

# CONTROLE QUÍMICO DE DOENÇAS DE PLANTAS



Agrotóxicos  
ou  
Defensivos?



## AGROTÓXICOS

Registro de Agrotóxicos Fitossanitários – AGROFIT

[www.agricultura.gov.br](http://www.agricultura.gov.br)

**FUNGICIDAS** (princípio ativo = nome químico comum)  
**Produto comercial** (p.a. + inertes)

**Grupo químico** – nome dado a um grupo de fungicidas que compartilham o modo de ação ➡

**Nome químico** – nome do ingrediente ativo fornecido pelo sistema de nomenclatura internacional (International Union of Pure and Applied Chemistry – IUPAC) especificamente para compostos orgânicos ou pela Chemical American Society (CAS)

**CAS RN** – número de registro na CAS. Um único número de referência, diferenciando isômeros

**Nome comum** – nome proposto pelo fabricante para o ingrediente ativo, o qual deve ser ratificado pela IUPAC ou pela ACS

**Nome comum em português** – nome comum aportuguesado

**Nome comercial** – nome patentado sob o qual o produto é vendido



*Folicur* (Bayer)

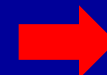
triazole

(RS)-1-p-chlorophenyl-4,4-dimethyl-3-(1H-1,2,4-triazol-1-ylmethyl)pentan-3-olthiabendazole

107534-96-3

tebuconazole

tebucoinazol

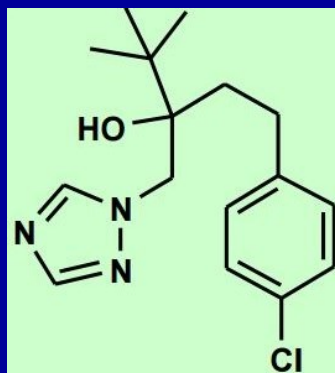


# COMPOSTOS HETEROCÍCLICOS

Presença de  
dupla ligação

| Hetero atom | Prefix   |
|-------------|----------|
| O           | Oxa-     |
| N           | Aza-     |
| S           | Thia-    |
| P           | Phospha- |

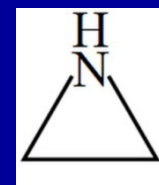
| Ring size | Fully unsaturated compounds |           | Fully saturated compounds |           |
|-----------|-----------------------------|-----------|---------------------------|-----------|
|           | With N                      | Without N | With N                    | Without N |
| 3         | -irine                      | -irene    | -iridine                  | -irane    |
| 4         | -ete                        | -ete      | -etidine                  | -etane    |
| 5         | -ole                        | -ole      | -otodine                  | -olane    |
| 6         | -ine                        | -in       |                           | -ane      |
| 7         | -epine                      | -epin     |                           | -epane    |
| 8         | -ocine                      |           | -ocin                     |           |



tebuconazole

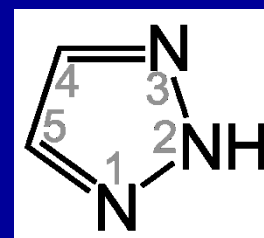
| Tamanho do anel | Hetero atom | Saturado |
|-----------------|-------------|----------|
|-----------------|-------------|----------|

3 N +

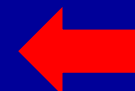


aziridine

5 N+N+N -



triazole



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## PESTICIDAS – UNIÃO EUROPEIA

<http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=activesubstance.selection&language=EN>

# CONTROLE QUÍMICO DE DOENÇAS DE PLANTAS

História

Mercado de Fungicidas e Fungicida ideal

Processo de descoberta

Tipos de Fungicidas

Aplicação de Fungicidas

# Um pouco de história...

## Fungicidas nos velhos tempos

| Ano  | Fungicida                                               | Uso primário                |
|------|---------------------------------------------------------|-----------------------------|
| AC   | Produtos naturais<br>(óleos, cinzas, incensos de ervas) | Cancros, requeimas          |
| 60   | Vinho                                                   | Sementes de cereais         |
| 1637 | Salmoura                                                | Sementes de cereais         |
| 1755 | Arsênico                                                | Sementes de cereais         |
| 1760 | Sulfato de cobre                                        | Sementes de cereais         |
| 1807 | Sulfato de cobre                                        | Cárie do trigo              |
| 1824 | Enxofre (pó)                                            | Oídios                      |
| 1833 | Enxofre + cal                                           | Várias doenças (fitotóxica) |

# Um pouco de história...

## 1885 – O ano da descoberta do primeiro fungicida

1854 – 80% perdas  
com oídio

1860 – variedades  
americanas,  
resistentes ao oídio

+

*Phylloxera*



1874 – Pierre Marie Alexis Millardet  
é chamado em Bordeaux



e recomenda a importação de  
porta-enxertos resistentes dos  
EUA

1876 – Millardet é contratado pela  
Universidade de Bordeaux

1878 – Millardet identifica  
*Plasmopara viticola* como o mais  
recente problema nas uvas  
bordalesas



Observa o efeito profilático da  
mistura de sulfato de cobre e  
cal em uvas doentes



1885 – relata com Ulysse Gayon  
a calda bordalesa e seus efeitos  
no controle do míldio

# Calda bordalesa FUNGICIDA E NÃO FITOTÓXICO



Preparo de calda bordalesa em  
pomar de macieiras em 1909 (Ainsworth,  
1981)

Reconhecimento com estátua  
e Rue Alexis Millardet



# Calda bordalesa é usada até hoje, mas fungicidas evoluíram...

Declínio nas doses e aumento na segurança  
com evolução dos fungicidas (Russel, 2005)



| Fungicida (época de introdução) | Dose kg/ha | DL50 oral, mg ia / kg |
|---------------------------------|------------|-----------------------|
| Enxofre (século 19)             | 10–20      | 400–500               |
| Sulfato de cobre (século 19)    | 10–20      | 472                   |
| Cloreto de mercúrio (1891)      | -----      | 1–5                   |
| Ditiocarbamatos (1940–1960)     | 1.5–3.5    | >8000                 |
| Ftalimidas (1950–1960)          | <2.0       | >5000                 |
| Clorothalonil (1964)            | 0.75–1.25  | >10 000               |
| Benzimidazois (1960)            | 0.25–1.0   | >15 000               |
| Dicarboximidas (1970)           | 0.75       | 3500–10 000           |
| Inibidores de esteróis (1970)   | 0.13–0.25  | 568–>6200             |
| Estrobilurinas (1990)           | 0.13–0.25  | >5000                 |

E.U.A. 1940 – 136.000 t/ano → 2000 – 58.000 t/ano

# **Calda bordalesa é usada até hoje, mas fungicidas evoluíram...**

Há alguns, no entanto que ainda não vêm formulados:  
calda sulfo-cálcica, sem registro

