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α,α,α-TRIFLUORO-3'-ISOPROPOXY-o-TOLUANILIDE (NNF-136), A NEW FUNGICIDE FOR THE CONTROL OF DISEASES CAUSED BY BASIDIOMYCETES

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Summary α,α,α-Trifluoro-3'-isopropoxy-*o*-toluanilide (NNF-136) is a new systemic fungicide with protective and curative properties primarily active against members of the Basidiomycetes. It has given successful control of black scurf on potato, snow blight on cereals, sheath blight on rice plant, rust on pear, and other diseases on various crops caused by *Rhizoctonia*, *Corticium*, *Typhula* and rust fungi.

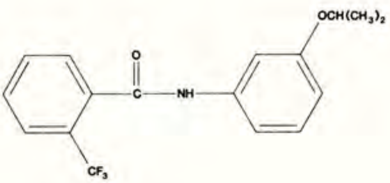
Résumé α,α,α- Trifluoro-3'-isopropoxy-*o*-toluanilide (NNF-136), un nouvel fongicide pénétrant à propriétés protectives et curatives, est principalement actif sur la famille des Basidiomycètes. Il elimine ou empêche avec succès les brunissures des pommes de terre, les nielles des céréales, les nielles des gaînes de la plante de riz, les cloques des poires, et des autres maladies sur les divers plantes agricoles causées par *Rhizoctonia*, *Corticium*, *Typhula*, et les fungi de rouille.

INTRODUCTION

α,α,α-Trifluoro-3'-isopropoxy-*o*-toluanilide (NNF-136, trade mark: Moncut (R)) was synthesized by Nihon Nohyaku Company in 1976 and found to possess a high level of activity against *Rhizoctonia solani* (imperfect stage of *Thanatephorus cucumeris*) and *Corticium rolfsii*. Official field trials since 1977 by the Japan Plant Protection Association (JPPA) have revealed its activity as a promising fungicide for the control of sheath blight (caused by *R. solani*) on rice plants, black scurf (*Typhula* spp) on cereals and rusts on various crops without any phytotoxicity. The aim of this paper is to give preliminary information on NNF-136 based on our studies and official studies by JPPA.

(a) Chemical and physical properties

Chemical structure: M.p.: 108°C



Molecular formula and weight: $C_{17}H_{16}F_3NO_2$ 323.3 Odour: odourless

Physical form: white crystalline solid V.p.: 1.33×10^{-5} mmHg at $20^{o}C$

Solubility: expressed as g/l at $20^{o}C$

Water 0.0096	Acetone 642	Chloroform 341
Methanol 480	Toluene 56	Xylene 29

(b) Toxicology

Toxicological studies have shown NNF-136 to have a very low toxicity orally and by contact with the skin or mucous membranes. Its acute oral LD50 is more than 10 000 mg/kg for rats and mice. It is non-toxic percutaneously at 5 000 mg/kg in rats and mice. Two-year feeding studies are in progress. The LC50 (48 h) to carp is 2.4 mg/l. Studies in bacteria have revealed no evidence of mutagenic effects.

(c) Residues

Quantitative and qualitative residue studies are in progress on rice, vegetables and top fruits. Fifty per cent loss of NNF-136 from soils occurs in 40 - 60 days under field conditions.

METHODS AND MATERIALS

(a) *In vitro* testing

The activity against fungal pathogens was determined by measurement of colony development on agar medium impregnated with the test compound.

(b) Glasshouse testing

(i) Rice sheath blight

The curative and protective activities were determined by spraying rice seedlings (cv. Nihonbare) with test compound two days after and 10 days before inoculation with rice husk-bran culture of *R. solani* to the basal part of the plants. The systemic activity was evaluated by application to the irrigation water five days before inoculation. Assessment was by measuring the height of lesion developed in 10 days after inoculation. Thirty plants were used for each dosage.

(ii) Damping-off of cucumber and kidney bean

Sixty seeds of cucumber and kidney bean for each dosage were sown in soil infested with *R. solani* and *C. rolfsii*, respectively. Compounds were drenched at 3 l/m^2 a day after sowing. Three weeks after sowing, damping-off of pre- and post-emergence was examined.

(c) Field trials

The field trials reported below vary in experimental design according to crop and disease. Data are presented from small scale, replicated trials using standard chemicals as references.

RESULTS

The results of laboratory, glasshouse and field experiments with NNF-136 are given in Tables 1 - 8.

(a) In vitro activity

In vitro agar impregnation tests indicate that NNF-136 has a high growth-inhibiting activity particularly against Basidiomycete fungi with exceptional activity against the yeast, *Rhodotorula glutinis* (Table 1).

Table 1

Activity of NNF-136 in agar impregnation tests

Pathogen	Growth inhibition (%) at		
	100 mg/1	10 mg/1	1 mg/1
Rhizoctonia solani	100	100	92
Corticium rolfsii	100	100	67
Coriolus versicolor	86	82	48
Glomerella cingulata	13	10	1
Sclerotinia mali	55	44	20
Fusarium oxysporum f. sp. *cucumerinum*	32	26	-
Phytophthora infestans	0	0	0
Rhodotorula glutinis	80	80	40

(b) Glasshouse testing

(i) Rice sheath blight (*R. solani*)

Table 2 shows the curative, protective and systemic activity of NNF-136 on rice sheath blight. The compound clearly showed outstanding curative, protective and systemic activity comparing favourably with the chemically-related fungicide, benodanil.

Table 2

Example of curative, protective and systemic properties of NNF-136 on rice sheath blight

	Disease control (%) with treatments below								
	Curative*			Protective*			Systemic**		
Fungicide	200	100	50	200	100	50	5	2.5	1.25
NNF-136	100	100	99	100	100	75	99	98	81
Benodanil	72	20	10	44	30	10	100	72	22

* Foliar spray at application rates (mg a.i./1)

** Application to irrigation water at rates (kg a.i./ha)

(ii) Damping-off of cucumber (R. solani) and kidney bean (C. rolfsii)

Outstanding control of damping-off of cucumber and kidney bean was obtained with NNF-136 at low rates of application compared with reference chemicals (Table 3).

Table 3

Activity of NNF-136 against damping-off of cucumber and kidney bean

Treatment	Dose ($g.a.i./m^2$)	Damping-off (%) of Cucumber	Damping-off (%) of Kidney bean
NNF-136 25% w.p.	2	0	0
NNF-136 25% w.p.	1	9.6	3
NNF-136 25% w.p.	0.5	27.8	10
Benomyl 50% w.p.	2	80.0	-
Quintozene 75% w.p.	1.7	-	77.3
Untreated - inoculated		88.3	100
Untreated - not inoculated		0	0

(c) Field trials

(i) Sheath blight (R. solani) on rice plant

NNF-136 has given successful control of rice sheath blight as well as organo-arsenic fungicides and antibiotics now in use (Yamaguchi, 1979). One of the examples is shown in Table 4 (JPPA, 1979a). In this trial fungicides were applied 21 and 7 days before heading and the infection (%) was examined 26 days after heading. Data are averages for three replicates of 25 m^2 each.

Table 4

Control of sheath blight on rice plant

Treatment	Dose (g a.i./ha)	Infection (%)	Yield rate
NNF-136 25% w.p.	300	3.8ab	103
NNF-136 25% w.p.	225	5.7ab	102
NNF-136 1.5% dust	600	2.2a	110
Ammonium hydrogen methylarsonate 6.5% e.c.	59	2.4a	104
Validamycin 0.3% dust	120	12.0b	101
Untreated		35.2	100

Figures in a column with like suffixes are not significantly different (*P* = 0.05) by Duncan's multiple range test.

(ii) Black scurf (R. solani) on potato (JPPA, 1979b)

Seed tubers (cv. Danshaku) were treated with dusting powder of fungicides before planting. The disease symptom developed and yields were assessed after two and four months, respectively. The averages given in Table 5 are for four replicates of 10 tubers each. Good control and yield increase were obtained with NNF-136.

Table 5

Control of black scurf on potato

Treatment	Dusting (mg a.i./kg tubers)	Infection (%) of Stolon	Infection (%) of Stem	Yield rate
NNF-136 1.5% dust	45	7.8	2.0	118
Validamycin 0.3% dust	9	28.3	17.8	90
Untreated		34.8	25.0	100

(iii) Snow blight (Typhula incarnata) on bentgrass (Shimanuki et.al., 1981)

From a little before the fall of snowflakes (the end of November) chemicals were sprayed three times with 7 - 14 day intervals. Diseased area was measured next April. Data in Table 6 are average for two replicates of 17 m^2 each. The control level of NNF-136 was comparable to that of oxine-copper. Similar good results are being obtained on wheat snow blight.

Table 6

Control of snow blight on bentgrass

Treatment	Dose (kg a.i./ha)	Infected area (%)
NNF-136 25% w.p.	6.25	4.1
Oxine-copper 40% w.p.	20.0	6.8
Untreated		52.6

(iv) Rust (Gymnosporangium asiaticum) on Japanese pear (JPPA, 1979c)

Japanese pear (cv. Chojuro) was sprayed (HV) four times from April 14th at weekly intervals. The first lesion appeared on April 28th on the untreated control. Infection (%) was examined on 200 leaves on May 15th. NNF-136 provided better control than the dithiocarbamate fungicide (Table 7).

Table 7

Control of rust on Japanese pear

Treatment	Dose (kg a.i./ha)	Infected leaves (%)
NNF-136 25% w.p.	3	0
NNF-136 25% w.p.	1.5	3.5
Dithiocarbamate* 75% w.p.	2.25	23.0
Untreated		59.5

* Dizinc bis(dimethyldithiocarbamate) ethylenebis(dithiocarbamate)

(v) Rust (Phakopsora ampelopsidis) and ripe rot (Glomerella cingulata) on vine

From June to August, four HV sprays of fungicides were made in a farmer's vineyard (cv. Delaware). Occurrences of rust and ripe rot were moderate. In late July, 60 bunches were examined for ripe rot infection and in early September, 300 leaves were examined for rust infection. As shown in Table 8, NNF-136 was as effective as mancozeb against these two diseases (Murakami, 1980).

Table 8

Control of rust and ripe rot on vine

Treatment	Dose (kg a.i./ha)	Infected (%)	
		Leaves (rust)	Bunches (ripe rot)
NNF-136 25% w.p.	1.5	11.9	18.8
Mancozeb 75% w.p.	2.25	9.5	21.5

(vi) Miscellaneous

Additional results with NNF-136 application favourably comparable with standard fungicides are being obtained on diseases such as brown patch and rust on turf, brown rust on wheat, pink disease on citrus and foliage blight on beet.

DISCUSSION

Thanatephorus (Rhizoctonia), Corticium, Typhula and rust fungi in Basidiomycetes cause serious damage on various main crops. Results given above show that NNF-136 is effective to control these diseases without any phytotoxicity. Its systemic properties (Table 2) may work efficiently in controlling various diseases.

In addition to the activity against Basidiomycete fungi, NNF-136 controlled well ripe rot on vine (G. cingulata in Ascomycetes) although its activity in vitro is very poor against the pathogen (Table 1). This fact suggests that activity in vitro is only an aspect of chemicals and we had better not stick to it in further work.

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NOTES

METHYL N-PHENYLACETYL-N-2,6-XYLYL-DL-ALANINATE (M 9834), A NEW SYSTEMIC FUNGICIDE CONTROLLING DOWNY MILDEW AND OTHER DISEASES CAUSED BY PERONOSPORALES

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Summary: Methyl N-phenylacetyl-N-2,6-xylyl-DL-alaninate (M 9834) is a new systemic fungicide controlling Peronosporales affecting grapes, tobacco, hops, ornamentals and several other crops. M 9834 is an acylalanine derivative of very low mammalian toxicity and favourable environmental properties. The results of field trials conducted in different countries are reported.

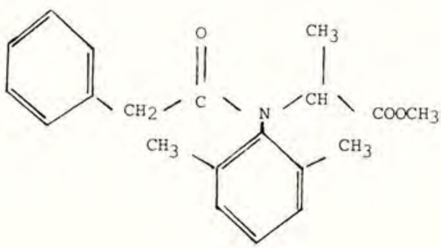
INTRODUCTION

Methyl N-phenylacetyl-N-2,6-xylyl-DL-alaninate (M 9834) is a new systemic fungicide presenting preventive and curative activity on a wide range of diseases caused by Peronosporales. It was first described by Garavaglia *et al*. (1981). Some aspects regarding structure-activity relationships of a group of its analogues have been discussed by Gozzo *et al*. (1981). It has been widely tested in the field since 1979 in Italy and is being developed in several countries under the trade name Galben (registered trade mark of Montedison S.p.A.). The results of field trials conducted under different environmental conditions are presented in this paper.

Chemical and physical properties:

Chemical name: methyl N-phenylacetyl-N-2,6-xylyl-DL-alaninate

Structural formula:



Trademark: Galben

The pure compound is a colourless crystalline solid with melting point 78-80 °C. Its solubility in water is 37 mg/l at 25 °C; it is readily soluble in most organic solvents except saturated hydrocarbons. At 25 °C its solubility ranges from 30% up to 60% for xylene, cyclohexanone, acetone, methanol, dichloromethane, while the solubility in hexane is 2%. Its vapour pressure is 5 x 10^{-6} mm Hg at 25 °C.

Toxicology: The toxicological properties of M 9834 are very favourable as the following data show:

		Formulation	LD50 mg/kg (figures are expressed as a.i.)
Mammals:	Acute oral to rats	tech. (92%)	4200
		25% w.p.	6700
	Acute dermal to rats	tech. (92%)	>5000
		25% w.p.	>5000
	Intraperitoneal to rats	tech. (92%)	1100
	Skin and eye irritation	Evaluated as "non irritating" on rabbits	
Birds:	Acute oral to quails	tech. (92%)	3700
	Acute oral to chickens	tech. (92%)	4600

			LC50 mg/l after 96h (figures are expressed as a.i.)
Fish:	Goldfish	tech. (92%)	7.60
	Guppy	tech. (92%)	7.00
	Rainbow trout	tech. (92%)	3.75
	Carp	tech. (92%)	6.00

In a 90-day feeding study on rats and in a one-year feeding study on dogs, M 9834 proved to be a very safe chemical. Several mutagenicity tests conducted on different biological systems demonstrated absolute lack of genetic effect. Chronic, carcinogenicity and reproduction assays are in progress.

Biological properties: M9834 is characterised by high and specific activity on Peronosporales, both on species with saprophytic phase as Pythium irregulare and on species with obligate parasites as Plasmopara viticola, Phytophthora infestans, Peronospora tabacina. On the first the product inhibits mycelial development while on the second it acts by inhibiting mycelial development into the host tissues and inhibiting zoospore release from sporangia and zoospore germination.

METHODS AND RESULTS

M 9834 has been tested either alone or in combination with different fungicides. The future trend will be to use M 9834 only in mixtures with preventive fungicides, in order to reduce the likelihood of selecting strains of pathogen resistant to M 9834, also according to the conclusions of specific meetings on this subject. In 1980 most of the trials were concentrated on grape downy mildew, a very important problem for European vineyards. Incidentally, in Italy, 1980 was a year particularly favourable to downy mildew infection and this fact led to significant results in all the trials carried out.

Grapes M 9834 was tested on grape downy mildew in the field in Italy, Spain and France. In the last country, artificial infection (twice on leaves and twice on the bunches) was made, according to a locally established method (brumisation), and this particular experimental condition should be taken into consideration when evaluating the results.

In all the trials reported here, sprays were applied at high volume. A randomized block design with four replications, at least 6 vines each, was adopted. The assessment of the results was made by visual evaluation of the percentage of diseased leaf surface, and the mean of 100 leaves per replication was taken.

Table 1

Control of downy mildew on grapes (Italy)

Treatments*	Rate g a.i./hl	% of leaf surface infected, mean of 400 leaves**	
		Trial A Novellara, Reggio, Emilia.	Trial B Limidi, Modena.
M 9834 + mancozeb	25 + 81	5.2 a	0.8 a
M 9834 + copper oxychloride	25 + 80	1.2 a	0.8 a
Zineb	140	13.9 b	0.6 a
Untreated	-	48.7 c	37.0 b

* All treatments were applied seven times at 15 day intervals except zineb applied 14 times according to preventive calendar

** In September, 20 days after last application

In each column, means followed by same letter postscripts are not significantly different at P = 5%

Table 2

Control of downy mildew on grapes (Italy)

Treatments*	Rate g a.i./hl	% of leaf surface infected; mean of 400 leaves**	
		Trial C Agna, Padova	Trial D Campotto, Ferrara
M 9834 + folpet	25 + 50	0.7 a	0.4 a
M 9834 + zineb	25 + 81	1.2 a	0.8 a
Metalaxyl + folpet	25 + 50	0.5 a	0.7 a
Metalaxyl + zineb	25 + 81	1.0 a	0.9 a
Zineb	140	5.4 b	4.5 b
Untreated	-	32.4 c	45.2 c

* All treatments were applied seven times at 15 day intervals except zineb applied 14 times according to preventive calendar

** In September 20 days after last treatment

In each column, means followed by same letter postscripts are not significantly different at P = 5%

Table 3

Control of downy mildew on grapes. (Barna, Spain)

Treatments*	Rate g a.i./hl	% of leaf surface infected; mean of 400 leaves**	
		Trial A	Trial B
M 9834 + mancozeb	25 + 81	5.2 a	7.7 a
M 9834 + copper oxychloride	25 + 80	5.4 a	6.6 a
Metalaxyl + copper oxychloride	25 + 60	7.8 a	5.4 a
Untreated	-	25.1 b	33.6 b

* All treatments were applied at 15 day intervals

** In September 22 and 15 days after last treatment

In each column, means followed by same letter postscripts are not significantly different at P = 5%

Table 4

Control of downy mildew on grapes (Bordeaux, France)*

Treatments**	Rate g a.i./hl	No of spots per plant Aug. 5, 1980	% of leaf surface infected; mean of 400 leaves Oct.6, 1980
M 9834 + mancozeb	25 + 81	2.1 a	12.5 a
M 9834 + copper oxychloride	25 + 80	1.4 a	8.0 a
Mancozeb	280	22.2 b	9.0 a
Untreated	-	87.4 c	54.0 b

* The trial area was artificially inoculated (June 17 and 24 on leaves; July 9 and 22 on bunches)

** All treatments were applied 6 times at 15 day intervals

In each column, means followed by same letter postscripts are not significantly different at P = 5%

Tobacco M 9834 was tested on tobacco blue mould in Italy and in Greece by high volume spray with a randomized block design, four replications, 20 m^2 per plot. The methods of assessment are reported in the tables along with the results.

Table 5

Control of blue mould on tobacco (Verona, Italy)

Treatments*	Rate g a.i./hl	% of leaf surface infected; mean of 600 leaves
M 9834	25	0.5 a
Metalaxyl	25	0.4 a
M 9834 + mancozeb	25 + 81	0.5 a
M 9834 + zineb	25 + 81	0.6 a
M 9834 + copper oxychloride	25 + 80	0.4 a
Metalaxyl + copper oxychloride	25 + 58	0.5 a
Untreated	-	33.2 b

* All treatments were applied three times at 15 day intervals

Means followed by same letter postscripts are not significantly different at P = 5%

Table 6

Control of blue mould on tobacco (Agrinion, Greece)

Treatments*	Rate g a.i./hl	Number of spots per 200 leaves	
		July 1	July 12
M 9834	30	35 a	38 a
Metalaxyl	29	21 a	90 a
M 9834 + mancozeb	29 + 92	45 a	46 a
Untreated	-	694 b	166 b

* All treatments were applied three times at 15 day intervals

In each column, means followed by same letter postscripts are not significantly different at P = 5%

Hops Two M 9834 formulations were tested in the field on downy mildew of hops. A 5% granular formulation was applied to the soil and a coformulation with copper oxychloride was applied by spraying the plants and the surrounding soil surface with 300 ml of water dispersion.
The trial reported in table 7 was carried out with a randomized block design, two replications, 50 plants per plot. Assessment was made on ten plants per plot evaluating the percentage of diseased leaves and shoots.

Table 7

Control of downy mildew on hops,* Tübingen, Germany

Treatments	Rate g a.i./rootstock	% of leaves infected per plant; mean of 20 plants	% of shoots infected; mean of 20 plants
M 9834 5% granules**	0.2	1 a	0.3 a
Metalaxyl 5% granules**	0.2	0 a	0.0 a
M 9834 + copper oxychloride 11% + 35% w.p.***	0.07 + 0.21	3 a	0.0 a
Metalaxyl + copper Oxychloride 15 + 35% w.p.****	0.07 + 0.16	0 a	0.0 a
Untreated	-	50 b	33.3 b

* Primary infection
** One application
*** Two applications
**** Three applications

In each column, means followed by same letter postscripts are not significantly different at P = 5%

Pythium blight A preliminary field trial was conducted in U.S. with M 9834, 25% w.p. on perennial ryegrass artificially infected with _Pythium aphanidermatum_ two days after spraying. Assessment was made 1 week after the application.

Table 8

Control of Pythium blight on perennial ryegrass,* Pennsylvania, USA

Treatments	Rate g a.i./ha	Disease severity**
M 9834	0.86	1.0
M 9834	1.72	0.0
Untreated	-	6.7

* All the plants were artificially inoculated.

** 0-10 visual rating scale : 0 = no disease, 10 = complete blighting

DISCUSSION

The results of the 1980 field trials with M 9834 show the high efficacy of this new systemic acylalanine fungicide in controlling Peronosporales diseases in different crops.

In grapes, an evident improvement is achieved in comparison to the conventional protective fungicides both for the higher control levels and for the lower number and more simple timing of treatments allowed by the curative properties of the systemic fungicide.

For instance, zineb performed at the same level as that of the systemic fungicide in only one of the four trials in spite of the higher number of sprays. No significant differences can be observed among the various formulations of M 9834 with zineb, mancozeb, copper oxychloride or folpet in terms of activity.

In tobacco and hops a confirmation of the excellent level of efficacy of the systemic fungicide is given by the results reported here, notwithstanding the lack of a direct comparison with a conventional protective fungicide applied alone.

An additional field of application appears to be opened by the promising data collected in the preliminary trial on *Pythium* blight on perennial ryegrass.

In the majority of the crops the high specificity of M 9834 will require the introduction of mixtures or coformulations in order to obtain a larger spectrum of activity when diseases other than Peronosporales are present; on the other hand, mixtures or coformulations would also be advisable to prevent resistance outbreak, as suggested by the knowledge available at present.

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CHLOBENTHIAZONE (S-1901), A NEW SYSTEMIC FUNGICIDE FOR THE CONTROL OF RICE BLAST

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Summary Chlobenthiazone (S-1901) 4-chloro-3-methylbenzothiazol-2(3H)-one, is a new systemic fungicide which is effective in controlling rice blast caused by *Pyricularia oryzae* Cav. The results of field trials during the past 4 years showed that leaf and ear blasts were controlled enough by the submerged application of 8% granular formulation at 2.4 kg a.i./ha and 3.2 kg a.i./ha respectively. The foliar application of 2.5% dust has also been shown to be effective. During the infection process of blast fungus, the fungicide effectively inhibited the development of infection pegs from appressoria without suppression of germination, elongation of germ tubes, or appressorial formation.

INTRODUCTION

Chlobenthiazone 4-chloro-3-methylbenzothiazol-2(3H)-one is a new systemic fungicide which showed excellent control of rice blast caused by *Pyricularia oryzae*.

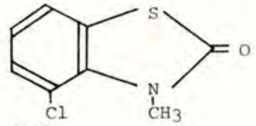
The present compound has been discovered by Sumitomo Chemical Co., Ltd., in 1974 and widely tested in cultivated areas of rice plants, e.g. Japan, Korea and Taiwan.

This report is primarily concerned with the general information of chlobenthiazone on phvsical and chemical characteristics and fungitoxic properties.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name : 4-chloro-3-methylbenzothiazol-2(3H)-one.

Structural formula :



Molecular formula : C_8H_6ClNOS

Appearance : Colourless crystalline solid, m.p. 131-132°C.

Vapour pressure : Vapour pressure at 20°C.
1.29×10^{-3} mmHg

Solubility : Soluble in organic solvents at 21.5°C.

Methanol	33	($^{w}/w$,%)
Acetone	33	
Ethyl acetate	20	
Chloroform	50	
Xylene	33	
Cyclohexanone	50	

Hardly soluble in water at 22°C.

0.0046 ($^{w}/w$,%)

Stability : Stable in acid and alkaline solutions.

TOXICOLOGY

Acute tests

Route	LD_{50} (mg/kg) to rats (SD)*		LD_{50} (mg/kg) to mice (dd)*	
	Male	Female	Male	Female
Oral	1940	2170	1430	1250
Subcutaneous	696	447	907	997
Intraperitoneal	564	532	611	625
Percutaneous	> 2500	> 2500	> 2500	> 2500

* SD and dd is a sort of strain of rat and mouse, respectively.

Subacute tests

In 26 weeks tests (body weight , food consumption, taking water consumption, hematological examination, ophthalmological examination and histopathological examination) there was no effect on rats receiving 100 mg/kg 'diet'.

Other long-term chronic tests have so far been favourable.

Irritation tests

Tests on rabbits showed chlobenthiazone to be non-irritant on abraded and intact skin and minimally irritant to the eye.

Fish toxicity

LC 50 (48h) to carp was ca 6 mg/l

BIOLOGICAL ACTIVITY

Materials and methods

Pot tests - Foliar application

Either 10% w.p. or 10% e.c. of chlobenthiazone was employed in the following tests. For a preventive application, the potted rice seedlings (Oryza sativa L., var. Kinki No. 33) of 2.5th leaf stage grown for 3 weeks in a greenhouse were sprayed with the chemical suspension 4 h before inoculation with conidial suspension of blast fungus (Ken 60-19). The treated-inoculated plants were placed in an air-conditioned room maintained at 27°C. under a relative humidity of more than 95% (hereinafter called the 'incubation room'). After 4 d incubation, disease severity was determined by the percentage of infected leaf area.

