SESSION 5

NEW COMPOUNDS, FORMULATIONS AND USES

CHAIRMAN	PROFESSOR T. LEWIS
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RESEARCH REPORTS 5-1 to 5-8

STOP PRESS

BSI Common Names for Pesticides

Because the camera-ready copy is required relatively early, in order that the *Proceedings* can be printed in time for the Conference, it sometimes happens that BSI names are adopted *after* the final copy was received and so are not mentioned in the text. Names recently adopted by BSI include:

Paper	*Firm's code no.*	*BIS common name*
2-2	CGA 106630	diafenthiuron
2-7	CGA 142705	fenpiclonil
5-1	LS 840606	furconazole-cis
5-8	PH 70-23	flucycloxuron
4B-1	PP321	lambda-cyhalothrin
	WL 85 871	alpha-cypermethrin

LS840606 - A NEW BROAD-SPECTRUM FUNGICIDE

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ABSTRACT

LS840606 is a new sterol inhibiting fungicide developed by Rhône-Poulenc Agrochimie, showing excellent activity against a wide range of phytopathogenic fungi belonging to the classes Ascomycetes, Basidiomycetes and Fungi Imperfecti.
Greenhouse and field trials have demonstrated that LS840606 is systemic and has protectant and curative activity against the major diseases of cereals, vines, fruit trees and tropical crops, in particular powdery mildews, rusts, scabs, leaf spots and other foliar pathogens.
Rates of use vary between 10 and 100 g a.i./ha.
Mixtures with other fungicides are under development.

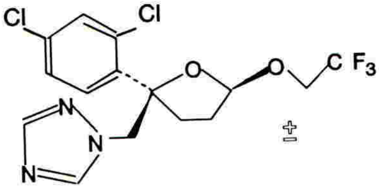
INTRODUCTION

LS840606 is a new triazole fungicide discovered by Rhône-Poulenc Agrochimie. In common with other chemicals belonging to this family, it inhibits the biosynthesis of sterols.

The aim of this paper is to review the general properties of LS840606, and demonstrate its biological activity against a broad range of pathogenic fungi in the following crops : cereals, fruit trees, vines and tropical crops such as coffee and bananas.

TECHNICAL DATA

Molecular formula : $C_{15}H_{14}Cl_2F_3N_3O_2$
Molecular weight : 396.2
Structural formula:



Chemical name :(IUPAC) : (2RS, 5RS)-5-(2,4-dichlorophenyl)tetrahydro-5-(1H-1,2,4-triazol-1-ylmethyl)-2-furyl 2,2,2-trifluoroethyl ether
Common name: *
Appearance : white to off-white powder.
Melting point : 86°C
Solubility : 21 mg/l in water
high solubility in many organic solvents : 370 g/l to 1400 g/l.
Vapour pressure : 1.09×10^{-7} mm Hg = 1.45×10^{-5} Pa at 25°C.

*Suitable modification of common name furconazole (which applies to the pair of racemates (2RS, 5RS; 2RS, 5SR)) is currently under discussion with ISO.

TOXICOLOGY

Acute oral LD50 rat = 450 to 900 mg/kg.
Acute dermal LD50 rat > 2000 mg/kg.
These values are an indication of the low acute toxicity of LS840606 to mammals.
No eye or skin irritation (rabbit).
No mutagenic effect was observed (Ames test, micronucleus test).
Chronic toxicology studies are in progress.

FORMULATION

In order to cover a wide range of possible uses, LS840606 is formulated as wettable powders, emulsifiable concentrates, and aqueous suspension concentrates. Other formulations of LS840606, and mixtures with fungicides with complementary activity, are under study.

BIOLOGICAL PROPERTIES

In vitro activity

The broad spectrum of activity of LS840606 is illustrated by the strong inhibition of mycelial growth of fungi obtained in vitro. (Table 1).

TABLE 1
Concentration of LS840606 producing 90% inhibition of mycelial growth

Fungus	mg a.i./l	Fungus	mg a.i./l
Alternaria brassicae	1	Phoma exigua	10
Alternaria solani	8	Phomopsis viticola	12
Cercospora beticola	6	Pleospora betae	3
Claviceps purpurea	8	Pseudocercosporella capsellae	< 1
Cochiobulus miyabeanus	16	Pseudocercosporella herpotrichoides	3
Colletotrichum gloeosporioides	3	Pyrenophora avenae	11
Cytospora cincta	< 1	Pyrenophora graminea	7
Diaporthe citri	8	Pyrenophora teres	3
Drechslera poae	14	Pyrenophora trichostoma	2
Elsinoe fawcetti	8	Pyricularia oryzae	20
Endothia parasitica	< 1	Ramularia beticola	4
Eutypa armeniacae	8	Rhizoctonia cerealis	30
Gaeumannomyces graminis	< 1	Rhizoctonia solani	20-30
Gibberella fujikuroi	6	Sclerotinia homeocarpa	< 1
Gloeocercospora sorghi	< 1	Sclerotinia minor	< 1
Glomerella tucumanensis	< 1	Sclerotinia sclerotiorum	15
Guignardia bidwellii	3	Sclerotinia trifoliorum	20
Laetisaria fuciformis	< 1	Sclerotium cepivorum	1
Leptosphaeria maculans (Phoma lingam)	2	Septoria glycines	20
Leptosphaeria nodorum	7	Ustilago avenae	4
Monilinia fructigena	< 1	Ustilago maydis	7
Monilinia laxa	1	Venturia inaequalis	0.01
Mycosphaerella musicola	5	Verticillium dahliae	3-15

In vivo activity

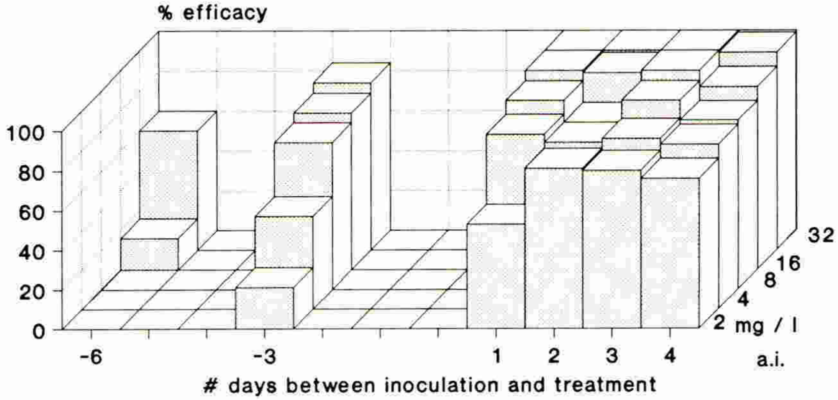
Cereals

LS840606 has been extensively tested against leaf and ear diseases of cereals, both in greenhouse trials and under practical field conditions. The results of these experiments demonstrate clearly three important characteristics of the compound :

LS840606 exhibits both curative and preventative activity; the relationship between the type of treatment (protectant or curative), the rate of active ingredient used and the efficacy against wheat brown rust under greenhouse conditions is shown in Fig. 1

Fig.1

Relationship between concentration, timing of application and efficacy against wheat brown rust (Puccinia recondita).



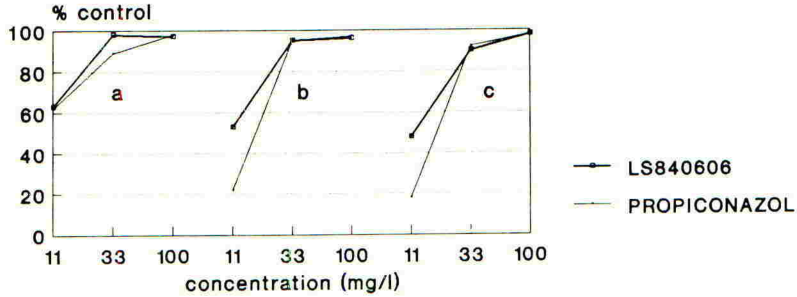
A significant vapour effect has been demonstrated in the greenhouse against barley powdery mildew (Erysiphe graminis) (Gouot et al 1988), when LS840606 was applied at concentrations similar to those used under field conditions. This property enhances the consistency of the activity, and thus reduces the risks of uneven spraying.

LS840606 penetrates rapidly into the plants through the leaf cuticles (Caruhel et al 1988). One of the major advantages of this property is that efficacy is less affected by adverse weather conditions. In Fig. 2, the efficacy of LS840606 is compared when the spray is followed by various weather conditions : "dry", "moist" or "moist and rainy".

Young seedlings were sprayed with various concentrations of LS840606. Some of these were kept in moist conditions causing leaf wettness for 12 hours. In addition, some of these plants then received 10 mm of artificial rainfall. Inoculation was carried out 6 hours after the artificial rainfall, and assessments were made 10 days after inoculation. Results are presented as % control of the disease. The results indicate clearly that the active ingredient is rain-fast.

Fig. 2

Efficacy against wheat brown rust (Puccinia recondita), Greenhouse rain-fastness test.



a : no dew, no rain b : dew, no rain c : dew plus rain.

Under field conditions, good efficacy was obtained against powdery mildew (E. graminis) in wheat and barley (Gouot et al 1988)

Fruit trees

Against powdery mildew on apples (Podosphaera leucotricha), LS840606 showed a good efficacy when used at low rates. Treatments with 20 to 25 g a.i./ha were the most efficient in Europe, USA, South America, Japan, when applied in spray programmes adapted to local conditions (3 to 6 treatments per year on a 10 to 20 day spray schedule).

The efficacy of the early treatments against primary shoot mildew is shown clearly in Table 2. This is of major importance for the development of the disease in the orchards, as the quantity of primary inoculum is dramatically reduced.

Later in the season, the combined preventative and curative activity of LS840606 kept the disease at a very low level (Table 3).

TABLE 2

Efficacy against primary infection of apple powdery mildew (P. leucotricha) 1986-1988

Treatment		Number of primary infected shoots			
		at first spray *	after five sprays *	after three sprays	
LS840606	10 g/ha				15
	20 g/ha	98	16	26	8
	25 g/ha			23	
Untreated control		100(1)	102(1)	105(2)	55(2)

*index : 100 = untreated control at first spray
(1) mean of three sites. (2) single site result.

Table 3

Efficacy against apple powdery mildew (P. leucotricha) leaf infection 1986-1988

Treatment		% infection on leaves *					
Untreated control		66	43	78.5	43	55	22
(Number of trials)		(1)	(4)	(2)	(2)	(3)	(2)
LS840606	10 g/ha		8.2	14			
	15 g/ha			6			2.4
	20 g/ha		3.3		6	5.2	2.1
	25 g/ha	0.6				2	

* Spray interval : 10 to 20 days, 5 to 7 sprays applied

Apple Scab (Venturia inaequalis) is also very well controled by LS840606. Rates of 15 to 20 g a.i/ha were sufficient to ensure a protection of the leaves and fruits and provided a curative action against spores inoculated 5 days prior to treatments (see Fig.3).

Under practical conditions, these two properties are complementary and results obtained with treatments sprayed every 10 -14 days, depending on the local disease pressure, were good in trials carried out over the period 1986 - 1988 (Tables 4 and 5).

Fig. 3

Curative efficacy against apple scab (V. inaequalis)

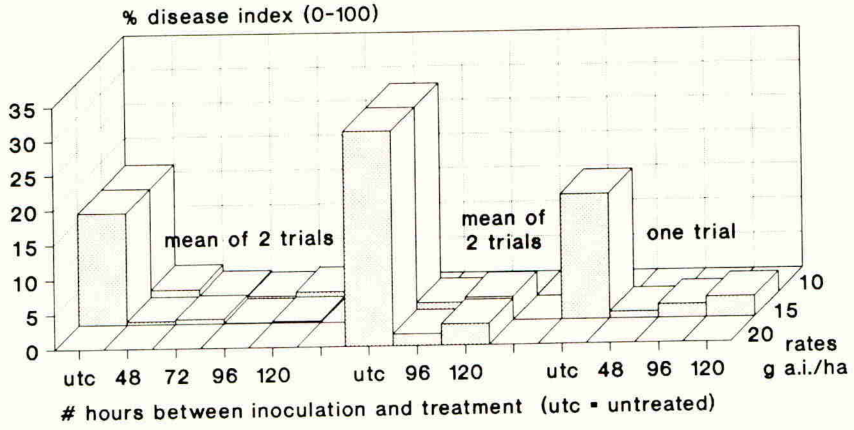


TABLE 4

Activity against leaf infection of <u>V. inaequalis</u> under practical field conditions 1986-1988

Treatment		% leaf area affected					(1)
Untreated control		34.7	67	21.2	21.5	58	35
(Number of trials)		(3)	(1)	(2)	(4)	(2)	(1)
LS840606	10 g/ha	1.6	0.5	1.1	1.8		
	15 g/ha		0.5	0.6		2.2	0.2
	20 g/ha			0.4	0.75		

5 - 7 treatments applied at 10 - 14 day intervals
(1) Number of spots per leaf.

TABLE 5

Activity against fruit infections of <u>V. inaequalis</u> under practical field conditions 1986 - 1988

Treatment		damaged fruits at harvest			
Untreated control		33	68	13	34
(Number of trials)		(2)	(1)	(2)	(2)
LS840606	10 g/ha	1.9	3.2		0.8
	15 g/ha	0.3		2	0.3
	20 g/ha	0.1		0.8	

5 - 7 treatments applied at 10 - 14 day intervals

In addition to these two diseases, LS840606 has also shown good efficacy against pear scab (<u>V. pyrina</u>), <u>Alternaria</u> leaf spots (<u>A.mali</u> and <u>A. kikuchiana</u> on apples and pears respectively), rusts (<u>Gymnosporangium haraeanum</u>),and brown rots on apples (<u>Monilinia</u> spp.). On stone fruit, brown rot (<u>M. laxa</u>), scab (<u>Fusicladium carpophilum</u>), and powdery mildew (<u>Sphaerotheca pannosa</u>), were also well controlled.

Various rates were necessary to achieve an acceptable control of these different diseases and several mixtures with other fungicides have been successfully investigated.

<u>Other temperate crops</u>
LS840606 has also been evaluated for use on many other crops. On grape vines, rates of 20 g a.i./ha are sufficient to control powdery mildew (<u>Uncinula necator</u>) (Gouot <u>et al</u> 1988). On sugarbeet, a rate of 100 g a.i/ha is effective against <u>Cercospora beticola</u> (Gouot <u>et al</u> 1988) and powdery mildew (<u>Microsphaera betae</u>). Further work with complementary products is needed in order to extend the possible uses of LS840606 to other sugar-beet diseases.

On vegetables and ornamentals, powdery mildew (<u>Erysiphe</u> spp., <u>Sphaerotheca</u> spp., <u>Leveillula</u> spp...) and rusts (<u>Puccinia</u> spp., <u>Uromyces</u> spp...) are controlled with rates ranging from 25 to 50 g a.i./ha.

<u>Tropical crops</u>

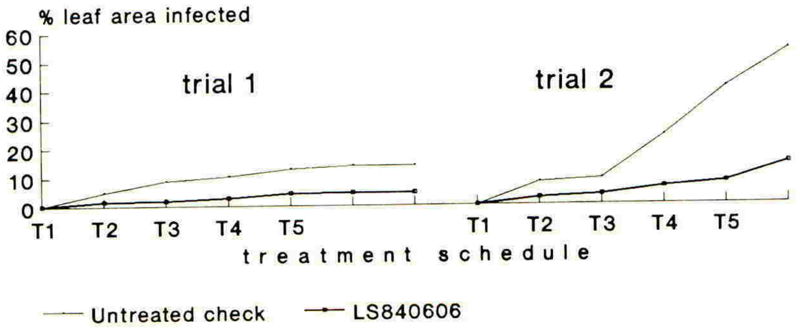
LS840606 performed well against many diseases of important tropical crops, such as powdery mildews, rusts, leaf spots and other diseases of peanuts, bananas, coffee, pecan, mango, etc.. As examples representative of these major diseases, results concerning banana sigatoka (<u>Mycosphaerella musae</u>) and coffee rust (<u>Hemileia vastatix</u>) are presented.

a) <u>Banana sigatoka</u>

LS840606 was tested against diseases caused by <u>Mycosphaerella</u> spp. on bananas in different regions, where disease intensity and susceptibility to fungicides are variable. In all cases, the compound performed well and an important suppression of the disease was obtained.

Fig. 4 shows the evolution of the disease in two trials (1986-1988), when the fungicide was applied on a 14 day schedule; the first spray was made before any symptoms were noticeable on the leaves.

