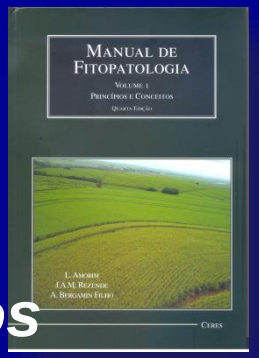
FUNGICIDAS

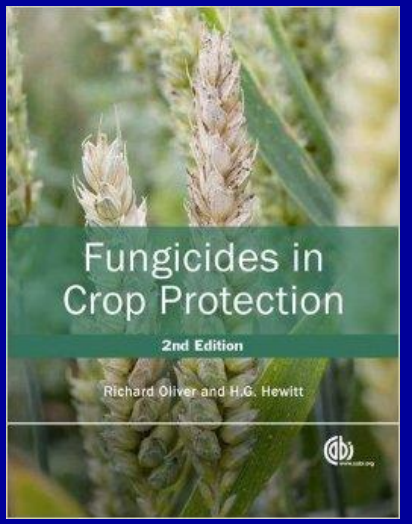


Fungicidas imóveis
INORGÂNCOS
ORGÂNICOS

Fungicidas sistêmicos
BENZIMIDAZÓIS
INIBIDORES DE OOMICETOS
INIBIDORES DA BIOSSÍNTESE DE ESTERÓIS

Inibidores de Oomicetos

M - Multi-sítios
INORGÂNCOS
ORGÂNICOS



B - Mitose
formação da tubulina
BENZIMIDAZÓIS

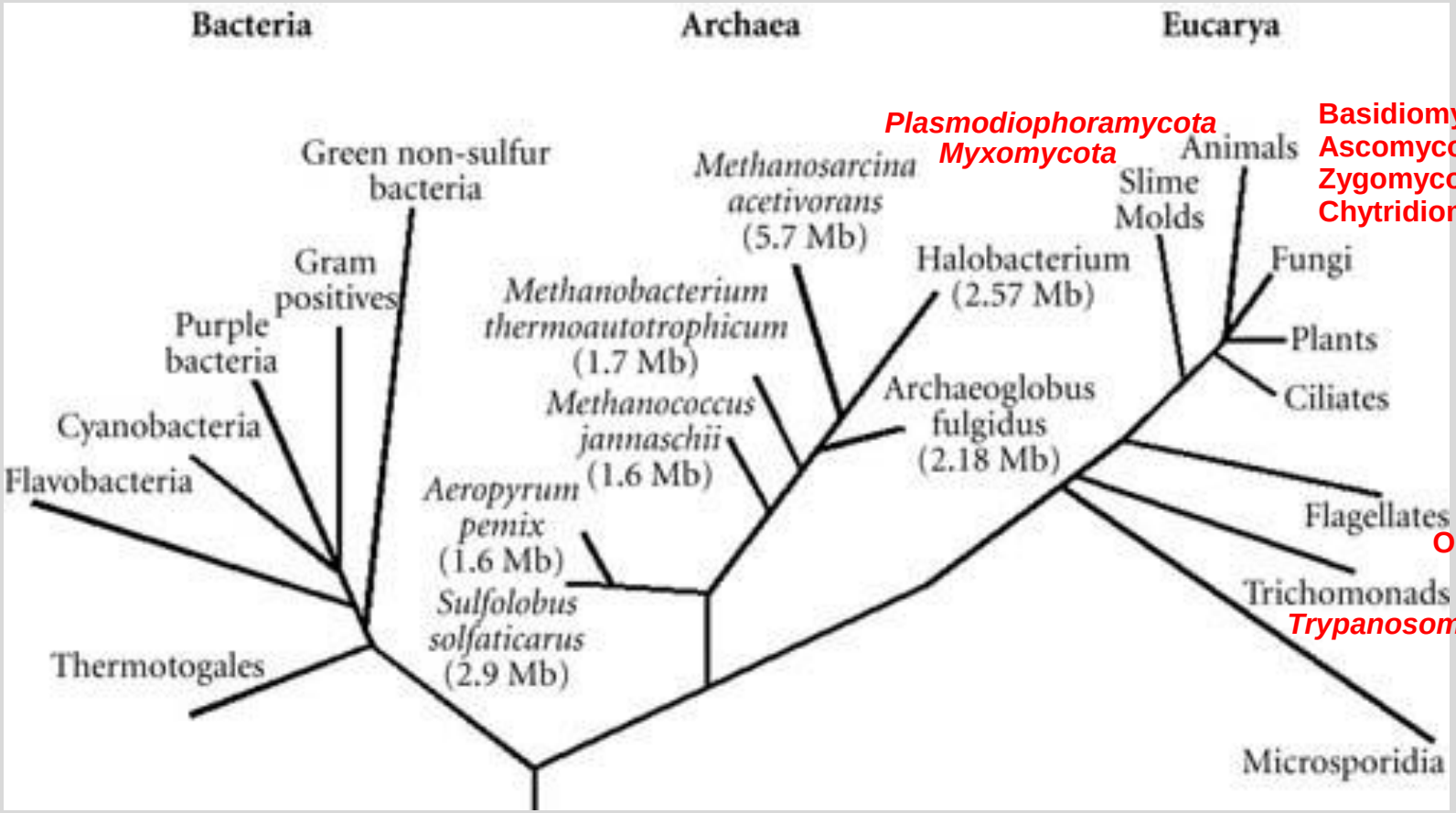
A - Síntese de ácido nucleico
FENILAMIDAS (ACILALANINAS)

G - Biossíntese de esterol em membranas
INIBIDORES DA BIOSSÍNTESE DE ESTERÓIS

U - Modo de ação indefinido
FOSETYL

Eukarya

rRNA



Basidiomycota
Ascomycota
Zygomycota
Chytridiomycota

Parede celular com glucana e celulose
Ergosterol ausente ou pouco importante na membrana
Indivíduos diploides

Oomycetes

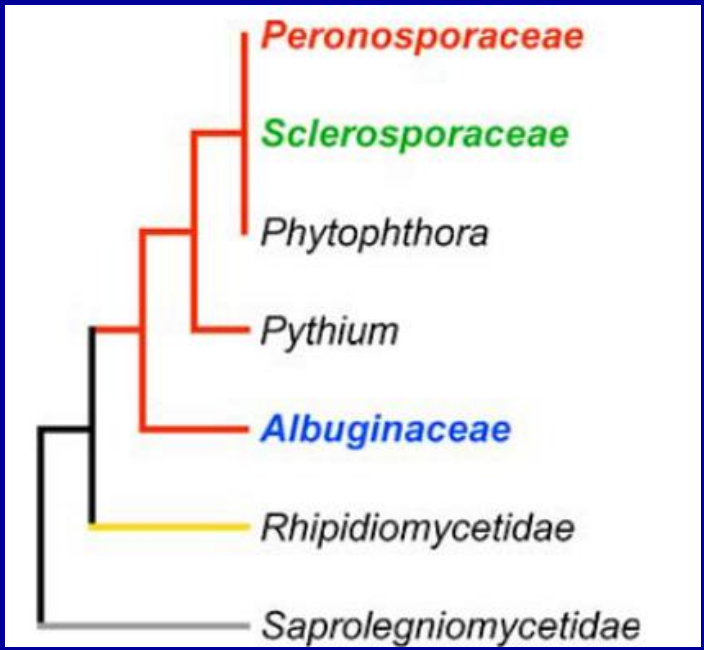
Peronosporales
- *Pythiaceae – Pythium* e *Phytophthora*
- *Peronosporacea – Plasmopara* e *Peronospora*
- *Albuginaceae – Albugo*

Table 1 Comparison of some ordinal, family and generic classifications of downy mildews, white blister rusts and relatives

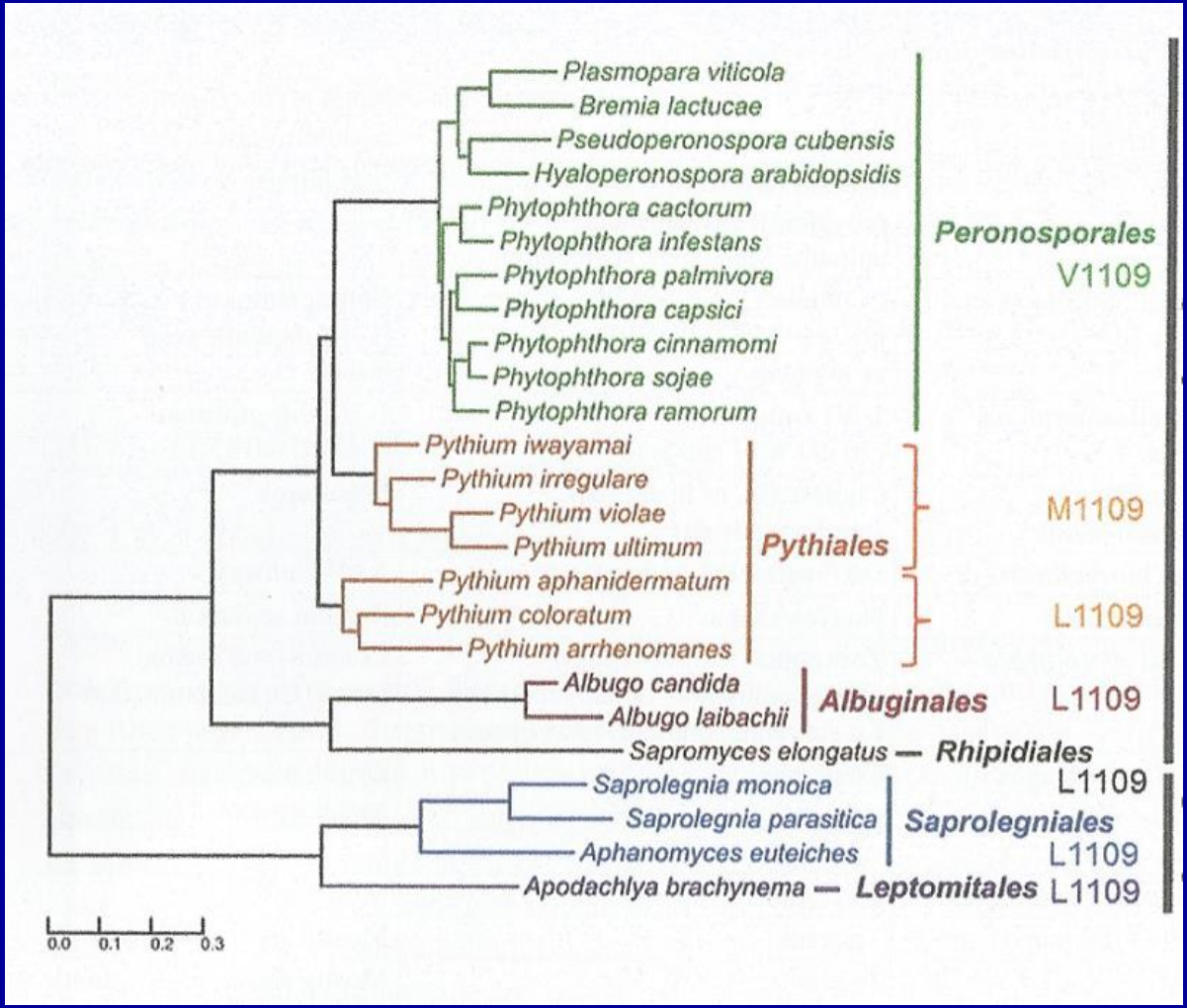
Waterhouse (1973)	Kirk et al. (2001)	Riethmüller et al. (2002)	Göker et al. (2007)[a], Thines and Spring (2005)[b]
Peronosporales	Peronosporales	(no order name)	Peronosporales
Peronosporaceae	Peronosporaceae	Peronosporaceae	Peronosporaceae
Basidiophora	*Basidiophora*	*Basidiophora*	*Basidiophora*
Bremia	*Benua*	(*Benua*)	*Benua*
Bremiella	*Bremia*	*Bremia*	*Bremia*
Peronospora	*Bremiella*	*Paraperonospora*	*Graminivora*
Plasmopara	*Paraperonospora*	*Peronophythora*	*Hyaloperonospora*
Pseudoperonospora	*Peronospora*	(*Peronosclerospora*)	*Paraperonospora*
Sclerospora	*Plasmopara*	*Peronospora*	*Perofascia*
Albuginaceae	*Pseudoperonospora*	*Phytophthora*	*Peronosclerospora*
Albugo	Albuginaceae	*Peronospora*	*Peronospora*
Pythiaceae	*Albugo*	*Plasmopara*	*Peronospora*
Phytophthora	Pythiales	*Pseudoperonospora*	*Plasmopara*
Pythiogeton	Pythiaceae	*Sclerospora*	*Plasmoverna*
Pythium	*Halophytopthora*	Albuginaceae	*Protobremia*
Sclerophthora	*Peronophythora*	*Albugo*	*Pseudoperonospora*
Trachysphaera	*Phytophthora*	Pythiaceae	*Sclerospora*
	Pythium	*Lagenidium*	*Viennotia*
	Trachysphaera	*Pythium*	(family not formally classified)
	Pythiogetonaceae	(*Pythiogeton*)	*Phytophthora*
	Pythiogeton	(*Trachysphaera*)	Albuginales
	Sclerosporales	(*Sclerophthora*)	Albuginaceae
	Sclerosporaceae		*Albugo*
	Peronosclerospora		*Pustula*
	Sclerospora		*Wilsoniana*
	Verrucalvaceae		
	Sclerophthora		

(Voglmayr, 2008)

Classificação de oomicetos



Classificação de acordo com SSU rDNA (Riethmuller et al. 2002)



Classificação baseada no gene *CesA3* (celulose sintase) e na configuração de aminoácidos na posição 1109, V=valina, M=metionina, L=leucina (Blum et al. 2012)

DOENÇAS CAUSADAS POR OOMICETOS

Míldio da videira – *Plasmopara viticola*



Míldio ou Mofo Azul do fumo
Peronospora tabacina



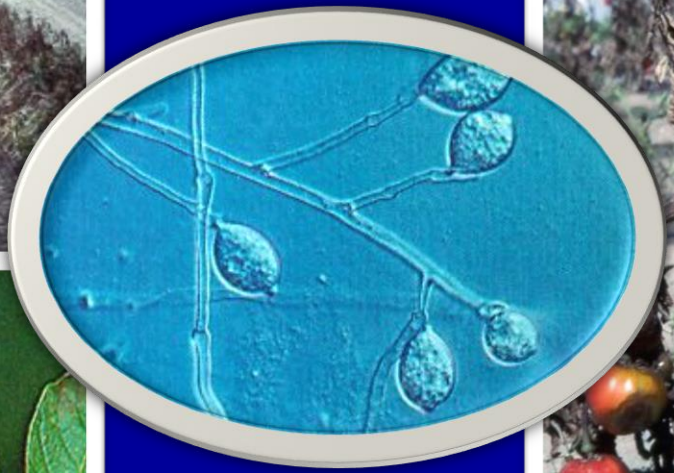
DOENÇAS CAUSADAS POR OOMICETOS

Requeima da batata e do tomate – *Phytophthora infestans*















DOENÇAS CAUSADAS POR OOMICETOS

Podridões – *Pythium*, *Phytophthora*





Podridões pós-colheita – *Phytophthora*





POR QUE O CONTROLE QUÍMICO É DIFÍCIL PARA ESSAS DOENÇAS?

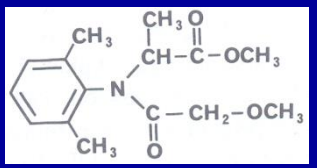
Constituição do Patógeno – parede com celulose; sem síntese de ergosterol e melanina; tubulina diferente dos fungos; núcleo diplóide

Sobrevivência

Epidemias explosivas

FUNGICIDAS SISTÊMICOS INIBIDORES DE OOMICETOS

ACILALANINAS (fenilamidas) – metalaxil, metalaxil-M

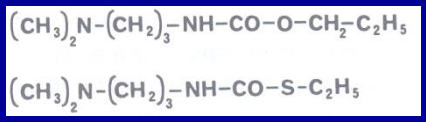


ACETAMIDAS – cimoxanil

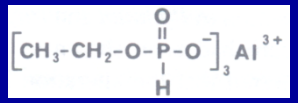


CARBAMATOS – cloridrato de propamocarbe

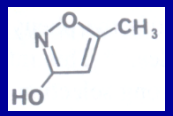
prothiocarbe



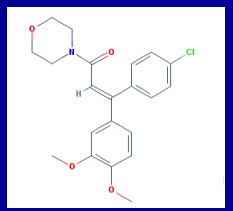
FOSFONATOS – fosetil



ISOXAZOL – hymexazol



MORFOLINA (CAA carboxylic acid amide) - dimethomorfe



Qol - Azoxistrobina

FUNGICIDAS SISTÊMICOS INIBIDORES DE OOMICETOS

ACILALANINAS (fenilamidas): produtos introduzidos de 1977 a 2007

metalaxil, metalaxil-M, benalaxil, benalaxil-M, oxadixyl → Misturas

furalaxyl, ofurace → Fora do mercado

ACILALANINAS – Herbicidas fenilamidas sem cloroacetil (1977)

Metalaxil $C_{15}H_{21}NO_4$

methyl N-methoxyacetyl-N-2,6-xylyl-D alaninate

FUNGICIDAS SISTÊMICOS INIBIDORES DE OOMICETOS

ACILALANINAS (fenilamidas): produtos introduzidos de 1977 a 2007

metalaxil, metalaxil-M, benalaxil, benalaxil-M, oxadixyl

furalaxyl, ofurace

ACILALANINAS – Herbicidas fenilamidas sem cloroacetil (1977)

Metalaxil $C_{15}H_{21}NO_4$ (1970) - RIDOMIL

Metalaxil-M $C_{15}H_{21}NO_4$ (1996) – RIDOMIL GOLD

methyl N-methoxyacetyl-N-2,6-xylyl-D alaninate

Primeiro sistêmico *Peronosporales*

- *Pythiaceae*
- *Peronosporacea*
- *Albuginaceae*

Mode of Action of Fungicides

FRAC classification on mode of action 2016 (www.frac.info)

A: Nucleic Acid Synthesis

A1: RNA polymerase I

A2: adenosin-deaminase

A3: DNA / RNA synthesis (prop.)

