6E oil, fenvalerate at 336.5 g ai/ha, and SN-72129 at 841.4 g ai/ha were applied three times, i.e. May 5, June 12, and July 17, 1985 with a handgun sprayer to mature pear trees of mixed varieties at the volume of 2805 l/ha, to determine their efficacies against nymphs of P. pyricola and E. pyri throughout the season. The evaluations were made periodically by collecting randomly 25 leaves from each of four trees in the center of each 1011 m^2 plot per treatment/evaluation. The presence of sooty mold that grows in psylla honeydew was also rated on 50 leaves from each of 4 centrally located trees per treatment by determining the percentages of leaves covered with the fungi.

In trial 001-87-5005, abamectin at 14 and 27 g ai/ha plus 9.3 l of spray oil/ha and amitraz at 1682.7 g ai/ha were applied once with an airblast sprayer to three replicates of 16 mature Bartlett pear trees each at the volume of 2338.2 l/ha, to determine their efficacies against nymphs of P. pyricola and T. urticae throughout the season. The evaluations were made periodically by collecting randomly 25 leaves per plot/evaluation.

In trial 001-86-0662, abamectin at 14 and 27 g ai/ha plus 0.25% of spray oil/ha, amitraz at 1682.7 g ai/ha, diflubenzuron at 560.9 g ai/ha, and fenoxycarb at 560.9 g ai/ha were applied three times, i.e. May 1, June 4, and July 22, 1986 (diflubenzuron and fenoxycarb also sprayed on April 11) with a handgun sprayer to mature Bartlett pear trees at the volume of 3741 l/ha, to determine their efficacies against nymphs of P. pyricola, E. pyri and P. ulmi throughout the season. The evaluations were made periodically by taking 50 leaves/replicate (5 replicates of 2 trees each) until May and from 10 terminal shoots/replicate thereafter. Fruit quality was also assessed at the end of the trial, using the US Grade Standards for fresh market Barlett pears.

Field evaluations against tomato pests

In trial 001-87-0055, abamectin at 8.4 and 11.2 g ai/ha, methamidophos at 1121.8 g ai/ha and cyromazine at 143.3 g ai/ha were applied 5 times on a weekly basis with a knapsack sprayer to field tomatoes at the volume of 1028-1262 l/ha, to determine their efficacies against L. trifolii throughout the season. The evaluations were carried out twice, i.e. 3 days after the second spray and 1 day after the fifth spray by counting all mines developed after a two-minute search in each of 4 replicates/treatment.

In trial 002-88-0008, abamectin at 9.0, 13.5 and 18.0 g ai/ha, cypermethrin at 100.0 g ai/ha, and permethrin + chlorpyriphos at 170 + 270 g ai/ha were applied 7 times on a weekly basis with a knapsack sprayer to field tomatoes at the average volume of 400 l/ha, to determine their efficacies against Liriomyza spp. and K. lycopersicella throughout the season. The evaluations were carried out eight times, one week after each spray by counting all Liriomyza spp. mines from 45 leaves from each of 4 replicates/treatment and by determining the percentage of fruit damage caused by K. lycopersicella, and the total and sound tomato production after one harvest (picking).

In trial 017-87-0025, abamectin at 15.0 g ai/ha, chlorobenzilate at 419 g ai/ha, dicofol + tetradifon at 703.9 + 251.4 g ai/ha were applied once with a knapsack sprayer to field tomatoes at the volume of 1676 l/ha, to determine their efficacies against A. lycopersici for 34 days. The evaluations were carried out six times by taking an entire plant for each of the four replicates/treatment and analyzing four-10 g of leaves/stems in the laboratory using the washing(surfactant)/filtering/ suspension method, and reading aliquota under the microscope.

In trial 023-86-0023, abamectin at 9.0 and 18.0 g ai/ha, and propargite at 649.0 g ai/ha were applied once (except for propargite that was sprayed twice) with a knapsack sprayer to field tomatoes at the volume of 1000 l/ha, to determine their efficacies against Tetranychus spp. for 56 days. The evaluations were carried out eight times by using

the mite population index, i.e. scouting 5 plants of each of 5 replicates/treatment, counting the adult females on the ventral sides of three leaves/plant (1 from the middle and 2 leaves from the upper region), and using the established index, e.g., 0=0, 1=1-10, 2=11-30, and 3=30 or more female mites/leaf.

RESULTS

TABLE 1: Field evaluations of abamectin against P. pyricola, E. pyri and sooty mold on pears (Trial 001-87-0119 USA)

Treatments	Rate g ai/ha	Season Average - 17/5 to 10/8/85 Psylla Nymphs/leaf	Mites/leaf	S. Mold*
Abamectin + oil	26.3 + 0.25%	0.25	2.9	4.0
SN-72129	841.4	0.19	10.4	20.3
Fenvalerate	336.5	1.20	16.9	53.3
Control	-	2.70	8.6	101.0

* Sooty Mold Rating = Maximum 150-Grades 0-3(3=50% or more/leaf)

TABLE 2: Field evaluation of abamectin against P. pyricola and T. urticae on pears (Trial 001-87-5005 USA)

Treatments	Rate g ai/ha	Season Average 8/6 to 11/8/87 Psylla Nymphs/leaf	% Psylla Infested leaves	Mites/leaf
Abamectin + oil	14.0 + 9.3 l	0.04	2.9	0.05
Abamectin + oil	27.0 + 9.3 l	0.20	2.7	0.01
Amitraz	1682.7	0.02	1.3	4.90
Control	-	2.90	47.5	5.40

TABLE 3: Field evaluation of abamectin against P. pyricola, E. pyri and P. ulmi on pears (Trial 001-86-0662 USA)

Treatments	g ai/ha	Season Average - 5/5 to 6/8/86 Psylla Nymphs/leaf	P.u./ leaf	E.p./ leaf	% Fruit Damage Psylla	Rust Mites
Abamectin + oil	14.0 + 0.25%	0.15	0.22	0.54	0.4	0.0
Abamectin + oil	27.0 + 0.25%	0.10	0.09	0.52	0.0	0.0
Amitraz	1682.7	0.33	0.24	3.96	2.8	5.6
Diflubenzuron*	560.9	0.91	4.70	2.88	6.8	39.6
Fenoxycarb*	560.9	0.77	1.81	4.60	8.4	29.2
Control	-	2.87	1.18	4.20	36.4	80.0

*Also sprayed on 11/4/86

TABLE 4: Field evaluations of abamectin against L. trifolii on tomatoes (Trial 001-87-0055 USA)