For a curative application, the chemical was sprayed on plants of the 2.8th leaf stage 18 h after inoculation when the developing hyphae from infection pegs were invading around adjacent epidermal cells, and then these treated plants were returned to the incubation room.

For a residual application, the chemical suspension was sprayed to the plants of 2.8th leaf stage and these plants were placed in a greenhouse. After 4 d, these plants were inoculated and kept in the incubation room.

Pot tests - Submerged application

The potted rice seedlings of 1.5th leaf stage were put in a plastic cup (250 ml) which contained the chemical suspension of 100 ml and the immersed pots were placed in a greenhouse. After 5, 10 or 15 days, the plants were inoculated and kept in the incubation room.

Field trials - Foliar application and Submerged application

All trials were based on 3 replicate plots of 20 m^2 with randomised block design. Application was made as follows : 2.5% dust was applied 5 times in total, 3 times at 0.75 kg a.i./ha against leaf blast and 2 times at 1 kg a.i./ha against ear blast respectively. Granules (8%) were applied twice at 2.4 kg a.i./ha against leaf blast and 3.2 kg a.i./ha against ear blast.

The standard fungicides used were edifenphos (O-ethyl S,S diphenyl phosphorodithioate) and phthalide (4,5,6,7-tetrachlorophthalide) in the tests of application of dusts, isoprothiolane (di-isopropyl 1,3-dithiolan-2-ylidenemalonate), IBP (S-benzyl O,O-di-isopropyl phosphorothioate) and probenazole (3-allyloxybenz[d]isothiazole 1,1-dioxide) in the test of submerged application of granules. All fungicides were treated at the rates and intervals recommended by their manufacturers.

The fungicidal efficacy was determined by counting all diseased and healthy in 20 hills per plot. Severity of leaf blast was assessed by the estimation of the percentage of infected leaf area. Disease index of ear blast was calculated from the rates of rotten neck and panicle blast incidence by the formula :

$$\text{Disease index}(\%) = \frac{(4A + 3B + 2C + D) \times 100}{4 \times \text{total investigated number}}$$

A is number of panicles with rotten neck;

B, C, and D are numbers where diseased parts >0.67;

between 0.33 and 0.67; and less than 0.33, respectively.

Systemic movement

Chlobenthiazone [$U^{14}C$]-labelled in the phenyl ring (19.2mCi/mmol) was prepared as a 500µg/ml aqueous suspension, and applied on the surface of the 3rd leaf of the plant at the 4th leaf stage by spreading 50µl.

In a root application, the roots were thoroughly washed with tap water and placed into Erlenmyer flasks with 100 ml of a Kasugai's nutrient solution containing 5µg/ml [^{14}C]-chlobenthiazone.

For autoradiography, these treated plants were harvested and dried by heating, and then exposed to X-ray film for one week in the dark.

Microscopic observation on the infection process

Conidial germination, elongation of germ tubes, appressorial formation and development of infection pegs were observed by an optical microscope on barley leaves (Hordeum vulgare L., var. Kanto No.6) which were treated with a chemical suspension and inoculated with blast fungus.

The observation was made after 4 d in the incubation room and samples were fixed with Carnoy solution.

RESULTS

Pot tests - Foliar application

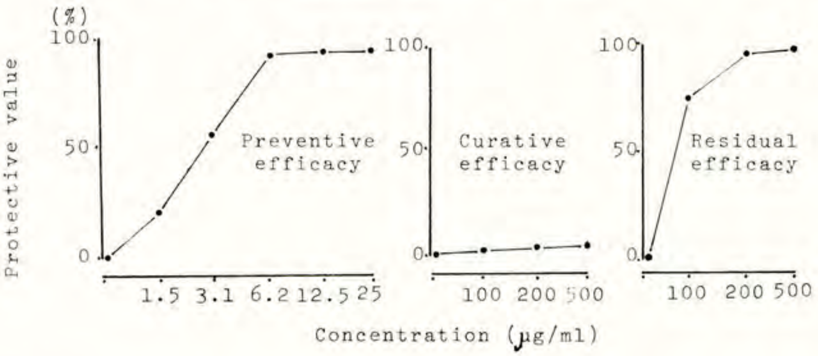
As shown in Fig.1, chlobenthiazone at 6.2µg/ml showed excellent efficacy in controlling blast by preventive application. Residual application has been also shown to be effective at 200µg/ml, while curative application was not effective even at a concentration as high as 500µg/ml.

It was shown that chlobenthiazone had a excellent preventive and residual activity eventually.

Figure 1

Preventive, curative and residual efficacy of

chlobenthiazone against rice blast



Pot tests - Submerged application

Efficacy of chlobenthiazone in relation between the time after treatment and dose was examined. As shown in Fig.2, at concentrations of 1.5μg/ml and 0.8μg/ml, effectiveness of the chemical gradually decreased from 10 days, although in 3 and 6μg/ml treated-pots its high efficacy was maintained during the incubation.

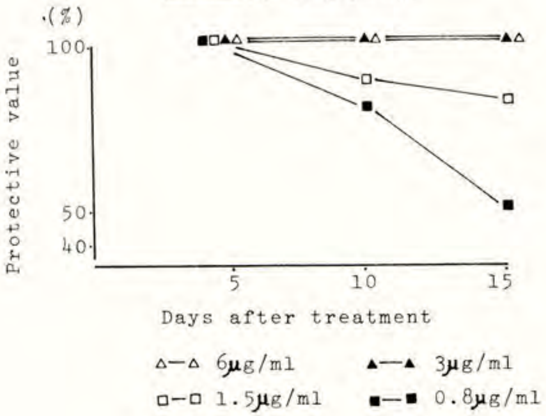
Since high level of protection was performed by submerged application of chlobenthiazone at all dosages tested within 5 days-incubation, it is clear that chlobenthiazone was rapidly absorbed from roots.

Figure 2

Efficacy of chlobenthiazone in relation

between the time of treatment and dose

submerged application



Field Trials - Foliar Application

When chlobenthiazone was applied by foliar application of 2.5% dust before disease outbreak, leaf blast was the most effectively controlled (Table 1).

Foliar application of chlobenthiazone at the booting and the middle heading stages was also shown to be the most effective in controlling ear blast.

It was shown that chlobenthiazone has a high preventive effect and long-lasting residual effect in comparison with reference fungicides.

Table 1

Control of leaf and ear blast by foliar application of dust

Treatment*	Rate (kg a.i./ha)		Leaf blast (%)	Ear blast		
	Leaf** blast	Ear*** blast		Rotten neck (%)	Panicle blast (%)	Disease index
Chlobenthiazone	0.75	1	0.2	8.1	8.2	13.8
Edifenphos	0.75	1	14.9	4.8	21.6	19.9
Phthalide	0.75	1	4.7	10.9	16.1	22.2
Untreated	--	--	23.0	28.5	14.9	39.0

* 2.5% dust of each fungicide was employed. Chemical name of edifenphos is O-ethyl S,S-diphenyl phosphorodithioate, Phthalide is 4,5,6,7-tetra-chlorophthalide.

** First application was made before primary disease outbreak, second and third applications were made according to change of disease outbreak.

*** Applications were made at booting and middle heading (50% panicle emergence).

Field trials - Submerged application

In submerged application of granule, 7 days before primary disease outbreak in controlling leaf blast, 8% granular formulated chlobenthiazone provided leaf blast control comparable to the reference fungicides (Table 2).

When chlobenthiazone was applied 14 days before booting in controlling ear blast, both rotten neck and panicle blast were the most effectively controlled (Table 2).

Table 2

Control of leaf and ear blast by submerged application of granule

Treatment*	Rate (kg a.i./ha) Leaf** blast	Ear*** blast	Leaf blast (%)	Ear blast Rotten neck(%)	Panicle blast(%)	Disease index
Chlobenthiazone (8% G)	2.4	3.2	1.2	4.8	11.8	10.7
Isoprothiolane (12% G)	3.6	4.8	1.9	13.6	18.0	22.6
Probenazole (8% G)	2.4	3.2	0.7	38.3	24.2	50.4
IBP (17% G)	5.1	6.8	3.0	33.6	29.7	48.5
Untreated	--	--	4.2	26.8	30.3	42.0

* Chemical name of isoprothiolane is di-isopropyl 1,3-dithiolan-2-ylidenemalonate, IBP is S-benzyl O,O-di-isopropyl phosphorothioate, probenazole is 3-allyloxybenz[d]isothiazole 1,1-dioxide.

** Application was made 7 days before primary disease outbreak.

*** Application was made 14 days before booting.

Systemic movement

The autoradiographs made 1, 4 and 7 days after the treatment to the 3rd leaves shown that ^{14}C-label from $[^{14}C]$-chlobenthiazone penetrated translaminary into the treated leaves and then translocated both upwards and downwards even within one day-incubation.

Upward translocation was rapid, because a considerable amount of ^{14}C-label from $[^{14}C]$-chlobenthiazone was translocated to aerial parts even 4 h after the treatment in Kasugai's solution.

Microscopic observation

The site of action of chlobenthiazone on barley leaves during the infection process was studied by an optical microscope.

As a result, formation of infection pegs was the most effectively inhibited by the chemical.

The rates of disease control were quite comparable to those of the inhibition of formation of infection pegs.

On the other hand, conidial germination, elongation of germ tubes and appressorial formation were hardly inhibited with the exception of the treatment at the highest concentration.

Table 3

Effect of chlobenthiazone on the respective stage

in the infection process of blast fungus

Chloben-* thiazone (uM)	Conidial[a] germination (%)	Elongation of germ tube (%)	Appressorial[b] formation (%)	Formation of[c] infection peg (%)	Disease control (%)
5000	3.6**	< 50	0.9**	0.0**	100
1000	95.1	0	22.3	0.0	100
500	93.1	0	68.2	0.0	100
100	91.3	0	65.3	0.0	100
50	87.0	0	75.1	0.6	93
10	94.1	0	67.2	10.9	51
5	96.3	0	73.1	43.2	0
1	98.1	0	64.2	41.5	0
0	98.3	0	72.6	38.2	0

* Aqueous suspensions of e.c.were sprayed on the leaves of barley at 60 ml/pot.

** A number of germinated conidia,[a] appressoria,[b] or infection pegs[c] which were formed developing hyphae was divided by a number of observed conidia, and the percentage was calculated.

DISCUSSION

Clobenthiazone is a new, toxicologically safe fungicide which shows excellent control of rice blast as confirmed in pot tests and field trials.

Chlobenthiazone is classified as a preventive fungicide like phthalide (4,5,6,7-tetrachlorophthalide) among currently used fungicides (Murata & Kurono, 1974; Schrader *et al.*, 1965; Takeuchi *et al.*, 1958; Umezawa *et al.*, 1965; Watanabe *et al.*, 1977), according to the characters, that is, their preventive and residual effects without curative effect by foliar application. Chlobenthiazone has also good effect in submerged application in pot tests.

These properties are also confirmed in field trials when 2.5% dust or 8% granule was applied to foliage or paddy water respectively.

The ^{14}C-label from $[^{14}C]$-chlobenthiazone was rapidly taken up by both the leaves and roots of rice plant, and immediately translocated to other parts. It seems that untreated and newly developing leaves after treatment are therefore successfully protected by this systemic effect. These characters are similar to those of the systemic fungicides such as IBP (*S*-benzyl *O*,*O*-di-isopropyl phosphorothioate) (Yoshinaga *et al.*, 1965) and isoprothiolane (di-isopropyl 1,3-dithiolan-2-ylidene-malonate) (Fujishama & Murata, 1974).

During the infection process of blast fungus, chlobenthiazone effectively inhibited the development of infection pegs from appressoria without suppression of germination, elongation of germ tubes and appressorial formation. This result suggests that the fungicide primarily affects the formation of infection pegs.

Acknowledgement

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NOTES

Proceedings 1981 British Crop Protection Conference - Pests and Diseases

[1RS,2RS]-2-NITRO-1-PHENYLTRIMETHYLENE DI[ACETATE] [EGYT - 2248], A NOVEL FUNGICIDE

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Summary [1RS,2RS]-2-Nitro-1-phenyltrimethylene di[acetate], EGYT-2248, is a new fungicide active against a number of fungus species in laboratory tests. Its main mode of action is inhibition of RNA synthesis. EGYT-2248 is very promising as a seed-dressing for cereals, corn and sunflowers. It inhibits powdery mildew of apple and grape.

INTRODUCTION

A new type of biologically active compounds has been found among derivatives of nitroalkyl esters, which have been synthetised in the Plant Protection Research Laboratory of EGYT Pharmacochemical Works [Lévai et al.,1976].

Compounds of this type show fungicidal and mild bactericidal activity on a large number of phytopathogenic organisms. This has been established in laboratory, greenhouse and field trials.

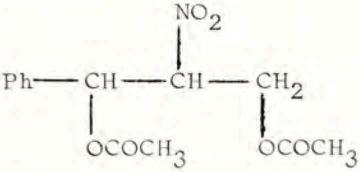
Physical and chemical properties

Chemical name: [1RS,2RS]-2-Nitro-1-phenyltrimethylene di[acetate] [IUPAC];
[1RS,2RS]-2-nitro-1-phenyl-1,3-propanediyl diacetate
[Chemical Abstracts]

Trade mark: VOLPAROX[R]

Code number: EGYT-2248

Chemical structure:



Molecular formula and weight: $C_{13}H_{15}NO_6$ 281.27

Colourless crystalline powder, m.p. 70-72°C, with a slightly acidic odour.

Solubility at 25°C: 0.03 g/kg water, 1250 g/kg chloroform, 350 g/kg xylene, 450 g/kg chlorobenzene.

The structure, conformation and purity of the products were determined by TLC, IR, UV, NMR, MS, X-ray diffraction studies in the EGYT analitical screening method [A. Kovács et al., 1980].

The product was quantitatively assayed by polarography.

Formulations: 20 % e.c., 15% flowable [for pre-em. and post-em. application].
seed-dressing,
aerosol [for wound-dressing of fruit trees]

Toxicology [Hungarian Agricultural and Food Ministries, 1980]

Table 1

Toxicity [LD50] of EGYT-2248 to rats

Material	Sex	Acute oral mg/kg	Acute intraperitoneal mg/kg
Active ingredient	Male	3237 ± 11	21.3 ± 9
	Female	3852 ± 11	29.1 ± 10
Formulation [20%e.c.]	Male	3200	80
	Female	3200	120

Sensitisation:

The sensitising properties of EGYT-2248 were evaluated in New Zealand rabbits using the method of Draise, there was no significant eye or skin irritation.

Sub-acute Toxicity:

EGYT-2248 has been studied by 90-d feeding trials in rats, "no effect level" was 2000 mg/kg daily. No mutagenic or teratogenic effect was observed.

Long term and more extensive investigations on the toxicity of EGYT-2248 and its formulations are in progress.

BIOLOGICAL TESTS

Laboratory tests

The fungicidal effect of EGYT-2248 was first established by in-vitro tests.

Testing of conidia germination:

The inhibition of germination of conidia caused by EGYT-2248 was investigated by slide germination tests on fungi, *Nigrospora oryzae* and *Helminthosporium sativum*. The experiment was carried out by mixing on caved microscope slides the appropriate concentration of water suspension of the a.i. with a fungus conidia suspension. After incubation at 25 °C for 24 h the germinated and ungerminated conidia were counted and the concentration giving 50 % inhibition [EC50] and the minimal total inhibitory concentration [MIC] were calculated.

Table 2

Testing of conidia germination

Fungus	Concentration [mg/kg] EC50	MIC
Nigrospora oryzae	1.7	3.3
Helminthosporium sativum	0.6	2.0

Investigations of the inhibition of mycelial growth of different fungus species grown on malt agar show, that *Cytospora cincta*, *Phytophthora infestans* and *Helminthosporium sativum* have EC50 values less than 100 mg/kg.

In the case of *Alternaria tenuis*, *Aspergillus niger*, *Nigrospora oryzae*, *Fusarium oxysporum*, *Ascochyta pisi*, *Botrytis cinera*, *Fusarium graminearum*, *Fusarium moniliforme* and *Verticillium albo-atrum* EC50 is between 100 and 1000 mg/kg, and for *Mucor sp.* and *Rhizopus nigricans* above 2000 mg/kg.

Inhibition of RNA synthesis

To have information about the biochemical background of fungicide action we continued experiments on different changes of the main metabolic processes [respiration, protein synthesis, etc.] of *Fusarium oxysporum*. The results indicated the inhibition of ribonucleic acid synthesis. The extraction of RNA fractions [rRNA and tRNA] from 10 g fungus mycelium was made by the method of Mirzabekov [1969]. The RNA content was characterised by the UV absorbance [A_{260}] of the extract measured at 260 nm.

Table 3

Ribonucleic acid content of 10 g mycelium of Fusarium oxysporum treated with EGYT-2248

Fungicide concentration [µg/l]	tRNA A_{260}	rRNA A_{260}
Untreated	95	705
50	49	370
75	26	195
100	22	160

Seed treatment

The use of EGYT-2248 for seed treatment was tried in laboratory test with winter wheat [Triticum aestivum] infected with Tilletia caries. Film coating was done with the fungicide in three different doses, in four replicates, using oxine-copper [Quinolate 15] as standard. After sowing the seeds in flower pots, germination and infection were observed.

As seed treatment seeds were placed into a dragee pan rotating the pan and wetting the seeds with an aqueous solution of a binding agent e.g. sodium carboxymethyl cellulose and aqueous solution of EGYT-2248 e.c. and drying by air draught, T_{max} 40°C.

Table 4

Winter wheat seed treatment laboratory test

	Film coating agents	Dosage kg a.i./t	Infection[x] %	Germination[x] %
Without artificial infection				
	EGYT-2248	0.4	15.5	97.0
	"	0.8	4.5	97.5
	"	1.5	6.5	89.5
	Film coated without a.i.	-	37.0	97.0
	Oxine-copper [15 % formula]	2.0	42.5	96.5
	Untreated	-	71.0	96.0
Infected with Tilletia caries				
	EGYT-2248	0.4	12.5	97.5
	"	0.8	6.0	98.0
	"	1.5	3.5	92.5
	Film coated without a.i.	-	27.0	98.0
	Oxine-copper [15 % formula]	2.0	36.5	98.0
	Untreated	-	62.0	96.5

x Means for 4 trials

Field trials

Corn seed treatment

EGYT-2248 was tested against Fusarium wilt on corn /Pioneer 3780/, using seed treatment mentioned above. Dosage was 1750 g a.i./t corn. The experiment was carried out on a plot of 0.5 ha, without replication. Germination and ear yield were measured.

Table 5

Pioneer corn seed dressing with EGYT-2248

Seed dressing	Germination /as % of no fungicide/	Ear yield t/ha
Film coated /no fungicide/	100.0	6.235
1750 g a.i./t	148.4	8.330

Control of apple powdery mildew

The control of the disease of apple caused by Podosphaera leucotricha was examined by spraying at 1000 l/ha four replicate plots, each of 0.1 ha. 2 years old Jonathan apple was used and benomyl was the standard fungicide. The experiments were carried out in County Veszprém in 1978. The dates of spraying were: 18. 05., 02.06., 15. 06., 05.07., 24.07., 14.08., 30.08.

Table 6

Control of Podosphaera leucotricha in Jonathan apple

Treatment	Dosage kg a.i./ha	Infection index[x] on 14.09. 1978.
EGYT-2248	2.00	0.00
"	0.40	0.09
"	0.04	0.29
Benomyl	0.50	0.38
Untreated	-	0.43

[x]Infection index /I/ was calculated by using the formula:

$$I = \frac{\sum k \cdot a}{n}$$

where $\underline{k}$ is the number of leaves having infection value $\underline{a}$;

$\underline{a}$ is an infection scale value varying from 0 to 1 /0 means no infection, 1 means 100% infection/

$\underline{n}$ is the number of all leaves having been examined

DISCUSSION

Since the last decade our firm has paid great attention to the investigation of nitroalkyl esters. We have found various interesting biological activities in this group, insecticidal, antifeeding, plant growth regulating, and antimicrobial effects.

We have been studying the correlation between the biological activity and chemical structure /Gy. Mikite et al.,1982./.

The antimicrobial effect was the main activity of EGYT-2248 but we have found plant growth promoting effect too, e.g. with corn and apples. The structural formula of EGYT-2248 covers various isomers, but the most advantageous are the racemic /1RS,2RS/ isomers which are easy to synthesise in high yield however the antifungal effect of the /1RS.2 SR/ isomers is the same as that of the former racemate compound.

EGYT-2248 easily decomposes in the environment by cleavage of acetic acid but the breakdown product is effective, too. The biological effect and degradation of the product can be regulated by chosing a suitable formulation /e.g. microencapsulated form/. A further important advantage is that EGYT-2248 is of low toxicity to mammals.

EGYT-2248 shows potent fungicidal activity in laboratory tests. Its main effect occurs upon the sprouting of conidia /Jakucs 1980./ and spores of fungi /in our experiments Nigrospora oryzae and Helminthosporium sativum/, but it inhibits mycelial growth of several fungus species, too. The biochemical mode of acition seems to be the inhibition of of RNA synthesis.

In order to show the antifungal activity in agriculture, we carried out in-vivo tests on various plant pathogenic fungi. The results show, that EGYT-2248 is useful as seed dressing agent in wheat and corn against Tilletia caries and Fusarium wilt and as spray against powdery mildew on apple.

Experiments are in progress and to be continued on the control of other plant diseases, on sugar-beet, onion and ornamental flowers, and on the precise mode of action. We are going to carry out experiments on peach and apricot trees by use of EGYT-2248 as wound-dressing aerosol.

Although we do not yet know the total biological spectrum of activity and the precise mode of action, we hope on the basis of our results that EGYT-2248 will be a fungicide suitable for use in agriculture.

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THE EFFICACY OF FLOWABLE AND DUST FORMULATIONS OF IPRODIONE ON A RANGE OF CROPS

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Summary Two iprodione formulations, a dust and a flowable, have been evaluated during 1980 and 1981 on a wide range of crops for the control of several diseases.

Iprodione dust (1.25% a.i. w/w) has successfully controlled *Botrytis cinerea* on glasshouse lettuces at 0.025g to 0.041g a.i./m^2 with 5 and 3 applications per crop, respectively. Extremely good control of *Rhizoctonia solani* on glasshouse lettuce and radish has also been achieved with a pre-plant application of the dust at 0.5g a.i./m^2 coupled with a post plant/emergence HV iprodione w.p. spray programme.

Iprodione flowable (25% a.i. w/v [EXP 1861]) has shown superior control to that of iprodione w.p. on *B. cinerea* on vines, green beans, strawberries, glasshouse tomatoes and blackcurrants, using 500 to 750g a.i./ha and similarly with *R. solani* on potatoes, *Alternaria brassicae* on oilseed rape and *B. squamosa* on onions at 400 to 1000g a.i./ha. It has also shown promise for further development against *Fusarium nivale* on sports turf, *Pyrenophora teres* on barley and *Sclerotinia* spp. on stone fruit and lettuces.

Resumé Deux formulations d'iprodione, une formulation poudre pour poudrage, et une formulation créme fluide (flowable) ont éte experimentés intensivement aux cours des deux dernières années sur un grand nombre de cultures et dans le cas de champignons pathogèns variés.

La formulation poudre pour poudrage s'est révelée extrèmement efficace pour la lutte contre *Botrytis cinerea* dans le cas de cultures de laitue sous serre à des doses de 0, 025g ma/m^2 et 0,04g/ha avec un programme mettant en oeuvre respectivement 5 et 3 applications de fongicide. Contre *Rhizoctonia solani* des applications en traitement de sol a la dose de 0,5g ma/m^2 ont assures une bonne protection des cultures de radis ou de laitue. Des aspects complementaires d'iprodione sous forme de pulverisations foliaires ont été appliqués en complément du sol.

La formulation flowable d'iprodione a montré que grâce à sa bonne persistance d'action une excellente protection des cultures etait obtenue contre les attaques de pourriture grise (*B. cinerea*). Une experimentation importante à été conduite sur cultures maraichères (haricot, tomate) petits fruits rouges (fraisier, cassissier) et dans le cas de la vigne à des doses comprises entre 500 et 750g ma/ha.

Des résultata analogues ont été obtenus dans le cas du R. solani sur pommes de terre, de l'Alternaria brassicae sur colza et du B. squamosa sur oignon.

Des essais prometteurs ont de plus été initiés sur Fusarium nivale du gazon, Pyrenophora teres de l'orge - et Sclerotinia spp. des fruits à noyaux et sur laitue.

INTRODUCTION

Iprodione as a 50% a.i. w/w formulation ('Rovral' w.p.) has been commercially available for over 5 years as a broad spectrum contact fungicide for use on a wide range of crops. Two other iprodione formulations have recently been developed to improve efficacy of disease control in certain situations where crops are subjected to climatic extremes and/or are grown with different commercial husbandry techniques.

The two formulations are:-

(a) Iprodione dust ('Rovral' dust) [1.25% a.i. w/w] intended for use in protected crops for the control of foliar and soil-borne diseases where moisture levels are already high and additional water in the form of wet sprays might increase disease levels.

(b) Iprodione flowable ('Rovral' flowable - Code EXP 1861) [25% a.i. w/v] formulated to improve ease of use and disease control efficacy.

METHODS AND MATERIALS

Summary of trials

Iprodione dust 1.25% a.i. w/w

Crop	Glasshouse lettuce	Glasshouse lettuce	Glasshouse radish
Target pathogen	Botrytis cinerea	Rhizoctonia solani	Rhizoctonia solani
Trial types	Small plot replicated X4 User trial	Small plot replicated X4	ADAS replicated X4
Varieties (examples)	Dandie, Miranda, Ravel, Renate, Plus	Vasco, Plevanos, Bellona, Salena, Bizet, Miranda	Robino
Plot size	8-16m^2	9m^2	3.5m^2
Standard(s)	Iprodione w.p. Thiram dust	Quintozene	None
No. of trials	8	5 + ADAS series	1
Application equipment	Knapsack sprayer/ duster	Knapsack sprayer/ dust applicator	Dust applicator
Assessments	Crop tolerance, yield, disease levels	Crop tolerance, yield, disease levels	Yield, disease levels

Trial Type Key Small plot replicated ≡ Applications and monitoring by scientist.