A4: DNA topoisomerase type II (gyrase)

B: Cytoskeleton and motor proteins

B1: ▶ ß-tubulin assembly in mitosis

B2: ▶ ß-tubulin assembly in mitosis

B3: ▷ß-tubulin assembly in mitosis

B4: cell division (prop.)

B5: delocalisation of spectrin-like proteins

B6: actin/myosin/ fimbrin function e.g. in vesicle trafficking

C: Respiration

C2: inhibition of complex II: succinate-dehydrogenase

C: Respiration

C1: inhibition of complex I NADH Oxido-reductase

C4: inhibition of complex III ▸ cytochrome bc1(ubiquinone reductase) at Qi site

C3: inhibition of complex III cytochrome bc1 (ubiquinol oxidase) at Qo site (*cyt b* gene)

C8: inhibition of complex III

C7: ATP production (prop.)

C6: inhibitors of oxidative phosphorylation, ATP synthase

C5: uncouplers of oxidative phosphorylation

D: Amino Acid and Protein Synthesis

D1: methionine biosynthesis (cgs gene) (prop.)

D2: protein synthesis

D3: protein synthesis

D4: protein synthesis

D5: protein synthesis

E: Signal Transduction

E1: Signal transduction (mechanism unknown)

E2: Osmotic signal transduction ▶MAP / histidine- kinase (os-2, HOG1)

E3: Osmotic signal transduction ▶MAP / histidine kinase (os-1, Daf1)

F: Lipid Synthesis and Membrane Integrity

F2: phospholipid biosynthesis ▶ methyltransferase

F3: lipid peroxidation (prop.)

F4: cell membrane permeability, fatty acids (prop.)

F6: microbial disrupters of pathogen cell membranes

F7: cell membrane disruption (prop.)

I: Melanin Synthesis in Cell Wall

I1: reductase in melanin biosynthesis

I2: dehydratase in melanin biosynthesis

I3: polyketide synthase in melanin biosynthesis

G: Sterol Biosynthesis in membranes

G1: C14-demethylase in sterol biosynthesis (*erg11*/cyp51)

G2:Δ14-Reductase and Δ8→Δ7-isomerase in sterol biosynthesis (erg2, erg 24)

G3:3-Keto reductase in C4-de-methylation (erg27)

G4: Squalene epoxidase in sterol biosynthesis (erg1)

H:Cell Wall Biosynthesis

H4: chitin synthase

H5: cellulose synthase

P: Host Plant Defence Induction

P1: salicylic pathway

P2:

P3:

P4:

P5:

M: Multi Site Action

Unknown Mode of Action

NC : Not Classified

Legend:

C: Respiration

C2: inhibition of complex II: ▶ succinate-dehydrogenase

7 SDHI (Succinate dehydrogenase inhibitors)

FRAC

FUNGICIDE RESISTANCE ACTION COMMITTEE

FRAC Mode of Action Poster ©

Updated February 2016

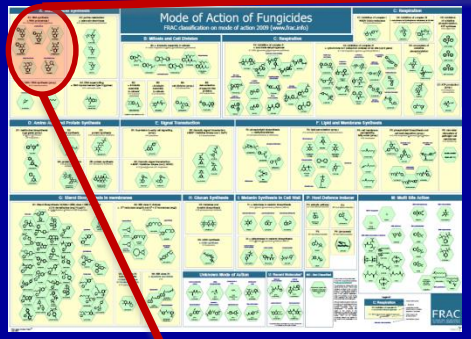
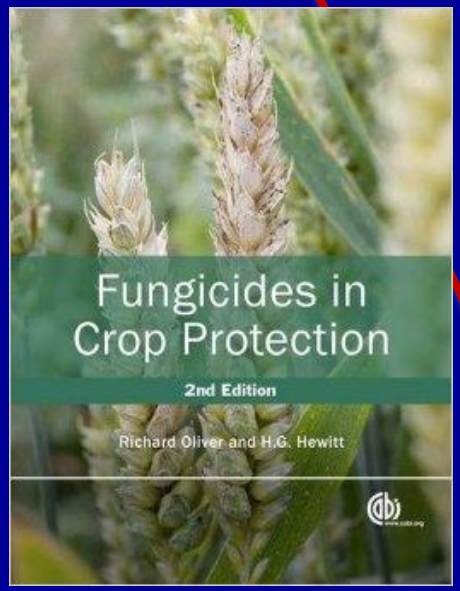


Table 5.2. The spectrum of different classes of fungicides

Mode of action (FRAC)	Oomycete	Basidiomycete
A1	All	None
A2	None	None
A3	Some	None
A4	None	None

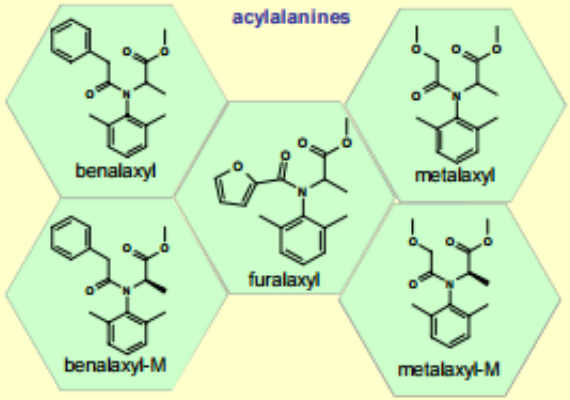


A: Nucleic Acid Synthesis

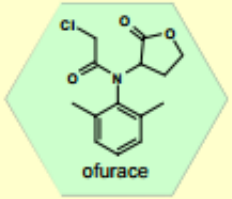
A1: RNA polymerase I

4: PA-fungicides (PhenylAmides)

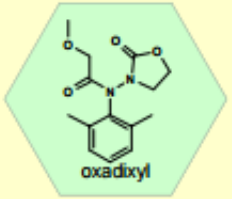
acylalanines



butyrolactones

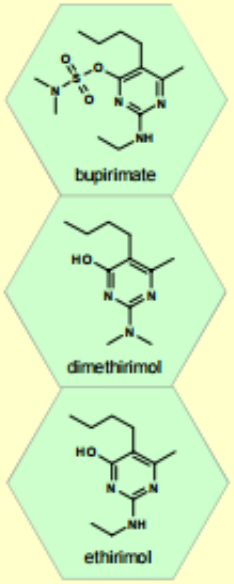


oxazolidinones



A2: adenosin-deaminase

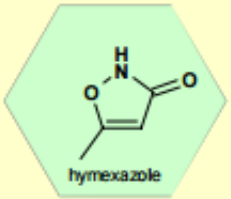
8: hydroxy (2-amino)-pyrimidines



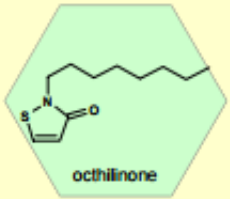
A3: DNA / RNA synthesis (prop.)

32: heteroaromatics

isoxazoles

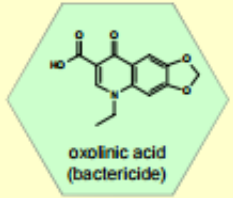


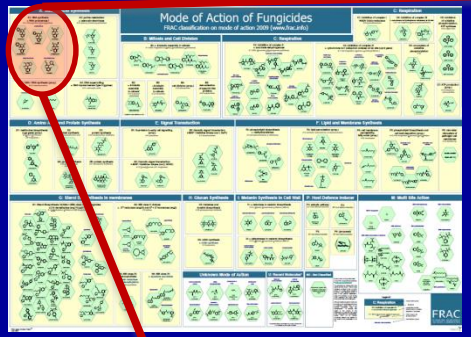
isothiazolones



A4: DNA topoisomerase type II (gyrase)

31: carboxylic acids





Benalaxyl e metalaxyl mistura racêmica (enantiômetros D e E)

benalaxyl-M (=kiralaxyl)

metalaxyl-M (=mefenoxam)

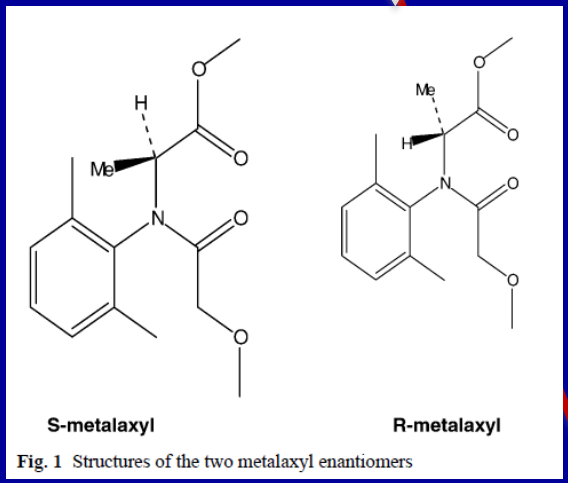


Fig. 1 Structures of the two metalaxyl enantiomers

Monkiedje & Spiteller (2002)

A: Nucleic Acid Synthesis

A1: RNA polymerase I

4: PA-fungicides (PhenylAmides)

acylalanines

benalaxyl

metalaxyl

furalaxyl

benalaxyl-M

metalaxyl-M

butyrolactones

ofurace

oxazolidinones

oxadixyl

A2: adenosin-deaminase

8: hydroxy (2-amino)-pyrimidines

bupirimate

dimethirimol

ethirimol

A3: DNA / RNA synthesis (prop.)

32: heteroaromatics

isoxazoles

hymexazole

isothiazolones

octhilinone

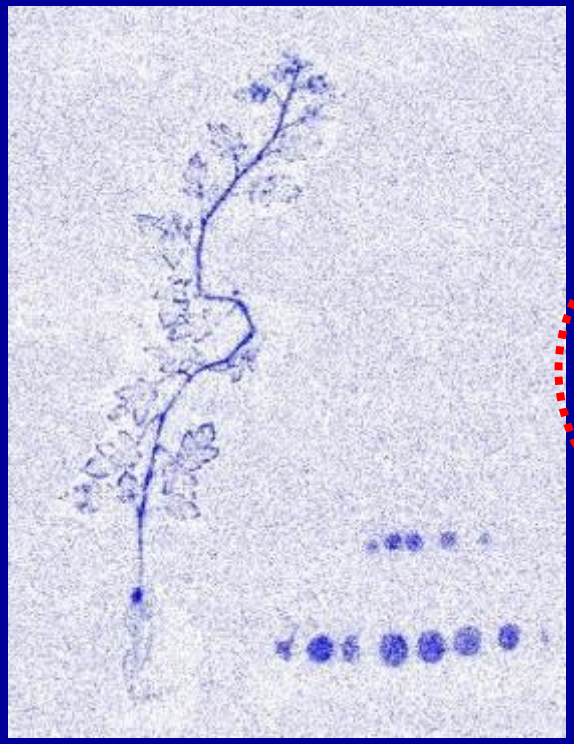
A4: DNA topoisomerase type II (gyrase)

31: carboxylic acids

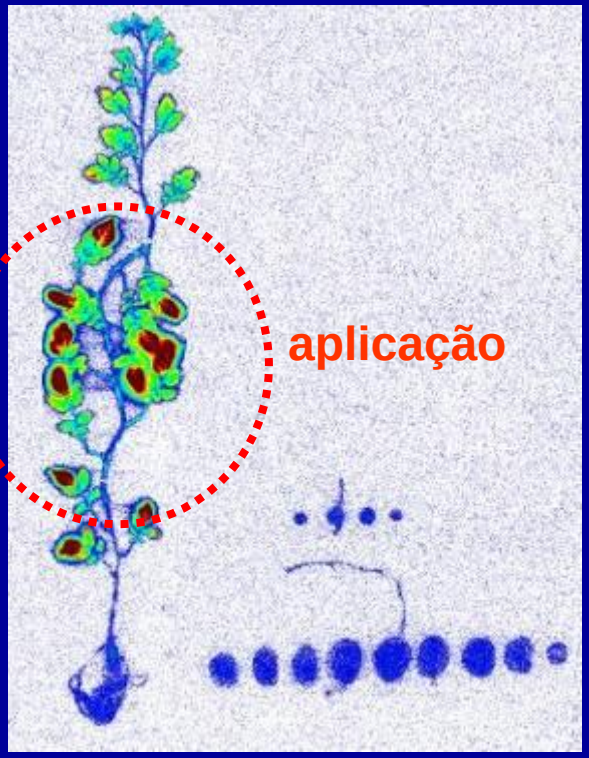
oxolinic acid (bactericide)

SISTEMICIDADE

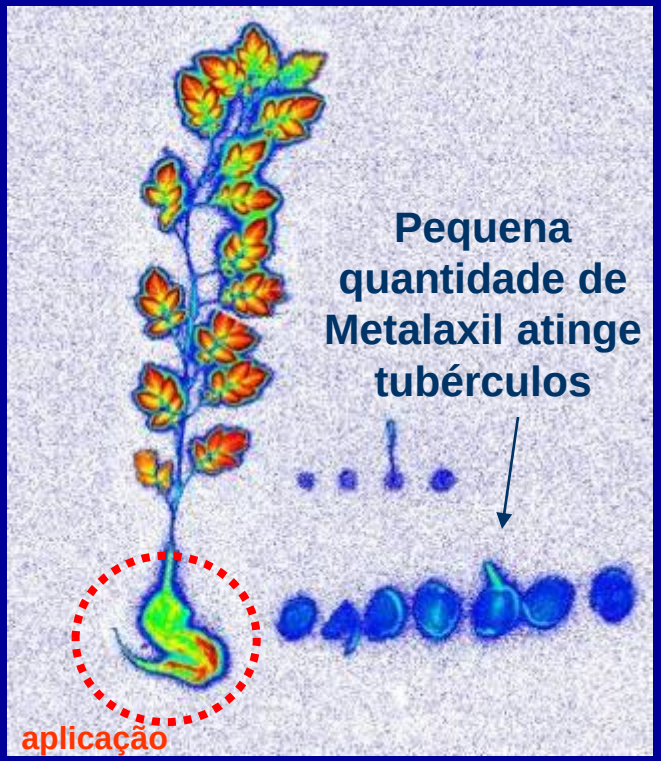
Movimento de metalaxyl em plantas e tubérculos de batata



