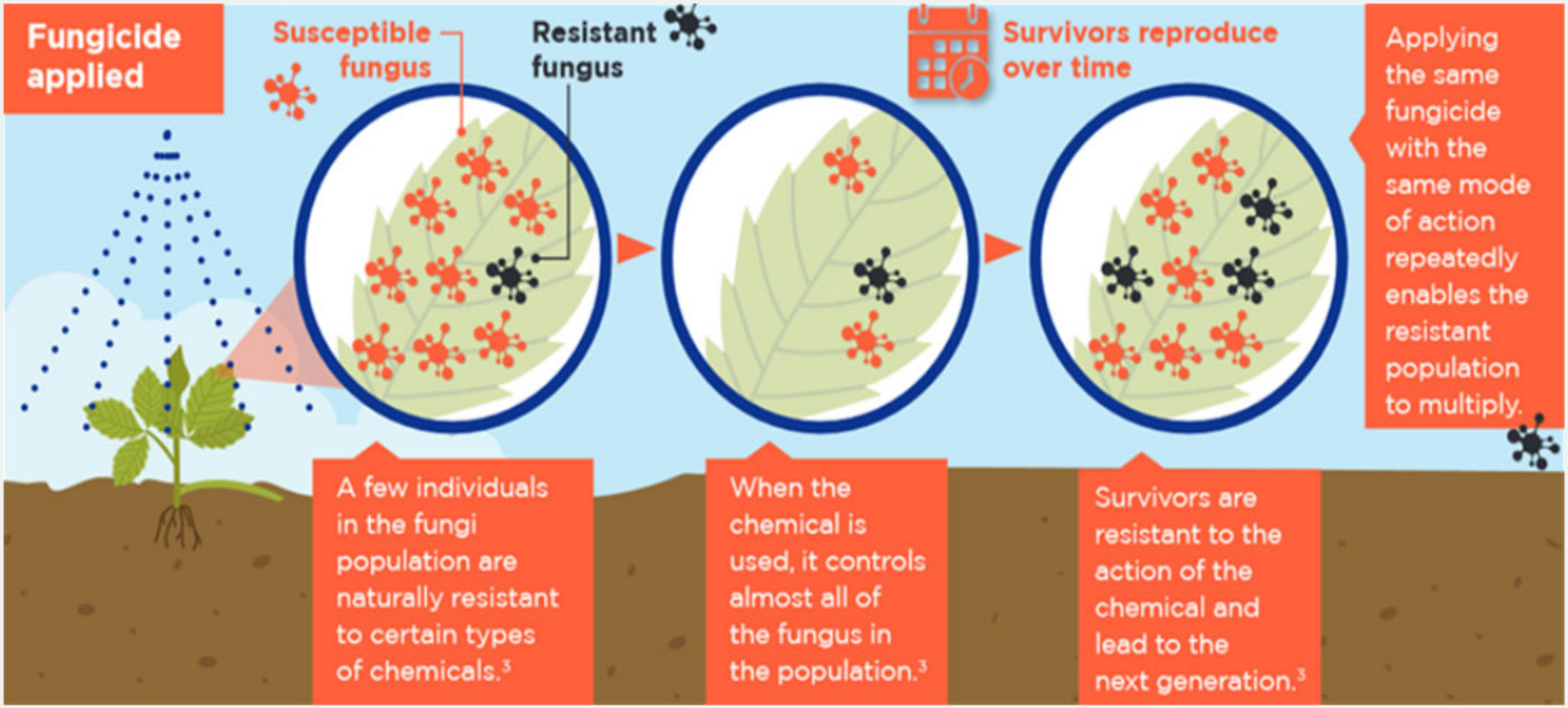
The Basics of Pesticide Resistance Management

GRANTLY RICKETTS

UF/IFAS EXTENSION /ST LUCIE COUNTY DIRECTOR/COMMERCIAL HORTICULTURE AGENT,

How does Fungicide Resistance evolve?