User trial ≡ Unreplicated large-scale trial applications by farmer monitored by scientist.

Iprodione flowable (EXP 1861) 25% a.i. w/v against Botrytis cinerea

Crop	Vines	Green beans	Blackcurrants	Strawberries	Glasshouse tomatoes*
Trial types	Small plot replicated X4	Small plot replicated X4	Small plot replicated X4 User trials	Small plot replicated X4 User trials	Small plot replicated X2
Varieties (examples)	Muscadet, Aligoté Senilion, Pinot Noir, Gredadie, F.Blanche, Aronon		Greens Black	Cambridge Favorite Pantagruella, Royal Sovereign, Domanil, R.Gauntlet	Sonato, Sonatine, Curabel, Odine, Estrella, Nemato, Angela, Virosa, Shirley
Standard(s)	Iprodione w.p. Vinclozolin w.p.	Iprodione w.p.	Iprodione w.p.	Dichlofluanid w.p. Iprodione w.p. Vinclozolin w.p.	Dichlofluanid w.p. Iprodione w.p. Vinclozolin w.p.
Plot size	$50m^2$	$5m^2$	$4m^2$	$12m^2$	$1.25m^2$
No.of trials	19	2	2	9 + 9	9
Application equipment	Knapsack sprayer	Knapsack sprayer	Self-propelled small plot sprayer/farmer's equipment.	Self-propelled small plot sprayer/farmer's sprayer.	Knapsack sprayer/ grower's equipment.
Assessments	Disease levels	Disease levels	Yield, tolerance disease levels	Yield, tolerance disease levels	Yield, tolerance disease levels

* especially 'Ghost spot'

Assessment explanations:

Yield - Equal representative samples taken per plot noting weights and quality e.g. grade.

Crop tolerance - S.P. trials usually have incorporated in the treatment lists a double rate i.e. 2X the standard rate, of product. All treatments are checked visually at 7-14 days post application for any form of phytotoxicity i.e. scorch, deformity etc., and thereafter at 14 day intervals. Yield data can be used to check loss of crop due to treatment.

Disease levels - Percentage infection levels by number, surface area or weight are recorded according to the crop being tried.

RESULTS AND DISCUSSION

Iprodione Dust

Table 1

Iprodione dust (1.25% a.i. w/w) for the control of Botrytis cinerea on protected lettuces

Example of trials in North Humberside. Winter/Spring 1980

Treatment	Rate (g a.i./m^2)	No. of applications	% No. of lettuce lost due to B. cinerea	Marketable wt (kg/m^2)	Individual marketable head wt (g)
Iprodione dust	0.025	5	3.8	4.6	220
" "	0.041	3	3.2	4.6	223
Iprodione w.p. spray	0.025	5	3.7	4.5	215
Thiram dust	0.330	3	7.5	4.3	216
Untreated control	-	-	7.2	3.9	197
L.S.D. 5%			N.S.	0.284	14.14
1%				0.431	21.43

Iprodione treatments gave superior control of B. cinerea on lettuce to that of thiram dust. All treatments had statistically higher marketable weights than the untreated control and the iprodione dust and w.p. treatments gave the best overall final weights. The iprodione dust treatments seem to keep the plants dry at application, as opposed to sprays which increase the moisture level around the plants and thus increase the risk of spreading the disease and enhancing its multiplication.

Further benefits of this dust treatment appear to be ease of application while still maintaining accurate distribution and increased speed of application.

Table 2

Iprodione dust (1.25% a.i. w/w) for the control of Rhizoctonia solani on protected lettuce. Yield per plot (50 plants)

Treatment	Rate (g a.i./m^2)	Plus iprodione Botrytis programme post planting	Total disease index *	Total marketable yield (kg)	% Number marketable: Total	% Number marketable: 1st class heads
Iprodione dust	0.5	-	81.0	3.42	36	30
" "	0.5	✓	58.8	6.94	72	60
Untreated control		-	87.5	2.48	26	12
" "		✓	76.8	3.69	44	24

Regression of total marketable yield on total disease index:

Y (yield) = 16.064 - 0.157 X (disease index) r = 0.99377 (P = 0.1)

* A = No. with slight infection, little or no extra trimming necessary.

B = No. with moderate infection requiring extra trimming and resulting in a reduced head weight but leaving a marketable lettuce.

C = No. with severe infection leaving an unmarketable lettuce after trimming.

$$\text{Disease index} = \frac{(A + 2B + 3C) \times 100}{3 \times \text{Total No. of lettuce assessed}}$$

ADAS (Clark & McPherson, 1981) for some years have tried a number of compounds for the control of Rhizoctonia solani on lettuce, this prompted the trial with results given in Table 2. It can be clearly seen that iprodione dust at 0.5g a.i./m^2 applied pre-planting and followed by an iprodione w.p. protectant programme against B. cinerea increased the final marketable weight and number of heads by over 150%, also the percentage of 1st class heads was increased by 400 when compared to the untreated control. This is further evidence that an iprodione post planting spray programme enhances R. solani control (Griffin et al 1980[a] and 1980[b]).

Table 3

Control of Rhizoctonia solani on protected radish
ADAS (Bristol) trial

	Numbers and weights of healthy and diseased radish per plot (1.5m^2)						
Treatment (g a.i./m^2)	Seedling numbers 30 d after sowing	Number of healthy radish	Weight of healthy radish (kg)	Number of infected radish	Weight of infected radish (kg)	Number of marketed bunches	Weight of marketed bunches (kg)
Untreated	342	228	2.03	79	0.62	11	1.52
Iprodione dust 0.5	408	324	2.94	29	0.26	16	2.20
Iprodione dust 0.5 + iprodione w.p. spray 0.5 g/l at emergence and 2 weeks later	432	364	3.41	20	0.17	19	2.61
L.S.D. 5%	-	68.2	0.639	24.3	0.107	4.7	0.746
1%	-	94.3	0.884	33.6	0.147	6.5	1.032

ADAS extended their past work with iprodione against R. solani on lettuce to radish* (Table 3) and similar trends to the lettuce results can be seen with the iprodione dust pre-plant treatment at 0.5g a.i./m^2 followed by two iprodione w.p. sprays at 0.5g a.i./l at emergence and again 2 weeks later giving the best overall control of the disease and increasing marketable yield by 65% compared with no fungicide.

The iprodione dust treatment alone significantly increased yield by 45%. It should also be stated that the above treatments may well have been even more effective if the crop had been sown immediately post application instead of the 12 day delay experienced in that particular trial.

No standard treatment was included because there are no fungicides which have a specific recommendation for control of Rhizoctonia on radish in the UK.

* R. solani appears to be quite a problem on both glasshouse and field grown radish also the risk of disease transference in glasshouse radish is increased as they are often grown as catch crops after lettuce crops.

Iprodione flowable

Table 4

Effect of simulated rainfall on tomato plants sprayed with iprodione w.p. and flowable

Treatment	Spray concn. (g a.i./1000 l)	% disease incidence after: Omm water	5mm water	10mm water
Iprodione w.p.	375	0	56	87
Iprodione flowable	375	0	36	31
Water control	-	100	100	100

Eurocross B.B. tomato plants 150mm tall were sprayed with iprodione w.p. and flowable. The leaves were allowed to dry and some plants were subjected to different levels of artificial rainfall administered by simulated rainmaking apparatus. Sample leaves were then taken from all treatments, inoculated with B. cinerea mycelium plugs, incubated for 4 days at 20°C in an illuminated, saturated atmosphere and then assessed for disease incidence.

When subjected to 5mm and 10mm of artificial rainfall, tissue treated with iprodione flowable showed disease incidence lower than that of iprodione w.p.

Table 5

Iprodione flowable for the control of Botrytis cinerea (grey mould) on field grown vines in France - 1977-1980

Treatment (X4 applications)	Rate (g a.i./ha)	% disease incidence 1977	1978	1979	1980
Iprodione w.p.	750	12.6	8.1	26.8	11.0
Iprodione flowable	750	9.8	6.5	16.1	7.1
Vinclozolin	750	-	-	16.1	9.0
Dichlofluanid	2000	23.2	16.3	-	-
Untreated control		35.1	28.1	41.2	39.3

Iprodione flowable showed at least similar Botrytis control on vines to that of vinclozolin w.p. and was consistently superior to iprodione w.p.

Similar results have been obtained from trials carried out in South Africa. The flowable formulation has produced no adverse effects on fermentation and organileptic properties of the wines.

Table 6

Control of Botrytis cinerea on green beans with iprodione formulations - Holland 1980

Treatment (X2 applications*)	Rate (g a.i./ha)	No. of diseased pods/plant Expt. I	Expt. II
Iprodione flowable	750	4.3	4.8
Iprodione w.p.	750	16.7	14.0
Untreated	-	32.7	21.8

* 1st spray at beginning of flowering
2nd " " end " "

Table 7

Iprodione flowable for the control of Botrytis cinerea (grey mould) on strawberries - 1980

Example from site in Wisbech area

Treatment	Rate (kg a.i./ha)	No. of applica- tions	% No. Botrytis-infected fruit Angular transformation	(%)	Marketable yield (kg/row)
Iprodione w.p.	0.75	4	18.88	(10)	1.26
Iprodione flowable	0.75	4	14.69	(6)	1.47
Dichlofluanid w.p.	1.70	4	16.36	(8)	1.37
Untreated control	-	-	35.47	(34)	0.84
L.S.D. 5%			10.000		0.3565
1%			13.617		-

Here again, iprodione flowable proved to be superior to the wettable powder.

Table 8

Iprodione flowable and w.p. for the control of Botrytis cinerea on glasshouse tomatoes - 1981

Treatment	Rate (g a.i./l)	% Ghost spotting Truss No. 6	7	No. plants (%) with active stem lesions 30 July	No. plants (%) with leaf lesions 17 June	30 July
Iprodione flowable	0.5	3	0	1.35	0	3.8
"	0.375	2.9	0	1.35	0	5.0
Iprodione w.p.	0.5	5.4	3.3	6.3	3.8	3.8
Untreated control	-	16.5	5.6	20.0	3.8	8.8

Iprodione flowable reduced ghost spotting (B. cinerea) on tomatoes to an acceptable level, especially the 0.5g a.i./l rate. Active stem lesions were reduced to a negligible level and leaf lesions were reduced also. No adverse effect was found on fruit set.

Table 9

Iprodione flowable for the control of Botrytis cinerea on blackcurrants - 1981

Treatment	Rate (kg a.i./ha)	Yield g/bush	No. of currants infected (%) with B. cinerea after 17 days storage Angular transformation	(%)
Iprodione flowable	0.75	635	16.4	7.9
Iprodione w.p.	0.75	561	25.3	18.3
Untreated control	-	307	45.8	51.5
L.S.D. 5%		237.8	13.70	
1%		-	19.68	

Other crops/disease complexes where the advantages of the flowable formulation are becoming apparent but not included in this report are:-

Oilseed rape	Alternaria and Sclerotinia spp. (Cox et al 1981)
Onions	Botrytis squamosa (Presly et al 1981)
Potatoes	Rhizoctonia solani
Stone fruits and lettuce	Sclerotinia spp.
Barley	Pyrenophora teres
Turf	Fusarium nivale

CONCLUSIONS

1. Iprodione dust has been shown to exhibit:

   (a) good control of B. cinerea on glasshouse lettuce with the added benefits of ease and speed of application.

   (b) good control of R. solani on glasshouse lettuce and radish, especially when combined with a post plant iprodione w.p. spray programme.

2. Iprodione flowable has proved to be consistently superior to the wettable powder in controlling B. cinerea on a range of crops including vines, green beans, strawberries, glasshouse tomatoes and blackcurrants.

In no case has any phytotoxicity been observed in the above trials.

Iprodione dust is commercially available for the control of B. cinerea on lettuce and a recommendation for control of R. solani is imminent.

It is intended to make the flowable formulation commercially available in the UK for use in a number of crops during 1982.

Acknowledgment

The assistance of all who made this report possible is acknowledged.

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NEW CARBARYL FORMULATIONS REDUCING HAZARDS OF FIELD APPLICATIONS TO HONEYBEES

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Summary Sevin® XLR formulation of carbaryl was 4.5-fold, and Sevin® SL, 2-fold safer to honeybees than Sevin® 80 Sprayable in commercial size field tests. The XLR formulation has been extensively tested under a wide range of spray dilutions applied by aeroplane and ground sprayers to seed alfalfa and citrus trees. Comparative tests of six formulations showed that a slight alteration of the physical properties of each formulation will significantly reduce the hazard to honeybees to acceptable levels under certain circumstances.

Résumé Quelques formulations de carbaryl sont comarées: Sevin® XLR était 4.5-X, et Sevin® SL était 2-X moins hasardeaux aux abeilles que Sevin® 80 Sprayable dans les épreuves des champs de grande taille commercial. La formulation XLR est éprouve extensivement avec une protée étendu de dilutions dans les essais au brouillard applique par avion et par machine sur terre à la luzerne cultivée pour la graine et à l'oranger. Les épreuves avec six formulations a indiqué que le remaniement léger des qualités physiques de chacun préparation de carbaryl peut reduire significativement le risque aux abeilles au niveau acceptable dans certains cas.

INTRODUCTION

Our honeybee research over the last 25 years has devised many methods, techniques and guidelines which provide the agricultural industry with integrated pest management strategies for protecting honeybees from pesticides (Atkins, et al, 1978). Most notable of these are night applications instead of daytime applications; pyrethroids, even though they are highly toxic to bees, can usually be applied safely if the applications are properly timed; lower dosages and/or less toxic and/or less persistent formulations of pesticides; applying combinations of selective pesticides; adding bee repellents to a toxic pesticide(s); covering the colonies during pesticide application; utilizing the distance honey-producing bee colonies are located from a treated crop; predicting the honeybee hazard of toxic pesticides; and, utilizing modified pesticide formulations having a lower hazard to bees.

Generally, pesticides applied as dusts are more hazardous to honeybees than those applied as sprays. Pesticide spray formulations often vary significantly in their toxicity to bees. Wettable powder formulations are often more hazardous to bees than are either water-soluable concentrates or emulsifiable concentrates. Fine sprays are less toxic than coarse sprays. Sprays of undiluted technical pesticide (ULV) may be more toxic than diluted sprays. Pesticides applied as granules are usually the safest method of treatment (Atkins, et al, 1981). This paper is primarily concerned with formulations of carbaryl.

By 1958 carbaryl was being used for agricultural pest control and was frequently causing heavy honeybee kills on blooming crops since most treatments were applied during the daytime. In 1962 while carbaryl was being developed for corn earworm (*Heliothis zea*) control on sweet corn it was determined that carbaryl would be applied as a spray in the late afternoon, evening and night thus reducing honeybee kills since the hours of intense bee visitation occurred during the morning. By 1971 the manufacturer was developing new spray formulations of carbaryl to be used in place of dusts. These formulations, Sevin® 4-Oil and Sevimol® 4, were somewhat less hazardous to bees than Sevin® 80 Sprayable.

Subsequently, the manufacturer has developed additional formulations which possess a greater reduction in hazard to honeybees.

METHODS

The laboratory testing protocol is described in Atkins, et al (1975) and utilizes a bell-jar vacuum duster. The laboratory technique primarily measures the contact effect of a pesticide. The pesticide dusts are uniformly prepared with an appropriate diluent which is nontoxic to bees. Dusts are prepared by blending the technical chemical, dust preparations, wettable powders, or emulsifiable liquid concentrate formulations with the diluent. These prepared dusts usually store without deterioration or hydrolyzation that is often a disadvantage of liquid preparations. Dusts do not separate from the diluent.

The bell-jar vacuum duster has been utilized since 1952. The duster and technique have been modified many times. The present duster is automatically and electrically operated to eliminate operator variation.

The laboratory testing procedures and technique are as follows. Worker honeybees of uniform age are obtained from a colony and placed in a stock-bee cage. The bees are aspirated from the stock-bee cage into dusting cages before feeding. The dusting cage with the bees is placed in the duster. A watch glass containing 200 mg of pesticide dust is placed in the duster and the air exhausted to a vacuum of 931mm Hg. Outside air imploding onto the dust sample replaces the vacuum and uniformly disperses pesticide onto the caged bees. Treated bees are removed from duster and transferred through a funnel into clean 12.7 X 12.7 X 12.7cm holding cages of 3.175-mesh/cm hardware cloth. Each holding cage is closed with a 14ml vial containing 1:1 honey-water solution for food. Treated bees are kept at a constant 26.7°C and 65% r.h. Mortality is recorded at 24, 48, 72 and 96 h. Each pesticide is evaluated using a series of dust dilutions. For this evaluation, 3 replicates of 25-30 bees each are used for each dosage level. This dosage series is repeated 3 times using a different colony each time, providing nine replicates for each pesticide at each dosage.

The LC values, using a conversion factor, are converted directly to LD values. The linear-regression/dosage-mortality curve is obtained using a computer to obtain the LD values in μg/bee, slope and intercept values in probits, and, the correlation coefficient. In most instances the laboratory LD_{50} value of a pesticide in μg/bee times 1.12 can be directly converted to the equivalent dosage in kg/ha to predict bee hazard in the field.

A time-mortality curve may also be calculated from laboratory data to determine stomach poison effect for those pesticides having this mode-of-action.

Our research unit, using the laboratory protocol, has tested each new carbaryl formulation as they have become available. These included Sevin® 80 Sprayable, Sevimol® 4, a suspension of carbaryl in molasses for dispersion in water sprays and Sevin® 4-Oil, a suspension of carbaryl in oil for spray application for the control of insect pests on corn, pasture, rangeland and forest. These were subsequently field tested. Later XLR and SL were laboratory tested. Linear-regressions were determined for each of these formulations.

The field testing protocol is described in Atkins, et al (1981). Field test effects have been utilized on various crops to compare different treatment conditions such as day and night applications; aeroplane, helicopter, and ground machine applications; high-volume, low-volume, and ultra-low volume sprays; treatments over or near covered and uncovered colonies; dust and spray applications; repellents; and with different pesticide formulations.

Several parameters are used to measure the effects of pesticides on honeybees.

Colony strength All test colonies were inspected before and after pesticide applications. Colony strength was measured by determining the number of cm^2 of uncapped and capped brood, no. frames covered with bees, condition of queen, workers, drones, eggs, larvae; the amount of pollen and honey stores, etc. Dead bees at the colony Todd dead hive entrance traps were attached to 5 colonies in each plot and were utilized to collect and retain bees dying at the hive. Bee visitation in the field Two counters each made 5 bee visitation counts in each plot 3 times daily at 10:00, 13:00 and 17:00 h for several days before pesticide application and until the end of the test. A count constitutes the no. of bees foraging in 18.5 m^2 of crop/min. Caged bees in the field Three cages of honeybee workers, confined in 12.7 X 12.7 X 12.7cm 3.175-mesh/cm wire hardware cloth cages and provided with honey-water solution, were placed in the plot at time of application to measure the initial contact poison effect. The cages are removed 15 min. posttreatment and mortality of bees determined after 24 h. Foliage residue bioassay Following pesticide application the residue was bioassayed with bees. Foliage and blossoms were systematically collected from 10 areas within each plot, chopped into 2.5cm lengths, thoroughly blended, and placed in three 475ml cardboard cans. The lids of the cans were replaced with nylon tulle netting. Twenty-five to 35 worker bees were aspirated through the hole in the other end; the hole was closed with a rubber stopper fitted with a feeder containing honey-water food for the bees. Mortality of the bees in the cages was determined after 24 h. A series of bioassays of the foliage residue was made periodically posttreatment, until the absence of bee kill from continuous contact with contaminated foliage indicated that the pesticide residue was no longer toxic to bees. Weather conditions Temperature and humidity data were recorded throughout the test period. Wind, rain and cloud conditions were recorded as necessary.

Field test comparisons were made using one or more of the following technical carbaryl (1-naphthyl methylcarbamate) Sevin® formulations: 80 Sprayable, a wettable powder formulation which is often highly hazardous to bees, and modified formulations of FR, a molasses base flowable for rangeland and forest use, SL, XLR, UCSF-22 and UCSF-25. Patent considerations which are pending prevent Union Carbide Agricultural Products Co., Inc. from revealing more technical details of these formulations.

In 1980 and 1981 tests were conducted, using the field test protocol, in 250 ha commercial alfalfa fields (*Medicago sativa*) in full bloom and with honeybee colonies located in the center of each 6.5 ha test plot. Also in 1981 tests were conducted in an 8 ha bearing Valencia orange (*Citrus sinensis*) grove in full bloom using 0.5 ha plots with honeybee colonies located in the center of each plot.

The XLR formulation was extensively tested under a wide range of spray dilutions applied by aeroplane and groung sprayer to seed alfalfa and citrus trees during 1981. During March field test comparisons were made of XLR at the same dosage of 5.6 kg a.i. per ha but with 3 different dilutions applied with citrus spray-blower to citrus. The XLR spray dilutions and other data are summarized in Table 3, Plots 1, 2, 4 and 5. In July field test comparisons were made using XLR at 2 dosages and several dilutions, applied with aeroplanes to seed alfalfa, together with comparisons with/of SL, 80 S, FR, UCSF-22, and UCSF-25. These formulations, dosages and spray dilutions and other data are summarized in Table 3, Plots 20-33.

Footnotes for the data presented in Table 3 field test summary are as follows. [1]Time of application given in Pacific Daylight Time, one hour earlier than Pacific Standard Time. [2]Dead bee figures represent the net honeybee kill, above natural bee deaths obtained pretreatment, presented as an average per colony for 5 colonies with dead bee traps. [3] NIL equals no effect, toxicity or hazard; L, low; ML, moderately-low; M, moderate; MH, moderately-high; H, high; and, EH, extremely-high, respectively. These quantified designations are based on field test data of honeybee colony losses over the last 25 years, using moderate (M) at 350-750 bees killed per colony as the level which can be tolerated by a strong colony in actual situations. It was based on previous work by the late researcher F. E. Todd, USDA-ARS. The complete listing is in Table 1.

The overall honeybee hazard designated for each test in the righthand column in the Table 3 Summary is predicated on the total numerical raw field data as well as the observations of the investigators. [4]These data statistically analyzed using Duncan's Multiple Range Test: for each experimental series, numbers followed by the same letter are not significantly different at P= < 0.05.

RESULTS

In 1971 laboratory test linear-regressions were determined for Sevin® 4-Oil and Sevimol® 4 formulations compared to 80 Sprayable. These were retested in 1978-79 adding the XLR and SL formulations. The latter data, given in Table 2. indicated that there were differences between the various formulations which would significantly reduce the hazard to honeybees foraging agricultural crops.

In 1971 the first 3 formulations were field tested showing that Sevin® 4-Oil and Sevimol® 4 were 39 and 17 % less hazardous, respectively, to bees than 80 S. The 1980 field tests in alfalfa showed XLR and SL to be 13.6- and 3.5-fold safer, respectively, to bees than 80 S; XLR was 3.9-fold safer to bees than SL.

In 1981, the field tests on citrus showed that increasing the quantity of spray from 935 to 2338 l/ha did not change honeybee mortality statistically (P= < 0.05). However, increasing the quantity of spray to 4676 l/ha decreased bee mortality caused by the 2 lower spray quantities (see Table 3, Plots 1, 2, 4 and 5).

In 1981 field tests on alfalfa XLR was 4.5-fold safer and SL, 2-fold safer to honeybees, respectively, than 80 S. The results for the 80 S, XLR, SL, FR, UCSF-22 and UCSF-25 formulations show that there are differentially hazardous to bees depending upon the particular formulation utilized. These data are summarized in Table 3, Plots 20-33. In general, the 2 lowest spray dilutions with XLR applied by aeroplane and the highest dilution of 187 l/ha were more hazardous to bees than the 47 l/ha and the 93 l/ha dilutions.

DISCUSSION

It is interesting to note that in comparative laboratory studies of 5 carbaryl formulations having slightly different ingredients and physical properties the hazard to bees was significantly decreased. These decreases in bee toxicity are expressed both as an increased dosage to obtain the LD_{50} values and as a decrease in the slope values.

The omitted Plot 3 was a carbaryl/bee repellent field test which was unrelated to the subject of this paper; the plot numbers between 5 and 20 and above 33 belonged to other pesticides and bee repellents of the 54 field tests conducted during 1981.

The decreased bee mortality of the highest spray dilution of XLR in the citrus tests is similar to past experiences in citrus pest control where it is indicated that 80 S applied at the same dilution decreases pest control efficacy because of excessive dilution of the carbaryl and/or because a significant portion of the carbaryl is lost through runoff of the spray. However, adequate pest control was accomplished using 4676 l/ha.

We have presented a summary of 6 formulations of carbaryl having slightly different ingredients and physical properties which were compared in 18 field tests in 1981. In general, the data showed that by varying certain formulation and physical properties one may significantly reduce the hazard to bees. These modifications have not reduced the efficacy of carbaryl as an insecticide (Puech, 1981). The author received specimen labels for XLR, Sevimol® 4 , 80 S and SL showing that the formulations are comparable when using equivalent rates of active ingredient per area and are registered at equivalent rates a.i./area on all crops and insects listed. The main difference between XLR and other carbaryl formulations is that when used according to label directions, XLR resists wash-off by several inches of rainfall or overhead irrigation. Extensive documentation of the residues, efficacy and wash-off resistance of XLR was provided to the U.S.A. Environmental Protection Agency to support registration of the labels.

The modifications in XLR which impart the quality of resisting wash-off by rain and overhead irrigation were apparently responsible in XLR treated field corn (zea mays) in reducing the quantity of carbaryl bee foragers picked up and transported to

Table 1a

Comparative hazard of pesticides to honeybee colonies from field applications of pesticides

No. bees killed per colony *	Comparative bee hazard
< 25	NIL = essentially no hazard
25 - 150	L = low
150 -350	ML = moderately-low
350 - 750	M = moderate (can stand = DDT)
750 - 1250	MH = moderately-high
1250 - 1750	H = high (can stand once per season)
1750 - 2750	VH = very high
2750 - 4000	EH = extremely-high
> 4000	DH = disasterously-high

* Normal colony mortality from old age is established pretreatment using Todd Dead Bee Hive Entrance Traps; figures represent the net number of bees killed by a pesticide application.