Testemunha não tratada



Tratamento foliar:
MXL confinado à área tratada



Tratamento via solo: MXL move-se para raiz e folhas

SISTEMICIDADE

Movimento em plântulas de abacate

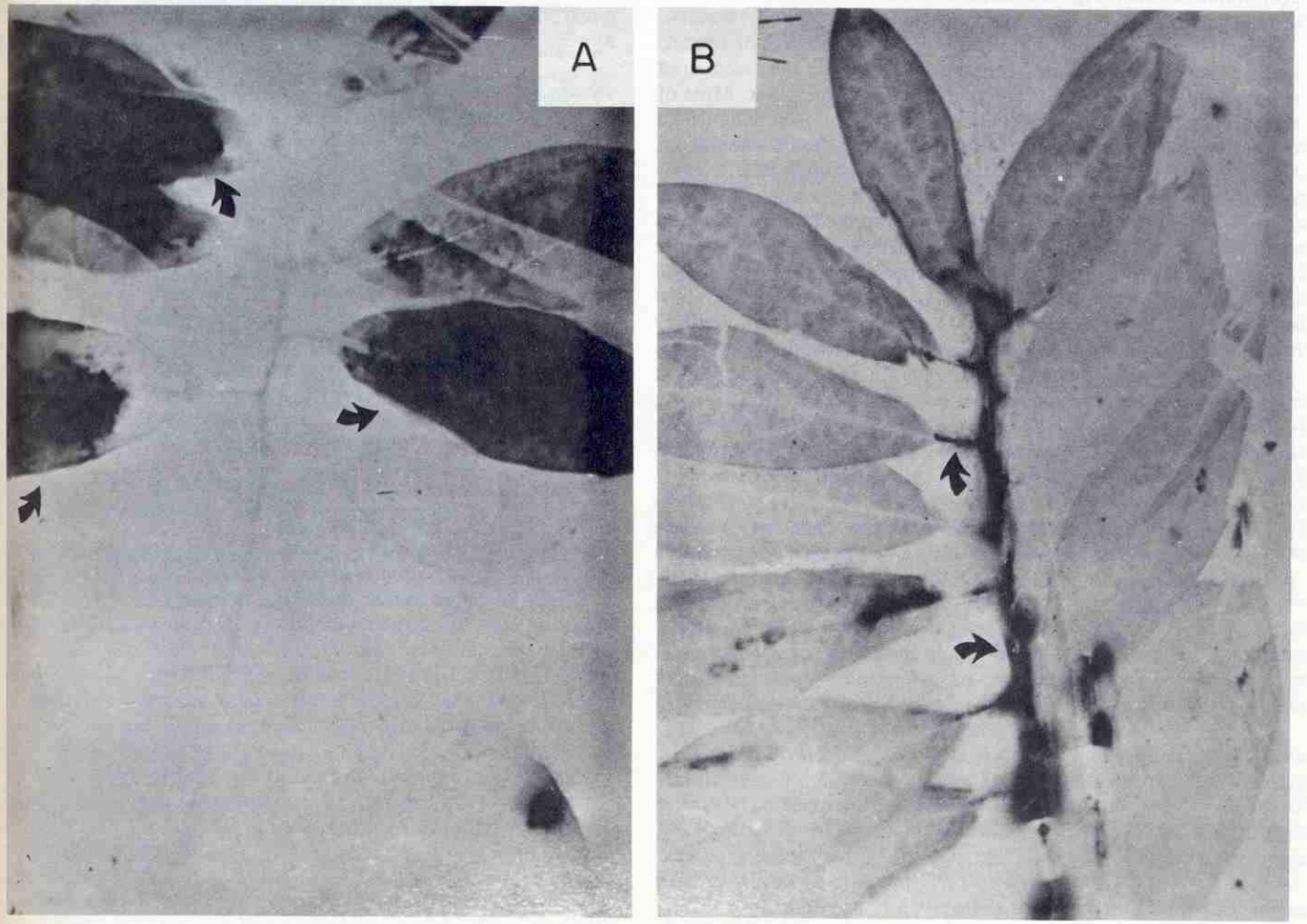
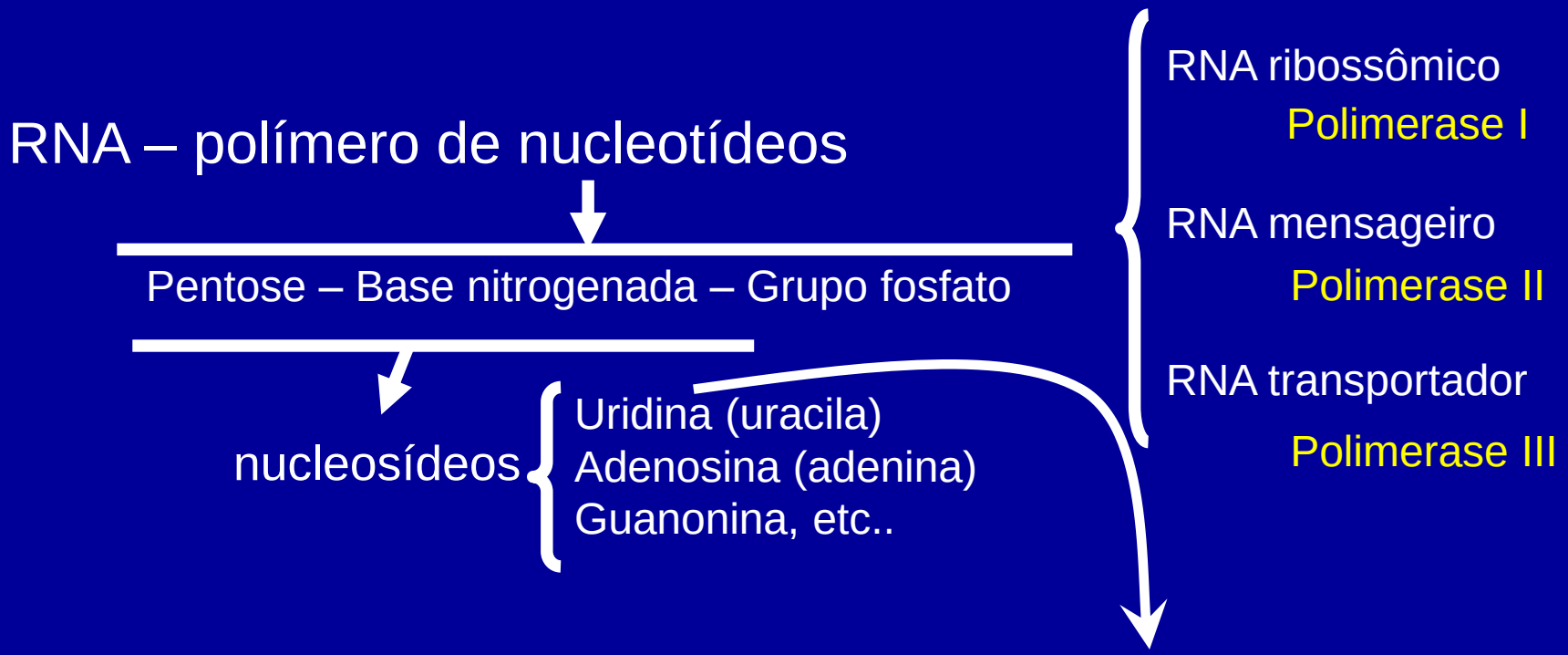


Fig. 2. Autoradiograms of avocado seedlings treated with ^{14}C-metalaxyl. **A,** The labeled fungicide was applied to the six uppermost leaf blades (arrows) (some radioactivity was detected in the lower part of the stem and petioles and very slight radioactivity was detected in leaf blades lower than the treated ones) or **B,** The labeled fungicide was applied to the stem and petioles (arrows) (considerable radioactivity was found in the leaf blades and no radioactivity was detected by autoradioactivity in the roots of either stem- or foliage-treated plants).

Zaki et al. Phytopathology 1981 (71):509-514

MECANISMO DE AÇÃO DO METALAXIL – Inibição da síntese do RNA



METALAXIL – Incorporação de Uridina

MECANISMO DE AÇÃO DO METALAXIL – Inibição da síntese do RNA

RNA – polímero de nucleotídeos

Pentose – Base nitrogenada – Grupo fosfato

nucleosídeos { Uridina, Adenosina, Guanonina, etc.

RNA [illegible] Polimerase I

RNA [illegible] Polimerase II

RNA transportador Polimerase III

METALAXIL – Incorporação de Uridina

INIBIÇÃO DE 20 – 60% DE RNA

POR QUE?

Table 16.12 Effects of phenylamides at concentrations of 10 µg/ml on endogenous RNA polymerase activity of nuclei isolated from a wild-type (S) and a metalaxyl-resistant (R) strain of *Phytophthora megasperma* f. sp. *medicaginis*

Phenylamides	Activities as a percentage of control[1]	
	S	R
metalaxyl	58	91
benalaxyl	51	97
cyprofuram	70	96
oxadixyl	63	92
metolachlor	72	92
propachlor	93	91

[1]) Isolated nuclei were incubated in a reaction mixture containing in a total of 100 µl: 50 mM Tris-HCl (pH 7.9), 1 mM dithiothreitol, 1 mM ATP, GTP and CTP, 0.01 mM UTP, 2 µCi [5,6-^{3}H] UTP, 4 mM $MnCl_2$, 50 mM ammonium sulphate, 10 µl of nuclear suspensions and the different phenylamides or solvent (control). Reaction mixtures were incubated at 25 °C and after 30 min acid-precipitable radioactivity was determined using standard procedures (Davidse *et al.* 1983 b).

Ação predominante na polimerase I (RNA ribossômico)

Algumas evidências...

Metalaxil em doses recomendadas

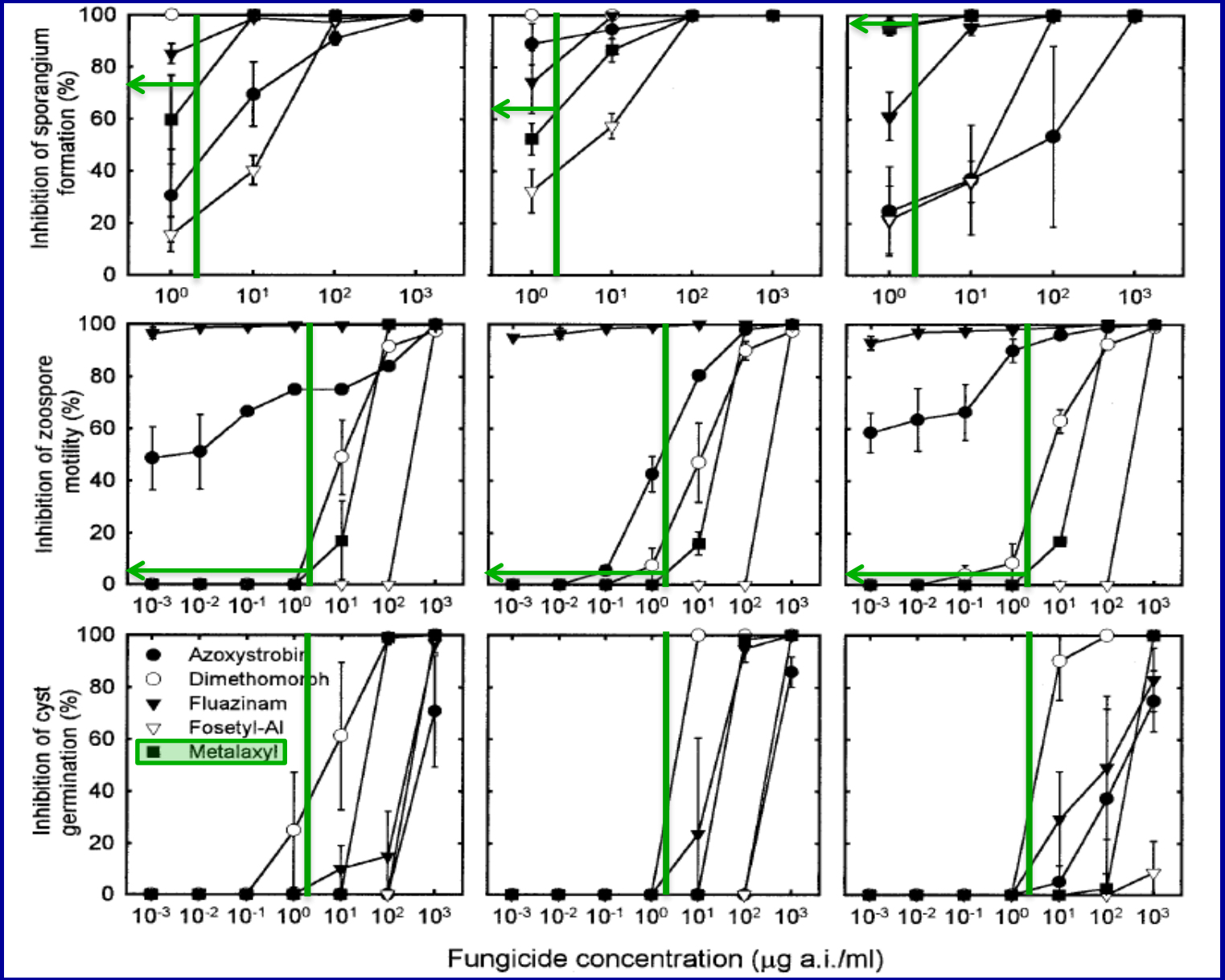
Inibe formação de tubo germinativo? → **Não**

Inibe motilidade de zoósporos? → **Não**

Inibe encistamento de zoósporos? → **Não**

Inibe colonização pelo patógeno? → **Sim**

Inibe esporulação (esporângio, oósporo)? → **Sim**

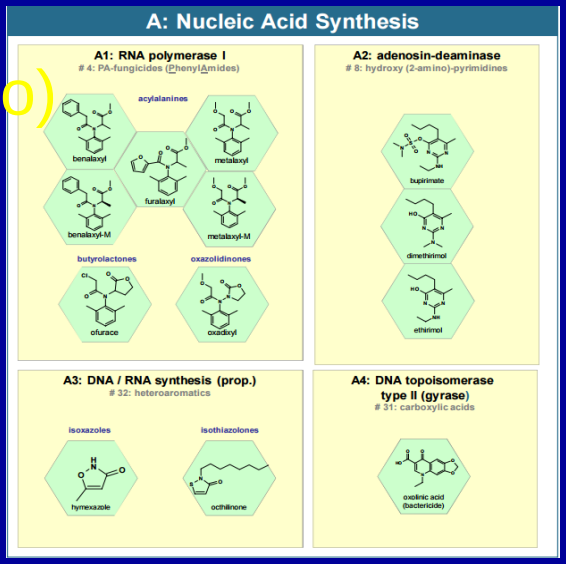


Dose recomendada de metalaxil-M 3 ppm

Matheron, M. E., and Porchas, M. 2000. Impact of azoxystrobin, dimethomorph, fluazinam, fosetyl-Al, and metalaxyl on growth, sporulation, and zoospore cyst germination of three *Phytophthora* spp. Plant Dis. 84:454-458.

Ação predominante na polimerase I (RNA ribossômico)

Mais evidências...



Precursores de rRNA estimulam formação de β1-3 glucana sintase

Acúmulo de β1-3 glucana sintase → engrossamento das paredes

Resistência cruzada com outras acilalaninas que interferem na polimerase I

TABLE 4. Sensitivity of three metalaxyl-sensitive and five metalaxyl-resistant isolates of *P. viticola* to five phenylamides and three fungicides of other chemical groups. Tests were carried out on grape leaf discs of the variety Gutedel

	sensíveis			EC_{50} values (p.p.m. a.i.)* of isolate no:			resistentes	
Product	CH 57/82	F 40/82	ZA 19/81	F 38/82	ZA 03/81	CH 01/83	GR 02/82	URU 01/82
Metalaxyl	0·16	0·02	0·02	4·70	5·80	430·00	570·00	140·00
Oxadixyl	0·38	0·40	0·48	330·00	700·00	750·00	520·00	620·00
Ofurace	0·01	0·03	0·06	650·00	>1000	>1000	>1000	>1000
Cyprofuram	0·24	0·55	0·42	48·00	240·00	2·00	4·00	1·40
Fosetyl-Al	26·00	21·00	23·00	18·00	—	—	17·00	34·00
Cymoxanil	2·40	2·20	6·20	1·70	—	—	4·00	1·80
Folpet†	0·08	0·07	0·60	0·44	—	—	0·90	0·08

* Based on estimation of % diseased leaf area; † Tested on whole grape plants of variety Gutedel.

Diriwachter et al. CROP PROTECTION (1987) 6 (4) 250-255

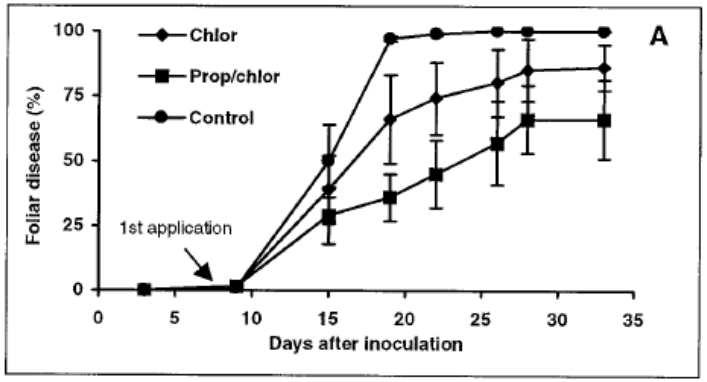
Resistência monogênica e dominante – 2 anos após lançamento do produto

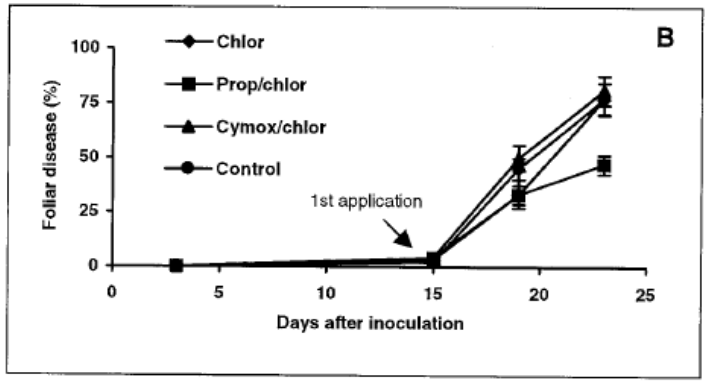
Mutação no gene *RNApolI* (Y382F) – associada a 85% dos casos de R a mefenoxam

Estratégias anti-resistência

- Alternância ou mistura com produtos sem resistência cruzada (Br só misturas)
- Na mistura, o produto adicional deve estar na dose recomendada
- Usar apenas no início da estação. Após o uso trocar por fungicida de outro grupo
- Duas a quatro aplicações da mistura/ano
- Utilizar preventivamente (na ação curativa/erradicante a população patogênica é elevada demais)
- Não utilizar no solo para proteção da parte aérea (formulações em mistura com não sistêmico)

Controle curativo de isolado da linhagem clonal US-8 (resistente a metalaxil) de *Phytophthora infestans*





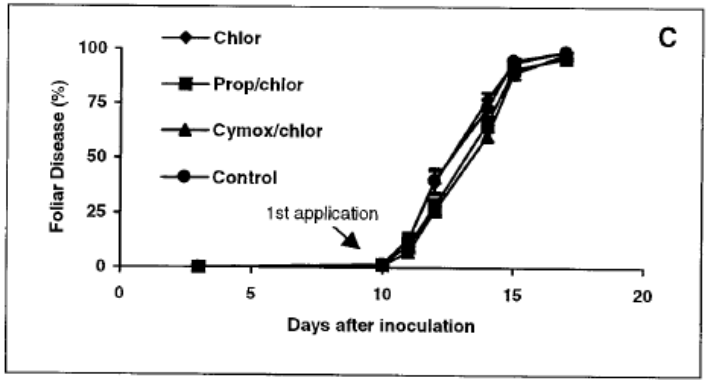


Fig. 1. Disease progress curves of potato late blight in small field plots as influenced by diverse fungicides. Fungicide applications were initiated at 1 to 5% disease (indicated by the arrow). Data are for **A,** 1997, **B,** 1998, and **C,** 1999. Fungicides were applied every 3 days in 1997 and 1999 and every 4 days in 1998. Error bars represent the standard deviation of the mean of either three (1998) or four replicates (1997, 1999) of percent foliar disease at each date.