Fig. 4 : Activity against banana sigatoka (<u>M. musae</u>)



b) <u>Coffee rust</u>

Against coffee rust (<u>Hemileia vastatrix</u>),LS840606 confirmed the good efficacy observed on other rusts. Foliar sprays or soil treatments gave an outstanding level of disease control. Results obtained with foliar sprays are presented in Table 6.

TABLE 6

Efficacy of foliar spray treatments against coffee rust (<u>H. vastatrix</u>)

Treatment	% infection	(leaves)	number of pustules per leaf
Untreated control	60	75	1.8
LS840606 45 g/ha		9	
60 g/ha	12	1	0.2
120 g/ha			0
Number of treatments *	(4)	(6)	(5)

* treatments applied at 30 days intervals

CONCLUSION

. LS840606 provides excellent control of a wide range of crop diseases using low rates of active ingredient.

. Selectivity on these crops is good when applied at the biologically effective rates.

. The spectrum of activity of LS840606 can be broadened, using combinations with other fungicides. Some of these have shown great promise.

REFERENCE

CARUHEL, P.; GOUOT,J.M.; GREINER,A.;MERINDOL,B.; ZECH,B. (1988) a new possibility for the control of cereal rusts : furconazol-cis. Proceedings of the Seventh European and Mediterranean Cereal Rusts Conference, 194.

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GREINER,A.; GOUOT,J.M.; MERINDOL,B.(1988) : Furconazole-cis (LS840606), a new broad spectrum fungicide. Proceedings of the Fifth International Congress of Plant Protection. Kyoto, Japan (in press).

RH-5849 - A NOVEL INSECT GROWTH REGULATOR WITH A NEW MODE OF ACTION

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ABSTRACT

RH-5849, 2'-benzoyl-1' tert - butylbenzohydrazide, respresents a new class of insect growth regulators (IGRs) which are non-steroidal ecdysone agonists. Premature moulting in lepidoptera is induced resulting in relatively rapid inhibition of feeding regardless of age or instar. Laboratory studies show RH-5849 is primarily an effective, moderately persistent stomach poison for larvae of lepidoptera and coleoptera by either foliar or soil application. Plant uptake from soil is rapid and unique for an IGR. RH-5849 was a feeding deterrent and prevented, or induced cessation of, oviposition in pyrethroid-resistant Leptinotarsa decemlineata. Similar effects on reproduction occur with Epilachna varivestis, Agrotis ipsilon, Anthonomus grandis grandis and Musca domestica. Field data indicate excellent control potential for resistant strains of L.decemlineata on potato and Leucoptera scitella on apples. Low acute mammalian toxicity and high environmental safety with respect to beneficial organisms suggest commercial utility as a selective insecticide in forestry and crop protection. RH-5849 is in early development status.

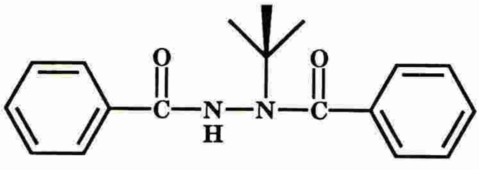
INTRODUCTION

RH-5849 is a novel insect growth regulator (IGR) discovered at the Rohm and Haas Company Research Laboratories in Pennsylvania, USA (Hsu and Aller, 1987). Laboratory and preliminary field trials have shown a high level of activity against a wide range of lepidoptera and some species of coleoptera and diptera. The chemical and biological properties of this unique IGR are described.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical Name : 2'-benzoyl-1' tert - butylbenzohydrazide

Formula: $C_{18}H_{20}N_2O_2$



Molecular Weight	:	296.4
Physical State and Colour	:	white crystalline solid
Melting Point	:	174-6°C
Odour	:	none
Vapour Pressure	:	1.8×10^{-6} torr at 25°C
Stability	:	stable under normal storage conditions

Solubility	:	in water	ca. $5x10^{-2}$ g/l
		in cyclohexanone	ca. 50 g/l
		in mesityl oxide	ca. 150 g/l
Partition Coefficient (n-octanol/water)	:	212	

Mammalian toxicity:

Acute oral LD_{50} (rat, 14 day observation)	435 mg/kg
Acute dermal LD_{50} (rat, 14 day observation)	>5000 mg/kg
Eye/skin irritation (rabbit, 72 h)	essentially non-irritating
Ames mutagenicity test	negative

Environmental toxicity:

Avian	-	mallard, quail LC_{50} (8 days)	>5000 ppm in diet
	-	quail LD_{50} (21 day observation)	1000 mg/kg
Aquatic	-	bluegill, trout LD_{50} (96 h)	>100 mg/l
	-	Daphnia LC_{50} (48 h)	7 mg/l
	-	Daphnia LC_{50} life cycle	0.5-0.9 mg/l
	-	honeybee LD_{50} (topical)	>100 µg/bee
Soil	-	half-life (laboratory) in silt loam at 23°C	27 days

Experimental Formulations	:	2F (239.7 g/l aqueous flowable)
		5G (5% granular)

LABORATORY PERFORMANCE

Lepidopera. Wing (1988) and Wing et al., (1988a) noted that RH-5849 and analogues function as non-steroidal ecdysone agonists in lepidoptera and do not directly interfere with chitin synthesis as do the familiar benzoylurea IGRs. Such ecdysone agonists induce relatively rapid and untimely premature moulting at any point in larval development. Further, they inhibit ovariole development, effecting prevention or cessation of oviposition. The first symptom of efficacy in larvae is premature apolysis or slippage of the head capsule. Formation of the double head capsule occludes the new and often non-sclerotized mouthparts thereby preventing further feeding. When RH-5849 is incorporated into tobacco hornworm (*Manduca sexta) artificial diet, the EC_{50} for head capsule slippage is ca. 0.008 g/l after a one day exposure and ca. 0.004 g/l after 2 days for first through fifth instar larvae (L1-L5). Other aberrations consist of adhesion of old cuticle remnants and rupture of the imperfectly formed new cuticle.

Conventional plant bioassays for mortality employed exposure intervals of 3 and 6 days. Southern armyworm (Spodoptera eridania) results (Table 1) illustrate the uniformity of response with respect to age and stage and the essentially complete response attained within 3 days after application. The LC_{50} values for RH-5849 approximate the estimated dose to reduce plant feeding by 80% relative to untreated checks. Persistence of foliar applications was moderate. RH-5849 is not effective as a contact spray. Ovicidal action has been too variable to characterize.

Rapid transport of RH-5849 from plant roots to foliage has been shown by bioassay where bare roots of lima beans were soaked in test solutions for as little as 1-3 h. Soil drench assays were effective for at least 2 weeks. Recent work by Hofmeister et al., (1988) suggests that an experimental benzoylurea IGR may be systemically active against some worm species but this was not confirmed in our laboratory. It is generally accepted that benzoylureas lack systemicity in plants; hence, the systemic action of RH-5849 is particularly significant for an IGR. Simulated row treatments of lima bean seedlings in 3 soil types indicated that the 5G formulation of RH-5849 was more effective than carbofuran (Fig 1) against southern armyworm. Comparable results were obtained 26 days after application of granules in the seed furrow in a similar simulation. Both greenhouse studies precluded vertical and lateral diffusion.

While relatively rapid responses to RH-5849 generally occur, low doses or proximity to pupation may preclude sufficient time to acquire a lethal dose. In such instances the response may be expressed later in the life cycle. With treated artificial diet the LC_{50} for L4 black cutworm (*Agrotis ipsilon) was nominally ca. 0.011 g/l. Considering also the subsequent mortalities in the prepupal and pupal stages an ultimate LC_{50} of ca. 0.0015 g/l was realized. Further, a 0.001 g/l dose of RH-5849 in the L4 diet resulted in two-thirds reduction in cumulative oviposition by the subsequent female moths. Comparable results have been obtained with tobacco budworm (Heliothis virescens) which is slightly less responsive than armyworm and cutworms.

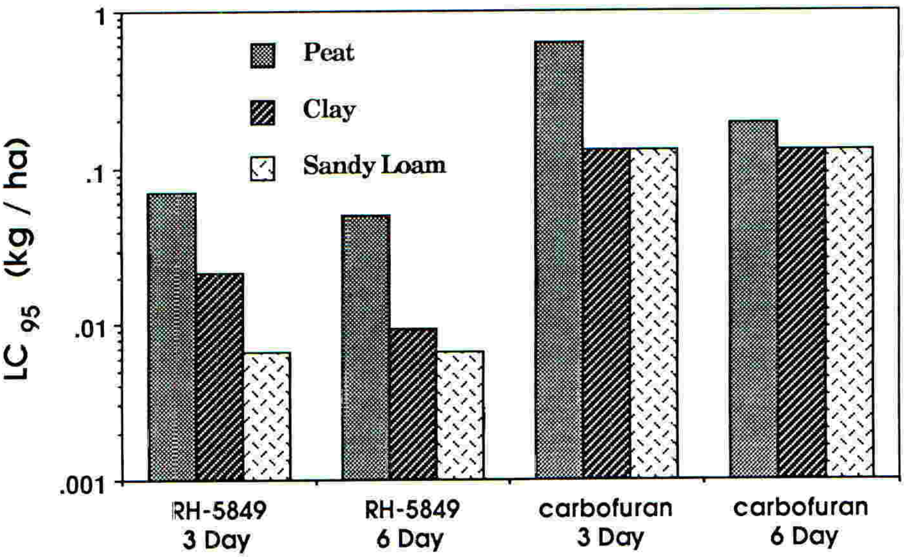
TABLE 1

Southern Armyworm (Spodoptera eridania) on lima bean: Laboratory responses to technical RH-5849.

Assay			LC_{50} (g/l a.i. x 1000) after exposure for specified number of days	
Method	Duration (days)	Instar	3 days	6 days
Residual	0	L2	18	12
		L3 early	19	14
		L3 mid	12	12
		L3 late	19	13
		L4	19	16
		L5	15	12
Residual	7	L3 mid	27	23
Residual	14	L3 mid	75	49
Systemic *	7	L3 mid	0.53	0.46
Systemic *	14	L3 mid	0.63	0.45
Contact		L3 mid	505	505

* g/l a.i. x 1000 in soil after drenching

Figure 1. **Efficacy of insecticides against Southern armyworm (Spodoptera eridania) on beans in three soil types after two week's systemic uptake from soil.**



Coleoptera. No indication of premature moulting has been observed in coleoptera. High concentrations appear to induce neurotoxic symptoms such as tremors followed by paralysis and death. The speed of action varies with species but is generally slower than observed with lepidoptera. A 6-day exposure of larvae (Table 2) appears to be inadequate for Mexican bean beetle (Epilachna varivestis) which is less sensitve than Colorado potato beetle (Leptinotarsa decemlineata). At concentrations below neurotoxic levels, RH-5849 tends to limit larval weight gain and functions as an antifeedant.

Although RH-5849 does not persist well on foliage against bean beetle, systemic residual action is good. Foliar and systemic persistence is good against field-collected OP/Pyrethroid-resistant potato beetles.

Ingestion of RH-5849 by adult coleoptera effects prevention or cessation of oviposition. Neonate potato beetles exposed to 0.05 g/l RH-5849 ceased feeding within two days and failed to oviposit, dissection of females revealing absence of developing oocytes. Ovipositing 6 day old females ceased to lay eggs 24 h after placement on treated plants, oocytes being resorbed. These effects are in accord with ecdysone agonism and are in marked contrast to benzoylureas which do not inhibit oviposition but tend to initially reduce egg viability. Similar effects on oviposition have been shown on boll weevil (Anthonomus grandis grandis) and Mexican bean beetle.

Oviposition inhibition has also been shown in diptera. Following USDA test protocols, 10 g/l RH-5849 in the diet of neonate adult house fly (Musca domestica), NAIDM strain) precluded oviposition.

TABLE 2

Colorado potato beetle (Leptinotarsa decemlineata) and Mexican bean beetle (Epilachna varivestis): Laboratory responses to technical RH-5849.

Assay Method	Duration (days)	Instar	LC_{50} (g/l a.i. x 1000) after exposure for specified number of days: potato beetle on tomato *** 3 days	6 days	bean beetle on lima bean 3 days	6 days	10-12 days
Residual	0	L2	38	12	225	42	
		L3	>150	11	105	54	35
		L4	<150	19	840	132	60**
Residual	7	L2	120	38	420	420	
Residual	14	L2	64	20	-	-	
Systemic *	7	L2	0.50	0.25	2.74	1.19	
Systemic *	14	L2	>2	0.37	1.98	1.50	
Contact		L2	150	150	420	420	

* g/l a.i. x 1000 in soil after drenching; ** includes post larval mortality; *** field-collected pyrethroid-resistant strain

FIELD PERFORMANCE

RH-5849 gave excellent control of L.decemlineata on potatoes. In New Jersey this species has 4-5 generations annually and is highly resistant to pyrethroid and other insecticides. Under severe pest pressure, RH-5849 reduced larval and adult feeding and virtually eliminated the larval population (Table 3). The single over-the-top band spray of plants and the soil surface was more effective than 2 foliar sprays. Comparable pre-emergence band sprays were less effective, suggesting limited soil longevity or a poor choice of formulation and application method in this test. Similar test results with RH-5849 were obtained in Wisconsin. At these and other locations, survivors pupated but adults apparently failed to emerge from the soil.

TABLE 3

Control of Colorado potato beetle (Leptinotarsa decemlineata) on potato (New Jersey, USA, 1987).

Treatment	Dose (kg a.i./ha)	9 DAT		18 DAT	
		larvae/ 20 sweeps	% defolated	larvae/ 20 sweeps	% defoliated
Foliar (2 applications):					
RH-5849, 2F	0.28	6	8	0	20
	0.56	4	8	2	12
	0.84	0	2	0	12
cyfluthrin, 2EC	0.06	90	25	17	36
Foliar/Soil band (1 application):		9 DAT		27 DAT	
RH-5849, 2F	1.12	3	7	3	8
	2.24	1	3	0	7
	3.36	2	1	0	10
Untreated:	-	332	47	1	86

RH-5849 gave excellent control of leafminers on apples in Italy (Tables 4, 5). High volume (runoff) application of RH-5849 applied at peak adult flight controlled Leucoptera scitella and Phyllonorycter blancardella. These trials also established RH-5849 was safe to beneficials and, thus, well-suited for IPM programmes.

TABLE 4

Control of leafminer (Leucoptera scitella) on apples (Ravenna, Italy, 1987)

Compound	Dose (g a.i./hl)	1st Generation (29 DAT)		2nd Generation (15 DAT)	
		No. mines/ 100 leaves	% control	No. mines/ 100 leaves	% control
RH-5849	6	9.8	93	11.7	86
	12	0.7	100	3.8	95
Diflubenzuron	12.5	107.0	28	39.9	53
Teflubenzuron	6	7.3	95	4.9	94
Untreated	-	149.0	-	84.0	-

TABLE 5

Control of first generation leafminer (Phyllonorycter blancardella) on apples (Italy, 1988)

Compound	Dose (g a.i./hl)	Verona (25 DAT) no. mines/ 100 leaves	Verona (25 DAT) % control	Ravenna (28 DAT) no. mines/ 100 leaves	Ravenna (28 DAT) % control
RH-5849	5	1.1	96	1.5	93
	10	0	100	0.8	96
Diflubenzuron	12.5	13.8	52	12.5	38
Teflubenzuron	5	17.3	40	13.4	33
Untreated	-	29.0	-	20.1	-

CONCLUSIONS

RH-5849 functions in a manner hitherto associated only with steroids such as the ecdysones (Robbins et al., 1970). Novel chemistry and mode of action suggest RH-5849 should control sensitive species resistant to other classes of insecticides, including current IGRs. Efficacy by ingestion has been shown against many other species of lepidoptera, including rice stem borer (Chilo supressalis), codling moth (Cydia pomonella), gypsy moth (Lymantria dispar), tortrix, leaf rollers, etc. RH-5849 is a rapid-acting IGR capable of reducing feeding, regardless of larval age, via foliar or systemic application. Further, oviposition inhibition appears to be general for lepidoptera and some species of coleoptera and diptera.

These unique attributes combined with a good toxicological profile suggest RH-5849 will be useful in protection of tree and row crops, in forests and other areas requiring an IPM-compatible selective insecticide.

ACKNOWLEDGEMENTS

We thank our colleagues for technical support. In North America they are: G.R.Carlson, S.E.Crane, A.C.T.Hsu, R.Hunter, M.Madle, D.J.Randazzo, V.L.Salgado, B.A.Sames, W.H.Schilling, R.A.Slawecki, M.Thirugnanam and K.D.Wing. In Europe they are: G.Regiroli, G.Siddi and M.Vietto.

