Introduction to Fungicides

What is a disease?

- Any force that interrupts the normal growth of a plant.
- May be biotic (alive) or abiotic (not alive)

Biotic Diseases

- May be any living organism such as animals, bird, insects, parasitic nematodes, bacterial, fungal, viral, etc.
- Many of these organisms may be helpful as well as harmful. Soil Food Web
- Growers should seek to enhance those organisms which help while suppressing those that harm.
- Today we will discuss control agents used to suppress pathogenic fungi.

What is a fungicide?

- An agent that will kill, repel or prevent or otherwise mitigate a fungus.
- It may be naturally derived, bio-rational, a biological extract (modified), reduced risk manufactured or chemical.
- May be Protective or Curative in nature

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Sclerotinia White Mold

Vinclozolin

Biological Fungicides

- What are Biological fungicides?

According to USDA, ... *they are beneficial Fungi and Bacteria which attack and control plant pathogens and the disease which they cause*

BCO = Biological Control Organism

How Do Biological Fungicides Work?

- Direct Competition
- Antibiosis
- Predation or parasitism
- Induced resistance of host plant

Direct Competition

- Most associated with soil borne pathogens
- If the good guys live in the rhizosphere, the bad guys won't find a room
- Inoculate before infection by pathogen occurs
- "Biological Control Organism" must become associated with roots or rhizosphere
- This area is nutrient rich, a food source
- Generally BCO must be present in large numbers to compete

Antibiosis

- Antibiosis involves the production of toxins which inhibit the growth of the pathogen.
- Once the pathogen enters the root, antibiosis may have no effect.
- BCO may have antibiosis and antagonistic abilities.

Predation or Parasitism

- Predation or parasitism is when the BCO attacks and feeds on the pathogen.
- Again the BCO must be present before the pathogen invades

Mycorrhizal inoculants usually last the season however Bacterial inoculants should be reapplied every 2-3 weeks.

Trichoderma moves vertically more than horizontally.

Induced Host Resistance

- Once attacked a defense system kicks in.
- Not an immune system, but internal biochemical warfare to inhibit infection
- Host plants are purposely inoculated to induce this resistance. The BCO is the trigger.

Advantages of Biological Fungicides

- They help reduce chemical use
- They help in resistance management
- They are mostly safer to use than chemicals
- They have lower REI s in most cases
- They are generally less phytotoxic
- May enhance growth by other means

Disadvantages of Biocontrol Fungicides

- Tend to be more difficult to implement
- Generally have a narrow target range
- May not work as quickly as chemicals
- Do not eradicate pathogen or rescue the host plant
- May have a shorter shelf-life
- Generally more expensive
- May not be compatible with chemical fungicides or bactericides
- Environment may be inhospitable for BCO
- Other microorganisms may be hostile or too abundant

Slide 14 BONUS QUIZ

Why is this plant wilting?

What is the weed growing next to the crown?

Bacterial Wilt
Common Ragweed

Keys To Successful Use of Bio-Fungicides

- Must be used in conjunction with good cultural practices
- Must be applied before the onset of disease
- Often need to be reapplied during the growing season
- Growth- Will gain a little in optimum soils but will improve results in suboptimum conditions

Trichoderma harzianum (TH)

- T22 strain is in Plantshield, Rootshield & Compete.
- Uses antibiosis and predation against soil borne pathogens such as Pythium, Rhizoctonia, Fusarium and Sclerotinia.

Compete® Plus

- **COMPREHENSIVE MICROBIAL TREATMENT FOR INFERTILE SOILS**
- **D E S C R I P T I O N**
- Compete® Plus is a dry, water soluble microbial inoculant containing a wide range of beneficial rhizosphere microbes including
- bacteria (6 species of *Bacillus*), fungi (*Trichoderma*), and actinomycetes (*Streptomyces*), selected for their favorable impact on soil
- fertility and structure. Compete® Plus will introduce a mixed microbial population to biologically depleted soils. Successful
- establishment of beneficial microbial flora is an important component of fertile soils.
- **P R O D U C T S P E C I F I C A T I O N S**
- Rhizosphere Bacteria
- 50 Million cfu/g *Bacillus licheniformis*
- 50 Million cfu/g *Bacillus megaterium*
- 50 Million cfu/g *Bacillus polymyxa*
- 50 Million cfu/g *Bacillus subtilis*
- 50 Million cfu/g *Bacillus thuringiensis*
- 50 Million cfu/g *Paenibacillus azotofixans*
- Rhizosphere Actinomycetes
- 1 Million cfu/g *Streptomyces griseoviridis*
- Fungi
- 10 Million cfu/g *Trichoderma harzianum*
- Soluble Humate Extract 24.5%
- 17% Humic acids
- Sugar (dextrose) 40%
- Sea Kelp Extract 19.5%
- Maltodextrin 8%
- Yeast Extract.....5%
- Inert Ingredients 3%