Table 1b

Comparative hazard of pesticide residues on plant foliage and blossom residues bioassayed by honeybee mortality (1981)

Av. % bees killed per bioassay cage	Comparative bee hazard
< 10	NIL = essentially no hazard
10 - 20 after 24 h continuous contact	L = low
20 - 40 "	ML = moderately-low
40 - 60 "	M = moderate
60 - 80 "	MH = moderately-high
80 - 100 "	H = high

Table 2

Laboratory tests of comparative toxicity of five carbaryl formulations to worker honeybees

Summary sheet no.	Sevin® formulation	Correlation coefficient	Intercept, probits	Slope probits	LD_{50}, μg/bee
	GROUP I				
664 A	80 Sprayable	0.92785	3.34945	2.50671	1.540
	GROUP II				
664 B	4-Oil	0.98304	1.84971	3.06600	3.602
664 C	Sevimol® 4	0.99514	1.96554	2.10400	9.360
	GROUP III				
664 E	SL	0.88129	2.47507	1.56991	13.721
664 D	XLR	0.93506	2.83659	1.14181	26.531

Table 3

Summary of 1981 comparative field test toxicity effects of newest carbaryl formulations to honeybees on citrus and seed alfalfa in California, U.S.A.

Treatment					Suppression of visits		Bee deaths [2]		Foliage toxicity [3]		Honey-bee hazard [3]
Plot no.	Carbaryl formulation	Dosage kg a.i.	Dosage l/ha	application[1]	%	No.days	No.dead	Days	Level	Days	
1	XLR	5.6	935	08:40-10:30	54	6	793	4 a[4]	–		MH
2	XLR	5.6	2338	11:30-12:05	49	5	1118	7 a	–		MH
4	XLR	5.6	4676	15:35-16:03	61	4	335	1 b	–		ML
5	Untreated (Citrus)		–	–	NIL	–	NIL	c	–		NIL
20	XLR	2.24	9.4	06:36	58	6	741	6	L	0.5	M
21	XLR	2.24	28	06:20	67	6	788	6	M	1	MH
22	XLR	2.24	47	06:15	78	7	658	6	M	1	M
23	XLR	2.24	94	05:58	78	5	305	6	ML	3.5	ML
24	XLR	2.24	187	06:10	51	4	735	6	M	6.25	M
25	XLR	1.12	187	06:35	40	5	434	6	L	0.5	M
26	FR	1.12	2.3	08:15	32	2	918	5	L	0.5	MH
27	UCSF-25	2.24	47	05:45	57	5	327	6	L	0.5	ML
28	80 S	2.24	47	05:10	67	5	2931	6	L	0.5	EH
29	UCSF-22	2.24	187	05:00	79	5	357	5	MH	6.25	M
30	UCSF-22	2.24	47	05:20	70	5	307	4	L	0.5	ML
31	SL	2.24	187	05:43	84	6	1578	5	MH	6.25	H
32	SL	2.24	47	05:35	56	7	1276	6	M	1	H
33	Untreated (Alfalfa)		–	–	NIL	–	NIL	–	NIL	–	NIL

[1] Pacific Daylight Time.

[2] Net honeybee kill, average/colony, above natural bee deaths in dead bee traps.

[3] L equals low effect, toxicity or hazard; ML, moderately-low; M, moderate; MH, moderately-high; H, high; and, EH, extremely-high, respectively.

[4] Statistically analyzed using Duncan's Multiple Range Test: for each experimental series, numbers followed by the same letter are not significantly diff. at $P < 0.05$

their colonies to be stored with pollen for food resulting in significant reduction of hazard to forager and hive bees (Ross and Harvey, 1981).

This is one more example showing that the ingenuity and persistence of the pesticide manufacturer has demonstrated that progress can be made and is being made to reduce the hazard from pesticides to acceptable levels for our invaluable honeybee pollinators so that the agricultural industry may continue to maximize production of food, fiber and seed.

Acknowledgements

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NOTES

CGA 73102, A NEW SOIL-APPLIED SYSTEMIC CARBAMATE INSECTICIDE

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Summary CGA 73102 is a systemic insecticide with contact and stomach action. It persists in soil up to 12 wk. As a consequence of these properties it controls soil pests and has useful side-effects against sucking and chewing insects attacking the young plants above ground. Its excellent compatibility with germinating seeds allows seed treatments at dosage rates which give protection against soil-inhabiting and early-season pests similar to that given by a granular application. As a foliar insecticide it is remarkably active against codling moth (*Cydia pomonella*) and damson-hop aphid (*Phorodon humuli*).

Résumé Le CGA 73102 est un insecticide systémique doté d'une action de contact et d'ingestion. Il agit dans le sol jusqu'à environ 12 semaines. De ce fait, il combat les insectes du sol et déploie d'appréciables effects secondaires sur les insects suceurs et broyeurs qui attaquent les jeunes plantes. Son excellente tolérance par les semences en germination permet d'effectuer des traitements de semences à des doses assurant une protection contre les insectes du sol et les insectes en début de saison, de manière similaire à l'application de granulés. Utilisé comme insecticide foliaire, il est remarquablement efficace contre le carpocapse des pommes (*Cydia pomonella*) et le puceron du houblon (*Phorodon humuli*).

INTRODUCTION

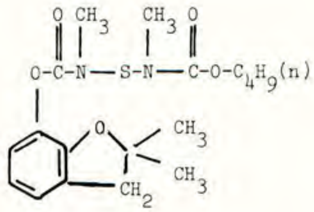
An insecticide suitable for the control of all important soil pests must primarily have three properties. Firstly, it must provide a broad spectrum of activity against not only insects but also other arthropods. Secondly, it must offer good plant- and particularly seed-tolerance and, thirdly, its chemical stability must guarantee a period of activity in the soil of at least 6 wk. If, at the same time, it is systemic, protecting the emerging young plants against early attack by foliar pests, its application possibilities are considerably enhanced. Finally, it should not be very toxic to warm-blooded animals so that the application risks will be minimal.

In numerous field trials it has been examined if CGA 73102 meets these standards and if it can successfully be applied both as a soil and foliar insecticide. CGA 73102 was first synthesized in the laboratories of CIBA-GEIGY Basle by J. Drabek and patent application was filed 1977.

TECHNICAL DATA

Common name:	Not yet approved
Systematic chemical name:	O-butyl O'-(2,3-dihydro-2,2-dimethylbenzofuran-7-yl) N,N'-dimethyl N,N'-thio-di(carbamate)
Empirical formula:	$C_{18}H_{26}N_2O_5S$

Structural formula:



Molecular weight:	382.48
Boiling point:	$160^{\circ}C$ at 0.01 mm Hg
Appearance:	Clear, yellowish liquid, odourless
Solubility at $20^{\circ}C$:	Water 10 ppm, soluble in most organic solvents
Toxicity:	Acute oral LD50 rat 100 mg/kg
Formulations:	Granules containing 5 % a.i.
	Seed dust containing 40 % a.i.
	Liquid e.c. containing 250 g a.i./l

BIOLOGICAL SPECTRUM

The following list comprises only species whose sensitivity has been tested in field trials. It does not therefore actually correspond with the whole spectrum of activity which may be considerably broader. The signs used are: ++ very good effect, + partial effect, - insufficient or no effect.

THYSANOPTERA:	Thripidae	Thrips tabaci	Onion thrips	++
HOMOPTERA:	Delphacidae	Laodelphax striatellus	Smaller brown planthopper	++
		Nilaparvata lugens	Brown planthopper	++
	Cicadellidae	Empoasca lybica	Green leafhopper	++
		Nephotettix cincticeps	Green rice leafhopper	++
	Psyllidae	Psylla piri	Pear psylla	-

	Aphididae	Many species except some resistent strains of Myzus persicae	++
	Diaspididae	Aonidiella aurantii California red scale	-
		Unaspis citri Citrus snow scale	++
COLEOPTERA:	Scarabaeidae	Costelytra zealandica Grass grub beetle	++
	Elateridae	Agriotes spp. Wireworms	++
	Cryptophagidae	Atomaria linearis Pygmy mangold beetle	++
	Chrysomelidae	Leptinotarsa decemlineata Colorado beetle	++
		Psylliodes chrysocephala Cabbage stem flea beetle (1 trial)	+(?)
		Chaetocnema tibialis Sugar beet flea beetle	++
		Phyllotreta spp. Flea beetles	++
		Diabrotica spp. Corn rootworms	++
	Curculionidae	Tanymecus dilaticollis Maize weevil	++
		Bothynoderes punctiventris Sugar beet weewil	++
		Ceuthorhynchus quadridens Cabbage stem weevil	++
		Anthonomus grandis Boll weevil	++
LEPIDOPTERA:	Hepialidae	Hepialus sp. Swift moth	++
	Plutellidae	Plutella xylostella Diamond-back moth	+
	Lyonetiidae	Leocoptera coffeella Coffee leaf miner	++
	Gelechiidae	Phthorimaea operculella Potato moth	++
	Tortricidae	Archips sp., Pandemis sp. Leaf rollers	-
		Sparganothis pilleriana Grape leaf roller	+
	Olethreutidae	Cydia pomonella Codling moth	++
		Lobesia botrana Grape berry moth	++
	Pyralidae	Tryporyza incertulas Yellow stem borer	++
	Noctuidae	Heliothis virescens Tobacco budworm	-
DIPTERA:	Tipulidae	Tipula sp. Crane fly	++
	Psilidae	Psila rosae Carrot fly	++
	Chloropidae	Oscinella frit Frit fly	++
	Anthomyiidae	Pegomya hyoscyami Beet leaf miner	++
		Delia brassicae Cabbage root fly	++
		Delia platura Bean seed fly	++
ACARINA:	Tetranychidae	Spider mites	-
MYRIAPODA:	Scutigerellidae	Scutigerella immaculata Glasshouse symphylid	++
	Blaniulidae	Blaniulus guttulatus Spotted millipede	++
NEMATODA:	Tylenchidae	Ditylenchus dipsaci Stem nematode	++
		Pratylenchus penetrans Root lesian nematode	++
	Criconematidae	Belonolaimus longicaudatus Sting nematode	++
	Diphtherophoridae	Trichodorus spp. Stubby-root nematodes	++

EXPERIMENTAL

Despite its incompleteness the list of pests that can be successfully controlled with CGA 73102 is so extensive that in the following report only results against some important pests and from a few trials can be cited.

The results of the trials have been grouped according to the three existing formulations or application methods and the data are the mean results of four replicates throughout.

Granular application In Central and Southern Europe wireworms are serious pests in potatoes, sugar beet and especially in maize. For the protection of the germinating seed and the emerging seedlings the application of insecticide containing granules into the seed furrow has found widespread use.

Table 1 shows the results of controlling wireworms (Agriotes spp.) in a trial with maize in 1981 in France (38 - Pommiers). The 5 % CGA 73102 granular formulation was applied on May 19 on 6 rows of 12 m length per replicate (row spacing 80 cm).

Table 1

Effects on stand of maize and on control of wireworms 41 days after application of granules to the seed furrow

Insecticide	g a.i./ha	mg/m	% reduction of damage	Relative plant number
CGA 73102	600	48	84	184
Carbofuran	600	48	71	176
Carbosulphan	500	40	65	166
Check: % destroyed seeds and plants			51	100

The effects of the protection on the yield appear in a trial carried out in 1980 (Table 2) in France (49 - Feneu). The details were the same as mentioned before and the variety of maize was Brutus.

Table 2

Effects of controlling wireworms on the stand and yield of maize after application of granules to the seed furrow on April 30, 1980

Insecticide at 600 g/ha = 48 mg/m	% reduction of damage	Relative plant number	Relative yield
CGA 73102	97	118	150
Carbofuran	100	121	143
Terbufos	98	118	127
Check: % plants destroyed	13.4	100	100 (4240 kg/ha)

In the sugar beet - growing areas of Northern Europe the pygmy mangold beetle (Atomaria linearis) is a serious pest and it is often difficult to control. CGA 73102 was particularly suitable for this application in a trial with an extremely high infestation in France (45 - Sceaux en Gatinais) in 1979 (Table 3). Plot size: 6 rows of 20 m length, row spacing 45 cm, variety Monomer.

Table 3

Control of pygmy mangold beetle on sugar beet and effect on the yield of sugar after application of granules to the seed furrow on April 19, 1979

Insecticide	g a.i./ha	mg/m	% reduction of damage	relative yield of sugar
CGA 73102	600	27	98	102
Carbofuran	600	27	90	100 (12.8 t/ha)
Aldicarb	1000	45	22	67
Check: % plants destroyed			99.4	0

Besides the pygmy mangold beetle, wireworms, symphylids and millipedes are a threat to young sugar beet. CGA 73102 proved very effective against this pest complex and it was not phytotoxic, making it very suitable for use on this crop. The emerging seedlings are attractive to the first generation of the beet leaf miner, to aphids and to flea beetles (Chaetocnema tibialis). Particularly in Southern Europe, the latter can cause serious damage and prophylactic protection by a systemic insecticide must be adopted. Table 4 shows the results of a trial carried out in Spain (Carbonero/Segovia) in 1980. Plot size 25 m2, row spacing 50 cm, variety Kawepoly.

Table 4

Control of flea beetle on sugar beet 40 days after applying granules to the seed furrow on April 28, 1980 and the effect on yield of beets

Insecticide	g a.i./ha	mg/m	% reduction of damage	Relative yield
CGA 73102	600	30	88	128
	800	40	91	133
	1000	50	91	134
Carbofuran	600	30	91	128
Aldicarb	1000	50	76	123
Check: % heavily attacked plants			91	100 (38.2 t/ha)

The effect of CGA 73102 against the beet leaf miner and early infestation by Aphis fabae is excellent, too, but Myzus persicae already shows a pronounced resistance against a number of carbamates, including CGA 73102 and carbofuran, in many regions.

CGA 73102 was applied as a drench or as granules against Delia brassicae on brassicas after transplanting, and with 30 mg a.i./plant it gave equal protection against this pest as the standard insecticides chlorfenvinfos and carbofuran. As a useful side effect the infestation of the treated plants by the cabbage aphid (Brevicoryne brassicae) is prevented for at least 4 wk.

Seed treatment CGA 73102 has been incorporated into the pellet of monogerm seed of sugar beet but, unfortunately, the results of the trials carried out so far do not allow a valid assessment of efficacy against pests because the infestations encountered were too low. However, it was not phytotoxic up to at least 90 g a.i./unit of 100 000 pellets. Further trials are being carried out.

With maize, for the first time in 1981, a seed coating has been tested which is fast to rubbing and maize, cotton, broad beans, rape, and cereal seeds and seed potatoes have been treated with seed dust formulation. The very promising results are summarized in Tables 5-8.

Table 5

Protection of maize by CGA 73102 applied as a seed treatment or as granules in the seed furrow against wireworms on May 18, 1980 in France (38-Faramans)

Formulation	Dosage rate (g/kg or g/ha)	% reduction of damage	Relative plant number
Coating	3	47	109
	6	85	110
Seed dust, 40 % a.i.	4	83	124
	8	89	122
Granules, 5 % a.i.	600	89	140
Check (nil): % attacked plants:	seed treat.	21.1	100
	granules	17.4	100

Official trials in Rumania 1981 (directed by Dr. F. Paulian) with CGA 73102, applied as a seed treatment with 10 g a.i./kg maize seed, resulted in an excellent protection against the attack of the maize weevil (Tanymecus dilaticollis).

Table 6

Protection of cotton plants against cotton aphid (Aphis gossypii) by CGA 73102 applied as a seed treatment or as granules in the seed furrow on April 8, 1980 at Cantillana/Spain

Formulation	Dosage rate (g/kg or g/ha)	% control after 40 days	74 days
Seed dust, 40 % a.i.	4	97	99
	8	97	99
	16	96	99
Granules, 5 % a.i.	1000	96	83
Check (nil): Number of aphids/40 leaves		1100	3100

Against Thrips tabaci in the same trial the effects of the seed treatment were significantly dose-related. Only the highest dosage was equal or slightly superior to granules.

Table 7

Protection of broad beans against black bean aphid (Aphis fabae) by CGA 73102 applied as a seed treatment or as granules in the planting hole on April 2, 1981, at 49-Tièrcé/France

Formulation	Dosage rate a.i.	% control after 68	74	81	88 days
Seed dust, 40 % a.i.	8 g/kg	94	77	79	70
	16 g/kg	100	94	90	88
Granules, 5 % a.i.	50 mg/plant	100	100	99	99
Check (nil): Number of aphids/10 plants		1240	840	2740	2840

Table 8

Protection of potatoes against colorado beetle by CGA 73102 applied as a seed treatment or as granules in the furrow on May 8, 1981, at Monthey/CH

Formulation	Dosage rate a.i.	% control after 40 days	49 days
Seed dust, 40 % a.i.	25 mg/tuber	98	99
	50 mg/tuber	99	98
Granules, 5 % a.i.	100 mg/m of row = ~ 1800 g/ha	99	99
Check: Number of larvae/12 m2		877	984

Foliar treatment Among the multiple possibilities which the insecticidal properties of the compound offer there are two uses for which the systemic activity of CGA 73102 is valuable. It is outstandingly effective against the damson-hop aphid (official trials at Hallertau/FRG) which has become increasingly difficult to control due to its resistance, and for protecting pip-fruit against codling moth, green and rosy apple aphids (Aphis pomi, Dysaphis plantaginea). In several trials in 1979 and 1980 at our experimental farm Les Barges (Switzerland) the protection against the attack of codling moth (35-53 % in the untreated plots) was at least equal to that given by azinphos-methyl and methidathion. The recommended dosage of the e.c. formulation in these foliar applications is 40 g a.i./hl. Further development of the preparation will show whether any other opportunities exist for this use.

DISCUSSION

Conventionally applied into the furrow, CGA 73102 has proved in numerous field trials over 3 yr to be at least equal to today's best standard preparations against wireworms in maize and sugar beet, as well as against the whole sugar beet pest complex. The systemic effect offers additional protection against early-season pests. Its low phytotoxicity on seed allows seed treatments with dosages which can equal the insecticidal performance of granules but at considerably reduced total expenditure per area protected. This application method still needs intensive further investigation before all its possibilities can be assessed.

The suitability of CGA 73102 for vegetable crops, especially against root flies and its nematicidal side effects are also potentially useful.

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2-tert-BUTYLIMINO-3-ISOPROPYL-5-PHENYLPERHYDRO-1,3,5-THIADIAZIN-4-ONE (NNI-750), A NEW INSECTICIDE

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Summary 2-tert-Butylimino-3-isopropyl-5-phenylperhydro-1,3,5-thiadiazin-4-one (NNI-750) is a new insecticide showing high level of nymphcidal activity against some members of the Hemiptera. Its effect on insects appears rather slowly but lasts for a long time. NNI-750 is particularly effective for the control of planthoppers, leafhoppers, whiteflies and some of scales both susceptible and resistant to carbamates and organophosphorus compounds. Its nymphcidal activity extends to Coleoptera and Acarina. It shows low toxicity to mammals and fish and no adverse effects on the beneficial insects and natural enemies examined.

Résumé 2-tert-Butylimino-3-isopropyl-5-phénylperhydro-1,3,5-thiadiazin-4-one (NNI-750), est un nouvel insecticide qui montre une activité élevée sur les Nymphes d'une certaine famille d'Hémiptères. Malgré son effet sur les insectes apparu plutôt lentement, son efficacité y reste pendant longtemps. NNI-750 est surtout effectif pour éliminer ou empêcher Derphacidae, Deltocephalidae, Aleyrodidae, Diaspididae et Pseudococeidae qui tous les deux susceptibles et résistants aux agents carbamates et organophosphates. Son activité élevée sur les nymphes s'etend encore à une certaine d'Coléoptères et Acarides, tandis qu'il faible toxicité sur les mammifères et les poissons, ne montrant aucun effet sur les insectes bénéficieux et les ennemies naturels.

INTRODUCTION

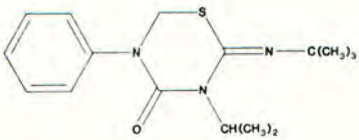
In the study of a group of thiadiazines conducted at Nihon Nohyaku Co. Ltd, 2-tert-butylimino-3-isopropyl-5-phenylperhydro-1,3,5-thiadiazin-4-one (NNI-750, trade mark: Applaud(R)) was selected from many derivatives as the most active compound (Kanno et. al., 1981). NNI-750 is quite unique not only for its chemical structure but also for the mode of action compared with conventional insecticides (Maekawa et. al., 1981). The purpose of this paper is to introduce the compound and some biological data.

Chemical and Physical Properties

Chemical name: 2-tert-Butylimino-3-isopropyl-5-phenylperhydro-1,3,5-thiadiazin-4-one

Code numbers: NNI-750, NNK-758, NN-29285

Structural formula:



Molecular formula and weight: $C_{16}H_{23}N_3OS$ 305.5

Melting point: 106.1 °C Vapour pressure: 9.4×10^{-6} mmHg at 25 °C

Solubility at 25 °C: 0.9 mg/l water, 240 g/l acetone, 520 g/l chloroform, 80 g/l ethanol, 320 g/l toluene.

Toxicity

Acute oral LD50:	Mice (male)	10 000 mg/kg
	Rats (male	8740 mg/kg

Primary irritancy: No dermal or eye irritation

Fish toxicity: Carp LC50 (48 h) 2-10 mg/l

Mutagenicity: Rec-assay negative at 4-4000 µg/disc
Ames test negative at 1-1000 µg/plate for 6 strains

Toxicity to beneficial insects and natural enemies:

NNI-750 has no serious toxicity on the following:

honey bee (*Apis mellifera*)
silkworm (*Bombyx mori*)
spider (*Lycosa pseudoannulata*)
predatory mites (*Phytoseiulus persimilis*)
(*Amblyseius longispinosus*)
parasitic wasp (*Paracentrobia andoi*)

Phytotoxicity:

Studies carried out so far show that NNI-750 is slightly phytotoxic to chinese cabbage.

METHODS

The trials reported below vary in experimental design according to crop and pest. In laboratory and glasshouse experiments, compounds were sprayed to run off and artificial inoculation techniques were implemented. In field trials, dust or granular formulation were applied. Comparison was made with relevant standard compounds. All dosages are expressed as active ingredient.

RESULTS

(a) Range of activity

The first instar nymphs of 42 species in 27 families were respectively released on host plants sprayed with NNI-750 at 250 mg/l. Major pests were picked out as ones susceptible to the compound when their mortality attained to more than 90% at the end of the 2nd instar. NNI-750 was primarily active against Hemipterous insects (Table 1).

Table 1

Major pests susceptible to NNI-750

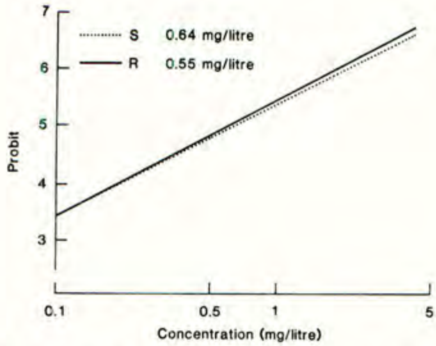
Order	Scientific name	
Hemiptera	*Aleurocanthus spiniferus*	*Nephotettix cincticeps*
	Arboridia apicalis	*Nilaparvata lugens*
	Bemisia tabaci	*Pseudaulacaspis pentagona*
	Chlorita onukii	*Pseudococcus comstocki*
	Empoasca abrupta	*Recilia dorsalis*
	Epiacanthus stranineus	*Sogatella furcifera*
	Icerya purchasi	*Trialeurodes vaporariorum*
	Laodelpjax striatella	*Unaspis yanonensis*
Coleoptera	*Epilachna varivestis*	*Henosepilachna vigintioctopunctata*
Acarina	*Aculops pelekassi*	*Polyphagotarsonemus latus*

(b) Planthoppers and leafhoppers

(1) Activity against nymphs

Thirty 3rd instar nymphs were released on the treated plants after the sprays had dried. The numbers of dead nymphs were counted 5 days later and the mortalities were calculated. This experiment was replicated three times. Table 2 shows that NNI-750 has an excellent activity against nymphs of planthoppers and leafhoppers and is about 100 times more effective than the reference insecticides. NNI-750 was a slow-acting insecticide. Nymphs on plants treated with NNI-750 died at 3 to 5 days after exposure and most of the nymphs died at the time of moulting. Recently, it was reported that the brown planthopper (*N. lugens*) had become resistant to some carbamate and organophosphorus insecticides (Kilin *et al.*, 1981). In another experiment NNI-750 was active even against the nymphs of a resistant strain, in which mortality was substantially similar to that in the susceptible strain (Figure 1).

