Fungicide Resistance in Field Crops

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Fungicide world is changing!

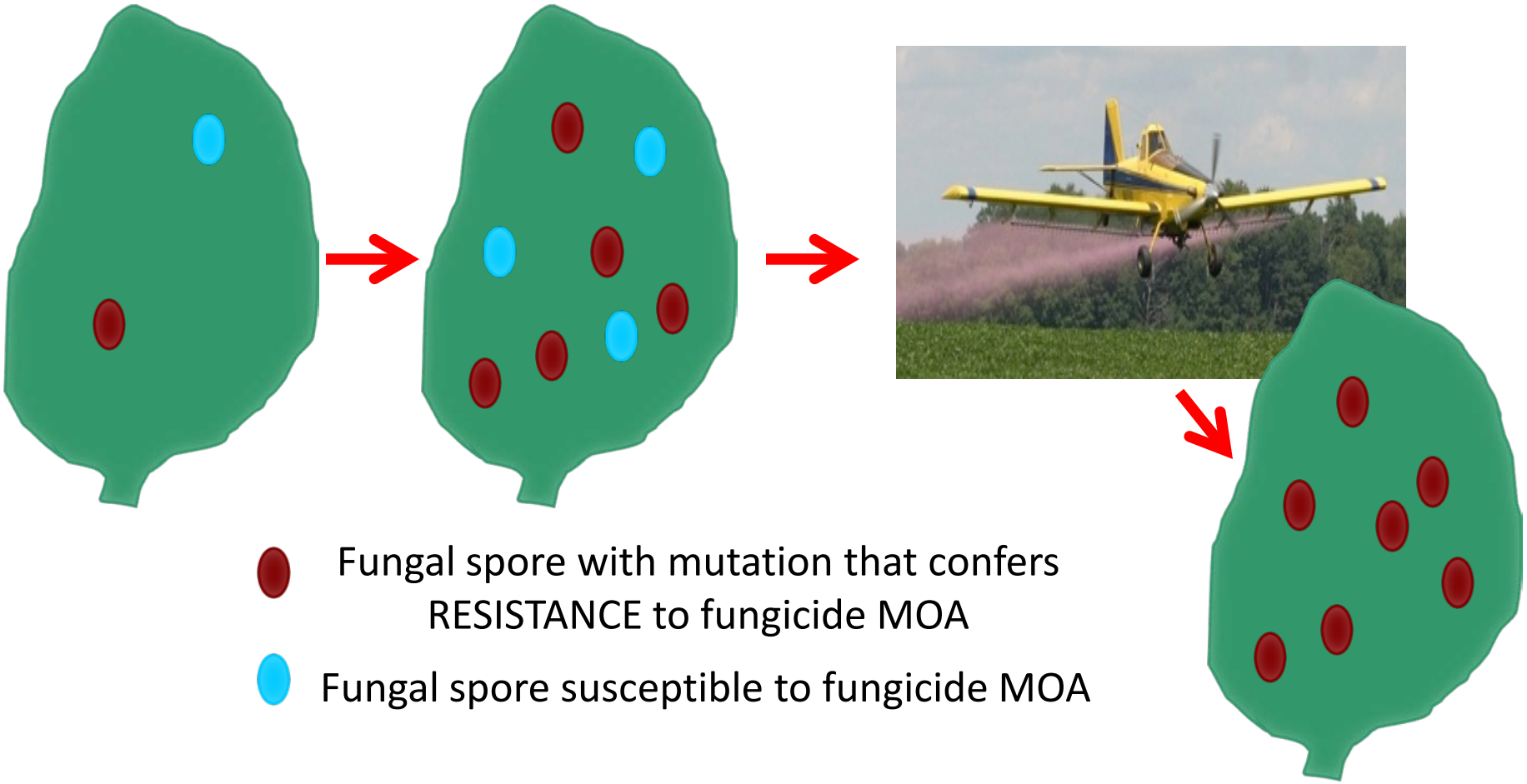
- More fungicides on market now
- Changing trade names but ingredients stay the same
  - Different rates
- Repackaging products
  - Similar to herbicide market
- No longer as simple as preventative vs. “curative”

Fungicide resistance development

Fungal spore with mutation that confers RESISTANCE to fungicide MOA

Fungal spore susceptible to fungicide MOA

Fungicide resistance development



Fungal spore with mutation that confers RESISTANCE to fungicide MOA

Fungal spore susceptible to fungicide MOA

When a fungal population is predominately RESISTANT to a fungicide MOA, chemical failures may occur