Table 4. Effects of fungicides on expansion rates of late blight lesions and sporulation from those lesions determined in inoculated field plots

	Lesion expansion rates cm^2/day		# Sporangia/cm^2
Treatment	1998	1999	1999
Chlor[x]	1.4 a	1.4 a	3.3×10^4 a
Cymox/chlor[y]	1.4 a	1.4 a	3.9×10^4 a
Prop/chlor[z]	0.9 b	1.0 b	2.1×10^4 a
Unsprayed control	1.6 a	1.6 a	3.1×10^4 a
LSD	0.4	0.4	1.4×10^4
P value	0.0029	0.0055	0.09

[x] Chlorothalonil (Bravo WS) applied at 1.3 kg a.i./ha.
[y] Cymoxanil (Curzate 60 DF) applied at 139 g a.i./ha plus chlorothalonil (Bravo WS) applied at 1.3 kg a.i./ha.
[z] Propamocarb hydrochloride plus chlorothalonil (Tattoo C) applied at 2.0 kg a.i./ha.

Mayton, H., Forbes, G. A., Mizubuti, E. S. G., and Fry, W. E. 2001. The roles of three fungicides in the epidemiology of potato late blight. Plant Dis. 85:1006-1012.

Estratégias anti-resistência

Produtos ainda eficazes, mesmo com aparecimento de isolados resistentes

Table 10.3 Sensitivity to mefenoxam of *Phytophthora infestans* bulk isolates[a] collected from potato fields in Europe (NL, F, A, CH, D, DK, UK, S, RU)[b] between 2004 and 2013

Year	Number of isolates	Sensitivity[c]		
		%S	%I	%R
2004	40	65	15	20
2005	57	47	6	47
2006	95	26	22	52
2007	124	11	15	74
2008	147	31	16	53
2009	28	39	11	50
2010	82	61	6	33
2011	85	57	15	28
2012	43	75	16	9
2013	Few[a]	nd	nd	nd

[a]Data from Syngenta internal sensitivity monitoring (unpublished). In 2013, only few samples were received, no reliable data available (nd)

[b]*NL* Netherlands, *F* France, *A* Austria, *CH* Switzerland, *D* Germany, *DK* Denmark, *UK* United Kingdom, *S* Sweden, *RU* Russia

[c]Thresholds: sensitive (S): $EC_{50} \leq 0.1$ mg/l; intermediate (I): $0.1 > EC_{50} \leq 10$ mg/l; resistant (R): $EC_{50} > 10$ mg/l

Table 10.5 Resistance to mefenoxam in soilborne *Pythium* and *Phytophthora* species in the USA (recent selected references)

Pathogen	Crop	Years	No. of isolates	Percent resistance	Reference
Pythium spp.	Carrot	2010	169	7	Lu et al. (2012)
Pythium spp.	Ornamentals	1996–2001	29	12–62	Moorman et al. (2002)
Pythium spp.	Ornamentals	2010–2011	20	60	Olaya (2011)[a]
Phytophthora cinnamomi	Ornamentals	1986–2004	65	15	Hu et al. (2010)
Phytophthora nicotianae	Tobacco	2006–2008	217	0	Parkunan et al. (2010)
Phytophthora erythroseptica	Potato	1997–2000	805	3–36	Taylor et al. (2002)
		2001–2002	224	70	Porter et al. (2007)
Phytophthora capsici	Diverse (see text)		498	13	Lamour and Hausbeck (2000)
			150	59	Parra and Ristaino (2001)
			53	51	French-Monar et al. (2006)
			120	7	Keinath (2007)
			75	63	Café-Filho and Ristaino (2008)
		2007	257	0–65	Dunn et al. (2010)
			75	10	Olaya (2009)[b]

[a]Data from Syngenta internal sensitivity monitoring 2011 (unpublished)

[b]Data from Syngenta internal sensitivity monitoring 2009 (unpublished)

(Gisi & Sierotzki, 2015)

FUNGICIDAS SISTÊMICOS INIBIDORES DE OOMICETOS

ACILALANINAS (fenilamidas) – metalaxil, metalaxil-M, benalaxil

ACETAMIDAS – cimoxanil

CARBAMATOS – cloridrato de propamocarbe e prothiocarbe

FOSFONATOS – fosetil

ISOXAZOL – hymexazol

FOSFONATOS – Fosetil Al (1977)
Sistemicidade total
Espectro mais restrito que acilalaninas
Eficiente no controle da doença e sem efeito *in vitro*

	EC_{50} (µg/ml) sensíveis			EC_{90} (µg/ml) resistentes		
Fungicide	*P. capsici*	*P. citrophthora*	*P. parasitica*	*P. capsici*	*P. citrophthora*	*P. parasitica*
Mycelial growth						
Fosetyl-Al	103	23.6	30.8	402	404	381
Metalaxyl	0.16	<0.1	0.38	10.0	725	40.2

Matheron & Porchas Plant Dis. 84:454-458. 2000

Table 16.6 Spectrum of activity of recent *Oomycetes* Fungicides

Common name	Pathogens on root/stem	Foliar pathogens	Activity against pathogens other than Oomycetes
Hymexazol	*Aphanomyces* *Pythium*	–	*Corticium sasaki* *Fusarium* spp.
Propamocarb	*Aphanomyces* *Pythium,* *Phytophthora*	*Bremia, Peronospora* *Phytophthora* *Pseudoperonospora*	–
Cymoxanil	–	*Plasmopara* *Peronospora* *Phytophthora* *Pseudoperonospora*	
Fosetyl	*Phytophthora* *Pythium*	*Bremia* *Plasmopora* *Pseudoperonospora*	*Phomopsis viticola* *Guignardia bidwelli* *Pseudopezzia tracheiphila*
Phenylamides (spectrum varies between individual compounds)	*Peronosclerospora* *Phytophthora* *Pythium* *Sclerospora* *Sclerophthora*	*Albugo* *Bremia* *Peronospora* *Peronosclerospora* *Phytophthora* *Plasmopara* *Pseudoperonospora* *Sclerospora* *Sclerophthora*	–
Fluazinam		*Phytophthora* *Pseudoperonospora*	*Botrytis cinerea*
Dimethomorph	*Phytophthora*	*Bremia* *Peronospora* *Phytophthora* *Plasmopara* *Pseudoperonospora*	
BASF 490F/ ICIA 5 504		*Phytophthora* *Plasmopara*	Foliar and glume diseases of cereals and rice, Powdery Mildews, *Venturia inaequalis, Aternaria* spp.

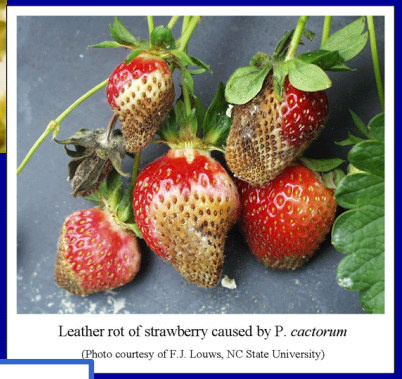
FUNGICIDAS SISTÊMICOS INIBIDORES DE OOMICETOS

Sensibilidade diferencial a fosetil no gênero *Phytophthora*

P. cinnamomi *P. citrophthora* *P. palmivora* *P. parasitica*	SENSÍVEIS
P cactorum *P. crytogea* *P. vignae*	MEDIANAMENTE SENSÍVEIS
P. capsici *P. infestans* *P. megasperma*	POUCO SENSÍVEIS

Gomose dos citros





Leather rot of strawberry caused by P. *cactorum*

(Photo courtesy of F.J. Louws, NC State University)

Requeima em pimenta



FUNGICIDAS SISTÊMICOS INIBIDORES DE OOMICETOS



Cancro em amendoeira

Pulverização Foliar 29/10/99

1 e 3 meses antes da inoculação

Browne et al. Plant Disease (2005)

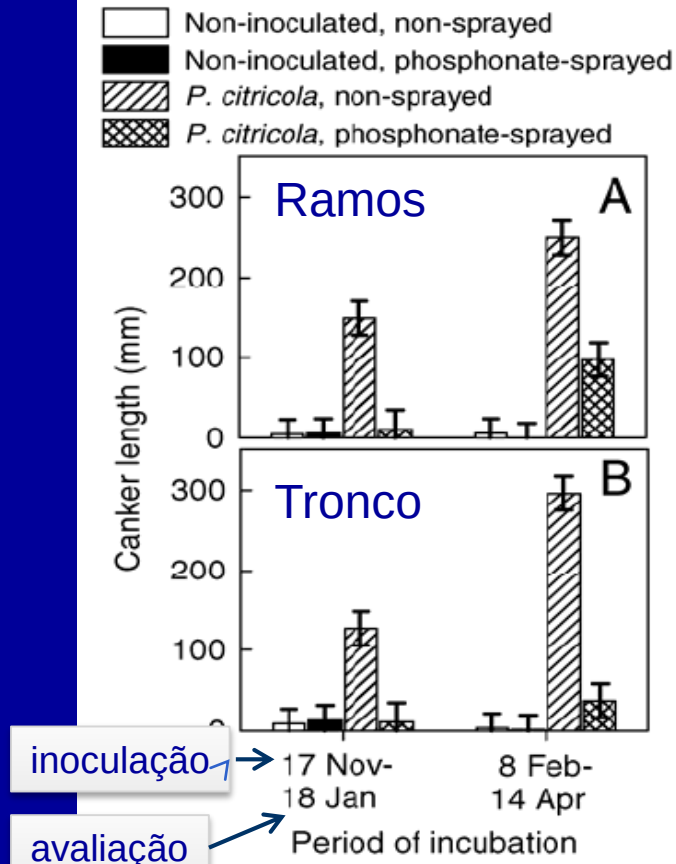


Fig. 1. Effects of a preventive foliar spray with phosphonate on development of cankers on **A,** scaffold branches and **B,** trunks of commercial almond trees inoculated with *Phytophthora citricola* in experiment 1. NutriPhite P+K 0-28-26 was applied at 4.7 liters/ha (2.2 kg phosphonic acid/ha) on 29 Oct 1999. A separate set of trees was inoculated at the beginning of each period of incubation (17 Nov 1999 and 8 Feb 2000), and canker lengths were determined at the end of each period (18 Jan and 14 Apr 2000, respectively). There were four replicate trees per treatment, each inoculated twice on the trunk and once on each of four separate branches. Vertical bars are 95% confidence intervals.

Fosetil → Ácido fosforoso

$C_2H_7O_3P \longrightarrow H_8PO_3 + CO_2$

Planta ou solo

Ácido fosforoso *in vitro*

Inibição de crescimento
Não inibe formação de clamidósporos

TABLE 1. Slope, EC_{50}, and EC_{90}[w] values[x] for inhibition of radial growth by phosphorous acid for individual cultures of *Phytophthora citricola* and *P. cinnamomi* grown on a modified Ribeiro's medium[y]

Species	Culture	Slope[z]	Inhibition of radial growth EC_{50}	Inhibition of radial growth EC_{90}
P. citricola	P1273	1.78	1.3 ± 1.1	4.7 ± 1.2
	P1315	1.63	1.3 ± 1.1	5.9 ± 4.1
	P1277	1.95	1.7 ± 1.1	6.1 ± 1.2
P. cinnamomi	Pc356	1.27	4.1 ± 1.2	27.9 ± 1.4
	Pc402	0.96	4.6 ± 1.2	64.2 ± 1.4
	Pc407	1.02	6.2 ± 1.2	71.7 ± 1.4

[w] EC_{50} and EC_{90} are the concentrations (micrograms per milliliter) required to inhibit radial growth 50 and 90%, respectively.
[x] Mean ± standard deviation of the mean based on a linear regression of the response (percent mycelial inhibition) plotted against the dosage (log concentration) H_3PO_3. The values are based on data from two experiments.
[y] Cultures grown on V8-$CaCO_3$ (V8C in the text) agar were transferred onto a modified Ribeiro's medium (11) at pH 6.2 containing 0.084 mM KH_2PO_4 and no β-sitosterol. Radial growth was measured after 4 days of incubation at 24 C.
[z] Correlation coefficients for all slope values were significant at $P = 0.01$.

TABLE 4. Influence of phosphorous acid on the number of chlamydospores produced by three cultures of *Phytophthora cinnamomi* incubated at 24 C[x]

Concentration of H_3PO_3 (μg/ml)	Chlamydospores (10^3) produced by *P. cinnamomi*[y] Pc402	Pc407	Pc356	Chlamydospore production inhibition (%) Pc402	Pc407	Pc356
0.0	15.3 a[z]	10.7 a	9.5 a	–	–	–
1.0	14.0 a	8.2 b	10.3 a	–	–	–
5.0	12.4 a	7.2 b	10.0 a	–	–	–
10.0	14.5 a	6.9 b	8.6 a	5	36	9
50.0	10.0 b	4.9 b	6.0 b	35	54	37
100.0	4.4 c	3.7 b	4.0 b	71	65	58

[x] Cultures were grown in half-strength carrot broth for 48 hr and then overlaid with solutions of H_3PO_3 and incubated in the dark at 24 C for 35 days.

Coffey & Joseph. Phytopathology 75(9):1042-1046. 1985

Nomenclatura

Entendendo a terminologia dos fosfonatos...

Phosphonate	Broadly, any compound containing a carbon to phosphorus bond. More commonly, used to describe products made of the salts or esters of phosphorous acid.
Phosphorous acid	Anhydrous solid substance, often cited by its chemical formula, $HPO(OH)_2$ or H_3PO_3. The basic ingredient in phosphonate products.
Phosphonic acid	Strong acid produced by dissolving phosphorous acid in water. The term phosphonic acid is often used synonymously with phosphorous acid.
Phosphite	Alkali metal salts of phosphorous acid. The most common phosphite is potassium phosphite, and is made by mixing a solution of potassium hydroxide with phosphonic acid. Potassium phosphite is also referred to as mono- and di-potassium salts of phosphorous acid on some phosphonate product labels. Plants take up phosphite ions ($H_2PO_3^-$) but they are not used in phosphorus metabolism. Phosphite products have fungicidal properties.
Ethyl phosphonate	Organic (carbon-based) compound bonded to an aluminum ion forming aluminum tris (O-ethyl phosphonate) or fosetyl Al; the active ingredient in Aliette and Chipco Signature fungicides.
Phosphoric acid	Strong acid used in the manufacture of phosphate fertilizer.
Phosphate	Principle component of phosphate fertilizer; usually in the form of ammonium phosphate, potassium phosphate, or calcium phosphate. Plants take up and use phosphate ions ($H_2PO_4^-$ or $HPO_4^{=}$) for ATP, DNA, photosynthesis, respiration, and other metabolic functions. Phosphate does not have fungicidal properties.

Eficácia de Fosetil e outros fosfonados contra *Pythium*

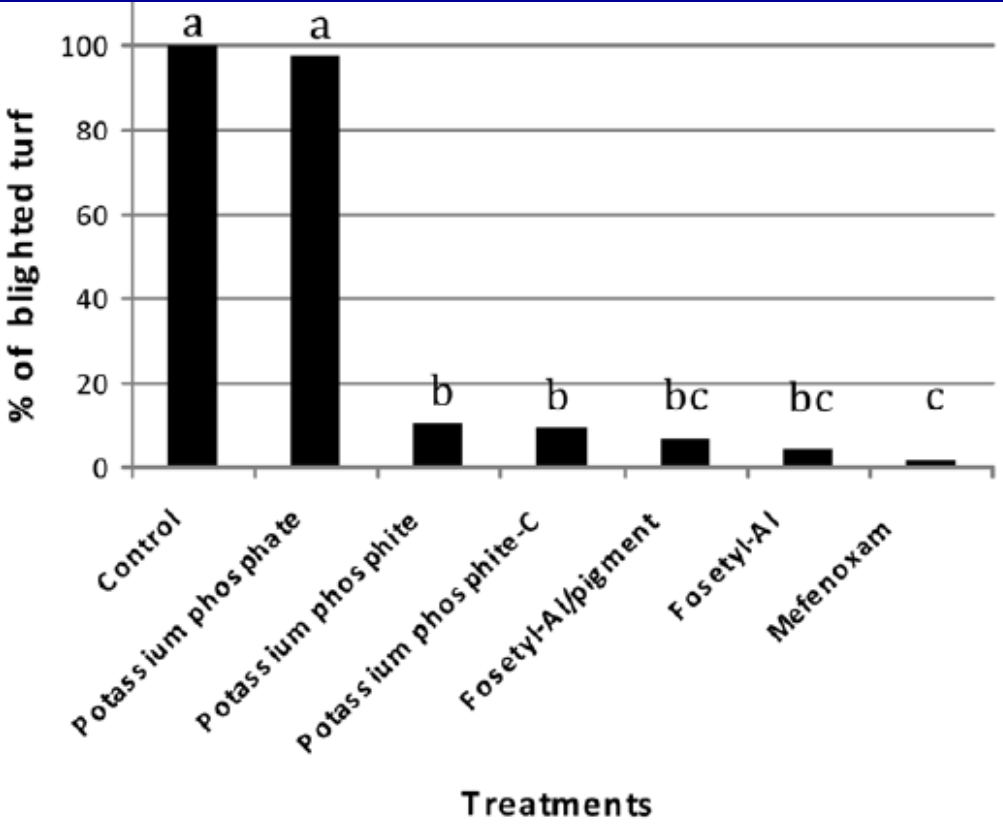


Fig. 2. Effect of phosphonate fungicides on Pythium blight development on perennial ryegrass cv. Integra in 2004, expressed as percentage of blighted turf. Potassium phosphite-C is a commercial formulation of potassium phosphite (Alude), fosetyl-Al is a commercial formulation fosetyl-Al (Aliette), and fosetyl-Al/pigment is a commercial formuation of fosetyl-Al and a propietary blue-green pigment (Chipco Signature). Bars with the same letter are not significantly different at $P = 0.05$.