Treatments	Rate g ai/ha	Mean No. Mines/2-Minute Search Total M. 3DAT2	Small M. 3DAT2	Total M. 1DAT5	Small M. 1DAT5
Abamectin	11.2	12.7	2.5	19.6	5.8
Abamectin	8.4	17.7	4.2	30.2	9.0
Methamidophos	1121.8	46.4	5.2	264.2	15.2
Cyromazine	143.3	27.6	4.8	138.3	107.5
Control	-	100.7	3.2	321.2	10.2

TABLE 5: Field evaluation of abamectin against L. trifolii and K. lycopersicella on tomatoes (Trial 002-88-0008 Mexico)

Treatments	Rate g ai/ha	Mean % Infested leaves by L.t. 7-49DAT1	% Fruit Damage (harvest) by K.l.	Yield M. Ton /Harvest Total	Sound Fruits
Abamectin	9.0	7.7	10.3	5.40	4.78
Abamectin	13.5	6.4	8.0	4.18	3.80
Abamectin	18.0	6.3	4.0	4.55	4.35
Cypermethrin	100.0	62.4	68.0	3.80	1.20
Permethrin + Chlorpyriphos	170 + 720	53.2	69.5	3.93	1.15
Control	-	97.9	88.8	3.70	0.43

TABLE 6: Field evaluation of abamectin against A. lycopersici on tomatoes (Trial 017-87-0025 Argentina)

Treatments	Rate g ai/ha	Mean mites/ 10 g leaves-stems 6-34DAT	Mean % Efficacy (H & T) 6-34DAT
Abamectin	15.0	5.5	81
Chlorobenzilate	419.0	13.0	71
Dicofol + tetradifon	703.9 + 251.4	28.5	27
Control	-	41.5	-

TABLE 7: Field evaluation of abamectin against Tetranychus spp. on tomatoes (Trial 023-86-0023 S. Africa)

Treatments	Rate g ai/ha	Mite Population Index* - DAT1 +0	+8	+15	+22	+29	+36	+44	+56	Mean P.I. 8-56 DAT1
Abamectin	9.0	1.24	0.24	0.72	0.36	0.66	0.88	0.88	0.48	0.60
Abamectin	18.0	1.36	0.16	0.48	0.28	0.62	0.76	0.80	0.12	0.46
Propargite**	649.0	1.48	0.60	0.76	0.72	1.26	1.48	1.64	0.52	1.00
Control	-	1.12	1.88	1.96	1.60	2.72	2.56	1.80	0.24	1.82

* Population Index: 0=0, 1=1-10, 2=11-30, 3=30 + Female mites/leaf
** Sprayed also on 1/5/86

DISCUSSION

Pear pests

Three spray applications of abamectin at 26.3 g ai/ha plus 0.25% oil controlled psylla nymphs efficiently throughout the season (17/5-20/8), being comparable to SN-72129, but better than fenvalerate. Abamectin treatment resulted in less sooty mold development than the other treatments, indicating an additional physiological effect on the nymphs by the compound, other than the straight mortality obtained. Moreover, abamectin provided the best control of pear rust mite (Table 1).

Abamectin applied once at 14.0 or 27.0 g ai/ha plus 9.3 l/ha of spray mineral oil controlled psylla nymphs efficiently and equally to amitraz for 75 days. This is considering both the mean number of nymphs/leaf and percent infested leaves encountered during the evaluation periods, i.e. 8/6 to 11/8. However, abamectin at both rates provided better Tetranychus spp. control than amitraz during the same period (Table 2).

Three spray applications of abamectin at 14.0 or 27.0 g ai/ha plus 0.25% oil provided better control of pear psylla nymphs, European red mites, and pear rust mites than amitraz, diflubenzuron, or fenoxycarb. This is considering the season average obtained, i.e. 5/5 to 6/8, for the individual pests, as well as the percent fruit damages obtained by pear psylla and pear rust mites. It should be mentioned that diflubenzuron and fenoxycarb received one additional spray application(Table 3).

Tomato pests

Five weekly spray applications of abamectin at 8.4 or 11.2 g ai/ha provided less total or small/large leafminer mines in comparison with methamidophos or cyromazine by considering the evaluations taken at 3 days after the second spray or at 1 day after the fifth spray (Table 4). Liriomyza leafminer mine development is a more efficient diagnostic tool than pupal emergence when comparing different products because the latter evaluation method does not take into account the damage inflicted to the foliage by the different larval developmental stages.

Seven weekly spray applications of abamectin at 9.0, 13.5 or 18.0 g ai/ha resulted in much lower percent of leaves infested with Liriomyza leafminer mines for 49 days than cypermethrin or the mixture of permethrin plus chlorpyriphos (Table 5). This trial was conducted under extremely high incidences of Liriomyza spp. and K. lycopersicella in the Culiacan Valley, Sinaloa, Mexico, where up to 40 sprays/season are carried out for the control of both pests. The evaluations taken at harvest to assess the damage caused by the tomato pinworm also show that the three abamectin rates were highly superior to the other compounds (Table 5). In addition, the total productivity obtained and the total weight of undamaged fruits obtained by the abamectin treatments also confirm the excellent performance against these two important pests. By analyzing trial Nos. 001-88-0008 and others, it was learned that abamectin is able to penetrate the leaf tissues and kills the developing larval stages of the tomato pinworm.

Abamectin at 15 g ai/ha applied once provided better tomato russet mite control than chlorobenzilate or the mixture of dicofol plus tetradifon, considering the evaluations taken from +6/+34 days after treatment (Table 6). Abamectin at 9.0 and 18.0 g ai/ha also applied once resulted in lower mite population indices than propargite for Tetranychus spp. control for up to 56 days on field tomatoes (Table 7).

CONCLUSION

Although abamectin is still under extensive field evaluations worldwide for the primary pests of pears and tomatoes, the results to date show that the product will be an effective psylla, leafminer and pinworm insecticide, as well as an effective acaricide, particularly where resistance or tolerance against other compounds exists or is suspected.

REFERENCE

Dybas, R.A. (1983) Avermectins: Their chemistry and pesticidal activities. IUPAC Pesticide Chemistry, Human Welfare and the Environment. J. Miyamoto (ED). Pergamon Press, pp. 83-90.