Risk of fungicide resistance

Fungicide resistance risk depends on TWO factors:

- Fungus (each is unique)
  - How the fungus reproduces (i.e., genetic diversity) and how quickly it reproduces
- Fungicide
  - Mode of action (MOA) single site vs. multi-site
  - Inherent risk of resistance associated with certain fungicide MOAs
  - Amount of selection pressure (# of sprays) and amount of fungus present at application

Risk of fungicide resistance

Seed production of some herbicide resistant weeds

- Kochia – 4,000 seeds per plant
- Wild oat – 200-2,000 seeds per plant

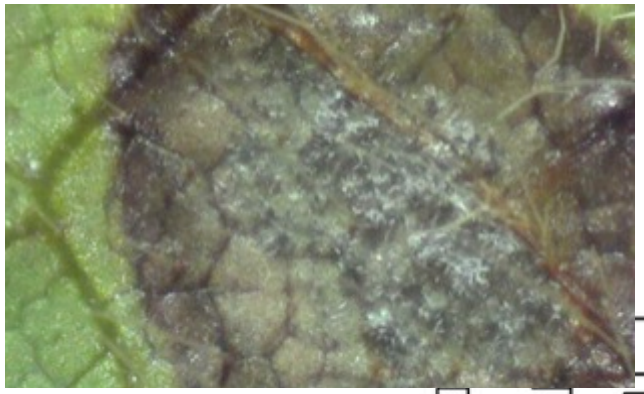
Example of a plant pathogen spore production

- 1,000+ spores can be produced from one rust pustule
- 64 billion spores produced on a barberry plant

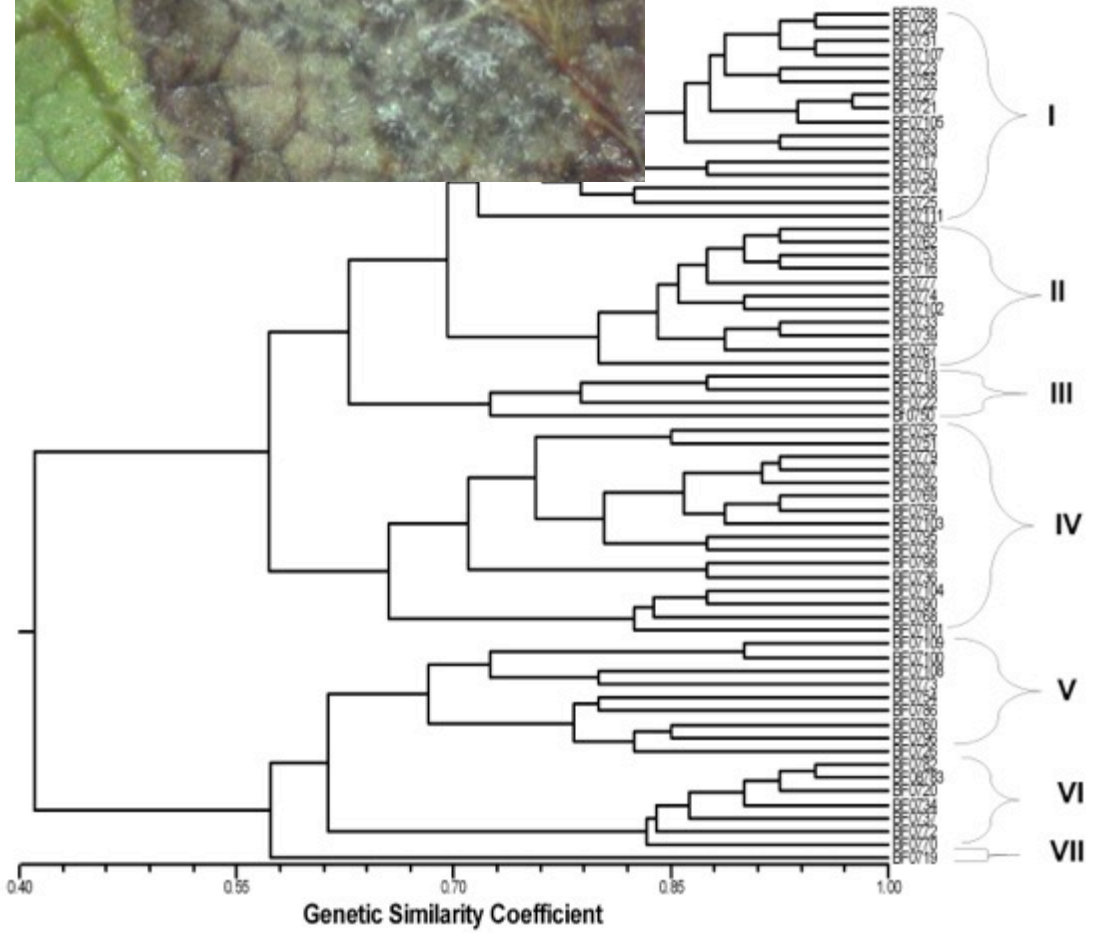

Farmers Academy – Yellow rust


IITA – Soybean rust

Risk of fungicide resistance



- Multiple infection sites on a plant
- Multiple infection events if conditions are favorable
- Fungicide-resistant biotypes already exist in nature!



