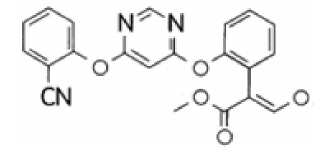
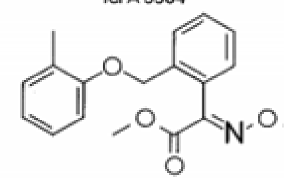
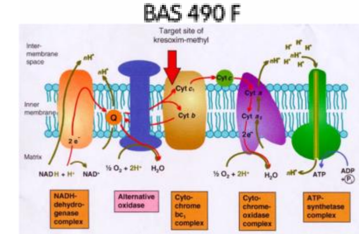
Universidade de São Paulo
Escola Superior de Agricultura "Luiz de Queiroz"
Departamento de Fitopatologia e Nematologia
Controle Químico de Doenças de Plantas



Azoxystrobin
ICI A 5504



Kresoxim-methyl
BAS 490 F



Estrobilurinas

Dr. Antonio Nogueira Júnior
Profa. Dra. Lilian Amorim

Piracicaba
Março de 2017

Fungicidas produzidos fungos...

806 THE JOURNAL OF ANTIBIOTICS OCT. 1977

THE STROBILURINS — NEW ANTIFUNGAL ANTIBIOTICS FROM THE BASIDIOMYCETE *STROBILURUS TENACELLUS* (PERS. ex FR.) SING.

T. ANKE and F. OBERWINKLER

Lehrbereich Spezielle Botanik der Universität
74 Tübingen, Auf der Morgenstelle 1, B.R.D.

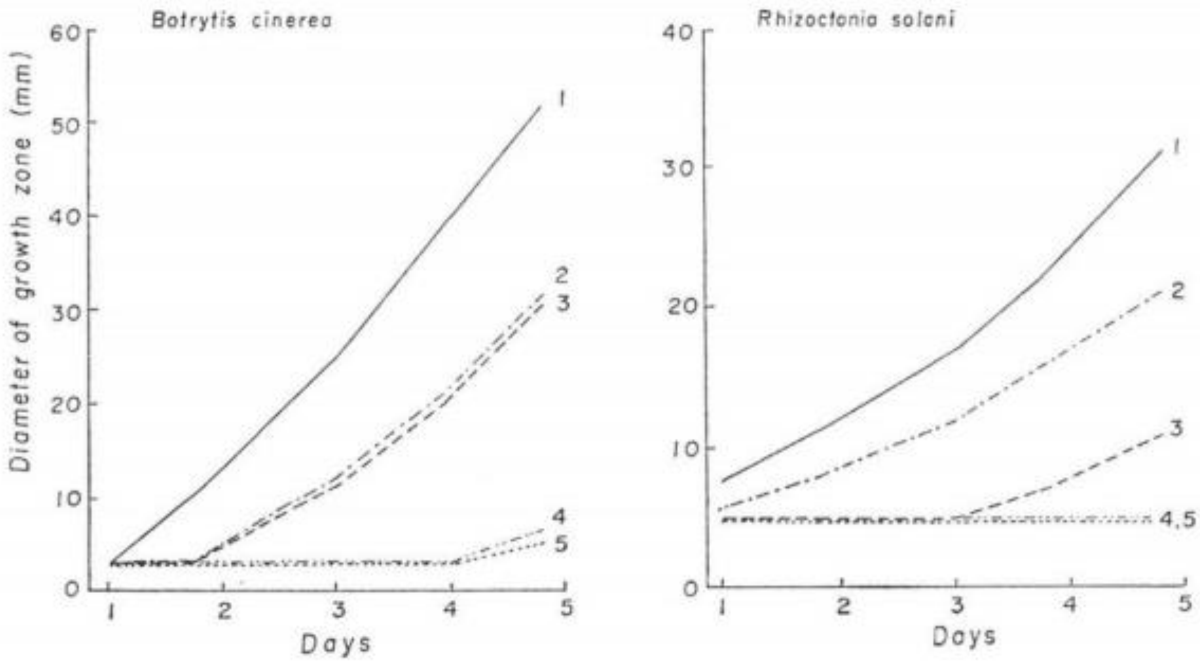
W. STEGLICH and G. SCHRAMM

Institut für Organische Chemie und Biochemie der Universität
53 Bonn, Max-Planck-Str. 1, B.R.D.

"The strobilurins are two antifungal antibiotics which were isolated from the mycelium of Strobilurus tenacellus strain No. 21602. The strobilurins A and B are highly active against yeasts and filamentous fungi".

Fungicidas produzidos fungos...

Fig. 3. Effect of strobilurins A and B on the growth of *Botrytis cinerea* and *Rhizoctonia solani*. Control without antibiotic (1); growth on agar plates containing 1 μg/ml strobilurin A (2) or B (3); growth on plates containing 10 μg/ml strobilurin B (4) or A (5).



"The strobilurins are two antifungal antibiotics which were isolated from the mycelium of Strobilurus tenacellus strain No. 21602. The strobilurins A and B are highly active against yeasts and filamentous fungi".

Anke el al., 1977

Strobilurus tenacellus


Foto: Enrique Rubio Domínguez


Foto: David Mitchel

Strobilus*: *pinha

Pinecone cap

Strobilurus tenacellus

Foto: Enrique Rubio Domínguez

Foto: David Mitchel

Many scientists excluded the idea of looking for fungicides in fungus. However, once Anke et al.[1] isolated Strobilurin-A from the liquid cultures of the mushroom *Strobilurus tenacellus* many scientists looked for other strobilurins in many other fungi. As a result of this new interest many natural compounds of strobilurin structures were isolated and identified.

Balba, 2007

Fungicidas produzidos fungos...

1112 THE JOURNAL OF ANTIBIOTICS NOV. 1979

ANTIBIOTICS FROM BASIDIOMYCETES. IX[1)]

OUDEMANSIN, AN ANTIFUNGAL ANTIBIOTIC FROM *OUDEMANSIELLA MUCIDA* (SCHRADER ex FR.) HOEHNEL (AGARICALES)

TIMM ANKE, HANS JÜRGEN HECHT*, GEORG SCHRAMM** and WOLFGANG STEGLICH**

Institut für Biologie I der Universität, Auf der Morgenstelle 1, D-74 Tübingen, FRG
*Forschergruppe Röntgenstrukturanalyse Biologischer Makromoleküle, Universität Würzburg, Am Hubland, D-87 Würzburg, FRG
**Institut für Organische Chemie und Biochemie der Universität, Gerhard-Domagk-Str. 1, D-53 Bonn, FRG

(Received for publication July 2, 1979)

"In this publication we describe the isolation and structural elucidation of oudemansin, a new antibiotic from *Oudemansiella mucida* showing similar biological activity to strobilurin A".

Oudemansiella mucida

Fungo de Porcelana

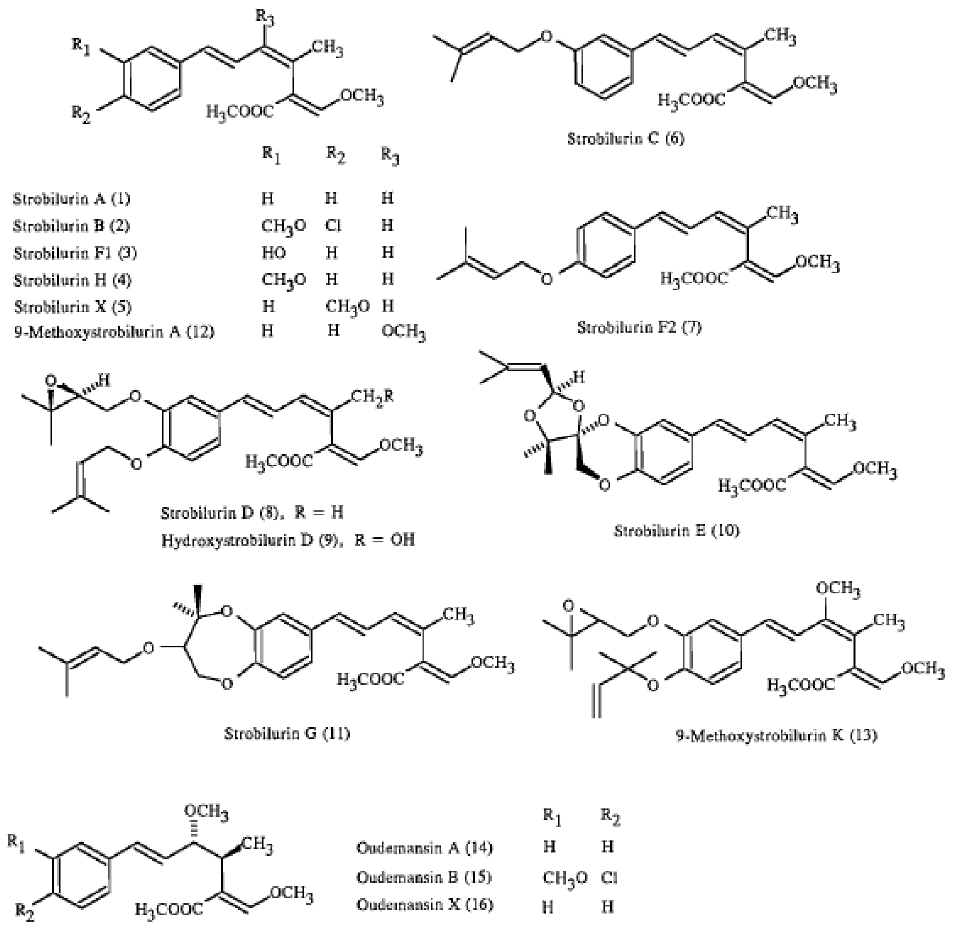
Fungicidas produzidos fungos...

Estrobilurinas - Naturais

Table 1. Fungi producing strobilurins and oudemansins.

Producer	Compound	Ref.
Basidiomycetes		
Agaricus sp. 89139	**1,3,8**	Zapf et al. 1993
Crepidotus fulvotomentosus	**10**	Weber et al. 1990*a*
Cyphellopsis anomala	**1,3,8**	Weber et al. 1990*b*
Favolaschia sp. 87129	**1,3,9,12,13,14**	Zapf et al. 1994
Filoboletus sp. 9054	**10**	Simon 1993
Hydropus scabripes	**1**	Bäuerle 1981
Mycena aetites	**1**	Bäuerle 1981
M. alkalina	**2**	Bäuerle 1981
M. atromarginata	**1**	Bäuerle 1981
M. avenacea	**2**	Bäuerle 1981
M. cf capillaripes	**1**	Bäuerle 1981
M. crocata	**2**	Bäuerle 1981
M. fagetorum	**1**	Schramm et al. 1978
M. galopoda	**1**	Bäuerle 1981
M. galopoda var alba	**1**	Bäuerle 1981
M. oregonensis	**1**	Bäuerle 1981
M. polygramma	**14**	Bäuerle 1981
M. purpureofusca	**1**	Bäuerle 1981
M. rosella	**1**	Bäuerle 1981
M. sanguinolenta	**9**	Backens et al. 1988
M. vitilis	**2**	Bäuerle 1981
M. zephirus	**1**	Schramm et al. 1978
Oudemansiella mucida	**1,14**	Anke et al. 1979
O. radicata	**1,16**	Anke et al. 1990
Strobilurus conigenoides	**1**	T. Anke, unpublished
S. esculentus	**1**	T. Anke, unpublished
S. stephanocystis	**1**	T. Anke, unpublished
S. tenacellus	**1,2**	Anke et al. 1977
Xerula longipes	**2,6**	Anke et al. 1983
X. melanotricha	**1,2,15**	Anke et al. 1983
Ascomycete		
Bolinea lutea	**4,7,11**	Fredenhagen et al. 1990*a*, 1990*b*

Fig. 1. The strobilurins and oudemansins.

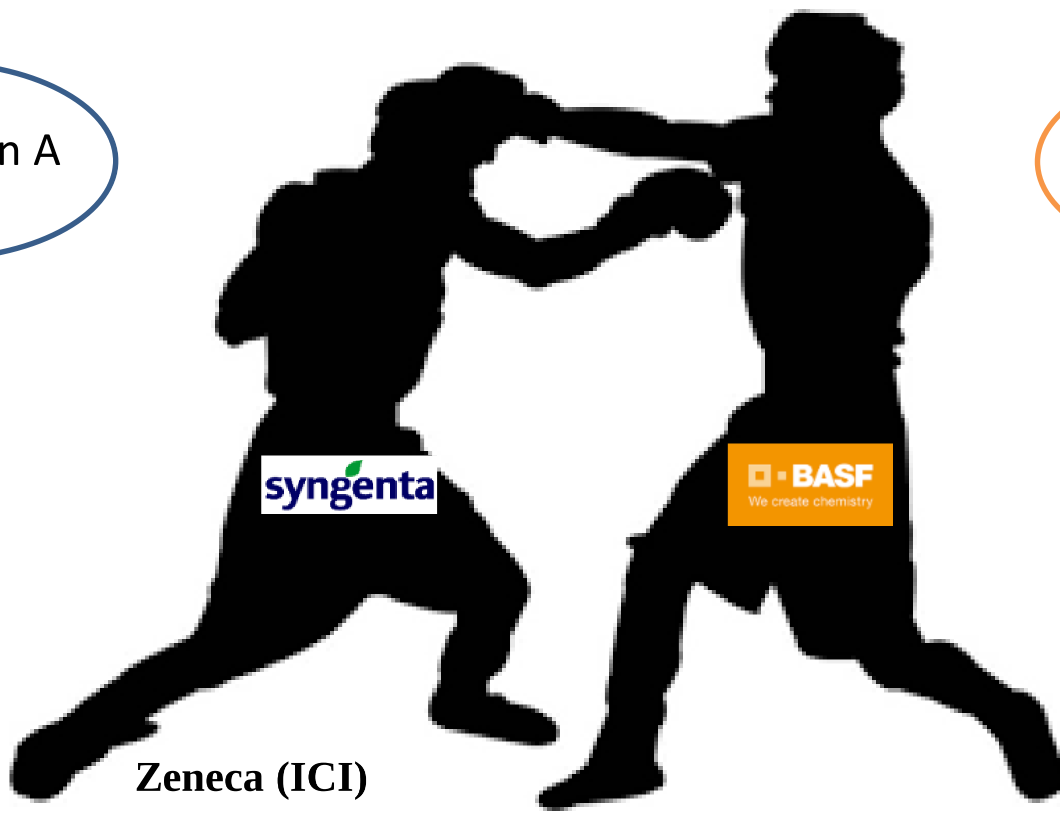


Anke, 1995

Estrobilurinas – A Síntese

- Strobirulin A – fungitóxica apenas em meio de cultura – foto inibição e volátil
- Início dos trabalhos das empresas em 1992

Strobirulin A



Oudemasin A

Zeneca (ICI)

