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#### Using Fungicides More Effectively: Understanding Mode of Action and Other Characteristics



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#### **Fungicide Basics**

- Fungicides are pesticides that specifically kill fungi or inhibit fungal development
- About 40 different classes of fungicides used for plant protection
- Classes are based on target site and biochemical mode of action



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### **Multi-site Inhibitors**

- Many work by breaking the molecular bonds that hold proteins together
- Others smother or otherwise physically damage the fungus











#### **Single-site Inhibitors**

- Affect a spe metabolic process
- Bind to prote Substant via "lock and key" process





Enzyme-substrate complex fits like a key into a lock

Products and unchanged enzyme



## **Single-site Inhibitors**

- Amino Acid and Protein Synthesis
  - > Anilinopyrimidines
- Sterol Biosynthesis
  - > DMIs
- Respiration (MET complex III)
  - > Qols
- Osmoregulation (unknown)
  - > Phenylpyrroles

- Lipid Biosynthesis
  - Sub. Aromatic Hydrocarbons
  - > Dicarboxymides
- mRNA Synthesis
  - Phenylamides
- Nuclear Division
  - Benzimidazoles
    Respiration (MET
- complex II)
  - Carboxins



#### Systemicity Non-systemic



- > Do not penetrate into plant
- Redistribute on plant surfaces
- Multi-site inhibitors
- Kills spores/inhibits germination
- Protectant only
- Broad spectrum

#### **Systemic**



- Penetrate into plant
- Redistribute on & within plants
- Single-site inhibitors
- Inhibits spore germination and or mycelial growth
- Protectant and curative
- Selective



#### **Non-systemics**

- Mimimal redistribution from the point of deposition
- Works by contact with the fungus
- Adequate coverage is essential
- > On the cuticle
- Redistributed washed off by water



## **Systemics**

- Local Systemic
  - Local redistribution from the point of deposition
  - On the cuticle
  - Through the leaf (translaminar)
  - Extent is variable





# **Systemics**

- Limited systemic (acropetal penetrant)
  - Good movement from the point of application
  - Through tissues
  - Inside the vasculature
  - Bulk movement
  - DMIs, Phenylamides



## **Systemics**

- True Systemics (Basipetal penetrant)
  - Only phosphonates
  - Moves through plant
  - Down into roots
  - Good against soil-borne oomycetes



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### **Physical Mode of Action**



Fungicides tend to work best against spore germination and formation, and are less effective against mycelial growth inside the plant



#### **Selection for Resistance**

The development of *Practical Resistance* is a step-wise process



Survivor Population



#### **Cross-Resistance**

- Once resistance develops to a fungicide all fungicides with the same biochemical mode of action are affected
- "Cross-resistance class" is defined as a class of fungicides that share the same biochemical mode of action and mechanism of resistance
- Example: all DMI fungicides
  - > all affect sterol biosynthesis
  - > a change in the fungal enzyme affects all DMIs





# Fungicide Group M Multi-site fungicides

"Old but reliable workhorses"



# **Group M**

- All "contact" fungicides with a non-specific mode of action are represented in this class
- Coppers
- Mancozeb
- Chlorothalonil
- Bicarbonates
- > Oils
- Sulfur



# **Group M**

- Pros
  - Inexpensive
  - Moderate range of activity depending on AI
  - No resistance risk
- Cons
  - Foliar diseases only
  - Short application intervals





### Group 1 Fungicides Methyl Benzimidazole Carbamates

"Broad spectrum vs Ascomycetes and Basdiomycetes but beware of resistance"



#### **Group 1: Benzimidazole Fungicides**

Inhibit nuclear division during cell replication by binding to beta-tubulin





#### Group 1: MBC (Benzimidazole) Fungicides

- > Broad spectrum of activity
  - Ascomycetes (Botrytis, Powdery Mildew, Leaf Spots)
  - Basidiomycetes (Rhizoctonia, Rusts)
- Systemic, acropetal penetrant fungicides
- Curative abilities
- Thiophanate-methyl Clearys 3336



#### Group 1: MBC (Benzimidazole) Fungicides

- Pros
  - Broad spectrum of activity vs ascomycetes and basidiomycetes
  - Systemic acropetal penetrant activity
  - Lasting residual activity & long application intervals
- Cons
  - Not effective vs. Oomycetes
  - Development of resistance for some diseases