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HF-6305, A NEW TRIAZOLE FUNGICIDE

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ABSTRACT

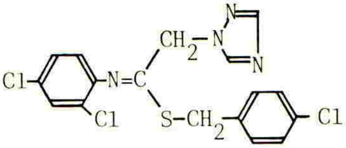
HF-6305 is a new triazole fungicide possessing protective and curative properties. It is highly active against a wide range of pathogenic fungi including Ascomycetes, Basidiomycetes and Deuteromycetes. Field trials since 1985 demonstrated its excellent performance against apple scab (*Venturia inaequalis*), apple powdery mildew (*Podosphaera leucotricha*), apple rust (*Gymnosporangium yamadae*), pear scab (*V. nashicola*), pear rust (*G. asiaticum*), grape powdery mildew (*Uncinula necator*), grape anthracnose (*Elsinoe ampelina*), peach scab (*Cladosporium carpophilum*), wheat brown rust (*Puccinia recondita*), wheat bunt (*Tilletia caries*), rose black spot (*Diplocarpon rosae*), chrysanthemum white rust (*P. horiana*), and turf rust (*P. zoysiae*) at low rate application. No phytotoxicity was observed in any of applied crops at effective dosage in both glasshouse and field conditions. It was locally systemic and showed a high level of residual and rainfall resistant activities. It has low toxicity to mammals, fishes, bees and other wildlife species.

INTRODUCTION

HF-6305 (HF-8505), 4-chlorobenzyl *N*-(2,4-dichlorophenyl)-2-(1*H*-1,2,4-triazol-1-yl)thioacetamidate, is a new, highly active, broad spectrum fungicide first introduced by Hokko Chemical Company (Ohyama,H.;Morita,K.; Wada,T., 1984,1986). It has been evaluated worldwide for control of many diseases in fruits, vegetables, cereals and ornamentals. This paper describes the properties of the fungicide and its performance on various diseases of apples, vines and other crops.

TECHNICAL DATA

Structural formula :



Molecular formula and RMM	: $C_{17}H_{13}Cl_3N_4S$, 411.7
Appearance and M.P.	: light yellow crystals, 89.5-90°C
Solubility	: water at 20°C : 1.7 mg/l
	organic solvents at 25°C (g/l) :
	acetone 1030, xylene 250, methanol 120
Vapour pressure	: 85 nPa at 25°C
Formulation	: 15 % WP, 15 % EC, 5 % EC

TOXICOLOGY

Acute oral LD50	: rat (male, female)	>5000 mg/kg
Acute dermal LD50	: rabbit (male)	>5000 mg/kg
Irritation	: rabbit (skin, eye)	non-irritating
Mutagenicity	: negative	

BIOLOGICAL ACTIVITY

Materials and methods

The antifungal activity against a number of plant pathogens was determined by measurement of mycelial development on agar medium treated with the test compound.

For glasshouse tests, small seedlings, seeds or soils were treated with the chemical before or after inoculation. After inoculation, the degree of infection was determined by visual estimation and % control was then calculated by comparison with untreated plants.

All field trials were laid down as randomised block designs with 3 replicates. Plot sizes varied with the crops: pome fruits, 1-2 trees; grapes, 2-4 plants; cereals, 4 x 5m; roses, 5 plants; chrysanthemums, 2 rows x 2m. Fungicides were applied at 2000-3000 l/ha to pome fruits and grapes, and at 1000-2000 l/ha to cereals and ornamentals by knapsack sprayer.

For seed treatment trials, seeds were dressed at a dose of 1-4g wettable powder formulation per kg seed by shaking in polyethylene bag. Assessment of disease levels was made by estimating the disease severity on leaves and fruits or by counting the infected plant parts.

A 15 % WP formulation of HF-6305 was used in all trials except on ornamental crops which were treated with 5 % EC.

Results

Laboratory and glasshouse tests

HF-6305 showed a broad spectrum of activity. It was highly active *in vitro* and *in vivo* against most of economically important fungi of the Ascomycetes, Basidiomycetes and Deuteromycetes. It had little activity against Phycomycetes fungi.

Very high levels of activity were obtained against all tested powdery mildews, *Cochliobolus*, *Elsinoe*, *Mycosphaerella*, *Venturia*, all rusts, *Cercospora*, *Cladosporium* and *Phomopsis*. Interesting levels of activity were also observed against *Monilinia*, *Taphrina*, *Phoma*, *Pseudocercosporella*, *Rhynchosporium* and *Septoria* (Table 1). Results are expressed as concentration giving 50 % inhibition of growth (EC50 value) and as a disease control index (1-5 scale) at 100 mg/l.

In glasshouse tests, HF-6305 had excellent protective, curative, residual and rainfall resistant activities against wheat brown rust (*Puccinia recondita*) at a very low rates application (Table 2). The effectiveness was superior to that of the standard triadimefon.

HF-6305, when applied to the soils, was not taken up by the roots. To assay local systemic activity in leaf, the proximal or the distal half surface of wheat leaf was treated with the compound and non-treated part was inoculated by spraying a spore suspension of *P. recondita*. Movement within the leaf provided very good protection to the upper distal untreated part and moderate protection to the proximal part.

TABLE 1

Fungicidal activity of HF-6305 in laboratory (in vitro) and glasshouse (in vivo) tests*

Pathogen	In vitro EC50 mg/1	In vivo activity at 100 mg/1**	
PHYCOMYCETES			
Phytophthora capsici	>100	1	s
Pythium iwayamai	>100	1	s
ASCOMYCETES			
Cochliobolus miyabeanus	0.8	5	s
Elsinoe ampelina	0.4	nt	
Erysiphe graminis f. sp. hordei	-	5	s
Erysiphe graminis f. sp. tritici	-	5	s
Glomerella cingulata	0.5	2	s
Monilinia fructicola	0.1	4	s
Mycosphaerella fragariae	nt	5	s
Podosphaera leucotricha	-	5	s
Pyrenophora graminea	0.1	nt	
Sclerotinia sclerotiorum	3.0	1	s
Sphaerotheca fuliginea (cucumber)	-	5	s
Taphrina deformans	0.1	nt	
Valsa ceratosperma	0.5	2	s
Venturia inaequalis	0.05	5	s
Venturia nashicola	0.08	5	s
BASIDIOMYCETES			
Coriolus versicolor	0.1	nt	
Corticium rolfsii	2.3	2	sd
Puccinia recondita	-	5	s
Puccinia horiana	-	5	s
Typhula incarnata	0.8	3	s
DEUTEROMYCETES			
Alternaria mali	1.0	3	s
Botrytis cinerea (cucumber)	0.6	4	s
Cercospora beticola	1.0	5	s
Cladosporium cucumerinum	0.03	5	s
Fusarium moniliforme	1.5	2	st
Fusarium nivale	>100	2	s
Fusarium oxysporum f. sp. cucumerinum	>100	2	sd
Gloeosporium theae-sinensis	0.1	nt	
Phoma asparagi	2.5	5	s
Phomopsis sp. (peach)	0.01	4	s
Pseudocercosporella herpotrichoides	0.2	5	s
Pyricularia oryzae	3.4	2	s
Rhizoctonia solani (rice)	5.0	3	s
Rhynchosporium secalis	0.4	5	s
Septoria tritici	0.4	nt	
Verticillium dahliae	10	3	sd

* - : not applicable, nt : not tested

** rating 1 : ≦39%, 2 : 40-69%, 3 : 70-89%, 4 : 90-99%, 5 : 100%
methods s : spraying, sd : soil drench, st : seed treatment

TABLE 2

Preventive, curative, residual and rainfall resistant activities of HF-6305 against wheat brown rust (Puccinia recondita)

Treatment (ppm)	% disease control										
	Preventive 1 day*			Curative 3 days			Residual 5 days		Rainfall resistance**		
	10	5	2.5	10	5	2.5	10	2.5	10	5	2.5
HF-6305	100	99	95	100	97	86	99	94	100	99	94
Triadimefon	89	80	68	94	81	64	53	26	87	79	57
Untreated		(34)***			(38)		(34)			(42)	

* Interval between application of compound and inoculation

** Artificial rainfall (25 mm/30 min) was treated at 1 hour after application and inoculated one day later

*** Number of lesions per leaf

Field trials

Apples

HF-6305 has been tested at doses of 2.5-7.5g a.i./hl on a 14 day preventive spray schedule for the control of apple scab (Venturia inaequalis). Excellent control of leaf and fruit infections has been given with HF-6305 at 5g a.i./hl. The activity was equal to or superior to that of the standard bitertanol. At 3.8g a.i./hl, the compound also gave good control of apple scab. Under severe disease pressure, a dosage of more than 5g a.i./hl was required to control fruit scab.

TABLE 3

Control of apple scab (Venturia inaequalis)

Treatment	Dose (g a.i./hl)	% disease control				
		Trial 1 (Senshu)		Trial 2 (Red Gold)		
		Cluster	Terminal	Cluster	Terminal	Fruit
HF-6305	2.5	95	99	-	-	-
HF-6305	3.8	97	100	94	98	89
HF-6305	5.0	97	99	97	100	98
HF-6305	7.5	99	100	100	100	98
Bitertanol	2.5	87	89	-	-	-
Bitertanol	3.8	93	98	91	94	89
Bitertanol	5.0	96	95	99	99	96
Bitertanol	7.5	98	98	99	100	100
Captan + binapacryl	100 + 25	71	67	63	94	84
Untreated		(25)*	(16)	(35)	(56)	(48)

* % of infected leaves or fruits

In addition to apple scab, apple powdery mildew (Podosphaera leucotricha), apple rust (Gymnosporangium yamadae) are also major diseases of apples in Japan. Official field trials since 1985 by Japan Plant Protection Association (JPPA) have confirmed that HF-6305 had also very good activities against both diseases as similar to apple scab. No evidence of phytotoxic effects on foliages or fruits was noted (Table 4).

TABLE 4

Control of powdery mildew (Podosphaera leucotricha) and rust (Gymnosporangium yamadae) on apples, Japan 1985-1987

Treatment	Dose (g a.i./hl)	% disease control* Powdery mildew Primary	Rust Leaf
HF-6305	7.5	96	100
Captan + binapacryl	100 + 25	76	-
Dithane M-45	125	-	61
Untreated	-	(59)**	(49)

* Spray schedule p. mildew : 10-16 days; rust : 8-14 days
** Infected leaves

Japanese pears

When applied on a 14 day schedule, HF-6305 provided outstanding control of scab (Venturia nashicola) and rust (Gymnosporangium asiaticum) at a low rate application. Its efficacy was similar on leaf and fruit infections and was equal to or better than that of standard bitertanol (Table 5).

TABLE 5

Control of scab (Venturia nashicola) and rust (Gymnosporangium asiaticum) of Japanese pears

Treatment	Dose (g a.i./hl)	% disease control Scab Leaf	Scab Fruit	Rust Leaf
HF-6305	1.9	-	-	100
HF-6305	2.5	99	98	100
HF-6305	3.8	100	100	100
HF-6305	5.0	100	100	100
Bitertanol	1.9	-	-	96
Bitertanol	2.5	99	82	100
Bitertanol	3.8	99	95	-
Bitertanol	5.0	98	100	100
Untreated	-	(60)*	(20)	(41)

* % of infected leaves or fruits

Grapes

The activity against powdery mildew (Uncinula necator) and anthracnose (Elsinoe ampelina) was evaluated in Shizuoka Experimental Farm and official field trials by JPPA. A selection of results is shown in Table 6. Excellent control of powdery mildew has been given with HF-6305 at 7.5g a.i./hl. Its efficacy was superior to that of the standard triflumizole.

Recently, a serious occurance of grape anthracnose developed all over Japan as a result of the prohibiting the use of pentachlorophenol which used to be applied in dormant period and an early registration of new effective fungicides has been needed. HF-6305 gave excellent control of grape anthracnose. A dose of 3.8g a.i./hl was adequate to control infection on leaves and bunches. No phytotoxicity has been noted on any of the main grape varieties.

TABLE 6

Control of powdery mildew (Uncinula necator) and anthracnose (Elsinoe ampelina) of grapes, Japan 1987

Treatment	Dose (g a.i./hl)	% disease control* Powdery mildew Bunch	Anthracnose Leaf	Anthracnose Bunch
HF-6305	3.8	-	84	99
HF-6305	5.0	-	87	99
HF-6305	7.5	97	92	99
HF-6305	15	100	87	99
Triflumizole	15	82	-	-
Dithane M-45	94	-	44	70
Untreated	-	(47)**	(31)	(66)

* Spray schedule mildew : 12-16 days; anthracnose : 10-14 days
** % of infected leaves or bunches

Cereals

In two years of field trials, HF-6305 gave excellent control of seed-borne bunt (Tilletia caries) on wheat as a seed treatment (Table 7). The effective dose was extremely low and 15g a.i./100kg seed resulted in almost complete control. No phytotoxicity was observed even at 120g a.i./100kg seed.

When applied as a foliar fungicide, HF-6305 gave statistically significant control of a range of diseases including eyespot (Pseudocercosporella herpotrichoides), glume blotch (Septoria nodorum), brown rust (Puccinia recondita) on wheat, leaf blotch (Rhynchosporium secalis) on barley and mildew (Erysiphe graminis) on both crops. HF-6305 gave particularly good control of brown rust and leaf blotch.

TABLE 7

Control of wheat bunt (Tilletia caries) by seed treatment

Treatment	Dose g a.i./ 100kg seed	% disease control 1987	1988
HF-6305	15	96	92
HF-6305	30	100	97
HF-6305	60	100	97
Triflumizole	30	-	66
Triflumizole	60	100	97
Triflumizole	120	100	94
Untreated	-	(9)*	(49)

* % of ear infection

Ornamentals

Fungicides were applied to run-off at weekly intervals. Infection on unsprayed plants were severe in both trials. On rose, 5-7.5g a.i./hl of HF-6305 gave excellent control of rose black spot. On chrysanthemum, 7.5 g a.i./hl showed good activity against rust (Table 8).

TABLE 8

Control of rose black spot (Diplocarpon rosae) and chrysanthemum white rust (Puccinia horiana)

Treatment	Dose (g a.i./hl)	% disease control Black spot	Rust
HF-6305	5.0	98	-
HF-6305	7.5	100	93
HF-6305	15	100	95
Bitertanol	15	98	94
Triforine	15	100	72
Untreated	-	(98)*	(107)**

* Disease severity
** Number of lesions per leaf

Other crops

HF-6305 showed good efficacy against many other diseases in field trials. Some of these are summarized in Table 9.

TABLE 9

Crop	Disease (Pathogen)	Dose (g a.i.)
Apple	Sooty blotch (Gloeodes pomigena)	5-7.5/hl
Peach	Brown rot (Monilinia fructicola)	15/hl
Peach	Scab (Cladosporium carpophilum)	5-7.5/hl
Japanese apricot	Scab (Cladosporium carpophilum)	7.5/hl
Tea	Anthracnose (Colletotrichum theae-sinensis)	7.5-15/hl
Tea	Blister blight (Exobasidium vexans)	7.5-15/hl
Sugar beet	Cercospora leaf spot (Cercospora beticola)	150/ha
Peanut	Brown leaf spot (Cercospora arachidicola)	150/ha
Peanut	Leaf spot (Cercospora personata)	150/ha
Phaseolus bean	Rust (Uromyces appendiculatus)	50/ha
Cucurbits	Powdery mildew (Sphaerotheca fuliginea)	7.5-15/hl
Cucurbits	Scab (Cladosporium cucumerinum)	7.5-15/hl
Tomato	Leaf mold (Cladosporium fulvum)	7.5-15/hl
Asparagus	Stem blight (Phoma asparagi)	7.5-15/hl
Turf	Rust (Puccinia zoysiae)	25/ha

CONCLUSIONS

1. HF-6305 has given excellent control of a range of diseases affecting economically important agricultural crops at a low rate application.

2. HF-6305 has not been phytotoxic in any trials, thus it can be recommended without particular restriction for use on fruits, vegetables, cereals and ornamentals.

3. On grapes, HF-6305 gave excellent control against anthracnose at a low rate application coupled with good activity against powdery mildew. Among many azole fungicides, a specific feature is good activity against anthracnose.

4. To reduce ratio of resistance developing, work has been conducted on various mixtures with other types of fungicide.

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CGA 80000 : A NEW PHENYLAMIDE FUNGICIDE AGAINST SOIL-BORNE PERONOSPORALES

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ABSTRACT

CGA 80000 is a new systemic phenylamide fungicide with specific activity against plant pathogens of the Order Peronosporales. It is being developed by Ciba-Geigy Limited for use against soil-borne *Phytophthora* and *Pythium* spp. causing root and lower stem disorders of a range of crops including tobacco, citrus, avocado, pimento, carrots, soft fruits and ornamentals.