<https://www.youtube.com/watch?v=tV9ZBj78ZIQ>



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# Fungicidas *versus* outros agrotóxicos

**World and U.S. Pesticide Expenditures at User Level  
by Pesticide Type, 2006 and 2007 Estimates**

| Year and<br>Pesticide Type | World Market   |     | U.S. Market    |     | U.S. Percentage<br>of World Market |
|----------------------------|----------------|-----|----------------|-----|------------------------------------|
|                            | Millions of \$ | %   | Millions of \$ | %   |                                    |
| 2006                       |                |     |                |     |                                    |
| Herbicides <sup>1</sup>    | 14,247         | 40  | 5,673          | 48  | 40                                 |
| Insecticides <sup>2</sup>  | 10,259         | 29  | 4,091          | 35  | 40                                 |
| Fungicides <sup>2</sup>    | 7,987          | 22  | 1,165          | 10  | 15                                 |
| Other <sup>3</sup>         | 3,320          | 9   | 855            | 7   | 26                                 |
| Total                      | 35,814         | 100 | 11,784         | 100 | 33                                 |
| 2007                       |                |     |                |     |                                    |
| Herbicides <sup>1</sup>    | 15,512         | 39  | 5,856          | 47  | 38                                 |
| Insecticides <sup>2</sup>  | 11,158         | 28  | 4,337          | 35  | 39                                 |
| Fungicides <sup>2</sup>    | 9,216          | 23  | 1,375          | 11  | 15                                 |
| Other <sup>3</sup>         | 3,557          | 9   | 886            | 7   | 25                                 |
| Total                      | 39,443         | 100 | 12,454         | 100 | 32                                 |

Note: Totals may not add due to rounding. Table data do not cover wood preservatives, specialty biocides, and chlorine/hypochlorites.

Source: Cropnosis Limited ([www.cropnosis.com](http://www.cropnosis.com)), USDA/NASS ([www.nass.usda.gov](http://www.nass.usda.gov)), and EPA proprietary data.

1. "Herbicides" include herbicides and plant growth regulators (PGRs).

2. "Other" includes nematocides, fumigants, and other miscellaneous conventional pesticides, plus other chemicals used as pesticides (e.g., sulfur and petroleum oil).

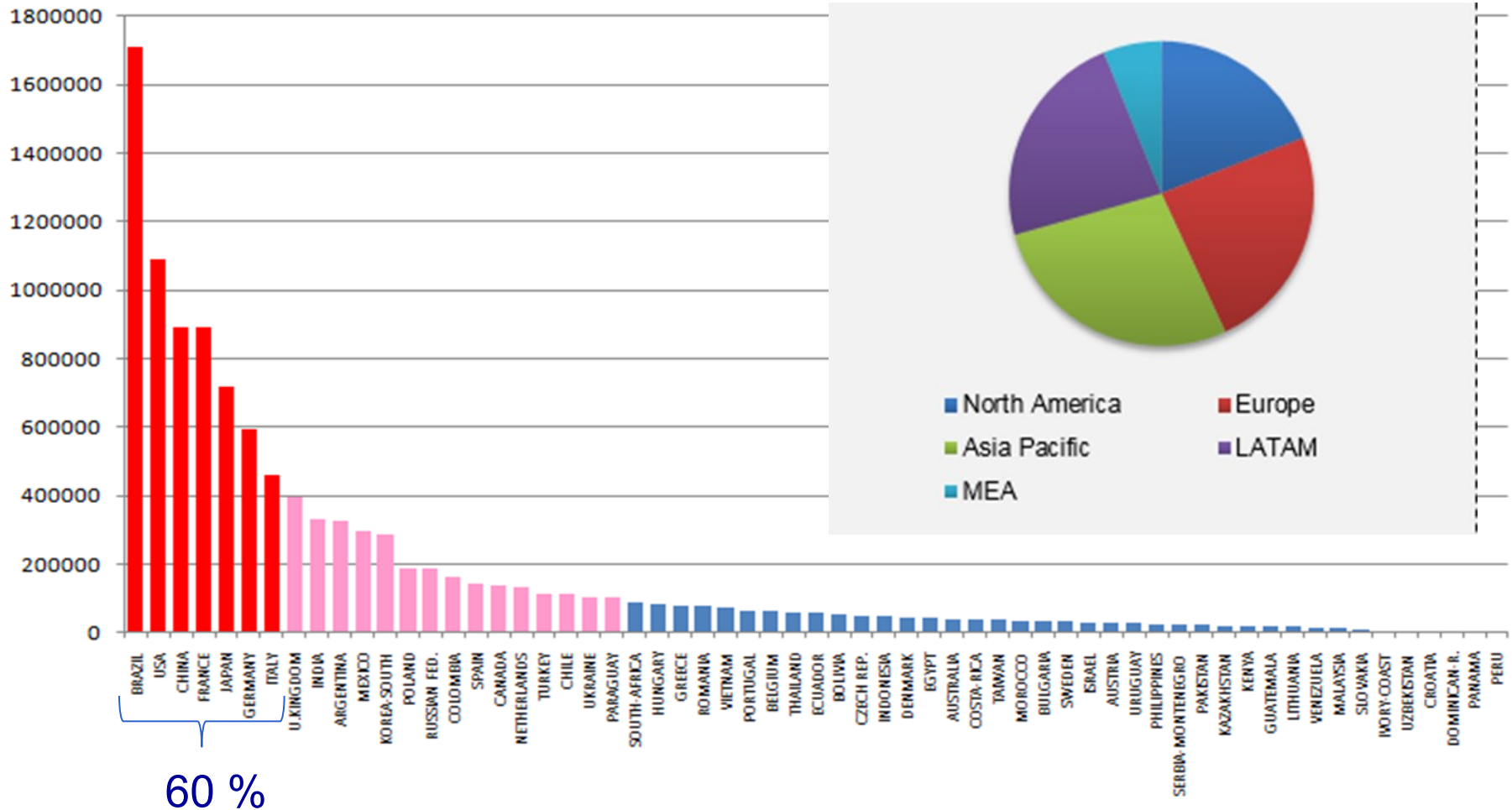
# Estimativa do Mercado de Defensivos

## Outubro 2010 vs 2011 (Milhões R\$)

| Segmentos    | MERCADO (Estimativa) |               |            |
|--------------|----------------------|---------------|------------|
|              | 2010                 | 2011          | % VAR      |
| Herbicidas   | 3.205                | 3.455         | 8%         |
| Fungicidas   | 2.679                | 2.750         | 3%         |
| Inseticidas  | 2.899                | 3.512         | 21%        |
| Acaricidas   | 127                  | 147           | 16%        |
| Outros       | 369                  | 334           | -9%        |
| <b>TOTAL</b> | <b>9.278</b>         | <b>10.199</b> | <b>10%</b> |