Estrobilurinas – A Síntese

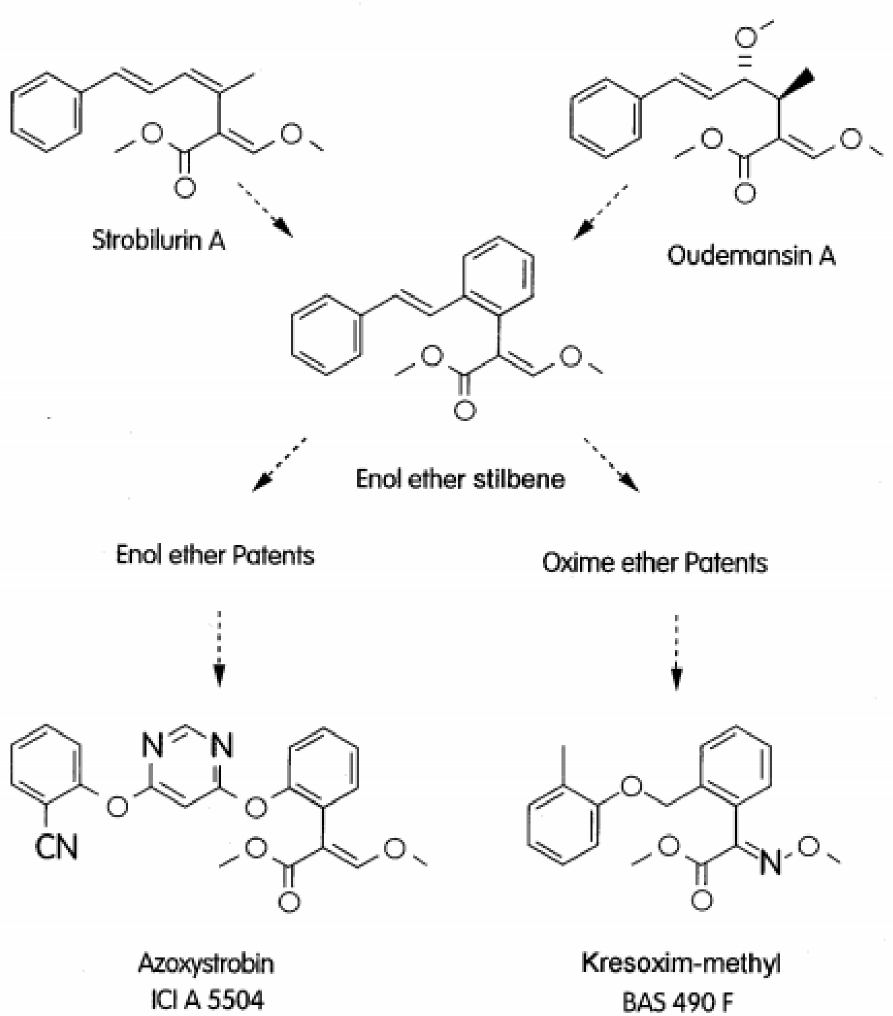


Fig. 3. Parallel development at Zeneca and BASF of synthetic strobilurin fungicides. Although Zeneca initiated its research with oudemansin and BASF with strobilurin A, both companies used the enol ether stilbene (or β-methoxyacrylate stilbene) as a lead molecule for synthesis of their fungicide products, azoxystrobin and kresoxim-methyl, respectively. Source: (77).

and 4). The earliest patents claiming synthetic fungicidal strobilurins containing the natural (*E*)-methyl *β*-methoxyacrylate group were filed by Syngenta about seven months ahead of the first strobilurin patents from BASF. The publication of these earliest patents blocked BASF's activities around the natural toxophore. BASF then found that the (*E*)-methyl methoxyiminoacetate group, isosteric with (*E*)-methyl *β*-methoxyacrylate, also confers activity when linked to a suitable backbone. In fact, Syngenta made the same discovery at about the same time but, in this case, the order of patenting was reversed, and BASF filed just two days ahead of Syngenta.

Ypema and Gold., 1999

Estrobilurinas – A Síntese

- Liberação dos produtos comerciais em 1996

- Controle de doenças em cereais

Table 1. The strobilurins and related fungicides

Fungicide	*Company*	*Announced*	*First sales*
Azoxystrobin[a]	Syngenta	1992	1996
Kresoxim-methyl	BASF	1992	1996
Metominostrobin	Shionogi	1993	1999
Trifloxystrobin[b]	Bayer	1998	1999
Picoxystrobin	Syngenta	2000	2002
Pyraclostrobin	BASF	2000	2002
Famoxadone	DuPont	1996	1997
Fenamidone[c]	Aventis	1998	2001

[a] Discovered by ICI, the agrochemical interests of which are now part of Syngenta.

[b] Discovered by Novartis, sold to Bayer in 2000.

[c] Discovered by Rhône-Poulenc, the agrochemical interests of which are now part of Aventis.

8 fungicidas

Bartlett et al., 2002

Fenamidona e famoxadona são quimicamente distintos das estrobilurinas, mas apresentam comportamento semelhante.

Estrobilurinas – A Síntese

- Liberação dos produtos comerciais em 1996

- Controle de doenças em cereais

Fungicide	Code number	Originator	Current owner	Launch date
Kresoxim-methyl	BAS490F	BASF	BASF	1996
Azoxystrobin	ICIA5504	ICI	Syngenta	1997
Metominostrobin	SSF-126	Shionogi	Bayer	2000
Trifloxystrobin	CGA279202	Ciba	Bayer	2000
Picoxystrobin	ZA1963	Zeneca	DuPont	2001
Pyraclostrobin	BAS500F	BASF	BASF	2002
Fluoxastrobin	HEC5725	Bayer	Bayer	2004
Dimoxystrobin	BAS505F	BASF	BASF	2004
Orysastrobin	BAS520F	BASF	BASF	2007
Famoxadone	DPXJE874	DuPont	DuPont	1997
Fenamidone	EXP10745	Rhône-Poulenc	Bayer	2001
Cyazofamid	IKF916	Ishihara	Ishihara	2001
Amisulbrom	NC224	Nissan	Nissan	2008

13 fungicidas

Oliver and Hewitt, 2014

Pest Management Science
Pest Manag Sci **58**:649–662 (online: 2002)
DOI: 10.1002/ps.520

Review

The strobilurin fungicides†

Dave W Bartlett,[1] John M Clough,[1] Jeremy R Godwin,[1]* Alison A Hall,[1] Mick Hamer[1] and Bob Parr-Dobrzanski[2]
[1]*Syngenta, Jealott's Hill International Research Centre, Bracknell, Berkshire RG42 6EY, UK*
[2]*Syngenta, Central Toxicology Laboratory, Alderley Park, Macclesfield, Cheshire SK10 4TJ, UK*

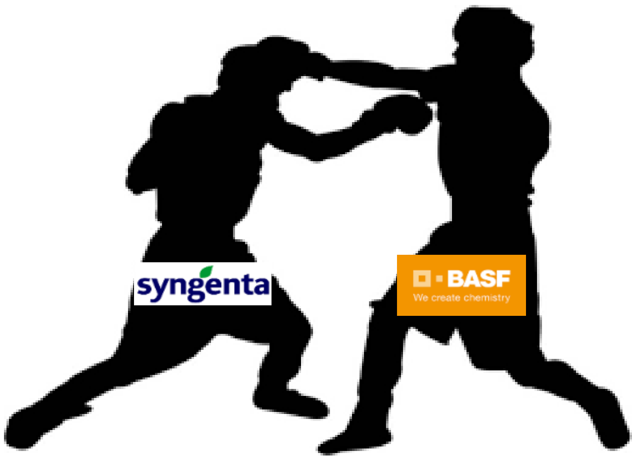
KRESOXIM-METHYL

MODIFICATION OF A NATURALLY OCCURRING COMPOUND TO PRODUCE A NEW FUNGICIDE

H. L. Ypema and R. E. Gold
BASF Corporation, Research Triangle Park, NC

Publication no. D-1999-1106-01F

4 Plant Disease / Vol. 83 No. 1

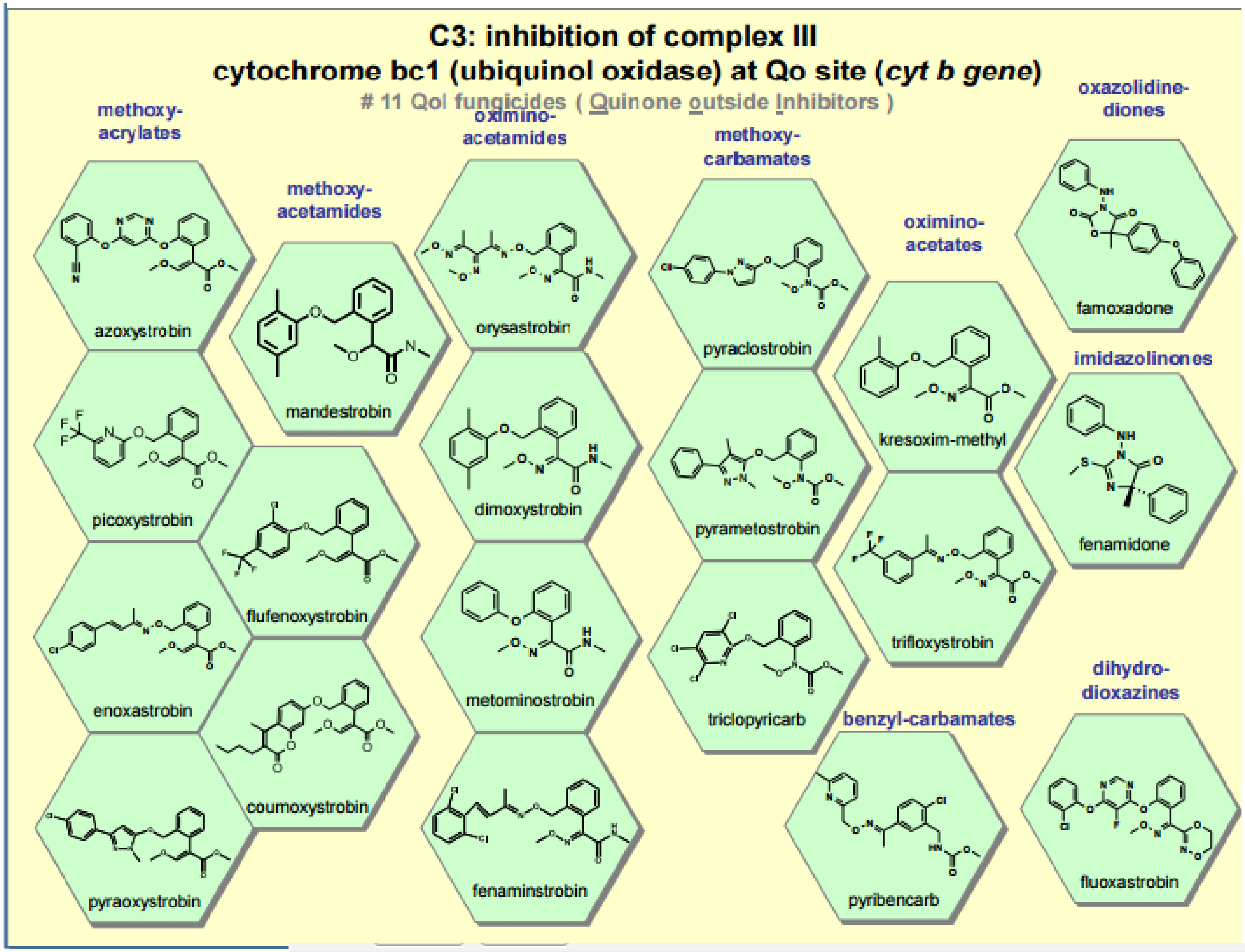


Pest Management Science
Pest Manag Sci **57**:143–152 (2001)

Famoxadone: the discovery and optimisation of a new agricultural fungicide†

Jeffrey A Sternberg,[1]* Detlef Geffken,[2] John B Adams Jr,[1] Reiner Pöstages,[2] Charlene G Sternberg,[1] Carlton L Campbell[1] and William K Moberg[1]
[1]*DuPont Crop Protection Products, El du Pont de Nemours and Co, Stine-Haskell Research Center, Building 300, Newark, Delaware 19714, USA*
[2]*Institut Für Pharmazeutische Chemie, Universitat Hamburg, Bundesstrasse 45, 20146 Hamburg, Germany*

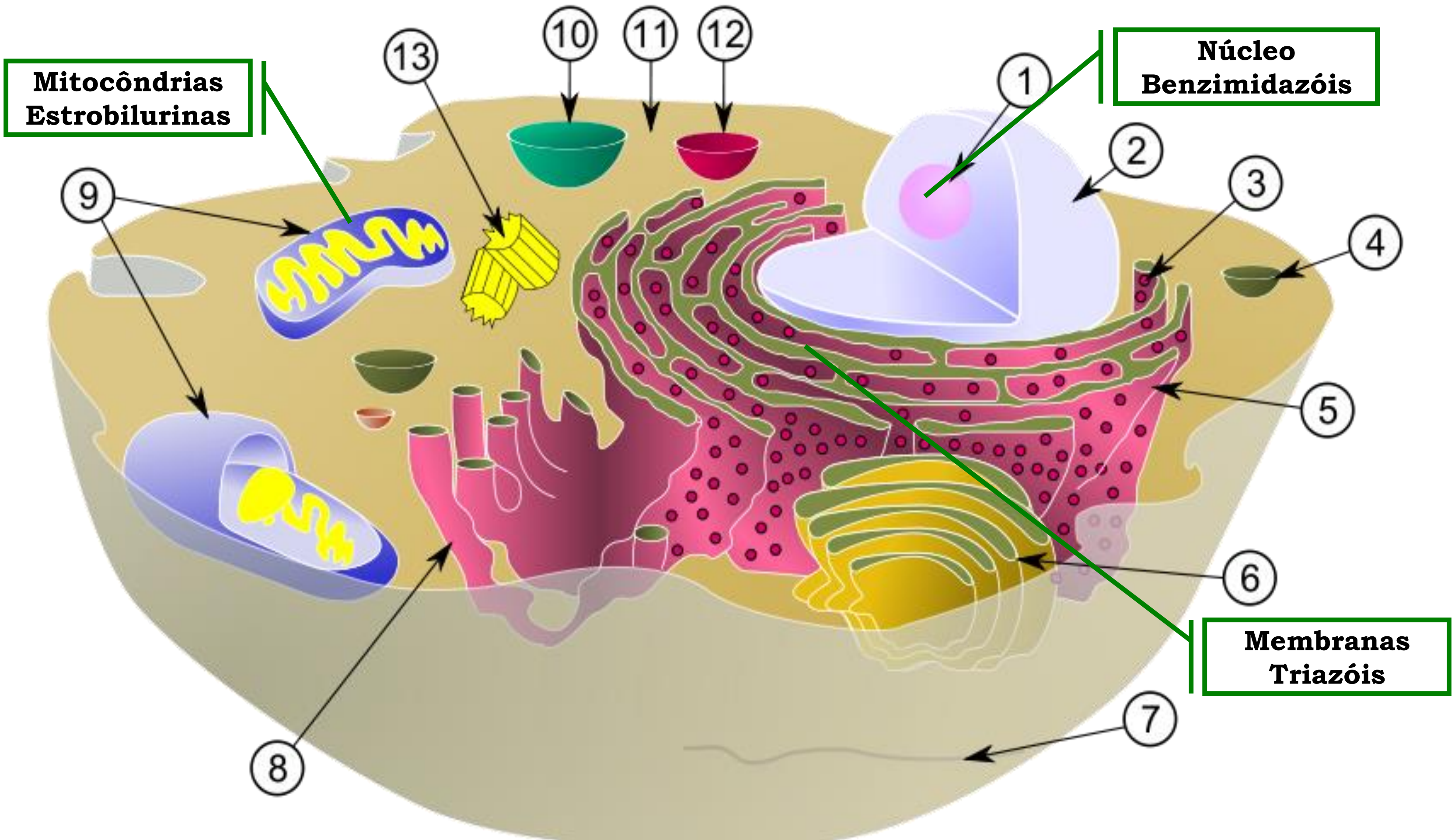
QoI – Inibidores extracelulares de Quinona



C3	Inibidores do complexo III: citocromo bc1 (ubiquinol oxidase) no sítio Qo	QoI-fungicidas (Inibidores extracelulares de Quinona)	Metoxi-acrilato	Azoxistrobina

Site FRAC - Brasil

Modo de Ação
QoI



Santos, P. S. J. - BASF

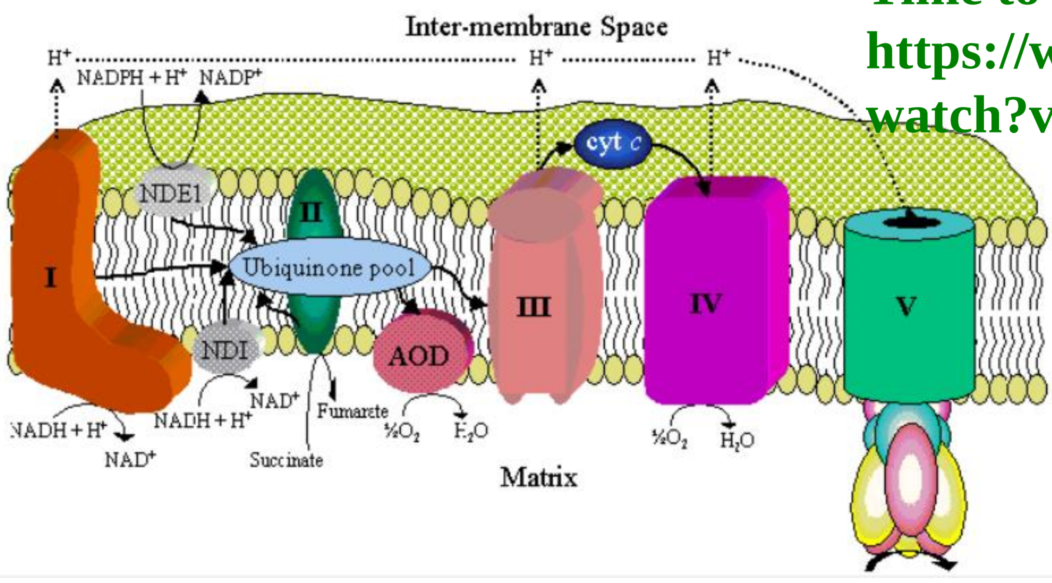
Modo de Ação
QoI

- Fungicidas inibidores extracelulares de quinona (QoI)

- Atuam no complexo III da cadeia transportadora de elétrons na mitocôndria

- A ligação de um inibidor ao sítio da quinona oxidase (Qo) bloqueia a transferência de elétrons no complexo III (citrocromo b e c1), impedindo a produção de energia (ATP)

Figure 1. The mitochondrial respiratory chain. (from http://pages.slu.edu/faculty/kennellj/)



Time to sing....
https://www.youtube.com/watch?v=VER6xW_r1vc

Modo de Ação

- Germinação de esporos e a motilidade de zoósporos são extremamente sensíveis às estrobilurinas: devido ao elevado requerimento de energia.