In the soil it is less mobile, more stable and less subject to microbial degradation than metalaxyl. It is taken-up very rapidly by roots and higher concentrations are achieved in the root tissues than for metalaxyl. These properties, together with its higher biological activity, ideally suit its use as a soil fungicide. It offers benefits in permitting lower rates of use or reduced numbers of applications compared with other phenylamides and gives a high reliability of performance.

INTRODUCTION

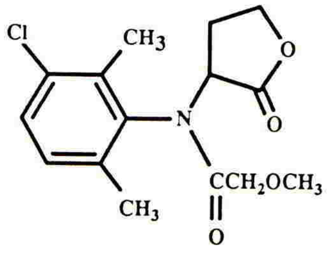
CGA 80000 is the code number for α-[N-(3-chloro-2,6-xylyl)-2-methoxyacetamido]-γ-butyrolactone, a new phenylamide fungicide discovered and patented by Ciba-Geigy Ltd., Basle, Switzerland. Its biological and physico-chemical properties ideally suit its use as a soil-applied fungicide for the control of soilborne *Pythium* and *Phytophthora* spp. on crops where protection from these pathogens is required for relatively long periods.

It will be introduced under the trade name "Vangard" [R] in a suspension concentrate formulation containing 400 g a.i./litre and as a granule containing 20 g a.i./kg.

CHEMICAL AND PHYSICAL PROPERTIES

Common name: not yet established

Structural formula:



Chemical name: α-[N-(3-chloro-2,6-xylyl)-2-methoxyacetamido]-γ-butyrolactone

Molecular formula: $C_{15}H_{18}ClNO_4$

Molecular weight: 311.77

Melting point: 94.9°C

Vapour pressure at 20°C: 5.0×10^{-7} Pa (3.8×10^{-9} mm Hg)

Solubility in water at 20°C:	680 ppm
Partition coefficient:	log P = 1.55 (reverse phase TLC method)
Hydrolysis:	Half life at 20°C in buffered solution pH 1-5 stable pH 7 22 weeks pH 8 19 days
Relative Mobility Factor (RMF):	1.26 (metalaxyl 2.3)

TOXICOLOGY AND ENVIRONMENTAL STUDIES

Acute toxicity

The following values were determined in rats:

oral	LD50	808 mg/kg
dermal	LD50	greater than 2000 mg/kg
inhalation (4h)	LC50	greater than 1728 mg/m^3 lower than 5502 mg/m^3

The product is slightly hazardous (WHO classification III)

Irritation / Sensitization

The product is non-irritant to the skin and eye. It has a marginal skin sensitization potential in the guinea pig.

Environmental Toxicity

Based on acute oral toxicity studies CGA 80000 is considered to be practically non-toxic to birds, fish and bees. Concentrations occurring in soil after application of recommended rates had no effect on earthworms and no growth inhibition of the alga *Scenedesmus* was found at 3.2 mg/l, the highest concentration tested.

BIOLOGICAL ACTIVITY

Laboratory studies

The spectrum of activity comprises fungi in the Order Peronosporales. *In vitro* results for inhibition of mycelial growth of *Phytophthora* and *Pythium* spp. show CGA 80000 to be 1 to 8 times more biologically active than metalaxyl. Cross resistance exists between CGA 80000 and other phenylamides such as metalaxyl, oxadixyl, benalaxyl and ofurace, suggesting a similar mode of action.

Climate Room Studies

Uptake of CGA 80000 by the roots of pimento plants occurred very rapidly when roots were immersed in a fungicide solution. The rate of uptake was dependent upon concentration and at 250 mg/l, 50 % and full saturation in the root tissues were reached after 15 minutes and 24 hours, respectively. Concentrations in the root tissues after 24 hours were 4-6 times higher than for metalaxyl and this resulted in a longer period of protection after roots were removed from the fungicide solution.

Field Trials

Tobacco

CGA 80000 applied as a single plant drench or broadcast and incorporated into soil prior to planting has given outstanding control of tobacco black shank (*Phytophthora nicotianae* var. *nicotianae*) on very susceptible air-cured varieties under high disease pressure conditions in South Africa (Table 1). Drench treatments were more efficaceous than broadcast incorporated treatments but the latter method gave appreciably higher yields. Season-long control was obtained by a single treatment using either of the application methods.

TABLE 1

Control of tobacco black shank on 2 trial sites, South Africa 1986-1988

Treatment	Rate a.i.	Method	1986-87 % plants affected 8 WAT[2]	10 WAT	13 WAT	Yield kg/ha	1987-88 % plants affected 6 WAT	10 WAT	14 WAT
Untreated			58	86	96	0	60	100	100
CGA 80000	0.5 kg/ha	ppi[1]	9	24	46	1093	-	-	-
CGA 80000	1.0 kg/ha	ppi[1]	4	11	23	1739	-	-	-
CGA 80000	1.5 kg/ha	ppi[1]	1	3	15	2562	0	10	20
CGA 80000	0.025 g/plant	drench	10	34	59	802	-	-	-
CGA 80000	0.050 g/plant	drench	1	10	19	1567	-	-	-
CGA 80000	0.075 g/plant	drench	0	0	12	1818	0	5	7
Tukey SD	5 %					886			

[1] broadcast preplant incorporated
[2] Weeks after transplanting

Pimento (*Capsicum annuum*)

Broadcast and incorporated soil treatment with CGA 80000 prior to planting of pimento transplants gave excellent protection from root rot (*Phytophthora capsici*) in trials in Italy. Repeated applications of metalaxyl at 28-day intervals were needed to obtain a moderate level of control whereas protection for the whole cropping period was achieved with a single pre-plant application of CGA 80000 (Table 2).

TABLE 2

Mean control of root rot of pimento in 3 trials, Italy 1987

Treatment	Rate kg a.i./ha	Method	% plants affected 10 WAT[2]	12 WAT	14 WAT	16 WAT
Untreated			8	21	51	76
CGA 80000	1	ppi	1	5	20	35
CGA 80000	2	ppi	1	2	8	11
CGA 80000	4	ppi	0	1	4	5
Metalaxyl	2+2+2	ppi + band [1]	3	10	33	50

[1] Preplant broadcast incorporated followed by 30 cm band at 28 day intervals.
[2] Weeks after transplanting

Citrus

Soil treatment under the canopy of orange trees arrested the development of collar rot caused by *Phytophthora nicotianae* var. *parasitica* over a period of 18 months (Table 3). Lesion expansion was stopped and the relative size was reduced due to new growth. The condition of the foliage of untreated trees declined over the test period whereas there was a marked improvement in treated trees. CGA 80000 at 1-2 g a.i./m^2 produced a similar reponse to metalaxyl at 2 g a.i./m^2.

TABLE 3

Control of root rot and trunk rot of citrus on 2 trial sites, South Africa 1986-88

Treatment	Rate[1] (g a.i./m^2)	Navel oranges % stem circumference cankered Before treat-ment	18 months later	Valencia oranges % stem circumference cankered Before treat-ment	18 months later	Canopy condition 0-100 [2] Before treat-ment	18 months later
Untreated		42	74	50	68	80	64
CGA 80000	0.5	38	68	47	52	82	92
CGA 80000	1.0	42	42	44	52	84	90
CGA 80000	2.0	34	28	50	38	73	95
Metalaxyl	2.0	38	22	40	40	85	94

[1] Applied to the soil surface under the canopy at 6 monthly intervals.
[2] Foliage rated according to density and colour where healthy tree = 100

TABLE 4

Control of cavity spot of carrots, United Kingdom 1987-88

Treatment	Rate (g a.i./ha)	Timing	Peaty-loam soil Cavity spot Index (NIAB) 228DAD[1]	Market-able Yield t/ha 255DAD	Sandy-loam soil Cavity spot Index (NIAB) 173DAD	% mar-ketable Yield 173DAD
Untreated			29.9	37.2	19.9	86
CGA 80000	250	At drilling	9.8	51.3	3.6	100
CGA 80000	500	At drilling	6.7	45.0	2.5	100
CGA 80000	1000	At drilling	6.5	47.9	3.1	100
CGA 80000	500	4 wks after drilling	23.4	48.4	5.9	98
Metalaxyl+thiram	1200+6000	At drilling	12.3	44.0	7.1	98
Tukey SD 5 %			7.9	10.0	5.2	

Seed used in treatment plots was coated with metalaxyl + thiabendazole + iprodione at 68.5+37+205 g a.i./100 kg seed.
[1] Days after drilling

Carrots

Cavity spot (*Pythium* spp.) is a disorder which affects the quality of carrots, thereby affecting their marketability. In two trials conducted in the United Kingdom topical treatment with CGA 80000 gave superior disease control at much lower rates than metalaxyl (Table 4). Application at drilling gave better results than when treatments were applied 4 weeks after drilling, as had been observed with metalaxyl (Gladders & McPherson 1986). Assessments for disease in the trials were made using the NIAB method in which incidence of disease is multiplied by severity of disease (in six infection categories) to give a Disease Index.

Strawberries

Soil treatment or dipping of roots with CGA 80000 prior to the planting of strawberries has given excellent protection from red core disease (*Phytophthora fragariae*) until harvest in the following year. In the case of bare-root planting material, soil treatment alone at 400 g a.i./ha led to significant improvements in vigour which was enhanced when plantlets were immersed in a solution containing 10 g a.i./hl prior to planting (Table 5). The greatest responses to dip treatments were seen in plantlets which were rooted in a peat-based medium where dip treatments alone perform well but can be improved if combined with a soil treatment. The absorbent rooting medium in this case serves as a reservoir and the fungicide is less exposed to the influences of rainfall and soil type.

TABLE 5

Control of red core of strawberries, Switzerland 1987-88

	Rate a.i.	Method	Site 1 Bare-root plantlets		Site 2 Peat-rooted plantlets	
			Biomass[1] 0-100		Biomass 0-100	Total Yield (t/ha)
Rating Date			28 April	22 June	8 June	
Untreated			15	11	36	5.4
Fosetyl Aluminium	2x4 kg/ha	Foliar	59	36	76	13.9
CGA 80000	10 g/hl	Dip [2]	29	25	73	15.3
CGA 80000	400 g/ha	Soil [2]	53	61	70	16.6
CGA 80000	10 g+100 g	Dip + Soil [2]	69	44	86	17.4
CGA 80000	10 g+200 g	Dip + Soil	90	81	91	19.1
CGA 80000	10 g+400 g	Dip + Soil	90	93	91	18.9
Tukey SD 5 %						5.9
Planting date			18.8.87		12.8.87	
Foliar treatment dates			10.9.87;	7.10.87	10.9.87;	1.10.87

[1] Best plot per replicate = 100 [2] Dip and soil treatments applied on planting date

Raspberries

Raspberry root rot caused by *Phytophthora* spp. is an increasing problem in parts of France, U.K., Switzerland and Germany. Soil treatment with CGA 80000 after the removal of diseased canes and replanting with meristem-produced plants has given excellent growth responses in trials in Switzerland. During the first season, good growth responses were obtained from both metalaxyl and CGA 80000. In the second season, treatments with CGA 80000 gave the best results (Table 6).

TABLE 6

Control of *Phytophthora* root rot of raspberry, Switzerland 1987-88

	Rate (g a.i./m^2) (1 metre band)	Total shoot length in cm. November 1987	Biomass 0-100 September 1987	June 1988
Untreated		84	65	35
Metalaxyl + folpet	0.4+1.6	148	90	59
CGA 80000	0.1	120	88	79
CGA 80000	0.2	110	93	78
CGA 80000	0.4	130	90	89
Tukey SD 5%		53		

Planted: 12.6.87 Treated: 12.6.87; 15.9.87; 14.4.88

Ornamentals

In naturally infested soil supplemented with additional inoculum of *Phytophthora cinnamomi*, CGA 80000 has given an exceptionally long period of protection from root rot of *Chamaecyparis ellwoodii* (Table7). CGA 80000 was much more effective than furalaxyl both as a drench and a soil-incorporation treatment. In practice, where pot-grown plants are potted-on to larger containers, it would be necessary to drench or dip the root-ball of the transplants as well as treating the new potting soil.

TABLE 7

Control of root rot of ornamental cypress, France 1987

Treatment	Rate a.i.	Method	% plants affected 97 DAA [1]	120 DAA	160 DAA
Check non-inoculated			20	24	44
Check inoculated			63	85	100
CGA 80000	8 g/hl	soil drench	0	1	8
CGA 80000	4 mg/l	soil mix	0	0	0
Furalaxyl	50 mg/l	soil mix	30	83	93
Tukey SD 5 %			33	26	24

[1] Days after application

Soil Degradation

Enhanced microbial degradation of metalaxyl has been reported from avocado soils in South Africa and California with a history of metalaxyl use (McKenzie & Margot 1982; Bailey & Coffey 1985).

In trials carried out in South Africa using young avocado trees potted in soil naturally infested with *Phytophthora cinnamomi*, either with no previous history of metalaxyl use or with 10 years history of use, CGA 80000 gave superior responses in both situations (Table 8).

In soils with no previous history of metalaxyl use, the persistence of metalaxyl is variable (Table 9). By contrast, the persistence of CGA 80000 is consistent and is therefore more likely to result in a reliable performance and a longer period of protection. A probable explanation for the higher stability of CGA 80000 is the rigid configuration of the lactone ring combined with steric hindrance such that an esterase cannot attack as easily as it can the more flexible ester moiety of metalaxyl.

TABLE 8

Control of avocado root rot in soils with and without a history of metalaxyl use.

Treatment	Drench (g a.i./ container)	After 10 years metalaxyl use Height (cm) 12 MAT [1]	Root dry wt. (g) 18 MAT	No previous metalaxyl use Height (cm) 12 MAT	Root dry wt. (g) 18 MAT
Untreated		83.3	3.8	72.0	3.1
Metalaxyl	0.0300	83.0	3.4	105.7	10.0
CGA 80000	0.0300	99.8	11.2	122.2	15.3
CGA 80000	0.0120	93.7	7.1	108.8	7.5
CGA 80000	0.0075	96.3	9.0	96.8	9.8
Tukey SD 5 %		18.4	7.1	27.3	8.5

Containers with 6 kg of soil and single tree plots with 6 replicates

[1] Months after first treatment

TABLE 9

Persistence of CGA 80000 and metalaxyl in 9 agricultural soils at a constant 25°C and a water-holding capacity of 40 % using a bioassay method.

Country of origin	Soil type	pH	DT90[1] IN DAYS Metalaxyl	CGA 80000
Italy	Sandy loam	7.6	10	112
United Kingdom	Sandy loam	7.6	14	147
Switzerland	Loam	7.7	15	115
Switzerland	Clay loam	7.6	21	198
Spain	Loam	7.9	28	189
S. Africa	Sandy clay	7.2	32	140
Spain	Loam	8.3	49	84
Spain	Clay loam	8.0	49	160
S. Africa	Clay	6.7	125	165

[1] time taken for 90 % of a.i. to disappear

CONCLUSIONS

CGA 80000 provided outstanding control of soilborne *Pythium* and *Phytophthora* spp. on a range of crops when applied as a preplant soil incorporated treatment, as a drench or as a root dip of peat grown transplants. Best responses were obtained when it was applied protectively prior to planting.

Its greater stability, lower mobility and less liability to enhanced biodegradation in the soil together with its higher biological activity confer benefits over metalaxyl, particularly in situations where a long period of protection is required.

Season-long control is often possible by means of a single soil treatment prior to planting. Under heavy rainfall conditions, particularly on lighter soils, follow-up treatments may be necessary.

ACKNOWLEDGEMENTS

The authors are indebted to their colleagues in Switzerland and in R&D countries around the world who have contributed to the data presented in this paper.

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NC-170, A NEW COMPOUND INHIBITING THE DEVELOPMENT OF LEAFHOPPERS AND PLANTHOPPERS

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ABSTRACT

NC-170 exhibits juvenile hormone(JH)-like activity and inhibits metamorphosis selectively against leafhoppers and planthoppers. Residues of less than 1mg a.i./l inhibit insect development. Affected insects cannot complete their nymph to adult or ensuing first to second intermediate ecdysis, and subsequently die. Furthermore, this activity remains high for more than 40 days when NC-170 is sprayed on potted rice plants at 50mg a.i./l aquatic solution. These results provide encouraging prospects for the practical use of NC-170 against these important pests of paddy fields. NC-170 also has intriguing physiological effects on their pigment synthesis, reproduction, embryogenesis, diapause, and polymorphism.

INTRODUCTION

For the past two decades, juvenile hormone analogues(JHA's) have received much attention as physiological tools or pest control agents. With regards to hoppers, however, most of the physiological or biochemical roles of natural JH's have remained unclear, probably because of the small size of the insects and their unsuitability as experimental animals.