Delivery of Biological Control Organisms

- D I R E C T I O N S F O R U S E
- Area Treatment for Flower Beds or Gardens: Mix with water to apply 4-Lbs per acre (1-Lb per 10,000 sq ft) initially. Follow with
- water application to rinse product into the soil. Thereafter, apply 2-Lbs per acre (1/2 Lb per 10,000 sq ft) every 2 weeks.

BCO Attack Strategy?

- Root and crown rots should have product applied before planting clean materials
- Foliar sprays applied before onset of disease, or before disease conditions become apparent
- What is the best delivery method/timing for the products?

Some of the Registered Bio-Fungicides/Bactericides

- Companion...*Bacillus subtilis*...Soil borne diseases
- Kodiak...*Bacillus subtilis*...Soil borne diseases
- Plant Shield...*Trichoderma harzianum* T-22...Soil & foliar disease
- Trichodex...Trichoderma harzianum...Soil borne disease
- Mycostop...*Streptomyces griseoviridis* K-61...Soil borne disease
- SoilGard...*Gliocladium virens* GL-21...Soil borne disease
- Taegro...*Bacillus subtilis amyloliquefaciens* FZB24...soil disease
- Actinovate...Streptomyces lydicus...Soil borne disease
- AQ-10...*Ampelomyces quisqualis* M-10...Powdery Mildew
- And many others

Soft Chemical Fungicides

- Alfred C. Hottes' *A Little Book of Climbing Plants*, published in 1933 by the A.T. De La Mare Co. of New York, made mention of using one ounce of baking soda per gallon of water to control powdery mildew (PM) on climbing roses. The author credits the idea to a Russian plant pathologist.

Baking Soda plus Hort Oil

- Cornell has focused on controlling fungal diseases on cucurbits. A single spray application (to runoff) of 0.5% (wt./vol. of water) baking soda, plus 0.5% (vol./vol. of water) SunSpray UFP® horticultural oil almost completely inhibited PM on heavily infected pumpkin foliage. Baking soda **without** spray oil was ineffective, and a 2% (wt./vol. of water) solution of baking soda damaged the leaves.
- JMS Stylet Oil is registered OMRI & reduced risk

Potassium Bicarbonate for PM

In 1996 Dr. Horst at Cornell discovered that Potassium Bicarbonate is superior to Sodium bicarb (baking soda) for controlling Powdery Mildew on Cucurbits.

1998, Church & Dwight Co. (the manufacturer of Arm & Hammer™ baking soda) received EPA registration for Armicarb 100® which is now carried by Helena. Others include FirstStep® by the W.A. Cleary Chemical Co, & Remedy®, by Bonide™.

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That was Downey Mildew

ZeroTol
Broad Spectrum Algaecide/Fungicide

Other Biologicals & Soft Chemicals

- Neem Oil.....every 7-14 days
- M-Pede.....every 7-10 days
- Compost Teas....every 2-7 days
- ZeroTol & others

M-Pede
OMRI Listed
NOP Compliant

Harpin Protein

- Messenger STS from EDEN.....3% WDG
- 4-6 oz per Acre stimulates a plants natural defenses against stresses.

“Conventional” fungicide definitions Fungicides defined by their MOA

- Protectant – Surface Active - prevents fungus from infecting plant
- Curative – Penetrant - kills active fungus usually in the plant
- Contact – works outside – surface active
- Local penetrant – penetrates a little
- Translaminar – moves without plant – gasses off
- Penetrant – penetrates a lot
- Systemic – enters sap steam
- Acropetal penetrant – moves up
- Basipetal penetrant – moves down
- True systemic – moves up & down
- Plant sterols – plant fats
- Fungal sterols – enzymes used by fungus
- Quinone - An enzymatic cofactor that plays an important role in photosynthesis and respiration. More specifically, it is part of the electron transport chain in mitochondria and chloroplast membranes.