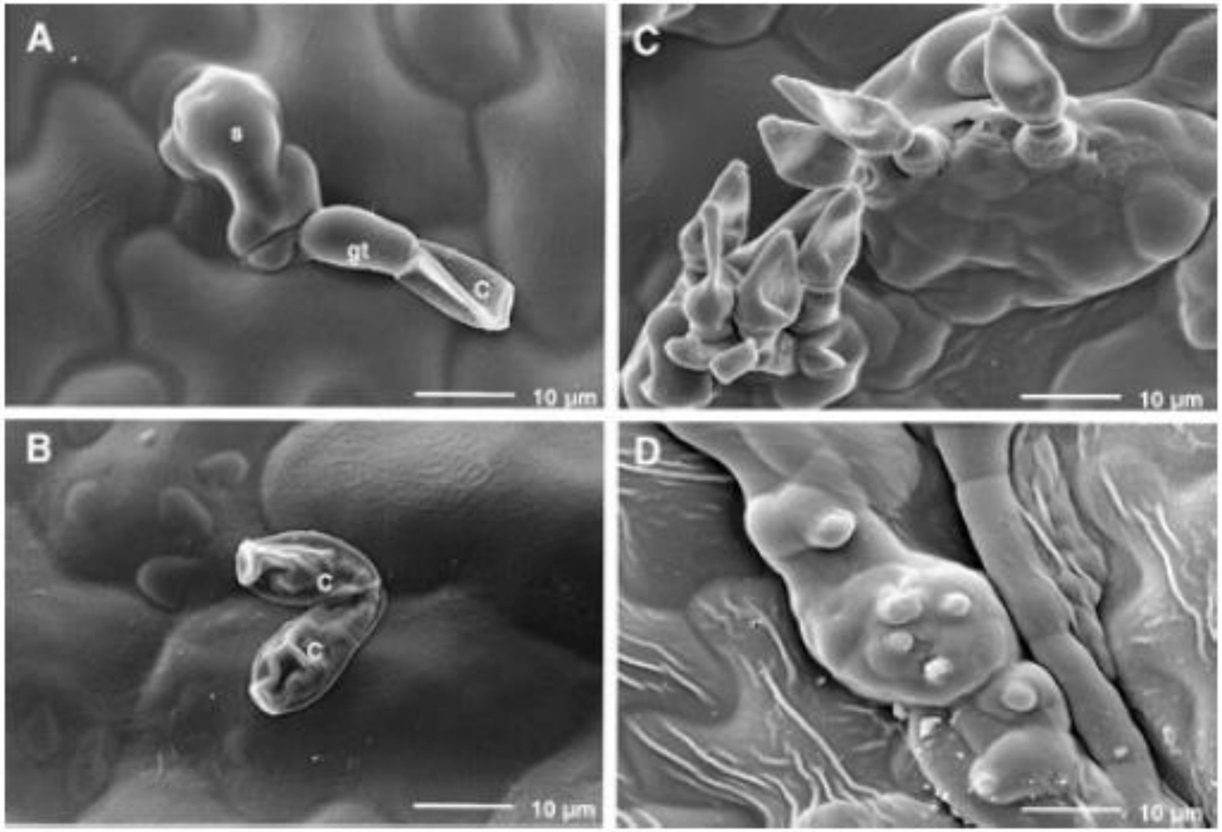


Fig. 6. Scanning electron microscopy of *Venturia inaequalis*. (A) A conidium germinated and initiated stroma formation under the cuticle of an unprotected apple leaf in less than 24 h. (B) Kresoxim-methyl, applied to leaves at 1 mg/liter 1 day prior to inoculation, caused collapse of conidia and completely inhibited germination and subsequent infection. (C) *Venturia inaequalis* sporulated abundantly on untreated apple leaves 16 days after inoculation. (D) Kresoxim-methyl, applied 2 days after inoculation at 67 mg/liter, provided complete inhibition of sporulation.

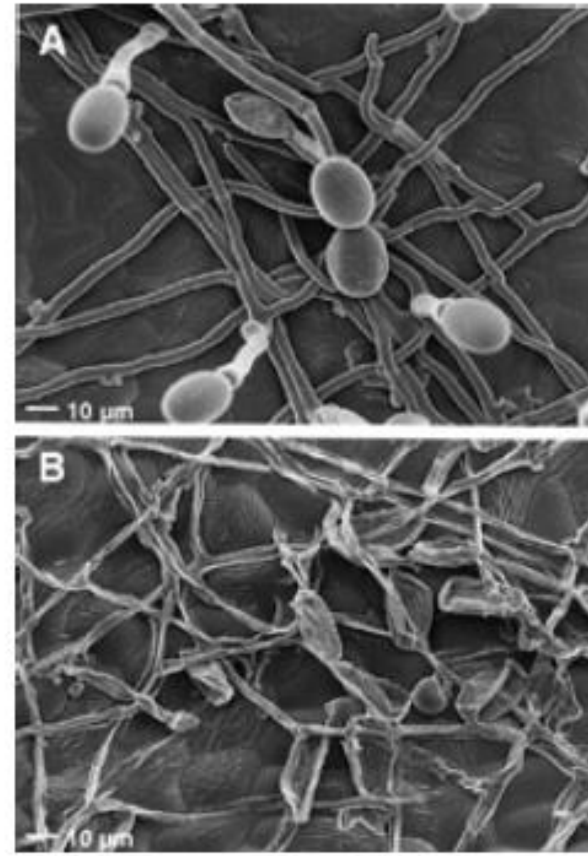


Fig. 7. Scanning electron microscopy of *Uncinula necator*. (A) Eight days after inoculation, hyphae grew profusely over the grape leaf surface and conidia formation had been initiated. (B) Kresoxim-methyl at 67 mg/liter, applied 3 days after inoculation, resulted in complete collapse of conidia and hyphae.

Ypema and Gold., 1999

Modo de Ação

- Germinação de esporos e a motilidade de zoósporos são extremamente sensíveis às estrobilurinas: devido ao elevado requerimento de energia.

- As estrobilurinas apresentam altos níveis de atividade preventiva - melhores resultados obtidos com aplicações realizadas antes ou logo após a infecção do hospedeiro pelo fungo;

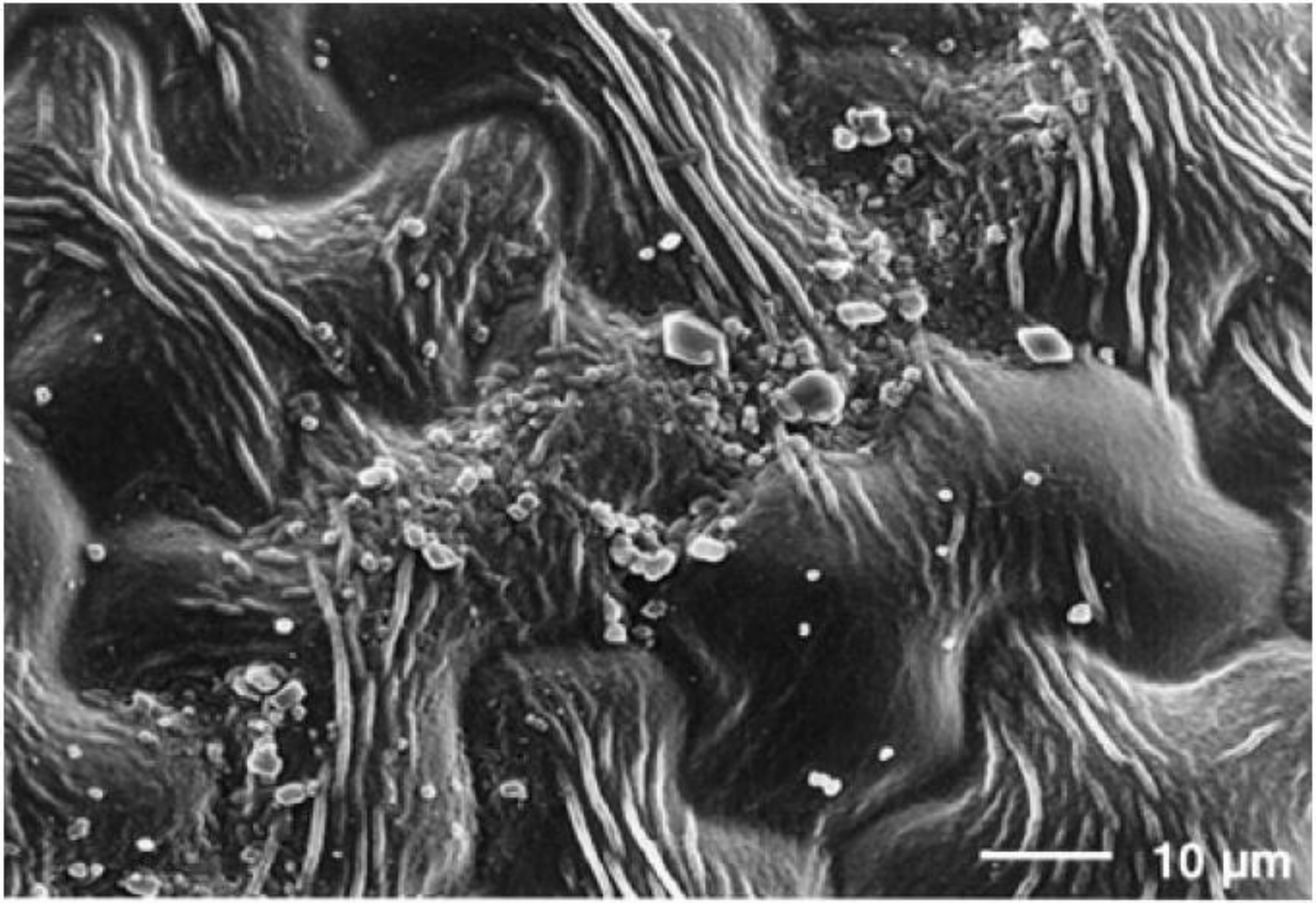


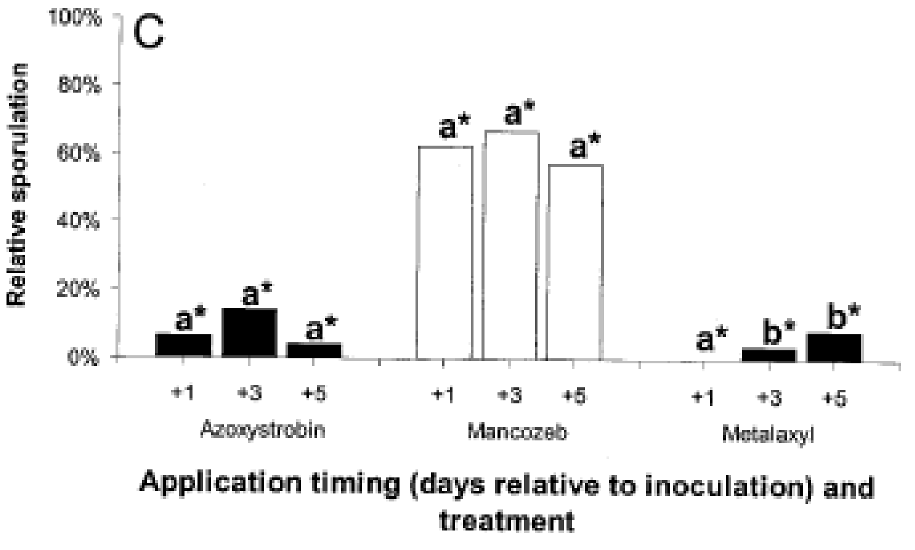
Fig. 4. One day after application, kresoxim-methyl formed a particulate deposit on this apple leaf surface.

log*Pow* = 3.5

Ypema and Gold., 1999

Comparative Physical Modes of Action of Azoxystrobin, Mancozeb, and Metalaxyl Against *Plasmopara viticola* (Grapevine Downy Mildew)

Francis P. Wong and **Wayne F. Wilcox,** Department of Plant Pathology, Cornell University, New York Agricultural Experiment Station, Geneva, NY 14456



Azoxystrobina:

Redução da incidência em aplicações pré-inoculação;

Redução da esporulação do míldio;

Espectro de ação

Table 5.2. The spectrum[a] of different classes of fungicide.