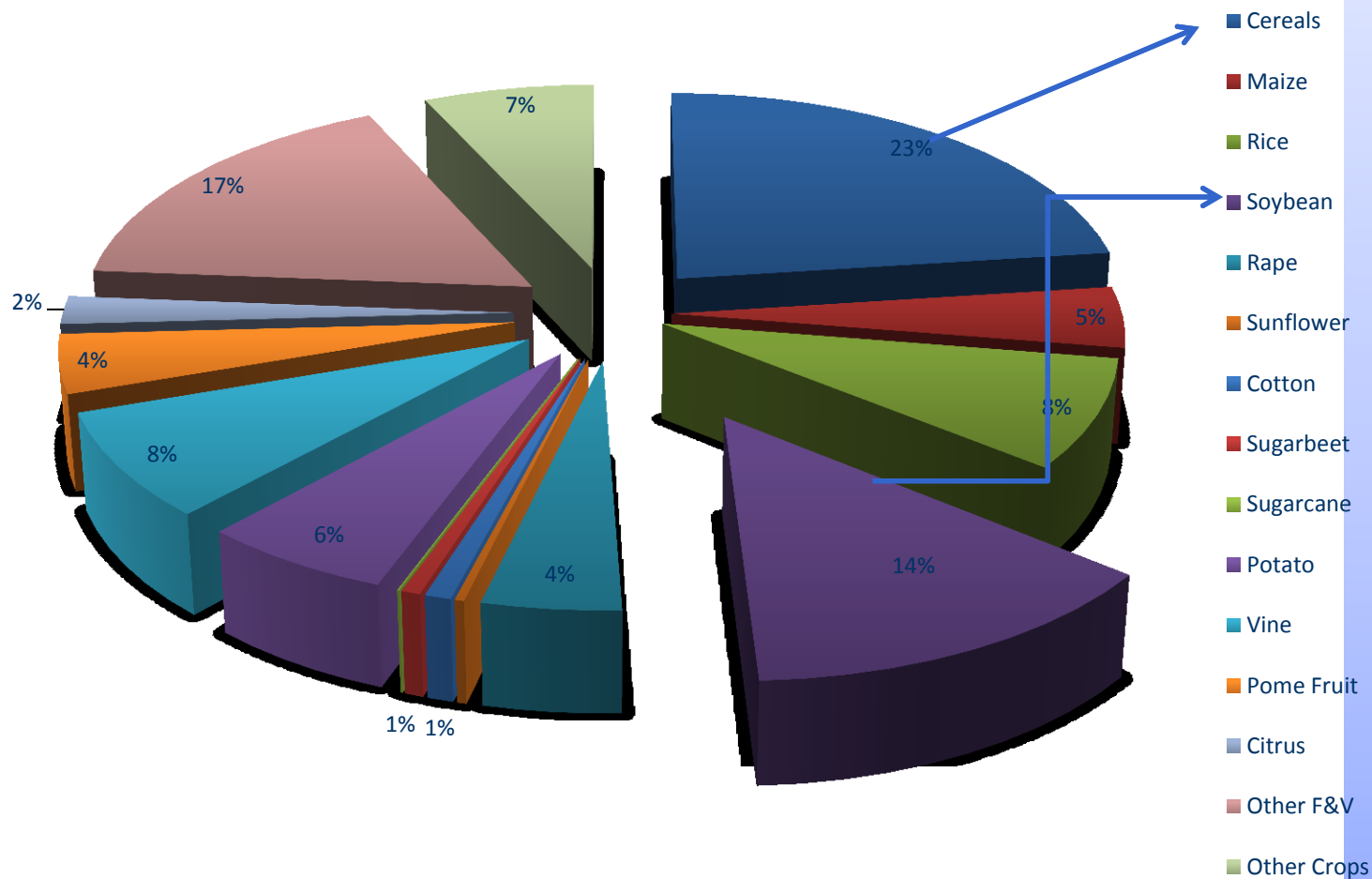
# Mercado Global de Fungicidas: 2013

total US\$ 15.7 B (2011 – US\$ 10.7 B)



