SESSION 5

NEW COMPOUNDS, FORMULATIONS AND USES – FUNGICIDES

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RESEARCH REPORTS 5-1 to 5-7

CGA 173506: A NEW PHENYLPYRROLE FUNGICIDE FOR BROAD-SPECTRUM DISEASE CONTROL

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ABSTRACT

CGA 173506 is a new non-systemic phenylpyrrole fungicide. It is being developed by Ciba-Geigy Limited as a foliar fungicide for grapes, stone fruit, vegetables, rice, field crops and turf, and as a seed treatment for both cereals and non-cereal crops.

CGA 173506 provides a high-level, broad-spectrum activity as a foliar fungicide against plant pathogenic fungi in the Genera *Botrytis*, *Monilinia*, *Sclerotinia*, *Rhizoctonia* and *Alternaria*; and as a seed treatment at low rates against species of *Fusarium*, *Septoria*, *Tilletia* and *Helminthosporium*. Also it is outstanding as a rice seed treatment against *Gibberella*. It is well tolerated by all crops tested and has no negative effect on wine fermentation.

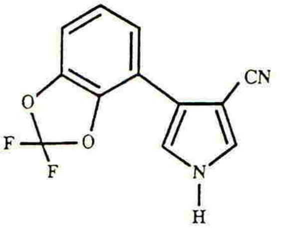
This compound represents "new" chemistry as a foliar fungicide. There is no cross resistance to this compound by pathogens that are resistant to products in other known chemical groups (e.g. benzimidazoles, dicarboximides and guanidines).

INTRODUCTION

CGA 173506 is the code number for 4-(2,2-difluoro-1,3-benzodioxol-4-yl) pyrrole-3-carbonitrile, a new phenylpyrrole fungicide invented and patented by Ciba-Geigy Ltd., Basle, Switzerland. It is being developed by Ciba-Geigy as a foliar fungicide and as a seed treatment and will be marketed under various trademarks including ®'Saphire'. This paper describes the properties of CGA 173506 and its performance on several economically important crops and diseases under field conditions.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical class:	Phenylpyrrole
Chemical name:	4-(2,2-difluoro-1,3-benzodioxol-4-yl) pyrrole-3-carbonitrile
Structural formula:	



Molecular formula:	$C_{12}H_6F_2N_2O_2$
Molecular weight:	248.19
Appearance at 20°C:	colourless, odourless crystals
Melting point:	199.4°C
Solubility in water at 20°C:	1.53 ppm
Partition coefficient:	log P = 2.6 (n-octanol/water)
Hydrolysis:	practically no hydrolysis at 70°C between pH 5 and 9

TOXICOLOGY

Acute Toxicity:	oral rat (LD 50)	> 2000 mg/kg
	dermal rat (LD 50)	> 2000 mg/kg
	inhalation rat (4 h, LC 50)	> 2600 mg/m^3
Skin and eye irritation:	non-irritant, no skin sensitizing potential	
Teratogenicity:	no teratogenic potential	

FORMULATIONS

For seed treatment uses CGA 173506 will be available in a wettable powder formulation (WS 10) as well as water-based flowable formulations (FS 025 and FS 100). For foliar applications it will be introduced as a wettable powder formulation (WP 50), as a water dispersible granule formulation (WG 50) as well as a flowable formulation (SC 500).

BIOLOGICAL ACTIVITY AS A SEED TREATMENT

CGA 173506 is highly active at low use rates on a wide range of both cereal and non-cereal crops (Leadbeater *et al*. 1990). In cereals, at 5 g AI/100 kg seed, control of *Gerlachia nivalis* (*Fusarium nivale*), *Fusarium culmorum*, *Tilletia caries* and seed-borne *Septoria nodorum* is equivalent to that given by the best commercial products. CGA 173506 is also outstanding on many non-cereal crops, e.g. at 5 g AI/100 kg seed against *Fusarium graminearum* on maize, and at 25 g AI/100 kg seed against *Gibberella fujikuroi* on rice. Table 1 shows its spectrum of activity as determined in field trials in 1987-1990.

Strains of fungi resistant to products from other chemical classes as e.g. benzimidazoles show no cross-resistance to CGA 173506. This is particularly important for a seed treatment to control MBC-resistant *Fusarium* spp. (e.g. *Gerlachia nivalis*, *Gibberella fujikuroi*).

CGA 173506 is generally very well tolerated as a seed treatment and it does not cause any delay of emergence.

TABLE 1. Main spectrum of activity of CGA 173506 as a seed treatment as determined by field trials in 1987-1990.

Crop	Pathogen
Wheat	*Tilletia caries, Gerlachia nivalis, Fusarium culmorum, Leptosphaeria nodorum (Septoria nodorum)*
Barley	*Gerlachia nivalis, Ustilago hordei, Pyrenophora graminea (Helminthosporium gramineum), Cochliobolus sativus*
Rye	*Gerlachia nivalis, Urocystis occulta*
Maize	*Fusarium graminearum*
Rice	*Gibberella fujikuroi, Cochliobolus miyabeanus (Helminthosporium oryzae)*
Peas	*Ascochyta* spp., *Fusarium* spp.
Potatoes	*Rhizoctonia solani, Fusarium* spp., *Helminthosporium solani*
Oilseed rape	*Leptosphaeria maculans (Phoma lingam), Alternaria brassicae*

BIOLOGICAL ACTIVITY AS A FOLIAR FUNGICIDE

Materials and methods

Grapes

Plot sizes were 5-20 plants with 3-4 replicates in randomised complete block design. Two to four applications were made into the bunch zone at growth stages 23-25 EL (full flowering), 31-33 (before bunch closure), 35 (start of ripening) and about 4 weeks pre-harvest using 150-1000 l/ha. Disease assessments were made by estimating disease severity on bunches. The effect on wine fermentation and wine taste was evaluated.

Vegetables

Trials against *Botrytis* on various vegetable crops and against *Alternaria* on tomatoes had plot sizes of 5-10 plants, whereas 40-60 plants were used in trials against *Sclerotinia* on lettuce. All trials reported had 3-4 replicates in randomized complete block design. Against *Botrytis* 3-5 applications were made at about 10- to 14-day intervals using 1000-2000 l/ha after the first symptoms became visible. On lettuce 3-4 sprays were applied using 800-1200 l/ha at about 14-day intervals from transplanting. Against tomato early blight 10 sprays with 400-1600 l/ha were applied in weekly intervals. Disease attack was assessed by counting the number of infected plant parts and/or estimating disease severity on leaves, stems and fruits.

Stone fruit and almonds

Plot sizes were 2-4 trees with 3-4 replicates in randomised complete block design. Trees received 2-3 sprays at flowering and 1-2 sprays pre-harvest using 2800-3000 l/ha. Disease assessments were made by estimating disease severity on inflorescences and fruits.

Field crops

All trials reported were conducted with plot sizes of 20-50 m^2 with 3-4 replicates in randomised complete block design. On oilseed rape and field beans the treatments were applied twice at flowering. On potatoes there were 5 sprays in weekly intervals. Disease assessments were made by counting the number of infected plants per plot or by estimating the percentage of leaf surface infected.

Results and discussion of field trials

CGA 173506 provides a new mode of action as a foliar fungicide and there is no cross resistance to this compound by pathogens that are resistant to products in other known chemical groups. This is of particular importance for the control of e.g. strains of *Botrytis* which are resistant to dicarboximides and benzimidazoles (Lorenz & Eichhorn, 1982; Leroux & Clerjeau, 1985).

Grapes

CGA 173506 gave outstanding control of moderate to severe attacks of *Botrytis cinerea* in more than 50 field trials in Switzerland, France, Italy, Germany and Austria in 1986-1989. With 2-4 sprays at 500 g AI/ha it consistently gave superior control to commercial standard products (Table 2).

TABLE 2. Control of *Botrytis cinerea* on grapes in France, Switzerland, Germany, Italy and Austria in 1986-1989

Treatment	Rate (g AI/ha)	% infected bunch surface at harvest				
		Switzerland	France	Italy	Germany	Austria
Untreated		49	35	30	41	40
Standard [1]		27	23	17	39	18
CGA 173506 [2]	500	7	8	2	5	5
Number of trials		29	13	6	3	3

1 vinclozolin at 500-750 g AI/ha or spray sequence (alternation of dicarboximides alone, vinclozolin + thiram, carbendazim + diethofencarb or dichlofluanid)

2 CGA 173506 with 2-4 applications

In official trials in 1989 in France (INRA Bordeaux - Station de Pathologie Végétale, Service de la Protection des Végétaux) and in Switzerland (Federal Research Stations Wädenswil and Changins), CGA 173506 at 500 g AI/ha with 3-4 sprays was clearly superior to current standard products (Table 3).

TABLE 3. Control of *Botrytis cinerea* on grapes in official trials in Switzerland and France in 1989

Treatment	Rate (g AI/ha)	% infected bunch surface at harvest France [1]	Switzerland [2]
Untreated		18	41
Vinclozolin	750	10	-
Vinclozolin + thiram	3700	9	-
Carbendazim + diethofencarb	625	-	32 [3]
CGA 173506	500	3	12
Number of trials		6	3

All treatments applied 3-4 times

1 French results from INRA Bordeaux - Station de Pathologie Végétale and Service de la Protection des Végétaux

2 Swiss results from the Federal Research Stations Wädenswil and Changins

3 only 2 trials

CGA 173506 had no negative effects on wine fermentation and did not taint in official tests in France and Switzerland.

Vegetables

CGA 173506 provides a broad spectrum of activity on vegetable crops. At 50 g AI/100 l in 10- to 14-day intervals it showed excellent activity against *Botrytis* spp. on tomatoes, Phaseolus beans and eggplants in Spain. In Italy, CGA 173506 at 12.5-25 g AI/100 l was clearly superior to the standard against *Sclerotinia minor* on lettuce. In South Africa it showed a high level of activity at 25 g AI/100 l against *Alternaria solani* on tomatoes (Table 4).

Stone fruit and almonds

CGA 173506 gave excellent control of diseases on stone fruit and almonds (Table 5). At 7.5-15 g AI/100 l it was highly active against blossom blight and brown rot caused by *Monilinia laxa* and *M. fructicola*. It also showed significant activity against shot hole on almonds (*Coryneum beijerinckii*) and *Rhizopous nigricans* on peaches, which was not controlled by the standard products.

TABLE 4. Control of disease on vegetable crops in Spain (E), Italy (I) and South Africa (SA) in 1988-1990

Treatment	Rate (g AI/100 l)	% Disease [1] tomato stems *Botrytis*	tomato fruits *Botrytis*	bean pods *Botrytis*	eggplant fruits *Botrytis*	lettuce plants *Sclerotinia*	tomato leaves *Alternaria*
Untreated		44	25	14	26	41	69
Vinclozolin	75	24	10	6	16	22	-
Mancozeb	160	-	-	-	-	-	7
CGA 173506	50 [2]	11	2	2	5	4	1
Number of trials		6	5	4	2	4	1
Country		E	E	E	E	I	SA

1 assessments as % infected plants or plant parts or % infected leaf surface
2 against *Sclerotinia* 12.5-25 g, against *Alternaria* 25 g

TABLE 5. Control of diseases on stone fruit and almonds in USA and South Africa (SA) in 1989 and 1990

Treatment	Rate (g AI/100 l)	% Disease [1] various stone fruit [2] *Monilinia* spp. flowers	various stone fruit [2] *Monilinia* spp. fruits	peaches *Rhizopus* fruits	almonds *Monilinia* spp. flowers	almonds shot hole nuts
Untreated	-	88	35	57	26	16
Iprodione	30 [3]	3	16	47	10	-
Ziram	120	-	-	-	-	5
Dichloran	75	-	-	40	-	-
CGA 173506	7.5	1	9	-	9	3
CGA 173506	15	1	5	-	4	4
CGA 173506	25	-	-	19	-	-
Number of trials		3	11	2	1	2
Country		USA	USA	SA	USA	USA

1 assessments as % infected flowers, fruits or nuts; blossom blight on almonds as strikes/tree
2 apricots, peaches, nectarines, cherries, plums
3 on almonds at 15 g, in South Africa at 50 g

Field crops

CGA 173506 at 500 g AI/ha gave a high level of control of *Sclerotinia sclerotiorum* on oilseed rape and at 250-500 g AI/100 l of *Botrytis fabae* on field beans and *Alternaria solani* on potatoes (Table 6). Its level of activity was equal to or better than the commercial standards.

TABLE 6. Control of diseases on field crops in Germany (D), France (F), United Kingdom (UK) and Brazil (BR) in 1988-1990

Treatment	Rate (g AI/ha)	Oilseed rape *Sclerotinia sclerotiorum* % infected plants	Field beans *Botrytis fabae* % infected leaf surface	Potatoes *Alternaria solani* % infected leaf surface
Untreated	-	38	28	100
Vinclozolin	750	2 [1]	-	-
Iprodione	1000	-	-	83
Chlorothalonil	900	-	0	-
+ carbendazim	200			
CGA 173506	250	-	1	27
CGA 173506	500	2	0	10
Number of trials		5	2	1
Country		D, F	UK	BR

[1] mean of only 4 trials

Other crops and diseases

In addition to the above mentioned pathosystems, CGA 173506 is also active as a foliar spray on turf against *Rhizoctonia solani*, *Sclerotinia homoeocarpa*, *Drechslera poae* and *Microdochium nivalis*; on strawberries and lettuce against *Botrytis cinerea*; on grapes against *Glomerella cingulata*; on rice against *Rhizoctonia solani* and *Ophiobolus oryzinus*; on peanuts against *Sclerotinia minor*; and on ornamentals against *Rhizoctonia solani* and *Botrytis* spp.