Figure 1 Effect of NNI-750 on 3rd instar nymphs of two strains of *Nilaparvata lugens*



S: strain susceptible to } carbaryl, diazinon, fenitrothion, isoprocarb,
R: strain resistant to } malathion, m-tolyl methylcarbamate,

Table 2

Activity of NNI-750 on the 3rd instar nymphs of planthoppers and leafhoppers

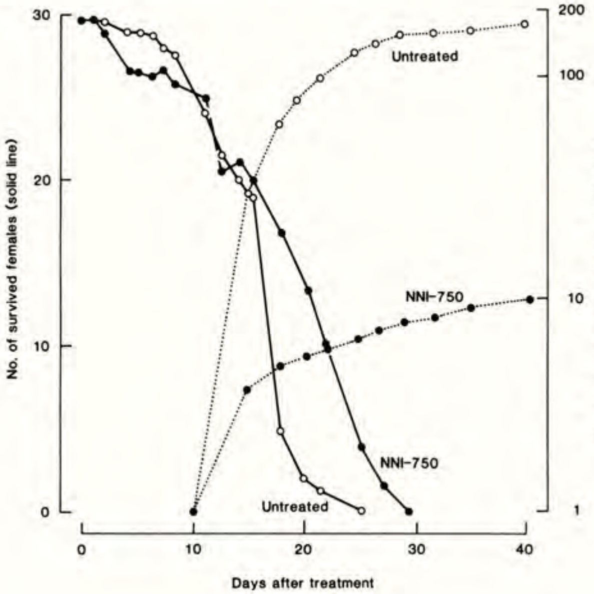
Treatment	Concn (mg/l)	% Mortality N. l.	S. f.	L. s.	N. c.
NNI-750	1	100	100	100	100
	0.5	73	100	100	77
	0.25	33	100	100	17
2-sec-Butylphenyl methylcarbamate (Compound 1)	50	87	100	100	50
	10	27	100	67	13
	1	0	3	3	3
4-(Methylthio)phenyl dipropyl phosphate (Compound 2)	50	97	100	100	100
	10	13	100	100	87
	1	3	53	47	0
Untreated		3	0	10	0

N. l. : Nilaparvata lugens L. s. : Laodelphax striatella
S. f. : Sogatella furcifera N. c. : Nephotettix cincticeps

(2) Activity against adults

Thirty macropterous females and males of brown planthopper were released on rice plants sprayed with NNI-750 at 250 mg/l. The numbers of survived adults and hatched nymphs were counted up to 40 days after exposure. NNI-750 did not have direct killing effect on the adults. However, NNI-750 reduced drastically the number of progenies (Figure 2). An ovicidal activity of NNI-750 was observed, but was weaker than the nymphcidal activity.

Figure 2 Effect of NNI-750 on adults of brown planthopper *(Nilaparvata lugens)*



(3) Field trials

NNI-750 was applied at 1.6 kg(a.i.)/ha (as a 4% granule) or 0.8 kg(a.i.)/ha (as 2% dust) in the paddy field on August 1 1978 where paddy rice had been transplanted on June 13. Each treatment was applied to two 25 m^2 plots. The number of brown planthoppers per 40 hills per plot was counted up to two months after treatment.

Results of field trials demonstrated that NNI-750 is excellent in controlling brown planthoppers and has a remarkable long residual effect. NNI-750 gradually reduced the population density of the brown planthopper after treatment (Figure 3). NNI-750 could be available not only for foliar spray application by wettable powder and dust but also submerged application by granule.

(c) Greenhouse whitefly

Compounds were sprayed on tomato leaves which were infested by 32-97 of the nymphs. Mortality was determined by counting dead and survived nymphs 9 or 11 d after treatment and the results were expressed as LC50 values. NNI-750 was extremely active against nymphs except for the late stage of the 4th instar (Table 3).

Figure 3 Effect of NNI-750 on the field population of brown planthopper *(Nilaparvata lugens)* in Japan, 1978

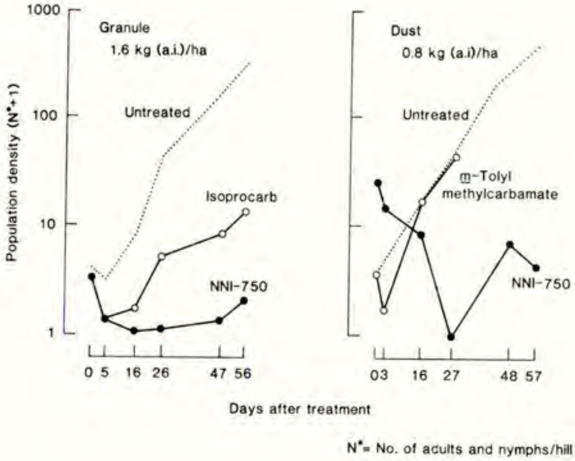


Table 3

Activity of NNI-750 against nymphs of greenhouse whitefly (*Trialeurodes vaporariorum*)

Treatment	LC50 (mg/l) for instars 1st	2nd	3rd	4th early	4th middle	4th late
NNI-750	0.7	0.5	2.5	12	16	500-2000
Methidathion	28.5	132.0	414.0	469	582	1419
Quinomethionate	30.0	10.9	69.8	1176	689	301

(d) Arrowhead scale

Compounds were sprayed over the nymphs on leaves of grapefruit. NNI-750 also showed the delayed nymphcidal activity against arrowhead scale (Table 4). When the first instar nymphs were treated with NNI-750, they died at the 1st or 2nd instar and none of them grew to adults.

(e) Comstock mealybug

The first instar nymphs were released on apple leaves which had been dipped in suspensions of compounds and allowed to dry. The numbers of survived nymphs were counted up to 14 d after treatment. Compared with methidathion, effect of NNI-750 appeared slowly but all nymphs died within 14 d (Table 5).

Table 4

Activity of NNI-750 against the 2nd instar nymphs of arrowhead scale (*Unapsis yanonensis*)

Treatment	Concn (mg/1)	No. of nymphs tested	No. of survivals: female adults (23DAT*)	No. of survivals: nymphs of next generation (69DAT*)
NNI-750	500	453	14	0
	250	380	60	0
	125	667	134	0
Methidathion	250	928	0	0
Untreated		580	370	2053

* DAT : days after treatment

Table 5

Activity of NNI-750 against the 1st instar nymphs of Comstock mealybug (*Pseudococcus comstocki*)

Treatment	Concn (mg/1)	No. of nymphs tested	No. of survived nymphs 3DAT*	10DAT*	14DAT*
NNI-750	250	59	58	8	0
	50	63	58	2	0
Methidathion	250	68	0	0	0
	50	72	0	0	0
Untreated		57	56	42	36

* DAT : days after treatment

(f) Broad mite

Compounds were sprayed over eggs on kidney bean leaves. The numbers of survived nymphs were counted 3 and 6 days after treatment. On broad mite NNI-750 showed the delayed nymphcidal activity similar to that on Hemipterous insects (Table 6).

Table 6

Activity of NNI-750 against broad mite (*Polyphagotarsonemus latus*)

Treatment	Concn (mg/l)	No. of eggs tested	No. of survived nymphs 3DAT*	6DAT*
NNI-750	250	77	62	0
	100	68	51	0
Bromopropylate	250	74	1	0
Untreated		70	54	44

* DAT : days after treatment

DISCUSSION

Results described above clearly show that NNI-750 is unique in its chemical structure and biological effects. Its toxic effect is characterized by its high nymphcidal activity and excellent persistency of the activity. NNI-750 exerts its characteristic effect on planthoppers, leafhoppers, greenhouse whitefly, arrowhead scale, Comstock mealybug and broad mite. Field trials on brown planthopper proved NNI-750 as a promising insecticide for practical use. Because of its low toxicity to mammals, fish, beneficial insects and natural enemies, we believe that NNI-750 is helpful for integrated pest management.

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NC 21314, A NOVEL COMPOUND FOR CONTROL OF PHYTOPHAGOUS MITES

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Summary NC 21314 is a compound of novel structure which has been shown to give very good control of mites, particularly on top fruit. It is a specific acaricide, acting primarily as an ovicide with some effect on young motile stages and long residual activity. It is effective against winter eggs of *Panonychus ulmi* but no activity has been demonstrated on adult mites. Laboratory tests and field observations have shown NC 21314 to be safe to predatory mites and beneficial insects. It is of low mammalian toxicity.

Résumé NC 21314 est une formulation d'une structure nouvelle, qui s'est révélée comme très efficace dans la lutte contre les acariens, en particulier sur les cultures fruitières. C'est un acaricide spécifique, d'une rémanence prolongée, qui agit surtout comme ovicide mais attaque également les jeunes stades mobiles. Il est efficace contre les oeufs d'hiver de *Panonychus ulmi*, mais ne s'est pas montré actif sur les acariens adultes. Les tests de laboratoire et les observations faites en conditions réelles ont montré que NC 21314 n'est pas dangereux pour les acariens prédateurs ni les insectes utiles. Les résultats des tests de toxicologie indiquent que NC 21314 est peu toxique pour les mammifères.

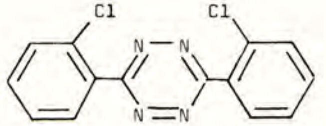
INTRODUCTION

The spider mite ovicidal activity of ortho-halo phenyl substituted tetrazines was discovered at Chesterford Park Research Station in 1976. The bis-ortho chlorophenyl tetrazine was selected for further development from a large number of compounds subsequently synthesized and screened in both laboratory and field trials.

Chemical and physical properties

Chemical name: 3,6-bis(2'-chlorophenyl)-1,2,4,5-tetrazine

Structural formula:



Molecular formula and weight:	$C_{14}\ H_8\ Cl_2\ N_4$, 303
Physical appearance:	Magenta solid
Melting point:	179-182°C
Vapour pressure:	9.76×10^{-17} mm Hg at 25°C
Solubility:	Chloroform 50 g/l
	Benzene 2.5 g/l
	Hexane < 1 g/l
	Water < 1 mg/l
Specific gravity:	1.5 g/cm^3

Formulations

Three formulations are available for experimental use:

50% Wettable powder
80% Wettable powder
50% Aqueous based suspension concentrate

Toxicological Properties

Active ingredient	Acute oral toxicity:	LD50 rat ♂ and ♀	> 3200 mg/kg
		LD50 mouse ♂ and ♀	> 3200 mg/kg
		LD50 Bobwhite quail	> 750 mg/kg
		LD50 Mallard duck	> 3000 mg/kg
	Acute dermal toxicity:	LD50 rat ♂ and ♀	> 1332 mg/kg
	Fish toxicity:	LC50 (96h) Rainbow trout	> 100 mg/l
Formulation 50%w.p.	Acute oral toxicity	LD50 rat ♂ and ♀	> 5000 mg/kg
	Acute dermal toxicity	LD50 rat ♂ and ♀	> 5000 mg/kg

Acute toxicity tests show both technical and formulated NC 21314 to be of low toxicity to mammals, birds and fish. Slight skin irritancy was noticed in rats, one formulated sample being a little more irritant than the technical material. A negative result was obtained in the Ames test. Further toxicological studies are in progress.

Decline of residues in the soil

In the U.K., residues in the top 7.5 cm of soil declined to 0.2 - 0.4 mg/kg at 100-150 days after one or two applications at 1 kg a.i./ha. In Texas, under hot conditions with irrigation, residues declined more rapidly and less than 0.1 mg/kg were present at 3 months after one application. In practice, the total rate of application on apples in a season will probably be less than 1 kg a.i./ha.

BIOLOGICAL ACTIVITY IN LABORATORY TESTS

Primary screening tests have shown NC 21314 to be very effective as a mite ovicide with some effect on immature mites but no direct effect on adults at 1 g ai/l, although some sterilant effect has been observed at this very high concentration. It has shown no insecticidal properties in laboratory and field trials on eggs, immature motile stages or adult insects.

Activity on spider mite eggs

Table 1 shows the high level of activity against eggs of resistant and susceptible strains of the two-spotted spider mite (*Tetranychus urticae*) and the carmine spider mite (*T. cinnabarinus*) treated by dipping French bean leaf discs, infested with spider mite eggs, into aqueous suspensions of technical NC 21314.

Table 1

% Mortality of spider mite eggs

Species		NC 21 314 Treatment rate in mg/l			LC50 (mg/l)
		10	3	1	
Two-spotted spider mite	susceptible strain	100	100	100	< 1
	multi-resistant strain	85	40	0	4
Carmine spider mite		100	93	59	< 1

When eggs were left to develop for varying times before treatment with technical NC 21314 at 10 g ai/l, susceptibility declined shortly before hatching. Mortalities after 1, 2, 4 and 5 days being 100, 97, 54 and 3% respectively.

Effect on winter eggs of fruit tree red spider mite (Panonychus ulmi)

One of the needs in the product range for control of fruit tree red spider mite is a new material which will kill overwintering eggs. The only material at present available is mineral oil which has a limited application period due to its phytotoxicity and to the necessity of spraying at the correct stage of development of the egg. Therefore an early study of the effect of NC 21314 on winter eggs was carried out in the U.K.

Apple twigs infested with winter eggs of the fruit tree red spider mite were cut and brought into a heated greenhouse about 3 wk before their normal time of hatching. Groups of twigs sprayed to run-off with NC 21314 50% w.p. at 0.1, 0.3 and 1 g a.i./l were held with their cut ends in pots of water and observed daily, until eggs on an untreated group of twigs had completed emergence. To prevent desiccation, all twigs were given a very light daily misting with distilled water. Counts of unhatched eggs were made before treatment and again 3 wk later. At the time of the second count there was no significant reduction in numbers of unhatched eggs on the twigs treated with NC 21314 at any of the rates tested compared with 80 - 100% hatch on untreated twigs. Other, similar tests, in North America in 1980 confirmed this activity. It should be noted that in all these tests the eggs were not in diapause.

Foliar persistence and translaminar activity

Dwarf French bean plants sprayed with aqueous formulations of NC 21314 containing 1 g a.i./l retained 100% toxicity to eggs of the carmine spider mite for over 5 wk in a controlled temperature room at 25°C.

When an aqueous suspension of technical NC 21314 containing 1 g a.i./l was applied to the upper surface of dwarf French bean leaves, 90% of eggs on the underside were killed. There was no evidence of systemic movement within the plant.

Activity against spider mite nymphs and larvae

Direct treatment of spider mite larvae by dipping infested leaf discs into aqueous suspensions of NC 21314 50%w.p. resulted in useful levels of activity. The LC50's for the two-spotted mite were 10 and 35 mg a.i./l for the susceptible and resistant strains respectively and 10 mg a.i./l for the carmine spider mite. This activity was less than that shown against eggs in Table 1.

BIOLOGICAL ACTIVITY IN FIELD TRIALS

Fruit tree red spider mite on apples

NC 21314 50% w.p. is in its third season of testing in field trials in both the northern and southern hemispheres where the major effort has been concentrated on the control of fruit tree red spider mite (P. ulmi) on apples. Results presented in this paper are from trials carried out in the Vaucluse area of France and in the UK during 1979, 1980 and 1981.

All trials were carried out on single tree plots in a randomised block lay-out. In France, treatments were applied with a air-blast knapsack sprayer and assessments were made weekly on the number of adult mites on 10 - 25 leaves/tree. In the UK, treatments were applied with a CO_2-pressurised knapsack sprayer and assessments were made of the number of motile stages on 25 leaves/tree using a leaf brushing machine.

Early field trials showed NC 21314 to be promising for the control of fruit tree red spider mite at rates of 100 - 400 mg a.i./l HV against a low mite population.

In France a single application sprayed when mites numbered about 1 adult/leaf, compared well with two applications of cyhexatin, giving control for 8-9 wk after which the mite numbers declined naturally. The results (Table 2), also indicated a very flat dose response relationship.

Table 2

Control of P. ulmi on Apples. France 1979 (mean no. of adult mites/leaf)

Acaricide 15th May '81	mg a.i./l	Weeks after treatment 0	2	3	4	6	8	9
NC 21314	50	1.1	0.1	0.1	0	0.5	2.1	2.3
	100	1.3	0.1	0.1	0	0.2	1.0	1.4
	200	0.7	0	0.3	0	0.3	3.7	1.8
	400	1.3	0.2	0.7	0	0.3	1.8	0.7
Cyhexatin	300	1.3	0	2.8*	0.4	1.1	4.5	12.4
Untreated	-	0.7	5.1	7.5**	-	-	-	-

* Treatment resprayed   ** Untreated sprayed to limit infestation

In other trials in France, on higher populations, three applications of NC 21314 at 400 mg a.i./l or four applications at 100 or 200 mg a.i./l kept the number of mites below 1 adult/leaf throughout the season, being equal to two applications of cyhexatin at 300 mg a.i./l. Treatments at 200 and 400 mg a.i./l applied to a high mite infestation of above 25 adults/leaf reduced mite numbers to below 2/leaf at 2 wk, after which numbers started to rise again. A second application was necessary at 3 wk to keep the mite levels below 2/leaf for the rest of the season, equal to one application of cyhexatin at 300 g a.i./l.

In 1980, further trials were carried out to confirm the effectiveness of early sprays of NC 21314. In the U.K., concentrations of 200 and 400 mg a.i./l were applied at three different times, one trial being treated at the beginning of the hatch of winter eggs, a second when about 75% of eggs had hatched and a third in mid-July. It was intended to spray the first trial just before the winter eggs began to hatch but a warm spell at the end of May caused them to hatch quickly and treatments were actually applied after egg-hatch had begun. Consequently there was only 1 wk between spraying the first and second trials.

The earliest treatments gave good control of mites for 12 wks at both concentrations whereas applications made 1 wk later, when most of the winter eggs had hatched, only gave control for 6 wk with 400 mg a.i./l. Even after a second application the control was not as persistent as with the earlier spray although it was still comparable to that achieved by the standard, cyhexatin (Table 3). Treatments applied in mid-July, when the mite population was well established, were also effective for about 6 wk.

Table 3

Control of P. ulmi on Apples. U.K. 1980 (No. motile stages/leaf)

Acaricide 20 May '80	mg a.i./l	Weeks after treatment 0	1	3	5	7	10	12	14
NC 21 314	200	1.5	1.4	1.7	0.9	1.0	1.8	2.3	3.8
	400	2.0	1.1	1.6	0.5	0.6	1.1	1.9	3.8
Untreated	-	1.6	5.5	10.7	5.3	17.0	15.2	28.9	21.2

Acaricide 27 May	mg a.i./l	Weeks after treatment 0	1	2	4	6	7	9	11
NC 21 314	200	3.1	5.9	5.4	3.1	5.1*	3.1	4.3	7.3
	400	3.2	5.1	1.8	1.4	2.7*	1.9	1.4	5.3
Cyhexatin	200	9.1	4.2	5.5	3.5	15.0*	3.0	1.4	3.5
Untreated	-	3.2	8.6	4.7	4.5	23.2	9.7	12.5	39.5

* treatments resprayed 8.8.80

(Note: No standard treatment was included with the early sprays as it was intended to spray before winter eggs began to hatch and there is no standard available in the U.K. for such a treatment.)

In the South of France in 1980 treatments were applied when the adult mites first appeared (i.e. as standard local commercial practice). With this timing and in situations where the build-up of mites was slow, a single application of NC 21314 at 300 mg a.i./l gave satisfactory control of mites throughout the season. Where mite pressure was stronger, a second application was necessary after 11 wk to keep mite levels below 1 adult/leaf for the rest of the season. There was, again, very little dose response with no difference in control between concentrations of 150 - 600mg a.i./l (Table 4).

Table 4

Control of P. ulmi on apples - France 1980 (No. of adult mites/leaf)

Acaricide 14 May	mg a.i./l	Weeks after treatment 0	3	5	7	10	12	14	18
NC 21 314	300	1.0	0	0	0.1	0.3	0.4	0.2	0.4
Cyhexatin	300	2.1	0	0.2	1.1	7.3*	0.3	0.1	2.0
Untreated	-	0.8	0.1	0.4	0.6	3.5	10.6	17.0**	-
Acaricide 20 May	**mg a.i./l**	**Weeks after treatment 0**	**3**	**6**	**8**	**10**	**11**	**12**	**14**
NC 21 314	150	0.8	0.1	0.2	0.2	0.6	0.9*	0.1	1.0
	300	2.5	0.7	0.1	0.3	2.1	2.7*	0.3	0.8
	600	1.9	0.1	0.2	0.2	1.0	1.3*	0.2	0.2
Cyhexatin	300	0.2	0.1	0.7	3.3	7.3	19.8*	0.3	2.3
Untreated	-	1.3	2.2	8.7	11.3	15.7**			

* Treatments resprayed ** Untreated sprayed to limit infestation

Other trials carried out by collaborators during 1980 in the USA and Europe have generally confirmed the good activity of NC 21314 at concentrations of 200-400 mg a.i./l particularly when applied to winter eggs just before, or at the time of, egg-hatch. Good results have also been obtained with late sprays, provided that the mite numbers are low at the time of application. The lack of adulticidal activity means that the knockdown effect of NC 21314 is inadequate although the numbers of mites are reduced, relative to untreated trees, after 2 wk. The level of control from late sprays on high populations, however, is generally not equal to that of standard acaricides in initial action but is at least as effective in residual activity. The possibility of mixtures of NC 21314 with knockdown acaricides is being considered to overcome this problem.

Field Trials against winter eggs of fruit tree red spider mite

During the winter of 1980/81 a field trial was laid down in the UK to confirm the effect of NC 21314 against winter eggs. Concentrations of 50, 100 and 200 mg a.i./l were applied at HV in December, March and April to trees with high populations of winter eggs. The December application was made on eggs still in diapause and the March and April applications when diapause was almost certainly ended. In December and March there was no foliage present, tree buds being fully dormant in December and only at bud burst in March. At the time of the April spray foliage was present and the flowers were at the 'pink bud' stage. Some residual activity from deposits on this early foliage could thus be expected, but in the December and March sprays there would only be a direct contact effect on the winter eggs. The eggs began to hatch during the second week of May and first counts of mites were made at the beginning of June. Treatments at all dates gave control of winter eggs, relative to the untreated trees, with no significant differences between concentrations. No treatment gave complete control, probably because the spray cover was not adequate. Populations on treated trees remained low relative to the untreated until the end of June, when the first generation of summer eggs hatched onto foliage, which was not present at the time of spraying. Results of the first mite count are shown in Table 5, illustrating the control of diapausing eggs.

In France, Italy, Spain, Holland and Belgium all current 1981 trials indicate very effective and prolonged control of fruit tree red spider mite on apple at a concentration of 300 mg a.i./l applied pre-blossom and before commencement of winter egg hatch.

Table 5

Control of 1980/81 winter eggs of P. ulmi on apples on 2nd June 1981

Date of treatment...		9 Dec. 80		24 Mar. 81		23 Apr. 81	
Stage of tree...		dormant		bud burst		pink bud	
	mg a.i./l	No. Mites/ leaf	% control	No. Mites/ leaf	% control	No. Mites/ leaf	% control
NC 21 314	50	2.5	91	5.2	71	2.5	82
	100	3.4	88	5.7	68	3.6	74
	200	1.1	96	5.3	70	1.6	89
Untreated	-	28.2	-	18.0	-	14.1	-

During 1981 trials are also in progress in North America where NC 21314 has been applied in direct comparison with mineral oil sprays applied pre-blossom to the over-wintering eggs. Results confirm those obtained elsewhere and demonstrate that NC 21314 is an effective alternative to mineral oil with the added properties of being non-phytotoxic and also controlling the dormant winter eggs of fruit tree red spider mite.

Control of other mite species

NC 21314 has given good control of T. urticae on apples in North America and Australia and of Tetranychus spp. on cotton and ornamentals. On citrus in the USA it has shown good activity against citrus rust mite (Phyllocoptruta oleivora), citrus red mite (Panonychus citri) and Texas citrus mite (Eutetranychus banksi). It has also shown activity against yellow mite on vines (Eotetranychus carpini).

SAFETY IN USE

Crop safety

No phytotoxicity has been observed on any crop or cultivar at any dose rate tested.

Safety to beneficial species

A number of observations have been made and tests have been carried out in the laboratory and in the field to assess the effect of NC 21314 on beneficial species.

In laboratory tests, residual deposits of NC 21314 50% w.p. resulting from dipping leaf discs or spraying entire leaves to run-off, have shown no toxicity to the whitefly parasite Encarsia formosa or the predatory mite Phytoseiulus persimilis at concentrations up to 1 g a.i./l. Tests have been carried out on the following stages:-

E. formosa
- adults on treated leaf discs.
- adults, eggs and larvae on whitefly scale-infested leaves sprayed to run off.

P. persimilis
- adults, nymphs and eggs on treated leaf discs.
- eggs treated directly by dipping

Safety to honeybees

NC 21314 50% w.p. has shown no measurable toxicity to worker honeybees. (Apis mellifera). Laboratory tests have given the following results:-

LC50 (48 h) by direct spraying >1.5 g a.i./l.

LD50 (48 h) by oral intake in 20% sucrose >20 μg/bee

A replicated field trial was carried out by East Malling Research Station in 1980 in which NC 21314 was applied at 300 mg a.i./l to apples. Treatments of single-tree plots were replicated 6 times in each of two blocks, one block being infested with a native strain of Typhlodromus pyri and the other with an OP-resistant strain imported from New Zealand. Assessments of T. pyri and P. ulmi in each block are shown in Table 6.

Table 6
Effect of NC 21 314 on P. ulmi and T. pyri on apples
East Malling Research Station 1980

Mean number of active mites on 10 leaves
Weeks after treatment

	mg a.i./l	P. ulmi 0	P. ulmi 3	P. ulmi 6	T. pyri (native strain) 0	T. pyri (native strain) 3	T. pyri (native strain) 6
NC 21314	300	91	18.4	5.5	0.9	5.4	15.3
Untreated	–	104	230	390	1.6	8.6	17.2
		P. ulmi			T. pyri (OP-resistant)		
NC 21314	300	240	80	5.6	2.0	15.1	27.1
Untreated	–	160	210	310	1.2	9.4	10.4

These results demonstrate the safety of NC 21314 to T. pyri. Results from collaborators in the USA have also indicated that it is safe to Typhlodromus occidentalis and Amblyseius fallacis at 200 mg a.i./l and to Amblyseius potentillae at 400 mg a.i./l.

CONCLUSIONS

NC 21314 is a novel, highly active mite ovicide which also has desirable activity against dormant winter eggs of fruit tree red spider mite, and at the same time is completely non-phytotoxic. It also has some contact larvicidal activity but no direct effect against adult mites. In field trials it has given exceptionally long residual control of P. ulmi on apples when applied early in the season, preferably when applied just before the hatch of the winter eggs. Repeated summer sprays are also effective.

NC 21314 is very specific in its biological activity. It appears to have little effect on the predatory mite species and offers no hazard to predatory insects. It should therefore be of particular value in integrated pest management programmes.