Mode of action (A1 to U)	Group name	OO	B	GFA	GSA	PM	BC	PY
A1	Phenylamides (PAs)	A	N	N	N	N	N	N
A2	Hydroxy-(2-amino-) pyrimidines	N	N	N	N	A	N	N
A3	Heteroaromatics	S	N	N	S	N	N	N
B1	Methyl benzimidazole carbamates (MBCs)	N	S	A	S	S	S	A
B2	*N*-Phenylcarbamates	N	N	N	N	N	A	N
B3	Benzamides	A	N	N	N	N	N	N
B4	Phenylureas	N	N	S	S	N	N	N
B5	Benzamides	A	N	N	N	N	N	N
C1	Pyrimidinamines	N	N	S	S	A	A	S
C2	Succinate dehydrogenase inhibitors (SDHIs)	N	S	S	S	S	S	S
C3	Quinone outside inhibitors (QoIs)	S	S	S	S	S	A	A
C4	Quinone inside inhibitors (QiIs)	A	N	N	N	N	N	N
C5	Uncouplers	A	N	N	N	S	N	N
C6	Organo-tin	S	S	S	S	S	S	S
C7	Thiophene-carboxamides	N	N	N	S	N	N	N
C8	Quinone x inhibitors (QxIs)	A	N	N	N	N	N	N
D1	Anilinopyrimidines (APs)	N	N	S	N	S	S	S
E1	Azanaphthalenes	N	N	N	N	A	N	N
E2	Phenylpyrroles (PP)	N	S	N	S	S	S	S
E3	Dicarboximides	N	S	N	S	N	S	S
F2	Phosphorothiolates	N	N	S	N	N	S	S
F3	Aromatic hydrocarbons (AHs)	N	S	N	S	N	N	N
F4	Carbamates	S	N	N	N	N	N	N
G1	Steroid biosynthesis inhibitor (SBI) Class I	N	S	S	S	S	N	S
G2	SBI Class II	N	S	S	N	A	N	N
G3	SBI Class III	N	N	N	N	N	A	N
G4	SBI Class IV	N	S	N	S	N	N	N
H5	Carboxylic acid amides (CAAs)	A	N	N	N	N	N	N
I1/2	Melanin biosynthesis inhibitors (MBIs)	N	N	N	N	N	N	A
P1/2/3	Benzothiadiazole (BTH)	S	S	S	S	S	S	S
U	Various	S	S	S	S	S	S	S
U	Arylphenylketone	N	N	N	N	A	N	N
U	Guanidines	N	N	N	S	N	N	N
Multi-site	Various	S	S	S	S	S	S	S

A= all, S= some, N = none of the following pathogens subgroups: OO, **Oomycota;** B, **Basidiomycota**; GFA, general foliar **Ascomycota**; GSA, general soil or seed **Ascomycota**; PM, **powdery mildew**; BC, ***Botrytis cinerea***; PY, ***Pyricularia grisea***

Oliver and Hewitt, 2014

Table 1. Activity spectrum of kresoxim-methyl

Crop	Disease	Pathogen	Activity[y]
Apple	Scab	*Venturia inaequalis*	+++
	Powdery mildew	*Podosphaera leucotricha*	+++
	Sooty blotch	*Gloeodes pomigena*	+++
	Fly speck	*Zygophiala jamaicensis*	+++
	Brooks fruit spot	*Mycosphaerella pomi*	++
	Black rot	*Botryosphaeria obtusa*	++
	White rot	*Botryosphaeria dothidea*	++
	Cedar apple rust	*Gymnosporangium* sp.	P
	Quince rust	*Gymnosporangium clavipes*	P
	Bitter rot	*Colletotrichum* sp.	–
	Black pox	*Helminthosporium papulosum*	–
Broccoli	Downy mildew	*Peronospora parasitica*	P
Cherry	Powdery mildew	*Podosphaera clandestina*	+++
Cereals	Powdery mildew	*Erysiphe graminis*	+++
Cucurbits	Powdery mildew	*Sphaerotheca fuliginea*	+++
	Gummy stem blight	*Didymella bryoniae*	+++
	Downy mildew	*Pseudoperonospora cubensis*	P
Grape	Powdery mildew	*Uncinula necator*	+++
	Black rot	*Guignardia bidwellii*	+++
	Phomopsis	*Phomopsis viticola*	++
	Downy mildew	*Plasmopara viticola*	P
Lettuce	Powdery mildew	*Erysiphe cichoracearum*	+++
	Downy mildew	*Bremia lactucae*	P
Pecan	Pecan scab	*Cladosporium caryigenum*	+++
Pear	Scab	*Venturia pirina*	+++
	Powdery mildew	*Podosphaera leucotricha*	+++[z]
Rose	Powdery mildew	*Sphaerotheca pannosa*	+++
	Black spot	*Diplocarpon rosae*	+++
	Rust	*Phragmidium* sp.	P

Espectro de ação

Cresoxim-metil

Ypema and Gold., 1999

[y] +++ = excellent, ++ = good, + = satisfactory, – = unsatisfactory, P = satisfactory when applied preventatively. The activity rating is based on data published in *Fungicide and Nematicide Tests* between 1995 and 1998 and on unpublished data from trials performed by BASF and independent researchers.

[z] Efficacy rating derived from greenhouse trial data and kresoxim-methyl's activity on apple powdery mildew, which is caused by the same pathogen.

Table 4. Efficacy of strobilurin fungicides against a range of commercially important fungal diseases

Disease	*Azoxystrobin*	*Kresoxim-methyl*	*Metominostrobin*	*Trifloxystrobin*	*Picoxystrobin*	*Pyraclostrobin*
Ascomycete						
Grape powdery mildew (*Uncinula necator*)	***	***	NA	***	NA	***
Banana black sigatoka (*Mycosphaerella fijiensis*)	***	NA	NA	***	NA	***
Barley net blotch (*Helminthosporium teres*)	***	**	NA	***	***	***
Wheat *Septoria tritici* (*Mycosphaerella graminicola*)	***	**	NA	***	***	***
Basidiomycete						
Wheat brown rust (*Puccinia recondita*)	***	*	NA	**	***	***
Barley brown rust (*Puccinia hordei*)	***	*	NA	*	***	***
Rice sheath blight (*Rhizoctonia solani*)	***	**	***	***	NA	NA
Deuteromycete						
Tomato early blight (*Alternaria solani*)	***	**	NA	***	NA	***
Oomycete						
Grapevine downy mildew (*Plasmopara viticola*)	***	**	NA	**	NA	***
Turf pythium blight (*Pythium aphanidermatum*)	***	**	**	**	NA	***

Source: Syngenta—substantially based on data from independent field trials: Japanese Plant Protection Association official trials and References 33, 34, 72.
NA, Not applicable (not publicly declared to be a development outlet).
* Poor efficacy.
** Moderate efficacy.
*** Good efficacy.

Bartlett et al., 2002

Modo de Ação

- Germinação de esporos e a motilidade de zoósporos são extremamente sensíveis às estrobilurinas: devido ao elevado requerimento de energia

- As estrobilurinas apresentam altos níveis de atividade preventiva - melhores resultados obtidos com aplicações realizadas antes ou logo após a infecção do hospedeiro pelo fungo

- Atividade curativa limitada - ***Biocinética***

Biocinética

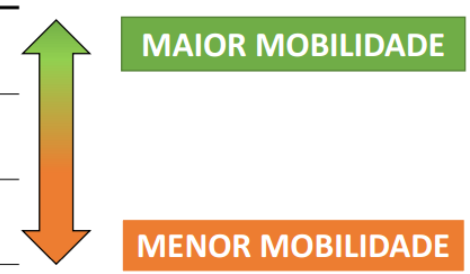
- Cada estrobilurina possui um mecanismo diferente de absorção e mobilidade nos tecidos:

Table 3. Redistribution properties of strobilurins

	Azoxystrobin	*Kresoxim-methyl*	*Metominostrobin*	*Trifloxystrobin*	*Picoxystrobin*	*Pyraclostrobin*
Uptake into leaf	Low	Low	High	Very low	Medium	Very low
Molecular redistribution by air	No	Yes	nt[a]	Yes	Yes	No
Metabolic stability in leaf	Yes	Low	nd[b]	Low	Yes	Yes
Translaminar movement	Yes	Low	Yes	Low	Yes	Low
Xylem systemic	Yes	No	Yes	No	Yes	No
Systemic movement to new growth in wheat and barley	Yes	No	nr[c]	No	Yes	No
Phloem mobile	No	No	No	No	No	No

Source: Syngenta.
[a] nt = not tested.
[b] nd = no data.
[c] nr = not relevant crop outlet.

INGREDIENTE ATIVO	NOME COMERCIAL	Log P_{OW}
AZOXYSTROBINA	AMISTAR	2,5
PIRACLOSTROBINA	COMET	4,0
TRIFLOXYSTROBINA	FLINT	4,5



Bartlett et al., 2002

Biocinética

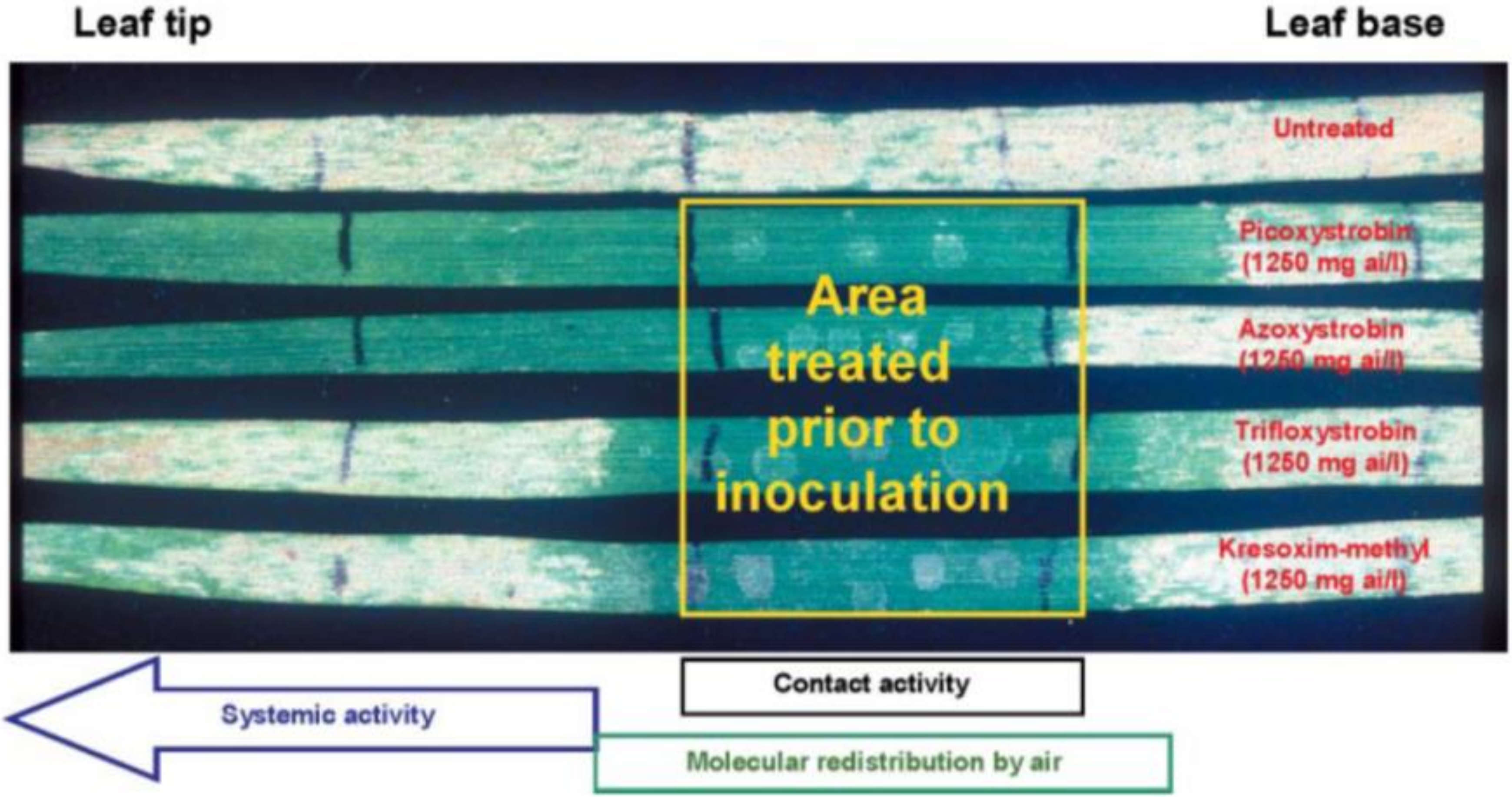


Plate 1. Redistribution of strobilurins in wheat to control powdery mildew. (Source: Syngenta).

Bartlett et al., 2002

Biocinética

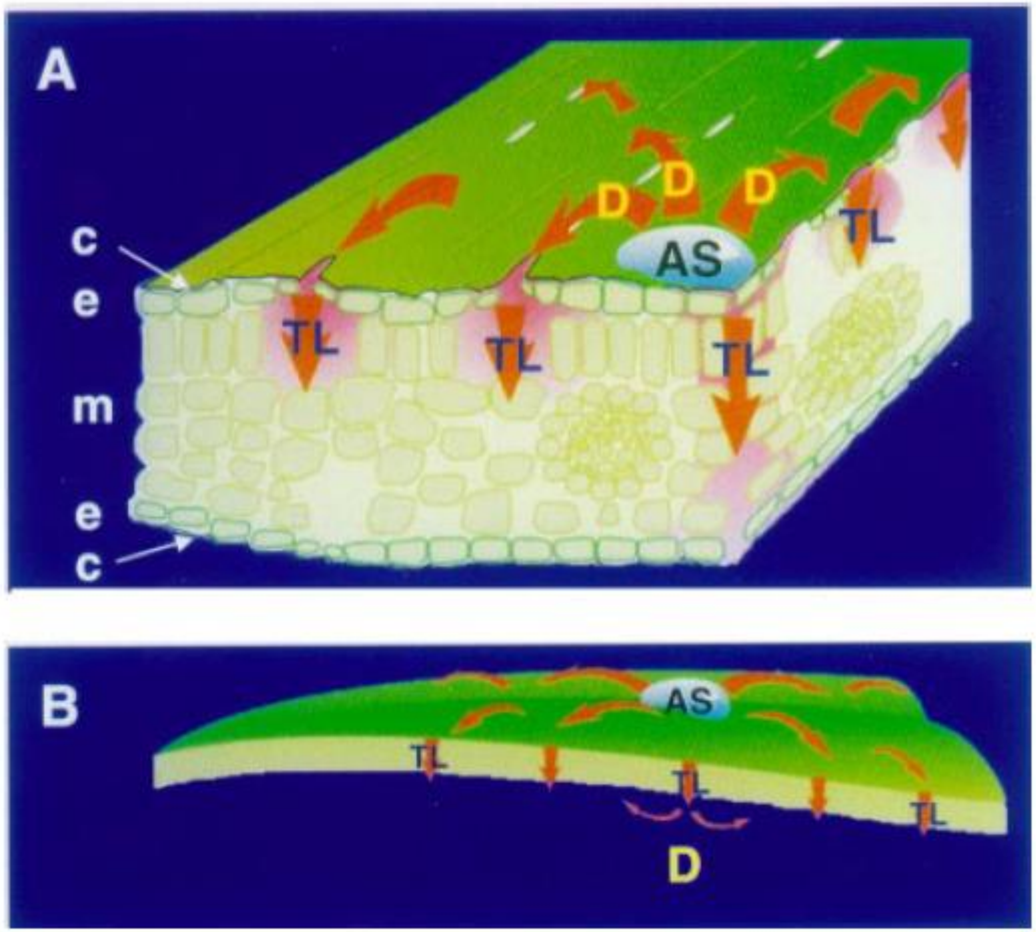


Fig. 5. Schematic diagrams showing surface systemic and translaminar movement of kresoxim-methyl from the site of application (AS). (A) Upon application, kresoxim-methyl diffuses over and through the cuticular wax layers (D). It penetrates the leaf and diffuses in the intercellular spaces translaminarly (TL). (B) Upon reappearance at the other leaf surface after translaminar transport (TL), the compound further diffuses over the lower leaf surface (D). In this manner, kresoxim-methyl can protect plant parts distant from the application site from fungal infection. c = cuticle, e = epidermis, m = mesophyll.

Ypema and Gold., 1999

Biocinética

- Cada estrobilurina possui um mecanismo diferente de absorção e mobilidade nos tecidos:

Absorção:

Azoxystrobin – após 24h : 1-3% em videira e 25% em cereais e em bananeira;

Picoxystrobin – após 24h: 30-45% em cereais.