Crop tolerance

CGA 173506 is generally very well tolerated except on some ornamental crops. At the indicated rates no symptoms of phytotoxicity were observed.

CONCLUSIONS

CGA 173506:
- provides a new mode of action as a foliar fungicide;
- provides a broad spectrum and a high level of activity both as a seed treatment and as a foliar spray on a wide range of crops;
- gives excellent control of many economically important diseases in grapes, vegetables, cereals, rice, stone fruit and field crops.

As CGA 173506 is active against pathogens resistant to current standard products, it is extremely suitable as a component of strategies to overcome resistance problems present in many crops and to meet the needs of modern agricultural practice.

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BAS 480 F - A NEW BROAD SPECTRUM FUNGICIDE

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ABSTRACT

BAS 480 F - (2RS, 3SR)-1-[3-(2-chlorophenyl)-2-(4-fluorophenyl)oxiran-2-ylmethyl]-1H-1,2,4-triazole - is a new broad spectrum triazole fungicide which, in several years of field trials, has demonstrated its outstanding control of cereal diseases such as *Puccinia* spp., *Septoria* spp., *Rhynchosporium secalis* and its good activity against *Pyrenophora teres, P. tritici-repentis, Erysiphe graminis, Fusarium* spp. and *Pseudocercosporella herpotrichoides*. It is also very effective against the following disease complexes: in sugar beet against *Cercospora beticola*, in peanuts against *Mycosphaerella arachidis, M. berkeleyi* and *Puccinia arachidis* and in oilseed rape against *Alternaria brassicae*, as well as against other diseases in turf, roses and stone fruits.

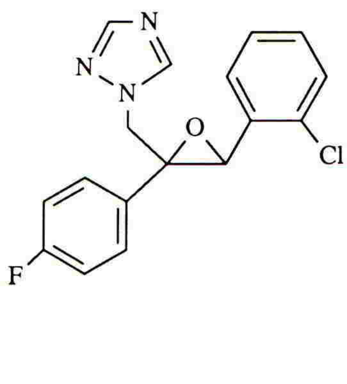
BAS 480 F has a good protective, curative and eradicative activity with excellent residual performance. The active ingredient is acropetally transported within the plant.

INTRODUCTION

BAS 480 F is a new broad spectrum triazole fungicide which was discovered and patented by BASF AG (Meyer *et al*., 1981; Karbach *et al*., 1985). This product is currently under development to be marketed under the trade name "Opus". Its properties determined in laboratory, glasshouse and field trials are described below.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name	:	(2RS,3SR)-1-[3-(2-chlorophenyl)-2-(4-fluorophenyl)oxiran-2-ylmethyl]-1H-1,2,4-triazole
Code number	:	BAS 480 F
Structural formula	:	



Stereochemistry	: racemic mixture of the cis-diastereomer
Molecular formula	: $C_{17} H_{13} Cl F N_3 O$
Molecular weight	: 329.76
Appearance at 20 °C	: colourless, odourless crystals
Melting point	: 136.2 °C
Vapour pressure at 20 °C	: < 1 x 10^{-7} mbar
Solubility (g/100 ml solvent at 20 °C):	

water	6.63 x10^{-4}
acetone	18
dichloromethane	14
n-heptane	<0.1

Partitition coefficient	: log P = 3.44 (n-octanol/water at pH7)
Stability	: no hydrolysis at pH 3 and at pH 7 within 12 days

TOXICOLOGY

Acute toxicity of the technical active ingredient:

Acute oral LD50 rat	:> 5 000 mg/kg body weight
Acute dermal LD50 rat	:> 2 000 mg/kg body weight
Acute inhalation LC50 rat (4h)	:> 5.3 mg/l air (dust aerosol)
Skin irritation rabbit	:non irritating
Eye irritation rabbit	:non irritating

FORMULATION

Two formulations will be available: 25 WP with 250 g AI/kg and 125 SC with 125 g AI/l.

BIOLOGICAL ACTIVITY

Material and methods

LC50-values were determined using BAS 480 F-amended agar plates, in a range of concentrations, which were inoculated with discs of fungal mycelium and assessed by comparison with untreated plates.
In glasshouse experiments, pot grown plants were used which had been cultivated under standard conditions. Inoculation was done either using aqueous spore suspensions or dusting the plant with spores (*Erysiphe, Puccinia*) and subsequent cultivation under conditions favourable for disease development. Visual assessment of the disease development was made in percent.
The field trials were laid out in randomized blocks with 4 replications. The size of the blocks varied from 10 to 20 m^2. All trials were sprayed at the beginning of attack either using special small plot tractor-spray equipment or a hand-held precision plot sprayer. Treatments were applied in 200 - 800 l water/ha.
A visual assessment of the infected leaves or ears was made in percent (0 - 100) for the plot as a whole. Growth stages (GS) are described for cereals according to Zadoks *et al.* (1974).

Results

Mode of action and systemic transport

The mode of action of BAS 480 F was found to be the inhibition of the C-14-demethylase in the sterol biosynthesis like that of many other triazole fungicides (Akers *et al.*, 1990).
Whereas soil-drench experiments in the glasshouse gave strong hints of an acropetal systemic transport into the plants, experiments with C^{14}-labeled active ingredient clearly revealed these properties as shown by Koehle (Akers *et al.*, 1990).

In vitro activity

In in vitro tests, BAS 480 F showed a very strong activity towards a broad range of Ascomycetes, Basidiomycetes and Deuteromycetes, whereas the control of Phycomycetes was poor. From 57 representative facultative plant pathogenic fungi tested, 48 had LC50 values < 1 mg/l, 6 > 1 < 10 mg/l and 3 had LC50 values > 10 mg/l.

Glasshouse results

In glasshouse tests, the good and broad activity of BAS 480 F was found against plant pathogenic fungi belonging to the families of the Ascomycetes, Basidiomycetes and Deuteromycetes. Special tests revealed the strong curative activity in the control of *Puccinia* on wheat. A single foliar spray-treatment with an aqueous suspension containing 125 mg/l BAS 480 F completely controlled the disease, even 72 h after inoculation. This trial was assessed 12 days after inoculation.

TABLE 1. Curative effect of a single spray-treatment against *Puccinia recondita* f. sp. *tritici* on wheat after artificial inoculation.

	Mean % leaf area affected			
Time after inoculation (h)	48	72	96	120
Treated	0	0	2	35
Untreated	60	60	60	60

BAS 480 F was applied as aqueous suspension containing 125 mg AI/l .

Experiments on the vapour-phase activity of BAS 480 F against *Erysiphe graminis* f. sp. *tritici* in closed glass containers revealed that this characteristic is very weak in comparison with triadimenol.

Field test results in cereals

After several years of field trials, BAS 480 F has demonstrated its good potential to control the major and minor disease problems in wheat, barley and rye. In all cases, the disease control achieved by the use of BAS 480 F resulted in significant yield increases (Saur *et al.*, 1990). One characteristic feature of BAS 480 F can be seen in its excellent activity against *Puccinia* spp.. Thus rust diseases, such as brown and yellow rust of wheat or brown rust of rye and barley, can be efficiently controlled by one application of 62 g AI/ha.

TABLE 2. Control of *Puccinia* spp. on winter wheat 1987 - 1989.

Treatment	Dose (g AI/ha)	Mean % leaf area affected *P. recondita*[1] f. sp. *tritici*	*P. striiformis*[2]
BAS 480 F	62	7	1
BAS 480 F	125	4	0
Propiconazole	125	11	3
Untreated		45	12
Number of trials		5	2

1. Applied at GS 51, 2. Applied at GS 39 - 61 (Denmark, Federal Republic of Germany, France).

TABLE 3. Control of *Puccinia* spp. on rye and barley in Federal Republic of Germany 1986-1988.

Treatment	Dose (g AI/ha)	Mean % leaf area affected *P. recondita*[1] f. sp. *recondita*	*P. hordei*[2]
BAS 480 F	62	3	4
BAS 480 F	125	1	2
BAS 480 F	250	1	0
Propiconazole	125	10	1
Untreated		59	10

1. Applied at GS 51 - 55 (Mean of 3 trials). 2. Applied at GS 49 - 55 (Mean of 5 trials).

The activity of BAS 480 F against *Septoria* species on the leaves or ears and *Pyrenophora tritici-repentis* has also been well established.

TABLE 4. Control of *Septoria* spp. on winter wheat 1986-1989.

Treatment[1]	Dose (g AI/ha)	Mean % leaf area affected *S. nodorum*	*S. tritici*
BAS 480 F	62	14	8
BAS 480 F	125	11	7
BAS 480 F	250	8	7
Propiconazole	125	16	8
Untreated		37	35
Number of trials		11	5

1. Treatments were applied at GS 39 and GS 61 (Federal Republic of Germany, France, The Netherlands, United Kingdom).

TABLE 5. Control of *Pyrenophora tritici-repentis* on winter wheat in Federal Republic of Germany 1989.

Treatment	Dose (g AI/ha)	Mean % leaf area affected
BAS 480 F	125	8
Propiconazole	125	7
Flusilazole+Tridemorph	160 + 350	9
Untreated		33

Result from one treatment at GS 39 (one site).

The control of the leaf diseases of barley caused by *Rhynchosporium secalis* or *Pyrenophora teres* further strengthens its profile.

TABLE 6. Control of leaf diseases on barley 1987-1989.

Treatment	Dose (g AI/ha)	Mean % leaf area affected *Rhynchosporium secalis*	*Pyrenophora teres*
BAS 480 F	62	11	9
BAS 480 F	125	9	6
BAS 480 F	250	7	5
Propiconazole	125	7	6
Untreated		24	15
Number of trials		5	2

Treatments were applied at GS 32 and GS 51 (Denmark, Federal Republic of Germany, United Kingdom).

Fusarium-diseases in cereals have been a long, unsolved problem for which the new generations of triazole fungicides start to offer solutions. BAS 480 F has a good potential to control these species.

TABLE 7. Control of *Fusarium* spp. in winter wheat in Federal Republic of Germany 1987 - 1988.

Treatment	Dose (g AI/ha)	Mean % ear affected
BAS 480 F	125	14
BAS 480 F	250	10
BAS 480 F	375	9
Fenpropimorph+Propiconazole	300 + 125	29
Untreated		53

Treatment was applied once at GS 65 one day after artificial inoculation with a spore suspension containing *Fusarium avenaceum, F. graminearum, F. culmorum* and *Monographella nivalis* (= *F. nivale*) (Mean of 2 trials).

Erysiphe spp. in wheat, rye and barley can be controlled by two treatments of 125 g AI/ha, which gave results comparable to flusilazole + tridemorph (160 + 350 g AI/ha), however a distinct improvement was achieved by combinations with morpholine fungicides such as fenpropimorph (Saur *et al.*, 1990).
Against *Pseudocercosporella herpotrichoides* in wheat 188 g AI/ha gave a good disease reduction but not completely equivalent to that obtained with prochloraz when used at its recommended rate of 400 g AI/ha. Good enhancement was seen by the use of combinations with MBC-fungicides.

Sugar beet

In sugar beet, 3 treatments with 125 g AI/ha of BAS 480 F reduced the attack of *Cerospora beticola* significantly and lead to corresponding yield increases.

TABLE 8. Control of *Cercospora beticola* on sugar beet in Federal Republic of Germany 1988.

Treatment	Dose (g AI/ha)	Mean % leaf area affected
BAS 480 F	125	3
Fentin-acetate	600	5
Untreated		66

Treatments were applied 3 times at GS 48, 49 (Mean of 2 sites).

Peanuts

For the control of peanut diseases is BAS 480 F, with its broad spectrum of activity, an interesting new product. Control of *Mycosphaerella* species equivalent to that of the commercial standards was achieved by 3 treatments of BAS 480 F at the rate of 62 g AI/ha. An obvious advantage was seen in situations where additional disease problems were caused by *Puccinia arachidis*. Here rates of 60g AI/ha BAS 480 F achieved total rust control.

TABLE 9. Control of *Mycosphaerella* spp. in peanuts 1987 - 1988.

Treatment	Dose (g AI/ha)	Mean % leaf area affected *M. berkeleyi*	*M. arachidis*
BAS 480 F	62	13	6
BAS 480 F	125	13	5
BAS 480 F	250	11	4
Propiconazole	125	15	8
Chlorothalonil	1000	26	5
Untreated		36	14
Number of trials		4	2

Treatments were applied 3 times (Brazil, South Africa, USA).

TABLE 10. Control of *Puccinia arachidis* in peanuts in USA 1988.

Treatment	Dose (g AI/ha)	Mean % leaf area affected
BAS 480 F	40	8
BAS 480 F	60	1
BAS 480 F	80	1
Propiconazole	125	28
Untreated		30

Treatments were applied 3 times (Mean of 2 sites).

