

Fungicide Basics and Use in Vegetable Disease Management

Univ. of Florida In-Service Training/The Great CEU Round-Up 2013
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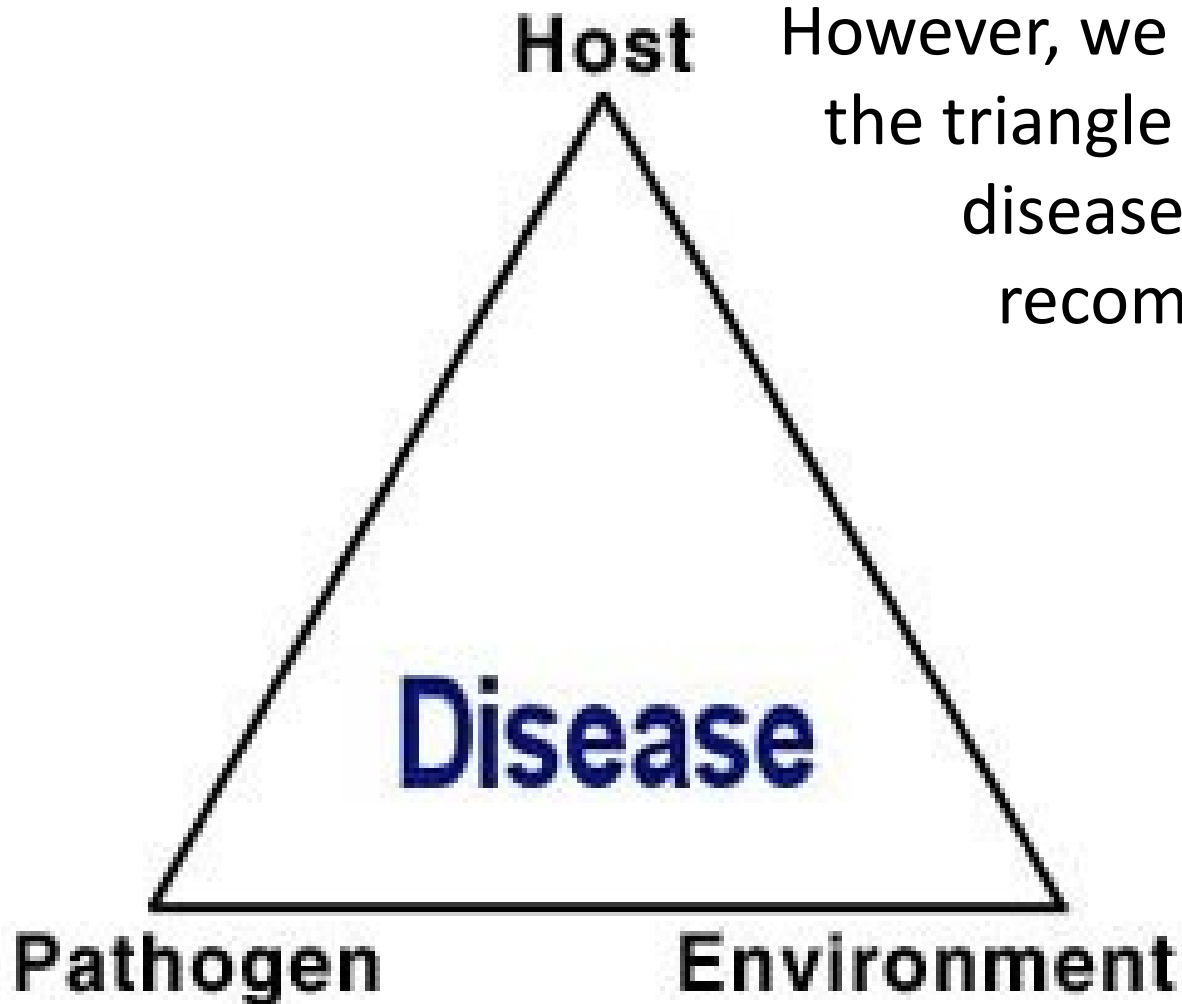
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Understanding how and when a disease occurs is critical to determining management.