Quiz

- Your new customer plants are infected with Alternaria and the former landscaping company was unable to get the disease under control. Which chemicals would you rotate?
- Compass
- Heritage
- Emblem
- Eagle

Answer

- Compass- AI is Trifloxystrobin- Group 11
- Heritage– AI is Azoxystrobin – Group 11
- Emblem- AI is Fludioxonil- Group 12
- Eagle – AI is Myclobutanil- Group 3

What we will cover….

- What's in a name?
  - Chemical name
  - Common names
  - Trade names
- What about "generics"?
- Resistance management and FRAC guidelines
- Fungicides: application methods & timings
  - Strategies
  - Considerations
  - Efficacy

What is a fungicide?

Fungicide

Any chemical that control fungus.

Fungicides are used to manage plant diseases caused by fungus

Actually most fungicides are fungistats which inhibit the target fungus.

HeritageMaxx® Fungicide

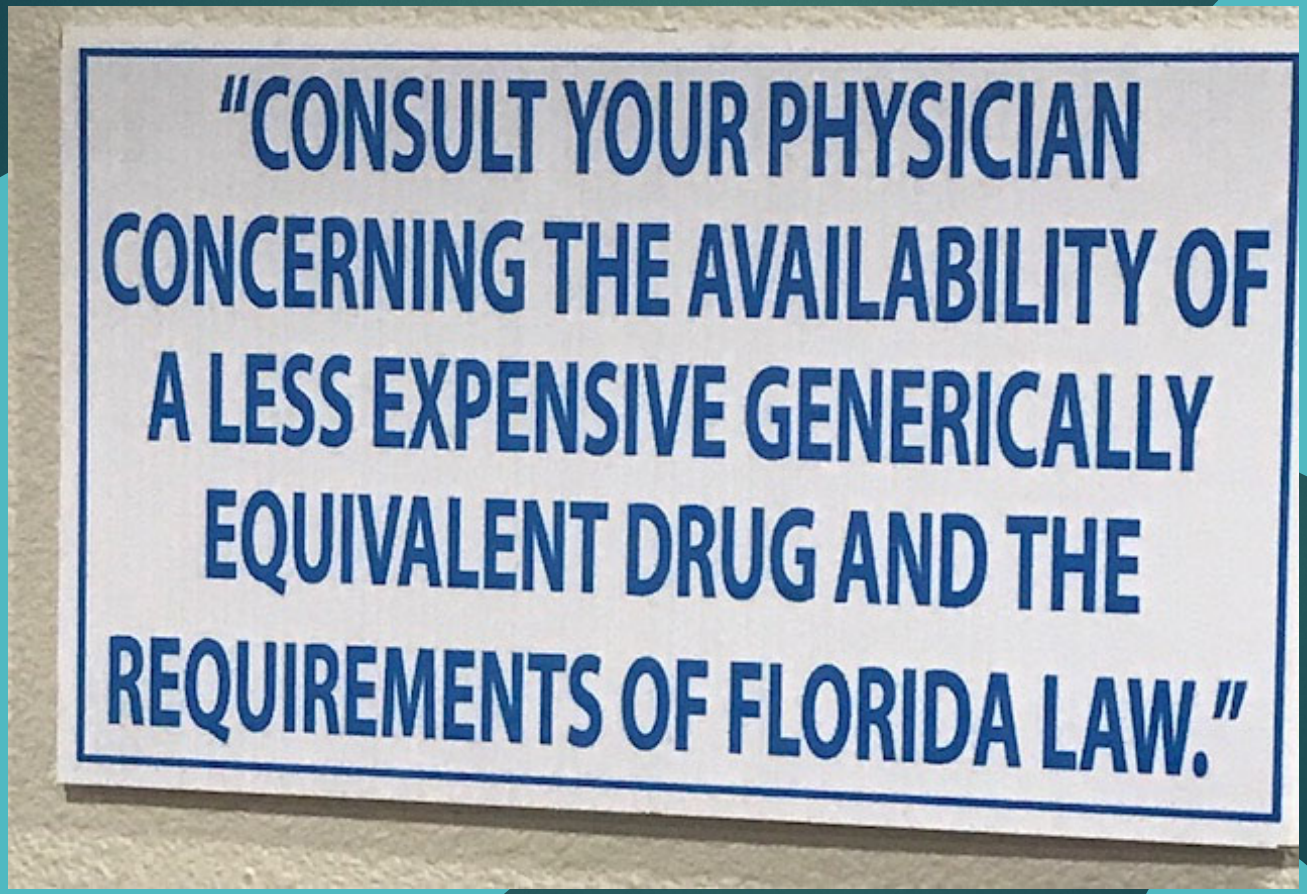
Nomenclature

- All fungicides have 3 names:
  - Chemical name: by internationally sanctioned authority.
  - Common name: assigned by committee; based upon standards, much less complex.
  - Trade name: assigned by the manufacturer; the name used for marketing.
- These names can be found on the label.
- Different fungicide products may have same common name of active ingredient.

Nomenclature

- Examples :
  - Chemical name:Methyl (E)-2-{2-[6-(2-cyanophenoxy) pyrimidin-4-yloxy]phenyl}-3-methoxyacrylate)
  - Common name:azoxystrobin
  - Trade name:
    - Heritage
    - Abound
    - Bankit
    - Quadris

What about Generic Products?



Generic Products

- Different fungicide products may have same common name or active ingredient.
- In such cases, legal protection for the registered active ingredient has expired.
- The basic manufacturer no longer has exclusive rights.
- Companies that specialize in formulating products acquire the off-patent (generic) compound and produce their own products with different trade names.
  - Chlorothalonil, propiconazole, tebuconazole metalaxyl

Generic Products

- Generic products tend to be more economical than brand name products.
- Generic products may not have been separately evaluated for disease control efficacy.