In the peanut trials, a good additional activity of BAS 480 F against *Phoma arachidicola* was observed at the rates used to control *Mycosphaerella* spp..
Other *Mycosphaerella* species, such as *M. fijiensis* and *M. musicola* in bananas, were well controlled at a rate of 100 g AI/ha BAS 480 F in the usual spray schedule.

Oilseed rape

BAS 480 F has an additionally good potential for the control of rape diseases. Disease caused by *Alternaria brassicae* was significantly reduced by one treatment at GS 63. Other rape diseases, such as *Phoma lingam* and *Sclerotinia sclerotiorum*, were controlled at the same time with good results.

TABLE 11. Control of *Alternaria brassicae* in winter oilseed rape in Federal Republic of Germany 1987 - 1988.

Treatment	Dose (g AI/ha)	Mean % leaf area affected
BAS 480 F	125	13
BAS 480 F	250	9
Prochloraz	600	14
Iprodione	750	9
Untreated		32

One treatment at GS 63 (Mean of 2 trials).

Ornamentals and other crops

The broad, fungicidal spectrum of BAS 480 F is also suitable for the control of diseases in ornamentals. Very good performance of BAS 480 F was observed in roses, where *Sphaerotheca pannosa* and *Diplocarpon rosae* were controlled simultaneously by 8 treatments in 14 days interval using rates of 50 g AI/ha.

TABLE 12. Control of rose diseases in Federal Republic of Germany 1987 - 1988.

Treatment	Dose (g AI/ha)	Mean % leaf area affected	
		Sphaerotheca pannosa	*Diplocarpon rosae*
BAS 480 F	50	5	0
Triforine	190	22	9
Untreated		44	95

Treatments were applied 8 times at 14 days intervals (Mean of 2 trails).

Gladiolus rust, *Uromyces transversalis*, was efficiently controlled by 5 g AI/hl BAS 480 F. The broad fungicidal activity of BAS 480 F allows its application for the control of diseases in turf. 125 g AI/ha performed well against *Rhizoctonia solani*, *Drechslera* spp. and *Puccinia* spp.. Other areas for the useful application of BAS 480 F were defined to be in stone fruits, to control *Monilinia* spp. and in vegetables, to control *Uromyces* spp., *Puccinia* spp., *Alternaria* spp. and *Erysiphe* spp.. However, the use of BAS 480 F in some fruit crops, vegetables and grape vine is limited due to problems of insufficient crop tolerance.

CONCLUSION

BAS 480 F is a very active, broad spectrum fungicide with strong curative, eradicative and long residual disease control. The systemic BAS 480 F has an excellent potential to control diseases caused by Ascomycetes, Basidiomycetes and Deuteromycetes in cereals, sugarbeet, peanuts, oilseed rape and ornamentals. A pronounced feature is its strong efficacy against *Puccinia* and *Septoria* species. Minor gaps in its fungicidal spectrum can be filled by combinations with other fungicides, such as morpholines or MBC-derivates. Disease control achieved by the use of BAS 480 F resulted in a significant yield increase.

ACKNOWLEDGEMENTS

We would like to express our thanks to those many colleagues who have contributed to the international development of BAS 480 F.

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MEPANIPYRIM(KIF-3535), A NEW PYRIMIDINE FUNGICIDE

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ABSTRACT

Mepanipyrim, 2-anilino-4-methyl-6-(1-propynyl)pyrimidine, is a new fungicide having an excellent activities on grey mould(*Botrytis cinerea*) of vine and vegetables, scab(*Venturia* spp.) of apple and pear and brown rot(*Monilinia fructicola*) of peach. Mepanipyrim possesses a high preventive activity against grey mould and is also highly effective against benzimidazole and dicarboximide resistant strains of *B. cinerea*. Mepanipyrim causes no phytotoxicity at the rate required for disease control. Toxicology and environmental fate studies so far show favourable results for this fungicide.

INTRODUCTION

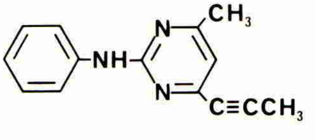
Mepanipyrim is a new type of fungicide, invented by Kumiai Chemical Industry Co., Ltd. and Ihara Chemical Industry Co., Ltd. Mepanipyrim can be used for control of grey mould, scab and brown rot on various crops without phytotoxicity. This paper describes the properties of the fungicide and its performance on several economically important crops and diseases.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name : 2-anilino-4-methyl-6-(1-propynyl)pyrimidine

Common name : mepanipyrim

Structural formula :



Molecular formula : $C_{14}H_{13}N_3$

Molecular weight : 223.28

Appearance	: white crystalline solid
Melting point	: 125 - 126℃
Vapour pressure	: 1.03 x 10^{-5} torr(20℃)
Solubility	: 5.58 mg/l in water(20℃) soluble in most organic solvents
Partition coefficient	: log P = 3.42(octanol/water)
Stability	: Stable under pH4.0 - 9.0

TOXICOLOGY

Acute toxicity

Mouse oral	LD50	: > 5000 mg/kg(male and female)
Rat oral	LD50	: > 5000 mg/kg(male and female)
Rat dermal	LD50	: > 2000 mg/kg(male and female)

Irritation, Sensitization

Skin(rabbit)	: no irritation
Eye(rabbit)	: slight irritation
Dermal sensitization (guinea pig)	: no sensitization

Mutagenicity

DNA repair, Ames test : negative

Avian

Acute oral LD50 (bobwhite & mallard)	: > 2250 mg/kg
Dietary LC50 (bobwhite & mallard)	: > 5620 mg/l

Aquatic

Bluegill LC50	: 3.8 mg/l
Rainbow trout LC50	: 3.1 mg/l

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 mepanipyrim.

For pot(*in vivo*) tests, small seedlings, seeds or soils were treated with the chemical before or after inoculation. After incubation, control activity was assessed as a percentage of that on the untreated.

All field trials were laid out to a randomized block design and replicated 2-4 times. Each plots consisted of small numbers of plants and varied with the crop: strawberry, 8-12 plants; eggplant, 5 plants; vine, 5-15 plants; apple, 1-3 plants; peach, 1 plant. Fungicides were applied at 1000 l/ha to vine; 1000-2000 l/ha to apple; 1500-3000 l/ha to peach, strawberry and eggplant. Spray timing followed the normal grower practices for the area. The numbers of leaves or fruits infected were assessed.

A 50% WP or 40% SC formulation of mepanipyrim was used in all trials.

Results

Mode of action

The precise mode of action of mepanipyrim remains to be clarified. Preliminary tests showed that ergosterol and melanin biosynthesis are not directly affected.

Laboratory and glasshouse tests

Mepanipyrim inhibited the growth of some fungal pathogens(Table 1), but it showed limited fungicidal activity. Very high levels of activity were obtained against Alternaria, Botrytis, Cochliobolus, Curvularia, Diplocarpon, Monilinia and Venturia. In glasshouse tests, mepanipyrim had excellent protective, residual and rainfall resistance activities in grey mould control, but the curative activity was low(Tables 2 & 4). Against apple scab(Venturia inaequalis), mepanipyrim showed not only preventive, but also curative activity (Table 3). Mepanipyrim was highly effective against benzimidazole and dicarboximide resistant strains of B. cinerea (Table 5).

Field trials

Strawberry

Mepanipyrim was tested at dose rates of 100-250mg AI/l for the control of strawberry grey mould. Mepanipyrim gave an excellent control of fruit infection(Table 6). Dose rates of 133-250mg AI/l were adequate to control the disease under high disease pressure.

Eggplant

Mepanipyrim was tested at dose rates of 100-200mg AI/l and showed an excellent control of fruit infection(Table 6). The activity was superior to the standard fungicide.

Vines

Mepanipyrim was tested at dose rates of 250-375mg AI/l on 2-4 times per season for the control of vine grey mould. Mepanipyrim gave an excellent control at 375mg AI/l(Table 7). The activity was superior to the standard dicarboximide fungicides.

Table 1. Fungicidal activity of mepanipyrim in laboratory(in vitro) and glasshouse(in vivo) tests

Pathogen	In vitro LC50(mg/l)	In vivo activity*
Pseudomonas syringae pv. lachrymans	> 300	×
Plasmodiophora brassicae	–	×
Plasmopara viticola	–	×
Phytophthora infestans	> 300	×
Pythium debaryanum	> 300	×
Rhizopus oryzae	> 300	nt
Cochliobolus miyabeanus	< 0.1	△
Diaporthe citri	> 300	○
Erysiphe graminis	–	○
Gibberella fujikuroi	> 300	×
Monilinia fructicola	nt	◎
Mycosphaerella melonis	nt	○
Sclerotinia sclerotiorum	7	○
Sphaerotheca fuliginea	–	○
Valsa ceratosperma	20	nt
Venturia inaequalis	< 0.1	◎
Corticium rolfsii	> 300	×
Puccinia recondita	–	×
Alternaria alternata(pear)	< 0.1	○
Botrytis cinerea	< 0.1	◎
Cercospora beticola	> 300	×
Cladosporium fulvum	> 300	×
Colletotrichum lagenarium	> 300	×
Curvularia clavata	< 0.1	nt
Diplocarpon rosae	nt	○
Fusarium oxysporum	> 300	×
Gloeosporium lacticolor	20	nt
Penicillium digitatum	0.7	×
Pestalotia longiseta	> 300	○
Pyricularia oryzae	> 300	×
Rhizoctonia solani	> 300	×

* : ◎: Excellent; ○: Good; △: Fair; ×: Poor
- : not applicable, nt : not tested

Table 2. Preventive and curative activities of mepanipyrim on cucumber grey mould in the glasshouse

Treatment	% disease control			
	Preventive			Curative*
(AI mg/l)	30	10	3	300
Mepanipyrim	100	95	66	21
Thiophanate methyl	98	73	10	47
Iprodione	81	22	6	60
Untreated		(100)**		(100)**

* : Chemical was applied 40h after inoculation
**: % leaf area infected

Table 3. Preventive and curative activities of mepanipyrim on apple scab in the glasshouse

Treatment	Rate (AI mg/l)	% disease control	
		1 day protectant	2 days curative
Mepanipyrim	50	100	100
Mepanipyrim	12.5	96	94
Mepanipyrim	3.1	75	30
Bitertanol	50	100	100
Bitertanol	12.5	100	98
Bitertanol	3.1	85	83
Untreated		(31)*	(60)*

* : % leaf area infected

Table 4. Residual and rainfall resistance activities of mepanipyrim on cucumber grey mould in the glasshouse

Treatment	LC50 (AI mg/l)			
	Residual		Rainfall resistance	
	0 day	7 days	no rain	rain*
Mepanipyrim	2.7	7.5	< 1	5.3
Thiophanate methyl	2.9	10.3	< 1	3.9

* : 60mm/h for 30 min

Table 5. Preventive activity of mepanipyrim on benzimidazole and/or dicarboximide resistant strains of cucumber grey mould in the glasshouse

Treatment	Rate (AI mg/l)	% disease control SS*	RS*	RR*
Mepanipyrim	30	100	100	100
Mepanipyrim	10	100	100	99
Mepanipyrim	3	76	60	72
Thiophanate methyl	30	100	9	0
Thiophanate methyl	10	100	0	2
Thiophanate methyl	3	38	0	0
Iprodione	100	100	100	45
Iprodione	30	42	61	9
Iprodione	10	13	3	0
Untreated		(100)**	(100)**	(100)**

* : SS; Strain sensitive to benzimidazole and dicarboximide
RS; Strain resistant only to benzimidazole
RR; Strain resistant to both benzimidazole and dicarboximide
**: % leaf area infected

Table 6. Control of grey mould on strawberry or eggplant (Germany, Japan)

Treatment	Rate (mg AI/l)	% disease control: Strawberry, Germany 1989	Strawberry, Japan 1989	Eggplant, Japan 1989	Eggplant, Japan 1990
Mepanipyrim	250	85	-	-	-
Mepanipyrim	200	-	82	100	-
Mepanipyrim	133	-	69	96	93
Mepanipyrim	100	-	69	-	85
Procymidone	250	-	42	-	-
Iprodione	333	-	54	76	66
Iprodione	375	42	-	-	-
Untreated		(82)*	(58)*	(15)*	(37)*

* : % fruits or petals infected

Apples

Mepanipyrim at dose rates of 100-400mg AI/l gave an excellent control of leaf and fruit scab. The activity was equal to or superior to the standard fungicides. Under severe disease pressure, a dosage of more than 200mg AI/l was required to control fruit scab.

Table 7. Control of grey mould on vines (1988-1989)

Treatment	Rate (mg AI/l)	% disease control					
		Germany		France		Switzerland	
		1988	1989	1988	1989	1988	1989
Mepanipyrim	375	81	78	-	72	-	81
Mepanipyrim	250	74	68	99	-	71	-
Iprodione	750	-	-	76	11	28	-
Iprodione	333	-	-	-	-	-	-
Procymidone	375	40	31	-	-	-	-
Vinclozolin	1000	-	-	-	-	-	44
Untreated		(32)*	(55)*	(50)*	(24)*	(64)*	(26)*

* : % bunch area infected

Table 8. Control of scab on apples (1988-1989)

Treatment	Rate (mg AI/l)	% disease control				
		U.S.A.	Germany		Switzerland	
		1988	1988	1989	1988	1989
Mepanipyrim	400	-	-	97	-	-
Mepanipyrim	375	-	-	-	-	84
Mepanipyrim	300	97	-	-	-	71
Mepanipyrim	250	-	-	-	88	-
Mepanipyrim	200	-	76	94	-	-
Mepanipyrim	150	92	-	-	-	75
Mepanipyrim	100	-	61	-	54	-
Bitertanol	125	-	64	-	-	-
Captan	1200	-	-	-	-	93
Fenarimol	36	-	-	88	-	-
Mancozeb	1950	95	-	-	76	-
Untreated		(79)*	(43)*	(68)*	(100)*	(87)*

* : % fruits infected

Peaches

Mepanipyrim was tested at dose rates of 150-600mg AI/l applied 2-3 times per season for the control of peach brown rot. Mepanipyrim gave an excellent control at 300-600mg AI/l(Table 9). The activity was equal to or superior to the standard fungicides.

