

# Fungicides - Modes of Action & Managing Resistance



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# Chemical Control – A critical component of many disease management programs

- Chemical controls complement other control measures such as regulatory (quarantines, seed tolerances), cultural (planting date, rotation, sanitation, irrigation and nutrition management), host resistance, biological and physical methods
- Chemicals are toxic to pathogens –
  - ◆ May be lethal to pathogen or
  - ◆ inhibit germination, growth, multiplication of pathogen
  - ◆ Some may affect quality of inoculum (survival, amount)
  - ◆ Some are multiple-site toxicants, others are single site
- General groups include -
  - ◆ Fungicides, bactericides, nematocides, viricides, fumigants

# Chemical Control – Fungicides – Common Uses

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- Seed treatments
- Soil applications – broadcast, in-furrow
- Foliar sprays, dusts, paints, systemics
- Post harvest sprays, dips, aerosols
- Use of fungicides requires thorough knowledge of host, pathogen and effect of environment
- Goal is to eliminate the pathogen or at least slow the rate of disease development

# Chemical Control – Key Terms

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- Preventative – prevents establishment of pathogen
- Curative – interrupts development of established infection which is not showing symptoms
- Eradicant – interrupts further development of established infection which is showing symptoms
- Antisporulant – prevents or decreases inoculum production without stopping vegetative growth
- Systemic – movement of fungicide in plant; locally systemic or translocated through plant via xylem or phloem

# Preventative Fungicides

- Preventative –prevents establishment of an infection (sometimes termed protectant)
  - ◆ Provides chemical barrier to pathogen
  - ◆ Must be present on plant before infection
  - ◆ Not absorbed or translocated by plant
  - ◆ Can't stop established disease, but slow spread
  - ◆ Complete coverage is critical
  - ◆ Affected by environmental variables
  - ◆ Insurance treatment

# Curative Fungicide

- Curative – interrupts development of established infection which is not showing symptoms
  - ◆ Can cure disease
  - ◆ Systemic (e.g. local, translaminar, whole plant)
  - ◆ Coverage not as critical as for preventatives
  - ◆ Kickback activity – window of opportunity
  - ◆ Often used after disease appears
  - ◆ Resistance in pathogen population more likely than with preventatives

# Grouping Fungicides By Mode of Action

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- Currently there are over 40 groups of fungicides classified by Mode of Action
- Reference: [www.frac.info](http://www.frac.info) for complete listing
- Additional fungicides and Mode of Action groups added when discovered or identified

# Critical Issues in Use of Fungicides

- Coverage
  - ◆ Growth phases of crop
  - ◆ Equipment choice and calibration
  - ◆ Weathering
  - ◆ Weather variables
- Timing
  - ◆ Complete protection - start to finish
- Resistance management
- Safety – Environment, applicator, consumer
- Economics of use



# Fungicide Resistance

**Defined – Inherited change in pathogen's susceptibility to a fungicide**

**Factors:**

**Fungicide mode of activity**

Multi-site e.g. mancozeb, chlorothalonil

Single-site e.g. metalaxyl, members of strobilurin group

**Pathogen**

Single-cycle e.g. White mold

Multi-cycle e.g. Late blight, Early blight

# WI Case Example - Early Blight

Annual appearance on irrigated sands

Progressive loss in foliage

Affect on yield and tuber quality

Traditional fungicide program included:

Mancozeb, metiram, chlorothalonil, triphenyl tin hydroxide

Arrival of strobilurin class of fungicides

Field plot evaluation - best early blight control ever seen

Experimental Use Permit - Quadris - 1998 - ~5,000 acres

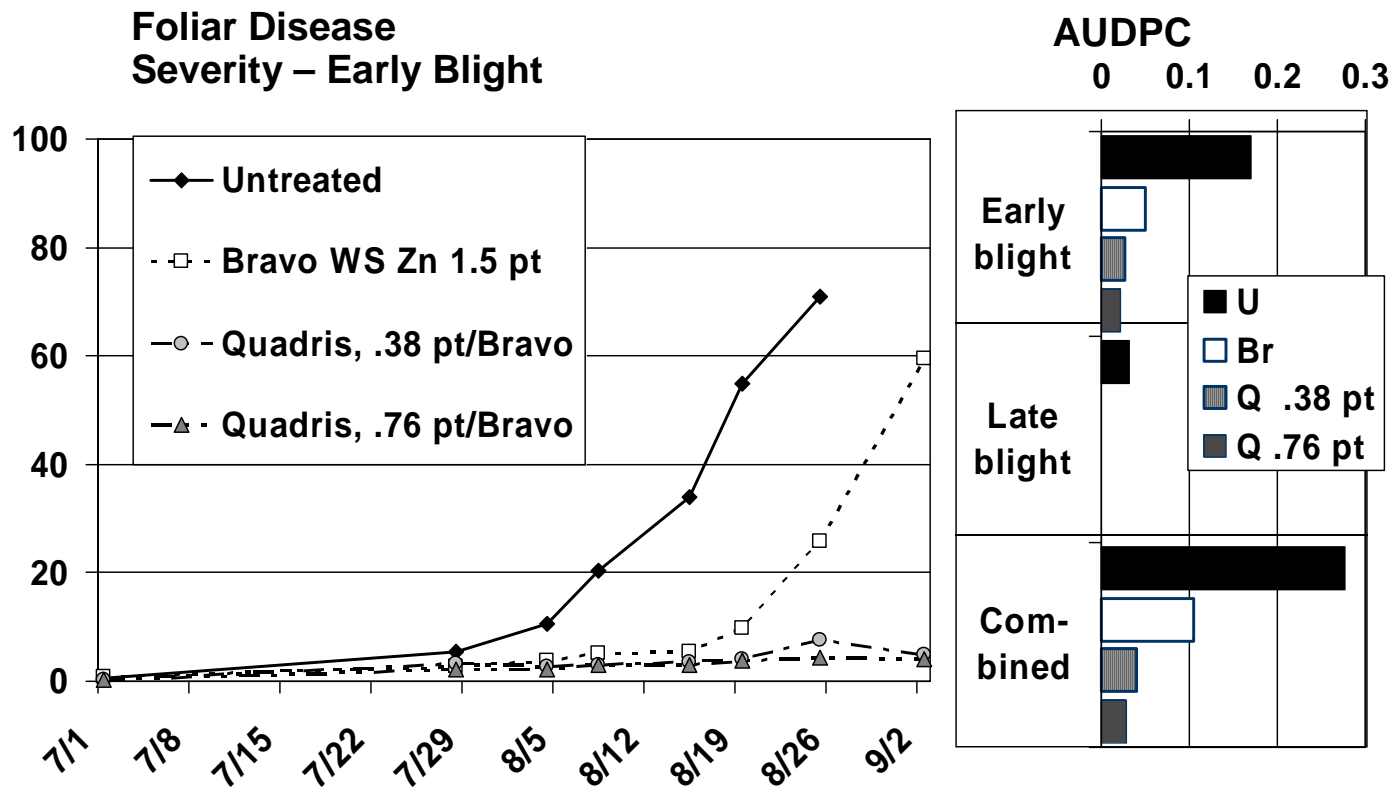
Outstanding control in split field trials

Full Label (national) - Quadris - 1999

Thereafter - Additional strobilurin products released

Amistar, Headline, Gem, Tanos (also contains cymoxanil), Reason, Evito

# Comparison of Treatment Efficacy Hancock Potato Trial, 1997



**Figure 2. Spray programs in 1997 that contained azoxystrobin (Quadris) and chlorothalonil (Bravo) flattened the early blight progress curve in comparison with the untreated check and plots sprayed with chlorothalonil (Bravo) alone.**