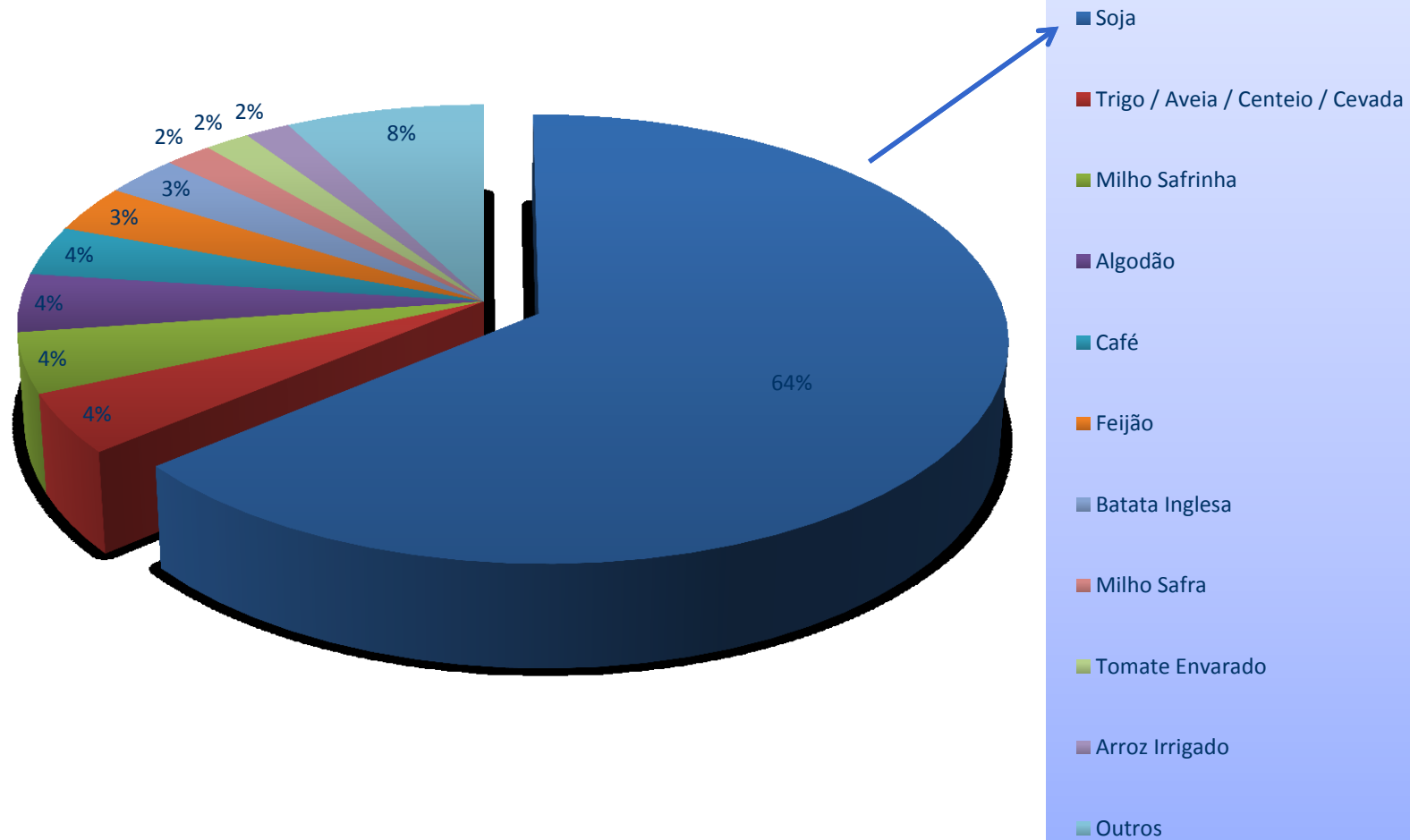
# Mercado Global de Fungicidas: 2013

## US\$ 15.7 B



# Mercado Brasileiro de Fungicidas: 2014

## US\$ 2.8 B



# FUNGICIDA IDEAL

## Biologicamente

Deve ser efetivo e consistente no controle de várias doenças  
Não deve ser fitotóxico na dose recomendada  
Não deve afetar de forma adversa outras partes do ecossistema

## Formulação

Deve ser seguro no transporte e estocagem  
Deve ser de fácil aplicação e permanecer na planta por longo período

## Toxicologicamente

Deve ser inócuo ao aplicador  
Resíduos não devem causar problemas no consumo

## Economicamente

O lucro decorrente de seu uso tem que exceder o custo das aplicações



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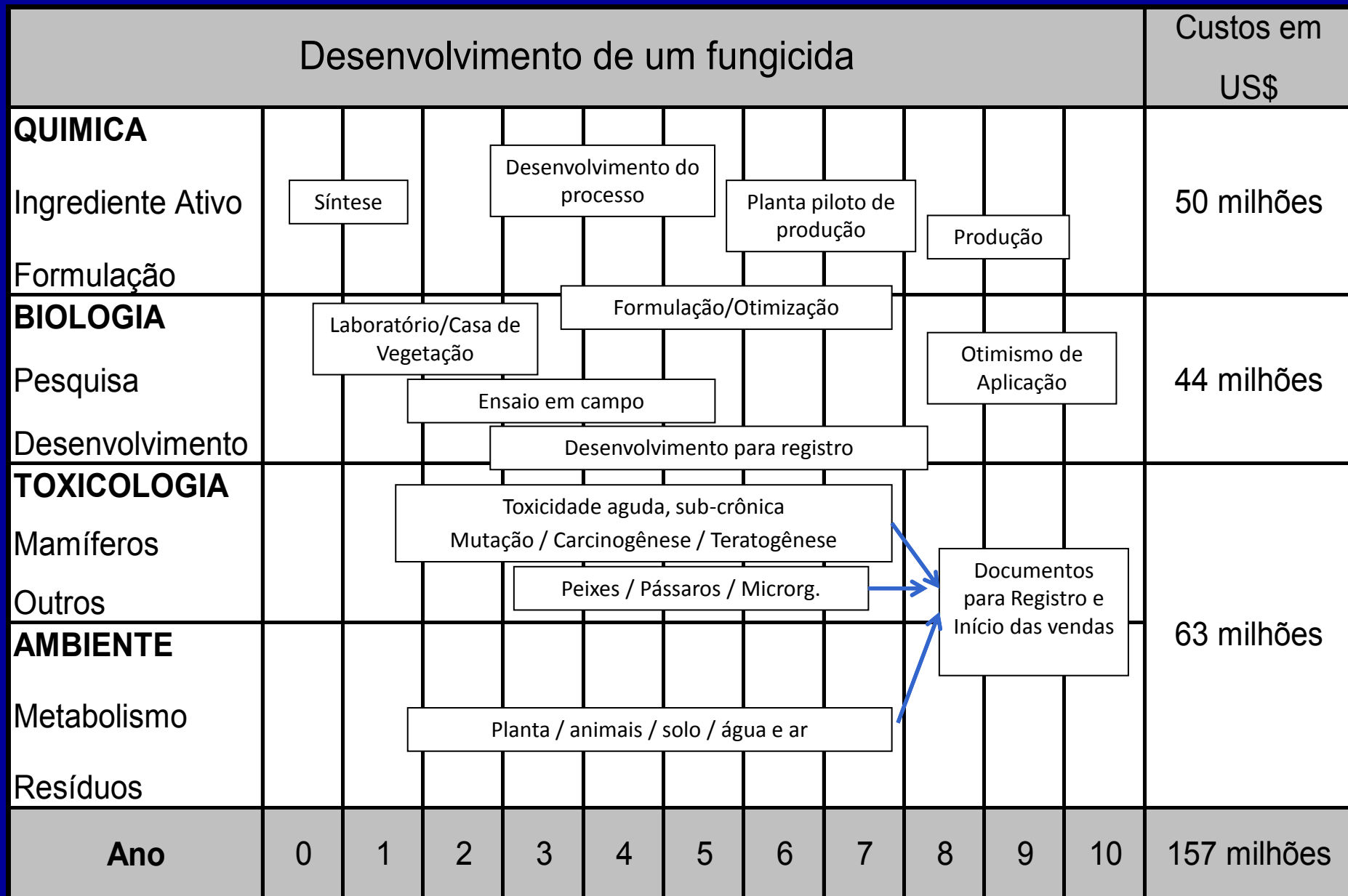
Processo de descoberta