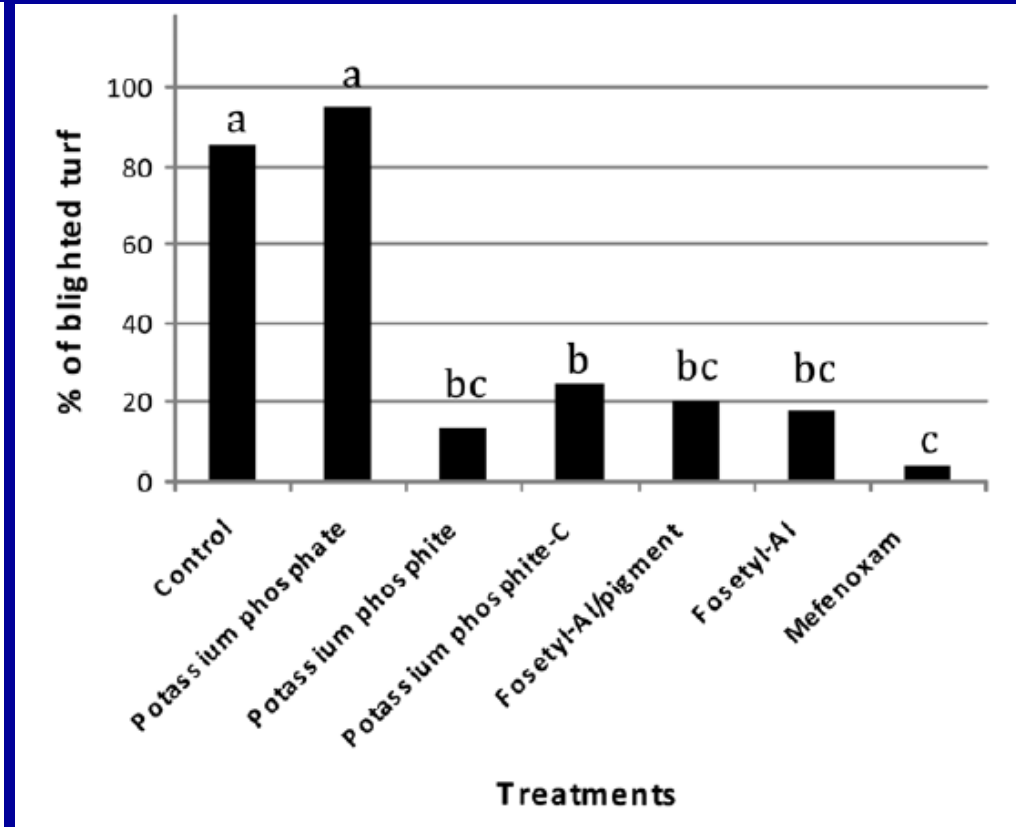


Fig. 3. Effect of phosphonate fungicides on Pythium blight development of creeping bentgrass cv. Penncross in 2005, expressed as percentage of blighted turf. Potassium phosphite-C is a commercial formulation of potassium phosphite (Alude), fosetyl-Al is a commercial formulation fosetyl-Al (Aliette), and fosetyl-Al/pigment is a commercial formuation of fosetyl-Al and a propietary blue-green pigment (Chipco Signature). Bars with the same letter are not significantly different at $P = 0.05$.

Cook et al. Plant Disease. 2009.

Fosetil e ácido fosforoso *in vivo*

TABLE 1. Control of *Phytophthora cinnamomi* root rot of seedlings of *Persea indica* in the greenhouse with fosetyl-Al and H_3PO_3[x]

Treatment[y]	Root dry weight (g)	Shoot dry weight (g)	Shoot growth (cm)	Percent healthy roots[z]
Noninfested steamed soil + H_2O	2.81 a	7.81 a	16.7 ab	92.4 a
Infested soil + H_2O	0.17 b	3.02 b	1.4 c	0.0 b
Infested soil + fosetyl-Al-foliar	2.09 a	6.13 a	16.5 ab	81.8 a
Infested soil + fosetyl-Al-soil	1.53 ab	6.31 a	16.1 ab	84.2 a
Infested soil + H_3PO_3-foliar	2.31 a	6.92 a	19.9 a	84.6 a
Infested soil + H_3PO_3-soil	2.31 a	7.42 a	10.9 b	84.4 a

[x]Values at 6 wk after planting are the means of five replicates. Values with the same letter are not significantly different according to Duncan's multiple range test, $P = 0.05$.

[y]Soil drenches were applied 1 and 7 days after transplanting 9-wk-old seedlings into soil naturally infested with *P. cinnamomi*. Foliar sprays were applied 1, 7, and 8 days after transplanting. Concentrations of the chemicals used were 1.5 g a.i. of fosetyl-Al and 1.0 g H_3PO_3 per liter, which are 12.7 PO_3 meq/L concentrations.

[z]Based on visual observation of roots rinsed free of soil.

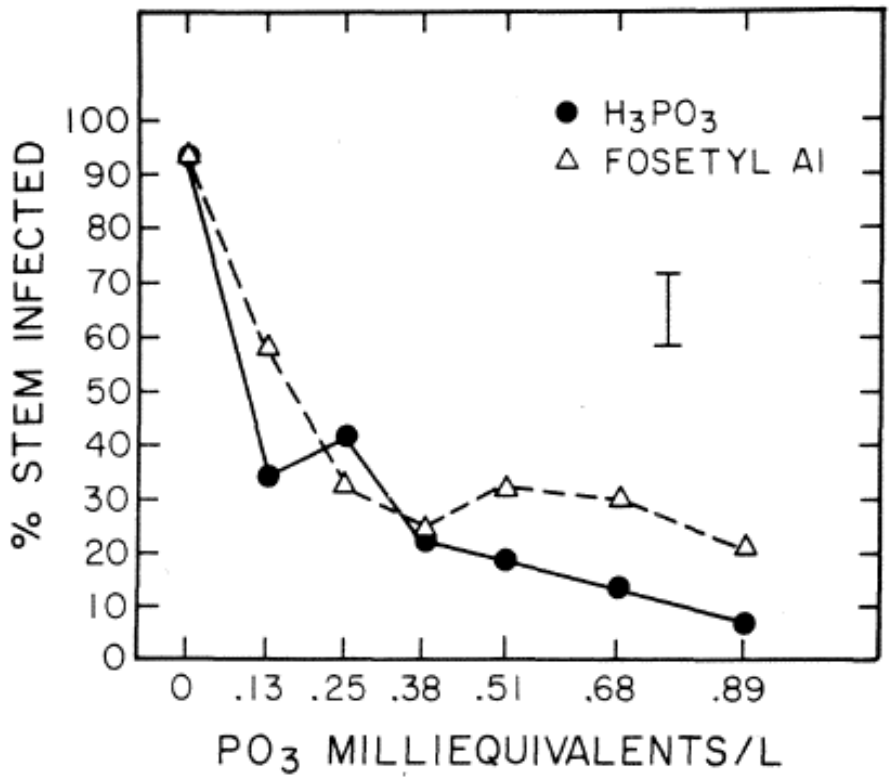
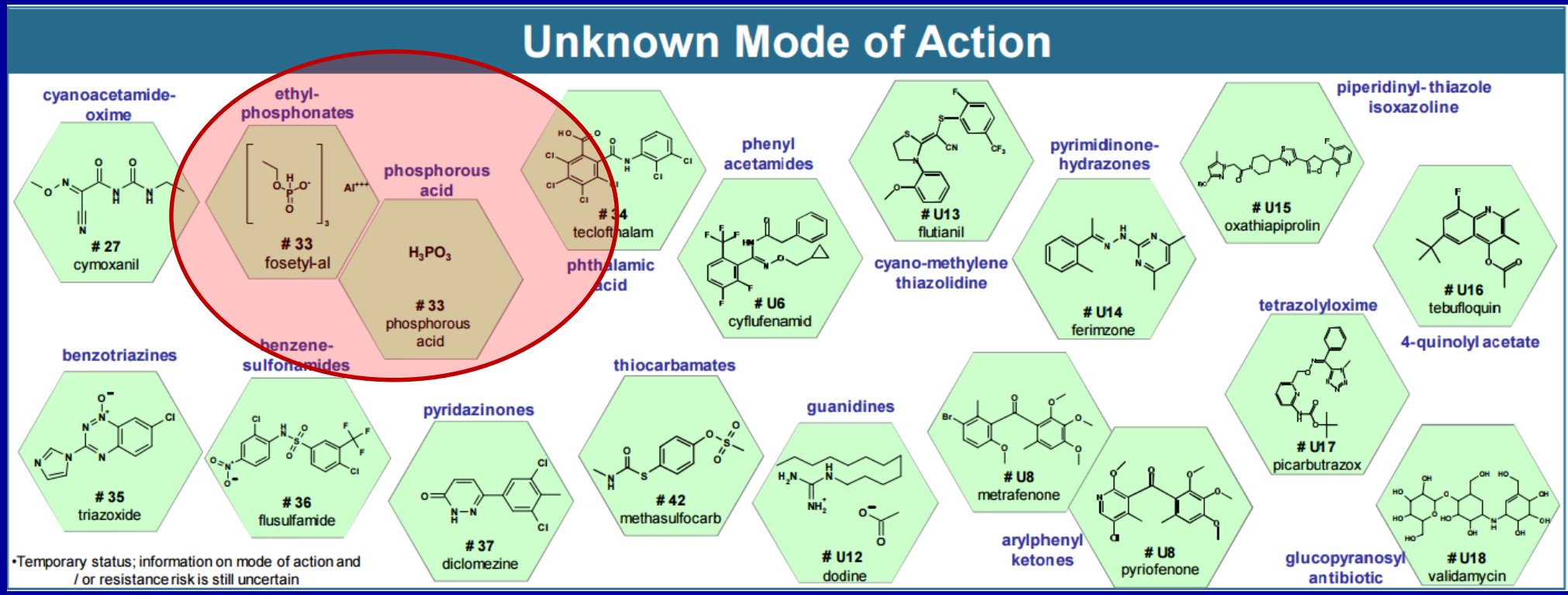


Fig. 1. Percentage of stems of *Persea indica* infected by *Phytophthora citricola*, isolate P1273, as a function of the PO_3 meq concentration of H_3PO_3 or fosetyl-Al. Seedlings were immersed in either H_3PO_3 or fosetyl-Al 27 hr after inoculation with 2×10^4 zoospores per plant. Vertical bar represents LSD ($P = 0.05$).

Modo de ação – indefinido

Fenn & Coffey Phytopathology 1984 (74):606-611



Resistência – pouco importante no campo

Bremia lactucae	Downy mildew	lettuce	Brown *et al.* 2004	field
Phytophthora citrophthora	Collar rot / foot rots		Angeles Diaz Borras & Vila Aguila 1988	*in -vitro*
Plasmopara viticola	Downy mildew	Grape vine	Khilare *et al.* 2003	field
Pythium aphanidermatum		Not specified	Sanders *et al.* 1990	*in-vitro* mutation

INIBIDORES DA BIOSÍNTESE DE ESTERÓIS (EBI)

Esteróis – componentes da membrana celular de eucariotos

Ergosterol – 95% do conteúdo de esteróis da membrana de fungos
esteróis 22% do total de lipídeos

Exceções { Oidium
Oomicetos – fucosterol ou síntese de outros lipídeos

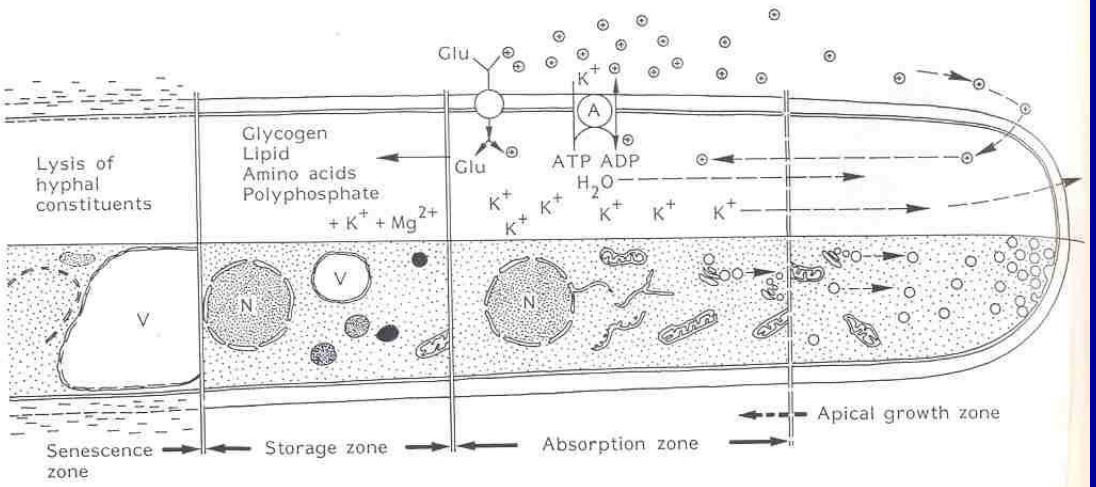
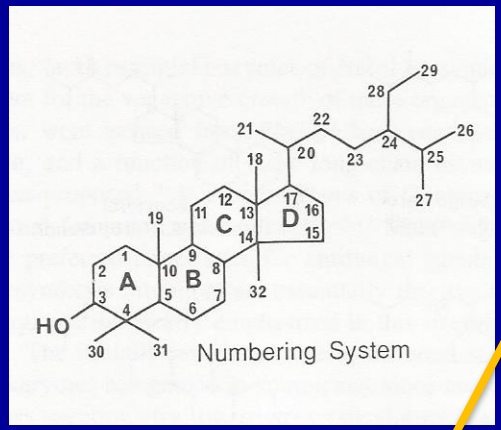
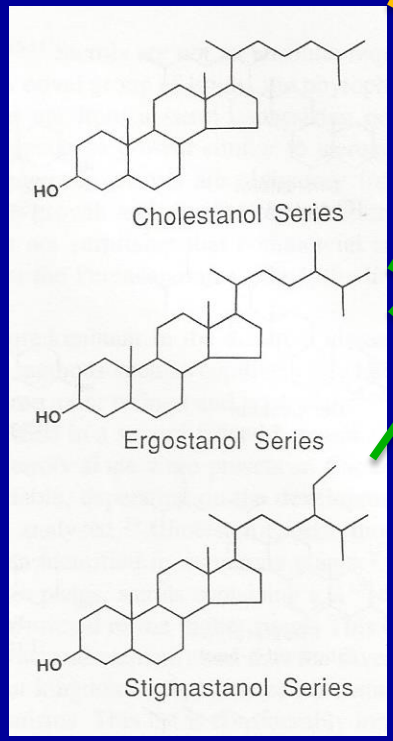


Figure 1.3: The main ultrastructural features (lower half) and main processes and storage compounds in the storage zone (upper half) within the principal zones of a growing hypha. A, ATPase; Glu, glucose; N, nucleus; V, vacuole; →, active solute movement; ⇢, solute movement by diffusion or through water flow; ⊕ hydrogen ions/protons. The other organelles, endoplasmic reticulum, dictyosomes, mitochondria and vesicles, have not been labelled but are readily recognized.