# WI Case Example - Early Blight

## Resistance risk of strobilurin group

- Initially considered low

- Resistance management wording on label

- Number of sprays per season, Seasonal use of products

## Resistance began to emerge

- Most cases, gradual loss of efficacy over years

- Other states, rapid loss of efficacy - 1-2 seasons

## Resistance associated with site mutation -

- Mutation at site F129L in cytochrome b gene

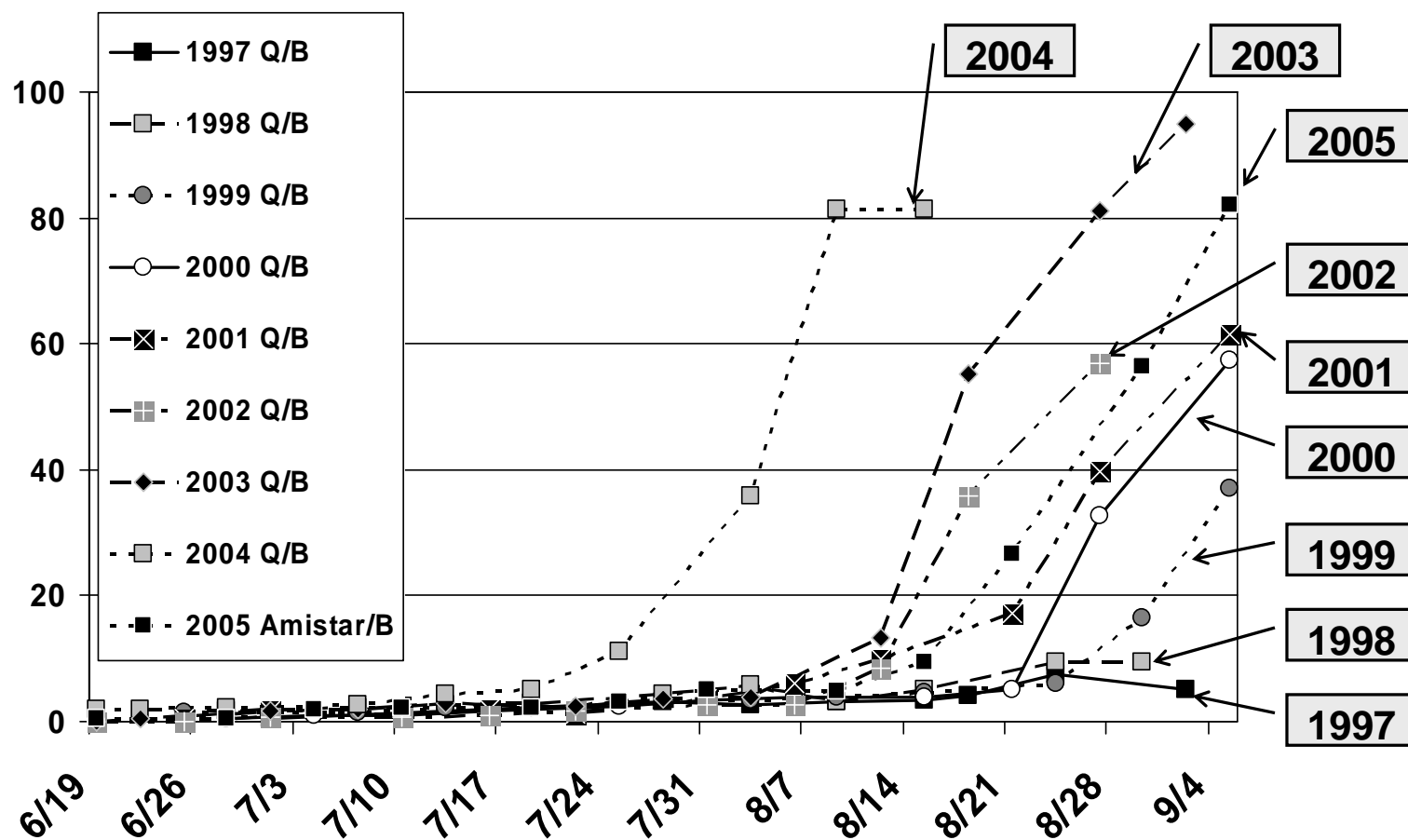
- Distribution of mutation throughout several states

- A 10-20 fold change in sensitivity to strobilurins

## Control of early blight with standard protectants

- Difficult with standard "old time" protectants

# Azoxystrobin Treatment, Hancock Potato Trials, 1997-2005 Foliar Disease Severity – Early Blight



**Figure 3B. Early blight progress in field trials conducted in 1997-2005 in plots treated with a seasonal program containing both azoxystrobin (Quadris) (Q) and chlorothalonil (Bravo) (B)**

# WI Case Example - Early Blight

## What Does Resistance To Group 11 Materials Mean For Future Management Of Early Blight?

- Introduction of new chemistries

  - E.g. boscalid (Endura)

- Use of multiple chemistries (modes of action) in season-long control programs

- Reduction in number of sprays with any single mode of action, especially newer chemistries with single site activity

  - Programs using base program of chlorothalonil or mancozeb

  - Add 2 sprays with strobilurin mixed with protectant

  - Add 1-2 sprays with boscalid mixed with protectant

  - Add 1-2 sprays with triphenyltin hydroxide mixed with protectant

- Cost goal - <\$100/A for chemical inputs in disease management program

# Recommendations – Early Blight

1. Limit sprays with Group 11 fungicides to  $\leq 3$  for season (1/3 or less of total sprays)
2. Use Group 11 fungicides early in season alternated or tank mixed with fungicides having different mode of action such as Group 7 fungicide
3. Never apply back-to-back Group 11 fungicides
4. Never use Group 11 fungicides as curative
5. When disease pressure is high, if at all possible avoid using Group 11 fungicides
6. Be alert for control failures
7. Monitor for resistance