Tipos de Fungicidas

Aplicação de Fungicidas

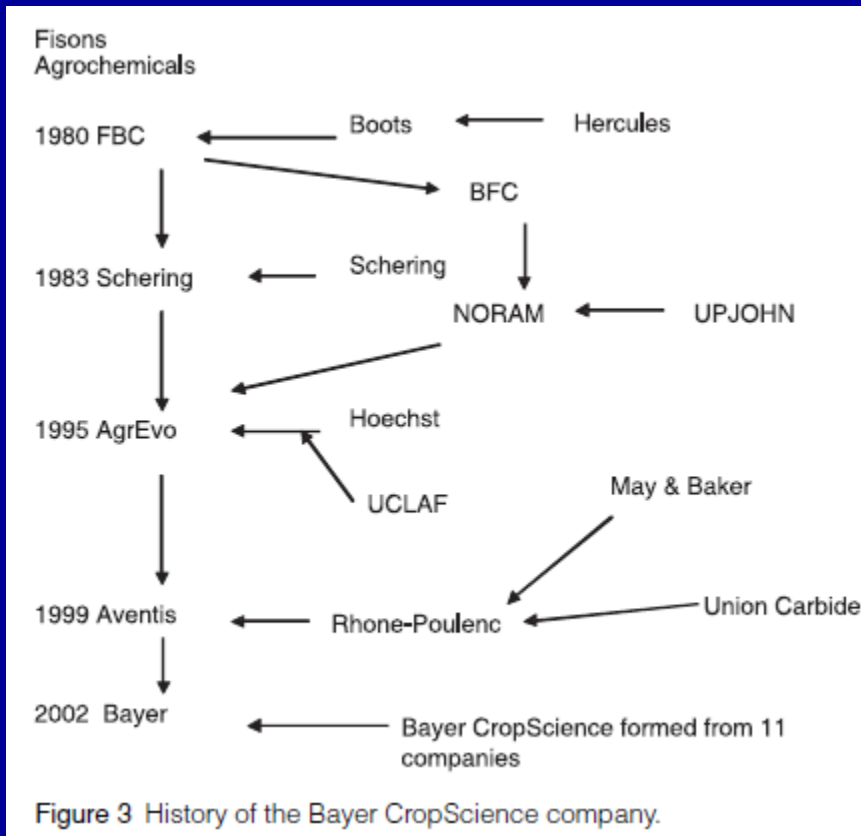
# PROCESSO DE DESCOBERTA DE FUNGICIDAS



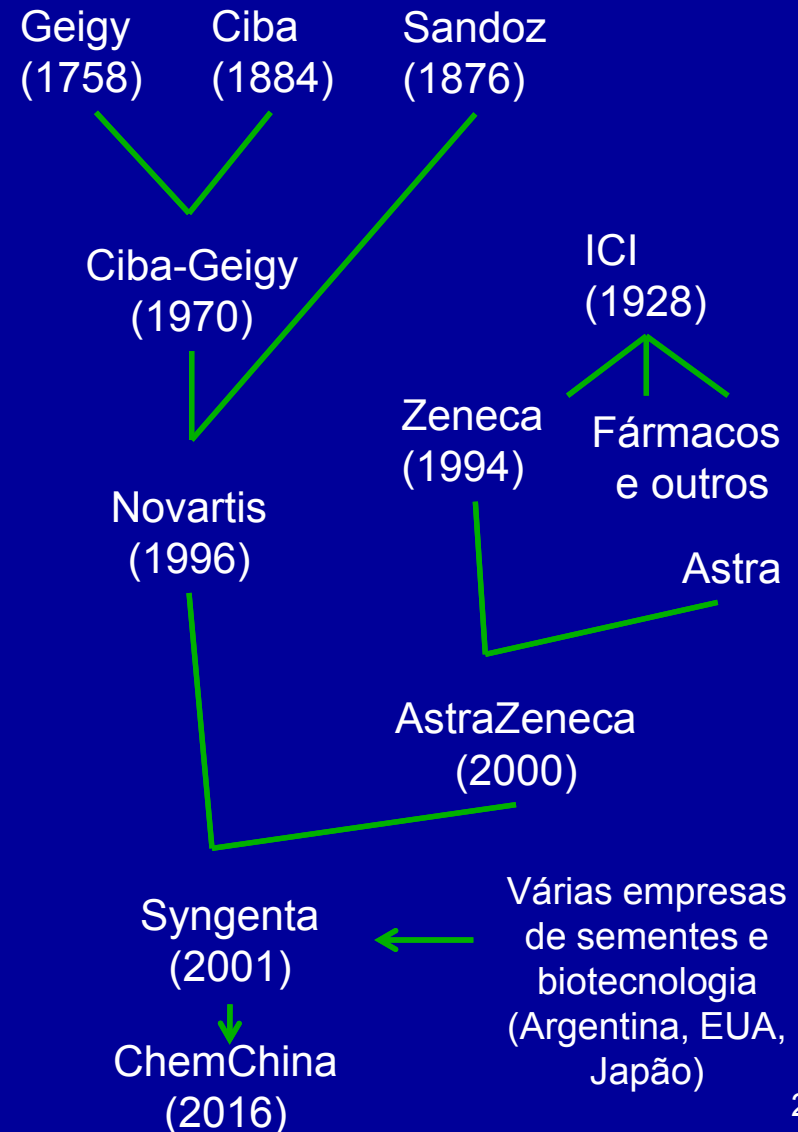


# PROCESSO DE DESCOBERTA DE FUNGICIDAS

## A FUSÃO DAS EMPRESAS



**Monsanto foi para a Bayer (2016)**



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# TIPOS DE FUNGICIDAS

- Mobilidade na planta – contato ou sistêmicos
- Princípio de controle – erradicantes, protetores ou curativos
- Alvo biológico – “uni-sítio”, “multi-sítio”



- Modo de ação (MOA) – processos enzimáticos, danos em membranas, interferência em processos produtores de energia...

- Tipo de ingrediente ativo – moléculas inorgânicas ou orgânicas

GRUPOS  
DE FUNGICIDAS –  
FRAC

**A: nucleic acids synthesis**

**B: Cytoesqueleton and motor proteins**

**C. respiration**

**D: amino acids and protein synthesis...**

**U: unknown mode of action**

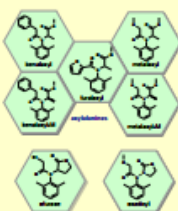
# Mode of Action of Fungicides

FRAC classification on mode of action 2017 ([www.frac.info](http://www.frac.info))

## A: Nucleic Acid Synthesis

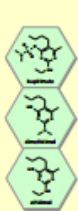
### A1: RNA polymerase I

# 6: Phthaloguanine (Phthaloguanine)



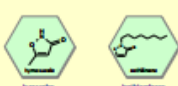
### A2: adenosine-deaminase

# 8: Hydrazide (Hydrazide)



### A3: DNA/RNA synthase (prop.)

# 23: Inhibitors (Inhibitors)



### A4: DNA topoisomerase type II (gyrase)

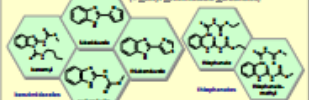
# 21: Quinolones (Quinolones)



## B: Cytoskeleton and Motor Proteins

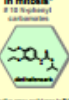
### B1: $\beta$ -tubulin assembly in mitosis

# 1: BCC (BCC)



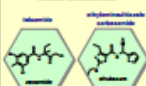
### B2: $\beta$ -tubulin assembly in mitosis