RECENT DEVELOPMENTS WITH AMITRAZ FOR MITE CONTROL ON TOP FRUIT

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ABSTRACT

Recent work with amitraz as an acaricide for the control of spider mites and rust mites on top fruit is described and amitraz is presented as one of the few remaining effective compounds suitable for mid-season application following the withdrawal of cyhexatin. In laboratory tests with Tetranychus urticae, amitraz although less temperature dependent than propargite was found to be less active than cyhexatin at lower temperatures. Spider mites obtained from apple orchards in Spain and Italy were found to be highly susceptible to amitraz in laboratory tests. In the field, amitraz was found to give optimum control when applied at higher spray volumes and when applied at the start of mite build-up. Amitraz alone and in mixture with clofentezine or bifenthrin has given good control of spider mites in apple orchards and amitraz is also being developed for the control of the rust mite, Aculus schlechtendali.

INTRODUCTION

Amitraz is registered and sold in many countries as an acaricide on a range of crops including cotton, citrus, vegetables and top fruit but has become better known in top fruit growing regions as an insecticide for the control of pear psylla. Also, at the time of introduction in the mid 1970's, amitraz was seen as less cost effective than cyhexatin. Today, amitraz is one of the few remaining, effective adulticidal acaricides available for use on top fruit. This paper examines the benefits and limitations of amitraz as a top fruit acaricide.

MATERIALS AND METHODS

In all the field and laboratory tests described, amitraz has been applied as a 200 g/l EC which is the recommended formulation for mite control on top fruit. Amitraz 200 g/l EC plus clofentezine 50 g/l SC was applied as a tank mixture.

In laboratory tests on the effect of temperature on the activity of amitraz, adult female Tetranychus urticae were placed on leaf discs cut from French beans and maintained on moist pieces of filter paper placed on foam kept in a tray of water. The leaf discs were treated either before or after infesting with T. urticae in order to investigate the effect of temperature on residual and contact activity. Mortality was assessed 3 days after treatment.

A similar method was used to assess the susceptibility of adult female Panonychus ulmi to amitraz in Spain and Italy. Ten adults were placed on each of 3 or 4 leaf discs already dipped into the various acaricide solutions plus a wetting agent, Agral at 0.1%. Adult mortality was assessed at 3 days after treatment.

Field trials were carried out in replicated plots of 1 or 2 trees and treated by knapsack sprayer at high volume to run off, with the exception of the spray volume trial in the UK in 1988 (Table 7). In this trial, amitraz was applied to plots of 0.1 ha with a tractor driven air-blast sprayer. Assessments of P. ulmi were based on the number of motiles per leaf but only the adult T. urticae were assessed in the trial carried out in South Africa. In the trial against the apple rust mite, Aculus schlechtendali, apple leaves were immersed in water and detergent and the number of mites were counted in sub samples of the detergent solution.

RESULTS AND DISCUSSION

Influence of temperature on mite control

In laboratory trials, cyhexatin showed very little change in activity on adult T. urticae at temperatures of 15, 23 and 30°C. In contrast, amitraz and dicofol showed improved residual activity at higher temperatures when mites were placed on treated leaf discs. This effect was not seen with amitraz and dicofol when both leaf discs and adult mites were directly treated. Propargite was the most temperature dependent compound tested. Although there is no supportive evidence from the field this may partly explain why cyhexatin was relatively successful as a top fruit acaricide.

TABLE 1

Percentage control of adult T. urticae at three different temperatures.

		Adults + leaf discs treated			Leaf discs only treated		
	ppm ai	15°C	23°C	30°C	15°C	23°C	30°C
amitraz	160	95	97	98	49	84	95
amitraz	64	72	93	98	0	44	85
propargite	160	74	84	96	13	64	77
propargite	64	7	64	86	0	0	0
cyhexatin	160	98	96	98	74	95	93
cyhexatin	64	91	92	96	74	84	88
dicofol	160	88	93	98	18	51	77
dicofol	64	72	56	92	0	24	31

Susceptibility of spider mites to amitraz

In early studies, amitraz was shown to be effective against tetranychid mites resistant to dicofol and organophosphorous compounds (Harrison et al. 1972). In the UK Cranham (1981) found that strains of P. ulmi resistant to binapacryl and tetradifon were not cross-resistant to amitraz.

Since then, resistance to amitraz has been reported in Panonychus citri in Japan (Inoue 1984) and indicated for Tetranychus cinnabarinus in South Africa (Gilliomee and Pringle, 1985). There have been no reports of resistance in Panonychus ulmi on top fruit in Europe.

In laboratory studies in Spain in 1987, adult P. ulmi from a large number of sites from different regions were found to be susceptible to a single discriminating dose of amitraz but a variable response was seen with cyhexatin (Table 2). Similar studies in Italy in 1988 showed that P. ulmi and T. urticae from four apple orchards were susceptible to amitraz (Table 3).

TABLE 2

Laboratory tests on P. ulmi, Spain 1987

Site	Percentage control (Abbott corrected)	
	cyhexatin 400 ppm ai	amitraz 500 ppm ai
Fobru	12	100
Albesa	0	100
Menarguens 1	91	100
Seros	94	100
Gerona	25	100
Torresserona	100	100
Alagor	58	100
Menarguens 2	100	100

TABLE 3

Laboratory tests with amitraz on spider mites, Italy 1988.

Site	Species	Percentage control (Abbott corrected)			
		400	200	100	50 ppm ai
Ferrara	P.ulmi	100	-	100	-
Ferrara	P.ulmi	100	-	87	-
Bolzano	P.ulmi	96	-	-	96
Bolzano	T.urticae	96	93	-	68
Verona	P.ulmi	100	100	-	91

Control of spider mites in the field

Amitraz has generally shown good control of spider mites and although sometimes less effective than cyhexatin, amitraz often gave equivalent and occasionally better activity as shown in recent trials in France and South Africa (Tables 4 and 5).

TABLE 4

Control of P. ulmi on apples, France 1987

		motiles/leaf at dates indicated				
	g ai/hl	9/7	13/7	7/8	24/8	7/9
amitraz	60	7.1	0.3	1.0	1.8	13.2
cyhexatin	30	6.3	1.1	1.6	22.5	85.4
untreated	-	7.4	15.8	103.2	140.9	177.1

Treated 9.7.87 at 1250 l/ha.

TABLE 5

Control of T. urticae on apples, S. Africa 1987.

		adults/leaf at dates indicated				
	g ai/hl	5/2	13/2	20/2	27/2	11/3
amitraz	40	2.4	0.4	0.9	0.1	2.1
cyhexatin	30	2.1	0.0	0.1	0.0	0.0
untreated	-	1.7	1.2	2.3	0.4	3.2

Treated 6.2.87 at 700 l/ha.