Group 7 & 11 Fungicides

- QoI = Quinone outside Inhibitors
- Strobilurin fungicides are highly effective yet considered to be at *very high risk* of failure due to disease resistance.
- Work by respiration inhibition – interrupts electron transport or signal chain
- Narrow site plan -Always alternate with a different group
- Do not exceed 6 applications per year
- “Reduced Risk” due to low toxicity, EF, etc
- Derived from a field obtained natural isolate
- Penetrates cuticle so weather fast & long lasting hence
- Very good preventive properties. Poor curative.

Azoxystrobin

- The first Group 11 Strobilurin fungicide
- Amistar 80%.....3.5-5.0 oz/Acre
- Quadris 22.9%.....11.0-15.4 oz/Acre
- Heritage 50%.....3.2-8.0 oz/Acre
- Heritage TL 8.8%.....Turf Only

Trifloxystrobin

- Group 11 strobilurin fungicide
- Flint 50%.....1.5-4.0 oz/Acre
- Compass 50%.....NC

Downey & Powdery Mildews only on cucurbits. Site absorbed, minimal translaminar movement.

FLINT

Compass 50WG

Pyraclostrobin

- Group 11 strobilurin fungicide
- Cabrio.....20% (Cucurbits OK)
- Headline.....23.6% (Ag. No Cucurbits)
- Insignia.....20% (T&O No Cucurbits)
- One pound per acre not more than 4x per year. Alternaria, Antracnose, Cerospora, Gummy stem blight, Plectosporium, Powdery Mildew & Target leaf spot.
- Rainfast in 2 hours due to unique penetration
- Do not tank mix with Malathion, Kelthane, Thiodan, Phaser, Lannate, Lorsban, M-Pede, or Bortran or crop injury may occur.

Famoxadone

- DuPont's entry to the strobilurin market
- Tanos in combination with cymoxanil

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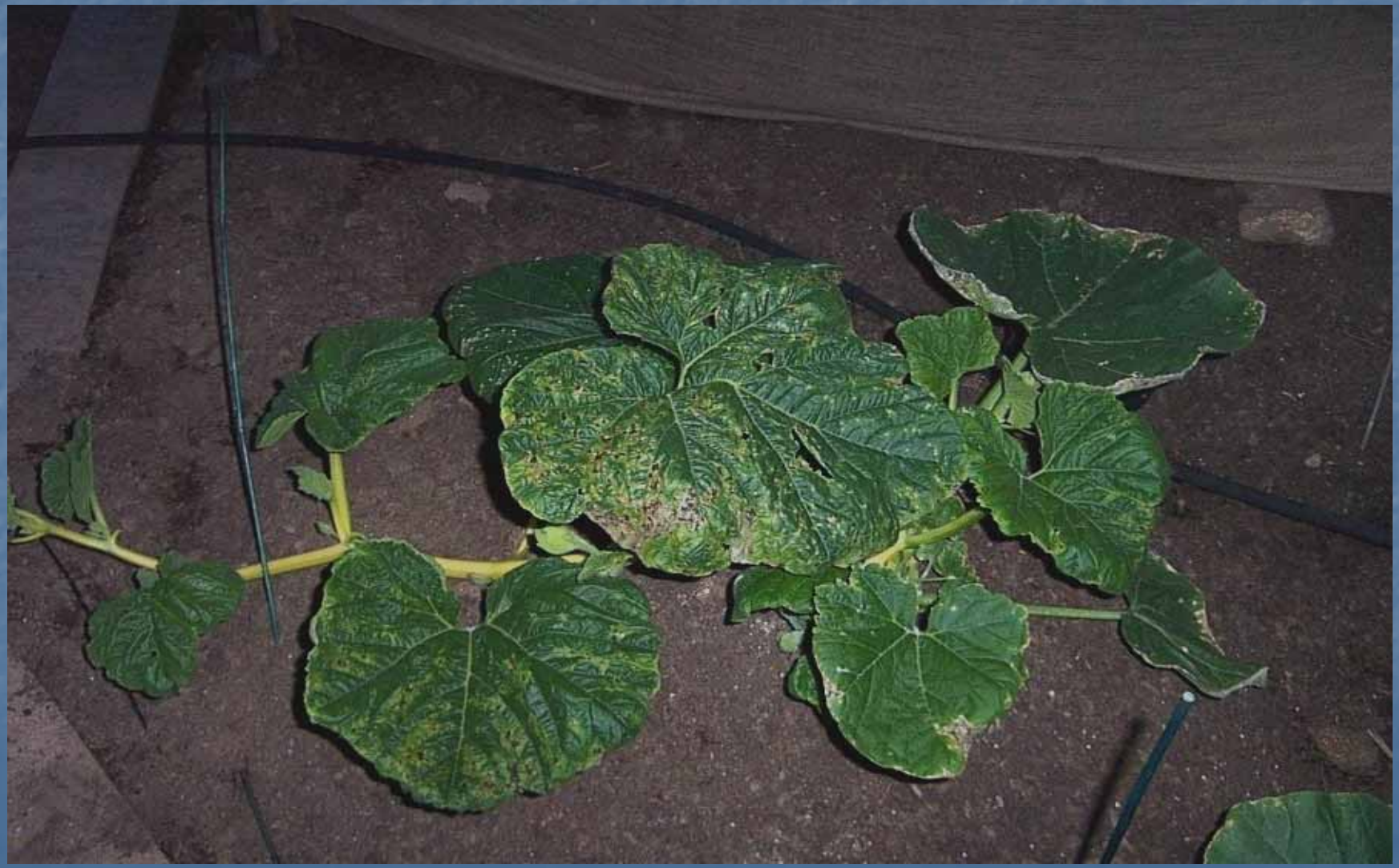