- Generic products are PRESUMED to be similar in disease control efficacy to their brand name counterparts.
- Minor variations in efficacy, behavior, or even phytotoxicity may occur due to formulation differences.
- Do not assume labels of generic products are exactly the same as name-brand products

Fungicide Formulations

- **Formulation**:
  - Is the mixture of active and inert ingredients in a fungicide and it describes the physical state (solid or liquid) of the product.

- **Pesticide applicators should have a sound understanding of pesticide formulations**:
  - To use chemicals effectively.
  - To prepare themselves for questions from workers
  - Those who can explain the characteristics and advantages of products instill confidence that products are being used correctly.

Fungicide Formulations

- **Active ingredient (AI)**:
  - The part of the chemical that acts to control the fungus.
- **Inert ingredients**: essential!
  - Combined or "formulated" with active ingredients
  - Improve fungicide performance.
  - Lessen risk of phytotoxicity.
  - Inert can make the difference b/w 2 fungicides with the same active ingredient.

Formulation

- The Carrier, such as an organic solvent
- Surface-active ingredients, such as stickers and spreaders
- Other ingredients such as stabilizers, dyes and chemicals that improve activity
- Note: A single AI may be sold in several formulation

Fungicide Formulations

- **DRY**:
  - **WP** (wettable powder).
  - **WSP** (water-soluble packet).
  - **G** (granule).
- **Liquid**:
  - **EC** (emulsifiable concentrate). Oil based liquid
  - **EW** (emulsion in water).
  - **SE** (suspoemulsion).
  - **ME** (microemulsion).
  - **F** (flowable). Finely ground, dry particles suspended in water
  - **SC** (suspension concentrate)

Formulation

- The amount of AI and the kind of formulation are listed on the product label.
- For example, an 80 percent soluble powder (SP) contains 80 percent by weight of AI. If the fungicide is packaged in a 10-pound bag, it contains 8 pounds of AI and 2 pounds of inert.
- Liquid formulations indicate the amount of AI in pounds per gallon. For example, 4F means 4 pounds of the AI per gallon in a flowable formulation.