Amitraz plus cyhexatin has been used extensively in certain parts of Spain and Italy where mite problems were particularly severe. Amitraz tank mixed with clofentezine applied early season has given excellent long term control of P. ulmi (Table 6).

TABLE 6

Control of P. ulmi on apples, Italy 1987.

	g ai/hl	motiles/leaf at dates indicated 10/6	20/6	15/7	4/8
amitraz/clofentezine	40/15	0.5	0.2	0.3	1.9
hexythiazox	5	0.1	0.2	0.6	2.4
untreated	-	9.0	8.4	57.4	13.2

Treated 28.5.87

A co-formulation of amitraz plus bifenthrin is currently under development in certain countries for use as both an insecticide and as a top fruit acaricide with both good knockdown and persistence characteristics.

In the UK, a large scale grower trial (Table 7) to investigate the effect of spray volume indicated that at 600 g ai/ha higher volumes of 1000 or 2000 l/ha gave improved control compared with lower volumes of 250 to 800 l/ha. Another important factor of this trial was a large variation in the initial mite population. At 3 weeks after treatment, amitraz regardless of the rate used was more effective in those plots with a lower initial infestation of 1 to 5 mites/leaf compared with higher initial mite populations of 6 to 15 mites/leaf.

TABLE 7

Control of P. ulmi on apples, UK 1988.

Amitraz g ai/ha	Spray volume l/ha	motiles/leaf 23/5	13/6	20/6	% control 20/6
600	2000	3.0	0	0.9	70.0
600	1000	1.4	0	0	100
600	800	6.0	0.2	5.3	12.0
600	500	9.2	0.5	6.2	32.6
600	250	6.5	0.4	6.5	0
400	1000	1.9	0.2	1.3	31.6
800	1000	14.8	0.9	9.6	35.1

Treated 27.5.88.

In summary, amitraz is an effective acaricide for the mid-season control of spider mites on top fruit and the basic recommended rate is 60 g ai/hl in 1000 l/ha but it can be used at rates of 400 to 1200 g ai/ha depending on local conditions. There is some evidence to suggest that application at the start of mite build-up (1 to 5 mites/leaf) at high spray volumes (1000 to 2000 l/ha) would give optimum control.

Control of the apple rust mite

The apple rust mite, Aculus schlechtendali is commonly found on apples and is known to cause russetting of the fruit. Easterbrook and Buss (1988) have reported that amitraz was as effective as pirimiphos-methyl which is registered for this use in the UK. Table 10 shows good control of A. schlechtendali following both early and mid-season applications in the UK.

TABLE 8

Control of A. schlechtendali in the UK, 1987.

	g ai/ha	motile rust mites/leaf T1 + 18	T1 + 33	T2 + 7
amitraz	200	47	34	28
amitraz	400	39	34	20
pirimiphos-methyl	900	18	36	20
untreated		122	96	95

Treated 22.4.87 (T1) and 26.5.87 (T2).

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REFERENCES

Cranham, J.E. (1982). Resistance to binapacryl and tetradifon, and the genetic background, in fruit tree red spider mite, Panonychus ulmi, from English apple orchards. Annals of Applied Biology 100 25-38.

Easterbrook, M.A.; Buss, D.S. (1988). Tests of acaricides against apple rust mite (Aculus schlechtendali). Tests of Agrochemicals and cultivars 9, Annals of Applied Biology 112 (supplement).

Giliomee, J.H.; Pringle, K.L. (1985). The sensitivity of six colonies of the red spider mite, Tetranychus cinnabarinius (Boisd.), to amitraz. Journal Entomological Society of South Africa 48 325-330.

Harrison, I.R.; Kozlik, A; McCarthy, J.F.; Palmer, B.H.; Weighton, D.M. (1972). Properties of some triazapentadienes - a new group of biologically active compounds. Mededelingen Faculteit Landbouw. Gent, 1972, 37, No 2.

Inoue, K. (1984). Resistance to amitraz in the citrus red mite, Panonychus citri (McGregor) in relation to population genetics. Japanese Journal Applied Entomology and Zoology 28, 260-268.

OCCURRENCE AND CONTROL OF THREAD BLIGHT DISEASE OF APPLE IN KENTUCKY

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ABSTRACT

Thread blight caused by Ceratobasidium stevensii (Burt) Talbot was identified in apple orchards in nine counties in eastern and southeastern Kentucky. The disease was most damaging in orchards having one or more of the following characteristics: less fungicide applied than normal or recommended, inadequate pruning, near to forested areas, situated on north and northeast facing slopes, overshadowed by high hills or bluffs which block direct sun for part of each day, and subject to frequent morning fogs. Benzimidazole, mancozeb, or triadimefon applied every two weeks from mid-June to mid-August controlled leaf blight and preventing formation of sclerotia and rhizomorphs on current season's shoot growth.

INTRODUCTION

Thread blight in the United States was first reported in North Carolina on apple in 1906 (Stevens, 1907). Stevens and Hall (1909) calling the disease leaf blight or hypochnose described its symptoms and range: it was found primarily on neglected trees in the humid mountain valleys of western North Carolina. Although superficially resembling fire blight (Erwinia amylovora), closer inspection of thread blight revealed roundish or elongate sclerotia on twigs, and mycelial ribbons on shoots and petioles. Wefts of fungal mycelium were also found on infected leaves. F. A. Wolf and W. J. Bach (1927) compared the thread blight disease of citrus with that of apple. They described thread blights as those diseases of various trees and shrubs which produce conspicuous white to dark brown strands of hyphae on the leaves, twigs, and smaller branches. Thread blights were considered rare in temperate countries, but of common occurrence in the tropics. The fungus found on citrus and other hosts in Florida was considered to be the same as the hypochnose fungus of apple; its spread and development seemed to be favored by high humidities and temperatures. Wolf and Bach cultured the fungus, proved its pathogenicity to apple and showed that the fungus penetrates the leaves of the host through stomata and develops intercellularly. The fungus overwinters by means of sclerotia and infection of leaves is confined to twigs bearing sclerotia; however, dissemination to uninfected branches and trees is by means of basidiospores. Thread blight has been reported on apple from Indiana and West Virginia to the Gulf states (Anonymous, 1960). More recently, thread blight has been reported in Kentucky (Hartman, et al, 1981).

The thread blight fungus has been referred to as Hypochnus (Stevens & Hall, 1909), Corticium stevensii Burt (Burt, 1918, 1926), Corticium koleroga (Cooke) v. Hohn (Wolf & Bach, 1927), Pellicularia koleroga Cooke (K) (Rogers, 1943), Koleroga noxia Donk (Donk, 1958), and Ceratobasidium stevensii Burt (Talbot) (Talbot, 1973).