NOMENCLATURA DE ESTEROIS



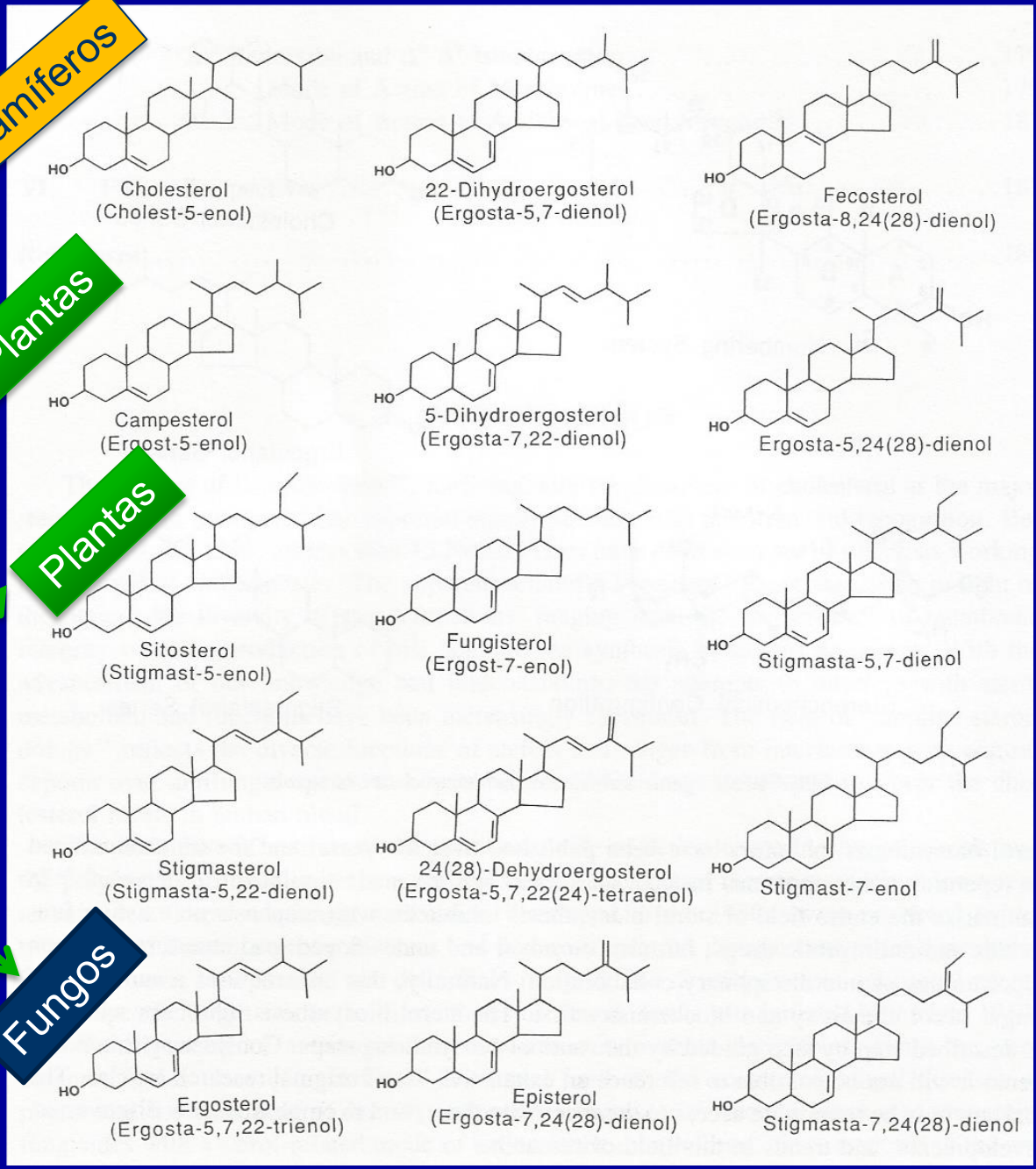


Mamíferos

Plantas

Plantas

Fungos



Nome comum *ergosterol* - proposto em 1889 para esterol isolado de escleródios de Clavicsps purpurea (ergot)

INIBIDORES DA BIOSÍNTESE DE ESTERÓIS (EBI)

1967 Basf – derivados de morfolinas

Bayer – imidazóis

Eli Lilly – pirimidinas

1968 Boehringer – piperazinas

Bayer – triazóis

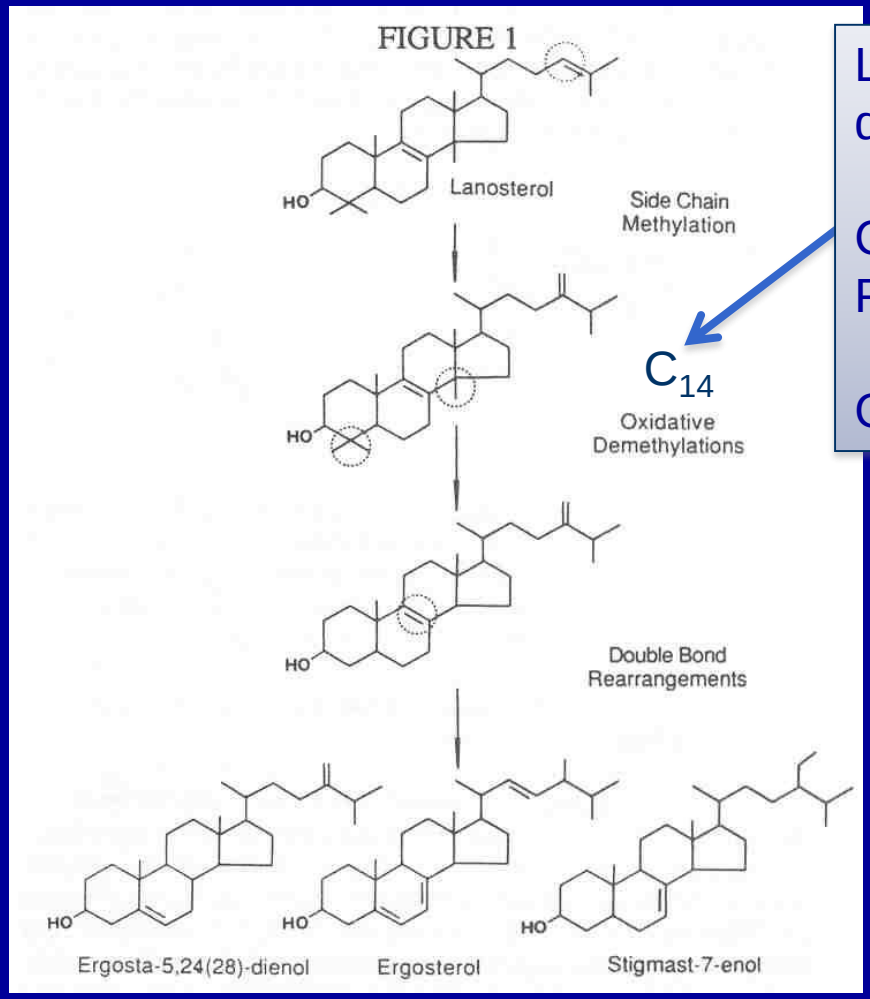
1970 Sumimoto - piridinas

Inibidores da biossíntese do ergosterol – inibição da demetilação no lanosterol (14)

DMI

Grupos mais importantes

INIBIDORES DA BIOSÍNTESE DE ESTERÓIS (EBI)



Lanosterol α-demetilase

Citocromo P450 (CYP)

Gene *CYP51*

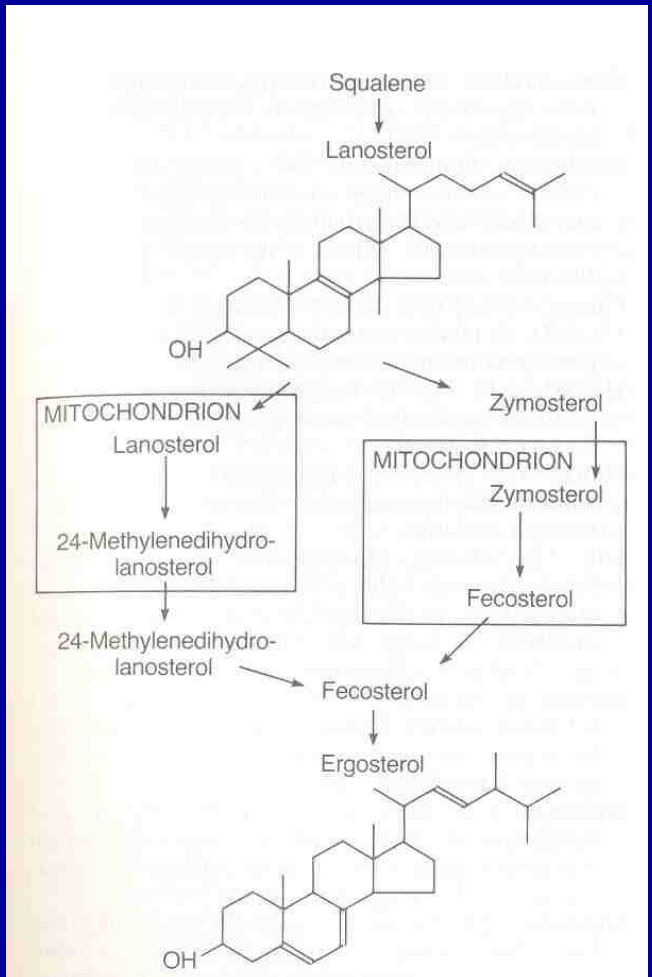


Figure 4.5 Biosynthesis of ergosterol in fungi. In most fungi (LHS) lanosterol is 24-methylated in the mitochondrion; in *S.cerevisiae* (RHS) it is zymosterol that is 24-methylated, to give fecosterol.

Mode of Action of Fungicides

FRAC classification on mode of action 2016 (www.frac.info)

A: Nucleic Acid Synthesis

A1: RNA polymerase I

A2: adenosin-deaminase

A3: DNA / RNA synthesis (prop.)

A4: DNA topoisomerase type II (gyrase)

B: Cytoskeleton and motor proteins

B1: ▶ ß-tubulin assembly in mitosis

B2: ▶ ß-tubulin assembly in mitosis

B3: ▷ß-tubulin assembly in mitosis

B4: cell division (prop.)

B5: delocalisation of spectrin-like proteins

B6: actin/myosin/ fimbrin function e.g. in vesicle trafficking

C: Respiration

C2: inhibition of complex II: succinate-dehydrogenase

C: Respiration

C1: inhibition of complex I NADH Oxido-reductase

C4: inhibition of complex III ▸ cytochrome bc1(ubiquinone reductase) at Qi site

C3: inhibition of complex III cytochrome bc1 (ubiquinol oxidase) at Qo site (*cyt b gene*)

C8: inhibition of complex III

C7: ATP production (prop.)

C6: inhibitors of oxidative phosphorylation, ATP synthase

C5: uncouplers of oxidative phosphorylation

D: Amino Acid and Protein Synthesis

D1: methionine biosynthesis (*cgs gene*) (prop.)

D2: protein synthesis

D3: protein synthesis

D4: protein synthesis

D5: protein synthesis

E: Signal Transduction

E1: Signal transduction (mechanism unknown)

E2: Osmotic signal transduction ▶MAP / histidine- kinase (os-1, Daf1)

E3: Osmotic signal transduction ▶MAP / histidine kinase (os-1, Daf1)

F: Lipid Synthesis and Membrane Integrity

F2: phospholipid biosynthesis ▶ methyltransferase

F3: lipid peroxidation (prop.)

F4: cell membrane permeability, fatty acids (prop.)

F6: microbial disrupters of pathogen cell membranes

F7: cell membrane disruption (prop.)

I: Melanin Synthesis in Cell Wall

I1: reductase in melanin biosynthesis

I2: dehydratase in melanin biosynthesis

I3: polyketide synthase in melanin biosynthesis

G: Sterol Biosynthesis in membranes

G1: C14-demethylase in sterol biosynthesis (*erg11/cyp51*)

G2:Δ14-Reductase and Δ8→Δ7-isomerase in sterol biosynthesis (*erg2, erg 24*)

G3:3-Keto reductase in C4-de-methylation (*erg27*)

G4: Squalene epoxidase in sterol biosynthesis (*erg1*)

H:Cell Wall Biosynthesis

H4: chitin synthase

H5: cellulose synthase

P: Host Plant Defence Induction

P1: salicylic pathway

P2:

P3:

P4:

P5:

M: Multi Site Action

Unknown Mode of Action

NC : Not Classified

Legend:

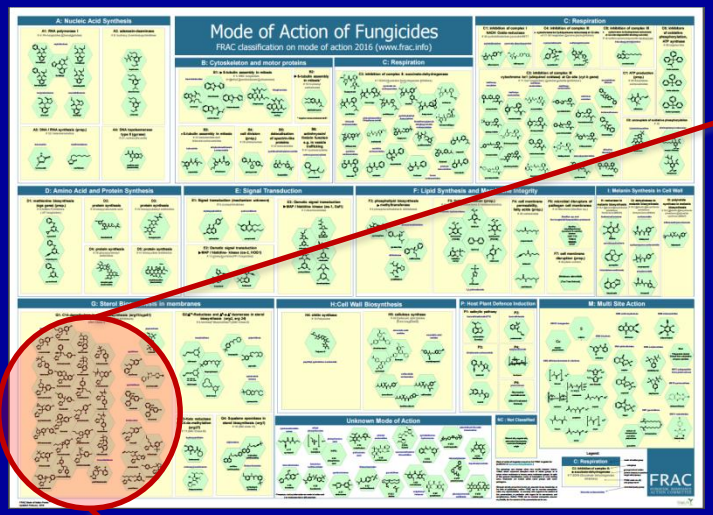
C: Respiration

C2: inhibition of complex II: ▶ succinate-dehydrogenase

7 SDHI (Succinate dehydrogenase inhibitors)

FRAC FUNGICIDE RESISTANCE ACTION COMMITTEE

FRAC Mode of Action Poster ©
Updated February 2016



SISTEMICIDADE ACROPÉTALA

Radioactivity concentration

High ***Low***

G1: C14-demethylase in sterol biosynthesis *(erg11/cyp51)*

3 DMI-fungicides (DeMethylation Inhibitors)

(SBI: Class I)

triazoles

etaconazole
azaconazole
ipconazole
fenbuconazole
tebuconazole
bitertanol
metconazole
fluquinconazole
tetraconazole
bromuconazole
myclobutanil
flusilazole
triadimefon
cyproconazole
penconazole
flutriafol
triadimenol
difenoconazole
propiconazole
hexaconazole
triticonazole
diniconazole
simeconazole
imibenconazole
epoxiconazole

triazolinthione

prothioconazole

piperazines

triforine

pyridines

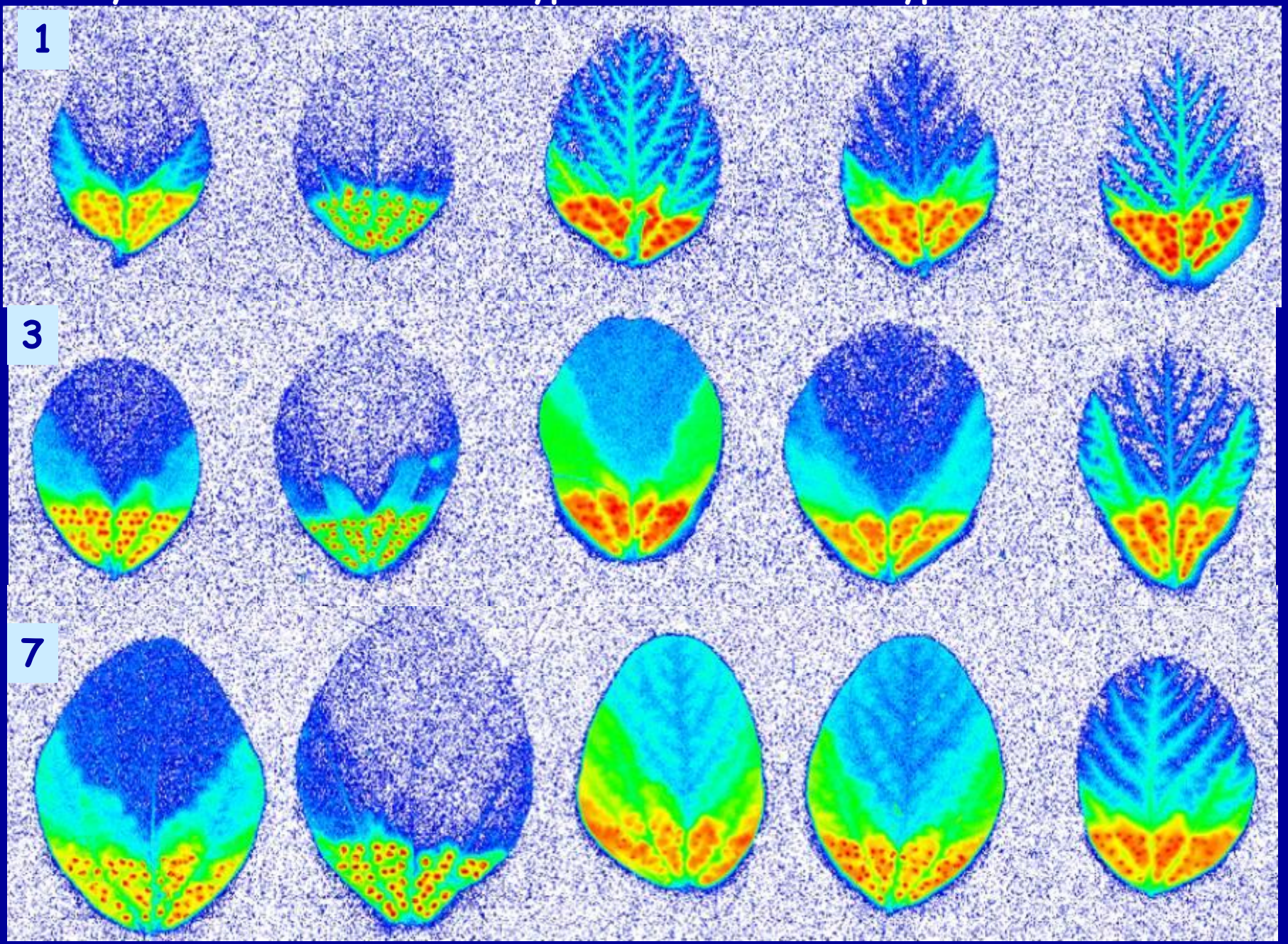
pyrifenox
pyrisoxazole

pyrimidines

nuarimol
fenarimol

imidazoles

imazalil
triflumizole
pefurazoate
oxpoconazole
prochloraz


Azoxystrobin
Other strobi
Cyproconazole
Azo+Cypro
Other triazole
1
3
7

INIBIDORES DA BIOSÍNTESE DE ESTERÓIS (EBI)

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Quantitative review of fungicide efficacy trials for managing soybean rust in Brazil

H. Scherm [a,*], R.S.C. Christiano [a], P.D. Esker [b], E.M. Del Ponte [c], C.V. Godoy [d]

71 ensaios uniformes de 2003 a 2007



Table 2
Median values of weighted response ratios for soybean rust severity (R_S) and yield (R_Y) for different active ingredients, based on a synthesis of 71 fungicide efficacy trials conducted in Brazil from 2003/2004 to 2006/2007.