# Group 2 Fungicides Dicarboximides

"Proven chemistry for Botrytis and Rhizoctonia"



#### **Group 2: Dicarboximides**

- Function by inhibiting osmotic regulation pathways in fungi (os-2)
- Local penetrant fungicides
- Iprodione Chipco 26019



#### **Group 2: Dicarboximides**



#### Treated

Untreated



#### **Group 2: Dicarboximides**

- Pros
  - Strong vs Botrytis & Rhizoctonias
  - Control of leaf spots
  - Good vs Fusarium but not 100% effective
- Cons
  - Local penetrant activity only
  - No powdery mildew activty
  - No Oomycete activity
  - Some tolerance present in Botrytis





#### Group 3 Fungicides Sterol Demethylation Inhibitors

"Good enough for my feet and many Ascomycete and Basidiomycete diseases"



### **Group 3: DMI Fungicides**

- Inhibit demethylation of ergosterol used in cell membranes
- Called SBI, SI or DMI fungicides
- Widely used for plants, animals and medical purposes
- Systemic, acropetal penetrant fungicides
  - Fenarimol Rubigan
  - Myclobutanil Hoist
  - Propiconazole Banner MAXX
  - Triadimefon Strike
  - Triflumazole Terragaurd







# **Group 3: DMI Fungicides**

- Pros
  - Strong vs powdery mildew, Rhizoctonia, rust and some leaf spots
  - Good curative activity & lasting effects
- Cons
  - Some plant growth regulator effects at high rates or high temperatures
  - Limited activity vs Botrytis
  - No activity vs Oomycetes





#### Group 4: Phenylamides

"Your Oomycete specialist"



#### **Group 4 : Phenylamides**

- These are
  Ooymcete specific
  fungicides
- Mefenoxam -Subdue MAXX
  - Inhibits RNA polymerase and protein synthesis





#### **Group 4 : Phenylamides**

- Pros
  - Very effective vs Pythium, Phytophthora, and Downy Mildews
  - Strong protectant and curative activity
- Cons
  - Does not work against Ascomycetes & Basidiomycetes
  - Resistance likely if over used





#### Group 7 Fungicides Succinate Dehydrogenase Inhibitors

"A growing class of fungicides with a diverse spectrum of activity"



## **Group 7: SDHI Fungicides**

- Affect mitochondrial respiration by binding to succinate dehydrogenase in complex II
- Different fungicides in this group that share the same mode of action but have very different ranges of activity
- Flutolanil Rhizoctonia
- > Boscalid Botrytis & powdery mildew



## **Group 7: SDHI Fungicides**

- Use in nursery/floriculture is "limited" at this time
- Boscalid + pyraclostrobin is the 'Pageant' combination
- Expect more SDHIs to be coming in the market





# Group 11 Fungicides Qo-Inhibitors

"Broad-spectrum strobies + narrow range non-strobies in the same class"



#### **Group 11: Qo-Inhibitors**

- Two distinct groups of chemicals that target mitochondrial respiration
- Strobilurins
  - Azoxystrobin (Heritage)
  - Kresoxim-methyl (Cygnus)
  - Pyraclostrobin (Insignia)
  - Trifloxystrobin (Compass)
- Non-strobilurins
  - Fenamidone (Fenstop)





#### **Qol Class of Chemistry**





#### **Group 11: Qo-Inhibitors**

- Qols shut down respiration in mitochondira
- Strongest vs. spore germination
- Some have stronger curative or systemic properties than others





## Group 11: Qols

#### Pros

- Broad spectrum vs all fungal classes for some strobies
- Systemic, local to acropetal penetrant activity
- Lasting residual activity & long application intervals
- Cons
  - Fenamidone only good vs. Oomycetes
  - Less systemic fungicides not very good for root infecting and soil fungi
  - High risk resistance for some diseases





# Group 12 Fungicides Phenylpyrroles

"Nature's gift vs. Botrytis, Fusarium & Rhizoctonia"



### **Group 12: Phenylpyrroles**

- Function by inhibiting osmotic regulation pathways in fungi (os-1)
- Derived from a natural product derived from a soil *Pseudomonad*
- Local penetrant fungicide
- Good soil stability
- Fludioxonil (Medallion)