Thread blight of citrus was controlled effectively by using Bordeaux mixture sprays (Wolf & Bach, 1927). Summer sprays of Bordeaux mixture reduced thread blight of tung in Louisiana by about two-thirds, and pruning reduced disease by 80% when compared with unpruned orchards (Large, 1943). Benomyl controlled thread blight of coffee in Guatemala, but copper hydroxide and difolatan were less satisfactory fungicides for this use (Sanchez de Leon, 1977).

The purpose of this research was to determine the extent of thread blight in Kentucky and to evaluate several fungicides for control of the disease.

MATERIALS AND METHODS

Thread blight survey

Thread blight outbreaks during 1979 and 1980 were recorded on the basis of samples submitted to the plant disease diagnostic laboratory by county extension agents and orchard visits in response to agent's calls. In 1981, a survey was made of apple orchards primarily in eastern and southern Kentucky. Thirty-eight apple orchards ranging in size from a few trees to twenty hectares were examined for thread blight in 24 counties. Interior and shaded branches throughout each orchard were examined for leaf blight. Twigs and branches having blighted leaves were carefully examined for sclerotia and rhizomorphs, which are diagnostic of C. stevensii. The unusual topography and vegetation in the vicinity of orchards were noted. Trees located on north or east facing slopes, in the shade of nearby buildings or forested areas, or in deep hollows restricting the amount of direct sunlight were especially scrutinized.

Fungicide tests

Fungicides for control of thread blight were evaluated in the field in 1982, 1983, and 1984. Trial plots were established in a mature Red Delicious apple orchard in Johnson County, Kentucky. In 1982, thirty uniformly diseased, widely separated limbs on nine trees were selected for treatment. Six treatments were replicated five times in a completely random design. In 1983, twenty-four diseased limbs from sixteen trees were selected and four treatments were replicated six times in a completely random design. In 1984, treatments were assigned to thirty separate infected limbs from 16 different trees; five treatments were replicated six times in a completely random design. Materials used and timing of application are shown in Table 1. Initial fungicide applications were normally timed to coincide with the first emergence of fungal mycelium from overwintering mycelium, but, in 1982, the initial application was about two weeks late. Fungicide sprays to run-off were applied to the bark and foliage using a hand-pumped backpack sprayer operating at 25 psi. Disease was assessed on August 30 by estimating the percentage of blighted foliage on each treated limb. The presence of sclerotia and rhizomorphs on new growth in 1983 and 1984 was also recorded.

RESULTS

Thread blight survey

Thread blight disease was found in apple orchards in ten of 24 counties surveyed in Kentucky (Fig. 1). Fifteen of 38 orchards examined showed evidence of the disease. Disease severity ranged from one blighted branch to 50% or more foliage blight on most trees. In each case, thread blight was confirmed by the presence of rhizomorphs and sclerotia of C. stevensii. These structures were normally found on the undersides of twigs and branches to which blighted leaves were attached. Environmental factors found to be associated with the disease were: a) Location of the entire or part of the orchard in a hollow or narrow valley or between hills (which restricted the length of time direct sunlight fell on the planting). b) Presence of wooded or forested areas adjacent to the orchard. c) Location on a north or east facing slope. d) Location in a river valley where morning fog commonly occurs. e) Trees with dense canopies as a result of light pruning. f) Infrequent fungicide sprays.

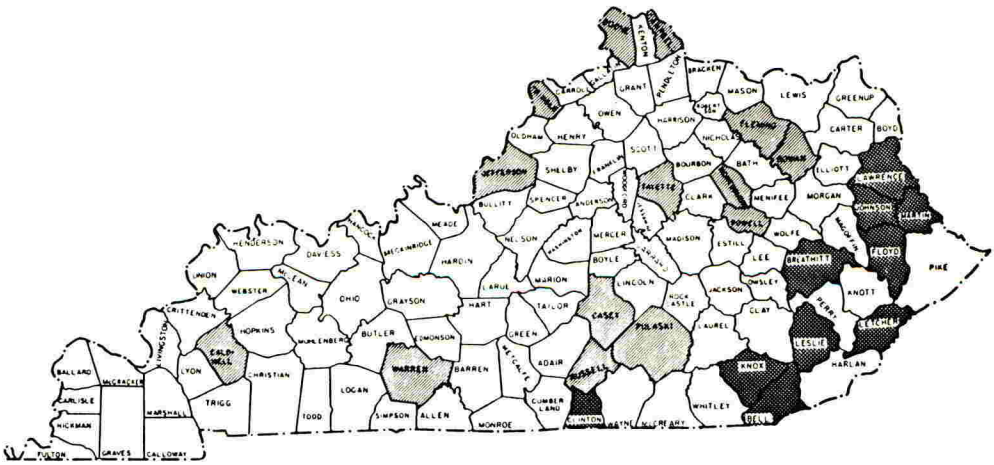

Fig. 1. Distribution of thread blight disease of apple in Kentucky (dark shading) and counties where surveyed orchards showed no thread blight (light shading).

However, there were apple orchards where one or more of the environmental factors were present, yet had no thread blight. These orchards were identified in counties where thread blight was present and also in counties geographically separated from thread blight areas.

Fungicide tests

In 1982, benomyl, triadimefon, dodine, and mancozeb reduced severity of thread blight significantly whereas captan provided no control (Table 1). Benomyl, triadimefon, and thiophanate-methyl each reduced thread blight disease in 1983 (Table 1). In the latter trial, rhizomorphs and sclerotia did not develop on current season's shoots and twigs treated with fungicides, whereas the fungus was very conspicuous on unsprayed shoots and twigs. Thiophanate-methyl applied at four times the normal rate early and mid-schedule or at the normal rate full schedule, and mancozeb full schedule gave excellent control of the disease in 1984, whereas thiophanate-methyl applied only during the early schedule provided moderate disease control (Table 1). Few or no sclerotia and rhizomorphs were formed following fungicide application.

TABLE 1

Effect of fungicide application on control of apple thread blight disease.