Kamm & Swenson(1973) and Reissig & Kamm(1974) demonstrated that natural JH and some JHA's inhibited the metamorphosis and terminated the adult reproductive diapause of *Draeculacephala crassicornis*. Mitsui *et al*.(1973) and Babu(1975) observed inhibition of metamorphosis by natural JH and JHA's on *Nephotettix cincticeps* and *Ne. virescens* respectively. Saxena *et al*.(1981), and Iwanaga & Tojo(1986) discussed the role of JH on polymorphism in *Nilaparvata lugens* and Chen *et al*.(1979) discussed its effects on ovarian development. However, from the practical

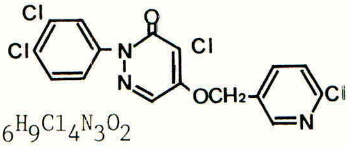
standpoint of pest control, substantial data have not been obtained, and even JHA's examined by the above-mentioned authors do not seem promising.
NC-170 is a JHA with a novel chemical structure and a new insectstatics acting selectively on hoppers. This paper discusses its biological activities and prospects for its practical use.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name: 4-chloro-5-(6-chloro-3-pyridylmethoxy)-2-(3,4-dichlorophenyl)-pyridazin-3(2H)-one

Code number: NC-170

Structural formula:



Molecular formula: $C_{16}H_9Cl_4N_3O_2$

Molecular weight: 417.1

Melting point: 180-181°C

TOXICOLOGICAL PROFILE

Acute oral (14 days)	LD_{50} rat:	>10,000mg/kg
	LD_{50} mouse:	>10,000mg/kg
Acute dermal (14 days)	LD_{50} rabbit:	>2,000mg/kg
Mutagenicity	Ames test:	negative
	micro nucleus test:	negative
Aquatic organisms		
	LC_{50}(48h) carp:	>40mg/l
	LC_{50}(48h) rainbow trout:	>40mg/l
	LC_{50}(96h) Daphnia:	>1mg/l
Irritation	rabbit eye:	non-irritating
	rabbit skin:	non-irritating

BIOLOGICAL ACTIVITIES

Effects on Metamorphosis of Leafhoppers and Planthoppers.

Activity of metamorphosis inhibition by NC-170.

NC-170 strongly inhibited the metamorphosis of 7 species of hoppers when fourth instar nymphs were released on potted rice plants sprayed with NC-170 and examined 10 days after release (Table 1).

TABLE 1

Inhibition of metamorphosis in hoppers by NC-170.

Species	IC_{50} (IC_{95}) mg a.i./l
Leafhoppers	
Nephotettix cincticeps	0.08 (0.25)
Ne. nigropictus	0.01 (0.07)
Ne. virescens	0.03 (0.13)
Recilia dorsalis	0.30 (1.50)
Planthoppers	
Laodelphax streatellus	0.25 (1.20)
Nilaparvata lugens	0.07 (0.25)
Sogatella furcifera	0.02 (0.10)

Mode of metamorphosis inhibition.

Fig. 1 schematically describes the mode of metamorphosis inhibition by NC-170. Except for some unusual coloration, fourth instar nymphs of leafhopper species treated with NC-170 ecdyse normally to fifth(final) instars. They then develop to nymphal-adult intermediates at adult ecdysis, the length of the final instar also being shortened.
For example, the 5 days mean duration of the final instar of male *Ne. cincticeps* is a little shorter than that of female (6 days). This difference between the sexes is one of the reproductive strategies of this insect. Application of NC-170 decreases the duration of males and females to 3.9 days. Having lost the character of the final instar nymph, they do not develop to normal adults. In the ensuing instar, the intermediates survive for about 5 days, and then ecdyse to second intermediates. This ecdysis is not completed, however, and results in death.
In planthopper species, the mode of metamorphosis inhibition proceeds in almost the same manner as with leafhoppers, with the exception that males and females die at different ecdyses. The ecdysis inhibition occurs mainly during the first to second intermediate ecdysis in males, and mainly during the adult ecdysis in females.

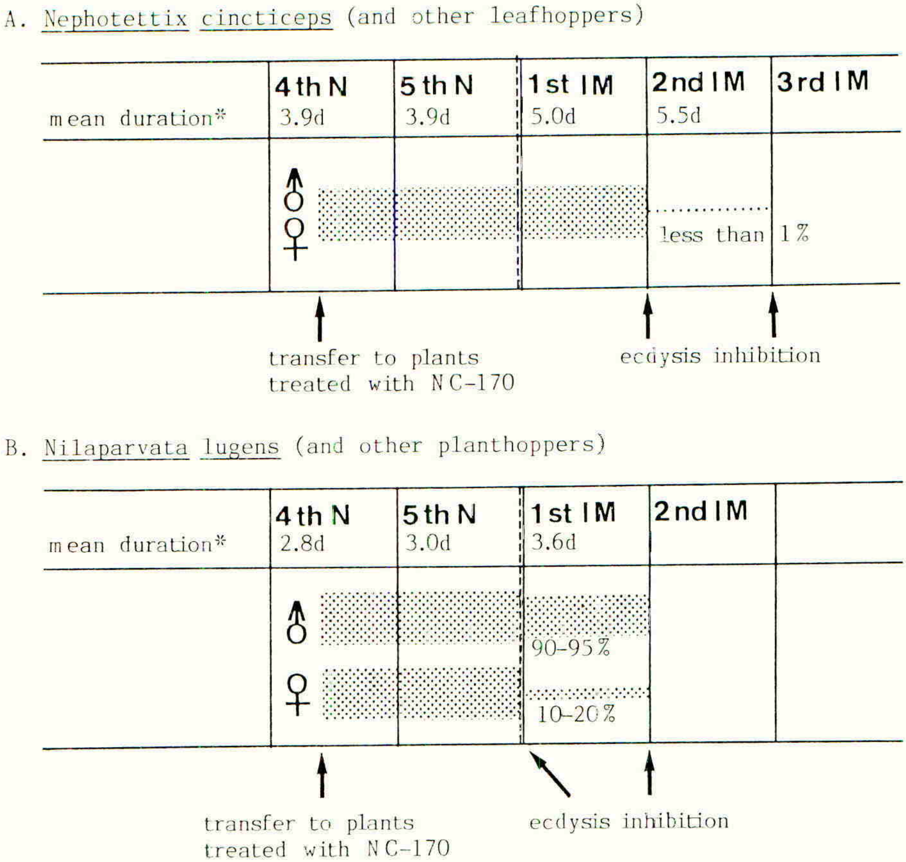


FIGURE 1

Diagrammatic representation of the mode of metamorphosis inhibition in hoppers by NC-170.

* under 25°C, 16L:8D condition

<u>Sensitivity of different stages.</u>

The sensitivity to NC-170 of *Ni. lugens* increases from first to fourth instar nymph, and rapidly decreases after fourth to fifth nymphal ecdysis (Fig. 2). The critical time of this sensitivity is within 24h of final nymphal instar. Other species of hoppers exhibit a similar pattern of sensitivity to NC-170.

<u>Residual activity.</u>

NC-170 has long residual activity on rice plants. The metamorphosis inhibiting activity of NC-170 against *Ne. cincticeps* and *Ni. lugens* remains high for more than 40 days when sprayed at 50mg a.i./l aquatic solution.

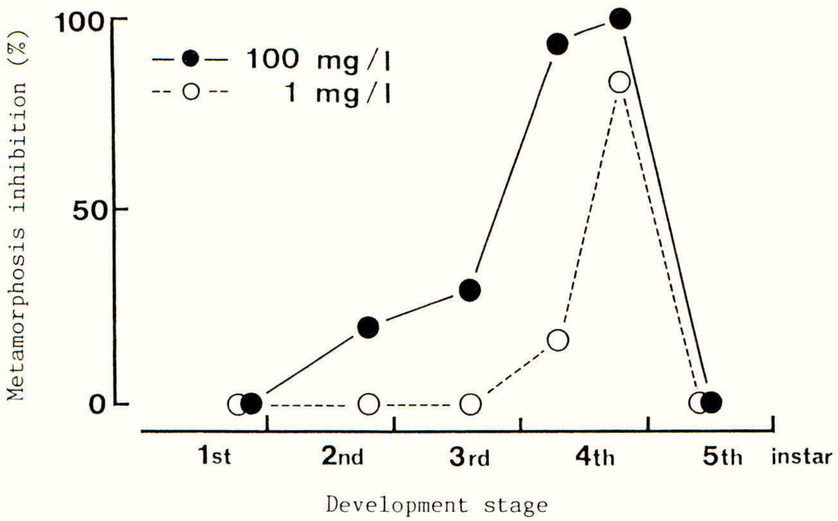


FIGURE 2

Sensitivity of different stages of Ni. lugens to NC-170, determined by exposing nymphs of fixed age to NC-170 for 24h and then rearing them on untreated rice plants until metamorphosis.

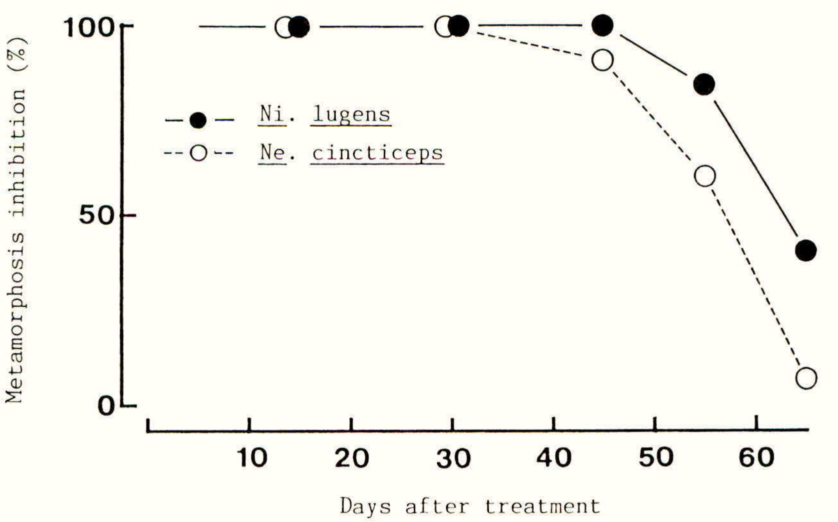


FIGURE 3

Residual activity of NC-170 determined by spraying rice plants with NC-170 at 50mg a.i./l, holding them in the glasshouse, and then releasing fourth instar nymphs on to the plants prior to assessment 10 days later.

Selectivity

NC-170 has not exhibited any sign of JH-like activity against any of 15 non-hopper species examined, except for some species at high doses (Table 2). The selectivity shown in favor of non-target organisms, mammals, fish and insects, is an important requirement of new generation insect control chemicals. Therefore NC-170 has a marked advantage and would cause little disturbance to agroecosystems.

TABLE 2

Metamorphosis inhibiting activities of NC-170 in a range of insects.

Species	IC or ID_{95}	method of application*
DYCTIOPTERA		
Blattella germanica	>50 μg	T
HEMIPTERA		
Myzus persicae	>500 mg/l	S
Pseudococcus comstocki	>500 mg/l	S
Trialeurodes vaporariorum	>500 mg/l	S
LEPIDOPTERA		
Adoxophyes sp.	>100mg/l	LD
Ephestia cautella	~100mg/l~	I
Plutella xylostella	>100mg/l	LD
Spodoptera litura	>50 μg	T
COLEOPTERA		
Callosobruchus chinensis	>500mg/l	I
Haenosepilachna vigintioctopunctata	~100mg/l~	LD
Sitophilus oryzae	>500mg/l	I
Tenebrio molitor	~500mg/l~	I
Tribolium casteneum	~500mg/l~	I
DIPTERA		
Culex pipiens palens	>1mg/l	I
Musca domestica	>500mg/l	I

* Insects were treated with NC-170 by these methods:

I: incorporation in diet or breeding media
LD: leaf dipping, S: spray, T: topical application,

Other physiological activities of NC-170.

Beside metamorphosis inhibition, NC-170 has intriguing effects on several physiological events of hoppers (Table 3).

TABLE 3

Other physiological effects of NC-170 on hoppers.

Effects	Species
Inhibition of embryogenesis	Ne. cincticeps
Stimulation of pigment synthesis	
a, melanin of cuticle	Ne. cincticeps Ne. nigropictus
b, intracellular pigment	Ne. virescens
Prevention and termination of nymphal diapause	L. streatellus
Stimulation of ovarian development	Ni. lugens
Production of brachypterous form	Ni. lugens

CONCLUSIONS

1. NC-170 is a JHA of a new chemical class.

2. NC-170 strongly inhibits metamorphosis of leafhoppers and planthoppers at low doses. NC-170 is almost inactive against many other insects, including related small homopterans.

3. Due to its high activity, allied with long foliar persistence, NC-170 is a promising candidate for control of leafhoppers and planthoppers.

4. Its high selectivity among insects and low toxicity against other organisms make NC-170 suitable for IPM programs.

5. As a JHA, NC-170 has many intriguing activities on physiological events of hoppers, which merits further detailed examination.

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CGA 169374, A NEW SYSTEMIC FUNGICIDE WITH A NOVEL BROAD-SPECTRUM ACTIVITY AGAINST DISEASE COMPLEXES IN A WIDE RANGE OF CROPS

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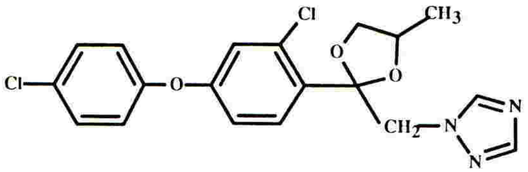
ABSTRACT

CGA 169374, is a new systemic triazole fungicide with a novel broad-spectrum anti-fungal activity that protects the yield and quality of crops by foliar and seed treatment. The compound provides long-lasting preventive and curative activity against a wide range of plant pathogenic Ascomycetes, Basidiomycetes and Deuteromycetes, including species of *Alternaria, Septoria, Cercospora, Cercosporidium, Ascochyta, Ramularia, Venturia, Guignardia, Phoma, Colletotrichum*, rust fungi, powdery mildews and several seed-borne pathogens.
The exceptionally broad-spectrum activity against the disease complexes in wheat, sugarbeet, peanuts, potatoes, pome fruit, grapes and various vegetable crops at relatively low rates (30-250 g a.i./ha) has led to significant yield increases and quality improvements in these target crops.

INTRODUCTION

CGA 169374, 3-chloro-4-[4methyl-2-(1H-1,2,4-triazol-1-ylmethyl)-1,3-dioxolan-2-yl]phenyl 4-chlorophenyl ether, is a new broad-spectrum triazole fungicide synthesized and patented by Ciba-Geigy Ltd., Switzerland. Extensive evaluation of biological performance as well as studies in toxicology and environmental behaviour have been carried out since 1984. The compound is available in a range of formulations (100 EC, 250 EC, 10 WP, 50 WP, 25 WG) and will be marketed under various trademarks including "Score"®. This paper describes the properties of CGA 169374 and its performance on several economically important crops and diseases under field conditions.

CHEMICAL AND PHYSICAL PROPERTIES

Common Name:	not yet established
Chemical Name (IUPAC):	3-chloro-4-[4methyl-2-(1H-1,2,4-triazol-1-ylmethyl)-1,3-dioxolan-2-yl]phenyl 4-chlorophenyl ether
Structural Formula:	
Molecular Formula:	$C_{19}H_{17}Cl_2N_3O_3$
Molecular Weight:	406.27
Appearance:	white crystalline solid
Melting Point:	76°C
Vapour Pressure:	1.2×10^{-7} Pa (9×10^{-10} Torr) at 20°C
Solubility at 20°C:	5 mg/l in water very soluble in most organic solvents
Partition coefficient:	Log P 4.3 (by reverse phase-TLC)

TOXICOLOGY AND ENVIRONMENTAL STUDIES

Mammalian Toxicity

Acute oral LD_{50}	rat	1453 mg/kg
Acute dermal LD_{50}	rabbit	greater than 2010 mg/kg
Irritation:	rabbit	non-irritant to skin and eye
Sensitization:	guinea pig	no skin sensitization

The product is slightly hazardous (WHO classification III)

Toxicity to wild-life

Practically non-toxic to birds

Practically non-toxic to earthworms

In laboratory trials CGA 169374 is toxic to fish

BIOLOGICAL ACTIVITY

Materials and methods

Cereals

All trials reported had plot sizes of 18-50 $\cdot$ m^2 with 4 replications using randomized complete block design. Spray volume was 300-500 l/ha. Applications were made with a hand-held or tractor-mounted boom. Disease assessments were made by estimating disease severity on leaves and ears.