Angular Leaf Spot

- On 845 Bobier

Photo Ray Leonzi

Boscalid

- Group 7 analide fungicide
- Endura.....70% WDG Ag not Cucurbits
- Emerald.....70% WDG T&O only

Pristine (Pyraclostrobin + Boscalid)

- Excellent Powdery & Downey Mildew control
- 12.5 – 18.5 oz/Acre up to 4x per year
- Group 7 & 11 fungicides combined for enhanced & broadened efficacy

Pristine

Sovran

- New group 11 by BASF.....NC
- Kresoxim-methyl
- Inhibits spore germination, sporulation, & mycelial growth on leaf surface.
- Pome fruits, grapes & nuts.

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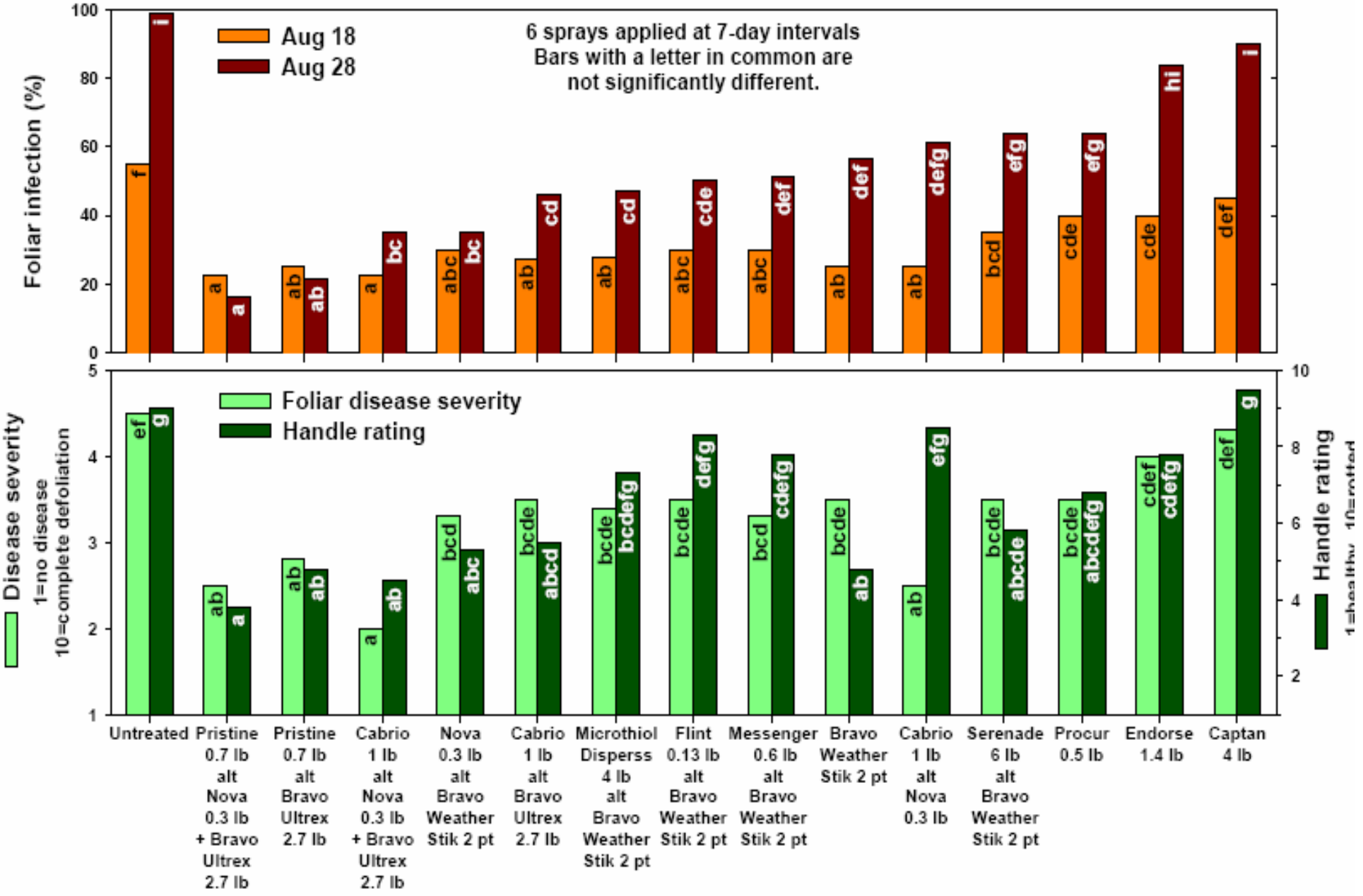
Powdery Mildew

- Chapel St School

Photo S. Jepsen

Figure 1. Evaluation of Fungicides for Control of Powdery Mildew of Pumpkin, 2003.



Contact Fungicides

- Multi-Site Contact Activity
- These fungicides act to kill the fungus by overwhelming it with materials that are poisonous to it.
- These fungicides are primarily based on inorganics such as aluminum, copper, and sulfur, and upon the dithiocarbamates combined with zinc and manganese ions.
- Low risk of resistance buildup.
- Must be present before infection begins

Protectant Fungicides

- inorganics (copper and sulfur)
- aromatic hydrocarbons
- nitriles
- carbamates
- phenylpyrrols
- Hydroxyanalids
- Can be a systemic if the molecule has fungistatic properties or works on spores/mycelia. But must be present on plant before disease inoculation.

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Bacterial Wilt & Powdery Mildew

Seaweed Only twice a week plus fish once a week didn’t cut it.

Photo S. Jepsen

Copper fungicides

- Copper ammonium complex (Copper-Count®-N, etc)
- Copper hydroxide (most common - Kocide, Nu-Cop, Ridomil Copper, etc)
- Copper oxychloride (Chemspray, Chem-Real's Best 4, etc)
- Copper resinate (Tenn-Cop 5E, paints, etc)
- Cupper sulfate (Basi-Cop, CP, Tri-Basic, Bordeaux Mix, etc)

Primarily used for bacterial & some fungal diseases (Angular Leaf Spot & Downey Mildew uses mostly)

Poor mammalian toxicology profile & environmental persistence is cause for copper fungicides lack of popularity.

Sulfur fungicides are Primarily for Powdery Mildew at low temperatures.