Other crops

Mepanipyrim gave an excellent control against grey mould(B. cinerea) of vegetables(cucumber,lettuce,onion,tomato,bean), scab(V. nashicola), black spot(Alternaria alternata) of pear, Alternaria leaf pot(Alternaria alternata) of apple, blossom blight or brown rot(Monilinia spp.) of stone fruits(apricot, plum) and black spot(Diplocarpon rosae) of rose at dose rates of 167-500mg AI/l.

Table 9. Control of brown rot on peaches (1987-1989)

Treatment	Rate (mg AI/l)	% disease control U.S.A. 1988	U.S.A. 1989	Japan 1987
Mepanipyrim	150	100	-	-
Mepanipyrim	300	100	87	-
Mepanipyrim	500	-	-	81
Mepanipyrim	600	-	94	-
Iprodione	150	82	-	-
Iprodione	900	-	84	-
TPN + Benomyl	500+200	-	-	81
Untreated		(22)*	(41)*	(12)*

* : % fruits infected

Crop safety

Mepanipyrim was safe on leading commercial varieties of many crops at dose rates required for effective disease control.

CONCLUSIONS

1. Mepanipyrim has an excellent activity on grey mould(*Botrytis cinerea*) of vine, vegetables, etc., scab(*Venturia* spp.) of apple and pear, and brown rot(*Monilinia fructicola*) of peach at doses of 167-500mg AI/l.
2. Mepanipyrim was highly effective against benzimidazole and dicarboximide resistant strains of *B. cinerea*.
3. Mepanipyrim can be used for various crops without phytotoxicity problem at the recommended application rates.

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SSF-109, A NOVEL TRIAZOLE FUNGICIDE: SYNTHESIS AND BIOLOGICAL ACTIVITY

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ABSTRACT

A new triazole fungicide, SSF-109 [(±)-*cis*-1-(4-chlorophenyl)-2-(1*H*-1,2,4-triazol-1-yl)cycloheptanol] was synthesized exclusively by Grignard reaction of 2-(1*H*-1,2,4-triazol-1-yl)-cycloheptanone because the reagent attacked the carbonyl group from the less hindered side of the magnesium complex intermediate. SSF-109 was resolved into its enantiomers by silica gel column chromatography of a diastereomeric mixture of L-menthoxyacetates of SSF-109. It has a broad spectrum of protective activities against plant disease with excellent activity against grey mould (*Botrytis cinerea*) and also acts systemically. Moreover, SSF-109 exhibits the same extent of activity on strains of *B. cinerea* both resistant and sensitive to dicarboximide and benzimidazole fungicides. In comparison with its *trans*-isomer, it was much more effective against most fungi *in vitro* and *in vivo*, but was less inhibitory to lettuce and rice seedling growth. The optically active (-)-SSF-109 shows about 2-4 times more fungicidal and plant growth retardant activity than (+)-SSF-109.

INTRODUCTION

SSF-109, (±)-*cis*-1-(4-chlorophenyl)-2-(1*H*-1,2,4-triazol-1-yl)cycloheptanol, is a new ergosterol biosynthesis inhibiting fungicide synthesized by Shionogi. It has a broad spectrum of preventive and curative activities against plant disease with excellent activity against grey mould (*B. cinerea*).

This paper describes the synthesis and biological activities of SSF-109, its diastereomers and its enantiomers.

CHEMISTRY

Synthesis of SSF-109

SSF-109, (±)-*cis*-1-(4-chlorophenyl)-2-(1*H*-1,2,4-triazol-1-yl)cycloheptanol was synthesized exclusively by Grignard reaction of 2-(1*H*-1,2,4-triazol-1-yl)cycloheptanone without detectable amounts of the stereoisomer on thin layer chromatography and HPLC. The *cis*-stereochemistry of hydroxyl and triazolyl groups was determined by X-ray crystallographic analysis.

As for the mechanism of the observed stereoselective Grignard reaction, the magnesium of the Grignard reagent is thought to form a stable complex with the carbonyl oxygen and nitrogen on the azole ring, then $R^{\ominus}$ attacks the carbonyl group from the less hindered side of the intermediate as illustrated in Fig. 1.

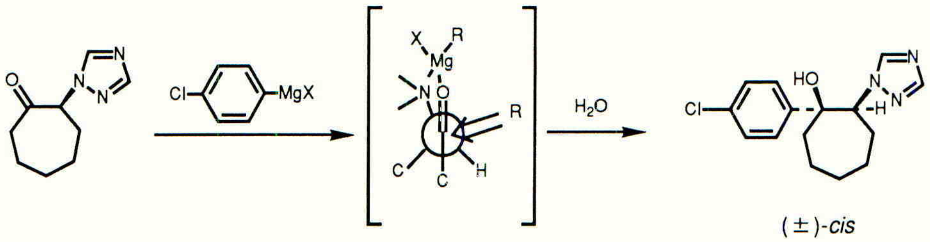


Fig. 1

Chemical and physical properties and toxicology of SSF-109

Molecular formula :	$C_{15}H_{18}N_3OCl$
Chemical name :	(±)-cis-1-(4-chlorophenyl)-2-(1H-1,2,4-triazol-1-yl)cycloheptanol
Appearance :	white crystalline solid
Melting point :	mp 128-129°C
Solubility :	125 ppm (H_2O) at 25°C
log P (octanol/H_2O) :	3.03
Acute oral toxicity : (LD_{50})	273 (95% C.L. 232-320) mg/kg in mouse 153<<214 mg/kg in rat
Ames test :	negative against Salmonella
Micro-nucleus test :	nagative
Fish toxicity	
Daphnia pulex :	100.5 mg/l (EC50 at 3 h)
Oryzias latipes :	10.9 mg/l (LC50 at 48 h)
Cyprinus carpio :	25.5 mg/l (LC50 at 48 h)
Toxicity on earth worm	
Eisenia foetida :	0.0072 mg/cm^2 (LC50 at 48 h by the OECD filter paper method) >1000 mg/kg soil (LC50 at 14 days by the OECD soil method)

Synthesis of diastereomer (trans-isomer) of SSF-109

In order to compare the biological activity of SSF-109 (cis) with its diastereomers, the trans-isomer of SSF-109 was synthesized in very poor yield from the sodium salt of 1,2,4-triazole and the bromohydrin which was obtained by the reaction of 1-(4-chlorophenyl)cyclohept-1-ene with N-bromoacetamide in aqueous acetone (Fig. 2).

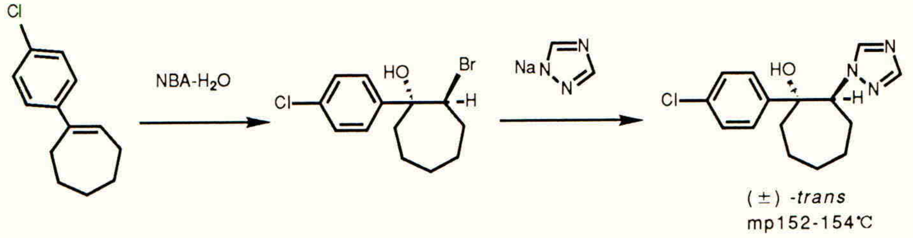


Fig. 2

Optical resolution of SSF-109

SSF-109 was optically resolved by separation of the diastereomeric mixture of L-menthoxyacetate of SSF-109 by column chromatography followed by hydrolysis.

(+)-SSF-109, mp 125-126°C, $[\alpha]_D^{23}$ +70.3±1.1° (CH_3OH, C = 1.012)
98% e.e (HPLC)

(-)-SSF-109, mp 125-126°C, $[\alpha]_D^{23}$ -69.7±1.1° (CH_3OH, C = 1.002)
97% e.e (HPLC)

BIOLOGICAL ACTIVITY

SSF-109 is a member of a fungicide family that inhibits ergosterol biosynthesis. It is systemic and exhibits preventive and curative activity against plant disease with excellent activity against grey mould (Botrytis cinerea).

In vitro activity of SSF-109 and its diastereomer

SSF-109 (cis) was about 10-70 times more active against S. sclerotiorum, V. inaequalis, B. cinerea, C. kikuchii, C. herbarum, A. alternata Japanese pear pathotype and A. alternata Apple pathotype than its trans-isomer. However, the trans-isomer was about 14 times more active than SSF-109 against Rosellinia necatrix (Table 1).

TABLE 1

In vitro activities of two diastereomers of 1-(4-chlorophenyl)-2-(1*H*-1,2,4-triazol-1-yl)cycloheptanol on hyphal growth of some plant pathogenic fungi

Fungus	EC_{50} (mg/l)	
	cis (SSF-109)	*trans*
PHYCOMYCETES		
Phytophthora melonis	37.9	>64
ASCOMYCETES		
Sclerotinia sclerotiorum	0.17	2.07
Glomerella cingulata	1.89	1.23
Gibberella zeae	9.91	31.2
Rosellinia necatrix	41.6	2.97
Venturia inaequalis	0.1	2.8
Pyrenophora graminea	1.19	6.26
BASIDIOMYCETES		
Ustilago maydis	4.8	3.95
Helicobasidium mompa	11.3	18.2
Corticium rolfsii	0.15	0.68
FUNGI IMPERFECTI		
Colletotrichum lagenarium	2.26	3.85
Botrytis cinerea (S)	0.1	2.2
Botrytis cinerea (BI-R)	0.04	2.8
Botrytis cinerea (DCI-R)	0.13	3.85
Botrytis cinerea (BI, DCI-R)	0.41	5.16
Pyricularia oryzae	0.76	3.16
Cercospora kikuchii	0.43	10.6
Cladosporium herbarum	0.24	5.91
Alternaria alternata		
Japanese pear pathotype (S)	0.38	4.36
Japanese pear pathotype (Polyox.-R)	0.49	4.58
Alternaria alternata		
Apple pathotype	0.71	7.75
Fusarium oxysporum		
f. sp. *cucumerinum*	5.15	10.2
Rhizoctonia solani	0.06	0.15

Method: Agar dilution
EC_{50}: Effective concentration producing 50% inhibition of hyphal growth
S: Sensitive to benzimidazole and dicarboximide
BI-R: Resistant to benzimidazole
DCI-R: Resistant to dicarboximide
BI, DCI-R: Resistant to benzimidazole and dicarboximide
Polyox.-R: Resistant to polyoxin

Disease control activity of SSF-109

SSF-109 was about 4-20 times more effective against grey mould (B. cinerea), powdery mildew (S. fuliginea), and sclerotinia rot (S. sclerotiorum) on cucumber by foliar application than the trans-isomer. It was also more active against blast (P. oryzae) on rice, powdery mildew (E. graminis) on wheat and crown rust (Puccinia coronata) on oat than its trans-isomer (Table 2).

TABLE 2

Preventive activity on foliar application EC_{50} (mg/l)			
Host	Fungus	cis (SSF-109)	trans
Cucumber	B. cinerea	2.4	55.6
	S. fuliginea	0.25	1.1
	S. scleotiorum	5.5	118.7
Rice	P. oryzae	6.2	31.2
	R. solani	23.0	19.7
Wheat	E. graminis	4.3	10.6
Oat	Puccinia coronata	4.8	7.8

Effects of SSF-109 against fungicide-resistant strains of B. cinerea

SSF-109 exhibited the similar activity on strains of B. cinerea which were resistant to either DCI or benzimidazole fungicides or sensitive to both chemical groups (Table 3).

TABLE 3

Compound	Preventive EC_{50} (mg/l)		
	Sensitive	Resistant	
	B.cinerea•B4	B.cinerea•R-26	B.cinerea•S-25
SSF-109	25	25	6.25
Iprodione(DCI)	25	>400	25
Benomyl(BI)	100	25	>400

DCI: Dicarboximide
BI: Benzimidazole

Effects of SSF-109 on growth of lettuce and rice seedlings

Seedling tests showed that the inhibitory activity of the trans-isomer on Lactuca sativa (I_{50} = 1.23 mg/l) was approximately two times stronger than SSF-109 (cis, I_{50} = 2.77 mg/l). Whereas, the activity of trans-isomer on Oryza sativa was approximately six times stronger than SSF-109, I_{50} value was 3.87 and 23.53 mg/l, respectively.