Mobilidade:

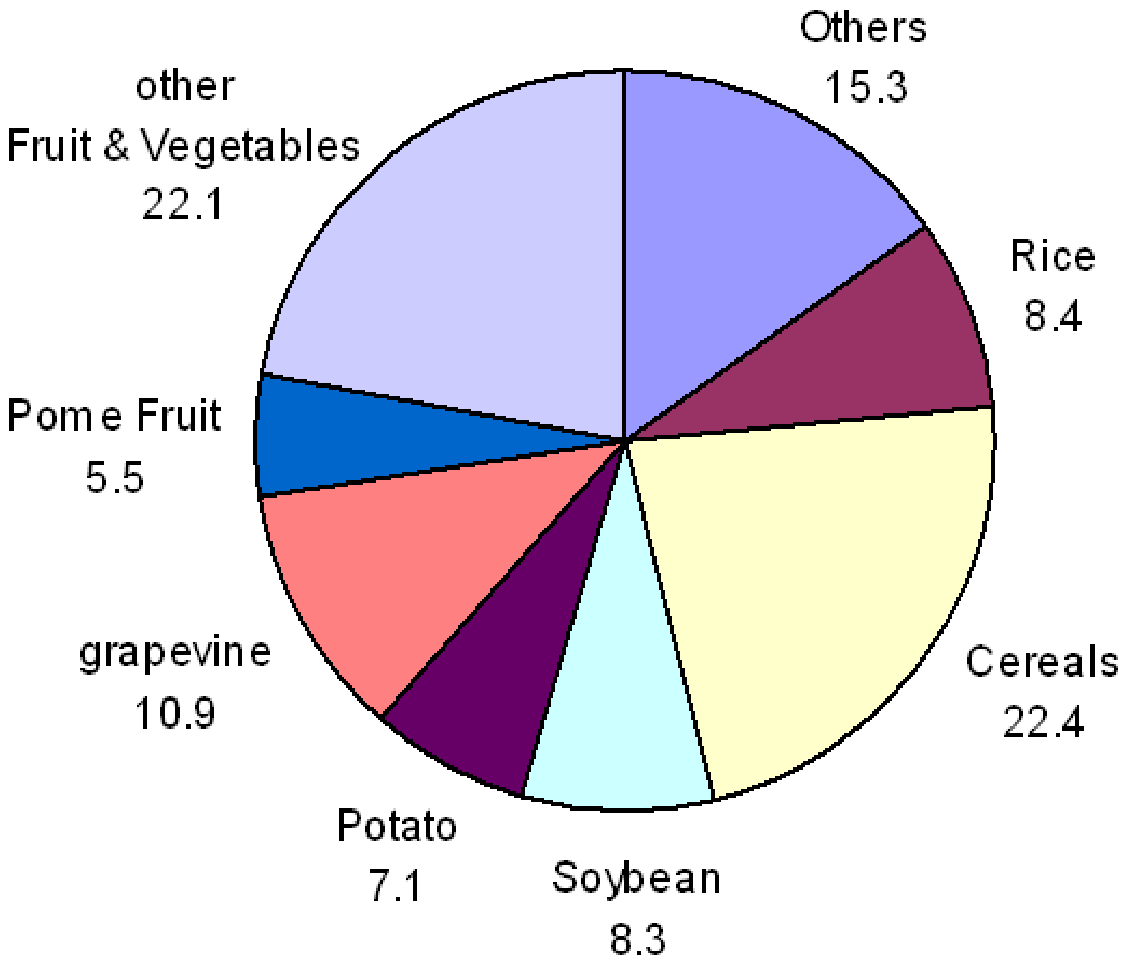
Picoxystrobin – após 8 dias: 20% do i.a. movimento ascendente em trigo;

Azoxystribin – após 8 dias: 8% do i.a. via xilema

Kresoxim-metil } não são sistêmicos
Trifloxystrobin

Mercado Mundial de Fungicidas

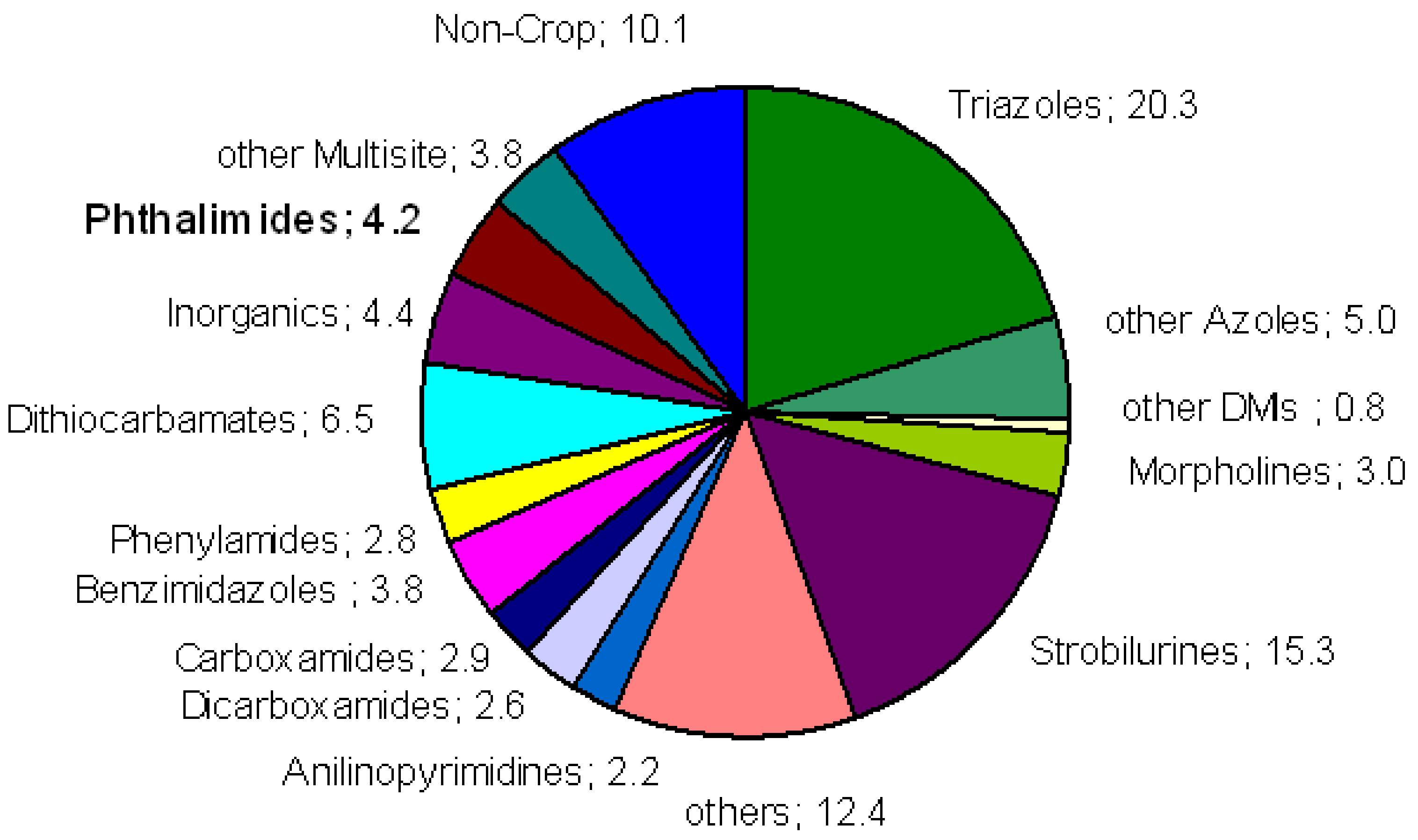
Mercado para os Fungicidas em 2005



Morton, V. and Staub, T. 2008 A Short History of Fungicides. Online, APS*net* Features. doi: 10.1094/APSnetFeature-2008-0308.

Mercado Mundial de Fungicidas

Porcentagem de Venda de Fungicidas em 2005 (~U$ 9 bi)



Morton, V. and Staub, T. 2008 A Short History of Fungicides. Online, APS*net* Features. doi: 10.1094/APSnetFeature-2008-0308.

Mercado Mundial de Fungicidas

Table 3.3. Market share of different fungicide groups. (From Krämer *et al.*, 2012.)

Fungicide group	Code	Market share (%)
Demethylation inhibitors (DMIs)	G1	29.2
Quinone outside inhibitors (QoIs)	C3	22.1
Dithiocarbamates	M3	6.8
Copper and sulfur	M1/M2	4.7
Phthalimides	M4	4.2
Methyl benzimidazole carbamates (MBCs)	B1	4.1
Succinate dehydrogenase inhibitors (SDHIs)	C2	3.5
Chloronitriles	M5	3.2
Phenylamides (PAs)	A1	2.5
Morpholines	G2	2.5
Melanin biosynthesis inhibitors (MBIs)	I1 and I2	2.4
Carboxylic acid amides (CAAs)	H5	2.1
Dicarboximides	E3	1.9
Anilinopyrimidines (APs)	D1	1.9
Others		8.1

Mercado Mundial de Fungicidas

Table 5.3. Commercialized strobilurins and other complex III inhibitors. (From Krämer *et al.*, 2012.)

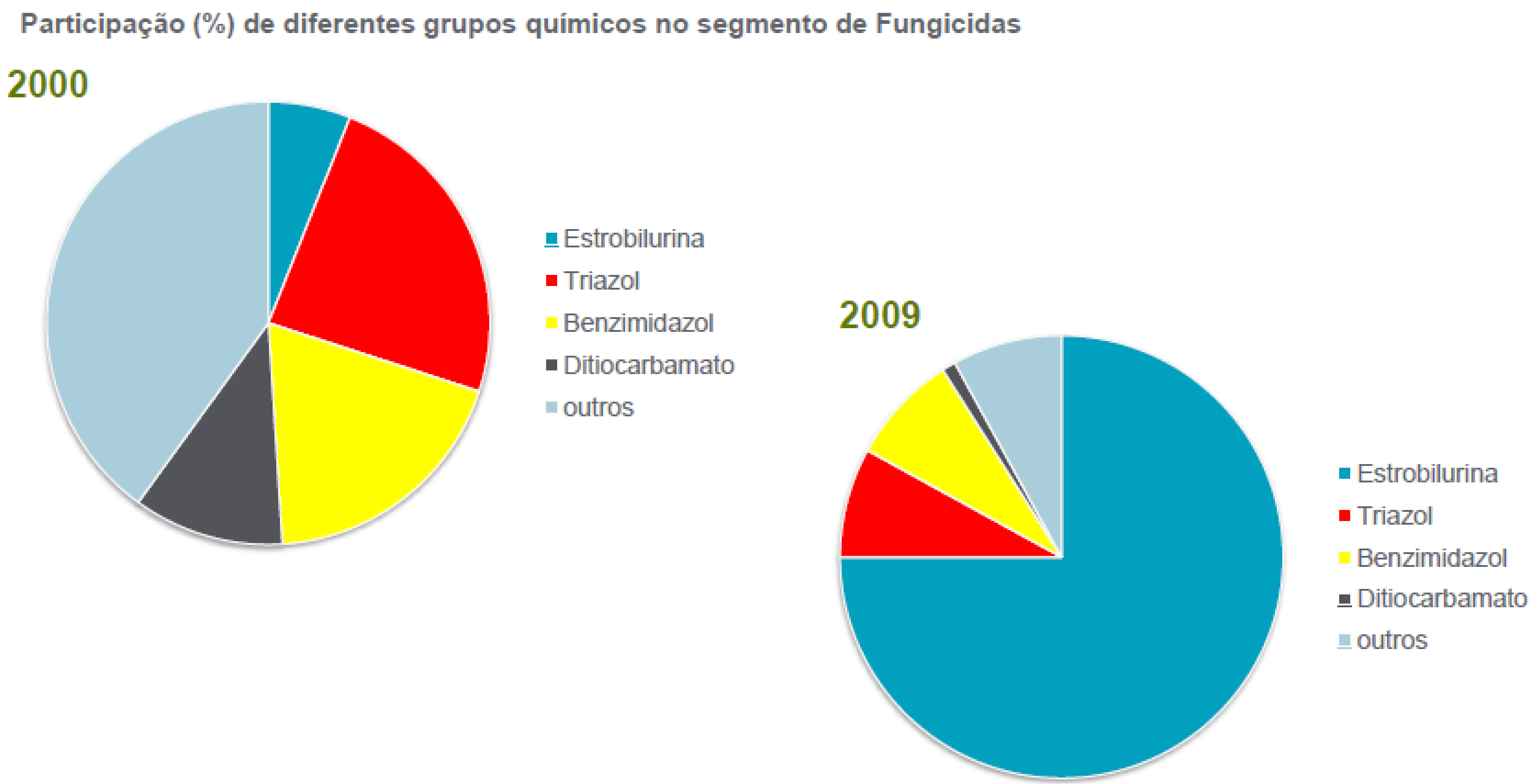
Fungicide	Code number	Originator	Current owner	Launch date	Sales volume (2009, US$ million)
Kresoxim-methyl	BAS490F	BASF	BASF	1996	130
Azoxystrobin	ICIA5504	ICI	Syngenta	1997	910
Metominostrobin	SSF-126	Shionogi	Bayer	2000	<10
Trifloxystrobin	CGA279202	Ciba	Bayer	2000	490
Picoxystrobin	ZA1963	Zeneca	DuPont	2001	145
Pyraclostrobin	BAS500F	BASF	BASF	2002	735
Fluoxastrobin	HEC5725	Bayer	Bayer	2004	150
Dimoxystrobin	BAS505F	BASF	BASF	2004	50
Orysastrobin	BAS520F	BASF	BASF	2007	45
Famoxadone	DPXJE874	DuPont	DuPont	1997	60
Fenamidone	EXP10745	Rhône-Poulenc	Bayer	2001	40
Cyazofamid	IKF916	Ishihara	Ishihara	2001	50
Amisulbrom	NC224	Nissan	Nissan	2008	<10

Table 4. Efficacy of strobilurin fungicides against a range of commercially important fungal diseases

Disease	Azoxystrobin	Kresoxim-methyl	Metominostrobin	Trifloxystrobin	Picoxystrobin	Pyraclostrobin
Ascomycete						
Grape powdery mildew (*Uncinula necator*)	***	***	NA	***	NA	***
Banana black sigatoka (*Mycosphaerella fijiensis*)	***	NA	NA	***	NA	***
Barley net blotch (*Helminthosporium teres*)	***	**	NA	***	***	***
Wheat *Septoria tritici* (*Mycosphaerella graminicola*)	***	**	NA	***	***	***
Basidiomycete						
Wheat brown rust (*Puccinia recondita*)	***	*	NA	**	***	***
Barley brown rust (*Puccinia hordei*)	***	*	NA	*	***	***
Rice sheath blight (*Rhizoctonia solani*)	***	**	***	***	NA	NA
Deuteromycete						
Tomato early blight (*Alternaria solani*)	***	**	NA	***	NA	***
Oomycete						
Grapevine downy mildew (*Plasmopara viticola*)	***	**	NA	**	NA	***
Turf pythium blight (*Pythium aphanidermatum*)	***	**	**	**	NA	***

Source: Syngenta—substantially based on data from independent field trials: Japanese Plant Protection Association official trials and References 33, 34, 72.
NA, Not applicable (not publicly declared to be a development outlet).
* Poor efficacy.
** Moderate efficacy.
*** Good efficacy.