Aromatic hydrocarbons

- Dichloran (Botran 75).....W.M.....NC
- Chloroneb (Chloroneb, Terraneb).....NC
- Etridiazole (Terrazole).....NC
- PCNB (Koban, PCNB, etc).....NC

Nitriles

- Chlorothalonil – the “work horse”
- Bravo Weatherstik, Daconil, Echo 90DF & 720, Equus 720 SST, etc
- Destroys enzymes needed for fungus to respire
- Labeled for every major fungal disease of cucurbits.
- 6 lb Flow =1.5 – 2 Pints/Acre (.5-.7 oz/gal)

Carbamates

- EBDC fungicide once thought carcinogenic
- Mancozeb (Dithane, Pentathlon, etc)....OK Cuc
- Ziram (Ziram).....NC
- Ferbam.....scabs, rusts.....NC
- Junction is mancozeb plus copper hydroxide
- Thiram

Mancozeb is an important cucurbit fungicide especially for Downey Mildew, Gummy Stem Blight, Cerospora leaf spot, Anthracnose & Scab.

Subject to weathering off leaves. Must be present before inoculation by disease.

phenylpyrroles

- fludioxonil (Maxim, Medallion) for seed & soil borne damping off & seedling blights
- fenpiclonil (Beret Dust) New Zealand

Hydroxyanalids

- Fenhexamid (Elevate).....NC (yet)

Dicarboximides

- Iprodione (Diva, Rovral, Chipco 26019, 26 GT, etc.)
- Vinclozolin (Ronalin EG, Ornalin, Touché)
- Captan (Captan – mostly seed treatment)
- Blights, molds & leaf spots especially Sclerotinia White Mold in Canola.
- This class is where fungicides begin to penetrate tissue. Vinclozolin is considered a local penetrant
- Inhibits membrane synthesis and promotes the oxidation of fungal lipid (“fat”) molecules.

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Gummy Stem Blight

Sterol Inhibitors (triazoles)

- Triazoles - the big group – aka DMI
- Imidazoles
- Pyrimidines (Rubigan, etc)

Triazoles

- bitertanol - Baycor
- cyproconazole Alto
- difenoconazole Score
- epoxiconazole Allegro (+ kresoxim methyl), Opus
- flutriafol Vincit (+ imazalil)
- flusilazol Nustar
- myclobutanil – Nova, Systhane, Eagle, etc THE GOLD STANDARD
- paclobutrazol Cultar (also a PGR)
- penconazole Topas
- propiconazole – Tilt, Banner, etc
- tebuconazole Folicur, Orius, Raxil
- triadimefon - Bayleton, Miltek
- triadimenol Assure (+ carbendazim), Baytan Universal (+ imazalil + fuberidazole), Cereous

Imidazoles

- Imazalil - Baytan Universal (+triadimenol + fuberidazole – seed treatment), Fungaflor (postharvest fungicide), Monceren IM (+pencycuron), Vincit (+flutriafol)
- prochloraz - Mirage, Octave, Sportak
- Not important for cucurbits

Demethylation Inhibitor (DMI) fungicides such as triazoles and imidazoles

- Inhibit the biosynthesis of sterol in fungal membranes. (Sterol Inhibitors)
- There are five classes of these sterol biosynthesis inhibitors (SBI) encompassing 44 different active ingredients.

Methyl Benzimidazole Carbamates

- Benomyl & Thiophanate-methyl
- Single site activity so prone to resistance
- Mitosis inhibiting chemicals
- No preventive properties. Can only work on active disease.