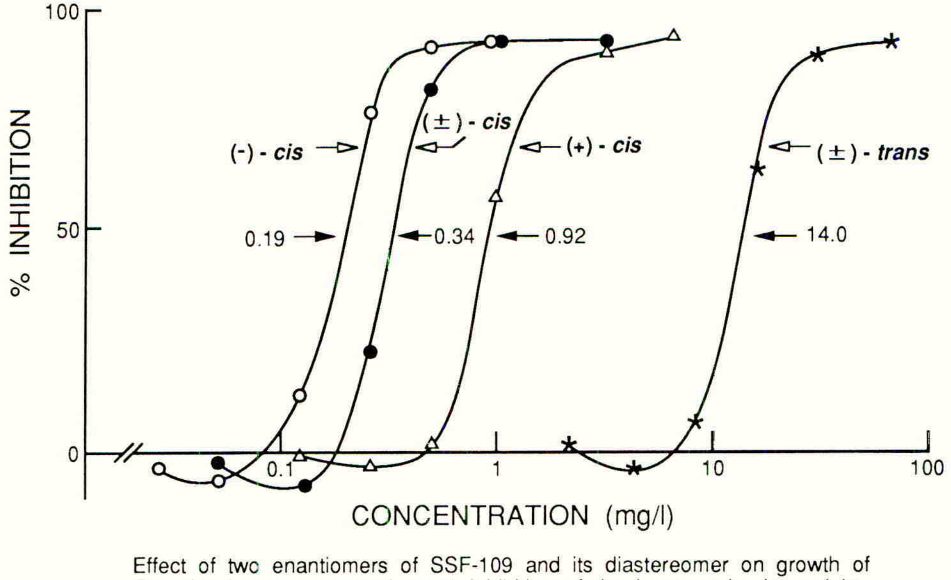
TABLE 4

Compound	I_{50} (mg/l)	
	Lactuca sativa*	Oryza sativa**
SSF-109 (cis)	2.77	23.53
trans	1.23	3.87

*: Hypocotyl elongation
**: 2nd leaf sheath

Effects of two enantiomers of SSF-109 and its diastereomer on mycelial growth of B. cinerea

SSF-109 was about 40 times more effective than the trans-isomer and (-)-SSF-109 was about 5 times more effective than (+)-SSF-109 against mycelial growth of B. cinerea (Fig. 3).



Effect of two enantiomers of SSF-109 and its diastereomer on growth of *Botrytis cinerea* expressed as % inhibition of the increase in dry weight. Preincubation : 21h, Fungicide treatment : 21h, ⟶ : EC_{50} (mg/l).

Fig. 3

Controlling activity of two enantiomers of SSF-109

The controlling activity of (-)-SSF-109 was 2-3 times more effective against powdery mildew and 2-4 times more active against grey mould than (+)-SSF-109 (Table 5).

TABLE 5

Compound	EC_{50} (mg/l)			
	Powdery mildew		Grey mould	
	Preventive	Curative	Preventive	Curative
(+)-SSF-109	5.06	2.61	4.08	7.89
(-)-SSF-109	2.45	0.78	1.90	1.94
(±)-SSF-109	3.35	1.77	2.37	3.52

Effects of the enantiomers of SSF-109 on lettuce and rice seedling growth

Plant growth retardant activity of (-)-SSF-109 against lettuce and rice was 3 times more effective than that of (+)-SSF-109 (Table 6).

TABLE 6

Compound	I_{50} (mg/l)	
	Lactuca sativa	*Oryza sativa*
(+)-SSF-109	4.64	51.01
(-)-SSF-109	1.59	17.22
(±)-SSF-109	2.77	23.53

CONCLUSIONS

SSF-109 is a novel fungicide which offers protection against a broad spectrum of plant diseases, and grey mould in particular.
In order to study the antifungal and plant growth retardant activity of the stereoisomers and optical isomers of SSF-109, these were synthesized and tested. The results showed that stereoisomers of SSF-109 exhibited different antifungal and plant growth retardant activities, and that the optical isomers of SSF-109 had similar properties.

ACKNOWLEDGEMENTS

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THICYOFEN: A NEW BROAD-SPECTRUM FUNGICIDE FOR SEED AND SOIL TREATMENT

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ABSTRACT

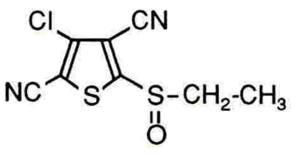
Thicyofen is a thiophene compound, showing broad-spectrum fungicidal properties, when applied as seed treatment or to soil. The compound is non-systemic in plants. Seed treatment of wheat, barley, maize, cotton and sorghum resulted in effective control of *Fusarium culmorum, F. graminearum, Tilletia caries, Pyrenophora graminea* and *Pythium* spp.. Treatment of soil with thicyofen prevented commercially grown flower bulbs from infestation by *Pythium* spp.
Thicyofen does not cause phytotoxicity at the rates recommended for disease control and is rapidly degraded in soil.

INTRODUCTION

In recent years Duphar B.V. has screened many compounds belonging to the chemical group of thiophenes. The compound thicyofen is the result of an optimization programme on these compounds. Its patent was first described by Dolman and Kuipers (Duphar, 1990). So far, compounds belonging to this group have not yet been developed commercially as pesticides. Thicyofen acts as a multi-site inhibitor with a higher toxicity to fungi than to other organisms. The biological characteristics of thicyofen are such that its fungicidal activity can be considered an excellent replacement for the organomercury fungicides. Thicyofen is rapidly degraded in the soil, so the compound does not have the detrimental properties of organomercury compounds.

TECHNICAL DETAILS

Chemical Name (IUPAC):	3-chloro-2,4-dicyano-5-ethylsulfinylthiophene
Common name:	thicyofen
Code numbers:	DU 510311, PH 51-07
Molecular formula:	$C_8H_5ClN_2OS_2$
Chemical structure:	



Molecular weight:	244.5
Melting point:	130°C

Solubility in water at 20°C:	0.24 g/l	
Partition coefficient:	Log P=2.54 (octanol/water)	
Vapour pressure at 20°C:	< 10^{-3} Pa	
Half life in soil:	< 1 month	
Formulation:	suspension concentrate	
Toxicity:		
Acute oral (gavage):	rat, male	LD_{50} = 395 mg/kg
	rat, female	LD_{50} = 368 mg/kg
	bobwhite quail	LD_{50} = 216 mg/kg
Acute oral (dietary):	bobwhite quail	LC_{50} > 5620 mg/kg
	mallard duck	LC_{50} > 5620 mg/kg
Acute dermal:	rat	LD_{50} > 2000 mg/kg
Mutagenicity:	not mutagenic in bacteriological and non-bacteriological in vitro tests	
Mode of action:	multi-site inhibitor	

MATERIALS AND METHODS

Formulation and application

Thicyofen was formulated as a water-based suspension concentrate. The concentration of AI in the formulation was dependent on the dosage required. Seeds were usually treated with 5 ml liquid per kg seed. Applications were made by spraying the required amount of liquid through a nozzle into a rotating drum onto the seeds. For some trials, seeds were placed in a jar to which the required amount of liquid was added with a pipette and subsequently distributed over the seeds by thoroughly shaking.

For the trials with flower bulbs, soil was treated in a concrete mixer with 20 ml spray liquid per litre soil.

Field trials

Wheat and barley were usually planted in clay soil in October or November. Approximately 1800 seeds per plot of 7.5 m^2 were used. Treatments were replicated four times. To study the effects of thicyofen on Fusarium-infected wheat, seeds naturally infected by *F. culmorum* and *F. graminearum* were used.

Effects on bunt (*Tilletia caries*) were studied using wheat seeds which had been artificially inoculated with a spore suspension. Since *T. caries* does not affect the emergence of wheat seeds, these seeds were also used to study the safety of thicyofen on wheat (reflected in emergence counts). Barley seeds that were naturally infested with *Pyrenophora graminea* were used to evaluate thicyofen for control of the disease and for crop safety.

Trials with maize were planted in sandy soil in The Netherlands. An average of 270 seeds were planted in 13.5 m^2 plots. All treatments were replicated four times. Planting was done in early March, which is approximately 6 weeks earlier than common agricultural practice. A severe disease pressure from *Pythium* spp. was created due to this very early planting in cold, wet soil. All seeds were given an additional treatment with the bird repellant methiocarb (500 mg AI per kg seed).

Pot trials with tulip bulbs, cv. 'White Dream' were done in unheated greenhouses. Planting was done in January in soil artificially infested with *Pythium ultimum*. Assessments were made about 5 weeks later when the bulbs in treated soil had produced flowers.

RESULTS AND DISCUSSION

Control of *Fusarium* spp. on wheat

Wheat is mostly grown on clay soil in The Netherlands. On clay the most important seedling diseases are caused by *Fusarium* spp. As may be seen in Table 1, treatment with thicyofen increased the emergence of Fusarium-infected wheat seeds significantly.

TABLE 1. Effect of thicyofen on the emergence of Fusarium-infected winter wheat.

Treatment	Dosage (mg/kg seed)	Emergence[1)] clay soil[2)]	organic sand[3)]
Thicyofen	200	101 b[4)]	105 b
Thicyofen	300	108 b	102 b
Thicyofen	400	100 b	107 b
Guazatine	700	100 b	100 b
Untreated	-	75 a	82 a

1) Numbers are related to numbers emerged from seeds treated with guazatine (= 100%).
2) Mean relative emergence from 5 trials in The Netherlands.
3) Mean relative emergence from 3 trials in The Netherlands.
4) Means in one column followed by same letters are not significantly different from each other ($P \leq 0.05$).

Three trials were conducted on an organic sand, known for its high disease pressure from *Pythium* spp. In these trials, thicyofen-treated seed gave a slightly higher emergence than guazatine-treated seed. This is most probably due to the excellent activity of thicyofen against *Pythium* spp., as this fungus is not controlled by guazatine. In greenhouse trials with the same soil, the effects were even more pronounced than under field conditions.

A clear dose-response was not observed. A dosage of 200 mg AI per kg seed gives adequate control of *F. culmorum* and *F. graminearum*. Only few trials were conducted on *Gerlachia nivalis*. Thicyofen appears to have insufficient residual activity to control this pathogen.

Embryo located pathogens like loose smut (*Ustilago tritici*) can not be controlled by thicyofen, since the compound does not act systemically. Combination of thicyofen with a systemically acting fungicide will be necessary to obtain control of embryo-located pathogens.

Control of bunt (*Tilletia caries*) on wheat

Table 2 illustrates that dosages of 200-400 mg thicyofen per kg seed are at least as effective as guazatine or carboxin to control *T. caries*. A dosage of 300 mg AI per kg seed appears to be the minimal dose for optimum disease control.

TABLE 2. Effect of thicyofen on the emergence of winter wheat infested with bunt (*Tilletia caries*) and on the percentage disease control (d.c.).

Treatment	Dosage (mg/kg seed)	Country[4)]					
		France[2)]		USA		The Netherlands	
		emergence[5)]	% d.c.	emergence	% d.c.	emergence	% d.c.
Thicyofen	200	99	95 a[3)]	110	92	98	94
Thicyofen	300	101	-	-	-	97	95
Thicyofen	400	-	100 b	118	100	101	96
Guazatine	700	100	97 a	-	-	100	90
Carboxin	115	-	-	100	99	-	-
Untreated	-	103	-	101	-	90	-
Disease level[1)]			79		81		45

1) Number of diseased heads in 2 m row of untreated seed.
2) In France the reference treatment was guazatine + imazalil in a dosage of 600 + 50 mg AI per kg seed.
3) Data in one column followed by same letters are not significantly different from each other ($P \leq 0.05$). If data in a column are not followed by letters, no significant differences were present.
4) Means in these trials were calculated from 2 trials in France, 1 trial in the USA and 5 trials in The Netherlands.
5) Numbers are related to numbers emerged from seeds treated with guazatine or carboxin (= 100%).

Control of leafstripe (*Pyrenophora graminea*) on barley

Barley leaf stripe (*P. graminea*) is a seed-borne pathogen, whose spores are usually found both on the outside and inside of the seed coat. Although thicyofen does not act systemically, it gives excellent control of *P. graminea*. A dosage of 300 mg AI per kg seed was equally effective as the reference treatment with guazatine + imazalil (Table 3).

Crop safety

In Tables 2 and 3 the relative emergence of seed infested by *T. caries* and *P. graminea* is presented. Neither pathogen is known to affect emergence of seeds, so the contaminated seeds can be used to study the crop safety of thicyofen. There were no significant differences in emergence between treatments observed in any of these trials. This shows that thicyofen does not cause phytotoxicity at rates that are recommended for disease control, or at slightly higher rates. In laboratory trials and in other field trials, dosages up to 600 mg thicyofen per kg wheat or barley seed were not phytotoxic.

TABLE 3. Effect of thicyofen on leaf stripe (*Pyrenophora graminea*) on barley[1].

Treatment	Dosage (mg/kg seed)	Emergence[2]	Number of infected plants/plot
Thicyofen	200	101	6.2 b[3]
Thicyofen	300	103	2.0 c
Thicyofen	400	104	1.6 c
Guazatine/imazalil	600/50	100	0.6 c
Untreated	-	98	77 a

1) Means from 5 trials in The Netherlands.
2) Numbers are related to numbers emerged from seeds treated with guazatine/imazalil (= 100%).
3) Data in one column followed by same letters are not significantly different from each other ($P \leq 0.05$). If data in a column are not followed by lettters, no significant differences were present.