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PRELIMINARY TRIALS IN THE U.K. WITH FLUBENZIMINE, A NEW ACARICIDE

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Summary Flubenzimine is a novel acaricide with a mode of action which prevents red spider mites from undergoing normal metamorphosis. In trials conducted on apples between 1979-1980 evaluating flubenzimine (500 mg a.i./l. HV) against the fruit tree red spider mite, *Panonychus ulmi*, single applications gave excellent control of *P. ulmi* when applied during petal fall or early fruitlet towards the end of winter egg hatch. A programme of two sprays of flubenzimine maintained better control of *P. ulmi* than a single spray over the summer period.

Flubenzimine appeared compatible with all apple cultivars tested, usually giving a considerable reduction in fruit russet as a result of controlling *P. ulmi*.

In addition, control of apple scab *Venturia inaequalis* was shown.

Résumé Le flubenzimine est un nouvel acaricide avec un mode d'action qui empêche la métamorphose des araignées rouges de se dérouler normalement. Au cours des essais sur pommiers entre 1979 et 1980, évaluant l'effet du flubenzimine sur l'araignée rouge des arbres fruitiers, *Panonychus ulmi*, une application suffit pour un excellent contrôle de *P. ulmi* quand elle fut effectuée pendant la chute des pétales ou les premiers petits fruits vers la fin de la l'éclosion des oeufs d'hiver. Durant l'été, un meilleur contrôle de *P. ulmi* fut obtenu par un programme de deux pulvérisations de flubenzimine plutôt que d'une pulvérisation.

Le flubenzimine est apparu compatible avec toutes les variétés de pommes étudiées qui apportaient généralement une considérable réduction de la rugosité des fruits résultant de la lutte contre *P. ulmi*.

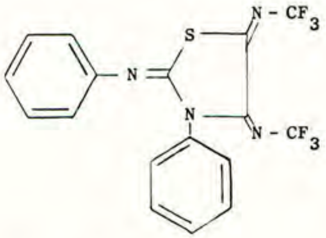
De plus, la lutte contre la tavelure du pommier *Venturia inaequalis* fut montrée.

INTRODUCTION

In 1978 Grohe *et al* reported the synthesis of bis-trifluoromethyl - imino - heterocyclic compounds with acaricidal and fungicidal properties. A diaryl thiazolodine, chemical name N^2, 3-diphenyl-N^4, N^5-bis (trifluoromethyl) thiazolodine - 2, 4, 5-trylidinetriamine, common name flubenzimine, was chosen as the best acaricide of the range for further development.

Chemical and physical structure of the active ingredient (Zoebelein et al, 1980)

Structural formula:



Molecular formula and weight: $C_{17}H_{10}F_6N_4S$, 416

Physical appearance: Yellow powder (technical active ingredient)

Melting point: 118.5°C (technical active ingredient)

Vapour pressure: 10^{-5} mm Hg at 20°C

Solubility: 30 mg/l. in water at 20°C

Formulations: For experimental purposes, a 50% w.p. was available

Toxicology: LD_{50} rats (oral) male and female, 3750 mg/kg body weight
LD_{50} quail (oral) female, ca 4500-5000 mg/kg body weight
LD_{50} rabbit (oral) female, ca 364 mg/kg body weight
LD_{50} rat (dermal) male and female, 500 mg/kg body weight

Bee toxicity: In laboratory and field studies, a 50% w.p. formulation was not toxic to bees at practical doses.

Beneficial insects: In field studies, flubenzimine 0.075% a.i. w/v solution was found to have no effect on Anthocorid adults or larvae and only a slight effect on Coccinellid larvae, none on adults (Tostmann, personal communication 1981).

Biological Properties

Flubenzimine is a highly effective acaricide when used on top fruit against fruit tree red spider mite, Panonychus ulmi, and against P. ulmi and Tetranychus urticae on grape vines.

In laboratory trials on T. urticae, Zoebelein et al (1980), showed that flubenzimine acted as a development inhibitor, interfering with the metamorphosis of spider mites and has a similar mode of action to the chitin synthesis inhibitors.

The most pronounced effect occurs when flubenzimine is used against the larval and nymphal stages. When treated, some of these stages may well pass into the next resting stage but further development is inhibited. Even if the next motile stage manages to emerge it often has the old exuvia clinging to it, and if it is an adult female, the remains interfere with egg-laying (Kasperlik, personal communication

1979). The effectiveness against adults is weak and there is only an ovicidal effect if eggs are treated on the same day as they are laid. In view of this, the best time to apply flubenzimine is when the mite population is mainly in the larval and nymphal stages. On apples in the U.K., this corresponds to an application in the spring when the majority of winter eggs have hatched but before adults have developed, usually at about petal fall in apples.

In addition to its acaricidal properties, flubenzimine has a fungicidal effect against apple scab (Venturia inaequalis).

This paper summarises field trials carried out on apples in the U.K. with flubenzimine during 1979 and 1980.

METHODS AND MATERIALS

All work described was carried out using a 50% w.p. formulation of flubenzimine. Results are given from four replicated, small plot trials, carried out in the south and east of England evaluating flubenzimine against P. ulmi on apples. There were 3-5 trees/plot (depending on the tree size) with four replicates of each treatment in a randomised block design. Treatments were applied with hand lances as HV sprays until 'run-off' using 1000-2000 l/ha. Flubenzimine was applied at a rate of 500 mg a.i./l. and compared to a standard HV treatment of 188 mg cyhexatin a.i./l.

P. ulmi populations were assessed by the 'imprint' method where 30 leaves, sampled initially from the rosettes and later from the extension shoots, were pressed in a mangle between sheets of Devon Valley parchment paper. Using this method it is only possible to differentiate clearly between the imprints made by the pre-adult stages, eggs, nymphs and larvae and the adults. In one trial (II), counts were carried out by examining a strip, 40 x 20 mm, along the midrib on the underside of 10 leaves/plot with a low power binocular microscope.

To test crop compatibility, a non-replicated trial (V) was carried out in 1980 at Elm Farm Trials Station, in which programmes of three sprays of flubenzimine at 500 mg or 1 g a.i./l. HV were applied to fifteen dessert and five culinary apple cultivars. Additionally, assessments of apple scab were made by sampling 50 leaves and 100 fruits per plot and recording presence or absence of disease. In this trial, a standard ten spray programme of 1 g captan a.i./l. HV was available for comparison.

On harvested fruit the parameters measured included yield, mean fruit weight, fruit size, fruit colour and degree of cheek russeting, calculated using the Townsend & Heuberger (1943) formula.

RESULTS

Results of P. ulmi control and fruit russet are presented in Tables 1-4. Assessments were made of fruit yield, weight, size and colour, however, results were not significant, probably because of the smallness of the plots. Similarly in the non-replicated safety trial (V) no adverse effects on either the trees or harvested fruit were recorded on the cvs Bramley's Seedling, Chiver's Delight, Cox's Orange Pippin, Crispin, Early Worcester, Egremont Russet, George Cave, Golden Delicious, Grenadier, Howgate Wonder, James Grieve, Kidd's Orange Red, Laxton's Fortune, Laxton's Superb, Lord Derby, Lord Lambourne, Newton Wonder, Spartan, Sunset and Worcester Pearmain. The cvs. Golden Delicious and Crispin were the most susceptible to apple scab in this trial and results of leaf and fruit scab assessments are given in Table 5.

Trial I   Site: Bury St. Edmunds, Suffolk

Treatments were applied to the cv. Grenadier on 6 May 1980 at pink bud (30% winter-egg hatch), 20 May 1980 at early petal fall (90-95% winter-egg hatch) and 9 June 1980 at fruitlet, 15-25 mm.

Table 1

% Reduction Panonychus ulmi in Trial I relative to untreated

Treatments	Application date	12 June adults	12 June pre-adult stages	2 July adults	2 July pre-adult stages	24 July adults	24 July pre-adult stages	Degree of russet
Flubenzimine	6 May	76 b	85 a	87 a	83 ab	45	69 a	1.8 b
	20 May	91 ab	93 a	88 a	92 a	70	88 a	2.6 b
	9 June	33 c	23 b	85 a	57 c	95	87 a	16.5 a
	20 May + 9 June	95 a	93 a	95 a	93 a	100	94 a	6.0 b
Cyhexatin	9 June	82 b	48 b	88 a	75 b	95	86 a	16.6 a
Untreated	-	0 d	0 c	0 b	0 d	0	0 b	25.3 a
(No. mites/30 leaves)		(172)	(3453)	(15)	(457)	(5)	(67)	-

Treatments having the same suffix letter are not significantly different (P = 0.05)

Trial II   Site: Bury St. Edmunds, Suffolk

Treatments were applied to the cv. Grenadier on 1 June 1979 at petal fall (10-14 days after 80% winter-egg hatch) and 18 June 1979 at fruitlet, 25-40 mm.

Table 2

% Reduction Panonychus ulmi in Trial II relative to untreated

Treatments	Application date	4 July adults	4 July pre-adult stages	19 July adults	19 July pre-adult stages	Degree of russet
Flubenzimine	1 June	97 a	97 a	89 a	87 a	6.0 a
	1 June + 28 June	100 a	97 a	100 a	98 a	10.3 a
Cyhexatin	1 June	99 a	100 a	83 a	69 a	6.5 a
Untreated	-	0 b	0 b	0 b	0 b	22.7 b
(No. mites)		(23 per 80 cm^2)	(173 per 80 cm^2)	(13 per 80 cm^2)	(235 per 80 cm^2)	-

Treatments having the same suffix letter are not significantly different (P = 0.05)

Trial III Site: Ixworth, Suffolk

Treatments were applied to the cv. Cox's Orange Pippin on 23 May 1980 at late petal fall (40-90% winter-egg hatch) and 18 June 1980 at fruitlet, 30 mm (50-100% winter-egg hatch).

Table 3

% Reduction Panonychus ulmi in Trial III relative to untreated

Treatments	Application date	18 June		28 July		Degree of russet
		adults	pre-adult stages	adults	pre-adult stages	
Flubenzimine	23 May	78 b	83 b	80 b	85 b	29.0 a
	23 May +	78 b	86 b	-	-	
	18 June	-	-	96 a	98 a	31.0 ab
Cyhexatin	23 May	94 a	94 a	93 ab	94 ab	21.1 a
	23 May +	92 ab	88 ab	-	-	
	18 June	-	-	96 a	98 a	21.5 a
Untreated	-	0 c	0 c	0 c	0 c	42.8 b
(No. mites/30 leaves)		(39)	(580)	(136)	(609)	-

Treatments having the same suffix letter are not significantly different (P = 0.05)

Trial IV Site: Tonbridge, Kent

Treatments were applied to the cv. Bramley's Seedling on 4 June 1980 at early fruitlet (95% winter-egg hatch) and 30 June 1980 at fruitlet, 30 mm.

Table 4

% Reduction Panonychus ulmi in Trial IV relative to untreated

Treatments	Application date	24 June		29 July	
		adults	pre-adult stages	adults	pre-adult stages
Flubenzimine	4 June	84 a	83 a	95 a	100 a
	4 June +	80 a	77 a	-	-
	30 June	-	-	96 a	100 a
Cyhexatin	4 June	95 a	94 a	96 a	100 a
	4 June +	90 a	94 a	-	-
	30 June	-	-	97 a	100 a
Untreated	-	0 b	0 b	0 b	0 b
(No. mites/30 leaves)		(361)	(1096)	(59)	(1045)

Treatments having the same suffix letter are not significantly different (P = 0.05)

Trial V Site: Bury St. Edmunds, Suffolk

500 mg a.i. flubenzimine/l. HV was applied on 22 May, 17 June and 17 July and compared with 1 g a.i. captan/l. applied on 6 and 22 May, 3 and 17 June, 3, 17 and 29 July and 14 August 1980, to the cvs Golden Delicious and Crispin.

Table 5

Apple scab assessment

Treatments	Leaf scab assessment - 12 August		Fruit scab assessment	
	Crispin % infected leaves	Golden Delicious % infected leaves	Crispin % infected fruit	Golden Delicious % infected fruit
Flubenzimine (3 sprays)	0	0	0	0
Captan (8 sprays)	0	0	0	0
Untreated	64	66	37	47

DISCUSSION

In all trials in the U.K., flubenzimine has been a very effective acaricide. Single sprays were applied over a range of timings, the most successful being when treatments were applied during petal fall or very early fruitlet towards the end of winter-egg hatch.

Although flubenzimine has a completely different mode of action to cyhexatin, which is a contact poison (Worthing, 1979), the only time any real difference could be found was in Trial I where an assessment three days after the final application (9 June) showed cyhexatin quicker acting against P. ulmi than flubenzimine. In later assessments no differences could be found.

A programme of two sprays of flubenzimine maintained better control of P. ulmi than a single spray over the summer period.

As a result of P. ulmi control, fruit russet was reduced by flubenzimine when it was applied before the fruitlets had formed. In Trial I flubenzimine was applied late at fruitlet (9 June) and fruit russet was not significantly reduced, suggesting that the pest was able to damage the fruit finish at a very early stage. Flubenzimine applied at pink bud or early petal-fall in this trial significantly reduced fruit russet.

Although not significant, there was a suggestion of a slight increase in russet where two sprays of flubenzimine had been applied.

There was a clear indication of a useful fungicidal activity against apple scab with flubenzimine in Trial V, although weather conditions in 1980 were not conducive to the development of this disease. If this scab control can be confirmed in further trials it may be possible to omit specific scab fungicides when applying flubenzimine.

Resistance to some groups of acaricides, particularly most organophosphorus compounds, has been reported (Helle, 1965) and flubenzimine, with its novel mode of action, may provide fruit growers with a highly effective alternative material which is safe to the crop and also has a very beneficial side-effect.

Acknowledgements

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NOTES

PIRIMIPHOS-METHYL FOR RUST MITE CONTROL IN UK ORCHARDS

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Summary Inspection of severely russetted fruit in several apple orchards in the south-east of England during the summer of 1979, led to the conclusion that the cause was the apple rust mite (Aculus schlectendali). Although recognised as a cause of leaf bronzing in orchards in late summer, this mite was not previously known to have caused fruit russetting in the UK. Pirimiphos-methyl (Blex) showed excellent activity against these mites in trials conducted in the summer of 1979. This paper reports trials carried out in 1980 on both apples and pears and confirms that pirimiphos-methyl applied at green cluster in apples and petal fall in pears controls both apple and pear rust mite and notably reduces fruit russet caused by the feeding of these mites.

INTRODUCTION

The apple rust mite (Aculus schlectendali) occurs in most apple growing areas of the world. Although not regarded as a major fruit pest it can be a problem and treatment is sometimes necessary. Leaf and fruit damage have been reported on the apple c.v. Golden Delicious in Italy (Ciampolini et al 1976) and pear mites have been known to cause fruit russet in the United States (Joos et al 1974; Westigard 1975). In England apple rust mite was first recorded on apples by Massee (1928) but remained at insignificant levels for over 20 years (Massee 1954). However, since the early 1970's leaf bronzing due to the summer feeding of these mites has been recognised, usually where non-acaricidal fungicides have been used but associated fruit russet has never been reported.

In July 1979 the attention of ICI Plant Protection was drawn to several severe cases of apple russetting in Kent and Sussex, especially on the c.v. Bramley. Chemical damage was very unlikely since russet was not associated with any particular chemicals or chemical spray programmes. However, a strong association did emerge between badly russetted fruit and the distortion and puckering of neighbouring rosette leaves. Undamaged fruit on the same trees had healthy leaves. In one case a severe, early attack by rust mite damaged the rosette leaves of a Bramley orchard and subsequently some severely russetted fruit was produced (Anon. 1979). Inspection of the rosette leaves on these trees revealed the same characteristic puckering and corky russetting at the base of the main veins on the lower surface found at other damaged orchards.

These observations suggested that the apple rust mite was possibly responsible for the damaged fruit but the absence of the pest on both fruit and leaves in July did not immediately support this view. No mites had ever been found on fruit and high summer leaf populations were only occasionaly to be found in orchards where russet occurred. However, the absence of mites was often associated with the use of one or more sprays of cyhexatin after petal-fall.

Exploratory trials with Low Volume (LV) treatments were carried out against summer populations of apple rust mite in 1979 with the Plant Protection range of top fruit chemicals. Pirimiphos-methyl (Blex) was included both on account of its activity against grain store mites, and its existing Clearance for use on apples and pears under the Pesticide Safety Precaution Scheme. These trials showed that permethrin and cyhexatin were partially effective, but pirimiphos-methyl gave by far the best control of apple rust mite. Further trials in the autumn with commercial orchard sprayers demonstrated that pirimiphos-methyl significantly reduced mites sheltering in preferred sites underneath leaf buds along the current year's shoot growth.

In 1980 trials were carried out from early green cluster to confirm the usefulness of pirimiphos-methyl in controlling apple rust mite and preventing rosette leaf distortion and subsequent fruit russet.

METHODS AND MATERIALS

In the spring of 1980, replicated and non-replicated trials were carried out in Kent on apples and pears using pirimiphos-methyl (as Blex 50% e.c.) always at the rate recommended for aphid, caterpillars and apple sucker control, i.e. 0.9 kg a.i./ha. Other materials tested included cypermethrin (as Ambush C 10% e.c.) at 0.026 kg a.i./ha, chlorpyrifos (as Dursban 48% e.c.) at 0.47 kg a.i./ha, mancozeb (as Karamate N 80% d.p.) at 4.48 kg a.i./ha, and carbaryl (as Carbaryl 85% d.p.) at 1.7 kg a.i./ha.

Replicated trials had 4 or 5 randomised trees per treatment and were sprayed with a motorised knapsack sprayer at 560 l/ha. Unreplicated grower trials were sprayed with commercial orchard mistblowers at volumes ranging from 560 -1120 l/ha. On the apple c.v. Bramley 10 rosette leaves per tree were assessed in the replicated trials and 25-30 rosette leaves or fruitlets selected at random from each treatment block in the grower trials. The following scores for grades of infestation were used for all assessments of live or dead mites per rosette leaf, fruitlet or axillary bud: -

0 = No mites
1 = 1 - 5 mites
2 = 6 - 20 mites
3 = 21 - 50 mites
4 = 50 or more mites

Percentage russet of mature apples was assessed by examining a minimum of 100 fruits per treatment.

With pears, 20 leaves per treatment were assessed and live mites scored on a 0-5 scale (5 = 300 mites per leaf) bronzing of leaves and eye russet of fruit were assessed on 20 leaves per treatment using a 0-5 scale (5 = severe bronzing or russet).

Other trial details are given in Table 1. The data were considered parametric and statistically analysed accordingly.

Table 1

Trial Details

Trial Number	Site	Cultivar	Dates(s) Sprayed	Growth Stage of Cultivar	Replicated
I	Yalding	Bramley	15 April	Green cluster	Yes
II	Marden	Bramley	14 April	Early green cluster	Yes
III	Linton	Bramley	18 April	Green cluster	No
			20 May (part orchard only)	Petal fall	
IV	Paddock Wood	Bramley	23 April	Green cluster	No
V	Canter-bury	Bramley	24 April	Green cluster	No
VI	Rainham	Doyenne du Commice	1 May	Petal fall	No
		Conference		Petal fall	
		Beurre Hardy		Petal fall	

RESULTS

Trial I on the c.v. Bramley confirmed the excellence of pirimiphos-methyl against A. schlectendali compared with a range of orchard chemicals (Table 2).

Table 2

Assessment of A. schlectendali on rosette leaves 6 days after spraying the c.v. Bramley with various chemicals at green cluster

Treatment	kg ai/ha	Score per leaf Live	Dead
pirimiphos-methyl	0.90	0.0	1.7
cypermethrin	0.026	1.3	0.6
chlorpyrifos	0.47	1.1	0.9
mancozeb	4.48	1.6	0.3
carbaryl	1.70	1.1	1.0
Untreated	-	1.8	0.0

	Live	Dead
Standard error (single plot)	0.4	0.2
LSD P = 0.05	0.5	0.3
LSD P = 0.01	0.7	0.4

In another replicated trial (II) on the c.v. Bramley, application of pirimiphos-methyl at green cluster also gave good control of overwintered mites which had emerged or were still partially hidden by leaf buds (Table 3).

Table 3

Assessment of A. schlectendali on rosette leaves and axillary buds 2 days after spraying the c.v. Bramley with pirimiphos-methyl at green cluster

Treatment	Score per leaf		Score per axillary bud	
	Live	Dead	Live	Dead
pirimiphos-methyl	0.2	2.1	0.2	0.8
Untreated	2.5	0.3	1.5	0.0

	Live	Dead
Standard error (single plot)	0.5	0.3
LSD P = 0.05	0.8	0.5
LSD P = 0.01	1.1	0.7

Mite and fruit russet data from three grower trials with the c.v. Bramley further confirmed that 0.9 kg a.i./ha of pirimiphos-methyl applied at green cluster notably reduced the number of live mites, and in all three experiments reduced the number of damaged fruits (Table 4). In trial III young mites were found feeding on fruitlets as well as on adjacent rosette leaves 31 days after spraying. Untreated fruitlets at this stage scored 3.8 when assessed for mite compared with 1.3 for those on trees sprayed with pirimiphos methyl. As the rosette leaves were already corky and badly damaged, the young mites may have found feeding difficult and may be forced to move on to adjacent blossoms and young fruitlets. Immediately following this assessment a second spray of pirimiphos-methyl was applied to part of this orchard. This controlled the developing mite population and entirely eliminated the incidence of fruit russet at harvest (Table 4).

Table 4

Assessment of A. schlectendali on rosette leaves and percentage fruit russet of the apple c.v. Bramley after spraying pirimiphos-methyl (P-m) at green cluster in three grower trials

Trial	Days after Spraying	Score per leaf (0-4)				% Fruit Russet	
		Live mites		Dead mites			
		Untreated	P-m	Untreated	P-m	Untreated	P-m
III	13	1.5	0	0.7	2.2	-	-
	31	3.6	0.4	-	-	-	-
	135	-	-	-	-	58	7*
IV	13	2.6	0	0.4	1.5	-	-
	131	-	-	-	-	16	0
V	131	-#	-	-	-	8	0

* Trees which received a second spray 32 days after the first application had no russetted fruit.

\# Mite present at time of spraying.

One unreplicated experiment with three cultivars of pears showed that the pear rust mite Epitrimerus piri was also controlled with pimiriphos-methyl at petal-fall, and that leaf bronzing and fruit eye russet were both reduced by this treatment (Table 5).

Table 5

Leaf bronzing, live E. piri and fruit eye russet on various pear cultivars 15 weeks after spraying pirimiphos-methyl at petal-fall

Treatment	Cultivar		
	Doyenne du Commice	Conference	Beurre Hardy
		Leaf bronzing/tree	
pirimiphos-methyl	0	0	0
Untreated	4.5	1.5	3.2
		Live mites/leaf	
pirimiphos-methyl	0	0	0
Untreated	3.8	4.0	4.1
		Eye russet/fruit	
pirimiphos-methyl	0.3	-	-
Untreated	3.0	-	-

Severe bronzing = 5, over 300 mites/leaf = 5 and severe russet = 5

DISCUSSION

The reduction of fruit russet accompanying the control of rust mites at green cluster with pirimphos-methyl and the observation of mites feeding on both fruitlets and adjacent leaves indicates that A. schlectendali does cause later fruit russet in apples. Similarly E.piri can also be responsible for russet damage in pears.

Pirimiphos-methyl applied at green cluster and petal-fall consistently gave an excellent kill of apple and pear rust mites and improved fruit quality. This was supported by experience on a large number of farms throughout fruit growing areas of England in 1980 and 1981.

Recent research on the apple rust mite has shown the mite to be more active, and to complete its life cycle more rapidly at higher temperatures (Easterbrook 1979). The long warm autumns of 1978 and 1979 and relatively high temperatures during the blossom period in 1979 and 1980 may therefore have contributed to the mite upsurge. In addition the development of resistance by rust mite to the two acaricidal fungicides, dinocap and binapacryl, cannot be discounted as a contributing factor. The theory that the pyrethroids kill the predatory mites (Typhlodromids) and are responsible for increased rust mite populations seems unlikely as these predatory mites were already uncommon in commercial orchards where DDT and organophosphorous compounds had been used.

Some references in the literature suggest that the apple rust mite has value as an alternative food source for predators when spider mites become scarce (Hoyt 1969; Herbert and Sanford 1969). This value must be weighed against reports of mite damage to shoots, leaves and fruit (Herbert 1974; Westigard 1975; Joos et al 1974; Ciampolini et al 1976) and the russetting caused in the UK in 1979. Undoubtedly even more damage would have occurred in the UK in 1980 if a suitable chemical had not been available, and the rust mite should perhaps be viewed with greater concern in the apple growing areas of the world.

Pirimiphos-methyl is now Ministry Approved in the UK for rust mite control on apples and pears and for aphid and caterpillar control on apples. The recommended timing of application on apples for rust mites, green cluster or earlier where severe infestations are present, conveniently coincides with the timing for the other pre-blossom pests.

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CONTROL OF FRUIT TREE RED SPIDER MITE WITH THE SYNTHETIC PYTHRETHROID FENPROPATHRIN

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Summary Fenpropathrin, the common chemical name for cyano-3-phenoxy benzyl 2, 2, 2,3-tetramethyl cyclopropane carboxylate, formerly known under the code number S3206, is a highly active, broad spectrum pyrethroid insecticide. When used at rates of 40 - 150 mg a.i./l fenpropathrin was shown to have outstanding activity against certain spp. of phytophagous mites and in particular the fruit tree red spider mite (Panonychus ulmi). Results are presented from trials conducted on apples in the U.K. over the past three years.

Résumé La fenpropathrine, nom commun chimique du carboxylate de cyano-3-phénoxybenzyl-2,2,2,3-tétraméthyl cyclopropane, et anciennement identifiée par le code S3206, désigne un insecticide pyréthrinoide à haute activité et à large spectre. En utilisation à des pourcentages de 0,0040 - 0.015% de matière active, la fenpropathrine s'est avérée extrêmement active contre certaines espèces d'acariens phytophages, en particulier l'araignée rouge des arbres fruitiers *(Panonychus ulmi)*. On presénte les résultats d'essais effectués au Royaume-Uni sur des pommes au cours des trois dernières années.