Can. J. Plant Pathol 34:410-416

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Limited number of fungicide classes

- Foliar fungicides
  - 3 classes
- White mold
  - Few extra
- Seed treatment
  - Few extra

Fungicide resistance

Resistance risk varies by pathogen and fungicide class

- Triazole (FRAC 3) – Medium Risk
  - Resistance as been documented
  - Slower, more gradual development (shift)
- SDHI (FRAC 7) – Medium-High Risk
  - Resistance has been documented
  - Single mutation in fungus confers resistance
- Strobilurin (FRAC 11) – High Risk
  - Resistance reported in a number of other fungal pathogens in U.S. and internationally (>20 fungal species)
  - Single mutation in fungus confers resistance – G143A, F129L, G137R (single step, amino acid substitutions)
  - Some pathogens will not survive the G143A mutation (lower risk)
  - G143A mutation is stable and does not go away

Cross-resistance

- Fungi with reduced sensitivity to a group of fungicides may exhibit “cross-resistance”
- For example, if a fungus is resistant to one fungicide in the strobilurin group, it is likely resistant to ALL fungicides in the strobilurin group. Even if a certain fungicide a.i. was never sprayed!
- There is NOT cross resistance between strobilurin and SDHI fungicides

Fungicide failure

- Many reasons a fungicide may not work (examples)
  - Incorrect disease diagnosis
  - Improper mixing of fungicides
  - Sprayer not calibrated correctly
  - Application not at ideal timing
- Fungicide may not be effective against targeted disease
- Fungicide resistance

Known fungicide resistance

Disease	Pathogen	Host	Comments
Fusarium graminearum	Scab	Wheat	Triazole (2009, 2013)
Mycosphaerella graminicola	Leaf spot	Wheat	Triazole (2000), SDHI (lab, 1998), strobilurin (2003 and 2005)
Pseudocercosporella herpotrichoides	Eyespot	Wheat	Triazole (1991)
Puccinia striiformis	Yellow / stripe rust	Wheat	Triazole (2000)
Pyrenophora tritici-repentis	Tan spot	Wheat	Triazole (2005), strobilurin (2005)
Erysiphe graminis tritici	Powdery mildew	Wheat	Triazole (1986), strobilurin (2000)
Microdochium nivale	Head blight	Wheat	Strobilurin (2009)
Phaeosphaeria nodorum	Leaf blotch	Wheat	Strobilurin (2009)
Magnaporthe oryzae	Wheat blast	Wheat	Strobilurin (2014)
Zymoseptoria tritici	Septoria tritici blotch	Wheat	Strobilurin (2013)

Source: www.frac.info

Known fungicide resistance

Disease	Pathogen	Host	Comments
Pyrenophora teres	Net blotch	Barley	Triazole (2005), strobilurin (2007)
Rhynchosporium secalis	Leaf blotch, scald	Barley	Triazole (1986), strobilurin (2008)
Ustilago nuda	Loose smut	Barley	SDHI (1988)
Erysiphe graminis hordei	Powdery mildew	Barley	Triazole (1981), strobilurin (2000)
Ramularia colli-cygni	Necrotic leaf spot	Barley	Strobilurin (2006)
Ustilago maydis	Smut	Corn	Triazole (1981), SDHI (1991), strobilurin (2002) (all in lab)
Phakopsora pachyrhizi	Soybean rust	Soybean	Triazole (2008)
Cercospora sojina	Frogeye leaf spot	Soybean	Strobilurin (2011)
Cercospora kikuchi	Cercospora leaf blight	Soybean	Strobilurin (2014)
Septoria glycines	Brown spot	Soybean	Strobilurin (2014)

Source: www.frac.info

Frogeye leaf spot on soybean

- Can be found in all soybean growing areas, but *historically* more of a problem in southern regions
- Management:
  - Crop rotation
  - Plant high-quality seed and resistant cultivars (*Rcs3* gene is very effective)
  - **Foliar fungicides (strobilurin fungicides)**