Control of damping-off (*Pythium* spp.) on maize

Table 4 shows that thicyofen gives excellent protection against damping-off of germinating maize seeds. The disease pressure in these trials was very severe, because of the very early planting date. Although thicyofen is rapidly degraded in the soil, the product offers a very good protection of the seeds and seedlings during the six weeks that it took the seedlings to emerge.

TABLE 4. Effect of thicyofen on the emergence of maize seeds[1].

Treatment	Dosage mg/kg seed	Relative[2] emergence
Thicyofen	500	103 b[3]
Thicyofen	750	110 b
TMTD	1200	100 b
Untreated	-	37 a

1) Means from 6 trials in The Netherlands.
2) Numbers are related to numbers emerged from seeds treated with TMTD (= 100%).
3) Data in one column followed by same letters are not significantly different from each other ($P \leq 0.05$).

In other field trials seeds were planted at the recommended planting time. In those trials emergence of untreated seeds was equal to treated seeds. Because of the higher soil temperature, seedlings emerged above the soil within 1-2 weeks so the chances for severe damping-off were much smaller. No significant differences between the treatments were detected, which shows the crop safety of thicyofen on maize.

Trials on many maize varieties were also conducted in the USA and France. In those trials that suffered from *Pythium* disease pressure, control of damping-off was at least as good as with captan, which was used as a standard in those trials. Phytotoxicity was not observed in any maize variety.

Control of damping-off (*Pythium* spp.) and *Rhizoctonia solani* on cotton

Seed treatment of cotton with thicyofen has been investigated in the USA and Australia. The trials in Australia were inconclusive due to a very low disease pressure, however, like in other trials, no phytotoxicity was observed.

Results from one trial in the USA are reported in Table 5. The disease pressure from *Pythium* spp. was very high and resulted in a very poor emergence of unprotected seed. Seed which had been treated with thicyofen gave a much better emergence than seed treated with the standard mixture of carboxin/quintozene/ metalaxyl. A clear dose-response from thicyofen was observed. Tolclofos-methyl did not protect seedlings from *Pythium* infestation. In other trials, where the disease pressure was not as high as in the trial presented in Table 5, thicyofen-treated seed also gave a higher number of emerged seedlings than seed treated with standards.

Soil-borne *Rhizoctonia solani* caused serious stem infections of the emerged cotton plants. Differences between treatments were not significant although in two trials the disease severity from *R. solani* was reduced by the highest dosage of thicyofen and by the combination thicyofen/tolclophos-methyl.

TABLE 5. Effect of thicyofen and other fungicides on the emergence and *Rhizoctonia* infection of cotton.

Treatment	Dosage (mg/kg)	Emergence[1)]	*Rhizoctonia*[2)] infection
Thicyofen	500	162 c[3)]	32
Thicyofen	750	329 d	27
Carboxin/quintozene/metalaxyl	1000/1000/300	100 b	30
Tolclofos-methyl	500	9 a	- 4)
Thicyofen/tolclofos-methyl	500/500	311 d	21
Untreated	-	6 a	- 4)

1) Numbers are related to numbers emerged from seeds treated with the standard (= 100%).
2) Means reflect the disease severity; 0=healthy, 100= dead.
3) Data in one column followed by same letters are not significantly different from each other ($P \leq 0.05$). If data in a column are not followed by letters, no significant differences were present.
4) Due to severe damping-off caused by *Pythium* spp., numbers of plants were too low for assessments on Rhizoctonia-infection.

Control of damping-off (*Pythium* spp.) on sorghum seedlings

Damping-off caused by *Pythium* spp. is an important disease of many seedlings. The trials on maize and cotton already illustrated the excellent activity of thicyofen against *Pythium* spp. Seeddressing of sorghum with thicyofen also provided excellent control of *Pythium* spp. A significant dosage-response was observed in the trials (Table 6). Dosages of ≥ 500 mg AI per kg seed resulted in at least 50% more emerged healthy seedlings compared to seed that had been treated with the reference product captan.

TABLE 6. Effect of thicyofen on the emergence of sorghum seed[1].

Treatment	Dosage mg/kg seed	Emergence[2]
Thicyofen	250	119 b[3]
Thicyofen	500	150 bc
Thicyofen	750	186 c
Captan	600	100 b
Untreated	-	53 a

1) Means from two trials in the USA.
2) Numbers are related to numbers emerged from seeds treated with captan (= 100%).
3) Means followed by same letters are not significantly different from each other ($P \leq 0.05$).

Storage protection of seed potatoes

One trial has been conducted to evaluate thicyofen for its activity towards silver scurf and Fusarium dry rot. At 200 g AI per 1000 kg of potatoes its activity towards silver scurf was much better than standard products, whilst at 100 g AI per 1000 kg, thicyofen was equally effective. Thicyofen did not control Fusarium dry rot, although it showed good activity towards *Fusarium* spp. both on wheat and in vitro tests. One of the reasons to explain the lack of activity may be the artificial wounding of the potatoes during inoculation with *Fusarium.* Since this was done one day prior to fungicide treatment, it may have given the fungus a route to escape the fungicide. A combination of thicyofen with a systemic fungicide may solve this problem. Further trials will be done under more practical conditions, i.e. treatment of tubers immediately after harvest.

In the greenhouse, a pot trial was conducted with potatoes that were heavily covered with sclerotia from *Rhizoctonia solani.* Dipping of tubers in a solution containing 750 mg thicyofen per litre water resulted in a strong reduction of stem infection by *R. solani.*

Control of soft rot (*Pythium* spp.) on bulbs

Promising results have been obtained by soil treatments with thicyofen to control *Pythium ultimum* on tulips. The length of the plants is a measure of the vigour of the root system. Infestation by *P. ultimum* decreases the root vigour and as a consequence the growth of tulips. At 10 and 21 mg thicyofen per litre soil, the number of flowers was 1 per bulb, which was comparable to a treatment with fenaminosulf (Table 7). A dosage of 4 mg thicyofen gave insufficient control of *Pythium.* In a number of other trials it was confirmed that the optimum dosage for control of *P. ultimum* was around 20 mg AI per litre soil. A bulb treatment without soil treatment did not control *P. ultimum.* Other fungi on which a good activity of thicyofen was observed were *Rhizoctonia tuliparum* on tulip by soil treatment and *Stromatinia gladioli* on gladiolus by bulb treatment.

TABLE 7. Effect of thicyofen on *Pythium ultimum* on tulips[1].

Treatment	Dosage (mg/l soil)	Length (cm)	Flowers (number/bulb)
Thicyofen	4	7 a[2]	0 a
Thicyofen	10	23 c	1 c
Thicyofen	21	22 c	1 c
Fenaminosulf	21	21 c	1 c
Untreated	-	7 a	0 a
Untreated (not inoculated)	-	13 b	0.5 b

1) A severe disease pressure was obtained by adding soil contaminated with *P. ultimum* to the potting soil. Thicyofen was applied as a soil treatment.
2) Means followed by same letters are not significantly different from each other ($P \leq 0.05$).

Control of diseases on other crops

In laboratory trials where thicyofen was mixed with soil or applied as a soil drench, the compound has shown great potential to control soil-borne *Pythium* spp., *Fusarium* spp. and *Rhizoctonia solani* on sugar beet and vegetables. These observations indicate the potency of the product for use as a seed bed fungicide.

CONCLUSIONS

Thicyofen is a broad-spectrum contact fungicide. Although the compound is rapidly degraded in the soil, its control of the major non-systemic seedling diseases is excellent. The spectrum of thicyofen is similar to that of organomercury compounds, but thicyofen has a much more favourable environmental impact and may therefore also be applied as a soil treatment.

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LS860263 - A TRIAZOLE FUNGICIDE WITH NOVEL PROPERTIES

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ABSTRACT

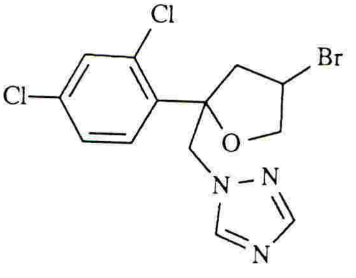
LS860263 is a sterol-inhibiting fungicide developed by Rhône-Poulenc Agro showing good activity against a wide range of diseases belonging to the classes Ascomycetes, Basidiomycetes and Fungi Imperfecti.
An extensive field testing programme has been carried out over the last three years, and the results have confirmed the efficacy of the compound against the range of diseases usually controlled by sterol-inhibiting products. In this respect, it is very well adapted to the protection of cereals, rice, fruit trees, grapes, vegetables and turf at rates ranging from 20 to 300 gAI/ha.
In addition, its spectrum of activity includes several diseases which are not normally sensitive to triazoles : its most interesting properties relate to the high level of efficacy against *Fusarium* and *Alternaria* spp. in several crops.

INTRODUCTION

LS860263, is a new broad spectrum sterol-inhibiting fungicide discovered and patented by Rhone-Poulenc Agro. Its biological properties have been evaluated since 1987 on a wide range of crops including cereals, fruits, vines and vegetables. This paper is a review of its performance against diseases of major importance in these crops.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical family :	triazole
Common name :	bromuconazole
Chemical name (IUPAC) :	1-[(2RS,4RS;2RS,4SR)-4-bromo-2-(2,4-dichlorophenyl) tetrahydrofurfuryl]-1H-1,2,4-triazole
Structural formula :	



Physical appearance :	white to off-white powder
Odour :	odourless
Melting point :	84°C
Vapour pressure :	0.3 10^{-7} mm Hg at 25°C
Solubility (water) :	50 mg/l
Solubility (organic solvents) :	moderate to high.

TOXICOLOGY AND ENVIRONMENTAL STUDIES

Mammalian toxicity

Acute oral LD50	Rat	:		365 mg/kg
Acute dermal LD50	Rat	:	>	2000 mg/kg
Acute oral LD50	Mouse	:		1151 mg/kg
Acute inhalation LC50	Rabbit	:	>	5 mg/l
Eye irritation	Rabbit	:		None
Dermal irritation	Rabbit	:		None
Dermal sensitization	Guinea pig	:		Negative

Mutagenicity

Ames test	:	negative
In vivo mouse micronucleus test	:	negative

Toxicity to wildlife

Avian	Bobwhite quail	LD50	: >	2150 mg/kg	practically non-toxic
		LC50	: >	5000 ppm	practically non-toxic
	Mallard duck	LD50	: >	2150 mg/kg	practically non-toxic
		LC50	: >	5000 ppm	practically non-toxic
Aquatic	Bluegill sunfish	LC50 (96 h)	:	3.1 mg/l	moderately toxic
	Rainbow trout	LC50 (96 h)	:	1.7 mg/l	moderately toxic
	Daphnid	LC50 (48 h)	: >	5.0 mg/l	slightly toxic

FORMULATIONS

Several formulations are available, including :

- suspension concentrates containing 200 g/l active ingredient especially designed for optimum efficacy and selectivity in cereals and vines or fruits respectively,

- an oil dispersible suspension containing 200 g/l active ingredient for use in crops where the spray carrier is oil

- mixtures with other fungicides, adapted for specific uses.

BIOLOGICAL PROPERTIES

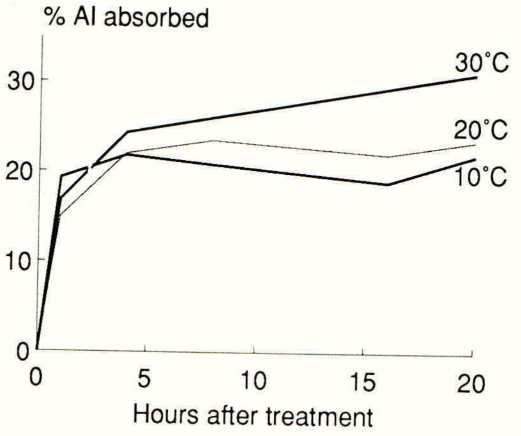
Absorption and systemicity

Tests have been carried out to study the up-take of the active ingredient through the leaf cuticle and epidermis, and its movement within the plant after it has been applied to the foliage.

Wheat seedlings were grown in pots outdoors for ten days, then kept in controlled environment cabinets at three different temperatures before being sprayed with C^{14}-labelled fungicide. Radio-activity analyses were carried out at various timings after the treatment was applied.

The results are given below, as the percent of the total active ingredient absorbed. They show a rapid absorption by the foliage, little dependant on the temperature, which may be an advantage, for the early treatment of cereals.

Fig. 1. Up-take of LS860263 by wheat seedlings at various temperatures.



In another study, a drop of radio-labelled fungicide suspension was applied to the upper surface of a barley leaf, at a point situated in the lower third of the leaf. Autoradiograms of the leaves were carried out 2, 8, 16, 24, 48 and 144 hours after treatment, and showed that the compound was evenly distributed within the apical part of the leaf after 24 hours, but did not move downwards.

Mode of action

Like other fungicides belonging to the triazole group, LS860263 is an ergosterol biosynthesis inhibitor.

In vitro activity

LS860263 has a broad spectrum of activity. Complete growth inhibition of fungi such as *Septoria* spp., *Helminthosporium* spp., *Venturia* spp., *Cercospora* spp., *Monilia* spp., *Fusarium* spp. and *Alternaria* spp. was obtained with low concentrations of the active ingredient *in vitro* (Table 1).