INTRODUCTION

Among the wide range of recently introduced synthetic pyrethroids few have exhibited any degree of acaricidal activity. One exception is fenpropathrin, the common chemical name for cyano-3-phenoxybenzyl 2,2,2,3-tetramethyl cyclopropane carboxylate. Discovered by Sumitomo Chemical Company of Osaka, Japan, fenpropathrin has been evaluated over the last four years for the control of a wide range of agricultural and horticultural pests including such mite species as Tetranychus urticae, Eotetranychus carpini and Tetranychus kanzawai but more particularly in the U.K. against Panonychus ulmi on apples. Since 1979 fifteen trials have been conducted on apples in the U.K. and the results of five trials are presented here.

METHODS AND MATERIALS

A series of high volume replicated trials were conducted in Essex and Suffolk in 1979, 1980 and 1981. The trials were laid down to a randomised block design with a minimum of four replications. A plot size of one tree was used in all trials. Fenpropathrin, formulated as an e.c. to contain 100 g a.i./l in xylene was compared at concentrations of 40, 50, 60, 100 and 150mg a.i./l with cyhexatin (w.p.; 250 g a.i./kg) at 188 g a.i./l. All treatments were compared with an untreated check. The treatments were applied at 25% winter-egg hatch, with the exception of Trial II where treatments were applied mid-season. Applications were made with a hand-lance operating at 6.89 bars. Assessments of the numbers of P. ulmi were conducted at

7-day intervals on 10 leaves/plot and continued for a minimum of 8 wks. The data were transformed to logarithms for analysis and geometric (de-transformed) means are given in Tables 1 - 5.

At one site, Trial II, the grower, as standard commercial practice, treated the whole orchard, including the trial plots, with the acaricidally-active fungicide, triforine (e.c.; 200 g/litre) at the recommended rate, applying 0.56 kg a.i./ha.

RESULTS

The results from trials conducted on apples in the U.K. are given in Tables 1 - 5.

TABLE 1

Trial I Numbers of motile mites/10 leaves as a percentage of the numbers on untreated leaves of Worcester Permain - at Trial I in 1979

Acaricide	Conc$^{n.}$ (mg a.i./l)	Days after treatment on 8/6/79				
		7	13	21	27	34
Fenpropathrin	50	6.8 a	3.6 ab	3.3 a	12.9 b	74.9 bc
	100	7.7 a	1.1 a	2.1 a	3.4 a	10.1 a
	150	7.0 a	2.1 ab	2.6 a	3.9 a	39.1 abc
Cyhexatin	188	39.2 b	4.7 b	2.8 a	4.3 a	20.5 ab
Untreated		(38.3)c	(103.4)c	(153.8)b	(157.8)c	(83.5)c
Least significant ratio between two means ($\underline{P} \leq 0.05$)		3.1	3.7	3.3	2.4	5.0
Greatest value significantly less than untreated ($\underline{P} \leq 0.05$)		39.6	34.1	37.1	48.1	26.7

Acaricide	Conc$^{n.}$ (mg a.i./l)	Days after re-spraying on 13/7/79						
		6	13	20	27	34	41	47
Fenpropathrin	50	0.0	11.8 a	5.5 b	7.9 c	12.1 b	37.4 c	47.9 b
	100	0.0	2.9 a	1.6 a	3.4 ab	5.1 ab	9.8 ab	10.3 a
	150	0.0	6.1 a	1.8 a	1.8 a	2.4 a	5.8 a	6.4 a
Cyhexatin	188	0.6	10.2 a	3.4 ab	4.1 bc	11.5 b	22.0 bc	15.3 a
Untreated		33.0	(39.6)b	(88.2)c	(111.1)d	(84.6)c	(43.0)d	(52.4)b
Least significant ratio between two means ($\underline{P} \leq 0.05$)		N/A	6.4	2.3	2.1	2.6	2.6	2.7
Greatest value significantly less than untreated ($\underline{P} \leq 0.05$)			21.6	51.0	54.0	45.6	45.0	44.0

( ) Geometric no. mites on untreated leaves 7 days after spraying = 84.8/10 leaves.
N/A Not analysed; values given are arithmetic means, expressed as a % of control.
Treatments with the same letter were not significantly different (P = 0.05).

TABLE 2

Trial II Numbers of motile mites/10 leaves as a percentage of the numbers on untreated leaves of Worcester Permain - at Trial II in 1979

Acaricide	Conc^n. (mg a.i./l)	Days after treatment on 6/7/79							
		6	13	20	27	34	41	48	54
Fenpropathrin	25	0.6	26.1ab	27.8ab	215.3c*	7.9a	21.0a	26.3a	168.6b
	50	0.0	3.5a	5.6a	24.6a	21.9ab	40.6ab	50.6a	69.7ab
Cyhexatin	188	0.3	17.2ab	5.3a	25.1a	17.7a	21.6a	29.3a	38.3a
Untreated		86.5 +	(34.1)b	(26.5)b	(23.7)b	(34.3)b	(21.3)b	(21.7)a	(16.2)b
Least significant ratio between two means ($P \leq 0.05$)		N/A	10.0	5.3	4.5	7.5	5.0	6.1	3.3
Greatest value significantly less than control			15.5	26.0	29.8	19.4	26.9	23.1	38.3

( ) Geometric no. mites on untreated leaves 7 days after spraying = 84.8/10 leaves.
N/A Not analysed; values given are arithmetic means, expressed as a % of control.
Treatments with the same letter were not significantly different (P = = 0.05).
+ Control treated with DICOFOL @ 400 mg a.i./l   * resprayed @ 25 mg a.i./l

TABLE 3

Trial III Numbers of motile mites/10 leaves as a percentage of the numbers on untreated leaves of Worcester Permain - at Trial III in 1979

Acaricide	Conc^n. (mg a.i./l)	Days after treatment on 7/6/79							
		7	14	20	28	35	42	49	56
Fenpropathrin	50	10.6 a	0.5	0.0	0.0	0.1	0.2	0.0	0.0
	100	10.0 a	0.5	0.0	0.0	0.6	0.7	0.0	0.0
	150	14.6 ab	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Cyhexatin	188	31.3 b	0.0	3.2	1.2	0.3	0.5	0.0	0.0
Untreated		*(100.0)c	42.0	31.6	180.6	179.0	183.8	94.0	47.6
Least significant ratio between 2 means ($P \leq 0.05$)		2.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Greatest value significantly less than untreated	48.0								

* Geometric no. mites on untreated leaves 7 days after spraying = 84.8/10 leaves.
N/A Not analysed; values given are arithmetic means, expressed as a % of control.
Treatments with the same letter were not significantly different (P = 0.05).

TABLE 4

Trial IV Numbers of motile mites/10 leaves as a percentage of the numbers on untreated leaves of Cox O.P. - at Trial IV in 1980

Acaricide	Conc^n. (mg a.i./l)	Days after treatment on 28/5/80 5	12	19	26	33	40
Fenpropathrin	40	42.4a	18.9ab	45.0ab	27.9a	35.5ab	27.6a
	50	49.9a	9.7a	25.1a	15.9a	26.1a	25.2a
	60	50.6a	31.8b	15.8a	16.9a	14.7a	20.4a
Cyhexatin	188	61.4a	20.0ab	18.6a	24.6a	25.7a	25.9a
Untreated		(33.2)a	(101.5)c	(36.3)b	(42.0)b	(40.2)b	(62.3)b
Least significant ratio between two means ($P \leq 0.05$)		3.3	2.4	3.9	3.7	4.4	2.7
Greatest value significantly less than control		37.5	49.0	33.0	34.6	29.9	43.9

( ) Geometric no. mites on untreated leaves 7 days after spraying = 84.8/10 leaves.
Treatments with the same letter were not significantly different (P = 0.05).

Acaricide	Conc^n. (mg a.i./l)	Days after re-spraying on 12/7/80 2	9	16	23	30	37	44
Fenpropathrin	40	4.7a	4.8a	3.2a	3.3a	4.2a	8.1a	6.0a
	50	8.3ab	6.4a	4.5a	4.4a	6.0a	10.8a	9.4a
	60	6.1a	5.8a	4.5a	3.6a	6.6a	7.9a	6.5a
Cyhexatin	188	17.8b	14.6a	8.1a	4.3a	5.9a	8.3a	9.2a
Untreated		(39.9)c	(24.6)b	(76.9)b	(141.3)b	(108.6)b	(87.3)b	(210.7)b
Least significant ratio between two means ($P \leq 0.05$)		2.8	3.2	3.4	2.6	6.7	3.1	3.4
Greatest value significantly less than control		43.5	38.4	37.0	45.2	21.1	39.6	36.8

( ) Geometric no. mites on untreated leaves 7 days after spraying = 84.8/10 leaves.
Treatments with the same letter were not significantly different (P = 0.05).

TABLE 5

Trial V Numbers of motile mites/10 leaves as a percentage of the numbers on untreated leaves of Worcester Permain - at Trial V in 1980

Acaricide	Conc$^{\underline{n}}$. (mg a.i./l)	Days after treatment on 28/5/80				
		5	12	19	26	33
Fenpropathrin	40	22.9 a	22.3 a	167.0 a	102.9 bc	81.8 bc
	50	20.2 a	19.9 a	32.8 a	36.9 ab	23.9 a
	60	16.2 a	9.9 a	53.8 a	19.3 a	27.8 a
Cyhexatin	188	31.5 a	30.2 ab	78.8 a	47.0 abc	39.5 ab
Untreated		(10.8)b	(23.2)b	(20.9)a	(30.6)c	(58.7)c
Least significant ratio between two means ($\underline{P} \leq 0.05$)		2.3	4.9	5.1	2.8	2.8
Greatest value significantly less than control		50.2	27.2	26.0	43.3	43.2

()Geometric no. mites on untreated leaves 7 days after spraying = 84.8/10 leaves
Treatments with the same letter were not significantly different (P = 0.05)

Acaricide	Conc$^{\underline{n}}$. (mg a.i./l)	Days after re-spraying on 3/7/80							
		4	11	18	25	32	39	46	53
Fenpropathrin	40	17.2a	11.4b	18.8b	15.7a	36.6b	16.3a	30.9b	30.6ab
	50	6.6a	5.0ab	6.5a	8.5a	10.6a	12.4a	29.3b	38.8ac
	60	6.4a	2.5a	6.5a	4.9a	6.4a	12.2a	9.5a	14.0ab
Cyhexatin	188	7.4a	8.0b	20.1b	7.6a	5.5a	11.9a	14.3ab	22.6ab
Untreated		(84.1)b	(62.2)c	(20.3)c	(88.6)b	(56.1)c	(51.0)b	(57.8)c	(99.8)c
Least significant ratio between two means($\underline{P} \leq 0.05$)		2.8	2.9	2.1	5.3	3.1	3.1	3.0	3.3
Greatest value significantly less than control		42.5	41.4	55.0	25.1	39.9	39.3	40.4	37.6

( ) Geometric no. mites on untreated leaves 7 days after spraying = 84.8/10 leaves.
Treatments with the same letter were not significantly different (P = 0.05)

1979 Trials

Numbers of motile mites/10 leaves as a percentage of the numbers on untreated leaves of Worcester Permain

Trial I; Rapid knock down was achieved by all rates of fenpropathrin and visual differences in the plots in the form of "bronzing" and leaf drop were apparent twenty one days after the commencement of the trial. Thirty days after treatment it was necessary to respray all plots including the untreated controls in order to contain migrating mites.

Trial II; Although fenpropatrhin continued to demonstrate its "knock-down" capacity, the rate of 25 g a.i./ha lacked persistence and it become necessary to respray after 27 days, (Table 2). Severe "bronzing" and leaf drop on the untreated trees necessitated treatment with dicofol at 400 mg ai/l which was applied after the first assessment.

Trial III; All treatments including the standard cyhexatin gave good control throughout the 8-wk assessment period while the population on untreated trees remained at unacceptably high levels (Table 3).

Application of the fungicide triforine is believed to have been the main factor preventing further development of the mite numbers on this trial site.

1980 Trials

Numbers of motile mites/10 leaves as a percentage of the numbers on untreated leaves of Worcester Permain

Trial IV; Protracted winter-egg hatch following the first application on this site continued to supplement the motile mite population, masking the knock-down effect of the compound. A second application 45 days later did, however, demonstrate the excellent knock-down effect of fenpropathrin.

Trial V; Winter-egg hatch continued slowly for a further 4 wks following the first application, accounting for the relatively low numbers of motile mites recorded during the period of the first four assessments. A second application was necessary 5 wks from commencement of the trial.

DISCUSSION

Fenpropatrhin has been evaluated at concentrations of 25 - 50 mg a.i./l in the trials reported. From the data presented the optimum concentration lies in the region of 50 mg a.i./l. Concentrations in excess of 60 mg did not show any marked increase in either speed of knock-down or persistence. Where the concentration was 50 mg a.i., no loss in knock-down activity was evident but persistence was reduced, except where a fungicide with acaricidal activity was included in the post-blossom fungicide programme, such activity being largely confined to protonymphs and short-lived. When applications were infrequent, mite populations were held in check rather than eliminated, as shown in Trial III.

Pyrethroid insecticides are well known for their rapid knock-down activity against many pest species. Fenpropathrin exhibited superior knock-down activity against P. ulmi at all rates tested compared with the standard cyhexatin. The first assessment after application on Trials I and III showed the level of control achieved with fenpropathrin at 50 mg a.i./l was significantly better than that achieved with cyhexatin. The excellent knock-down activity was also apparent in Trials I and II in 1979 and IV in 1980, though to a lesser degree on Trial V following the second application.

The persistence of fenpropatrhin showed little response to concentrations above 40 mg a.i./l. From the data reported the level of persistence varied from 27 to 45 days following the first application and from 44 to 54 days following the second application. The levels of control achieved were marginally superior with concentrations of 50 mg a.i./l and above. In Trial II 25 mg a.i./l gave 20 days control following both the first and second applications. The levels of control achieved with these two low concentrations were marginally inferior to one application at 50 mg a.i./l.

The degree of persistence achieved by fenpropathrin at 50 mg a.i./l and above was comparable to the standard cyhexatin.

The populations on Trials I, II and V were known to be resistant to all commercially available acaricides with the exception of cyhexatin and dicofol. The latter had never been used on these sites prior to its use on the check plots on Trial II. Data from this trial suggested that the population was partially resistant to this material but resistance or tolerance to fenpropathrin was not observed in any of the trials to date.

Although ovicidal activity has not been observed in the U.K., the twin properties of rapidity of action and persistence allied with its known activity in controlling both codling moth (Cydia pomonella) and "summer tortrix" (reported elsewhere) provides the grower with a very flexible tool.

Overall, therefore the trials evidence to date indicates that the optimum concentration and time of application of fenpropathrin for the control of P. ulmi is 50 mg a.i./l applied high volume at 100% winter egg hatch. In the U.K. this would usually coincide with the timing of the first application for the control of post blossom lepidopteran pests.

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NOTES

SESSION 4A

UNUSUAL MITE PROBLEMS

Proceedings 1981 British Crop Protection Conference - Pests and Diseases

OBSERVATIONS ON BROAD MITE (POLYPHAGOTARSONEMUS LATUS) (ACARINA: TARSONEMIDAE) ATTACKING CUCUMBER

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Summary The first record of broad mite (Polyphagotarsonemus latus) damage to cucumber in the United Kingdom is reported. Affected plants showed distorted shoots and brittle down-curled leaves while fruit was russeted. Two high volume sprays of dicofol or dicofol and tetradifon, applied at five day intervals, were effective against the mites but damage symptoms persisted for several weeks after treatment. Biological control programmes were also adversely affected.

INTRODUCTION

Broad mite (Polyphagotarsonemus latus) is widely distributed throughout the tropics where it is also known as the yellow tea mite, yellow jute mite or tropical mite. It is reported as causing injury to many crops, in particular cotton, potato, jute, tea and pepper (Hambleton, 1938; Kabir, 1979). In temperate regions it is a pest of glasshouse ornamental and vegetable crops (Fox Wilson, 1950).

Feeding injury is expressed on many hosts as sudden down-curling and crinkling of leaves with distortion of the growing points. Severely attacked plants are stunted and often die (Smith, 1939). The appearance of affected foliage often resembles that caused by hormone weedkillers (Gellatley, 1969).

During late June and July 1980, several cucumber crops in the Lee Valley, Hertfordshire, suffered severe damage to leaves, shoots and fruit by large infestations of broad mite. This is the first record of such damage in the United Kingdom.

MATERIAL AND METHODS

During June and July 1980, observations on symptoms caused by broad mite attacking cucumber were made on infested crops in the Lee Valley. Following diagnosis of the disorder, growers applied high volume sprays of dicofol, dicofol + tetradifon or cyhexatin at rates of 92.5, 400 + 125 and 125 g a.i./1 000 litres respectively. A fog of dicofol was also applied by one grower. Subsequent recovery of treated plants was monitored for several weeks. Samples of infested leaves were taken before and after treatment for laboratory investigation. They were examined under a low power binocular microscope using a fibre optic, cold light source. Populations of mites were estimated as the number of individuals/cm^2 of leaf surface.

In addition, small pieces of leaf infested with approximately 200 female mites were introduced to young cucumber plants (with five expanded leaves) growing in pots and maintained in a glasshouse at 20 - 23°C for five weeks. Tomato and sweet pepper plants were similarly treated. Infested leaves were also collected from *Cyclamen* and *Gloxinia*, and introduced to young cucumber plants.

Aspects of the life cycle of broad mite were studied on 1.5 cm diam. leaf discs taken from uninfested cucumber and kept on moist filter paper in Petri-dishes at 20°C. For each observation, a single male carrying an immature individual was introduced to each leaf disc. The position of each egg laid was noted and subsequent development monitored.

RESULTS

Glasshouse Observations

Plants attacked by broad mite showed open, distorted shoots which ultimately appeared burned and shrivelled. Expanded leaves were dark green, brittle and down-curled while fruits were russeted and cracked. Growers first attributed the symptoms to hormone weedkiller drift or spray contamination. However, subsequent investigations revealed very high numbers of mites on young leaves. Aubergines growing around the perimeter of infested glasshouses were also damaged.

Following application of high volume sprays of dicofol or dicofol + tetradifon by the growers, the plants produced side shoots which showed further damage symptoms although no mites were seen on this new growth. Many small leaves were produced with normal leaf colour, although several veins were fused and distorted causing localised down-curling of the leaf margins. Many fruits produced after treatment were mis-shapen and showed fusion of veins in the skin although russeting was not seen. These secondary symptoms persisted for several weeks after treatment with dicofol or mixtures but were not seen on plants treated with cyhexatin. No attacks of broad mite on cucumber were seen in the Lee Valley during 1981, although damage was reported from crops in Kent and Berkshire.

Young cucumber plants inoculated with approximately 200 mites showed typical leaf hardening and down-curling after seven days. Growing points and side shoots were completely destroyed after a further seven days. Infested plants remained stunted and all fruitlets aborted. However, tomato and pepper plants treated in the same way showed no unusual leaf symptoms. Inoculation of young cucumber plants with mites from *Cyclamen* and *Gloxinia* failed to induce damage symptoms.

Laboratory Investigations

Populations of mites often exceeded 200 individuals/cm^2 of leaf with young leaves measuring 2 - 3 cm being most heavily infested. High volume sprays of dicofol or dicofol + tetradifon substantially reduced mite numbers, whereas applications of cyhexatin as a spray or dicofol as a fog were ineffective (Table 1).

Table 1

Effect of acaricides on broad mite attacking cucumber

Mean number of mites per cm^2 leaf

	Eggs	larvae	pupae	males	females	no of observations
Pretreatment	209.3	63.3	21.1	12.5	97.0	35
cyhexatin spray	206.0	58.6	5.3	9.3	89.3	10
dicofol fog	206.0	30.0	0	3.0	37.3	10
dicofol spray	1.6	4.4	2.8	0.2	9.6	10
dicofol spray x 2	1.0	0.4	0.2	0	1.2	10
dicofol + tetradifon spray x 2	0	3.3	0	0	3.7	10

Observations on the life history of broad mite on cucumber leaves confirmed the findings of other works on tea and jute (Gadd, 1946; Kabir, 1979), although the duration of various stages differed slightly. The adult female was oval in shape and had a rich amber colour when feeding on cucumber. The body of the adult male was smaller and tapered towards a sucker-like organ at the posterior end. Males were noticeably more active than females.

After emerging, the female mites did not lay eggs for at least 24 h. The eggs were about 80 µm long, oval in shape and translucent with round, white tubercles on the dorsal surface. They were found on all areas of the abaxial leaf surface but were most often sited near veins and in depressions on the leaf. Most eggs hatched within 14 h. The larva had three pairs of legs and a distinct white stripe along the dorsal midrib. Within 24 h, the larva entered the quiescent "pupal" stage (Gadd, 1946). During this period, which lasted a further 24 h, males were often seen to carry "pupae" with the sucker-like organ and a fourth pair of legs. All "pupae" carried in this way subsequently developed into females. At 20°C and under laboratory conditions the life cycle was completed in five days. Although mating was not observed, progeny resulting from females which had been carried as "pupae" were of both sexes, whereas females reared in isolation produced males only. After 9 - 10 days, the leaf material began to deteriorate and observations on fecundity could not be made using this technique.

DISCUSSION

During 1980, damage by broad mite to cucumber was seen for the first time in this country, but no firm conclusions could be drawn on the source of these infestations. Biological control of red spider mite (Tetranychus urticae) using Phytoseiulus persimilis was practised on all affected crops. The reduction in pesticide usage associated with this technique would clearly favour development of broad mite. However, P. persimilis has been used on heated cucumber crops for several years (Gould, 1980). During this time broad mite has not been reported on cucumber. P. persimilis is usually introduced to crops on leaves of French bean which is a recorded host of broad mite (Gellately, 1969). However, infested crops were treated with P. persimilis from several sources. A single supplier could not therefore be implicated in the introduction of the pest.

Broad mite is usually associated with damp, shady environments (Jeppson et al, 1975). Examination of meteorological data from an infested nursery showed that weather conditions in the Lee Valley during spring and summer 1980 did not differ markedly from those experienced during the past five years. However, during May and June 1980, it was a common practice for growers to leave ventilators closed and reduce heating. The resultant high humidity favoured the development of some plant pathogens such as Didymella bryoniae (Mycosphaerella melonis) and Botrytis cinerea and may also have provided favourable conditions for the development of broad mite.

Symptoms of broad mite damage appeared very rapidly after infection and persisted for several weeks. Infested plants may, therefore, produce unmarketable fruit for several weeks after the detection of mites. Effective chemical control is difficult to achieve since dense hairs cover the young leaves on which most mites are found. The protection these hairs affords is shown by the ineffectiveness of dicofol when applied as a fog while the same material applied as a high volume spray gave better results. Furthermore, the short life-cycle of approximately five days makes repeated treatments necessary. All acaricides recommended for use on cucumber in the United Kingdom and effective against broad mite, will upset biological control programmes. This pest therefore presents a potentially serious problem and warrants further investigation.

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PROBLEMS ASSOCIATED WITH A VIRULENT STRAIN OF RED SPIDER MITE (TETRANYCHUS URTICAE) CAUSING HYPERTOXIC DAMAGE TO GLASSHOUSE TOMATOES

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Summary A virulent strain of red spider mite has caused severe damage to glasshouse tomatoes since it was first observed in 1977. Problems associated with control of this unusual pest are discussed.

Un acarien d'un type virulent a causé dégats sévère vers tomates sous serre depuis 1977 quand it était premierement observé. On discute les problèmes de la lutte contre ces acariens insolites.

INTRODUCTION

A strain of red spider mite (Tetranychus urticae) causing unusual and severe damage to commercially grown tomatoes was first recorded by Foster and Barker (1978). They reported that small numbers of mites had produced severe foliar damage which resembled manganese toxicity and culminated in flacid, dessicated leaves. There was no speckling of the leaves associated with classical red spider mite damage. Foster and Barker conducted bioassay tests to diagnose whether a viral agent was implicated in the severe damage, but failed to detect the presence of any virus.

Subsequent outbreaks of virulent mites have demonstrated that the appearance, damage symptoms and effectiveness of control measures are very variable.

OBSERVATIONS

Damage similar to that described by Foster and Barker was also seen on crops at the Glasshouse Crops Research Institute (GCRI) in 1978. Tomatoes (var. Ionella), grown in border soil, developed interveinal chlorotic patches on the leaves which rapidly extended and became dessicated so that the whole leaf, including the petiole, eventually withered and hung around the stem. The plants were about 2 m high but damage was concentrated in a narrow band about 1.3 m up the plants and did not spread upwards. Damage did not spread laterally along rows, being confined to a few small areas, usually on individual plants.

The small number of mites present were different in appearance from those reported by Foster and Barker since they were not typical ex-diapause mites but were of a distinctive maroon colour. However, they were similar in all other respects to normal glasshouse red spider mites. Because of their colour they were thought to be the carmine mite (Tetranychus cinnabarinus).

HV cyhexatin (0.025% a.i.) proved ineffective against these mites which were still active five days after spraying. However, subsequent use of HV dicofol (0.012% a.i.) gave successful control. HV quinomethionate (0.013% a.i.) was also effective.

The mites were also recorded (Anon., 1978) in S. Wales and S.E. England in 1978. In Wales, HV fenbutatin oxide, and the predator mite Phytoseiulus persimilis failed to control them but HV quinomethionate was, however, effective.

At Wye College in Kent, Wardlow and Jackson (1978) tested the resistance pattern of this mite from sites in the S.E. region and found it to be resistant to the organophosphorus acaricides diazinon, demeton-S-methyl and dimethoate, moderately resistant to the carbamate oxamyl, slightly resistant to quinomethionate, but susceptible to dicofol and cyhexatin.

Reports of virulent red spider mite were very sparse in 1979, though there was an outbreak at a large tomato nursery in Sussex (Van Heyningen Brothers) which was controlled with cyhexatin.