Treatment and rate g a.i./100 l	Mean % spurs and twigs showing blighted leaves	Sclerotia and rhizomorphs formed on new growth (*)
1982 (Fungicides applied June 30, July 16 and 30, August 13.)		
Benomyl 30	26.7 a (**)	
Triadimefon 15	54.5 b	
Dodine 30	56.9 b	
Mancozeb 90	64.8 b	
Untreated	85.7 c	
Captan 60	88.0 c	
1983 (Fungicides applied June 14, July 5 and 18, August 2 and 16.)		
Benomyl 30	10.0 a	-
Triadimefon 30	12.5 a	-
Thiophanate-methyl 42	13.7 a	-
Untreated	70.0 b	+
1984 (Fungicides applied June 19, July 6 and 19, August 1 and 15.)		
Thiophanate-methyl 168 (***)	2.3 a	0 a
Thiophanate-methyl 42	6.5 ab	0.8 a
Mancozeb 192 (****)	7.5 ab	0.8 a
Thiophanate-methyl 42 (*****)	15.7 b	1.7 a
Untreated	70.0 c	5.0 b

(*) Sclerotia and rhizomorphs present (+) or absent (-) or rated: 0-5, 0=none; 5=all twigs extensively covered.
(**) Means followed by the same small letter are not significantly different using Duncan's multiple range test (P=0.05).
(***) Fungicide applied only on June 19 and July 19.
(****) A mixture of mancozeb and thiophanate-methyl was applied on June 19.
(*****) Fungicide applied only on June 19, July 6, and July 19.

DISCUSSION

Although thread blight disease in the U.S. has occurred regularly in various parts of the mid-south and midwest for many years, economically important outbreaks have been confined mostly to humid southern regions. The outbreaks reported here were devastating only in three orchards and were a major limiting factor in orchard productivity. In the other orchards surveyed, the disease was of minimal importance. The fact that thread blight persisted in eastern Kentucky under the wide variety and extremes of climatic conditions that were experienced in Kentucky from 1979-1984 suggests that the disease may have been present at least at low levels for many years. C. stevensii may be endemic on native woody plants growing near affected orchards, a situation similar to that described for inoculum sources of tung in Louisiana (Large, 1943). The proximity of forested areas as sources of inoculum, and inadequate fungicide applications may be factors favoring the arrival and buildup of inoculum, while the other factors associated with thread blight would result in longer periods of leaf wetness and high relative humidity and may therefore favor disease development. If these factors are important in thread blight epidemiology, careful site selection and proper pruning could be used to reduce damage from this disease. Trials described here show that thread blight is relatively easy to control with a rigorous spray schedule of mancozeb, triadimefon, or a benzidamazole fungicide. The control of blight and development of new rhizomorphs and sclerotia by regularly spraying should reduce disease to negligible levels and may ultimately lead to eradication in orchards.

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REFERENCES

Anonymous. (1960) Index of Plant Diseases in the United States, Agriculture Handbook No. 165. United States Department of Agriculture, Washington D.C., p. 387.

Burt, E.A. (1918) Corticiums causing Pellicularia disease of the coffee plant, hypochnose of pomaceous fruits and Rhizoctonia disease. Annals of the Missouri Botanical Garden 13, 119-132.

Burt, E.A. (1926) The Thelephoraceae of North America. XV. Corticium. Annals of the Missouri Botanical Garden 13, 173-354.

Donk, M.A. (1958) Notes on resupinate Hymenomycetes-V. Fungus 28, 16-36.

Hartman, J.R.; Smith, C.A.; Stuckey, R.E. (1981) Thread blight disease in Kentucky. Abstr. Phytopathology 71, 1004.

Large, J.R. (1943) Recent observations on threadblight, Corticium stevensii, of tung and some native plants in the Southeastern United States. Plant Disease Reporter 27, 223-224.

Rogers, D.P. (1943) The genus Pellicularia (Thelephoraceae). Farlowia 1, 95-118.

Sanchez de Leon, A. (1977) New investigations on the control of Pellicularia koleroga on coffee. Revista Cafetalera 167, 21-25.

Stevens, F.L. (1907) Two interesting apple fungi. Science 27, 724.

Stevens, F.L.; Hall, J.G. (1909) Hypochnose of pomaceous fruits. Annals of Mycology 7, 49-59.

Talbot, P.H.B. (1965) Studies of Pellicularia and associated genera of Hymenomycetes. Persoonia 3, 371-406.

Talbot, P.H.B. (1973) Tulasnellales. In: The Fungi Vol. IVB. G.C. Ainsworth, F.K. Sparrow, and A.S. Sussman, (Eds), Academic Press, New York, 322-323.

Wolf, F.A.; Bach, W.J. (1927) The thread blight disease caused by Corticium koleroga (Cooke) Hohn., on citrus and pomaceous plants. Phytopathology 17, 689-710.

DEVELOPMENT OF PYRIFENOX FOR CONTROL OF FOLIAR DISEASES ON APPLES AND BLACKCURRANTS IN THE UK

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ABSTRACT

Pyrifenox, a new pyridine fungicide, has been evaluated for control of fruit diseases in the UK during the period 1984-87. Pyrifenox gave control of primary and secondary powderymildew (Podosphaera leucotricha) and apple scab (Venturia inaequalis) on apples equal or superior to commercial standard fungicides. Crop safety on a range of apple varieties was similar to the standard fungicides. Fruit finish on Cox was equal or superior to untreated fruit. Low rates of captan, dithianon or mancozeb applied in tank mixture with pyrifenox further enhanced fruit finish. Pyrifenox also provided excellent control of American gooseberry mildew (Sphaerotheca mors-uvae) and Leaf spot (Pseudopeziza ribis) on blackcurrants.

INTRODUCTION

Pyrifenox is a pyridine fungicide discovered by Dr. R. Maag AG, Switzerland, coded as RO15-1297, ACR-3675 or FD4060. Trials have demonstrated that it displays both protectant and curative activity on a range of important fruit diseases (Zobrist et al. 1986).

Since 1984 over 40 field trials have been conducted by ICI on top and soft fruit crops in the UK. These included 30 trials on the control of powdery mildew (Podosphaera leucotricha) of apples, apple scab (Venturia insaequalis) and pear scab (V. Pirina). Pirifenox has also been evaluated in eitht trials for control of leaf spot (Pseudopeziza ribis), American gooseberry mildew (Sphaerotheca mors-uvae) and grey mould (Botrytis cinerea) on blackcurrants.

When evaluating fungicides for use on apples and pears, effects on fruit quality are as important as fungicidal efficacy. It is well established that certain organic protectant fruit fungicides can have a cosmetic effect on the fruit skin of some varieties. This has been especially true on the apple cultivar Cox. This aspect of fruit fungicide use was investigated in 1986-88 in a programme of replicated trials on sites where skin finish on Cox was a known problem, and in 1987-88 in a series of large plot grower trials, when low rates (33% of label recommendations) of captan, dithianon and mancozeb were applied in tank mixture with pyrifenox.