# 12: BCC (BCC)



### B3: $\alpha$ -tubulin assembly in mitosis

# 22: Inhibitors (Inhibitors)



### B4: cell division (prop.)

# 20: Phosphonates (Phosphonates)



### B5: delocalisation of spectrin-like proteins

# 14: Inhibitors (Inhibitors)



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

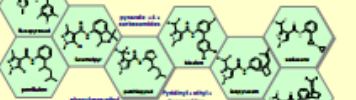
# 17: Inhibitors (Inhibitors)



## C: Respiration

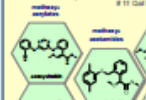
### C1: inhibition of complex I

# 7: Inhibitors (Inhibitors)



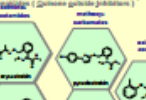
### C2: inhibition of complex II

# 7: Inhibitors (Inhibitors)



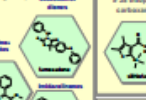
### C3: inhibition of complex III

# 14: Inhibitors (Inhibitors)



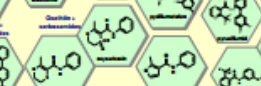
### C4: inhibition of complex IV

# 14: Inhibitors (Inhibitors)



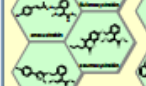
### C5: inhibition of complex I

# 7: Inhibitors (Inhibitors)



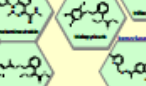
### C6: inhibition of complex II

# 7: Inhibitors (Inhibitors)



### C7: inhibition of complex III

# 14: Inhibitors (Inhibitors)



### C8: inhibition of complex IV

# 14: Inhibitors (Inhibitors)



## D: Amino Acid and Protein Synthesis

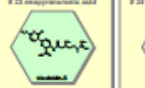
### D1: methionine biosynthesis (cys gene) (prop.)

# 9: Inhibitors (Inhibitors)



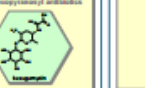
### D2: protein synthesis

# 24: Inhibitors (Inhibitors)



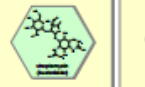
### D3: protein synthesis

# 24: Inhibitors (Inhibitors)



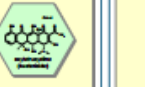
### D4: protein synthesis

# 24: Inhibitors (Inhibitors)



### D5: protein synthesis

# 24: Inhibitors (Inhibitors)



## E: Signal Transduction

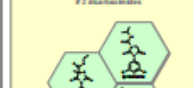
### E1: signal transduction (mechanism unknown)

# 13: Inhibitors (Inhibitors)



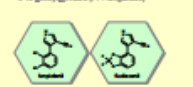
### E2: osmotic signal transduction

# 13: Inhibitors (Inhibitors)



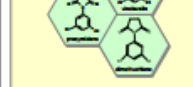
### E3: osmotic signal transduction

# 13: Inhibitors (Inhibitors)



### E4: osmotic signal transduction

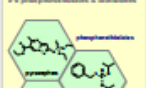
# 13: Inhibitors (Inhibitors)



## F: Lipid Synthesis or Transport / Membrane Integrity or Function

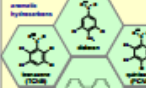
### F1: phospholipid biosynthesis

# 14: Inhibitors (Inhibitors)



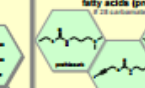
### F2: lipid peroxidation (prop.)

# 14: Inhibitors (Inhibitors)



### F3: cell membrane permeability, fatty acids (prop.)

# 25: Inhibitors (Inhibitors)



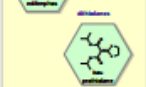
### F4: cell membrane permeability, fatty acids (prop.)

# 25: Inhibitors (Inhibitors)



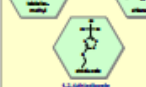
### F5: cell membrane permeability, fatty acids (prop.)

# 25: Inhibitors (Inhibitors)



### F6: cell membrane permeability, fatty acids (prop.)

# 25: Inhibitors (Inhibitors)



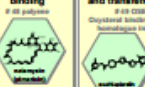
### F7: cell membrane permeability, fatty acids (prop.)

# 25: Inhibitors (Inhibitors)



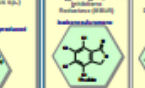
### F8: cell membrane permeability, fatty acids (prop.)

# 25: Inhibitors (Inhibitors)



### F9: cell membrane permeability, fatty acids (prop.)

# 25: Inhibitors (Inhibitors)



### F10: cell membrane permeability, fatty acids (prop.)

# 25: Inhibitors (Inhibitors)



## G: Sterol Biosynthesis in Membranes

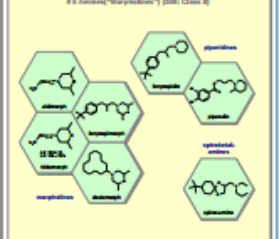
### G1: C14-demethylase in sterol biosynthesis (erg11cyp51)

# 3: Inhibitors (Inhibitors)



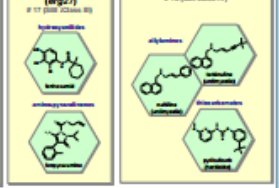
### G2: $\Delta^14$ -reductase and $\Delta^14$ -isomerase in sterol biosynthesis (erg2, erg24)

# 4: Inhibitors (Inhibitors)



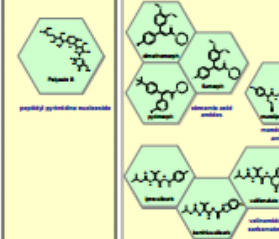
### G3: $\Delta^14$ -reductase in sterol biosynthesis (erg2)

# 4: Inhibitors (Inhibitors)



### G4: squalene epoxidase in sterol biosynthesis (erg3)

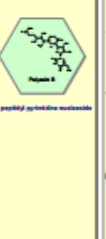
# 13: Inhibitors (Inhibitors)



## H: Cell Wall Biosynthesis

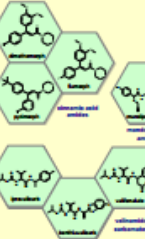
### H1: chitin synthase

# 10: Inhibitors (Inhibitors)



### H2: cellulose synthase

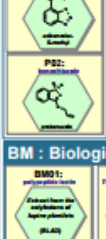
# 10: Inhibitors (Inhibitors)



## P: Host Plant Defence Induction

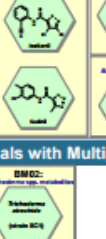
### P1: salicylic pathway

# 10: Inhibitors (Inhibitors)



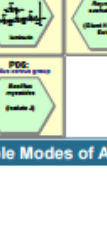
### P2: jasmonic pathway

# 10: Inhibitors (Inhibitors)



### P3: ethylene pathway

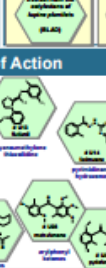
# 10: Inhibitors (Inhibitors)