Fungicide Resistance

- **Fungicide resistance occurs when a pathogen population changes from one that is sensitive to an active ingredient to one that is no longer sensitive**:
  - This genetic difference is passed on to the next generations.
  - The most important consequence is the loss of a good product

How Fungicides Work

- Fungicides damage or prevent specific processes in the fungus that are required for life (damage fungal cell membranes or interfere with energy production)

A genetic difference may protect the fungus from getting damage

History of fungicide resistance in plant pathogens

- few, sporadic cases before 1970
- incidence increased rapidly after introduction of site-specific systemic fungicides
- incidence of fungicide resistance has continued to increase since the 1970s
- many older non-specific compounds have maintained their effectiveness despite extensive use

Fungicide Resistance

- Older fungicides were less prone to resistance but were not as safe and effective as newer fungicides.
- Older fungicides affect a number of different metabolic sites within the fungus so fungicide resistance has never been a concern.
- Most new fungicides affect one specific site in one metabolic pathway of the fungus

FRAC

- FRAC (Fungicide Resistance Action Committee)
- **Fungicides sorted by mode of action**
- Assigned Numbers and letters are used to distinguish the fungicide groups according to their cross-resistance behavior.

FRAC Resistance Groups

- **43** fungicide resistance groups identified, though the most common fungicides fall in about 11 groups.
- Cross-resistance expected for fungicides within the same group.
- Resistance groups displayed on the fungicide label.
- 3 letter designations:
  - **P**: plant defense activator
  - **M**: multi-site inhibitors
  - **U**: compounds of unknown mode of action and resistance risk

FRAC

- **Examples**:
  - **11** strobilurins: azoxystrobin, pyraclostrobin).
  - **M** (chlorothalonil, mancozeb).
  - **3** (DMI: tebuconazole, propiconazole).
  - **1** (benzimidazole: thiophanate methyl).
  - **7** (carboxamide: boscalid, flutolanil).
  - **14** (aromatic hydrocarbon: chloroneb).
  - **U**(fosetyl aluminum).
  - **2** (dicarboximide: iprodione).
  - **4** (phenylamide: mefenoxam)

AI	TRADE NAMES	FUNGICIDE RESISTANCE GROUP	RESISTANCE RISK
azoxystrobin	Heritage	**11:** QoI	High
boscalid	Emerald	**7:** SDHI	Medium
chlorothalonil	Concorde, Daconil, Echo, Manicure	**M5:** Chloronitriles	Low
cyazofamid	Segway	**21:** QiI	Unknown, but assumed to be Medium to High
myclobutanil	Eagle, Golden Eagle	**3:** DMI	Medium
fluoxastrobin	Disarm	**11:** QoI	High
thiophanate-methyl	Cavalier, Cleary's 3336	**1:** MBC	High

Mode Of action

Examples of Mode Action:

1. nucleic acids synthesis -
2. Cytoskeleton and motor proteins
3. respiration
4. amino acids and protein synthesis
5. cell wall biosynthesis
6. host plant defense induction
7. Chemicals with multi-site activity

Fungicides

- Fungicides are not “magic”.
  - To understand resistance, you should understand how fungicides work.
  - Better understanding leads to better selection and more effective use of fungicides.
  - Better understanding leads to STRONGER SUPPORT of fungicide resistance management.

Fungicide Categories

TURF FUNGICIDES DIVIDED INTO 4 CATEGORIES BASED ON LOCATION OF THEIR ACTIVITY;

CATEGORY 1- CONTACT FUNGICIDE

CATEGORY 2- SYSTEMIC FUNGICIDE

CATEGORY 3- LOCAL- PENETRANT FUNGICIDE (PENETRATE PLANT SURFACE BUT ONLY MOVE SHORT DISTANCE

CATEGORY 4- MESOSTEMIC (EG. COMPASS)

ABSORB IN WAXY LEAF

Fungicide Characteristics

- Non-systemic (contact) - does not penetrate the plant; redistribute through vapor phase and rainfall.