In 1980, there were several more reports of virulent red spider mite (Anon., 1980). In Hereford it was found on plants imported from Holland. The predator was again ineffective but HV dicofol/tetradifon controlled the outbreak. In two places in S.E. England, predator was again ineffective though the outbreaks were successfully controlled with cyhexatin. Similar experience occurred on several nurseries in Guernsey.

Work in Holland (Dupont, 1979) has shown that the glasshouse red spider mite and the carmine mite are probably not separate species and are much more closely related than was previously thought. The carmine mite had long been considered distinct from the red spider mite because of its coloration, because of the inability of the two species to interbreed and produce viable offspring and because the red spider mite diapauses in winter whereas the carmine mite does not. Dupont, however, has shown that some forms of the two types can interbreed and that the offspring are often hybrids between the two parental forms. Dupont was able to produce diapausing carmine mites and concluded that there is no true specific difference between the carmine mite and the glasshouse red spider mite.

In recent experiments at GCRI three strains of red spider mite were compared. One was the classical red spider mite, another a virulent mite of classical appearance, found in Guernsey, and the third the virulent maroon-coloured mite. Comparisons were made of the morphology of the integumentary striae of female mites before, during and after placing them under diapause-inducing conditions. Only nymphs of the classical and the virulent/classical mites could be induced to diapause, but of all three strains only the classical mites showed the expected changes in the shape of the striae which accompanies the diapause state (Parr and Hussey, 1966).

In other experiments at GCRI the nature of the hypertoxic damage was investigated. Mites of classical and virulent types were homogenised and the liquid fraction was injected under the leaf cuticle and into the veins and apical stem of tomato plants (var. Craigella) using a hypodermic syringe. No hypertoxic damage could be induced in this way, though live virulent mites on plants did produce hypertoxic damage. By killing the virulent mites with oxamyl shortly after hypertoxic damage was seen the factor causing the damage was shown not to be systemically transmitted since damage did not appear elsewhere on the plants.

Carmine mites have been found at GCRI causing only the classical spider damage. The mites were present in such large numbers that widespread webbing occurred, but no hypertoxic damage was seen.

DISCUSSION

The first stage of pest control is to positively identify the pest. This is very difficult to do in the case of virulent red spider mite because it can exist either as brick-red ex-diapause mites or as the maroon carmine mites. To the untrained eye, these two forms and even the predator, can very easily be confused, leading to an incorrect diagnosis. To complicate matters further, ex-diapause mites and carmine mites can both occur as non-virulent forms producing the classical spider damage.

As an aid to correct diagnosis, the predatory mite is distinctly pear-shaped, the head end being the narrowest. The front pair of legs is much longer than those of the spider mite, and locomotion is generally more rapid and more jerky. To distinguish between carmine and ex-diapause mites, simply requires a reasonably good eye for colours. In contrast, however, when distinguishing between virulent and non-virulent forms of mites there seems to be no alternative but to observe the damage developing on infested plants.

When dealing with virulent red spider mite, speedy action is essential because severe damage is rapidly induced by only a few mites. This is one reason why predatory mites have failed to control this pest successfully. The predator requires a period of about a fortnight from its introduction before spider mite numbers are reduced, and during this time virulent mites may cause a great deal of damage. Another reason for failure is that the predator works best at relatively high pest densities, which do not occur in virulent spider mite populations.

Although chemical control is, theoretically, much faster-acting than biological control, resistance to acaricides can result in crop damage. Available information shows that resistance patterns in the virulent mite are very variable and that each population probably has its own individual resistance pattern. No one acaricide, therefore, was universally effective on every occasion, though cyhexatin was the most widely successful.

Diapause is an important factor in successful control of red spider mite. When mites enter diapause at the end of the growing season, as a result of short day-length and lack of food, they move off the plants and hide in cracks and crevices in the glasshouse structure. Once they are in their hibernation site it is extremely difficult to reach them with acaricidal treatments and so they are able to emerge safely when the next crop is established. Control measures should, therefore, be designed to ensure that no mites remain alive on the foliage about a month before the old crop is removed, thus eliminating the diapausing populations.

However, this approach is unnecessary in the case of non-diapausing mites because, when the old crop is removed any mites present rapidly die of starvation.

It is, therefore, very important to establish whether the mites are of the diapausing or non-diapausing type. However, as there is no simple method of establishing which type is present, the grower must play safe even if he possibly wastes money in eradicating non-diapausing mites.

Thus, the central problem with virulent mites is their ability to hybridize, so complicating decision-making by the grower. Which of many different manifestations of red spider mite is he faced with? Hybridization also opens the door to the creation of new tolerances to acaricides and explains the conflicting evidence from chemical control measures over the last four years.

Where virulent mites are suspected, the strategy for control of spider mites should take the following form:

1. Use oxamyl on seedlings to prevent contamination of new crops or propagated plants.

2. Where predatory control of spider mites is used, check that no carmine mites are present in predator consignments.

3. Make heavier introductions of predator, if possible.

4. Use spot-treatments of acaricides to minimise harmful effect on biological control, if in use.

5. If one acaricide does not work, use another from an unrelated chemical family.

6. Avoid all-year-round production to minimise the risk of carry-over to the new crop.

7. Prevent the migration of diapausing mites into glasshouse structure with clean-up sprays before the end of the growing season.

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FUNGAL PARASITISM OF THE ERIOPHYID MITE VECTOR OF RYEGRASS MOSAIC VIRUS

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Summary The discovery of fungi parasitising the eriophyid mite vector of ryegrass mosaic virus introduces the possibility of biological control of this important disease. The prospect is especially attractive because two of the fungi identified, Hirsutella thompsonii and Verticillium lecanii are already in use as biological control agents on other crops. H. thompsonii had not been recorded in Britain previously. Mites bearing fungal growth were found on half of the 40 ryegrass swards examined, which were mainly at the Grassland Research Institute and in the vicinity, but included two swards up to 70 km from the Institute. Mite mortality at one site was 16%.

Résumé La découverte de champignons parasitant le vecteur de la mosaique du raygrass, un acarien eriophyide, pourrait permettre la lutte biologique de cette importante maladie. Deux des champignons identifiés, Hirsutella thompsonii et Verticillium lecanii sont déjà utilises comme moyen de lutte biologique pour d'autres cultures, ce qui donne de bons espoirs sur leurs possibilités d'utilisation future. H. thompsonii n'avait pas été préalablement observé en Grande Bretagne. La présence de fragments mycèliens sur l'acarien eriophyide a été detectée dans la moitié des 40 prairies de raygrass au Grassland Research Institute et aux alentours, ainsi qu'à 70 km de l'institut. Dans une prairie la mortalité était de 16%.

INTRODUCTION

The dominant species in the 2.1 million ha of short-term grass leys in Britain are perennial ryegrass (Lolium perenne) and Italian ryegrass (Lolium multiflorum) and the most widespread and damaging disease of these leys is ryegrass mosaic virus (RMV) (Heard and Roberts, 1975). This disease is transmitted by the eriophyid mite Abacarus hystrix (Mulligan, 1960) which lives and feeds on ryegrass leaves and is present throughout the year (Lewis and Heard, 1981). Yield losses reported in the literature range from 15 - 30% of total annual dry matter production (Holmes, 1980). There is also a reduction in the response to nitrogen fertilizer (A'Brook and Heard, 1975), the quality of the grass for feeding (Holmes, 1979) and the rate of photosynthesis (Jones et al, 1977).

There is no practical possibility of eradicating RMV from an infected crop. The disease is not seed-borne and control, therefore, must be aimed at preventing infection and spread in newly established crops. Acaricides will control the mites present in a sward but the incidence of RMV will not be greatly reduced because of reinvasion by further infective mites (G.C. Lewis, unpublished). Although it is technically feasible to maintain good control of the mites with acaricides, the cost of crop protection chemicals is a major limitation to their use in grassland farming. Resistant cultivars probably offer the most likely long-term solution but these have not yet been developed. Biological control is a further alternative, but has not been considered previously because no natural predator of the mite has been reported. However, fungi, pathogenic to the mites, were discovered at the Grassland Research Institute in September 1980. This paper gives the results of the preliminary observations on the fungi and discusses the feasibility of biological control.

RESULTS AND DISCUSSION

Routine samples of ryegrass leaves were collected in September 1980, from a field experiment at the Grassland Research Institute. When the leaves were examined under a microscope in order to count the mites present, a proportion of the mites were dead and covered with a fungal growth which spread on to the leaf surface. This phenomenon had not been observed previously in 10 years of studies on the mite at the Institute. The fungus was found at 10 out of a further 19 swards at the Institute and on one sward the percentage mortality was assessed at 16%.

Ryegrass leaves were then collected from 17 farms in the vicinity of the Institute. Mites were present at 16 farms and the fungus was present on mites from 7 of these. Also leaves were collected from two farms which were 70 km from the Institute and mites bearing the fungus were present at both farms.

Since the original finding, the fungus has been found on mites in almost all of the leaf samples collected at the Institute. This includes periods during the winter of 1980-81 when the daily minimum temperature recorded above a grass sward was often below $0^{\circ}C$ and was occasionally down to $-10^{\circ}C$.

Slide preparations showed that a few living mites were carrying sterile fungal hyphae. The hyphae on dead mites was often sterile but sometimes bore conidiophores and conidia of an unidentified species of *Hirsutella*, a genus characteristically parasitic on arthropods (Minter and Brady, 1980). Dead mites were placed on agar and produced isolates of several different fungi. Two of these were the well-known parasites of arthropods *Hirsutella thompsonii* and *Verticillium lecanii*, this being the first record of *H. thompsonii* in Britain. Another two fungi are identified at present only as *Hirsutella* sp. 1 and sp. 2.

The prospect of biological control of the mite vector of RMV is greatly enhanced by the fact that two of the fungi identified are already available as commercial products for the control of arthropod pests. *H. thompsonii* is used in Florida to control the citrus rust mite (McCoy and Couch, 1979) and is being tested against an eriophyid mite pest of coconut (Hall *et al*., 1980). *V. lecanii* is used in Britain for the control of aphids in glasshouses (Hall and Burges, 1979) and it can readily be produced in large quantities in culture. *Hirsutella* sp. 1 was the most frequently isolated fungus on agar and is morphologically indistinguishable from the *Hirsutella* species observed in the slide preparations. We believe it is the same fungus and that it caused most of the mite mortality. Work is planned in collaboration with the Glasshouse Crops Research Institute to try to obtain sufficient amounts of this fungus in culture to allow test applications to mites on ryegrass plants.

A possible drawback of biological control is that mites entering a sward may be able to spread infection before being killed. Indeed, the lack of success of acaricide applications in previous work may be due to the same factor. However, the populations of mites are already being reduced by naturally occurring fungi and if this reduction is enhanced by artificial applications of fungal preparations, the spread of RMV may be slowed considerably. Also, this method could be readily integrated with other inexpensive control measures, e.g. manipulation of cutting date to curtail the build-up of mite populations.

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THE COCONUT MITE ERIOPHYES GUERRERONIS WITH SPECIAL REFERENCE TO THE PROBLEM IN MEXICO

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Summary The eriophyid mite, Eriophyes guerreronis is a serious pest of coconuts in Central and South America, The Caribbean and West Africa causing losses of copra in the order of 10-30%. In contrast, the mite has never been found in South East Asia or Polynesia. A recent study in Mexico revealed that the mite is more widespread in this country than was previously supposed. The worst affected areas are the Pacific Coast States (except Oaxaca). The problem in Vera Cruz (Caribbean seaboard) is incipient but is probably spreading rapidly. Some data are presented on the occurrence and behaviour of mites on coconuts of various sizes in Mexico. Owing to its sheltered habitat, chemical control is considered uneconomic. Biological control using the fungus, Hirsutella thompsonii, is the most promising means of control. The possibility of competitive displacement of E. guerreronis by another eriophyid, Colomerus novahebridensis, is discussed.

Résumé L'acarien, Eriophyes guerreronis, est un important ravageur des cocoteraies de nombreux pays d'Amerique latine, des Antilles et d'Afrique de l'Ouest et provoque des pertes de coprah qui sont de l'ordre de 10-30%. Au contraire, on n'a jamais découvert l'acarien en Asie du Sud-Est ainsi qu'en Polynesie. Une étude récente au Mexique a montré que l'acarien est plus répandu dans ce pays qu'on croyait préalablement. Les régions les plus touchées sont celles (sauf Oaxaca) du côté de l'océan Pacifique tandis que les attaques en Vera Cruz (du côté de la mer des Caraïbes) ne sont pas encore serieuses mais vraisemblablement s'étendent rapidement. Les auteurs ont presenté quelques données sur l'occurrence et le comportement de l'acarien sur des noix de cocos de plusieurs dimensions au Mexique. Puisque E. guerreronis est bien protegé par les bractes florales des noix, la lutte chimique est difficilement réalisable sur le plan economique. C'est la lutte biologique en utilisant le champignon, Hirsutella thompsonii, qui parait devoir présenter les moyens de contrôle les plus favourables. Du reste les auteurs ont consideré la possibilité d'un déplacement competitif du ravageur par un autre acarien, Colomerus novahebridensis.

INTRODUCTION AND RESULTS OF STUDY IN MEXICO

General Background

The eriophyid mite, Eriophyes guerreronis, is perhaps the most serious arthropod pest of coconuts in Central and South America, the Caribbean and West Africa. This mite has achieved major pest status in these areas during the last 20 years. Damage was pointed out for the first time in 1960 in Guerrero, on the West Coast of Mexico, by Cartujano (1963) and Ortega et al. (1965), who subsequently found an eriophyid mite associated with the damage. This was identified as a new species, E. guerreronis, by Keifer (1965). Since then it has been recorded in Venezuela (Doreste, 1968), Colombia (Cardona and Potes, 1971), Jamaica (Romney, pers. comm.), Cuba (Ortiz and Avila, 1975), Haiti, Grenada (Hussey, 1975), The Bahamas, Trinidad (Bennett, pers. comm.) and West Africa including the Gulf of Guinea (Sao Tomé and Principe Islands) (Cabral and Carmona, 1969), Benin and the Ivory Coast (Mariau, 1969; 1977). The position in other more Central African countries is less clear, although one unconfirmed report suggests that the mite may be present in Tanzania (Charlesworth, pers. comm.). In South East Asia and Polynesia, E. guerreronis has not been discovered but another eriophyid mite, Colomerus novahebridensis, has been found occupying the same feeding niche on samples of coconuts from Thailand, The Philippines, New Guinea and Vanuata (Hall et al., 1980) but provoking much milder and insignificant symptoms. The two species have not been recorded as co-existing.

Description of symptoms and infestation

Although it is exceptional to find E. guerreronis on non-fertilized coconut flowers, Mariau and Julia (1970) have found mites just after fertilization but then only under external bracts. A few weeks later, when the nutlet is about 5 cm long, damage in the form of triangular, pale yellowish-green or whitish marks may be seen on the green nut surface immediately below the tightly adpressed bract. Each blemish enlarges, goes brown and corky (suberization), sometimes forming deep fissures which may exude gum. This cracking is due to stresses arising from uneven growth of damaged nuts. Usually only part of each nut is scarred but the kernel is reduced in size. The estimated losses of copra yields vary from 10% in Benin (Mariau and Julia, 1970), 16% on certain varieties in the Ivory Coast (Mariau and Julia, 1979) to 25% in Grenada (Branch, 1976) and 30% in Mexico (Hernandez, 1977). It had been suggested (Doreste, 1968) that the mite can cause up to 70% premature nut fall, but later research has shown little evidence for this (Hussey, 1975; Mariau and Julia, 1970, 1979).

The coconut mite in Mexico

Until recently, the mite was known only in the state of Guerrero, on the Pacific Coast (Ortega et al., 1965; Hernandez, 1966). During a 3-week study of the mite in Mexico in March/April 1981, 160 nuts were collected at random and were divided into 6 categories according to size. The lesion sizes, mite numbers and percentage of damaged nuts were determined (Table 1). As can be seen, nutlets in category one possess virtually no mites. At this stage, the bracts are extremely tightly adpressed and mites are presumably unable to gain access. E. guerreronis evidently has a high reproductive potential since only a few weeks later, when the bracts are looser, the nuts harbour large numbers of mites feeding on the epidermis which, in this sample, reached a peak when the nuts were 9-11 cm long. In addition to feeding on the epidermis, mites are present in large numbers on the undersides of bracts apposed to the epidermis (Table 1). Somewhat smaller populations can be found feeding on the undersides of interstitial bracts. As the nuts get larger, populations decline and when nuts have reached a length of 20 cm, few mites can be found under the bracts. Despite the absence of mites after this stage, distortion will intensify as the development of the nut continues. The data in Table 1 suggest that conditions become unfavourable for mites by the time the nuts are 12-14 cm long. This may be related to hardening of the epidermis under the bract - in some cases, damaged areas on nuts 18-20 cm long had grown away from the bract leaving a band of healthy tissue between the bract and the damaged area. However, mite numbers can only be correlated with the damage within size categories 2 and 3, F values in subsequent categories being insignificant and correlation coefficients low (Table 1). This was because mite populations had often disappeared by the time lesions had exceeded 3-4 cm (in size categories 4 and upwards) suggesting that the damage the mites themselves had caused had encouraged their dispersion from the nut. On large nuts (18-20 cm long), another contributory factor to the disappearance of mites is likely to be predation - predators can gain access via the deep fissures arising on damaged tissue.

In the state of Guerrero, mite damage is ubiquitous. Palms bearing mite-damaged nuts were seen in every area visited. Severely damaged palms extended from the coast (of 100 nuts harvested from Acapulco beach, all were found to be damaged) to as far as Iguala and Zacatepec, 230 km inland.

A short time was allocated for visiting other coconut-growing areas in Mexico, since the mite was known only in Guerrero at the time. No damaged palms were observed around Juchitan (Oaxaca State, West Coast of Mexico), 600 km south of Acapulco, Guerrero State. At first, it was thought that the absence of the mite stemmed from a varietal difference in susceptibility. On the Caribbean seaboard, approaching Vera Cruz from the South, no mite damage was observed until about 20 km south-west of the city. Nuts on these palms were of the same variety as those unaffected further south and near Juchitan. Thirty-seven nuts of various sizes were collected and examined for damage and presence of mites. 86% of these nuts were damaged, most of them severely. Of these, 16 nuts were 20-24 cm long and harboured an average of 254 ± 75.9 mites/nut, compared to much fewer mites on the largest nuts (18-20 cm long) examined in Guerrero. The tissue on these nuts was noticeably softer than on those in Guerrero, either because of a varietal difference, or due to the wetter climate in Vera Cruz. The mite had been a problem in the area for about 4 years only but during that time, damage had become serious. In addition to the physical loss in copra yields, many kernels were invaded by fungi, probably gaining access via the epidermal fissures arising from mite damage. Given the rapid spread of <u>E. guerreronis</u> throughout Central and South America, The Caribbean and across the Atlantic to West Africa, the relatively recent invasion of Vera Cruz is curious, particularly so since Guerrero was probably one of the first areas affected.

With the exception of Colima State (Pacific Coast), where the mite has recently been observed (Carrillo, pers. comm.), the extent of damage in other coconut growing areas in Mexico is, as yet, unknown.

<u>Dispersion of</u> E. guerreronis

Little is known about the behaviour of the mite.

Polybutene traps, serving as a barrier to mite wanderings, were set up on coconuts in a plantation 50 km south of Acapulco. Examining such nuts 24 h later, over 3 times as many mites could be seen outside the bract than on untreated nuts. This accumulation of mites suggests that mites observed outside the bract were dispersing rather than wandering in and out of the bract. These mites were found all over the nut including the branches to which nuts were connected. It is thought that <u>E. guerreronis</u> migrates from infested coconut bunches to new uninfested bunches on the same tree simply by walking. As an inspection of the arrangement of the bunches revealed that the branches of one bunch often overlap with those of other bunches of widely differing ages, it is highly likely that infestation of new bunches can occur via this route. E. guerreronis adults were found dispersing on all categories of nuts which harboured mites, including even small nuts (those in size category 2, Table 1) showing minor damage symptoms and containing low numbers of mites (ca. 30 mites/nut). This suggests that migration may occur from nuts in which conditions are still very favourable for the pest. Thus, it would only be necessary for a single nut on a bunch to become infested, in order that other nuts on the same bunch be subsequently infested.

The polybutene bands trapped other insects also, particularly ants, which were sometimes observed passively picking up E. guerreronis adults. Presumably, mites could be transported by such insects to new bunches.

These mites were observed dispersing between 10 a.m. and 4 p.m., i.e. very warm conditions (mean max. temp. ca. 32°C). In one experiment, mites were counted on 36 nuts during the hottest part of the day. These nuts were observed again in the laboratory at 11 p.m. having been left in the dark for a few hours. There was no difference in mite numbers suggesting that the mites may have no specific migration time.

Wind-borne dispersal is well-known among eriophyid mite species, (e.g. Nault and Styer, 1969) and it is highly likely that E. guerreronis is transported in this way also, possibly over considerable distances. Six glass slides, coated with polybutenes and suspended vertically in a plantation for 48 h, caught two mites. This was a small number but demonstrated that such dispersal is possible.

Biological agents

Two types of predator were observed feeding on mites, Thysanoptera and a Typhlodromid, but only on older nuts on which damage had already occurred. The fungus, Hirsutella thompsonii, was found naturally occurring on one of a sample of 37 nuts in Vera Cruz but not on approximately 300 nuts examined in Guerrero, presumably due to the extreme aridness of this area at that time of year.

DISCUSSION

Because of the high reproductive potential of the mite, the protection afforded by the bracts and the constant presence of mites dispersing from a broad range of nut sizes, chemical control is not very effective. Various treatments using sprays and injections have been attempted in Mexico and West Africa (Ortega et al. 1965; Hernandez, 1977; Mariau and Julia, 1979) but they are not considered economic (Mariau, 1977; Hussey, 1975). Biological control is, perhaps, more feasible. Various predators including mites, thrips and Collembola have been recorded (Mariau and Tchibozo, 1973; Hussey, 1975; Hall et al., 1980; present paper) but are not considered to be of importance in the natural control of E. guerreronis, since most are unable to penetrate under the bract and are associated only with older, already damaged nuts, where deep cracks have developed on the suberized tissue. The natural enemies most likely to exert control are fungal pathogens. Hirsutella thompsonii, a well known pathogen of eriophyid mites, was found by Hall et al. (1980) on E. guerreronis populations on nuts sent to England from Jamaica and the Ivory Coast and on Colomerus novahebridensis populations on nuts from New Guinea and Vanuata (New Hebrides). The pathogenicity of these isolates for E. guerreronis has been confirmed in the laboratory (Hall et al., 1980). It is envisaged that the fungus would be superior to acaricides because, given favourable conditions, it should possess the capacity to spread.

Indeed, McCoy et al. (1975) have shown that following application of the fungus by spraying on to Citrus trees in Florida, H. thompsonii can develop and sporulate to a limited extent on the leaf surface. It is further envisaged that the development and sporulation of H. thompsonii on nuts and foliage of coconut palms, would provide a large reservoir of inoculum and itinerant mites, of which the present study has shown there are many at any given time, might transport spores underneath bracts where humidity conditions would be ideal for the fungus. It is probable that other mites entering the nut would soon succumb to infection and so the nut would be rendered 'immune' from further attack. Timing of field applications could be crucial. In Guerrero State, Mexico, it was obvious that during the dry season (December-May), conditions were too arid to permit development of the fungus on nuts or foliage although following a small field trial in March, 1981, in which H. thompsonii (Ivory Coast strain - Hall et al., 1980) was sprayed on to palms, there was evidence of mycosis one month later among mite populations under the bracts on some treated nuts. Be that as it may, an application would probably be most beneficial if made during the wet season in Guerrero. One disadvantage, however, could be loss of inoculum potential as the result of rain. Therefore, in other, wetter areas, e.g. Vera Cruz, where H. thompsonii was found even in the dry season, application may most profitably be made at this time of year. Temperatures in these areas are most certainly favourable. The mean optimum for growth of the 'Ivory Coast' strain of H. thompsonii which possesses desirable cultural characteristics for mass-production, is ca. 28°C with a maximum of 34-35°C (Hall, unpubl.). The mean temperature in Guerrero during the wet season is ca. 28°C with an average maximum and minimum of 32 and 24°C, respectively, these being slightly lower in Vera Cruz.

Another means of controlling E. guerreronis, not so far attempted, is by competitive displacement. This would necessitate introducing the apparently harmless mite, C. novahebridensis, into areas infested by E. guerreronis. Before this can be contemplated however, a thorough study of C. novahebridensis in its natural habitat should be undertaken to confirm its inoccuity before making introductions, especially with regard to any possible role of this mite in spreading Cadang-Cadang disease, a serious RNA viroid disease of coconut palms in The Philippines (Zelazny, 1979).

Therefore, in the short-term, the only possibility of controlling E. guerreronis is with the fungus, H. thompsonii. To this end small-scale field trials should be undertaken as soon as possible. If successful, much larger trials using a commercially-produced formulation of the fungus may then be contemplated. Given the widespread nature of the problem such work would best be undertaken and co-ordinated on an international scale.

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Table 1

E. guerreronis and damage on coconuts of different sizes

Category no. and length of nut (cm)	No. of nuts	Approx. age (days)	Mean lesion size (cm)	% nuts with damage symptoms	Mean no. mites per nut ± standard error		Correlation of mite numbers with lesion size	
					On epidermis of nut (under bract)	On underside of bract	Corr. coeff.	F-value
1. ≤ 5	30	20-25	0	0	0.05	0	-	-
2. 6-8	29	35	0.5	73.6	528 ± 107	199.7 ± 96.2	0.53	10.5*
3. 9-11	24	45	1.46	83.3	631.6 ± 245	229 ± 91.2	0.51	7.9*
4. 12-14	25	55	2.02	80.0	400 ± 133	175 ± 64.6	0.16	0.54
5. 15-17	22	65	1.85	86.3	277 ± 113	52.2 ± 19.9	0.1	0.0
6. 18-20	29	80	2.04	93.1	40.9 ± 32	43.5 ± 26.3	0.1	0.1

* $P < 0.05$