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#### Treated

#### Untreated



# **Group 12: Phenylpyrroles**

- Pros
  - Strong vs Botrytis, Fusarium & Rhizoctonias
  - Good soil stability
- Cons
  - Local penetrant activity only, strongest as a preventive application
  - No activity vs. Oomycetes, powdery mildew or rusts





# Group 14 Fungicides Aromatic Hydrocarbons



#### **Group 14: Aromatic Hydrocarbons**

- Chemically similar but different range of activity
  - PCNB: Rhizoctonia & Sclerotinia, some Botrytis activity for stored bulbs
  - Etridiazole (Terrazole): Pythium and Phytophthora only
- Affects lipid (membrane) synthesis
- Non-systemic



#### **Group 14: Aromatic Hydrocarbons**

- Pros
  - Good control of soil borne diseases
- Cons
  - Possible long term restriction on PCNB use due to contaminant toxicity issues
  - Limited activity of etridiazole
  - Contact only, best as a preventive application





#### Group 17 Hydroxyanalides

"Your neighborhood Botrytis specialist"



# **Group 17: Hydroxyanalides**

- A sterol-biosynthesis inhibitor with a different site of action than the DMIs
- Fexhexamid (Decree)
- Systemic and curative properties
- Works great vs. Botrytis, but almost nothing else other than Botrytis
- Some activity vs. powdery mildew but not a selling point





# Group 19 Fungicides Polyoxins

"Smells like Ramen – works great vs Rhizoctonia, and has Botrytis and mildew activity"



### **Group 19: Polyoxins**

- Function by inhibiting cell wall (chitin) synthesis
- Developed originally as a Rhizoctonia fungicide from natural products derived from Streptomyces soil microbes
- Local penetrant fungicide
- Polyoxin-D (Veranda O)



### **Group 19: Polyoxins**

#### > Pros

- Strong vs Rhizoctonias
- Good activity vs Botrytis & some powdery and downy mildews
- Cons
  - Local penetrant activity only
  - Does not control Pythium, Phytophthora, rusts and certain mildews





#### Group 21 Qi-Inhibitors

"The inside pocket Oomycete fungicide"



## **Group 21: Qi-Inhibitors**

- Affects mitochondrial respiration; same enzyme as the Qols, but on the "inside" binding site
- Systemic and curative properties
- Cyazofamid (Segway)
- Only affects Oomycetes





#### Group 33 Fungicides Phosphonates

"Oomycete fungicides that can go up & down inside the plant"



#### **Group 33: Phosphonates**

- > Unknown mode of action
- Unique that they can move upwards and downwards
- Active vs. Pythium, Phytophthora & downy mildews
- Fosetyl-AI (Aliette, Signature)
- Phosphite salts (Alude)





#### Group 40 Carboxylic Acid Amine (CAA) Fungicides

"The downy mildew & Phytophthora specialist"



#### **Group 40: CAA Fungicides**

- Inhibit cell wall formation
- Systemic and curative properties
- Highly effective vs. downy mildews and Phytophthora – no Pythium activity
- Dimethomorph (Stature)





# Combination Fungicides

"Multi-purpose in a jar"



### **Combination Fungicides**

- Mixtures combine the effectiveness of different fungicides for broad-spectrum activity
- Useful and avoids having to tank-mix
- > Know the properties of the tank mix partners
- Anti-resistance strategy?
- Sort of still have to worry about overuse of single-site partners



### **Combination Fungicides**

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# Group 44 Microbials

"Bacteria with their own fungicide factories"



#### **Group 44: Microbials**

- Bacillus subtilis bacteria formulated as pesticide (Serenade, Companion, etc.)
- These produce lipopeptides that disrupt fungal cell membranes
- Effective vs Botrytis, Fusarium, powdery mildew, rust, downy mildews
- > Best as a preventive foliar material
- May require short application intervals
- May break under heavy disease pressure





# Trichodermas

"It's a fungus eat fungus world out there"



#### Trichodermas

- There are at least 2 species used as pesticides
- Directly attack other fungi







#### Trichodermas

- Effective vs Botrytis, Rhizoctonia, Pythium and some Phytophthoras
- May require short application intervals
- May be affected by fungicide applications
- May break under heavy disease pressure



## **Questions???**