- Protectant - applied preventively; acts on spore germination to early infection (penetration of host tissues), no disease symptoms develop. Must be used often for best results.

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Fungicide Characteristics

- Systemic (penetrant)- moves into plant, mostly redistributes towards plant apex or leaf margins (acropetal movement).
  - Acropital (xylem-mobile), Local (diffuse in waxy layer), Sytemic (moves through living cells)
- Curative - acts on post-infection, pre-symptomatic phase.
- Eradicant - stops host colonization after symptoms develop

Protectant Fungicides

- Must be applied **before** infection occurs
- No curative activity
- Apply to leaf and stems

- Contact active only if pesticide remain on plant surface.
- Usually last 7-14 days

Systemic Fungicides

- Apply every 21-30 days
- Best applied as protectants before infection occurs
- Systemics absorbed and move into plant system
- Offer limited curative activity

Other Protectant Fungicides

- Cyazofamid- Interefere with cell division which stop the formation of pores and mycelium growth of fungus- ex. Segway. Good at controlling Pythium problem
- Chlorothalonil disrupts respiration and glycolysis. Multisite compound.
  - Daconil Zn
- Fluazinam (Secure) respiration inhibitor; good on dollar spot.

Benzimidazoles Family (Code1)

- Systemic protectant/curative fungicides
- Inhibits mitotic spindle formation
- Effective on many fungi : -
  best on Ascomycetes (*Cercospora* and *Colletotrichum*) and Deuteromycetes (*Botrytis* and *Fusarium*)
- Not effective on water molds like *Pythium*

Ex: benomyl (Benlate), thiophanate methyl (Cleary's 3336, T methyl Pro, T-Storm)

Resistance is a problem (systemic likely high resist).

Examples of Demethylase Inhibitors (DMI's) Family. FRAC Code 3

systemic (upward) fungicide

- The development of resistance to this family of fungicides is a serious problem.

Examples of DMIs

- Myclobutanil- Eagle
- Triademefon- Bayleton, Accost
- Triticonazole- Trinity

Strobilurins Family. FRAC 11

- Systemic protectant fungicides
- Respiration inhibited by blocking electron transport

- Broad spectrum
- Many examples:
  - azoxystrobin (Abound, Quadris, Heritage)
  - trifloxystrobin (Compass)
  - pyraclostrobin (Insignia)

- Resistance a problem!!!!!