Representative results from these trials for each disease on apples and blackcurrants are given to illustrate the fungicidal activity and crop safety demonstrated by pyrifenox.

MATERIALS AND METHODS

Details of replicated and grower trials giving design, cultivar spray interval and period of application for the results presented in this paper are shown in Table 1. Small plot trials had 4 replicates, each plot consisted of 1-4 apple trees, depending on tree spacing or 6-8 bushes for blackcurrants. Fungicides were applied by motorised knapsack mist-blower in 400-860 l/ha water on top fruit and 300-1800 l/ha on currants. In grower trials plots were 0.4-2.0 ha, and treatments were applied by commercial mist-blower in 200-500 l/ha water.

TABLE 1

Details of trials 1984-87

Trial No.	Cultivar	Spray intrvl days	Spray dates first	Spray dates last	Trial No.	Cultivar	Spray intrvl days	Spray dates first	Spray dates last
APPLES					86SE26	Cox	14	12/5	23/7
84SE1	Cox	10	8/5	8/8	86EA41	Cox	14	6/5	28/7
84SE2	Bramley	11	4/5	8/8	86EA02	Cox*	14	30/5	30/7
84SE6	Bramley	19	18/4	26/7	86EA06	Cox*	10	23/4	29/7
84SE7	Cox	19	25/4	26/7	86SE15	Cox*	14	28/4	27/8
84EA3	Cox	10	4/5	17/8	86SE17	Cox*	7	6/5	9/9
84AS1	Bramley	15	14/5	27/8					
84AS2	Cox	16	9/5	27/8	87SE16	Cox	15	27/4	11/8
					87EA19	Cox	16	29/4	14/9
85SE13	Cox	14	9/5	1/8					
85SE14	Cox	14	25/5	1/8	BLACKCURRANTS				
85SE15	Bramley	14	26/4	6/8	84SE02	Baldwin	14	27/4	23/7
85EA23	Bramley	13	2/5	12/8	86SE24	Baldwin	14	1/5	9/7
84EA28	Cox	14	1/5	6/8	86EA09	Ben Nevis**	14	22/5	2/7
					87SE18	Baldwin	14	14/4	23/6

* Grower trials (not replicated).
** Trial also included Ben Lomond, Black Reward and Westwick Choice.

Pyrifenox was applied as a 250 g a.i./l EC formulation in 1984 and as a 200 g a.i./l EC thereafter. Treatments were applied as spray programmes following normal commercial practice. On apples, spraying commenced at bud burst or green cluster and continued at regular intervals until terminal bud closure. Spray intervals varied from 7 to 16 days but treatment rates were adjusted to give the same dose of fungicide over any given period. Treatments are shown in the tables of results as rates for 14 day spray intervals. Blackcurrants were sprayed at 14 day intervals from the grape stage until 14 days before harvest. Pyrifenox was compared with a range of standard commercial fungicides applied according to label recommendations.

Primary infection of apple powdery mildew was scored as the degree of sporulation on a 0-5 scale, where 0= no sporulation and 5= uninhibited sporulation on infected blossom clusters. Secondary infection was assessed using the East Malling method, that is, the presence or absence of mildew on the top 5 expanded leaves on 10-20 shoots per plot. A similar method was used for mildew on blackcurrants and for assessing leaf scab infection on

apples. 100 fruit per plot were assessed for scab incidence at harvest and for old and new scab lessions after 3-4 months in cold storage. Blackcurrant leaf spot was assessed as the number of infected leaves on top 0.3 m of shoot on 10 stems per plot. The same shoot lengths were used to record the number of Botrytis infected berries.

Apple fruit quality was scored on a 0-4 scale, where 0 = no skin russet and 4 = severe russet with cracking. Scores of 0, 1 and 2 correspond to first grade fruit, 3 to second grade and 4 to waste or cider. Results are presented as % fruit in the first grade. Data from replicated trials have been analysed statistically using Duncan's multiple range test (Duncan, 1955), values within the same column followed by a common letter are not significantly different at the 5% level.

RESULTS

Apples

Powdery mildew (P. leucotricha)

Control of primary mildew sporulations by pyrifenox was similar to that given by the standard fungicides. (Table 2).

TABLE 2

Control of primary mildew (P. leucotricha) on apples, 1984-86

		% Reduction in sporulation compared with untreated.							
	Trial Ref	SE6	SE7	SE13	SE14	SE15	EA23	EA28	SE26
	Assessed	8DAT5*	14DAT6	14DAT2	8DAT3	7DAT3	14DAT3	8DAT5	8DAT3
Fungicide(s)	g a.i./ha								
Pyrifenox	60	49b	44b	55	66	85	21bc	23ab	-
Pyrifenox	80	-	-	64	76	81	21bc	43b	68bc
Bupirimate	350 +	35b	39b	33	62	78	11ab	47b	47b
+ dithianon	1260								
Penconazole	50 +	-	-	42	69	85	24c	47b	61bc
+ captan	950								
Untreated(**)	-	(84a)	(90a)	(66)	(58)	(54)	(92a)	(94a)	(95a)

* 8DAT5 = 8 days after treatment five.
** % of primary mildew showing uninhibited sporulation.

Pyrifenox also gave excellent control of secondary mildew, being superior to the standards bupirimate and fenarimol in some trials and similar to penconazole throughout. Although the higher rate of pyrifenox gave superior control on one trial (AS1), the level of mildew control by the two rates of pyrifenox were not significantly different on the other trials (Table 3).

TABLE 3

Control of secondary mildew (P. leucotricha) on apples, 1984-86

		% Control of secondary mildew compared with untreated.							
	Trial Ref	SE1	SE2	EA3	AS1*	SE6	SE7	SE13	EA23
	Assessed	6DAT9	21DAT10	10DAT9	15DAT8	4DAT7	14DAT6	15DAT5	17DAT8
Fungicide(s)	g a.i./ha								
Pyrifenox	60	94b	88c	85b	65c	82c	64c	88bc	95d
Pyrifenox	80	96b	89c	92b	76d	-	-	94c	95d
Bupirimate + dithianon	350 + 1260	92b	-	83b	44b	63b	51b	69b	59bc
Fenarimol	30/60**	-	70b	-	-	72c	-	-	-
Penconazole + captan	50 + 950	-	-	-	-	-	77c	95c	89cd
Untreated(***)		(48a)	(28a)	(31a)	(81a)	(69a)	(95a)	(12a)	(35a)

* Pyrifenox applied at 90g instead of 80 g a.i./ha on this trial.
** Applied at 30g pre-blossom followed by 60 g a.i./ha post-blossom.
*** % leaves (top 5 leaves/shoot) infected with secondary mildew.