Active ingredient and typical rate (g ha^{-1})	n[a]	R_S[b]	R_Y[c]
Single compounds			
Azoxystrobin (50)	23	0.568	1.366
Cyproconazole (30 or 40)	29	0.514	1.624
Difenoconazole (50)	26	0.738	1.169
Epoxiconazole (50)	60	0.559	1.298
Fluquinconazole (62.5)	21	0.809	1.185
Flutriafol (62.5)	24	0.510	1.430
Metconazole (54)	17	0.526	1.467
Myclobutanil (100)	23	0.427	1.242
Picoxystrobin (60)	18	0.465	1.425
Propiconazole (125)	17	0.559	1.307
Prothioconazole (75 or 100)	30	0.325	1.598
Tebuconazole (100)	141	0.379	1.629
Tetraconazole (50)	61	0.462	1.377
Combinations			
Azoxystrobin + cyproconazole (60 + 24)	37	0.241	1.586
Cyproconazole + propiconazole (24 + 75)	42	0.374	1.466
Flusilazole + carbendazim (100 + 50 or 75 + 150)	22	0.147	1.361
Flutriafol + carbendazim (50 + 300)	20	0.432	1.528
Flutriafol + thiophanate-methyl (60 + 300)	51	0.433	1.419
Pyraclostrobin + epoxiconazole (66.5 + 25)	31	0.388	1.563
Trifloxystrobin + cyproconazole (56.2 + 24)	36	0.346	1.653
Trifloxystrobin + propiconazole (50 + 50)	24	0.525	1.418
Trifloxystrobin + tebuconazole (50 + 100)	33	0.327	1.569

[a] Only products applied in at least 15 entries are included.
[b] R_S is defined as the disease severity of a given fungicide treatment divided by the disease severity of the corresponding untreated check. The smaller R_S, the better the control efficacy.
[c] R_Y is defined as the yield of a given fungicide treatment divided by the yield of the corresponding untreated check. The greater R_Y, the better the yield response.

RESISTÊNCIA AOS EBIS

1º CASO – OIDIO EM PEPINO APÓS 2 ANOS - ISRAEL E ESPANHA (1980)
OIDIO EM CEREAIS (1984)

Aspergillus nidulans	-	-	De Waard & van Nistelrooy 1979	genetic study
Blumeriella jaapii	Leaf spot	Cherry	Proffer *et al.* 2006	field
Botrytis cinerea	Grey mold	Vegetables Various	Elad 1992 Stehmann & De Waard 1996	field laboratory investigation of lack of intrinsic activity
Cercospora beticola	Leaf spot	Sugar beet	Henry & Trivellas 1989 Karaoglanidis *et al.*	Laboratory mutants Field isolates
Cladosporium caryigenum	Scab	Pecan	Reynolds *et al.* 1997	cross resistance, laboratory
Colletotrichum gloeosporioides	Anthracnose	Mango	Gutierrez-Alonso *et al.* 2003	postharvest / laboratory
Erysiphe graminis f .sp. *hordei*	Powdery mildew	Barley	Fletcher & Wolfe 1981	field
Erysiphe graminis f .sp. *tritici*	Powdery mildew	Wheat	De Waard *et al.* 1986	field
Fusarium solani. See *Nectria haematococca* var. *cucurbiae*	Cucurbits	Foot rot	Kalamarakis *et al.* 1991	genetic study
Microdochium (Fusarium) nivale	-	-	Cristani & Gambogi 1993	Laboratory

	Pyrenphora teres	Net blotch	Barley	Sheridan *et al.* 1985	field
	Pyrenophora tritici-repentis	Tan spot	Wheat	Reimann & Deising 2005	field
	Rhynchosporium secalis	Leaf blotch, scald	Barley	Hunter *et al.* 1986 Kendall & Hollomon 1990 Kendall *et al.* 1993 Cooke *et al.* 2004	Glasshouse field Field isolates field
	Sclerotinia homoeocarpa	-	-	Vargas *et al.* 1992	laboratory
	Septoria tritici				See *Mycosphaerella graminicola*
	Sphaerotheca fuligenea	Powdery mildew	Cucumber	Schepers 1983, 1985a, 1985b	field
	Sphaerotheca mors-uvae	Powdery mildew	Blackcurrant	Goszczynski *et al.* 1988	field
	Sphaerotheca pannosa	Powdery mildew	Nectarine	Reuveni 2001	field
	Trichoderma koningii	-	-	Figueras-Roca *et al.* 1996	Laboratory
	Uncinula necator	Powdery mildew	Grapevine	Steva *et al.* 1990 Reidi & Steinkellner 1996 Miller & Gubler 2003	field field field
	Ustilago avenae	Loose smut	Oats	Hippe & Koller 1986	laboratory
	Ustilago maydis	Smut / blister smut	Maize	Walsh & Sisler 1981	laboratory
	Venturia inaequalis	Scab	Apple	Stanis & Jones 1985; Köller *et al.* 1991	field laboratory
	Venturia nashicola	Japanese pear scab	Pear	Tomita & Ishii 1998	field

RESISTÊNCIA AOS EBIS

Maioria poligênica, facilmente obtida em laboratório, pouco detectada em campo

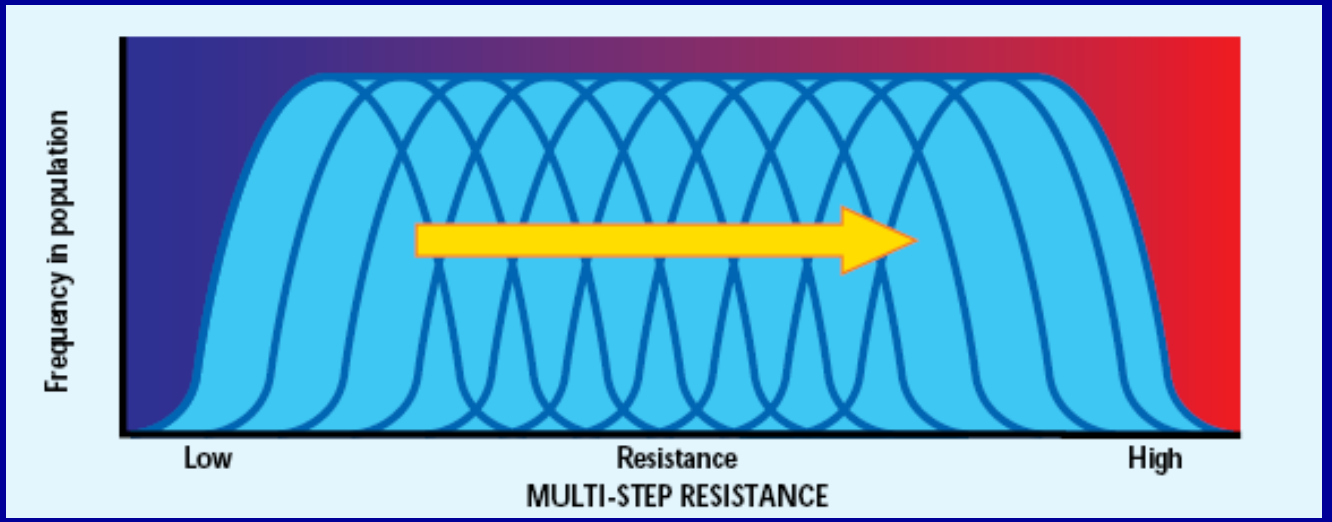


TABLE 1

Expression of Mutations for Resistance to Sterol Biosynthesis Inhibitors in N. haematococca var. cucurbitae

Strain designation	Locus mutated	Resistance factor[a]				
		Fenarimol	Triforine	Imazalil	Triadimenol	Fenpropimoph (morfolina)
FN-393	*fen*-1	3.2	3.0	2.0	6.0	1.0
FN-425	*fen*-2	2.4	2.5	2.0	5.2	1.0
FN-310	*fen*-3	3.0	2.5	3.3	6.0	1.0
FN-430	*fen*-4	2.0	2.0	3.3	5.3	1.0
FN-341	*fen*-5	2.4	3.5	4.0	8.0	1.0
FN-46	*fen*-6	2.0	2.5	2.0	5.1	1.0
FN-377	*fen*-7	2.0	2.5	2.0	5.2	1.0
FN-378	*fen*-8	4.0	3.0	3.3	6.0	1.0

PESTIC. BIOCHEM. AND PHYSIOL. 4, 212-220 (1991)

[a] relação entre a concentração inibitória do fungicida para o mutante e a concentração inibitória para o tipo selvagem

RESISTÊNCIA AOS EBIS

Maioria poligênica com efeitos secundários prejudiciais

TABLE 3

Comparison of Fenarimol-Resistant Mutants of N. haematococca var. cucurbitae to Their Respective Wild-Types No. 38 and No. 49 with Regard to Some Saprophytic Fitness Parameters on Agar Medium

Strain	Mutated locus	MIC of fenarimol	Radial growth[a]	Sporulation[b]	Spore germination[c]	Germ tube elongation[d]
No. 38	wt	2.5	24	9.44	99	18.0
No. 49	wt	2.5	24	9.44		
FN-393	*fen*-1	7.0	21	8.30	80	8.2
FN-37	*fen*-2	5.0	11	6.04		
FN-46	*fen*-2	5.0	11	7.17		
FN-427	*fen*-2	6.0	13	7.17	68	7.2
FN-310	*fen*-3	7.5	16	8.30	83	5.9
FN-314	*fen*-3	7.5	14	6.79		
FN-368	*fen*-3	7.5	11	5.28		
FN-380	*fen*-3	5.0	19	7.55		
FN-352	*fen*-4	5.0	20	7.55		
FN-430	*fen*-4	5.0	20	7.55		
FN-341	*fen*-5	6.0	15	7.05		
FN-377	*fen*-7	5.5	14	7.23	77	5.8
FN-378	*fen*-8	10.0	8	6.35		
FN-376	*fen*-7, *fen*-8	15.5	7	4.91		

[a] Mean colony diameter (mm) measured after 4 days of incubation at 25°C ($n = 4$).
[b] Mean number ($\times 10^3$) of conidia per mm^2 of colony after 4 days of incubation ($n = 4$).
[c] Proportion of germinated conidia after 13 hr of incubation ($n = 100$).
[d] Mean length (μm) of germ tube after 13 hr of incubation ($n = 84$).

MIC – minimum inhibitory concentration

PESTIC. BIOCHEM. AND PHYSIOL. 4, 212-220 (1991)

RESISTÊNCIA AOS EBIS

Mecanismos

- **Efluxo do fungicida (dependente de energia)**
- Efluxo do fungicida e acúmulo em vacúolos
- Afinidade da parede ao fungicida (redução no in
- Detoxificação
- Mutação ou superexpressão de *CYP*

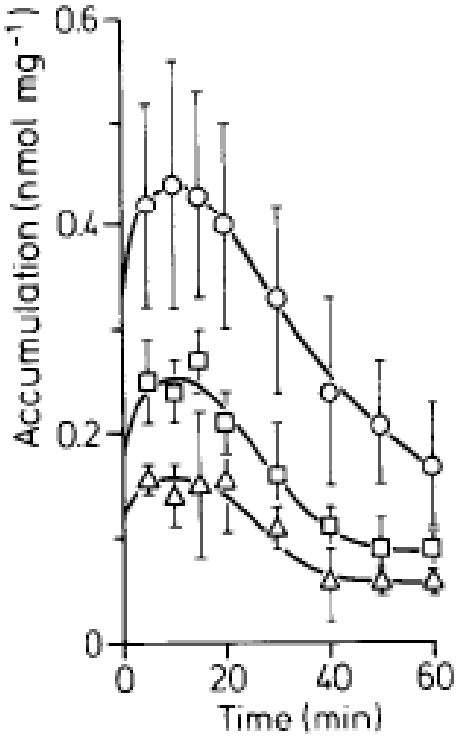


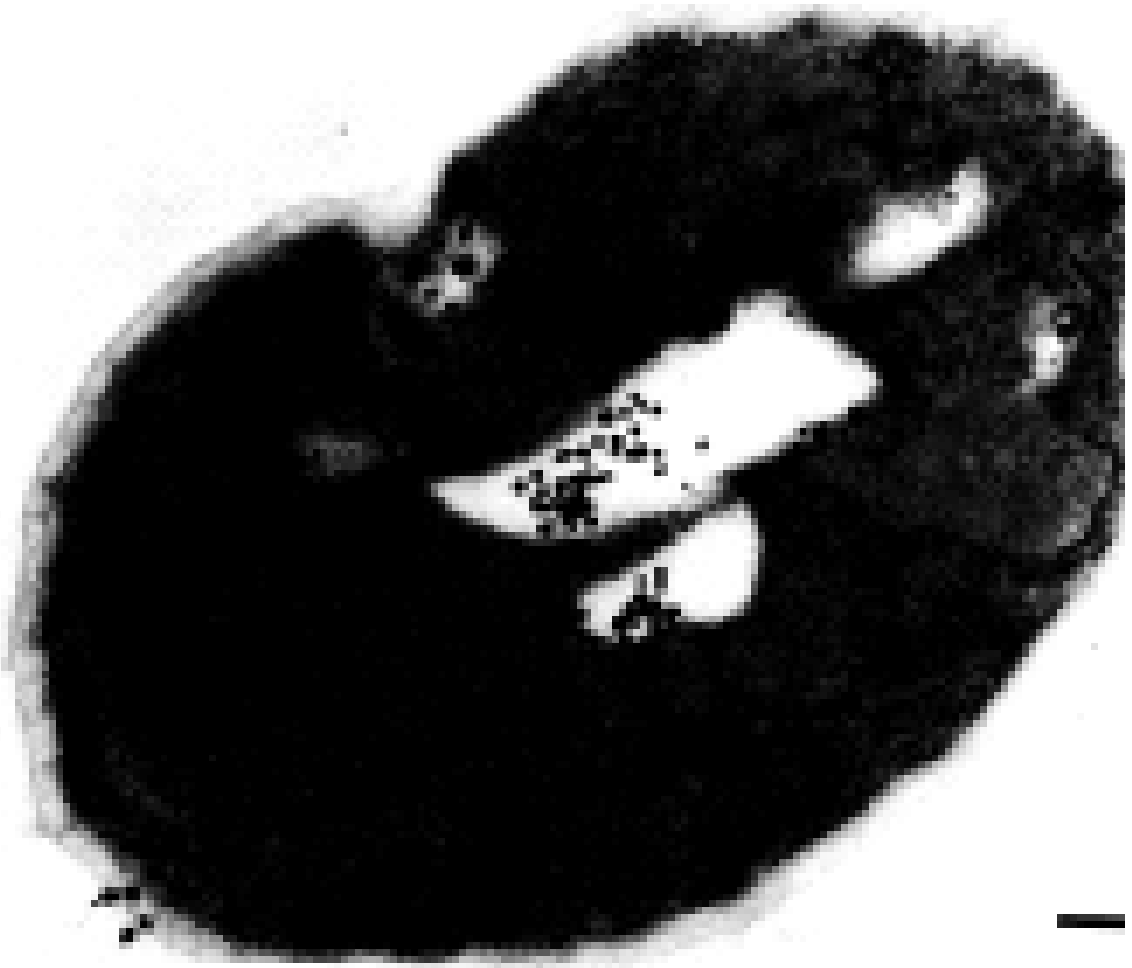
FIG. 3. *Accumulation of [^{14}C]fenarimol (10 μM) by mycelium of wild-type strain No. 38 (○) and fenarimol-resistant isolates FN-377 (□) and FN-76 (△) of N. haematococca var. cucurbitae.*

Pestic. Biochem. Physiol. 40:212-220. 1991

RESISTÊNCIA AOS EBIS

Mecanismos

- Efluxo do fungicida (dependente de energia)
- **Efluxo do fungicida e acúmulo em vacúolos**
- Afinidade da parede ao fungicida (redução no ingresso)
- Detoxificação
- Mutação ou superexpressão de *CYP*