TABLE 1. *In vitro* activity of LS860263

Fungus	IC90 mg/l	Fungus	IC90 mg/l
Altenaria alternata	4.8	*Laetisaria fuciformis*	2.6
Alternaria brassicae	<1	*Leptosphaeria nodorum*	3
Alternaria dauci	1	*Leptosphaeria maculans*	3
Alternaria kikuchiana	<1	*Monilia fructigena*	<1
Alternaria solani	<1-3	*Monilia laxa*	<1
Botrytis cinerea	2.2 - 8.8	*Monographella nivalis*	5.2
Ceratocystis fimbriata	<1	*Mycosphaerella fijiensis*	<1
Cercospora arachidicola	<1	*Mycosphaerella graminicola*	3
Cercospora musicola	<1	*Penicillium expansum*	<1 - 2
Colletotrichum coffeanum	3 - 6	*Penicillium italicum*	2
Corticium rolfsii	6.4	*Phytophthora spp*	>100
Cytospora cincta	<1	*Pseudocercosporella capsellae*	<1
Diaporthe citri	<1	*Pseudocercosporella herpotrichoides*	1.4-5.2
Elsinoe fawcettii	<1	*Pyrenophora graminea*	1.7
Eutypa armeniacae	<1	*Pyrenophora teres*	2.3
Fusarium culmorum	<1 - 3	*Pyricularia oryzae*	<1 - 2
Fusarium graminearum	1	*Pythium spp*	> 100
Fusarium moniliforme	<1	*Ramularia beticola*	<1
Fusarium oxysporum	<1 - 5	*Sclerotinia homoeocarpa*	<1
Fusarium solani	2.2	*Sclerotinia sclerotiorum*	<1 - 8
Gaeumannomyces graminis	1	*Sclerotium cepivorum*	<1
Gibberella fujikuroi	<1	*Stereum purpureum*	1
Guignardia bidwellii	<1	*Venturia inaequalis*	<1

IC 90 = Fungicide concentration providing 90 % inhibition of mycelium growth

Field trials

Materials and methods

Cereals

The trials were conducted using a randomised block design, with 4 replicates, on plots of 15-75 m^2. Treatments were applied twice at growth stages Z37-39 and Z55-59, except against stem based diseases were a single treatment at stage Z30-33 was applied. Spray volume was 250-600 l/ha. Severity of the disease was assessed on stems, leaves and ears.

Fruits , vines and vegetables

The trials were conducted using a randomised block design with 4-6 replicates. Plot size was 2-4 trees for fruit trees, 6-15 plants for vines and 5-15 m^2 for vegetables. Spray volumes used were 600-2500 l/ha in fruits, 500-1000 l/ha in vines and 400-600 l/ha in vegetables. Treatments were applied either on a routine basis or at specific growth stages, depending on the target organisms. Severity of the disease was assessed on blossoms, leaves and fruits.

Carrots, potatoes, oilseed rape (*Alternaria* spp.)

The trials were conducted using a randomised block design with 4 replicates. Plot sizes were 30-100 m^2 for oilseed rape or 10-50 m^2 for carrots and potatoes, and the treatments were applied either on a routine schedule (carrots and potatoes) or at first symptom appearance (oilseed rape). Severity of the disease was assessed on the leaves.

Results

Cereals

LS860263 provided a good control of stem based infections of eyespot (*Pseudocercosporella herpotrichoides*) and Monographella nivalis *(Fusarium nivale*) at rates of 300 gAI/ha (Table 2). Against eyespot, the efficacy was equal to that of the reference compound prochloraz in most situations ; however, when the proportion of 'R' strains of the fungus within the pathogenic population was high, it was slightly less effective than prochloraz, but remained as effective as fluzilazol. This small difference did not show in the yields, probably due to the greater efficacy against other early foliar diseases.

TABLE 2. Control of stem diseases (*P. herpotrichoides* and *F. nivale*) in winter wheat.

Treatment	Dose (gAI/ha)	% stem infection *P.herpotrichoides*			Yield (t/ha)	% stem infection *F.nivale*
Untreated	-	59	47	50	5.40	19
LS860263	300	33	18	33	5.90	8
Prochloraz	750	35	16	25.5	5.87	-
Flusilazole	300	-	17	32	6.00	-
Prochloraz + carbendazim	450 + 150	-	-	-	-	25
Number of trials		4	3[1]	4[1]	7[1]	1

Average of several trials, Europe 1988-89

[1] yields and efficacy originated in the same trials

Against high infections of foliar diseases (*Mycosphaerella graminicola, (Septoria tritici) Puccinia recondita, P.striiformis, Erysiphe graminis, Pyrenophora tritici-repentis, Pyrenophora teres, Rhynchosporium secalis*) in wheat and barley, rates close to 200 gAI/ha gave very good results (Tables 3 to 5). Against *E.graminis*, the combinations with a morpholine fungicide proved to be more effective in regions were D.M.I.-resistance was present. In other areas, the efficacy of LS860263 was not improved by the addition of such products. A special mention has to be made concerning the efficacy of LS860263 against *Fusarium roseum* on wheat ears (Table 5).

TABLE 3. Control of *Septoria tritici* in winter wheat.

Treatment	Dose (gAI/ha)	% leaf surface infected				
Untreated	-	35	25	18	13	52
LS860263	125	7	-	2.2	5	8.2
LS860263	200	5	6.9	1.1	5	3.5
LS860263	300	5	-	-	-	-
Propiconazole	125	-	-	2.3	5	3.3
Propiconazole + carbendazim	125 + 150	5	6.8	-	-	-
Flusilazole	200	-	-	2.9	-	-
Number of trials		4	5	2	2	4

Average of several trials, Europe 1988-89

TABLE 4. Control of foliar diseases in winter wheat

Treatment	Dose (gAI/ha)	% infected leaves *P.recondita*		% leaf area infected *P.striiformis*	*E. graminis* * (R+S)	(R)	(S)
Untreated	-	100	98	26.7	33	19	12
LS860263	125	17.5	-	1	14	-	-
LS860263	200	7.5	2	0.7	11	13.2	2.4
LS860263	250	-	0	-	4.3	-	-
LS860263 + tridemorph	200+350	-	-	-	-	4	3.2
Propiconazole	125	29.5	-	0.7	8	10.3	6.7
Fluzilazole	200	-	-	-	12.3	-	-
Tebuconazole	250	-	1	-	-	-	-
Number of trials		11	1	9	3	1	1

Average of several trials, Europe 1988-90
* Trials were conducted in areas with a high (R) or low (S) proportion of DMI-resistant strains of powdery mildew.

TABLE 5. Control of foliar and ear diseases in winter wheat and winter barley.

Treatment	Dose (gAI/ha)	% ear area infected *Fusarium roseum*	% leaf area infected *P.tritici -repentis*	*P.teres*	*R.secalis*
Untreated	-	12.3	15 (7.5-19)	19.3	23
LS860263	125	-	-	-	8
LS860263	200	-	4 (1-6)	1.6	5
LS860263	200-300	3.9	-	-	-
Propiconazole	125	-	3 (1-4)	1.2	6.5
Reference[1]		4.2	-	-	-
Number of trials		4	3	3	6

Average of several trials, Europe 1988-89
[1] : reference compounds used in these studies were propiconazole, tebuconazole, or prochloraz+carbendazim.

Fruit and vegetables

LS860263 was evaluated in various countries for the control of fruit, vine and vegetable diseases : good control of *Venturia inaequalis* and *Podosphaera leucotricha* in apples, *Uncinula necator* in vines and *Sphaerotheca fuliginea* in cucurbits was achieved with rates ranging from 20 to 40 gAI/ha (Table 6).

TABLE 6. Control of fruit diseases (*Venturia inaequalis* and *Podosphaera leucotricha* in apples), vine powdery mildew (*Uncinula necator*) and cucurbit powdery mildew (*Sphaerotheca fuliginea*).

Treatment	Dose (gAI/ha)	% area infected Zucchini *S.fuliginea*	Apples *V.inaequalis* Leaves	Apples *V.inaequalis* Fruits	Apples *P.leucotricha* Leaves	Vines *U.necator* Leaves
Untreated	-	19.7	31	36	34	19.5
LS860263	20	2.5	0.1	0.9	4.7	0.45
LS860263	30	-	0	0.9	3.9	-
LS860263	40	0.8	-	-	-	-
Reference		5.5[1]	0.1[2]	1.2[2]	4.0[2]	0.65[3]
Number of trials		1	2	4	4	2

Europe and U.S.A. 1988-89.
Reference compound : [1] = triadimefon, 75 gAI/ha; [2] = flusilazole, 20 gAI/ha or myclobutanil, 62 gAI/ha; [3] = penconazole, 25 gAI/ha.

Control of *Alternaria* spp. in several crops

In oilseed rape, potatoes and carrots, good control of various species of *Alternaria* has been obtained under temperate or subtropical conditions with rates of 125-400 gAI/ha LS860263 (Table 7). Further work is needed, however, to optimize the rate of use of the product especially when this is applied in combination with other fungicides.

TABLE 7. Control of *Alternaria* spp. in various crops.

Treatment	Dose (gAI/ha)	% leaf area infected Oilseed rape *A.brassicae*	Potatoes *A.solani*	Carrots *A.dauci*
Untreated	-	21	53	60
LS860263	125	8	-	-
LS860263	200	-	21	35
LS860263	250	4	-	-
LS860263	300	-	-	24
LS860263	400	-	13.2	-
Iprodione	500	5	-	-
Iprodione	750	-	22.2	39
Number of trials		1	3	1

Europe and Brazil - 1988-1989

Other crops

LS860263 has been tested against a number of diseases in several other major crops (Table 8) :

It gave excellent control of black and yellow Sigatoka in bananas (*Mycosphaerella fijiensis* and *Mycosphaerella musicola*) at rates of 100-150 gAI/ha, when applied either on a regular spray schedule or following the official warning systems. At these rates, its efficacy was equal to that of propiconazole applied at the registered rate.

In stone fruit (plums and peaches), when applied 2 to 4 times at 10-14 day intervals before harvest, LS860263 at 50-100 gAI/ha provided good protection against brown rot (*Monilia fructigena*) ; in peaches, this treatment was at least as effective as the reference products iprodione, benomyl and captan in improving fruit shelf-life. Combinations with other fungicides also showed promise.

In turf, a level of control equal to or better than that provided by propiconazole was obtained against some of the major diseases : dollar spot (*Lanzia* & *Moellerodiscus* spp.), rust (*Puccinia* spp.) summer patch (*Magnaporthe poae*), using rates of 2.5-10 gAI.LS860263 /100 m^2

In maize, at a limited number of sites, an excellent efficacy was obtained against *Fusarium moniliforme* using LS860263 at 250 gAI/ha applied as a foliar spray.

TABLE 8. Summary of efficacy of LS860263 against diseases in various crops

Crops	Diseases	Rates (gAI/ha)
Stone fruit	Blossom blight (*Monilinia laxa*) Brown rot (*Monilinia fructigena*)	50-100
Bananas	Yellow sigatoka (*Mycosphaerella musae*) Black sigatoka (*Mycosphaerella fijiensis*)	100-125 100-150
Turf	Dollar spot (*Lanzia* & *Moellerodiscus* spp) Rust (*Puccinia* spp.) Summer patch (*Magnaporthe poae*) Anthracnose (*Colletotrichum graminicola*)	1000 250 1000 250-1000
Coffee	Leaf rust (*Hemileia vastatrix*)	60-120
Peanuts	Early/late leaf spot (*Cercospora arachidicola Cercosporidium personatum*)	100-200
Rice	Sheath blight (*Rhizoctonia solani*) Narrow brown blotch (*Cercospora oryzae*) Brown spot (*Cochiobolus miyabeanus*) Leaf smut (*Entyloma oryzae*)	150-250
Pecan	Scab (*Fusicladium effusum*)	100-150
Ornamentals	Gladiolus *Fusarium spp.* (as a bulb dip)	10 gai/hl

CONCLUSIONS

LS860263 has shown excellent efficacy over the last three years in a number of crops against diseases of major importance. A special mention has to be made concerning the efficacy of LS860263 against cereal diseases, especially *Septoria* spp. and *Fusarium* spp., and against diseases caused by *Alternaria* spp. in several crops.

HEXACONAZOLE - A NEW FLEXIBLE CEREAL FUNGICIDE

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ABSTRACT

Hexaconazole combines excellent uptake and movement properties within the cereal leaf with a broad spectrum of activity to give a fungicide which can be used flexibly in any of the different disease situations which occur in France. Field trials in wheat carried out by the ITCF, SPV and by ICI in France have demonstrated excellent control of rusts (*Puccinia* spp.) and *Septoria* spp. and good control of mildew (*Erysiphe graminis* f.sp. *tritici*), eyespot (*Pseudocercosporella herpotrichoides*) and fusarium ear blight with hexaconazole + carbendazim. The product has a high level of crop safety and has been extensively applied in France in 1990.

INTRODUCTION

The properties of hexaconazole as a novel fungicide for horticultural, plantation and non-cereal broad acre crops were first described by Shephard *et al*. in 1986. This paper describes the characteristics of hexaconazole as a cereal foliar fungicide and its use in controlling the major diseases of wheat in France, where 'Planete', the first of a range of hexaconazole-based cereal products, was launched in autumn 1989.