Apple Scab (V. inaequalis)

Pyrifenox at 80 g a.i./ha gave complete control of leaf and fruit scab up to harvest, and was superior in this respect to bupirimate + dithianon (96-100% control) and penconazole/captan (97-100% control). Although fruit scab increased after 4 months cold storage in trial EA23, the increase was greatest on fruit treated with the standard fungicides (90-93% control) compared to 97% control on fruit treated with by 80 g a.i. pyrifenox. 60 g pyrifenox gave less control than 80 g a.i./ha of both leaf and fruit scab on trials EA23 and SE14 (Table 4).

Crop Safety

Pyrifenox displayed good crop safety in terms of leaf quality, colour and premature leaf drop on all varieties tested. Although there were variations in response from trial to trial, there was no clear treatment effect overall. Fruit skin finish also varied greatly, but pyrifenox treated fruit were of equal or superior quality to the untreated. (Table 5). When pyrifenox was applied in tank mixture with 1/3rd rate protectant fungicides, fruit quality was further enhanced. Although this was only significant on one trial (SE16) in which pyrifenox + captan or + mancozeb gave more first grade fruit than did the standard and untreated, there was an average (mean of eight trials) 10% increase in the number of first grade fruit when sprayed with pyrifenox + captan (73%) compared with 62-63% for pyrifenox alone and the standard treatments. (Table 5).

Pyrifenox also showed excellent crop safety (data not presented) when applied alone or in tank mixture with a range of fruit fungicides, insecticides, growth regulators and nutritional products on the most important apple cultivars and their pollinators. These included: Bramley, Discovery, Golden Delicious, James Grieve, Spartan, Cox, Egremont Russet, Idared, Millers Seedling and Malus pollinators. There were no problems of physical or biological incompatibility with any tank-mixture used.

TABLE 4

Control of leaf and fruit scab (V. inaequalis) on apples, 1984-86

Fungicide(s)	Trial Ref Assessed g a.i./ha	% Control leaf scab AS1 15DAT8	AS2 13DAT4	EA23 7DAT8	% Control fruit scab SE14 At Harvest	EA23	AS1 Storage**	EA23
Pyrifenox	60	99b	100b	82	95	99	99b	86
Pyrifenox	80	100b*	100b*	100	100	100	99b	97
Bupirimate + dithianon	350 + 1260	98b	100b	100	100	96	100b	90
Penconazole/ captan	50 + 950	-	-	100	97	100	-	93
Untreated(***)		(78a)	(4a)	(17)	(3.7)	(9)	(14.9a)	(48)

* Pyrifenox applied at 90 g instead of 80 g a.i./ha.
** Fruit assessed for old and newly developed scab lesions after 3-4 months cold storage.
***% leaves (top 5 leaves/shoot) or % fruit infected with scab.

TABLE 5

Fruit finish - Cox, 1986-87

Fungicide(s)	Trial Ref g a.i./ha	% of fruit in first grade (with least russet) EA41	SE26	SE16	EA19	EA02	EA06	SE15	SE17
Pyrifenox	80	93	68	41bcd	46	58	73	68	48
Pyrifenox + dithianon	80 + 368	92	68	38abc	56	-	-	-	-
Pyrifenox + captan	80 + 830	93	75	58cd	61	78	89	72	62
Pyrifenox + mancozeb	80 + 1600	95	74	44cd	51	-	-	-	-
Standard*		86	72	20ab	53	68	83	69	56
Untreated		88 N/S	84 N/S	18a	51 N/S	45	58	-	-

* Standard treatments for each trial were:-
Replicated trials:- EA41, SE26, SE16 and EA19 - bupirimate + dithianon.
Grower trials:- EA02 - binapacryl, nitrothaliscopropyl/sulphur.
EA06 - nitrothalisopropyl, binapacryl, captan.
SE15 - dithianon, bupirimate, triadimefon.
SE17 - penconazole/captan, triadimefon, bupirimate.

Blackcurrants

Pyrifenox at 80 g a.i./ha applied at 14 day intervals gave excellent control of leaf spot (P. ribis) (72-86%) and complete control of American gooseberry mildew (S. mors-uvae). Pyrifenox also gave a useful suppression of grey mould (B. cinerea) on the fruit (Table 6).

TABLE 6

Control of blackcurrant diseases 1984-87

		% Control S. mors-uvae		% Control P. ribis		% Control B. cinerea
	Trial Ref	SE02	EA09	SE24	SE18	SE18
	Assessed	7DAT6	7DAT4	14DAT4	35DAT6	35DAT6
Fungicide(s)	g a.i./ha					
Pyrifenox	80	72c*	86	100	100	67bc
Chlorothalonil	1850	14b	67	100	100	91c
Vinclozolin	750	-	26	63	-	-
Bupirimate +	500 +	-	-	-	99	46ab
Zineb	3920					
Untreated(**)		(78a)	(7)	(70)	(24)	(141a)

* Applied at 75 g a.i./ha.
** % leaves with mildew or leaf spot. Number of berries with Botrytis.

DISCUSSION

The results from trials on apples, pears and blackcurrants conducted over the period 1984-87 show that pyrifenox at 80 g ai/ha applied at 14 day intervals provides effective control of powdery mildew and scab on apples, leaf spot and American gooseberry mildew on blackcurrants. The levels of control were equal or superior to the commercial standard fungicide comparisons. Crop safety was excellent on all crops treated and fruit finish on apples and pears was equal or superior to that of untreated fruit. Results on pears (not presented) showed that pyrifenox was also safe on the important UK cultivars Conference and Comice. Data from one trial indicated that control of pear scab (V. pirina) with pyrifenox was similar to that given by dithianon.

Fruit appearance and quality is of the utmost importance for dessert apples and pears, especially naturally russeting varieties such as Cox. Tank mixing pyrifenox with low rate (1/3rd label recommendation) of captan had a cosmetic effect on the fruit, thereby enhancing fruit quality and gradeout.

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REFERENCES

Duncan, D.B. (1955) Multiple range and multiple F tests Biometrics 11,1-42.
Zobrist, P; Bohnen, K; Siegle, H, (1986) : Pyrifenox, a new pyridine fungicide against foliar and fruit diseases. Proceedings 1986 British Crop Protection Conference - Pests and Diseases 47-53.