Grapes, pome fruit

Plot sizes were 10-15 plants in grapes and 2-4 trees in pome fruit trials with 3-4 replications in randomized complete block design. Spray volume was 600-1000 l/ha in grapes and 1200-2000 l/ha in pome fruit. Efficacy was assessed by counting the number of infected plant parts and/or estimating disease severity on leaves and fruits. The effect on grape fermentation and wine taste was evaluated.

Sugarbeet, peanuts, potatoes, vegetable crops

Plot sizes were 15-25 m^2 with 3-4 replications in randomized complete block design. Spray volume ranged from 300-600 l/ha, and in tomatoes up to 1200/ha. Applications were made by tractor-mounted or hand-held boom on field crops and with spray-gun in some vegetable crops.

Statistical analysis was by analysis of variance and restricted LSD. In the tables, values in the same group of data followed by a common letter are not significantly different at $\underline{P}$ = 0.05.

Results and discussion of field trials

Sugarbeet

Severe attack of *Cercospora beticola* was excellently controlled by CGA 169374 at 75-125g a.i./ha with a 3-spray schedule at 14- to 18-day intervals. CGA 169374 was superior to standard products (Table 1). Two sprays at 21-day intervals at 75-125 g a.i./ha provided excellent control of other sugarbeet diseases including *Ramularia beticola, Uromyces betae* and *Erysiphe betae*. All treatments of CGA 169374 resulted in sugar yields superior to the standards (Table 2).

TABLE 1

Control of *Cercospora beticola* on sugarbeet and influence on yield
(Average of 8 trials in Italy in 1986-87)

Treatment	Dose (g a.i./ha)	*C. beticola* % attacked leaf surface	Yield (t sugar/ha)
CGA 169374	75	7	12.35
CGA 169374	125	4	12.26
Propiconazole	156	17	11.55
+ TPTA	255		
TPTA	360	21	11.41
Untreated		65	9.60

(TPTA = fentin acetate)

TABLE 2

Control of *Ramularia beticola*, *Uromyces betae* and *Erysiphe betae* in sugarbeet
(Results from France and Germany in 1985-86, 2 applications in all trials)

Treatment	Dose (g a.i./ha)	Mean % attack *R. beticola* [1]	*U. betae* [1]	*E. betae* [2]	Yield [1] (t sugar/ha)
CGA 169374	75	5	0	0.2	12.67
CGA 169374	125	2	0	0.0	13.14
TPTA	420	35	-	-	11.76
Sulphur + TPTH	4830 + 245	-	22	1.0	-
Untreated		58	46	22.0	11.12

(TPTH = fentin hydroxide, TPTA = fentin acetate)
[1] Results are means of 2 trials
[2] Mean of 8 trials

Wheat

CGA 169374 was evaluated for the control of ear and foliar diseases in major cereal growing countries. Rates of 125-250 g a.i./ha, applied once at growth stage 55-69, provided high-level control of *Septoria nodorum*, *Septoria tritici*, *Puccinia* spp. and sooty moulds (caused by several pathogens), which was superior to standard products, and was reflected in a high grain yield (Table 3). Activity against powdery mildew (*Erysiphe graminis*) and tan spot (*Pyrenophora tritici-repentis*) was equal to or slightly inferior to that of propiconazole.

TABLE 3

Control of ear and foliar diseases on wheat with a single application at growth stage 55-69 (Results from France, Germany and Switzerland in 1985-87)

Treatment	Dose (g a.i./ha)	Mean % attack *Septoria* spp. leaf	ear	*P. recondita* leaf	Sooty moulds ear	Mean yield (t/ha)
CGA 169374	125	8	12	3	15	7.51
CGA 169374	250	6	8	2	7	7.61
Propiconazole	125	9	18	10	16	7.27
Triadimenol	125	12	17	6	23	7.22
+ anilazine	1920					
Untreated		32	52	22	50	6.57
Number of trials		3	4	2	3	5

Peanuts

CGA 169374 has a wide spectrum of activity on foliar diseases of peanuts. It provides a high level of control of early leaf spot (*Cercospora arachidicola*), late leaf spot (*Cercosporidium personatum*), web blotch (*Phoma arachidicola*), scab (*Sphaceloma arachidis*) and rust (*Puccinia arachidis*). At rates of 125 g a.i./ha in 14-day intervals, control of the leaf spot diseases, web blotch, scab and rust was superior to the standard products. Yield increases were associated with disease control achieved by CGA 169374.

TABLE 4

Control of peanut diseases and impact on yield (Results from Brazil in 1985-87, rust trials from ZA and RI 1986-87)

Treatment	Dose (g a.i./ha)	Mean % leaf surface affected leaf spot	*Phoma*	*Sphaceloma*	*Puccinia*	Mean yield (kg/ha)
CGA 169374	125	2.8	3.6	2	11	3531 a
Chlorothalonil	1250	11.6	22.7	52.5	29	3087 ab
Propiconazole	125	4.4	25.6	44	-	2945 ab
Untreated		81.9	60.7	90	49	1945 c
No. of trials		8	3	2	5	4

Potatoes

CGA 169374 provided an outstanding control of early blight (*Alternaria solani*) in potatoes. Rates of 62.5 g a.i./ha at 7-day intervals or 100 g a.i./ha at 10-day intervals provided significantly better early blight control and yield than the standard. Mixtures with chlorothalonil did not improve the activity of CGA 169374 (Table 5). The results indicate that even under severe disease pressure excellent control can be achieved when applied at 7- to 10-day intervals. Spray intervals of 14 days require a dose rate of 125-250g a.i./ha for adequate control and should only be used under low to moderate disease pressure. Significant yield increases over the standard product were achieved.

TABLE 5

Control of *Alternaria solani* on potatoes at different spray intervals
(Mean of 7 trials, Brazil 1987)

Treatment	Dose (g a.i./ha)	Spray interval	% leaf surface affected 25 DAA	32 DAA	39 DAA	Yield (t/ha)
CGA 169374	62.5	7 days	2	3	5	27.21a
CGA 169374	75	7 days	2	2	3	27.10a
CGA 169374 + chlorothalonil	62.5 1000	7 days	2	3	4	27.81a
CGA 169374	100	10 days	2	5	7	26.95a
CGA 169374	125	10 days	2	4	5	27.09a
CGA 169374 + chlorothalonil	100 1000	10 days	2	4	6	27.42a
Chlorothalonil	1250	7 days	18	43	80	23.70b
Untreated			39	82	100	21.55b

(DAA = days after first application; first application 25-30 days after planting)
7-day intervals = 6 sprays
10-day intervals = 4 sprays

Apples

CGA 169374 was extensively evaluated in different disease situations and important apple growing countries around the world. Under high disease pressure CGA 169374 showed excellent protective and curative control of *Venturia inaequalis*. Rates of 2.5-5.0 g a.i./hl at 7- to 12-day intervals or 5-10 g a.i./hl at 14-day intervals from green-tip to 10 mm fruit size provide consistant high scab control. At high scab pressure, 14-day spray intervals appear to be too long (Table 6). Post-infection treatments applied according to scab forecasting systems with 2.5-3.75 g a.i./hl provide the required curative activity. Only 3-5 curative sprays were applied versus 7-10 sprays of a protective schedule (Table 7).

TABLE 6

Control of *Venturia inaequalis* on apples with a protective spray schedule at standard and extended spray intervals. (Trial Italy, 1987, cv. Stark Spur)

Treatment	Dose (g a.i./hl)	Spray interval	% leaves affected 13 May*)	2 June	% fruits affected 1 July
CGA 169374	2.5	7 days	2	1	1
CGA 169374	3.75	7 days	0.3	0	1
CGA 169374	5	7 days	0	0	0
Penconazole + Chlorothalonil	3.2 46.8	7 days	9	9	7
Mancozeb	160	7 days	17	19	50
CGA 169374	5	14 days	3	11	5
CGA 169374	10	14 days	7	1	5
Flusilazole	4	14 days	17	49	51
Untreated			76	100	100

*)Date of assessment
Number of sprays until June 18: 7-day intervals = 11 sprays
14-day intervals = 6 sprays

TABLE 7

Post-infection activity (96 hours) against *Venturia inaequalis* in different disease situations (Italy and The Netherlands, 1987)

Treatment	Dose (g a.i./hl)	1 trial Italy % leaves affected	Mean of 2 trials NL % leaves affected	Mean of 2 trials NL % fruits affected
CGA 169374	2.5	-	1.6	0.6
CGA 169374	3.75	7	-	-
Pyrifenox	5 *	28	3.4	5.2
Flusilazole	4	19	-	-
Bitertanol	25/20	21	3.7	5.1
Penconazole + captan	2.5 67.5	-	3.6	4.2
Untreated		95	25.6	31.5
Spray schedule		5 sprays from 11April-12 June	3 sprays between 10 April-5 June	

* Pyrifenox 6.25 g in trials NL

Good protective and curative activity against apple powdery mildew (*Podosphaera leucotricha*) was obtained with 2.5-10 g a.i./hl, although the activity was somewhat weaker than that of penconazole (Table 8). *Alternaria mali* is well controlled at rates of 5-10 g a.i./hl (Table 9). In the same trials leaf rust (*Gymnosporangium* spp.) was also controlled. CGA 169374 is therefore active against all major diseases of apples and it is safe even at 2-4 times the effective dose rate.

TABLE 8

Control of *Podosphaera leucotricha* in apples (Trial Switzerland, 1986, cv. Idared)

Treatment	Dose (g a.i./hl)	% curative activity on primary infected shoots	% secondary leaf infection	% infected terminal buds end of season
CGA 169374	2.5	65	30	18
CGA 169374	5.0	90	17	9
CGA 169374	10.0	93	9	6
Penconazole	2.5	97	4	1
Sulphur	480/240	20	50	27
Untreated		0	96	76

Spray interval 10-18 days

<u>Grapes</u>

Preventive spray programmes with CGA 169374 at 14-day spray intervals provided excellent control of grape powdery mildew (*Uncinula necator*), black rot (*Guignardia bidwellii*) and rot brenner (*Pseudopezicula tracheiphila*). Rates of 3-5 g a.i./hl (30-50 g a.i./ha) were equal to or superior to the standards (Table 10). Against black rot, curative activity of up to 7 days was demonstrated with 3-5 g a.i./hl.

TABLE 9

Control of *Alternaria mali* on apples
(Results from Japan and South Korea in 1985-86, cv. Starking)

Treatment	Dose (g a.i./hl)	Japan % leaves affected 17 July	2 September	South Korea % leaves affected 22 July	% defoliation [1] 17 September
CGA 169374	2.5	1	2	-	-
CGA 169374	5	2	3	4	12
CGA 169374	10	1	3	3	7
Captan	100	5	21	-	-
+ binapacryl	25				
Polyoxin	10	-	-	3	60
Untreated		25	70	24	85
Number of sprays		7 sprays		10 sprays	
Spray intervals		10-14 days		7 days	

[1] Premature leaf drop due to *A. mali*

TABLE 10

Control of *Uncinula necator*, *G. bidwelli* and *P. tracheiphila* on grapes
(Trials from South Africa and France in 1986-87)

Treatment	Dose (a.i./hl)	Powdery mildew % severity of bunch attack	Powdery mildew % leaves affected	Black rot % severity of bunch attack	Number of leaves affected by rot brenner/plot
CGA 169374	3 *	3.7	5.9	0.5	5
CGA 169374	5	2.5	4.4	-	-
CGA 169374	10	1.5	2.3	0	-
Penconazole	2.5	2.8	4.0	-	-
Flusilazole	3	-	-	0.5	2
Mancozeb	280	-	-	10.5	8
Untreated		57.4	66	46.7	120
Number of trials		3	3	3	3
Country		ZA	ZA	F	F

* CGA 169374 2.5 g in trials ZA

<u>Vegetable crops</u>

CGA 169374 at 125 g a.i./ha provided an excellent control of *Alternaria solani* on tomato and *Alternaria porri* in onions at spray intervals of 7-10 days. On tomato it also controls *Septoria lycopersici*. Rates of 125 g a.i./ha at 14-day intervals gave high level of control of *Septoria apii* in celery, *Ascochyta fabae* on broad beans, *Cercospora capsicicola* on chilli and *Uromyces appendiculatus* on beans. *Colletotrichum lindemuthianum* on beans is well controlled with 125 g a.i./ha but mixing with chlorothalonil provided an increase of healthy pods and yield (Table 11). CGA 169374 was generally safe on all vegetable crops tested.

TABLE 11

Control of leaf spot diseases, rust and anthracnose on various vegetable crops (Results from Brazil, Indonesia, Malaysia, Italy, Spain, South Africa in 1986-87)

Treatment	Dose g a.i./ ha	*Alternaria* tomato	onions	*Septoria* celery	*Ascochyta* beans	*Cercospora* chilli	*Uromyces* beans	*Colletotrichum* beans
		% attack						
CGA 169374	75	14	-	7	-	5	5	13
CGA 169374	125	9	8	2	8	4	4	9
Chlorothalonil	1500[1]	21	26	14	20	13	-	17
Mancozeb	1600	31	-	-	-	18	9	-
Untreated		63	62	55	38	58	18	45
Number of trials		13	7	5	2	3	3	5

[1] Chlorothalonil 1250 g in onions

CONCLUSIONS

The broad spectrum and the high level of activity of CGA 169374 ensures excellent control of economically important diseases in sugar beet, wheat, peanuts, pome fruit, grapes, potatoes and vegetable crops. Other crops and diseases need further investigation.

In wheat the product is especially suited for the control of the late season disease complex with one application at growth stages 55-69.

CGA 169374 combines a long-lasting protective and strong curative activity which is especially well demonstrated on apple scab and grape black rot. These properties allow more flexibility in application timing. Apple scab control according to scab predictors is particularly feasible for regions with a limited number of infection periods.

CGA 169374 provides exceptional activity on diseases caused by *Alternaria* spp. in potatoes, onions, apples and other crops.

Although CGA 169374 alone will provide protection against the major diseases as described in this paper, it may be desirable in some crops to apply CGA 169374 in mixture with suitable residual fungicides to complement its activity and/or to counteract the development of resistance.

ACKNOWLEGEMENTS

The authors are indebted to their colleagues in Switzerland and in R & D countries round the world who have contributed to the data presented in this paper.

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ICIA0001 : A NOVEL BENZAMIDE FUNGICIDE

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ABSTRACT

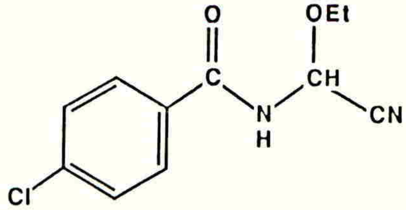
ICIA0001 is a systemic benzamide fungicide with excellent activity against a range of Oomycete pathogens. Glasshouse data are presented to demonstrate the outstanding curative, penetrant and distributive properties of the molecule. Field studies demonstrate its high level of performance against Oomycete pathogens on vines, potatoes, tomatoes, cucurbits, hops and cocoa.

INTRODUCTION

ICIA0001 ((RS)-4-chloro-N-[cyano(ethoxy)methyl]benzamide) is a new highly active systemic fungicide for the control of a broad spectrum of Oomycete pathogens. It is most effectively used in combination with a protectant molecule, in order to complement the curative and distributive properties of ICIA0001 with a persistent protectant action and to reduce the risk of resistance development. The molecule was synthesised at the Jealott's Hill Research Station of ICI Agrochemicals and is available in a number of wettable powder formulations, either alone or in mixture with a protectant component.

CHEMICAL AND PHYSICAL PROPERTIES

Structural formula :



Molecular formula	: $C_{11}H_{11}ClN_2O_2$
Molecular weight	: 238.7
Density	: 1.34 g/cm^3 at 25°C.
Vapour pressure	: 4.7 x 10^{-9} kPa at 20°C
Appearance	: light brown crystalline solid
Melting point	: 111°C
Solubility (g/l at 20°C)	: water 0.167 (pH 5.3) methanol 272, acetone >500 dichloromethane 271, toluene 26, ethyl acetate 336, hexane 0.12

Hydrolysis in water : ICIA0001 is hydrolysed in water with a half-life of 18 days at pH 5, and 6 days at pH 7.

Storage stability : stable for at least 9 months at ambient temperatures.

TOXICOLOGY AND ENVIRONMENTAL STUDIES

ICIA0001 has low toxicity to mammals, birds, bees and other wildlife species and is classified as a mild eye irritant. It is rapidly excreted by mammals with no significant retention in organs or tissues. It is not mutagenic.