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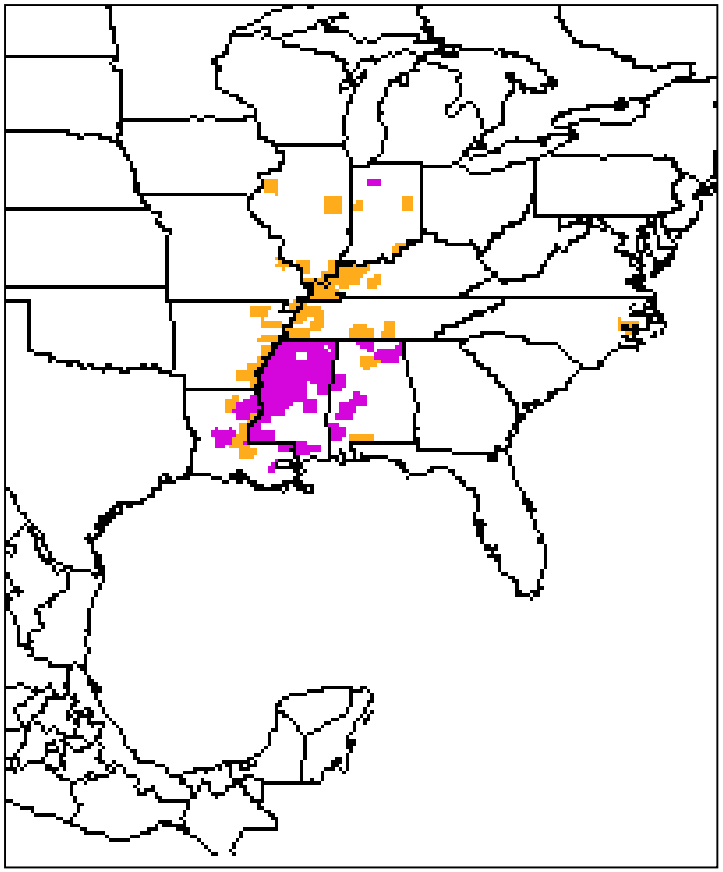
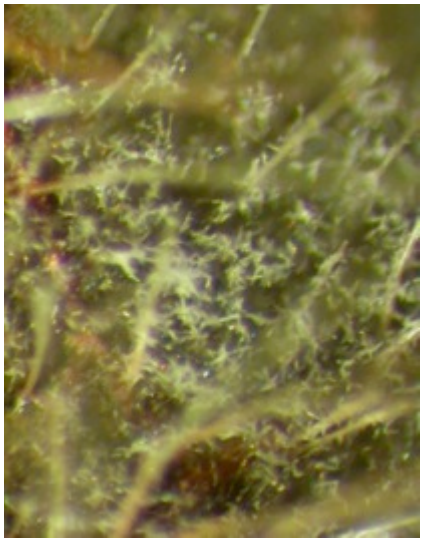
Frogeye leaf spot on soybean

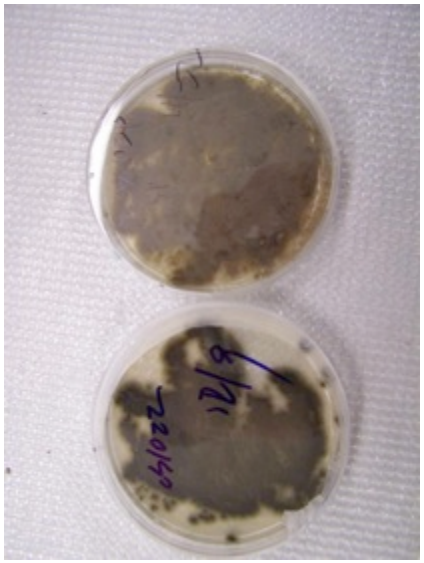
- Strains of *Cercospora sojina* resistant to strobilurin fungicides have been identified in several states

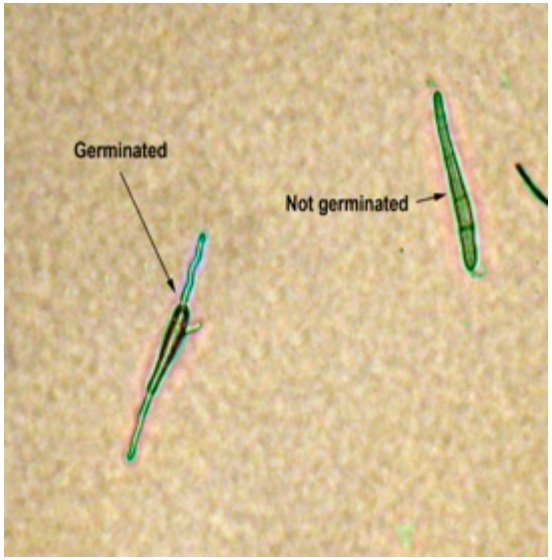


Frogeye leaf spot on soybean

- Collected isolates of *C. sojina* from fields that were applied with a strobilurin fungicide