Fungicide Resistance

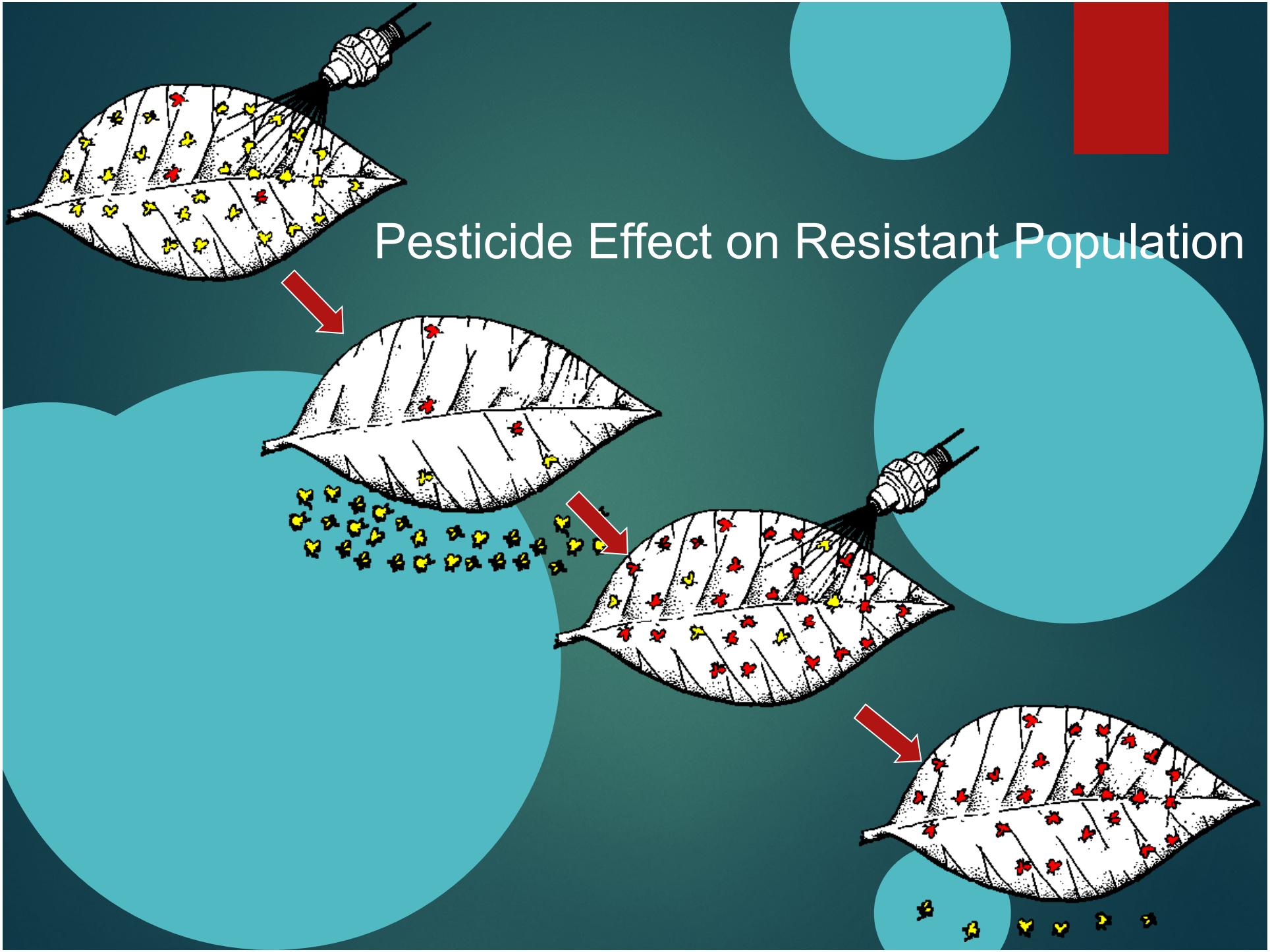
Question

- Which fungicide is from the same group and should not be rotated with each other
  - a. Heritage and Eagle
  - b. Dithane and Protect
  - c. Bayleton and Disarm
  - d. Trinity and Cleary's 3336

Answer

- Which fungicide is from the same group and should not be rotated with each other
  - a. Heritage and Eagle (11, 3)
  - b. Dithane and Protect (M3, M3)
  - c. c. Bayleton and Disarm (3, 11)
  - d. Trinity and Cleary's 33 (3, 1)

Pesticide Effect on Resistant Population



Cross resistance

Fungicides active at the same target site (i.e. within the same FRAC code #) are generally considered to be cross-resistant to each other.

Pathogen populations that develop resistance to one fungicide automatically and simultaneously become resistant to other fungicides. **Cross-resistance** occurs when resistance arises to one fungicide that also results in resistance to another fungicide

Multiple resistance

- pathogen populations that develop resistance to two or more unrelated fungicides, arising from independent mutations that are selected by exposure to each of the fungicides concerned

4 ways Fungus build up Resistance

- Fungus change target site so that sensitivity to the fungicide is reduced (During DNA Replication mutation occurs)
- Detoxification of the fungicide- This metabolic machinery may be able to modify the fungicide to a non-toxic form
- Overexpression of the target-The production of new target site enzyme
- Exclusion or expulsion from the target site-The fungicides expelled from the cell

Not always Resistance

- Loss of relative efficacy of a chemical is not necessarily proof of resistance, low performance can caused from:

  - breakdown of the pesticide by soil microorganisms
  - high pH of spray water
  - poor pesticide application procedures.