## BM: Biologicals with Multiple Modes of Action

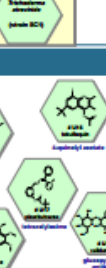
### BM1: biologicals with multiple modes of action

# 10: Inhibitors (Inhibitors)

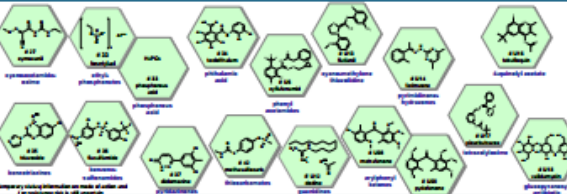


### BM2: biologicals with multiple modes of action

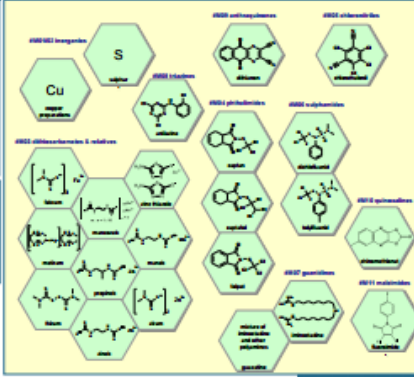
# 10: Inhibitors (Inhibitors)



## Unknown Mode of Action



## M: Chemicals with Multi-Site Activity



### Legend:

#### C: Respiration

C1: inhibition of complex I

C2: inhibition of complex II

C3: inhibition of complex III

C4: inhibition of complex IV

C5: inhibition of complex I

C6: inhibition of complex II

C7: inhibition of complex III

C8: inhibition of complex IV

C9: inhibition of complex I

C10: inhibition of complex II

C11: inhibition of complex III

C12: inhibition of complex IV

C13: inhibition of complex I

C14: inhibition of complex II

C15: inhibition of complex III

C16: inhibition of complex IV

C17: inhibition of complex I

C18: inhibition of complex II

C19: inhibition of complex III

C20: inhibition of complex IV

C21: inhibition of complex I

C22: inhibition of complex II

C23: inhibition of complex III

C24: inhibition of complex IV

C25: inhibition of complex I

C26: inhibition of complex II

C27: inhibition of complex III

C28: inhibition of complex IV

C29: inhibition of complex I

C30: inhibition of complex II

C31: inhibition of complex III

C32: inhibition of complex IV

C33: inhibition of complex I

C34: inhibition of complex II

C35: inhibition of complex III

C36: inhibition of complex IV

C37: inhibition of complex I

C38: inhibition of complex II

C39: inhibition of complex III

C40: inhibition of complex IV

C41: inhibition of complex I

C42: inhibition of complex II

C43: inhibition of complex III

C44: inhibition of complex IV

C45: inhibition of complex I

C46: inhibition of complex II

C47: inhibition of complex III

C48: inhibition of complex IV

C49: inhibition of complex I

C50: inhibition of complex II

C51: inhibition of complex III

C52: inhibition of complex IV

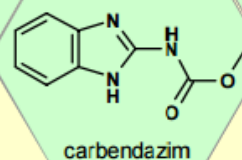
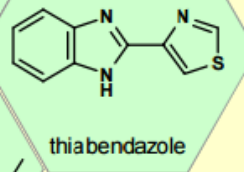
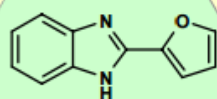
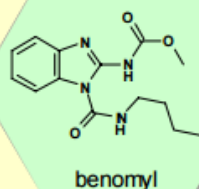
C53: inhibition of complex I

# B: Cytoskeleton and motor proteins

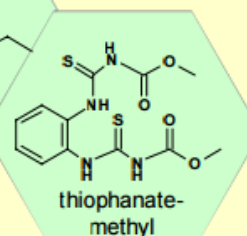
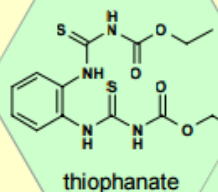
## B1: $\beta$ -tubulin assembly in mitosis

# 1: MBC fungicides  
(= Methyl Benzimidazole Carbamates)

benzimidazoles



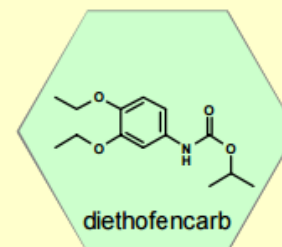
thiophanates



## B2:

### $\beta$ -tubulin assembly in mitosis\*

# 10 N-phenyl carbamates



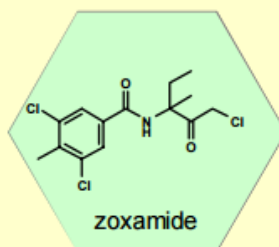
\* negative cross-resistance to B1

## B3:

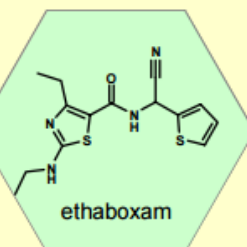
### $\beta$ -tubulin assembly in mitosis