Mercado de Fungicidas no Brasil



Fonte: Syngenta/Kleffmann, 2010

Estrobilurinas – no Brasil

Fungicida	Empresa	Marca Comercial
Azoxystribin	Syngenta	Amistar, Priori, Priori Xtra
Trifloxystrobin	Bayer	Flint, Sphere, Nativo
Picoxystrobin	Syngenta	Approach
Pyraclostrobin	Basf	Comet, Opera, Cabrio Top
Kresoxim-methyl	Basf	Arcádia, Brio, Stroby,

Estrobilurinas – no Brasil

Ministério da Agricultura, Pecuária e Abastecimento

Agricultura

AGROF

Pragas | Ingredientes Ativos cons | Produtos Formulados | Relatórios

Consulta de Ingrediente Ativo

Dados do Ingrediente Ativo

Nome Comum	Grupo Químico	Classe(s)
azoxistrobina	estrobilurina	Fungicida
cresoxim-metílico	estrobilurina	Fungicida
dimoxistrobin	estrobilurina	Fungicida
metominostrobin	estrobilurina	Fungicida
Picoxistrobina	estrobilurina	Fungicida
piraclostrobina	estrobilurina	Fungicida
trifloxistrobina	estrobilurina	Fungicida

Estrobilurinas – no Brasil

Estrobilurina	Culturas com registro de uso
Azoxystrobin	alface, algodão, alho, amendoim, arroz, aveia, banana, batata, beterraba, café, cebola, cenoura, cevada, citros, couve-flor, crisântemo, feijão, figo, melancia, melão, milho, morango, pepino, pêssego, pimentão, soja, tomate, trigo e uva.
Kresoxim-metil	batata, crisântemo, maçã, melão, pepino, rosa, tomate e uva.
Dimoxistrobin	Nenhuma Cultura cadastrada
metominostrobin	Nenhuma Cultura cadastrada
Picoxystrobin	algodão, arroz, café, cana-de-açúcar, feijão, milho, soja e trigo.
Pyraclostrobin	algodão, alho, amendoim, aveia, banana, batata, café, cebola, cenoura, cevada, citros, crisântemo, feijão, maçã, mamão, manga, melão, melancia, milho, pepino, pimentão, rosa, soja, tomate, trigo e uva.
Trifloxystrobin	algodão, alho, amendoim, arroz, aveia, banana, batata, café, caqui, cebola, cenoura, cevada, citros, feijão, goiaba, maçã, mamão, manga, maracujá, melancia, melão, milho, soja, tomate e trigo.

Fonte: Agrofit (2013)

Estrobilurinas

- Excepcional espectro de ação

- Baixa (excepcionalmente) toxidade à plantas e animais

- Mercado que movimenta mais de bilhões de dólares
- Porém:

"The Achilles´s heel of the strobirulin was revealed less than 2 years after release".

Oliver and Hewitt, 2014

Resistência

- Norte da Alemanha, 1998: Isolados de *Erysiphe graminis* (trigo) resistentes

- Itália e França, 1999: detecção de *Plasmopara viticola* com resistência aos QoI

- *Venturia inaequalis* – Alemanha

- *Mycosphaerella fijiensis* – Costa Rica

(...)

Resistência

- Ocorre em um ponto de mutação no gene do Citocromo b

Glicina → **Alanina** → **Posição 143 (G143A)**

Fenilalanina → **Leucina** → **Posição 129 (F129L)**

Glicina → **Arginina** → **Posição 137 (G137R)**

	Nucleotide sequence	Amino acid sequence
Sensitive:	5′ ... TGG G**G**T GCA ... 3′	... W**G**A ...
Resistant:	5′ ... TGG G**C**T GCA ... 3′ (143)	... W**A**A ... (143)

Fonte: www.frac-brasil.org.br
Glasso et al., 2006

Resistência

Cytochrome *b* gene structure and consequences for resistance to Qo inhibitor fungicides in plant pathogens

Valeria Grasso,[1,2]* Simona Palermo,[2] Helge Sierotzki,[2] Angelo Garibaldi[1] and Ulrich Gisi[2]

[1]*Centre of Competence for Innovation in the Agro-environmental Sector (AGROINNOVA), University of Turin, via L. da Vinci 44, 10095 Grugliasco (TO), Italy*

[2]*Syngenta Crop Protection, Research Biology, WST-540, Schaffhauserstrasse, CH-4332 Stein, Switzerland*

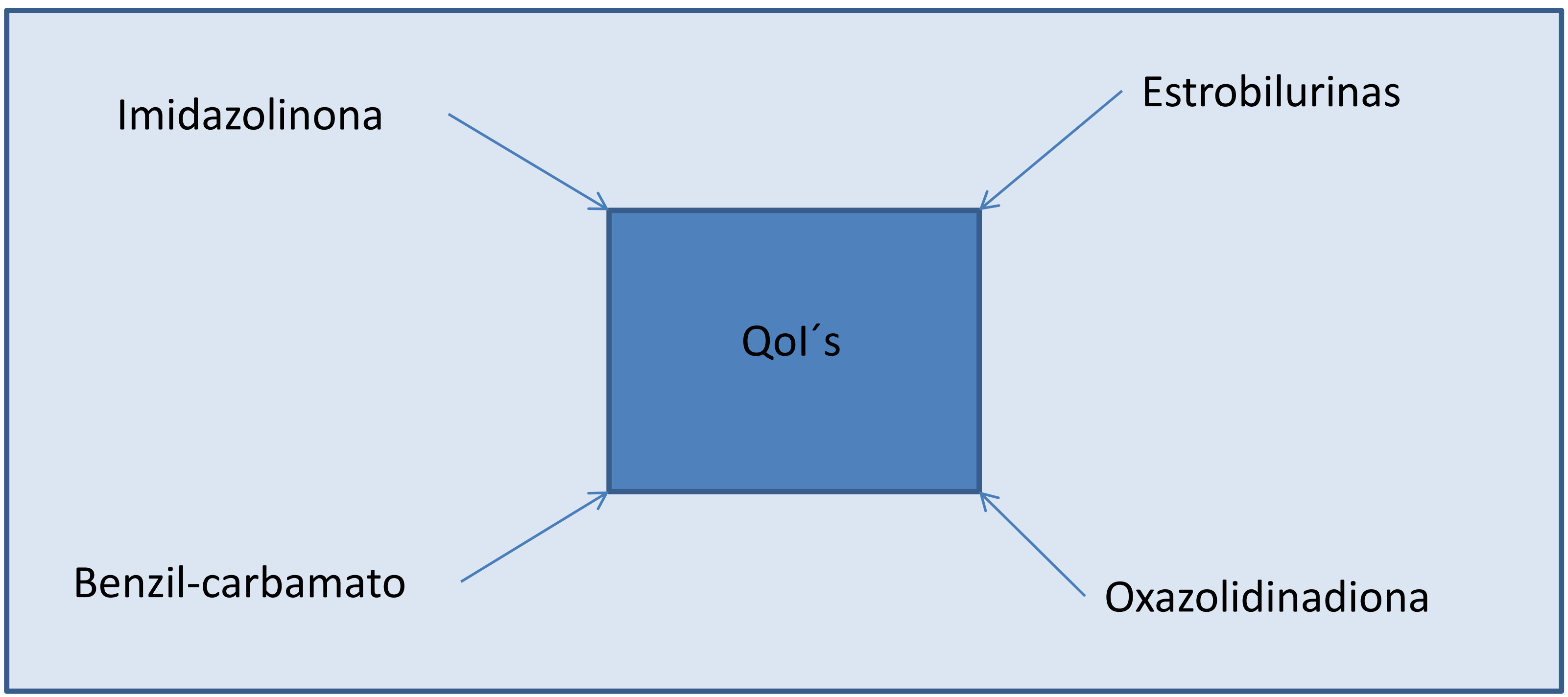
"In the strobilurin-producing Basidiomycetes *Strobilurus tenacellus* (Pers) Singer and *Mycena galopoda* (Pers) P Kumm, several point mutations are present in the *cyt b* gene which cause 'natural resistance' to their own metabolite"

Resistência

Resistência Cruzada

Azoxystrobin
Kresoxim-metil
Metominostrobin
Trifloxystrobin
Picoxystrobin
pyraclostrobin

Fenamidona



Pyribencarb

Famoxadone

Resistência

Lista de Patógenos com resistência aos QoIs – última lista FRAC – Janeiro de 2013

C3	**11**	**QoI fungicides (Quinone outside Inhib.) Complex III cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)**				
		Alternaria alternata	Alternaria late blight	Pistachio	Ma *et al.* 2003 Avenot & Michallides 2007	field / laboratory field
		Alternaria alternata	Alternaria blotch	Apple	Ishii 2008	field
		Alternaria alternata	Alternaria brown spot	Citrus	Mondal *et al.* 2009	field
		Alternaria alternata	Leaf spot	Potato	FRAC 2011	field, G143A, Europe
		Alternaria arborescens	Alternaria late blight	Pistachio	Ma *et al.* 2003	field / laboratory
		Alternaria mali	Alternaria blotch	Apple	Lu *et al.* 2003	field

MOA Code	FRAC Group Code	Pathogen	Common name	Crop	Reference	Remarks
		Alternaria solani	Leaf spot	Potato	Pasche *et al.*2002, 2004, Pasche *et al.* 2005 Pasche & Gudmestad 2008	field resistance mechanism fitness of F129L
		Alternaria tenuissima	Alternaria late blight	Pistachio	Ma *et al.* 2003	field / laboratory
		Ascochyta rabiei	Ascochyta blight	Chickpea	Wise *et al.* 2009	field. Northern Great Plains / Pacific N West
		Blumeria graminis, see *Erysiphe graminis*				
		Botrytis cinerea	Grey mold	 Strawberry Strawberry, citrus Kiwi fruit	Markoglou *et al.* 2006 FRAC 2007 Ishii 2008 Bardas *et al.* 2010	mutation study Field, G143A, Germany Field, Japan Multiple resistance
		Cercospora beticola	Leaf spot	Sugar beet	Keshav Burla *et al.* 2012 Bolton *et al.* 2013	Field G143A Italy Field G143A USA
		Cercospora sojina	Frogeye spot	Soya	FRAC 2011	Field, G143A, USA
		Colletotrichum graminicola	Leaf spot	Annual bluegrass / bent grass	Avila-Adame *et al.* 2003	field
		Colletotrichum gloeosporioides	Anthracnose	Strawberry	Ishii 2008	field

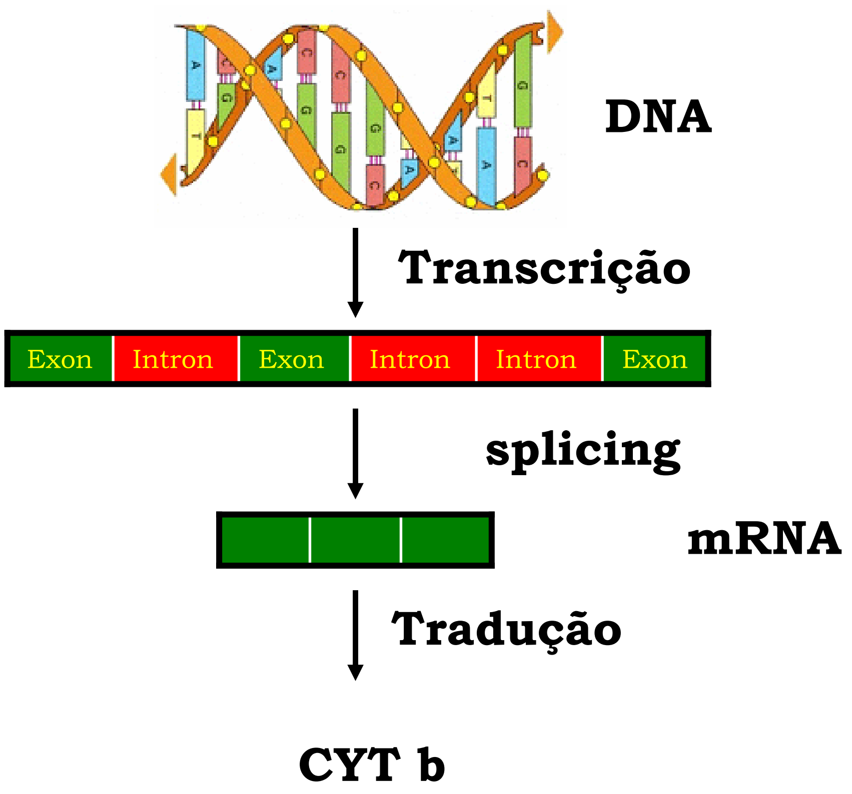
MOA Code	FRAC Group Code	Pathogen	Common name	Crop	Reference	Remarks
		Corynespora cassiicola	Leaf spot, target spot	Cucumber	Ishii 2004 FRAC Brazil G143A 2012	field field
		Didymella bryoniae	Gummy stem blight	Cucurbits Watermelon	Olaya & Holm 2001 Langston 2002 Stevenson *et al.* 2002	field field field
		Didymella rabiei	Ascochyta blight	Chickpea	Gossen & Anderson 2004	field
		Erysiphe graminis tritici	Powdery mildew	Wheat	Heaney *et al.* 2000 Sierotzki *et al.* 2000a	field resistance mechanism
		Erysiphe graminis hordei	Powdery mildew	Barley	Heaney *et al.* 2000	field
		Erysiphe necator: see also *Uncinula necator*				
		Fusicladium carpophilum	Leaf spot	Almond	Foerster *et al.* 2009	California orchards
		Glomerella cingulata (Colletotrichum gloeosporioides)	Anthracnose	Strawberry	Ishii 2004	
		Magnaporthe oryzae	Leaf spot	*Lolium perenne* (perennial ryegrass)	Ma & Uddin 2009	Study on 1 field isolate
		Microdochium nivale *Microdochium majus*	Stem / head blight.	Wheat	Walker *et al.* 2009	isolates from seed
		Microdochium nivale	Head blight	Wheat	FRAC 2011	FRAC Japan report
		Microdochium spp.	Stem / head blight	CeStempeals	FRAC 2008	field, France, G143A confirmed

MOA Code	FRAC Group Code	Pathogen	Common name	Crop	Reference	Remarks
		Monilinia laxa *M. fructigena* *M. fructicola*	Brown rots	Fruit	Meissner & Stammler 2010	Not resistance but evidence of an intron
		Mycosphaerella fijiensis	Black Sigatoka	Banana	Heaney *et al.* 2000 Sierotzki *et al.* 2000b Chin *et al.* 2001	field resistance mechanism field
		Mycosphaerella graminicola See also *Septoria tritici*	Leaf spot	Wheat	Armand *et al.* 2003 Clark 2005 Fraaije *et al.* 2005 Gisi *et al.* 2005	field field, review field field
		Mycovellosiella nattrassii	Leaf mold	Eggplant / aubergine	Yano & Kawada 2003 Ishii 2004	field / laboratory field
		Pestalotiopsis longiseta	Gray blight	Tea	Omatsu *et al.* 2012	field
		Phaeosphaeria nodorum	Leaf blotch	Wheat	Blixt *et al.* 2009	field, molecular data
		Pseudoperonospora cubensis	Downy mildew	Cucumber	Heaney *et al.* 2000	field
		Plasmopara viticola	Downy mildew	Grapevine	Heaney *et al.* 2000 Gullino *et al.* 2004 Sierotzki *et al.* 2005	field field review
		Podosphaera fusca	Powdery mildew	Cucumber	Ishii *et al.* 2001 Fernandez-Ortuno *et al.* 2006 Fernandez-Ortuno *et al.* 2008	Field Resistance mechanism
		Podosphaera xanthii	Powdery mildew	Cucurbits	McGrath & Shishkoff 2003a, b	field trial

MOA Code	FRAC Group Code	Pathogen	Common name	Crop	Reference	Remarks
		Pseudoperonospora cubensis	Downy mildew	Cucumber	Heaney *et al.* 2000 Ishii *et al.* 2001	field field
		Pyrenophora teres	Net blotch	Barley	FRAC Semar *et al.* 2007	field molecular analysis (F129L)
		Pyrenophora tritici-repentis	Tan spot	Wheat	Reimann & Deising 2005 FRAC	field field
		Pyricularia grisea	Gray leaf spot	Perennial ryegrass	Vincelli & Dixon 2002 Kim *et al.* 2003	field field / resistance mechanism
		Pyricularia oryzae	Blast	Rice	FRAC Japan	field (G143A)
		Pythium aphanidermatum	Damping off	Turf	Gisi *et al.* 2002 Olaya *et al.* 2003	laboratory field / resistance mechanism
		Ramularia colli-cygni	Necrotic leaf spot	Barley	FRAC 2006	field
		Rhizoctonia solani	Sheath spot	Rice	FRAC 2011	field, F129L, USA
		Rhynchosporium secalis	Scald, leaf blotch	Barley	FRAC 2008	field, single isolate, Picardie
		Saccharomyces cerevisiae			Di Rago *et al.* 1989	resistance mechanism
		Septoria nodorum, see *Sphaeosphaeria nodorum*				
		Septoria tritici See also *Mycosphaerella graminicola*	Leaf spot	Wheat	Fraaije & Lucas 2003	field