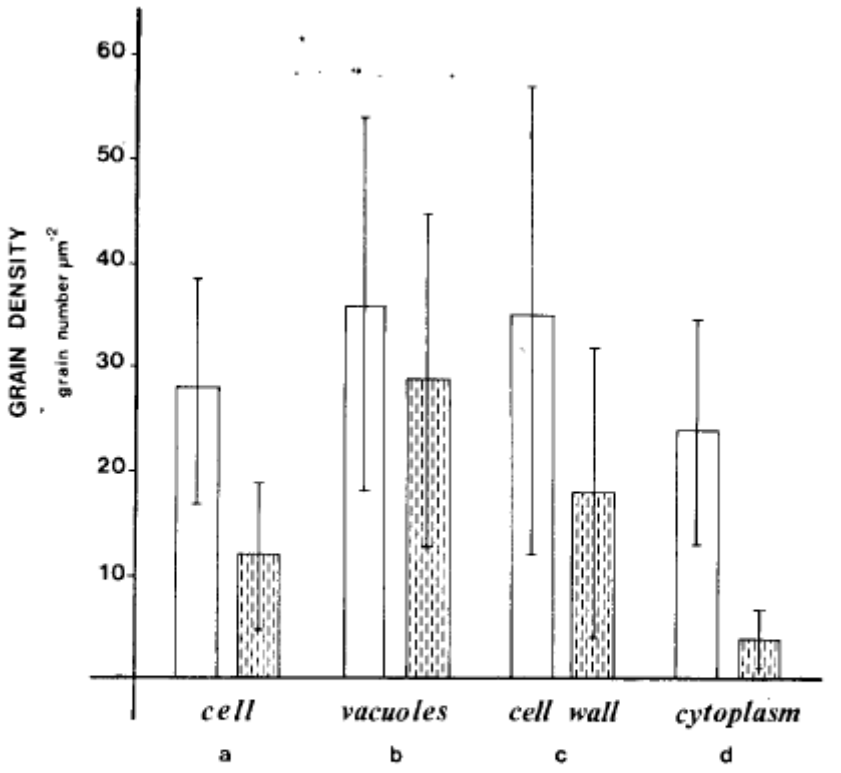


Fig. 7. Relative silver grain density (grain number μm^{-2}) over cross sectioned sporidia of *Ustilago aveane* (*a*), over the vacuoles (*b*), the cell walls (*c*) and the cytoplasm (*d*). Triadimenol sensitive sporidia (*open columns*) are compared with a fungicide resistant strain (*hatched columns*). The standard deviations are marked as ruled lines

Acúmulo de triadimenol marcado nos vacúolos de esporídios de *Ustilago avenae* (Hippe, 1987)

RESISTÊNCIA AOS EBIS

Mecanismos

- Efluxo do fungicida (dependente de energia)
- Efluxo do fungicida e acúmulo em vacúolos
- **Afinidade da parede ao fungicida (redução no ingresso)**
- Detoxificação
- Mutação ou superexpressão de *CYP*

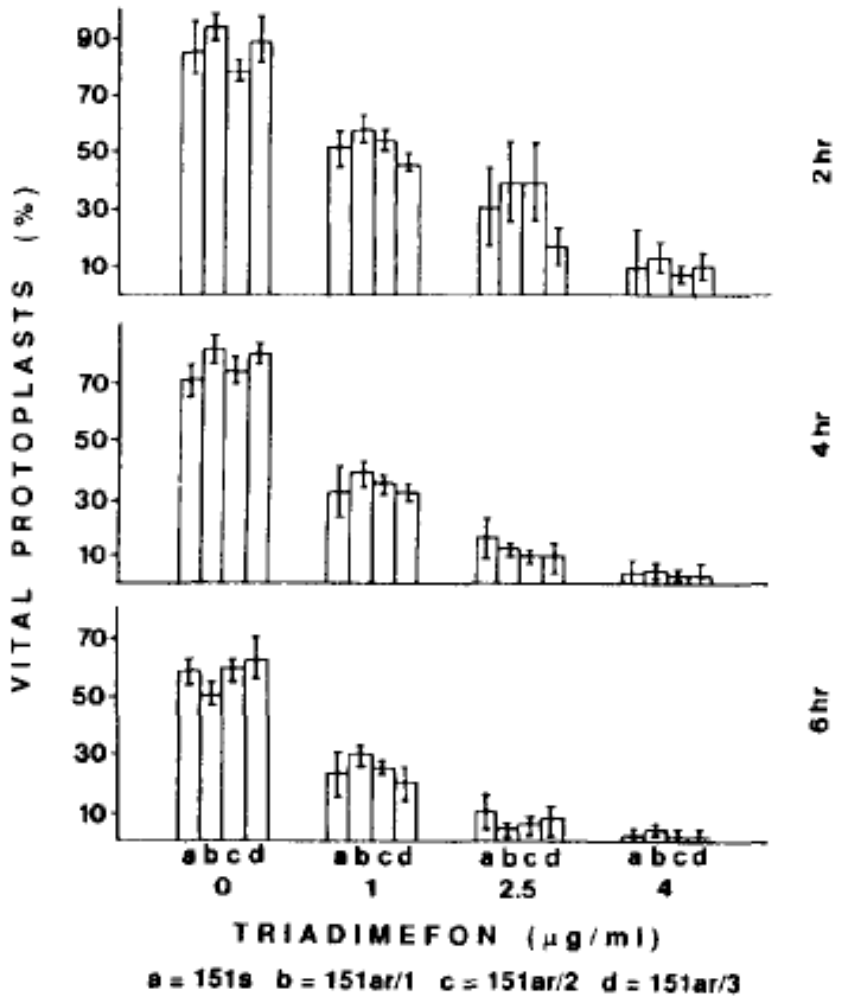


FIG. 1. *Vitality of protoplasts from sensitive (151s) and resistant (151ar/1, 151ar/2, 151ar/3) U. maydis strains after 2, 4, and 6 hr of regeneration in liquid culture at different triadimefon concentrations. Mean values and standard deviation (n = 3).*

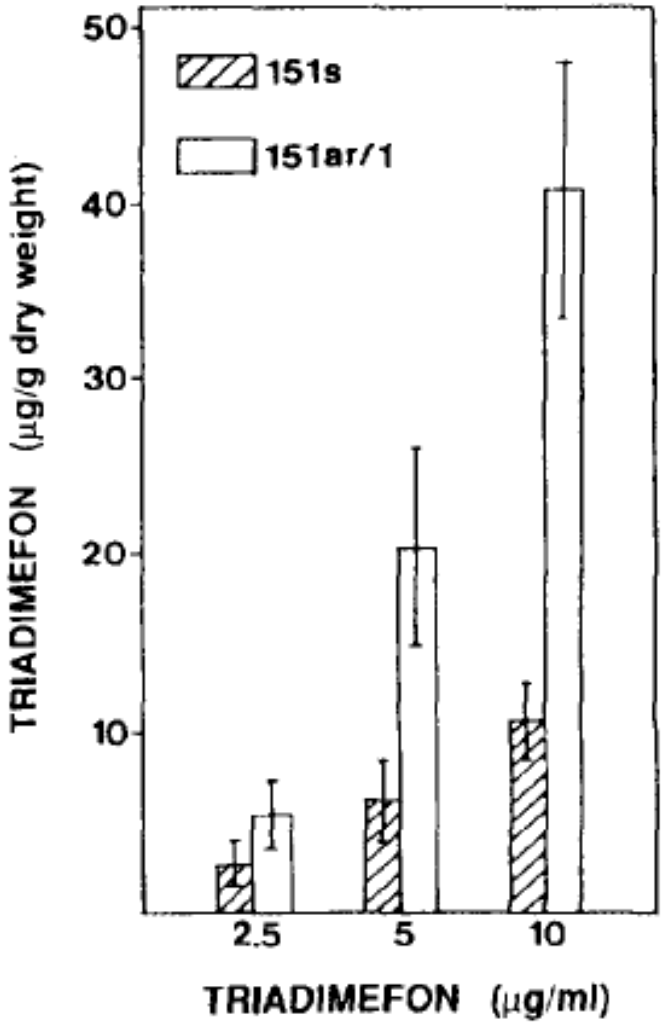


FIG. 2. *Triadimefon content of sporidia of a sensitive (151s) and a resistant U. maydis strain (151ar/1) after 4 hr of incubation at different fungicide concentrations. Sporidial age 12 hr. Mean values and standard deviation (n = 3).*

RESISTÊNCIA AOS EBIS

Mecanismos

- Efluxo do fungicida (dependente de energia)
- Efluxo do fungicida e acúmulo em vacúolos
- **Afinidade da parede ao fungicida (redução no ingresso)**
- Detoxificação
- **Mutação ou superexpressão de *CYP***

Resistência de *Monilinia fructicola* a DMI por superexpressão de *CYP*

Expressão do gene Mf*CYP51* avaliada por mRNA

Isolate	Relative growth (%)[a]	Propiconazole sensitivity phenotype[b]	MfCYP51			
			Untreated		Propiconazole treated	
			Mean	SD	Mean	SD
Bmpc7	29.7	R	11.2	0.0	10.8	1.4
Bmpc10	30.8	R	7.3	1.0	7.6	1.6
Bmpc13	29.5	R	10.1	0.8	9.5	1.4
GADL193	35.0	R	9.1	1.6	7.5	0.9
GAAP5	36.3	R	10.3	1.5	10.0	0.7
GAAP6	21.8	R	5.2	0.8	4.6	0.4
GAAP12	0	S	1.9	0.5	1.3	0.3
GADL3	0	S	3.4	0.2	1.9	0.4
SCDL72	3.1	S	1.2	0.1	1.8	0.3
SC99A3	5.0	S	2.3	1.0	1.8	0.0
SC99A4	1.3	S	1.0	0.1	1.6	0.5
Kac-18	0.4	S	1.0	0.2	0.9	0.4

- **No point mutations leading to an amino acid change were found in the Mf*CYP51* gene.**
- **Analysis of the upstream nucleotide sequence of the Mf*CYP51* gene revealed a unique 65-bp repetitive element at base pair position 117 in DMI-R isolates but not in DMI-S isolates. This repetitive element contained a putative promoter and was named Mona.**

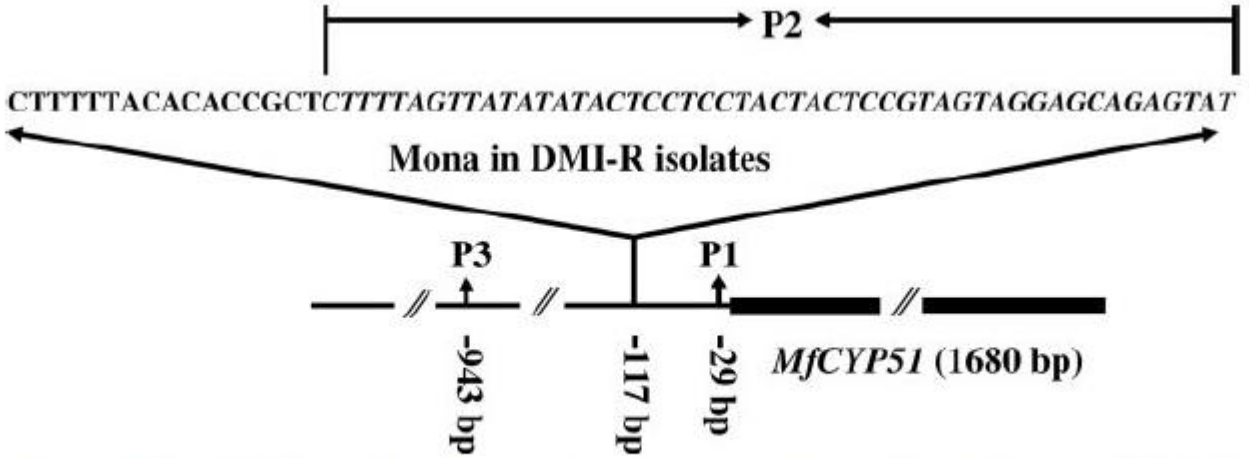


FIG. 2. Simplistic model of the upstream region of the Mf*CYP51* gene in *M. fructicola* isolates. P1, P2, and P3 indicate promoters 1, 2, and 3, respectively. A 65-bp repetitive element (Mona) was identified at bp −117 of the Mf*CYP51* gene in DMI-R isolates.

Espectro de ação de fungicidas

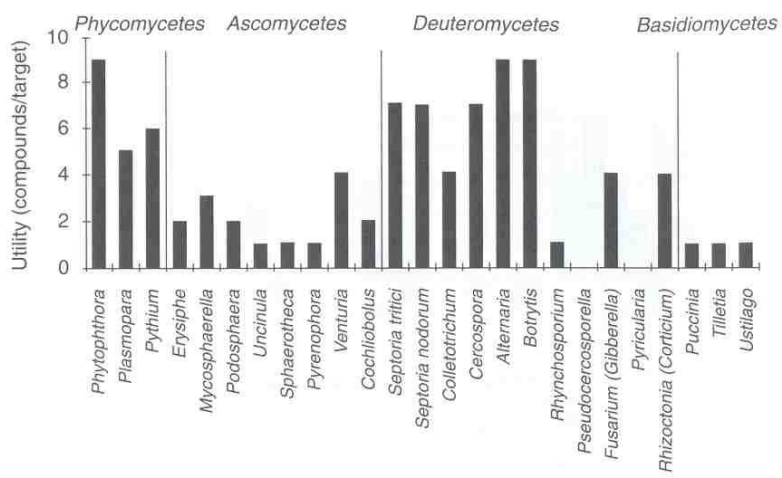


Fig. 4.2. Major use spectrum of general cell toxicants.

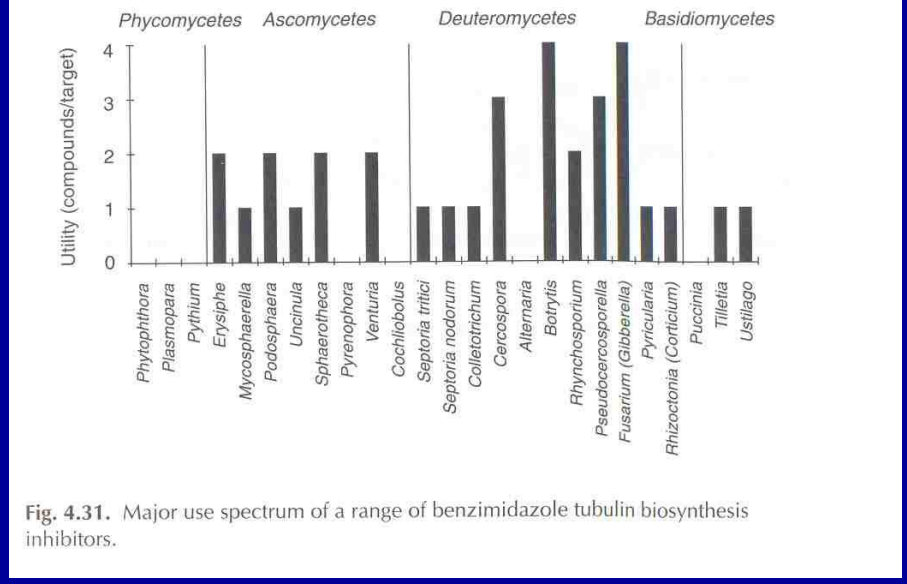


Fig. 4.31. Major use spectrum of a range of benzimidazole tubulin biosynthesis inhibitors.

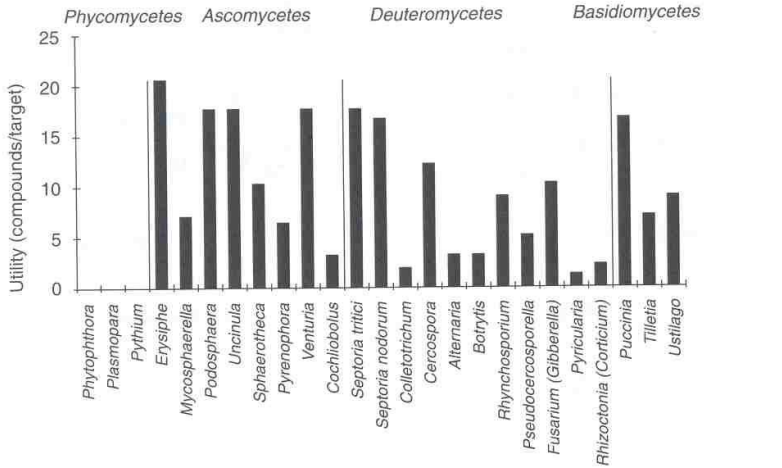


Fig. 4.14. Major use spectrum of a range of DMI fungicides.

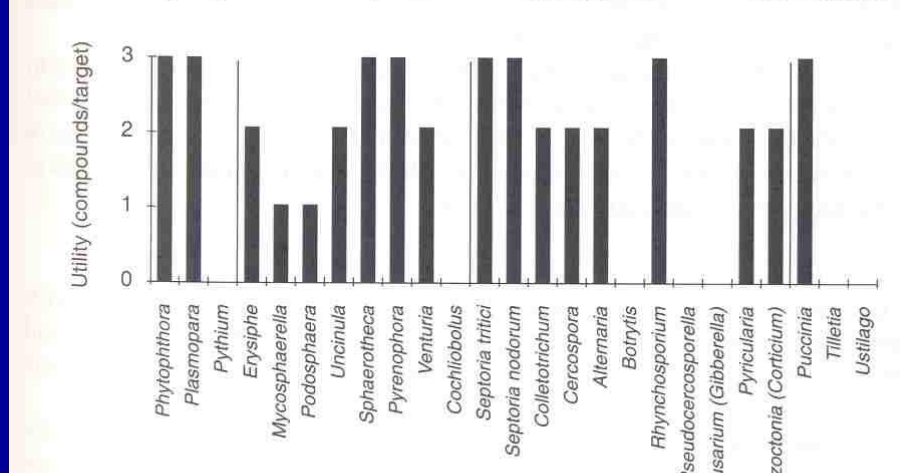


Fig. 4.48. Main use spectrum of inhibitors of complex III.

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