TABLE 1

Toxicology data

Acute Toxicity		Species	Rate
Oral	Median lethal dose	Rat (Male)	526 mg/kg
Oral	" " "	Rat (Female)	775 mg/kg
Dermal	" " "	Rat	>2000 mg/kg
Oral	" " "	Mallard Duck	>2100 mg/kg
Contact	" " "	Honey Bee	>200 µg/bee
24 hour EC50[1]		<u>Daphnia</u>	5.65 mg/l

[1] Concentration required to immobilise half of the population after 24h exposure to the chemical.

Residues of ICIA0001 in grapes treated with recommended rates have been very low (<0.01 to 0.02 mg/kg). Degradation in soils under laboratory conditions is rapid (half-life from 2 to 10 days), and mobility very low.

BIOLOGICAL ACTIVITY

<u>Materials and Methods</u>

The activity of ICIA0001 against a range of Oomycete pathogens was determined <u>in-vitro</u> on V-8 juice agar by measuring radial extension after 3-5 days on treated and untreated agar.

Glasshouse tests were carried out on young vine seedlings with 3-6 leaves, under controlled environmental conditions. Chemicals (technical material) were dissolved in acetone and diluted appropriately in water before being applied either as a root drench, or as a foliar spray to test plants. Plants were inoculated with a sporangial suspension (10,000 spores/ml) either after chemical treatment (protectant schedule) or before treatment (curative schedule). After incubation for 6 days, sporulating disease was assessed as a percentage of that on the untreated.

Field trials were laid out to a randomised block design, and replicated 4-6 times. Plot sizes varied for different crops : vines 6-10 plants; melons, cucurbits and tomatoes, 10-20 plants; hops, 80 plants; cocoa, 1 plant (replicated 10 times); potatoes 6 m x 4 rows.

ICIA0001 was applied in a sufficient volume to ensure thorough coverage of the foliage, from 300 l/ha for potatoes to 1500 l/ha for vines (most commonly 1000 l/ha) and 4200 l/ha for hops later in the growing season. Where air assisted sprayers were used instead of conventional high volume equipment, spray concentrations were increased to provide the same rate of a.i./ha as conventional equipment operating at an appropriate volume/ha.

Application intervals varied from 7-14 days, intervals being reduced under climatic conditions favourable for disease development as would be consistent with local grower practice.

Where trials were artificially inoculated (vines, potatoes, cocoa) ICIA0001 was applied either prophylactically or at the appearance of the initial disease symptoms. The numbers or percentage area of leaves or fruit infected were assessed at regular intervals through the season.

Significant treatment differences were established using either analysis of variance or logit analysis. In tables 6, 7, 8, 10 and 11, values in a common group of data followed by the same letter were not significantly different at $P = 0.05$.

RESULTS

In-vitro activity

ICIA0001 demonstrated a high level of intrinsic activity against a range of Oomycete pathogens *in-vitro*, and was equally effective against phenylamide resistant or sensitive strains (Table 2).

TABLE 2

In-vitro activity of ICIA0001 against Oomycete pathogens

Organism	LC50 (mg a.i./l)
Phytophthora infestans[1]	0.5
Phytophthora infestans[2]	0.5
Phytophthora citricola	0.9
Phytophthora cryptogea	5.0
Phytophthora megasperma[3]	3.5
Phytophthora cinnamomi	0.9
Pythium ultimum	6.0

[1] Phenylamide resistant strain
[2] Phenylamide sensitive strain
[3] Mean of 3 isolates

Glasshouse Studies : Vines

Curative and protectant activity

ICIA0001 demonstrated outstanding curative action against *Plasmopara viticola* and was significantly more effective than the standard cymoxanil as the duration of curative activity increased (Table 3). Protectant activity decreased over a 6 day period at a rate of 50% loss in activity every 3.4 days (Table 4).

Uptake and Movement

ICIA0001 when applied as a root drench to vines was translocated systemically in the xylem to provide excellent disease control on the foliage (Table 5). When applied to the adaxial leaf surface of vines, ICIA0001 penetrated across the laminar to provide significantly better control of disease than the standard cymoxanil (Table 5). Application to the stems of young vines at a concentration of 9.0 mg a.i./l reduced the level of disease in the leaf above the treated section by 81%. In a test where ICIA0001 was applied in a 1 cm band at the base of a young vine leaf (60 x 2 µl droplets at 9.0 mg a.i./l) the molecule re-distributed to the distal area reducing disease levels by 83%. In rainfastness studies a 9.0 mg a.i./l treatment of ICIA0001 demonstrated excellent activity (95% disease control) when 20 mm of precipitation was applied 4 hours after chemical application. Under identical conditions a 12.0 mg a.i./l treatment of cymoxanil showed only 8% disease control.

Similar movement properties have also been demonstrated on potatoes.

TABLE 3

Curative activity of ICIA0001 and cymoxanil against Plasmopara viticola in the glasshouse

Rate (mg a.i./l)	% Disease control			
	1 Day Curative[1]		3 Day Curative[1]	
	ICIA0001	Cymoxanil	ICIA0001	Cymoxanil
100	-	-	100	64
50	-	-	99	41
25	100	100	99	34
10	99	99	94	9
5	88	95	-	-
1	22	35	-	-
0	(89.9)[2]		(94.7)[2]	

[1]Mean of six tests; treatments applied one or three days after inoculation
[2]% leaf area infected in the untreated

TABLE 4

Protectant activity and relative persistence of ICIA0001 against Plasmopara viticola in the glasshouse

LC50 (mg a.i./l) 1 Day protectant[1]	LC50 (mg a.i./l) 7 Day protectant	Relative potency (LC50 1 day/LC50 7 day)	Biological half-life[2] (days)
12.6	42.6	0.3	3.4

[1]1 day protectant = chemical applied 1 day before inoculation
[2]Period of time required to lose half the biological activity defined by an LC50 value and calculated from: $\frac{6\ (\log 2)}{\log \frac{1}{0.3}}$

TABLE 5

Translaminar and root drench activity of ICIA0001, cymoxanil and metalaxyl against *Plasmopara viticola* in the glasshouse

Rate (mg a.i./l)	% Disease control Translaminar spray 1 Day Curative ICIA0001	Cymoxanil	3 Day Curative ICIA0001	Cymoxanil	Root drench 1 Day Protectant ICIA0001	Metalaxyl
50	100	100	99	18	-	-
25	98	82	85	3	100	100
10	93	69	83	14	100	97
5	40	28	8	8	100	73
1	-	-	-	-	76	21
0	(96.5)[1]		(90)		(74.2)	

[1]% leaf area infected in the untreated

Field studies

Plasmopara viticola

In field trials over several years in Europe and South America, ICIA0001 applied at a dose of 9 g a.i./hl in combination with a protectant partner has consistently demonstrated outstanding control of leaf and bunch disease equivalent to or better than the standards (Tables 6 and 7). The level of disease control provided by these mixtures was clearly superior to that of the protectant partner applied alone (Tables 6 and 7).

TABLE 6

Control of downy mildew on vines (Spain, Italy and Brazil)

Treatment[1]	Rate (g a.i./hl)	% Disease area Spain 1987 Leaf	Bunch 10DAT6[2]	Italy 1987 Leaf	Bunch 9DAT5	Brazil 1986 Leaf	Bunch 9DAT6
ICIA0001 + mancozeb	9 + 140	2b	0b	1b	8c	-	-
ICIA0001 + folpet	9 + 100	2b	0b	1b	12c	2c	1b
Cymoxanil + mancozeb	12 + 103.5	-	-	6b	19b	-	-
Cymoxanil + folpet	12 + 100	-	-	-	-	2c	1b
Metalaxyl + mancozeb	20 + 160	1b	0b	-	-	-	-
Folpet	100	-	-	-	-	9b	2b
Untreated	-	20a	1a	32a	61a	67a	31a

[1]Application interval 7-14 days dependent on climatic conditions
[2]10 days after application of the 6th spray

TABLE 7

Control of downy mildew on vines in France, 1986-88

Treatment	Rate (g a.i./hl)	% Disease area 1986 Leaf 31DAT11	1986 Bunch 7DAT5	1987 Leaf 2DAT7	1987 Bunch 9DAT6	1988 Leaf 8DAT5	1988 Bunch 8DAT5
ICIA0001 + mancozeb	9 + 140	3d	0b	3 c	3b	3d	16cd
ICIA0001 + folpet	9 + 100	11c	0b	4 c	1b	3d	12d
Cymoxanil + mancozeb	12 + 140	-	-	3 c	4b	8c	28c
Cymoxanil + folpet	12 + 100	15c	0b	4 c	2b	13b	21cd
Mancozeb	140	-	-	17 b	4b	-	-
Folpet	100	28b	0b	-	-	10b	55b
Untreated	-	100a	15a	88 a	94a	58a	87a

Phytophthora infestans

At a dose rate of 12.5-25 g a.i./hl, ICIA0001 in mixture with a protectant partner and with or without the wetter Nansa Hs80/s (sodium dodecyl benzene sulphonate) demonstrated good control of potato and tomato late blight, equivalent to or slightly inferior to phenylamide standards and superior to cymoxanil and protectant standards (Table 8).

TABLE 8

Control of late blight on potatoes and tomatoes

Treatment[1]	Rate (g a.i./hl)	% Disease UK 1986 (Potato) I 31DAT4	UK1988 (Potato) II 2DAT5	Italy 1988 (Tomato) 8DAT3
ICIA0001 +mancozeb	12.5 + 134	-	4c	-
ICIA0001 +mancozeb+Nansa Hs80/s	12.5 + 134 + 25	10b	-	-
ICIA0001 +folpet +Nansa Hs80/s	25 + 100 + 25	-	-	19b
Ofurace +vondozeb	11.6 + 134	4b	11b	-
Cymoxanil+folpet	20 + 80	-	-	39c
Cymoxanil+mancozeb	10 + 136	-	11b	-
Mancozeb	134	-	12b	-
Untreated	-	68a	90a	65a

[1] Applications made at 10-14 day intervals starting at canopy closure (potato) or at 11 day intervals from beginning of flowering (tomato)

Other Oomycete pathogens

At dose rates of 9.0-12.5 g a.i./hl, ICIA0001 in combination with a protectant only molecule was very effective in controlling Pseudoperonospora humuli on hops (Table 9), Pseudoperonospora cubensis on cucurbits (Table 10) and Phytophthora palmivora on cocoa (Table 11).

TABLE 9

Control of downy mildew on hops, Germany 1987

Treatment[1]	Rate (g a.i./hl)	% Cones infected	% Cone area infected
ICIA0001 + mancozeb	9 + 140	25	5
ICIA0001 + folpet	9 + 100	30	6
Mancozeb	140	40	7
Folpet	100	45	8
Untreated	-	100	100

[1]Application interval 10 to 29 days, dependent on climatic conditions

TABLE 10

Control of downy mildew on cucumber and melon, Japan 1987 and Spain 1988

Treatment	Rate (g a.i./hl)	% Leaf area infected	
		Japan[2] (cucumber) 7DAT3	Spain[1] (melon) 4DAT4
ICIA0001 + mancozeb	12.5 + 134	1c	3c
ICIA0001 + mancozeb	25 + 134	1c	2c
Metalaxyl + mancozeb	20 + 134	-	1c
Metalaxyl + mancozeb	15 + 135	0c	-
Cymoxanil + mancozeb	10 + 136	7b	-
Mancozeb	134	10b	10b
Mancozeb	280	12b	-
Untreated	-	47a	63a

[1]First treatment applied curatively, 10 day application interval
[2]First treatment applied preventively, lower 2 leaves assessed, 7-10 day interval

TABLE 11

Control of black pod on cocoa, Malaysia 1987 and 1988

Treatment[1]	Rate (g a.i./hl)	% Pods infected (cumulative)	
		1987 12WAT[2]	1988 12WAT
ICIA0001 + mancozeb + Nansa Hs80/s	12.5 + 134 + 25	11c	1c
ICIA0001 + copper oxychloride + Nansa Hs80/s	12.5 + 150 + 25	-	2c
Metalaxyl	25	6c	1c
Copper oxychloride	150	38ab	52a
Mancozeb	134	26b	36a
Untreated	-	52a	51a

[1] Prophylactic application schedule; 14 days between treatments
[2] 12 weeks after the 1st application

Crop safety

ICIA0001 has been used on a wide range of vine and potato varieties under diverse climatic conditions. Application rates which demonstrated high levels of disease control normally provided a substantial margin for safety on these crops. Similar findings have been reported for other crops though with fewer varieties and under a less diverse set of climatic conditions.

CONCLUSIONS

ICIA0001 is a novel, highly active benzamide fungicide, with a new mode of action, for the control of a range of Oomycete pathogens. The compound has exceptional curative properties and is able to penetrate leaf and stem tissue to re-distribute systemically within the apoplast.

In spite of its systemic nature, ICIA0001 is thought to carry a relatively low risk of selecting for resistance in practice. Short persistence and mixture of the molecule with a multi-site protectant partner both contribute to reducing the risk. Eacott (1986) failed to isolate benzamide resistant phenotypes from a mutagenesis programme with *P.infestans* and *P.megasperma* which successfully produced phenylamide resistant phenotypes.

Whilst the curative and distributive properties of ICIA0001 are the ideal complement to a non-mobile protectant partner, it is unwise in practice to advocate solely curative treatment of Oomycete pathogens. However, extended curative action is an important component of the total treatment of these pathogens, where climatic conditions which favour disease development often negate the possibility of chemical application. Application intervals in the trials described above have been based around a 10 to 14 day period between sprays. In practice this period should act as a guideline to determine application frequency with intervals being extended or reduced in response to changing climatic conditions.

ACKNOWLEDGEMENTS

The authors wish to thank all of their colleagues who have contributed in the preparation of data for this paper. Special thanks are due to Dr I.T. Kay for the design and synthesis of ICIA0001 and to Ms Gay Simms and Ms I.A. Dobson for carrying out much of the glasshouse experimentation.

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FIELD DATA ON PH 70-23, A NOVEL BENZOYLPHENYLUREA CONTROLLING MITES AND INSECTS IN A RANGE OF CROPS.

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ABSTRACT

PH 70-23 is a new benzoylphenylurea interfering with chitin synthesis. In contrast to most other benzoylureas, it is not only active on a range of insects but also on most economically important mite species. As only limited effects have been found on beneficial arthropods in field experiments, the compound has potential as a tool in Integrated Pest Management programmes. The mammalian toxicity is very low.

INTRODUCTION

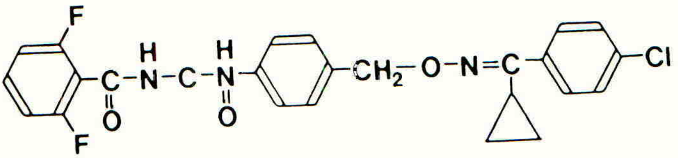
With the first registration of diflubenzuron (DIMILIN®) against *Thaumetopoea pityocampa* (processionary caterpillar) on pine trees in France in 1975, a new area was opened for the practical use of a new group of insecticides: the benzoylphenylureas. Although interest in the practical uses of benzoylphenylureas was limited in the seventies, it is now gradually increasing, due to growing demand for highly selective insecticides with low non-target toxicity.

Since the introduction of diflubenzuron, a number of other benzoylphenylureas have been developed. The most prominent activities of all these compounds were against insect species belonging to the Lepidoptera, Diptera and Coleoptera. Mites, except for Eriophyid mites, could not be controlled.

As a result of an optimization program to find benzoylphenylureas with acaricidal activity, Duphar found and patented (patent application: 1983) a new compound, PH 70-23, which combines the traditional activity of these chemicals against insects with an activity against spider mites. A first paper on PH 70-23 dealing with mode of action and acaricidal/insecticidal activity in laboratory experiments has been published earlier this year (Grosscurt *et al.*, 1988).
In insects PH 70-23 appears to have the same mode of action as diflubenzuron, i.e. interference with chitin synthesis. It was therefore not surprising to find activity on mites and insects in juvenile stages only. An ovicidal action is observed, both transovarially and by contact. The larvicidal (and nymphicidal) activity of PH 70-23 is mainly by ingestion. The acaricidal activity may be partly due to leaf-penetrating properties.

Field trials have been carried out with PH 70-23 since 1982. The results of a selection of these experiments are discussed in this paper.

TECHNICAL DETAILS

Code numbers:	DU 319722, PH 70-23, UBI-A1335, OMS 3041
Trade name:	ANDALIN®
Chemical name (IUPAC):	1-[α-(4-chloro-α-cyclopropylbenzylideneamino-oxy)-p-tolyl]-3-(2,6-difluorobenzoyl)urea
Structural formula:	
Isomer composition:	The compound consists of an isomer mixture of c. 70% E/30% Z
Molecular formula:	$C_{25}H_{20}ClF_2N_3O_3$
Molecular weight:	483.5
Appearance:	odourless, solid, crystaline powder
Melting point:	143.6°C
Vapour pressure:	< 4.4 mPa at 20°C
Solubility at 20°C:	water: < 1 µg/l; cyclohexane: 3.3 g/l; xylene: 0.2 g/l; ethanol: 3.9 g/l
Stability:	the technical material is stable for 24 h at 50°C (< 2% degradation)
Formulation:	liquid formulations with 10 or 25% a.i.