MOA Code	FRAC Group Code	Pathogen	Common name	Crop	Reference	Remarks
		Sphaerotheca aphanis var. aphanis	Powdery mildew	Strawberry	Ishii 2008	field
		Sphaerotheca fuligenea	Powdery mildew	Cucumber	Heaney *et al.* 2000 Ishii *et al. 2001*	field field
		Stemphylium vesicarium	Brown spot	Pears	FRAC 2006 Alberoni *et al.* 2010a	field as above, field
		Stemphylium vesicarium	Purple spot / sand blast	Asparagus	FRAC 2006	field
		Uncinula necator (see also *Erysiphe necator*)	Powdery mildew	Grapevine	Wilcox *et al.* 2003	field
		Ustilago maydis	Smut	Maize	Ziogas *et al.* 2002	laboratory mutants
		Venturia inaequalis	Scab	Apple	Zheng *et al.* 2000 Farber *et al.* 2002 Steinfeld *et al.* 2002 Dux *et al.* 2005	laboratory mutants field trial field field

Resistência

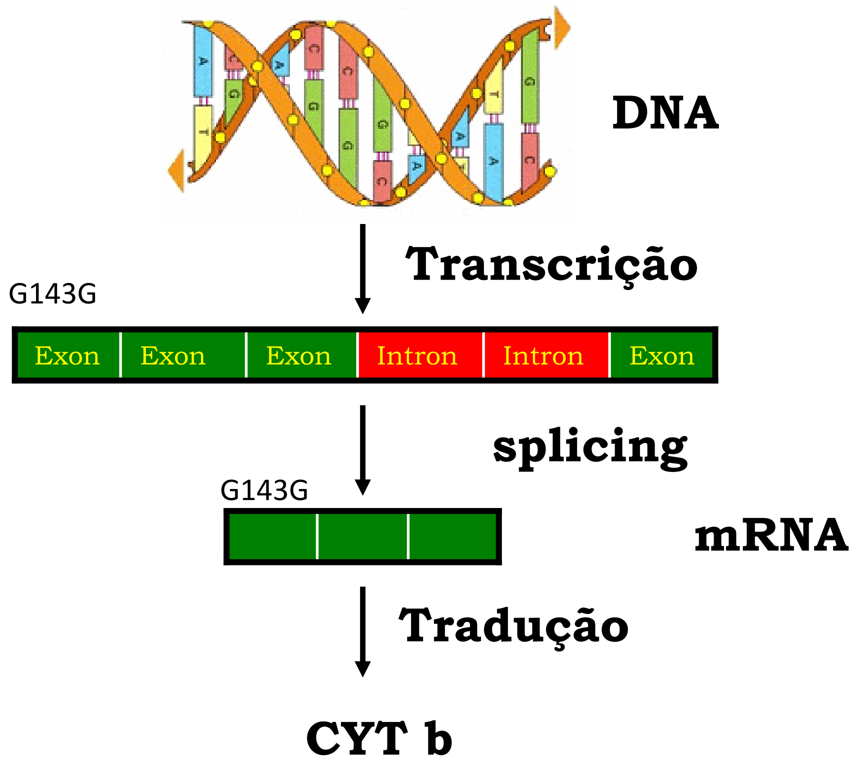


Filme - Splicing

Resistência

Ascomicetos e oomicetos

Não há introns (região do RNA que não é codificada) logo após o códon na posição 143.

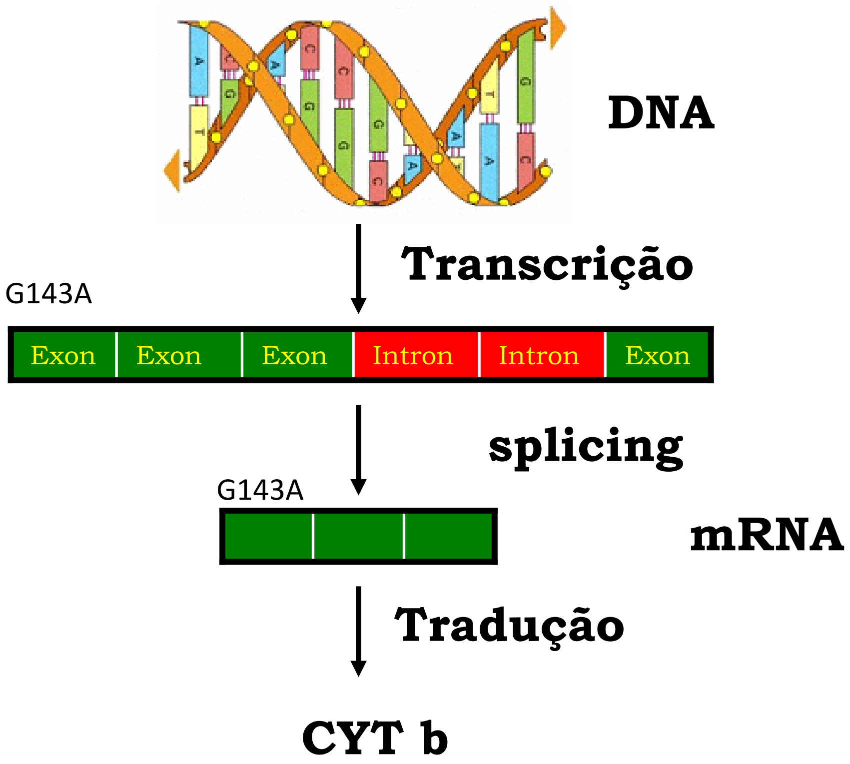


Patógeno suscetível

Resistência

Ascomicetos e oomicetos

Não há introns (região do RNA que não é codificada) logo após o códon na posição 143.

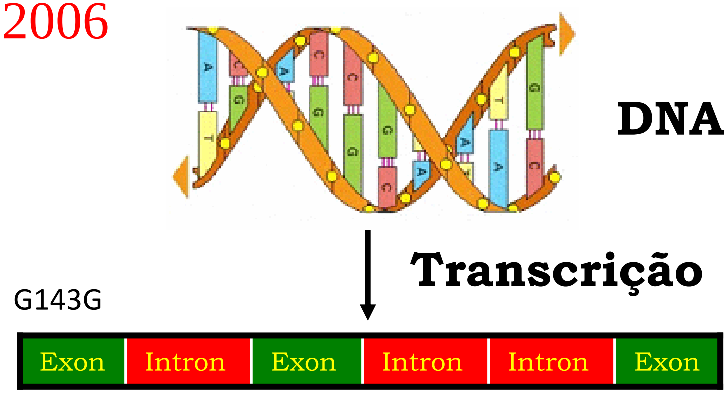


Patógeno Resistente

Resistência

Ferrugens

"In different *Puccinia* species, the presence of an intron has been observed directly after the triplet GGT that encodes for glycine at position 143". Grasso et al., 2006



	Nucleotide sequence	Amino acid sequence
Sensitive:	5′ ... TGG G**G**T GCA ... 3′	... W**G**A ...
Resistant:	5′ ... TGG G**C**T GCA ... 3′ (143)	... W**A**A ... (143)

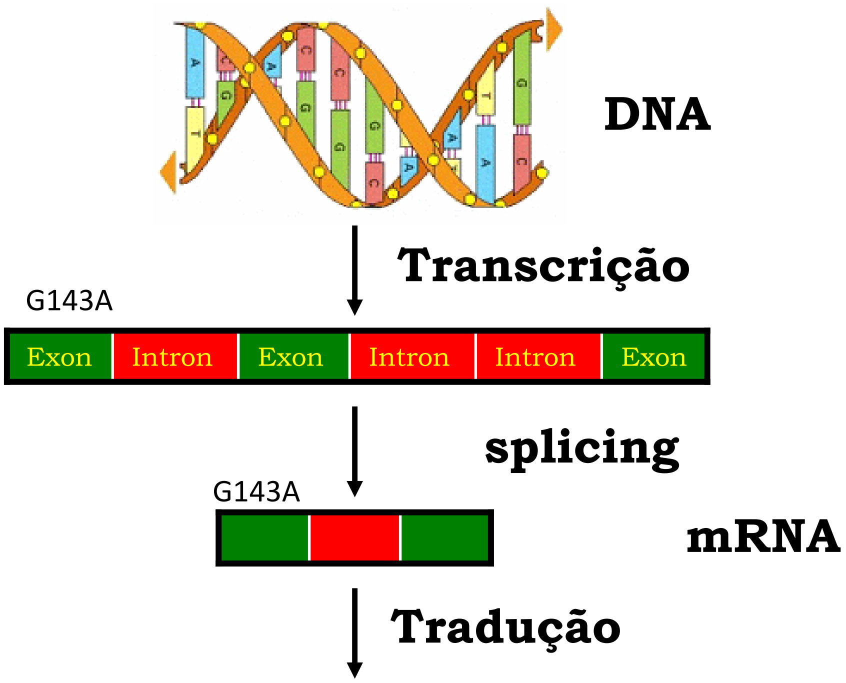
CYT b

Patógeno suscetível

Resistência

Ferrugens

Há um intron (região do RNA que não é codificada) logo após o códon na posição 143.



"A nucleotide substitution in codon 143, which is two nucleotides upstream from the exon/intron junction, will **strongly affect the splicing** process, leading to a **deficient cytochrome b**". Grasso et al., 2006

CYT b não funcional

Mutação letal

Resistência

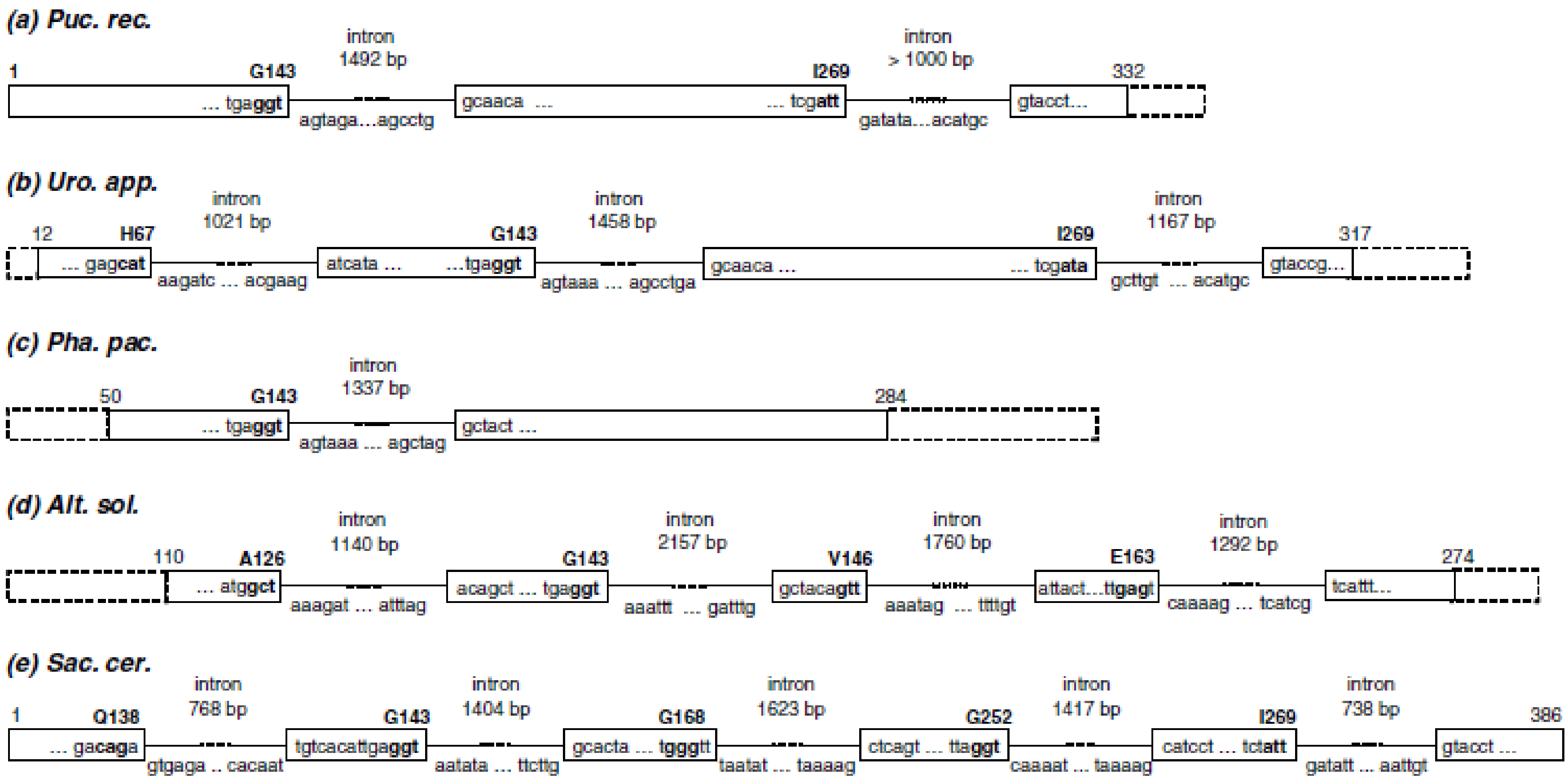


Figure 2. Comparison of the nucleotide sequences at the exon/intron junctions in the *cyt b* gene of different plant pathogen species. Empty boxes indicate exons and lines indicate introns. Dashed boxes represent non-sequenced parts of the gene. The length of exons and introns is not to scale. (a) *Puc. rec.: Puccinia recondita* f sp *tritici*; (b) *Uro. app.: Uromyces appendiculatus*; (c) *Pha. pac.: Phakopsora pachyrhizi*; (d) *Alt. sol.: Alternaria solani*; (e) *Sac. cer.: Saccharomyces cerevisiae*.

Resistência

Table 1. List of species, sequence origin and number of introns present in the *cyt b* gene

Species	Number of isolates	GenBank accession number	Reference number	Number of introns	Position and size (bp) of introns
Basidiomycetes					
Puccinia coronata f sp *avenae*	2	DQ209272	Present work	2[a]	G143 (1477); I269 (>1000)[h]
Puccinia graminis f sp *tritici*	2	DQ209273	Present work	2[a]	G143 (1477); I269 (>1000)[h]
Puccinia hordei	2	DQ209274	Present work	2[a]	G143 (1480); I269 (>1000)[h]
Puccinia horiana	6	DQ209275	Present work	2[a]	G143 (1734); I269 (>1000)[h]
Puccinia recondita f sp *tritici*	3	DQ209276	Present work	2[a]	G143 (1492); I269 (>1000)[h]
Puccinia recondita f sp *secalis*	1	DQ209277	Present work	2[a]	G143 (1480); I269 (>1000)[h]
Puccinia sorghi	4	DQ209278	Present work	2[a]	G143 (1474); I269 (>1000)[h]
Puccinia striiformis f sp *tritici*	2	DQ209279	Present work	2[a]	G143 (1546); I269 (>1000)[h]
Uromyces appendiculatus	2	DQ209280	Present work	3[b]	H67 (1021); G143 (1458); I269 (1167)
Phakopsora pachyrhizi	1	DQ209281	Present work	1[c]	G143 (1337)
Hemileia vastatrix	2	DQ209282	Present work	3[d]	I68–H82 (>1500);[h] Y132 (1396); G143 (1657)
Strobilurus tenacellus	–	X88000	3	3	A95 (272); Y274 (170); L289 (5)
Mycena galopoda	–	X87997	3	2	G131 (238); Y274 (344)
Mycena viridimarginata	–	X87998	3	5	V122 (12); G131 (479); A200 (470); Y274 (159); L289 (87)
Ascomycetes					
Alternaria alternata	5	DQ209283	Present work	0[e]	–
Alternaria solani	2	DQ209284/5	Present work	4[f]	A126 (1140); G143 (2157); V146 (1760); F164 (1292)
Blumeria graminis	–	AF343441	4	0	–
Magnaporthe grisea	–	AY245424/7	11	0	–
Mycosphaerella fijiensis	–	AF343070	5	1	L169 (1064)
Mycosphaerella graminicola	–	AY247413	Not published	0	–
Venturia inaequalis	–	AF004559	15	6	H53 (2432); I92 (2172); P135 (360); F169 (1202); V260 (2009); W274 (1302)
Saccharomyces cerevisiae	–	AJ011856	23	5	M139 (768); G143 (1404); F169 (1623); G252 (1417); I269 (738)
Oomycetes					
Plasmopara viticola	2	DQ209286	Present work	0[g]	–

Recomendação do FRAC para uso de QoI

Número total de aplicações na cultura	1	2	3	4	5	6	7	8	9	10	11	12	>12
Máximo recomendado para aplicações apenas de QoI	1	1[W]	2[W]	2	2	2	2	3	3	3	3	4	*
Máximo recomendado para aplicações em mistura com QoI	1	2	2	2	2	3	3	4	4	5	5	6	*

* Quando maior que 12 aplicações de fungicidas:

- Quando QoI são aplicados sem mistura, o número de pulverizações deve ser menor que 33% do total de aplicações por safra;
- Quando QoI são aplicados em mistura com outros fungicidas, o número de pulverizações contendo QoI deve ser menor que 50% do total de aplicações por safra;
- Quando no programa de pulverizações são utilizados tanto QoI em mistura ou sozinho, o número de pulverizações com QoI deve ser menor que 50% do total das aplicações por safra

[W] Preferencialmente mistura.