# 22 benzamides and thiazole carboxamides

toluamide



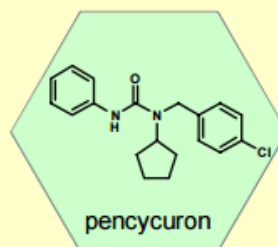
ethylamino-thiazole carboxamide



## B4:

### cell division (prop.)

# 20 phenylureas

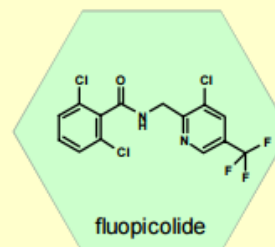


## B5:

### delocalisation of spectrin-like proteins

# 43 benzamides

pyridinylmethyl-benzamide

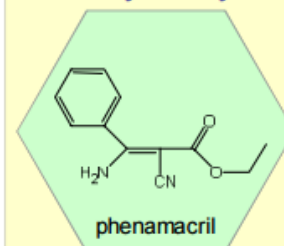


## B6:

### actin/myosin/fimbrin function e.g. in vesicle trafficking

# 47 cyanoacrylates

aminocyanoacrylates



# CONTROLE QUÍMICO DE DOENÇAS DE PLANTAS

História

Fungicida ideal

Processo de descoberta

Tipos de Fungicidas

Aplicação de Fungicidas

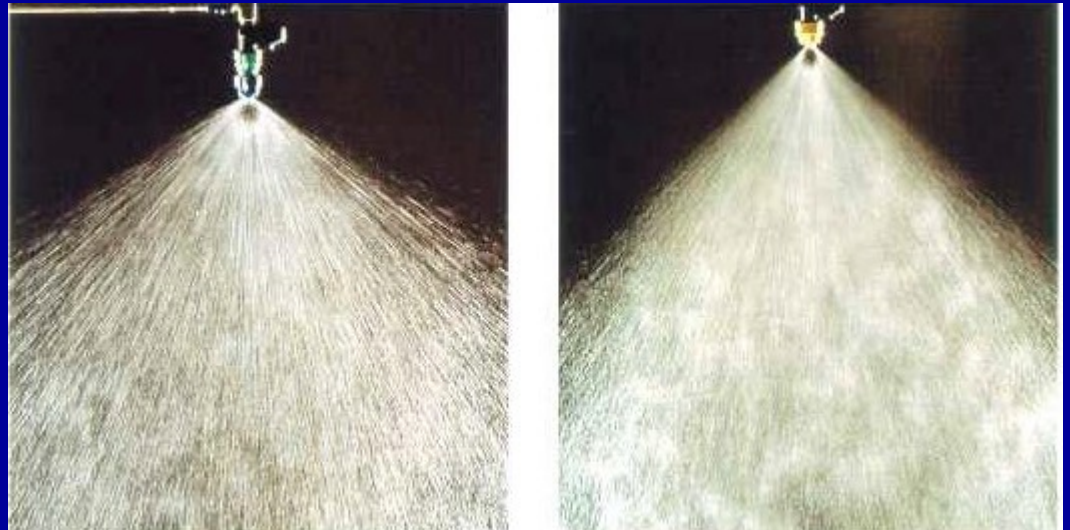
# APLICAÇÃO DE FUNGICIDAS

**Formulação** – Mistura do ingrediente ativo com outros produtos (adjuvantes) que melhoram a performance do fungicida. Ex. pós-molháveis, concentrados emulsionáveis, granulados, etc.

## Adjuvantes

Transferência do tanque para o alvo – efeito no tamanho de gotas, p. ex.

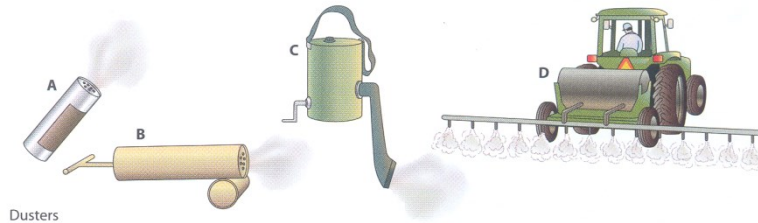
Dispersão do ativo e na absorção do ativo – efeito na molhabilidade e na aderência do produto



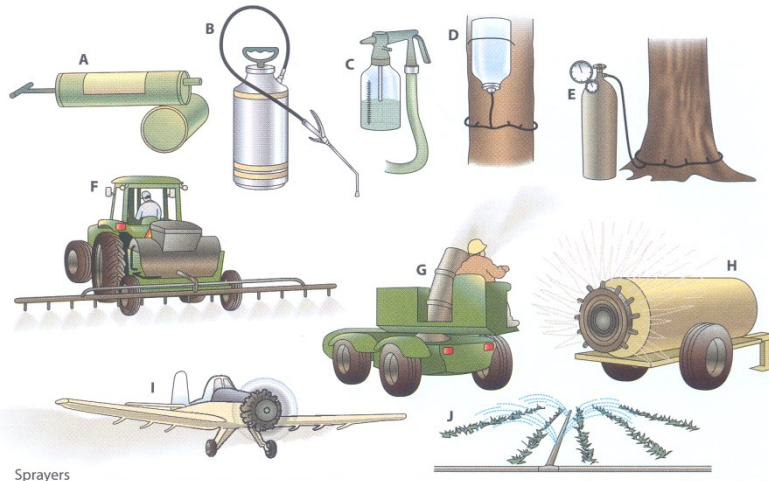
(Vargas & Roman, 2006)

# APLICAÇÃO DE FUNGICIDAS

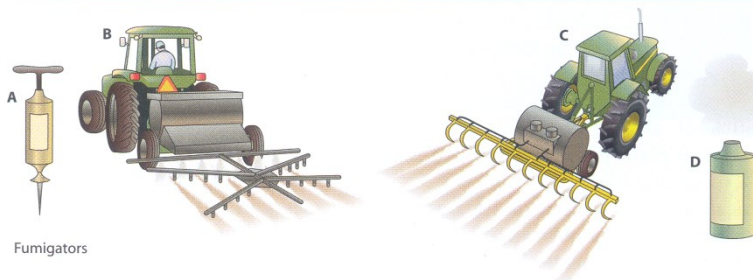
Aplicação de fungicidas (fosfonatos) em carvalho para controle de *Phytophthora ramorum* <http://www.suddenoakdeath.org/diagnosis-and-management/treatments/>



Dusters



Sprayers



Fumigators

**FIGURE 9-25** Various types of equipment used for the control of plant diseases by dusting, spraying, injection, or fumigation. Dusters: portable dusters (A–C) and tractor-mounted duster (D). Sprayers: portable sprayers (A–C), tree injection gravity-flow apparatus (D), apparatus for tree injection under pressure (E), tractor-mounted sprayers for annuals (F) and for trees (G and H), airplane spraying (or dusting) (I), and spraying through the irrigation system (J). Fumigators: handgun fumigator (A), tractor-mounted gravity-flow (B) or pump-driven injectors (C), and fumigation can for greenhouse or warehouse (D).

(Agrios, 2005)



Aplicação de fungicidas para controle da ferrugem da soja no Brasil. Ulisses

Antuniassi/

# APLICAÇÃO DE FUNGICIDAS

**Formulação** – Mistura do ingrediente ativo com outros produtos (adjuvantes) que melhoram a performance do fungicida. Ex. pós-molháveis, concentrados emulsionáveis, granulados, etc.



Pulverização de concentrado emulsionável em cebola (APS - G. Geitz)



Vapam aplicado ao solo. Solução fungicida aplicada ao solo e coberta com plástico (APS - P. Vincelli)

## Literatura

Kimati, H. Controle químico. In: Amorim, L., Rezende, J.A.M.; Bergamin Filho, A. (Ed.). Manual de Fitopatologia, v.1, 4 ed. 2011.

**Lucas, J.A. Plant Pathology and Plant Pathogens. Blackwell, 3a. ed. 1998. capítulo 11. pg. 195-216.**

Reis, E.M.; Reis, A.C. & Forcelini, C.A. Manual de Fungicidas: guia para o controle químico de doenças de plantas. Editora UPF, Passo Fundo. 2007.