Toxicity of the a.i.:

Acute oral rat	LD_{50}	> 5000 mg/kg
Acute dermal rat	LD_{50}	> 2000 mg/kg
Inhalation rat	LC_{50}	> 3.3 mg/l (4 h)
No effect level 90 d rat		200 mg/kg diet
Acute 96-h LC_{50} rainbow trout and bluegill sunfish		> 100 mg/l
Acute LD_{50} mallard duck		> 200 mg/kg

METHODS

In all trials, the formulated products were applied in water. The amount of spray liquid was such that the foliage of the crop was wetted to 'run-off'. Generally field trials contained at least four replicates per dose tested. All efficacy data were calculated at a defined number of days after treatment (DAT) using the formula of Abbott (1925).

RESULTS AND DISCUSSION

Results mentioned below are derived from experiments done with the 10% and 25% liquid formulations. No differences in effectiveness were found when both formulations were compared.

European red mite (*Panonychus ulmi*) on apple

In the Netherlands in 1986 and 1987, PH 70-23 at a rate of 10 g a.i./hl was compared with cyhexatin (25 g a.i./hl) and clofentezin (15 g a.i./hl). Application of clofentezin took place when winter eggs were still dormant. PH 70-23 and cyhexatin were applied when 75% of the winter eggs were hatched. Depending on the apple variety, this timing fell somewhere between the opening of the first flowers and last petal fall. Mite counts were done by sampling at least 25 leaves/plot. Plots contained 3-6 trees. The initial activity of PH 70-23 was not as rapid as that of the fast-acting acaricide cyhexatin (Fig. 1A). The apparently better initial activity of clofentezin is related to its earlier spraying time (Fig. 1B). The control of *P.ulmi* with PH 70-23 at 10 g a.i./hl lasted for at least 3 months, which is a better residual activity than with cyhexatin and clofentezin.

Good control of *P.ulmi* with 10-15 g PH 70-23/hl was also obtained in Australia, Belgium, France, Italy, Korea, New Zealand, Spain, Turkey, the USA and Yugoslavia.

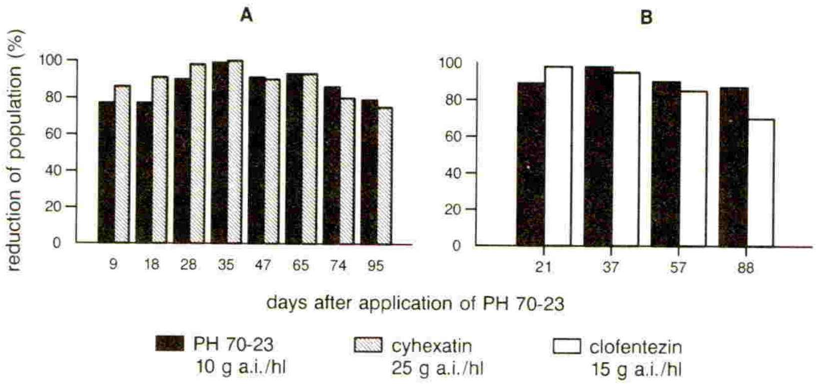


Fig. 1. Control of *Panonychus ulmi* on apple in the Netherlands, 1986/87. (Data from 10 (A) and 4 (B) trials).

In the Netherlands, an application of 10 g PH 70-23/hl on summer populations consisting mainly of eggs, larvae and nymphs generally resulted in very good control of the population. However, when many adults are present a combined application with an adulticide may be necessary. Good results with 15 g PH 70-23/hl on summer populations were obtained in the USA, Australia, Belgium, Israel, and France.

Citrus red mite (*Panonychus citri*)

In trials in Japan (Table 1) excellent results with 10 g PH 70-23/hl were obtained. Assessments were made by counting the number of mobile stages on 25 leaves from single plots. Initial activity was relatively slow compared to standard products. Residual activity, however, was excellent.

In Spain, a residual efficacy of almost 100% was obtained until 125 DAT when the untreated trees were occupied by 6-20 mites per leaf. In the USA, a dose of 3 g a.i./hl was sufficient for the complete control of *P.citri* until 35 days after application.

TABLE 1

Control of *Panonychus citri* on citrus (Japan, 1986) with treatments applied in mid June.

Treatment	Formulation	g a.i./hl	Reduction of the population (%)			
			3 DAT	10 DAT	19 DAT	29 DAT
PH 70-23	10% liquid	5	0	73	86	97
PH 70-23	10% liquid	10	59	96	99	95
Hexythiazox	10% WP	3.3	43	90	96	90
Cyhexatin	25% WP	12.5	100	100	100	97
Dicofol	40% EC	20	99	100	95	89
Amitraz	20% EC	20	99	100	97	98
Untreated*		-	169	466	371	308

* Numbers of mobile stages on 100 leaves.

Two spotted spider mite (*Tetranychus urticae*)

In Israel PH 70-23 showed good control of *T.urticae* in apples at 10 g a.i./hl when the population density of *T.urticae* was below 10 mites/leaf (Table 2). At higher densities, an adulticide should be added. Assessments were done by counting the number of mobile stages on 25 leaves per tree for one month.

Good results on *T.urticae* were also obtained on eggplants at a rate of 15 g a.i./hl (Japan), on greenhouse roses at 5 g a.i./hl (the Netherlands) and on almonds at 15 g a.i./hl (USA).

TABLE 2

Control of *Tetranychus urticae* on apple (Israel, 1986) with treatments applied to mixed populations in mid July.

Treatment	Formulation	g a.i./hl	Reduction of the population (%)		
			13 DAT	23 DAT	30 DAT
PH 70-23	10% liquid	10	95	92	100
Cyhexatin	25% WP	37.5	100	100	100
Untreated*		-	400	650	900

* Numbers of mobile stages on 100 leaves.

Carmine spider mite (*Tetranychus cinnabarinus*)

In Egypt, trials were done on strawberry, cowpea, artichoke, eggplant, cucumber, melon and soya using 100 m^2 plots sprayed once. Table 3 shows the effects of PH 70-23 on eggplant. During the initial 14 days the activity was moderate compared to dicofol. The residual activity of PH 70-23 was better than that of flufenoxuron and hexythiazox. Similar results were obtained in the other crops mentioned.

In Israel, almost complete control of *T.cinnabarinus* on eggplants was obtained with PH 70-23 applied twice at 100 g a.i./ha with a time interval of 19 days. To minimize damage to the crop by *T.cinnabarinus* and to give good initial control, PH 70-23 should be used with an adulticide.

TABLE 3
Control of *Tetranychus cinnabarinus* on eggplant (Egypt, 1987) with treatments applied in mid June.

Treatment	Formu-lation	g a.i./ha	Reduction of the population (%) 7 DAT	14 DAT	21 DAT	28 DAT
PH 70-23	25% liquid	95	41	62	75	84
PH 70-23	25% liquid	143	52	70	86	90
PH 70-23	25% liquid	190	62	78	86	93
Flufenoxuron	5% EC	143	57	55	44	34
Flufenoxuron	5% EC	190	72	68	58	42
Hexythiazox	10% WP	95	75	74	73	67
Tetradifon	7.5% EC	143	48	76	89	95
Dicofol	18.5% EC	440	91	88	86	83
Untreated*		-	2500	3060	3710	3740

* Numbers of *T.cinnabarinus* per 645 mm^2 of leaf surface.

Texas citrus mite (*Eutetranychus banksi*)

In trials on *E.banksi* on orange and grapefruit in Texas and Florida, a dose of 10 g PH 70-23/hl gave almost complete control until at least 2 months after treatment. PH 70-23 was more effective than chlorpyrifos at 60 g a.i./hl, but similar to fenbutatin oxide at 30 g a.i./hl.

Other *Tetranychid* mites

Other *Tetranychid* mites which can be controlled with PH 70-23 in the USA include *Eotetranychus hicoriae* on pecan with 10 g a.i./hl, *T.pacificus* on almonds with 5 g a.i./hl and *T. mcdanieli* on apple with 15 g a.i./hl.

Citrus rust mite (*Phyllocoptruta oleivora*)

In Florida and Texas, good control was obtained with 1 g PH 70-23/hl until three months after application. Only in trials with a very high mite pressure, was 3 g a.i./hl needed for complete control.

Apple rust mite (*Aculus schlechtendali*)

In the Netherlands PH 70-23 applied early in the season at 5 g a.i./hl to control *Panonychus ulmi* gave adequate control for at least 3 months. These results were confirmed in similar trials in Belgium.

Apple insects

Good activity, comparable to that of diflubenzuron, has been obtained with 10 g PH 70-23/hl against the codling moth (*Laspeyresia pomonella*) in the Netherlands, Belgium and France. Promising results were also obtained with 15 g a.i./hl against the light brown apple moth (*Epiphyas postvittana*) in Australia and New Zealand and at 10 and 20 g a.i./hl against the fruit tree tortrix (*Archips podana*) in Italy. Other leafrollers such as the summer fruit tortrix moth (*Adoxophyes orana*) and the barred fruit tree tortrix (*Pandemis ribeana*) were less sensitive.

Cotton insects

Trials against the Egyptian cotton leafworm (*Spodoptera littoralis*) were made in Egypt according to official Egyptian screening methods. The mortality of three groups of 50 2nd instar and 50 4th instar larvae (laboratory reared) was examined after a 5-day period during which larvae were fed with field-sprayed cotton leaves for 2 days and subsequently with unsprayed leaves for 3 days. The initial activity was determined by feeding one group of larvae with freshly sprayed leaves; the residual activity by feeding leaves with 5- and 10-day old residues, respectively, to the remaining two groups. PH 70-23 was twice as active as diflubenzuron and similar to teflubenzuron (Table 4). Residually, PH 70-23 was slightly less active than the standard diflubenzuron + methomyl but better than cyanophos.

Better results were obtained against the pink bollworm (*Pectinophora gossypiella*) following 3 biweekly sprays (Table 5). PH 70-23 appeared similar to diflubenzuron + methomyl, superior to teflubenzuron, and residually better than cyanophos.

TABLE 4

Control of *Spodoptera littoralis* on cotton (Egypt, mean values 1985/87) with treatments applied in mid-June.

Treatment	Formulation	g a.i./ha	Reduction of the population (%) initial activity (0-5 days)	residual activity (mean 5-10 + 10-15 days)
PH 70-23	10% liquid	71	81	61
PH 70-23	10% liquid	143	88	72
Diflubenzuron	25% WP	143	78	60
Teflubenzuron	15% SC	71	79	63
Teflubenzuron	15% SC	143	89	74
Cyanophos	50% EC	500	84	55
Methomyl + diflubenzuron	27% + 4% FL	(643 + 95)	99	77

TABLE 5

Control of *Pectinophora gossypiella* on cotton (Egypt, mean values 1985/87) with treatments applied in August/September.

Treatment	Formulation	g a.i./ha	Reduction of the population (%) (average 6 weekly observations/season)
PH 70-23	10% liquid	143	81
Teflubenzuron	15% SC	143	77
Cyanophos	50% EC	500	68
Methomyl + diflubenzuron	27% + 4% FL	(643 + 95)	82
Untreated*			18

* Number of larvae per 100 bolls.

Soybean insects

Trials were made in the USA to test the efficacy of PH 70-23 against the lepidopterous insect complex consisting of the green cloverworm (GCW) (*Plathypena scabra*), the soybean looper (SL) (*Pseudoplusia includens*) and the velvetbean caterpillar (VBC) (*Anticarsia gemmatalis*).

Plots were 120 m^2 (8 rows of 15 m). At the time of application GCW larvae were in 2nd-4th instar, SL larvae were in 1st and 2nd instar and VBC larvae in 5th and 6th instar. Evaluation took place by regularly counting the number of larvae in 50 sweeps/plot. The numbers of GCW and SL began to decrease rapidly 7 days post-treatment and never increased. Observations after that time are therefore not included. Good activity of PH 70-23 was obtained against all three insects at 35 g a.i./ha (Table 6). Most remarkable was the good control of *P.includens* larvae, which cannot be adequately controlled by diflubenzuron.

TABLE 6

Control of lepidopterous complex on soybeans (USA, La., 1986) with treatments applied at 5 September.

Treatment	Formu-lation	g a.i. /ha	Reduction of the population (%) GCW 4DAT	GCW 7DAT	SL 4DAT	SL 7DAT	VBC 4DAT	VBC 7DAT	VBC 21DAT	VBC 35DAT
PH 70-23	10% liquid	35	76.5	100	5.0	78.3	43.1	87.5	100	97.7
PH 70-23	10% liquid	70	64.2	91.5	27.2	88.0	83.7	87.5	100	96.3
Diflubenzuron	25% WP	70	72.8	97.1	0	0	75.6	87.5	100	97.7
Untreated*			40.5	17.8	15.8	8.3	12.3	4.0	0.5	21.8

* Number of larvae in 50 sweeps.

Diamond back moth (*Plutella xylostella*)

In Taiwan PH 70-23 was tested in 15 m^2 plots. Plants were sprayed 8 times at weekly intervals, starting 18 days after transplanting. Good control of the larvae was obtained, resulting in increased yield (Table 7).

TABLE 7

Control of *Plutella xylostella* on common cabbage (Taiwan, 1988) with treatments applied on 22 January-11 March.

Treatment	Formu-lation	g a.i. /ha	Reduction of the population (%) 6 DAT_2	6 DAT_5	6 DAT_8	marketable yield (t/ha)
PH 70-23	25% liquid	50	93.3	97.0	94.1	86.6
PH 70-23	25% liquid	75	89.3	90.5	97.0	87.9
PH 70-23	25% liquid	100	80.0	91.3	96.8	86.1
Flufenoxuron	5% WDC	40	76.0	91.3	99.2	83.9
Chlorfluazuron	5% EC	50	96.0	98.1	99.7	85.4
Untreated*			7.5	26.3	186.3	73.7

* Number of larvae + pupae in 10 plants.

Rice leaffolder (*Cnaphalocrocis medinalis*)

In the Philippines, 100% inhibition of adult emergence from 12-day old leaffolder larvae feeding on caged rice plants sprayed with PH 70-23 was obtained with 50 g a.i./ha. On unsprayed plants, 88.9% larvae developed to adults. These results were confirmed (Table 8) by field experiments in Korea. Evaluation was done by examination of the presence of dead or alive larvae/pupae in all folded leaves in 50 hills/plot.

TABLE 8

Control of *Cnaphalocrocis medinalis* on rice (Korea, 1987) with treatments applied on 24 August.

Treatment	Formu-lation	g a.i. /hl	No. of folded leaves observed	empty folded leaves (%)	reduction of population (%)
PH 70-23	25% liquid	8	668	87.5	95.0
PH 70-23	25% liquid	5	678	82.3	89.4
Diflubenzuron	25% WP	10	515	85.0	82.0
Cartap	50% SP	50	369	42.1	78.8
Untreated	-	-	310	38.9	0

EFFECTS ON NON-TARGET INVERTEBRATES

In the laboratory, PH 70-23 showed low to moderate toxicity to the predatory mites *Amblyseius potentillae*, *Phytoseiulus persimilis* and *Typhlodromus pyri*. In field trials in the Netherlands and New Zealand, numbers of *T.pyri* were slightly lower in trees treated with 10 and 20 g PH 70-23/hl than in untreated trees. Five weeks after application these differences had virtually disappeared.

Field experiments with PH 70-23 applied at 10, 15 and 20 g a.i./hl in the USA and Belgium showed a slight decrease in predatory mite populations of *Metaseiulus occidentalis*, *Typhlodromus occidentalis* and *Amblyseius finlandicus*. However, numbers of mites were often too low to draw statistically reliable conclusions.

PH 70-23 has little effects on bugs and spiders. In an acute contact toxicity study with adult bees (*Apis mellifera*) no mortality or any other effects were observed at a dose of 100 µg a.i./bee.

CONCLUSIONS

It is concluded that PH 70-23 offers good possibilities for selective use in integrated pest management systems. Field results have shown that PH 70-23 has a wide spectrum of activity, controlling many mite and insect species in various crops.

These results, combined with the low mammalian toxicity and the low toxicity of PH 70-23 to natural enemies of target organisms and to bees emphasize the potential of the compound for future commercial use.

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