“Greening effect” – efeito verde

Efeito Verde:

“Capacidade das estrobilurinas em manter as folhas verdes por mais tempo, maximizando o período de enchimento de grãos, resultando em aumento de produtividade”

2 Hipóteses:

- Efeitos fisiológicos
- Prevenção da germinação dos esporos patogênicos e saprofíticos, evitando as respostas de defesa dos hospedeiros, o que evitaria gastos desnecessários de energia

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http://www.urbanfischer.de/journals/jpp

JOURNAL OF Plant Physiology

Short Communication

Regulation of Phytohormone Levels, Leaf Senescence and Transpiration by the Strobilurin Kresoxim-methyl in Wheat (*Triticum aestivum*)[1]

KLAUS GROSSMANN, JACEK KWIATKOWSKI, and GÜNTER CASPAR
BASF Agricultural Center Limburgerhof, D-67114 Limburgerhof, Germany

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Summary

Using leaf discs and intact wheat plants (*Triticum aestivum* L.), the physiological effects of the strobilurin-type fungicide kresoxim-methyl were studied in relation to induced phytohormonal changes. Dose-response experiments revealed that kresoxim-methyl shifted the hormonal balance, favouring cytokinins particularly of the dihydrozeatin riboside-type, as opposed to ethylene and its biosynthetic precursor 1-aminocyclopropane-1-carboxylic acid (ACC). This was closely correlated with delayed leaf senescence. Kresoxim-methyl was shown to inhibit the induction of ACC synthase in ethylene formation. In addition, kresoxim-methyl caused an up to two-fold increase in endogenous levels of abscisic acid, relative to the control. Concomitantly, the stomatal aperture and water consumption of plants were reduced. It is suggested that kresoxim-methyl changes the hormonal constellation in wheat which leads to delayed leaf senescence and water-conserving effects.

ÁREAS BÁSICAS

EFEITO DA APLICAÇÃO DE PIRACLOSTROBINA NA TAXA FOTOSSINTÉTICA, RESPIRAÇÃO, ATIVIDADE DA ENZIMA NITRATO REDUTASE E PRODUTIVIDADE DE GRÃOS DE SOJA [1]

EVANDRO BINOTTO FAGAN [2]; DURVAL DOURADO NETO [2]; RAFAEL VIVIAN [2]; ROBERTA BRANCHER FRANCO [3]; MATHEUS PIZZINATO YEDA [3]; LUIS FERNANDO MASSIGNAM [3]; RICARDO FERRAZ DE OLIVEIRA [2]; KARLA VILAÇA MARTINS [4]

RESUMO

Com objetivo de avaliar o efeito da aplicação da piraclostrobina em variáveis fisiológicas e fenométricas da cultura de soja, realizou-se um experimento de campo entre novembro de 2005 e maio de 2006. Foram realizadas avaliações de taxa fotossintética e respiração. Também foi avaliada a atividade da enzima nitrato redutase, massa de mil grãos e produtividade. O delineamento experimental foi de blocos ao acaso com três tratamentos (T_1 - sem aplicação de fungicida, T_2 - duas aplicações da piraclostrobina e T_3 - duas aplicações de tebuconazol - triazol) com quatro repetições. A aplicação da piraclostrobina ocasionou incremento na taxa fotossintética. A atividade da enzima nitrato redutase foliar somente foi incrementada pela aplicação de estrobilurina nos 15 dias após a primeira aplicação. As plantas tratadas com estrobilurina tiveram o acréscimo de 7% e 8% na massa de mil grãos e de 1080 e 468 kg ha^{-1} na produtividade quando comparado à testemunha sem aplicação e ao tratamento com triazol (tebuconazol) respectivamente. Os resultados indicam que a piraclostrobina (estrobilurina) afeta a taxa de assimilação de carbono e de nitrogênio na cultura de soja, o que é refletido na produtividade de grãos.

Palavras-chave: *Glycine max*, taxa de assimilação líquida, incremento de fitomassa.

Bragantia, Campinas, v. 69, n. 4, 771-777, 2010

DOI: 10.5433/1679-0359.2012v33n1p77

Respostas fisiológicas em mudas de bananeira tratadas com estrobilurinas

Physiological responses in the banana plantlets treateds with strobilurins

Juliana Domingues Lima[1*]; Wilson da Silva Moraes[2]; Silvia Helena Modenese-Gorla da Silva[1]

Resumo

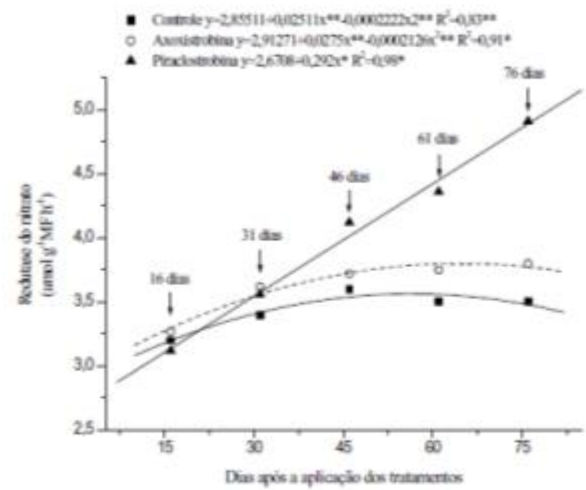
Há relatos de que estrobilurinas, além de atuarem como fungicida, promovem benefícios fisiológicos às plantas. Assim sendo, o presente trabalho teve como objetivo avaliar o efeito de estrobirulinas na fisiologia de mudas de bananeira. Para tal, mudas micropropagadas da cultivar Grand Naine foram repicadas para vasos contendo substrato e mantidas em viveiro a 50% de sombreamento. O delineamento experimental foi inteiramente casualizado, com três tratamentos (água, azoxistrobina e piraclostrobina) e cinco repetições. As estrobirulinas foram aplicadas com pulverizador manual aos 15, 30, 45, 60 e 75 dias após a repicagem, na dose de 100 g i. a. ha^{-1}. A altura da planta, diâmetro do pseudocaule e a massa da matéria seca da parte aérea de plantas tratadas com estrobilurinas foram superiores às de plantas não tratadas. O efeito do tratamento com fungicidas foi diferenciado, sendo mais pronunciado nas plantas tratadas com piraclostrobina do que nas plantas tratadas com azoxistrobina. Plantas tratadas com piraclostrobina apresentaram área foliar, atividade da redutase do nitrato e teor de clorofila *a* e de nitrogênio total foliar superiores às plantas tratadas com azoxistrobina e água, que não diferiram entre si. As estrobilurinas afetaram a fisiologia das mudas de bananeira, com destaque para a piraclostrobina.
Palavras-chave: *Musa* sp., efeito fisiológico, azoxistrobina, piraclostrobina

Abstract

There are reports that strobilurin besides having a fungicide effect can promote physiologic benefits to the plants. However, this effect on banana plants was not studied yet. The objective of the present study was to evaluate the effect of strobirulins on the physiology of banana plantlets. For this purpose, cultivar Grand Naine banana plantlets were transferred to pots containing substrate and kept in a nursery with 50% shading. The experimental design was a completely randomized design with three treatments (water, azoxystrobin and pyraclostrobin) and five replications. The treatments were applied at 15, 30, 45, 60 and 75 days after transplanting at a dose 100 g a. i. ha^{-1} with manual spray. Plant height, pseudostem diameter, shoot dry matter in strobilurin treated plants were higher than the untreated plants, however, the effect of fungicide treatment was different, being the most pronounced effect of pyraclostrobin compared to azoxystrobin. Plants treated with pyraclostrobin had higher leaf area, nitrate reductase activity and chlorophyll content of leaf total nitrogen than the plants treated with azoxystrobin and water, which did not differ. Strobilurins affect the physiology of the banana plantlets differently, the effect being more pronounced by pyraclostrobin.
Key words: *Musa* sp., physiological effect, fungicide, azoxystrobin, piraclostrobin

[1] Profs. da Universidade Estadual Paulista "Júlio de Mesquita Filho", UNESP, Campus Experimental de Registro. Registr
E-mail: judlima@registro.unesp.br; silvia@registro.unesp.br
[2] Pesquisador da Agência Paulista de Tecnologia dos Agronegócios, APTA, Pólo Regional Vale do Ribeira. Registro, SP. E-
wilson@apta.sp.gov.br

Figura 1. Atividade da redutase do nitrato *in vivo* em folhas de mudas de bananeira tratadas com água, azoxistrobina (100 g i. a. ha^{-1}) e piraclostrobina (100 g i. a. ha^{-1}), aos 5, 30, 45, 60, 75 dias após a aplicação dos tratamentos. As setas representam o tempo em dias em que foi feita a determinação da atividade. Valores representam a média de dois experimentos: significativo a 1** e 5* % de probabilidade pelo teste t.



EFEITO FISIOLÓGICO DE ESTROBILURINA F 500®
NO CRESCIMENTO E RENDIMENTO DO FEIJOEIRO

Physiological effects of strobilurins F 500® in the growth and yield of bean

Luiz Alberto Kozlowski[a], Diego Fabrício Morais Simões[b], Camila Duffeck de Souza[b], Marcelo Trento[b]

[a] Engenheiro Agrônomo, Professor adjunto III, Pontifícia Universidade Católica do Paraná (PUCPR), Curitiba, PR - Brasil, e-mail: luiz.kozlowski@pucpr.br

[b] Alunos de graduação do curso de Agronomia, Pontifícia Universidade Católica do Paraná (PUCPR), Curitiba, PR - Brasil, e-mail: diegofsimoes@hotmail.com; camilasouza_agro@yahoo.com.br; m-trento@hotmail.com

Resumo

O objetivo do trabalho foi o de avaliar os efeitos fisiológicos da estrobilurina F 500® no crescimento e rendimento do feijoeiro. O trabalho experimental de campo foi conduzido na Fazenda Experimental Gralha Azul (FEGA) da Pontifícia Universidade Católica do Paraná (PUCPR), no ano agrícola de 2006. O experimento foi implantado em uma área sob plantio direto, utilizando-se um delineamento experimental de blocos ao acaso com oito tratamentos de quatro repetições. Os tratamentos testados foram: testemunha absoluta, testemunha relativa (Mertin // Mertin), Nativo // Mertin, Nativo, Amistar // Mertin, Amistar, Comet // Mertin e Comet, com as aplicações realizadas em duas épocas, V4 e R7. Foram determinados o teor de clorofila e nitrogênio total nas folhas do feijoeiro, incidência e severidade de antracnose nas folhas e vagens do feijão, o rendimento de grãos e seus componentes, a curva de crescimento do feijoeiro e a área foliar das plantas de feijão. Não houve efeito dos diferentes tratamentos no teor total de clorofila e nitrogênio nas folhas do feijoeiro. O Comet foi o que apresentou as menores incidências e severidade de antracnose nas folhas e também a menor severidade de antracnose nas vagens. Comet foi o tratamento que apresentou o melhor rendimento de grãos, sendo que, quando realizada duas aplicações evidencia-se o efeito fisiológico do produto, apresentando também melhores resultados para nº de vagens/planta. As melhores taxas de crescimento absoluto (0,32 $g.dia^{-1}$) foram obtidas para Comet, que também apresentou o menor período de tempo (35 DAE) para atingir a maior taxa de aumento da área foliar.

Palavras-chave: Feijão. Área foliar. Acúmulo de biomassa. Doenças. Controle químico.

ELSEVIER

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Regular Article

Physiological Effects of Azoxystrobin and Epoxiconazole on Senescence and the Oxidative Status of Wheat

Yue-Xuan Wu, Andreas von Tiedemann[1]

Show more

https://doi.org/10.1006/pest.2001.2561

Abstract

The impact of two fungicides, azoxystrobin and epoxiconazole, on the senescence process of spring wheat (*Triticum aestivum* L. cv. 'Nandu') grown under greenhouse conditions until maturity was investigated. The senescence process could be well described by the decrease in total leaf protein content and the increase in electrolyte leakage from leaf tissue. The changes in these two senescence factors coincided with an increase in the level of superoxide ($O^{\cdot -}_2$) and a decrease in the activity of the antioxidant enzyme superoxide dismutase (SOD) during senescence. The senescence was significantly delayed by application of azoxystrobin and epoxiconazole, which induced an increase in total SOD activity and a reduction of $O^{\cdot -}_2$ levels, particularly at mature growth stages. The activity of peroxidase in fungicide-treated plants was about two times higher in flag leaves and three to four times higher in f-1 leaves than in untreated plants. Additionally, levels of H_2O_2 were significantly elevated in fungicide-treated plants. Paraquat induced a substantial increase in $O^{\cdot -}_2$ production at growth stages later than GS 65/69, being much delayed and reduced by azoxystrobin and epoxiconazole. At later growth stages (GS 59/61), azoxystrobin and epoxiconazole showed similar effects in delaying senescence of wheat plants, but azoxystrobin was more efficient when applied at early growth stages (GS 31/32). The results suggest that the fungicide-induced delay of senescence is due to an enhanced antioxidative potential protecting the plants from harmful active oxygen species. Thus, ethylene reduction may not be the primary mechanism by which strobilurins or triazoles interfere with the senescence process, as previously suggested, but may be rather a consequence of reduced oxidative stress in the plant tissue. Elevated levels of H_2O_2 possibly play a key role as second messengers in inducing the expression of antioxidant genes in the fungicide-treated plants.

Universidade de São Paulo
Escola Superior de Agricultura "Luiz de Queiroz"

Avaliação do efeito fisiológico do uso de fungicidas na cultura de soja

Marco Antonio Tavares Rodrigues

Tese apresentada para obtenção do título de Doutor em Ciências. Área de concentração: Fitotecnia

Piracicaba
2009

UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO"
FACULDADE DE CIÊNCIAS AGRONÔMICAS
CAMPUS DE BOTUCATU

EFEITOS FISIOLÓGICOS DE FUNGICIDAS NO DESENVOLVIMENTO DE PLANTAS DE MELÃO RENDILHADO, CULTIVADAS EM AMBIENTE PROTEGIDO

ANA CLAUDIA MACEDO

Dissertação apresentada à Faculdade de Ciências Agronômicas da UNESP – Campus de Botucatu, para obtenção do título de Mestre em Agronomia (Horticultura)

BOTUCATU – SP
(Fevereiro – 2012)

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