METHODS & TECHNIQUES

In vivo glasshouse and growth room studies

Cereal seedling plants were raised in John Innes Compost No 2 in growth room conditions of 21-24°C, 60% r.h. day and 17°C, 95% r.h. night. The light intensity was 1500 lumens for 16 h/day. Eight day old cereal seedlings were inoculated with spores freshly harvested from either stock plants or agar plates depending on the pathogen. Quantified spore suspensions and chemical suspensions to which a wetter was added to aid distribution on the leaf were spray applied to maximum retention using an airline pressured DeVilbiss hand spray gun. Assessments of percentage disease cover were made 7-14 days post inoculation.

In vitro laboratory studies

Chemically amended agar plates were inoculated with either a mycelial plug or a quantified spore suspension. Plates were incubated in a suitable constant temperature environment and assessed for percentage of fungal growth relative to the untreated 7-10 days post inoculation.

Field trials

All treatments were replicated at least three times and arranged in randomised block designs. Plot sizes were 13-50m^2. Fungicides were applied using knapsack sprayers in water volumes of 200-500l/ha. Applications were made between growth stages Z30 and Z65 depending upon the disease, the disease pressure and local recommendations. Disease control was assessed using standard methods involving visual estimation of infection on stem bases, leaves, ears or plots. Assessments were made at suitable intervals ranging from 15 to 60 days after application. Harvesting was by standard small plot harvesting equipment. Results are expressed relative to the level of disease or yield in untreated plots. Treatment means followed by different lower case letters are statistically significantly different at the 95% probability level.

RESULTS

In conventional laboratory and glasshouse screening experiments, hexaconazole has exhibited very good intrinsic activity and spectrum of efficacy against the major cereal pathogens (Table 1).

TABLE 1. Activity of hexaconazole and other triazole fungicides in laboratory and glasshouse tests.

Pathogen	Type of test*	Treatment Hexaconazole	Cyproconazole	Tebuconazole	Flusilazole	Propiconazole
Major pathogens:						
Puccinia recondita	(P,01)	<0.1	0.5-1	1	-	-
Mycosphaerella graminicola	(C,05)	5-10	5	1	-	-
Leptosphaeria nodorum	(P,01)	5-10	10	5	-	-
Erysiphe graminis f.sp. tritici	(C,02)	1-10	1-10	1-10	-	-
Pseudocercosporella herpotrichoides - rye type	In vitro	1-5	>5	1-5	-	-
Pyrenophora teres	(P,01)	5-10	5	5	-	-
Erysiphe graminis f.sp. hordei (triazole resistant)	(C,02)	5	1-5	1-5	-	-
Rhynchosporium secalis	(P,01)	1	5-10	<1	-	-
Other Pathogens:						
Fusarium culmorum	In vitro	0.4	0.8	0.14	0.21	0.22
Monographella nivalis	In vitro	1-3	1.5	0.94	0.12	2.2
Pyrenophora tritici-repentis	In vitro	0.22	0.79	2.4	0.85	0.13
Typhula incarnata	In vitro	0.16	-	0.59	<0.3	0.73

*Foliar spray coding: P = Protectant, C = Curative, 0x = x days between treatment and inoculation.

Data presented as LC95 values (mg AI/l to give 95% control) for major pathogens and LC50 values (mg AI/l to give 50% control) for others.

Hexaconazole has shown exceptional activity against brown rust (Puccinia recondita) of wheat in seedling tests from both protectant and curative foliar spray applications (Table 2). In similar tests against wheat powdery mildew (Erysiphe graminis f.sp. tritici), hexaconazole demonstrated good protectant activity (Table 3). When fungicide amended agar plates were seeded with spores of Mycosphaerella graminicola (S. tritici), colony development was inhibited at very low concentrations of hexaconazole (Table 4).

TABLE 2. Activity of hexaconazole and other triazole fungicides against Puccinia recondita on glasshouse grown wheat seedlings (cv. Armada).

Treatment		LD50 (mg AI/l)	
	Application type*:	Protectant	Curative
Hexaconazole		1.4	0.64
Propiconazole		8.6	1.2
Flusilazole		13	2.1
Triadimenol		23	2.2

*Treatments were applied 1 day before inoculation (protectant) or 4 days after inoculation (curative).

TABLE 3. Activity of hexaconazole and other triazoles at 5mg AI/l as 3 day protectant foliar sprays against Erysiphe graminis f.sp. tritici on glasshouse grown wheat seedlings (cv. Rapier).

Treatment	% Disease Control[1]
Hexaconazole	95
Tebuconazole	85
Triadimenol	60

1. Powdery mildew level in untreated = 36%.

TABLE 4. Inhibition of colony development of Mycosphaerella graminicola by hexaconazole and other triazole fungicides in vitro.

Treatment [1]	% Inhibition of mycelial growth[2]
Hexaconazole	100
Tebuconazole	90
Flusilazole	65
Cyproconazole	10
Carbendazim	10

1. Compounds incorporated into agar at 0.01 mg AI/l.
2. Assessed 7 days after seeding spores on fungicide amended agar plates.

When droplets containing hexaconazole were applied to wheat leaves in a zone one-quarter of the length from the base of the leaf, and the leaves subsequently bioassayed by inoculating with wheat brown rust uredospores seven days later, systemic movement of hexaconazole was revealed to be slow and acropetal only (Table 5). These movement properties give rise, under field conditions, to an excellent level of persistence of fungicidal effect and outstanding crop safety. As a formulated product in combination with carbendazim, hexaconazole is rainfast within two hours of application.

TABLE 5. Movement of hexaconazole in wheat leaves (cv. Armada) demonstrated by a Puccinia recondita bioassay.

Treatment	Rate (mg AI/l)	% Disease control in each leaf zone[1] A (zone of application)	B	C (leaf tip)
Untreated	-	0	0	0
Hexaconazole	1	100	100	100
Cyproconazole	1	71	87	100

1. Disease control assessed 15 days after chemical application to zone A and 8 days after inoculation of the whole leaf with uredospores of P. recondita.

The changing pattern of wheat diseases in France

During the past 20 years considerable changes have occurred in the relative importance of different cereal diseases in France, coincident with the intensification of arable agriculture.

Formerly, eyespot was the most important disease. This disease is now largely confined to the area north of the Loire, and is most damaging north of the Paris basin. The incidence of Leptosphaeria nodorum (S. nodorum) has greatly declined and has been replaced in importance by Mycosphaerella graminicola (S. tritici). Yellow rust (Puccinia striiformis), which until 1987 had largely been in recession, has now re-appeared as a consequence of mild winters and changing varieties. Brown rust is regularly important south of the Loire, but warm, wet springs can result in spectacular outbreaks as far north as Paris.

In recent years there has also been a resurgence of powdery mildew, particulary to the north and east of Paris and in Brittany. This resurgence can be attributed to changes in a number of agronomic factors, of which varietal sensitivity is the most important. Important attacks of mildew south of the Loire can occur following mild dry winters. In wet summers, ear blights dominated by Fusarium spp. are frequently present, particularly on hard wheats.

Field results with hexaconazole + carbendazim

Excellent control of brown rust was observed in trials carried out by the Institut Technique des Cereales et des Fourrages (ITCF), by the Service de la Protection des Vegetaux (SPV) and by ICI during 1989 (Table 6). Hexaconazole has consistently shown prolonged control of both *Puccinia recondita* and *P. striiformis* following application to wheat (Table 7).

TABLE 6. Control of *Puccinia recondita* on wheat in field trials during 1989.

Treatment	Rate (g AI /ha)	ITCF Trials[1] (mean of 6) % control	% yield increase	SPV Trials[2] (mean of 7) % control	% yield increase	ICI Trials (mean of 3) % control	% yield increase
(Actual % disease and t/ha yield)		(33-79)	(5.7-8.0)	(13-429*)	(3.6-6.2)	(5-40)	(3.9-5.1)
Hexaconazole + carbendazim	250 + 150	67ab	13	98	12	88	29
Cyproconazole + carbendazim	80 + 150	-	-	98	13	-	-
Tebuconazole	250	69a	15	98	12	85	26
Flusilazole + carbendazim	200 + 100	58bc	13	-	-	-	-
Propiconazole + carbendazim	125 + 150	51c	11	93	12	-	-

1. Data derived from Caron *et al*., 1989a.
2. Data derived from De La Rocque, 1990.
* Mean number of pustules per leaf.

TABLE 7. Control of *Puccinia recondita* and *P. striiformis* on wheat 4-6 weeks after treatment.

Treatment	Rate (g AI /ha)	*Puccinia recondita* 4 trials 26-46 DAT % Control Mean	Range	*Puccinia striiformis* 3 trials 45 DAT % Control Mean	Range
(Actual % disease)		(40)	(10-63)	(37)	(22-62)
Hexaconazole + carbendazim	250 + 150	91a	86-100	98a	97-99
Triadimenol	125	51b	15-87	92b	84-97

In trials carried out by different agencies in France, hexaconazole + carbendazim has given control of both _Septoria_ spp. equal to that of the best commercially available products (Table 8), with corresponding increases in yield (Table 9). Hexaconazole + carbendazim has also given good control of fusarium ear blight in ITCF trials (Jugnet _et al_., 1989).

TABLE 8. Control of _Septoria_ spp. on winter wheat.

Treatment	Rate (g AI /ha)	ITCF Trials[1] _Septoria_ spp. (5) % control	SPV Trials[2] _S. tritici_ (5) % control	ICI Trials _S. tritici_ (14) % control	ICI Trials _S. nodorum_ (11) % control
(Actual % disease)		(28-65)	(5-28)	(4-57)	(14-65)
Hexaconazole + carbendazim	250 + 150	41	73	69a	62a
Flusilazole + carbendazim	200 + 100	48	-	-	-
Propiconazole + carbendazim	125 + 150	45	77	68a	63a
Chlorothalonil	1100	-	-	51b	53b

Data derived from: 1. Caron _et al_., 1989b. 2. Murer, 1989 (unpublished).

TABLE 9. Yields from field trials for control of _Septoria_ spp. on winter wheat (see Table 8).

Treatment	Rate (g AI /ha)	ITCF Trials[1] _Septoria_ spp. (5) % yield increase	SPV Trials[2] _S. tritici_ (5) % yield increase	ICI Trials _S. tritici_ (14) % yield increase	ICI Trials _S. nodorum_ (11) % yield increase
(Yield in t/ha)		(6.1-7.3)	(6.1-8.6)	(4.8-9.5)	(3.4-10.4)
Hexaconazole + carbendazim	250 + 150	18	8	21a	18a
Flusilazole + carbendazim	200 + 100	19	-	-	-
Propiconazole + carbendazim	125 + 150	15	7	21a	16a
Chlorothalonil	1100	-	-	13b	10b

Data derived from: 1. Caron _et al_., 1989b. 2. Murer, 1989 (unpublished).

Hexaconazole and other triazole fungicides continue to give satisfactory control of powdery mildew and significant increases in yield in France (Table 10). Reduced sensitivity to triazoles is, however, evident in some populations of Erysiphe graminis f. sp. tritici, and an increase in the degree of insensitivity during 1989 has been reported (Daguenet et al., 1989). In these situations, tank mixtures with morpholine based products are commonly recommended.

TABLE 10. Control of E. graminis f.sp. tritici in 1989 field trials.

Treatment	Rate (g AI /ha)	ITCF Trials[1] (mean of 3) % control	ITCF Trials[1] (mean of 3) % yield increase	ICI Trials (mean of 5) % control	ICI Trials (mean of 5) % yield increase
(Actual % disease and t/ha yield)		(22-76)	(6.1-7.3)	(14-24)	(6.7-8.5)
Hexaconazole + carbendazim	250 + 150	37	28	63	18
Propiconazole + carbendazim	125 + 150	38	24	-	-
Tebuconazole	250	37	28	65	22
Triadimenol	125	-	-	63	14

1. Data derived from Daguenet et al., 1989.

In areas where the wheat strain of Pseudocercosporella herpotrichoides dominates, notably in east and west central France, hexaconazole + carbendazim gives disease control and yield responses similar to prochloraz (Table 11). In areas where the rye strain is prevalent, control is less effective, in common with other triazole fungicides (Migeon, 1989).

TABLE 11. Control of Pseudocercosporella herpotrichoides in SPV trials.

Treatment	Rate (g AI /ha)	Wheat strains dominant % control[1]	Wheat strains dominant yield[2] increase (t/ha)	Rye strains dominant % control[1]	Rye strains dominant yield[2] increase (t/ha)
(Actual % necrosis and t/ha yield)		(25-76)	(4.1-8.2)	(15-85)	(5.5-9.7)
Hexaconazole + carbendazim	250-300 + 150-180	64	0.8	19b	0.4b
Prochloraz	750	75	0.8	76a	0.8a

From Migeon, 1989.
1. Based on the percentage area of necrosis in a section of the stem base.
2. Increase in yield by comparison with the untreated control.

Hexaconazole based products exhibit a level of safety to cereal crops which is greater than most other triazole fungicides. There are no reports of phytotoxicity from either experimental or commercial usage of these products.

Hexaconazole can be formulated easily into safe, water based formulations which are compatible with a wide range of other agrochemical products. The broad spectrum of activity and persistence of effect permits hexaconazole + carbendazim to be applied with advantage at all application timings. It may be used alone or in combination with other more specific fungicides to give farmers a flexible approach to disease control in cereals.

Nine hundred thousand hectares of French wheat were treated with hexaconazole + carbendazim in 1990.

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