Risk factors associated with fungicide resistance:

Fungicide risk

- mode of action - MOA (single-site vs. multi-site)
- frequency of use (application interval)
- use patterns (number of applications, total amount applied)

Pathogen/disease risk

- pathogen reproduction (rate, sexual vs. asexual)
- dispersal mechanism
- number of disease cycles per season (monocyclic vs. polycyclic)
- mutation rate

Resistance Management

- Other modes of action

  -companion fungicides

  -alone or in mixtures

- Timely applications

  -use forecasts if available

Koller, W. and Scheinplung, H. 1987. Plant Dis. 71:1066-1074.

Resistance Management Strategies

- resistance management will ***delay***, but not prevent, development of resistance

1. *always use at-risk fungicides in combination with chemically unrelated fungicides (different MOAs), preferably with low risk*

- alternate single applications of unrelated fungicides

H – L – H – L – H – L – H – L

- alternate "blocks" of unrelated fungicides

H – H – L – L – H – H – L – L

- apply tank mixtures of unrelated fungicides (Note: both components of the mixture should be applied at effective concentrations)

H/L – H/L – H/L – H/L – H/L – H/L

2. *restrict the number of applications and/or total amount per season, and apply only when necessary*

- a restriction on the total number of applications and/or amount that can be applied per acre per season is often specified on the label
- use disease forecasting systems, if available, to eliminate unnecessary fungicide applications

3. *maintain manufacturers recommended application rate*

- reducing the rate below label recommendations can result in reduced disease control and encourage development of resistance, especially for quantitative-type resistance

4. *avoid eradicant (post-infection) use*

- applying fungicides before infections are established when pathogen populations are smaller, will expose fewer individuals to selection by the fungicide

5. *practice integrated disease management*

- using various cultural means and other non-chemical disease control measures will reduce fungicide selection pressure on the pathogen population

6. *maintain chemical diversity*

- maximize use of fungicides with different MOAs
- use less effective, lower-risk fungicides when disease pressure is low and save most effective, higher-risk fungicides for when disease pressure is high.

Resistance Management

USE multiple modes of action!

- avoid over-using one chemistry in a program
- use companion fungicides

Make timely fungicide applications!

Guidelines for nozzle tip maintenance

- Observe the output pattern frequently during use:
  - Foreign particles can disturb uniformity of spray pattern.
- Remove nozzles and clean tips regularly
- When cleaning nozzles, use clean water & detergent.
- Gently rub surfaces with a soft-bristle brush to remove residues.
- Use compressed air to remove obstructions from nozzle orifice.

Some reasons why fungicides fail

1. Problem not properly identified
2. Weather favors disease
3. Timeliness of application
4. Planted less resistant variety
5. Inadequate fungicide program
   - Too-few applications
6. Poor fungicide choice
   - Needed soilborne fungicide
   - Needed systemic activity
7. Improper coverage (pressure & volume)
8. Improper calibration
9. Using the same fungicide over and over.

Take Home Message

- Fungicide resistance is a serious problem
- Pay attention to FRAC groupings for fungicide program
- Rotate with fungicides from different groups

- Applying treatment without proper diagnoses is mal-practice
- Use your local extension service

Take Home Message

- Utilize as many resistance management strategies as possible such as:

a. Practice non-chemical control methods (Cultural)

b. Tank mix and/alternate appropriate fungicides

c. Limit number and timing of fungicide treatments

d. Maintain recommended dosage and ensure even coverage

Credits

- http://www.frac.info
- Dr. Bob Kemerait, UGA Extension