# Resistance Management Doesn't Cost – It Pays

Treatments Include:	Total Yield cwt/A	Fungicide Cost (\$/A)	Gross Crop Value (\$) Processing	Net Crop Value (\$) Processing	Effect on Crop Value (\$ Processing)
Untreated	469	0	1865	1865	0
Bravo Zn	529	65	2081	2016	151
Penncozeb 4F	521	33	1997	1964	99
Echo Zn, Headline, Endura, Dithane DF, Super Tin	622	92	2463	2371	506  <u>\$5.50</u> <u>Value/Cost</u>

**Table 1. Comparison of yield, fungicide cost, crop values and benefit to crop value of selected treatments – Russet Burbank - 2005 field trial - Hancock WI Ag Research Station**



# Resistance Management Doesn't Cost – It Pays

Treatments Include:	Total Yield cwt/A	Fungicide Cost (\$/A)	Gross Crop Value (\$) Processing	Net Crop Value (\$) Processing	Effect on Crop Value (\$ Processing)
Untreated	529	0	2250	2250	0
Bravo Zn	556	62	2389	2327	77
Penncozeb 4F	576	42	2484	2442	192
Echo Zn, Headline, Endura, Dithane DF, Super Tin	618	87	2921	2834	584  <u>\$6.71</u> <u>Value/Cost</u>

**Table 1B. Comparison of yield, fungicide cost, crop values and benefit to crop value of selected treatments – Russet Burbank - 2006 field trial - Hancock WI Ag Research Station.**

# How Can Growers Reduce The Risk Of Pathogen Resistance To Fungicides?

Crop rotation - as long as possible

Use cultivars with early blight resistance - fewer inputs

Use disease predictive models to time fungicide applications.

Scout fields frequently

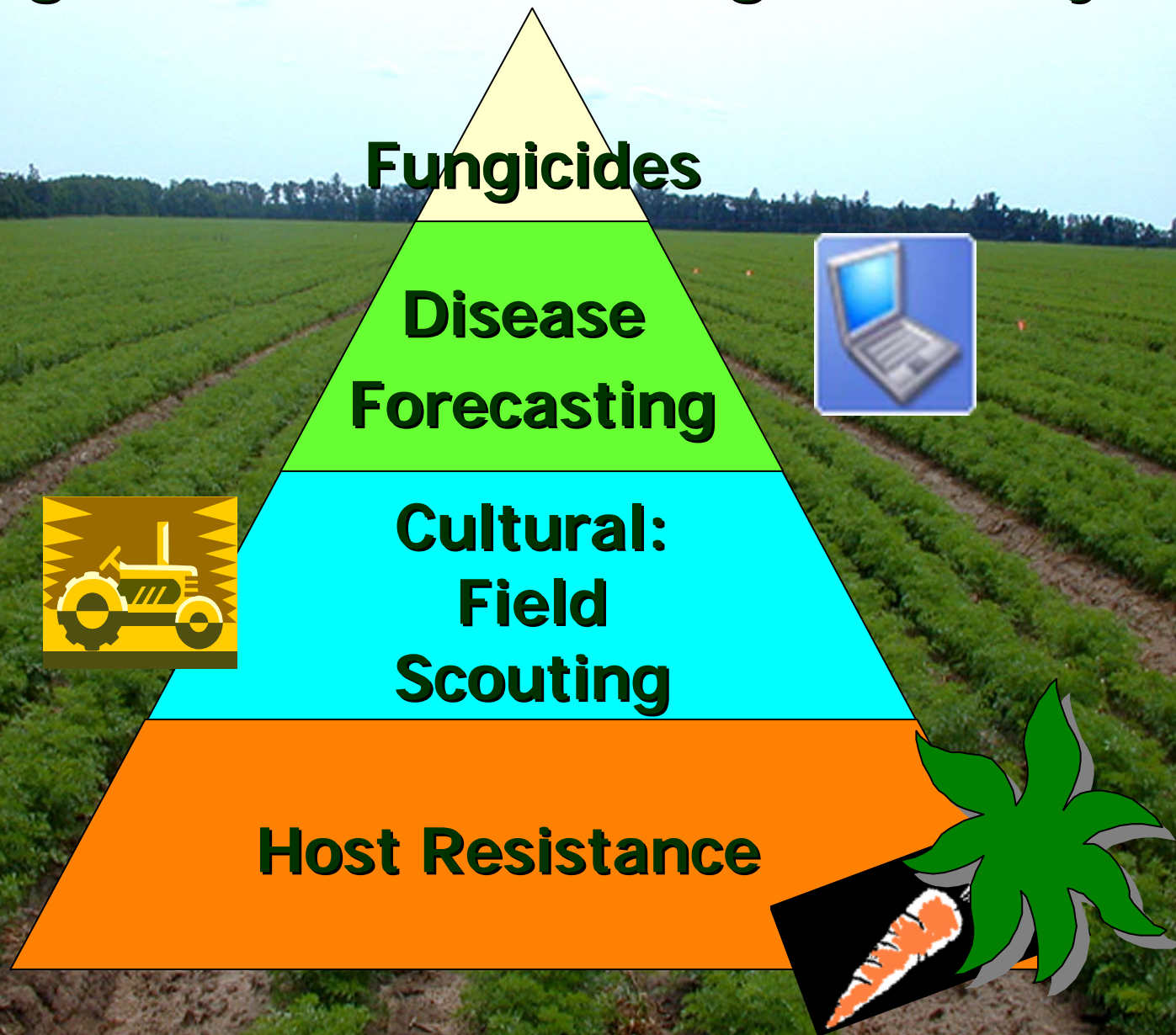
Practice crop hygiene by elimination of primary inoculum sources, e.g. volunteer management, proper cull disposal and alternate host management including weeds.