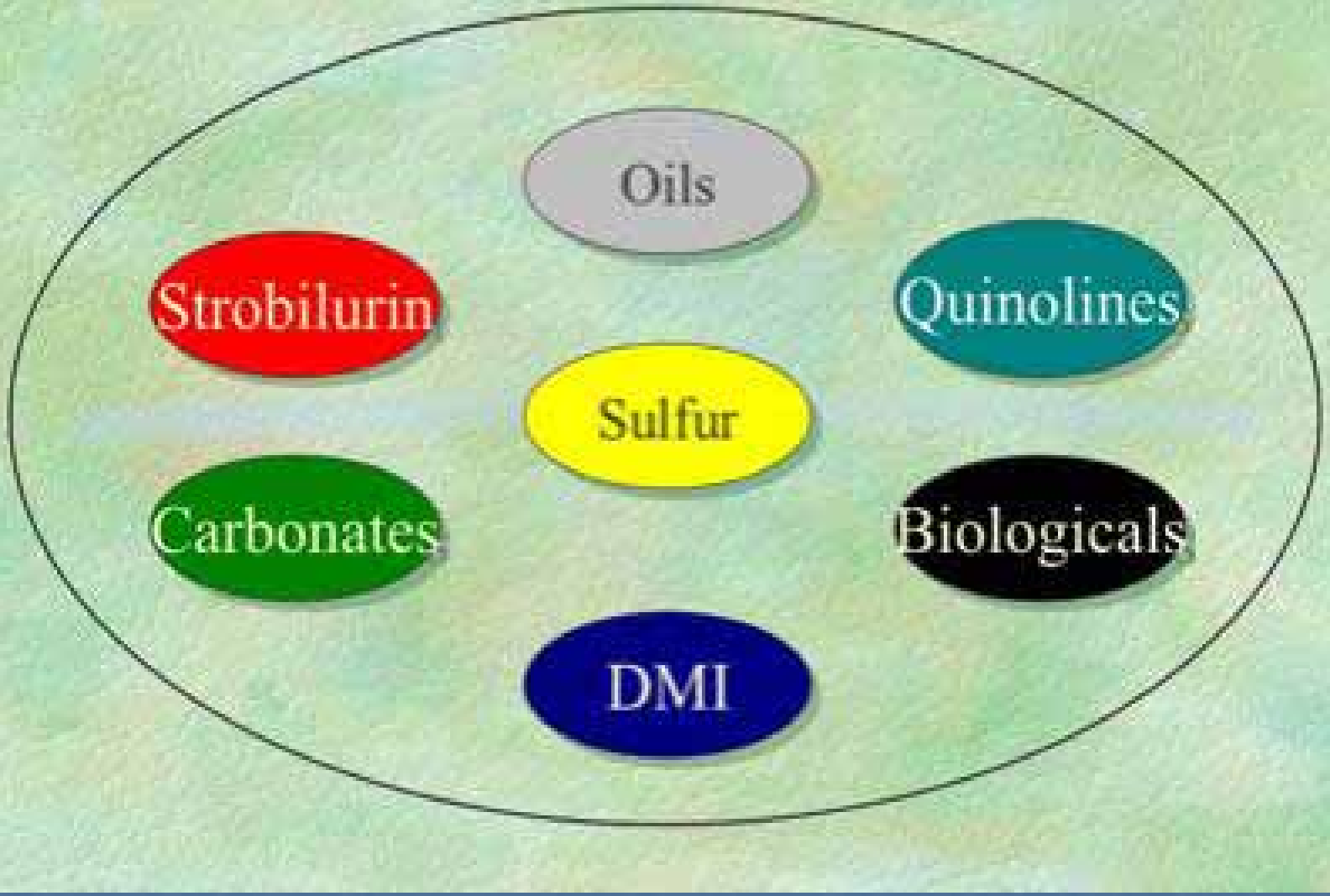
Phenylamides (PA) fungicides

- metalaxyl-M (mefenoxam) Subdue
- Inhibits the synthesis of nucleic acids, both DNA and RNA.
- Apply phenylamides preventatively when disease level is low, but disease risk is high. Do not apply phenylamides when disease has become obvious.

True Systemics

- Phosphonates such as Aliette (aluminum tris), Topaz, etc
- Many phosphonate fertilizers offer similar results
- Potassium Phosphites are also converted
- Illegal in US to claim fungicidal activity of P ferts
- Used for Pythium damping off & Phytophthora

Powdery Mildew Fungicide Programs



Take Home Points

- Utilize cultural practices to reduce pathogen populations whenever possible.
- Use as many fungicide classes as possible in the disease management program (3-4 min.).
- Use fungicides ***protectively*** before disease has become a problem.
- Do not use resistance-prone compounds to attempt to get a powdery mildew epidemic under control. Horticultural oils and carbonates are the best eradicative fungicides.
- Don't make more than 3 applications of resistance-prone fungicide classes in a growing season.
- Always anticipate upcoming weather. Is the next fungicide a good protector or eradicant?
- Adjust spray volume based on canopy development to attain excellent spray coverage.
- Use spray adjuvants that maximize cuticle penetration.
- Make no more than 2 consecutive applications of DMI, quinoline, or strobilurin fungicides in a row.
- Do include low resistance risk compounds sulfurs, carbonates, and petroleum spray oils in the spray program as much and whenever possible.
- Only apply fungicides during good conditions for spraying

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