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Field study with strobilurin - resistant strain of fungus

- 2012 and 2013
- Dixon Springs, IL
- Inoculate with a local strobilurin-resistant isolate on susceptible cultivar
- Applied foliar fungicide applications at R3
  - Solo strobilurin
  - Solo triazole
  - Strobilurin + triazole mixtures
  - Topsin M

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Fungicide trial – 2013 results

FRAC Code	Fungicide	Rate/A	FELS (%) [a]	Yield (bu/A)
--	--	--	40	50.2
1	Topsin 4.5L	20 fl oz	8	62.4
3	Proline	3 fl oz	13	57.1
3	Topguard	7 fl oz	13	55.4
3	Domark	5 fl oz	15	58.4
3 + 11	Stratego YLD	4 fl oz	34	55.2
3 + 11	Fortix	5 fl oz	13	59.3
3 + 11	Quadris Top	8 fl oz	11	59.9
3 + 11	Quilt Xcel	10.5 fl oz	17	59.0
11	**Quadris**	**6 fl oz**	**35**	**50.4**
11	**Headline**	**6 fl oz**	**38**	**49.1**
	LSD (0.05)		9	9.7

[a] Collected late August 2013, percentage of the leaf area affected in the upper third of the soybean canopy.

Carl Bradley, University of Illinois

Recommendations for management of frogeye leaf spot

- Plant a resistant variety
- Apply products that contain mixtures of a.i.s that are effective in controlling frogeye leaf spot and are from different fungicide classes (different MOAs such as triazole or MBC)
- Fungicide resistance management

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Fungicide resistance management

- Minimizing selection pressure is key in prolonging the effectiveness and lifespan of a fungicide.
  - Use resistant varieties and cultural practices to help manage diseases
  - Apply foliar fungicides to manage diseases only when warranted considering scouting and disease risk factors.
- Use fungicides early in disease development (i.e., spray fungicides preventatively) in response to predicted disease threat
- Avoid solo applications of single site MOA fungicides (especially strobilurins)
  - Fungicides from different FRAC groups can be alternated or possibly mixed to reduce the selection pressure being placed on fungal populations.
  - Do not let mixed modes of action lure you into a false sense of security
- Do your homework on fungicides
- Know the pathogens

Products vary in effectiveness

					G	VG	F	VG	U	VG-E	G	R5 (beginning seed)
MBC Thiophanates Group 1	thiophanate-methyl	Topsin-M® multiple generics	10.0-20.0	U	U	U	F	VG	U	G	G	21 days
SDHI Carboximides Group 7	boscalid 70%	Endura 0.7 DF®	3.5-11.0	U	NL	VG	U	P	NL	NL		

PURDUE EXTENSION

Resistance risk is unique to fungus

Gray leaf spot

Cercospora zeae-maydis

Frogeye leaf spot

Cercospora sojina

Disease still matters

Corn yield response to strobilurin fungicides from 2008 to 2010, as determined by data submitted to the regional corn fungicide summary of the Corn Disease Working Group. Data are pooled across all treatments that included a strobilurin fungicide applied between V15 and R3 growth stages. Data include only trials where disease severity ratings were submitted.

Disease severity of untreated (%)	Mean yield response (bu/acre)	Total treatments	Percent of treatments with break-even yield response of 6 bu/acre
< 5	1.5	347	31.6
> 5	9.6	266	59.0
Total		613	

Wise and Mueller (2011), www.apsnet.org/publications/apsnetfeatures/Pages/fungicide.aspx

Scout diseases post-application

- If you spray fungicides when diseases are present or risk is high, scout afterwards to assess how well fungicides worked.

Factors that may affect response to fungicide

• Foliar diseases (i.e., scouting)	Factor that can be determined
• Cultivar selection • Previous crop • Surface residue • Production practices (e.g., irrigation)	Factors that can affect disease
• Product and additives • Application timing	Factors that affect fungicide efficacy
• Economics • Weather conditions • Plant pathology in the news	Factors that you can weigh from the air conditioning

Questions?

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