Monitor factors such as soil moisture and crop nutrition to avoid crop stress throughout the season.

Follow label guidelines for application of all fungicides. Note label information on resistance management.

Look for the Fungicide Group Code on labels and on the fungicide containers.

# Layering the Disease Management Pyramid



Resistance Risk of Fungicide Groups				
Group Code	Chemical Group	Common Name	Product Names	Resistance Risk
1	benzimidazoles	thiabendazole	Mertect	High
	thiophanates	thiophanate, thiophanate-methyl	Tops, Topsin M	High
2	dicarboximides	iprodione	Rovral	M to High
4	phenylamides	metalaxyl mefenoxam	Ridomil Ridomil Gold, Ultra Flourish	High
7	carboxamides	boscalid flutolanil	Endura Moncut, Moncoat	Medium
9	anilino-pyrimidines	pyrimethanil	Scala	Medium
11	<u>strobilurins</u> methoxy acrylate methoxy carbamate oximino acetate ozazolidine dione imidazolinone dihydro-dioxazine	azoxystrobin pyraclostrobin trifloxystrobin famoxadone fenamidone fluoxastrobin	Quadris, Amistar, Quadris Opti Headline Gem Tanos (contains cymoxanil) Reason Evito	High
12	phenylpyrroles	fludioxonil	Maxim	L to Med
14	aromatic hydrocarbons	quintozene (PCNB)	Blocker	L to Med

# Resistance Risk of Fungicide Groups

Group Code	Chemical Group	Common Name	Product Names	Resistance Risk
15	cinnamic acids	dimethomorph	Forum	L to Med
21	cyanoimidazole	cyazofamid	Ranman	M to High
22	benzamides	zoxamide	Gavel (also contains mancozeb)	L to Med
27	cyanoacetamide oximes	cymoxanil	Curzate	L to Med
28	carbamates	propamocarb hydrochloride	Previcur Flex	L to Med
29	2,6-dinitro-anilines	fluazinam	Omega	Low
30	organotin compounds	triphenyltin hydroxide	SuperTin	L to Med
M	M1 – copper	copper hydroxide	Kocide, Champ	Low
M	M3–ethylenebis dithiocarbamates (EBDC's)	mancozeb maneb metiram	Dithane, Manzate, Penncozeb Maneb Polyram	Low
M	M4 – phthalimides	captan	Captan	Low
M	M5 – phthalonitriles	chlorothalonil	Bravo, Echo, Equus	Low

Source: FRAC Website - <http://www.frac.info/frac/index.htm>

# Useful References on the Web

- **Greenbook – source of labels and MSDS safety information on all pesticides used in U.S.**
  - ◆ <http://www.greenbook.net/>
- ◆ **CDMS Ag Chem Information Services**
  - ◆ [http:// www.cdms.net/](http://www.cdms.net/)
- **Fungicide Resistance Action Committee (FRAC)**
  - ◆ <http://www.frac.info/>
- **University of Wisconsin – Extension Publications**
  - ◆ <http://www.uwex.edu/topics/publications/>
- **Dow Agroscience – Periodic Table of Fungicides**
  - ◆ <http://learningstore.uwex.edu/Plants-C16.aspx>



## Questions

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# QUESTIONS

## Abstract

# 2019

# WATER










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# 2024

# Introduction










**EXPERIMENTAL PROCEDURE**

# EXPERIENCE

# உயிர்ப்பாண்டியம்

# Questions

# Projections