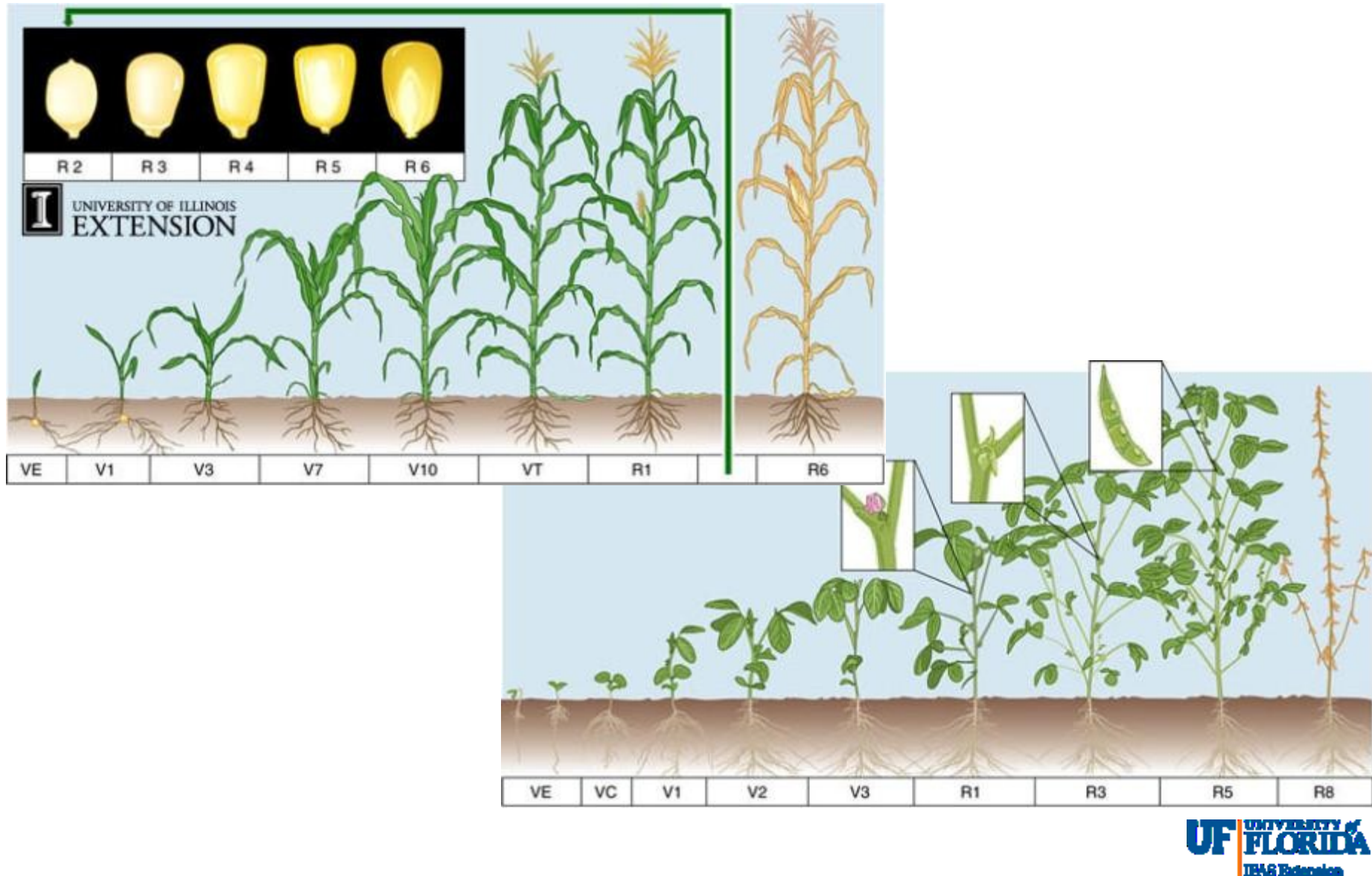


In plant pathology there are three principle components that affect the intensity of disease.



However, we must added **time** to the triangle when we consider disease management recommendations.

**For the host it is important to consider:
resistance, age and where the disease occurs.**



Environment is a key in determining the amount of disease that will be present.

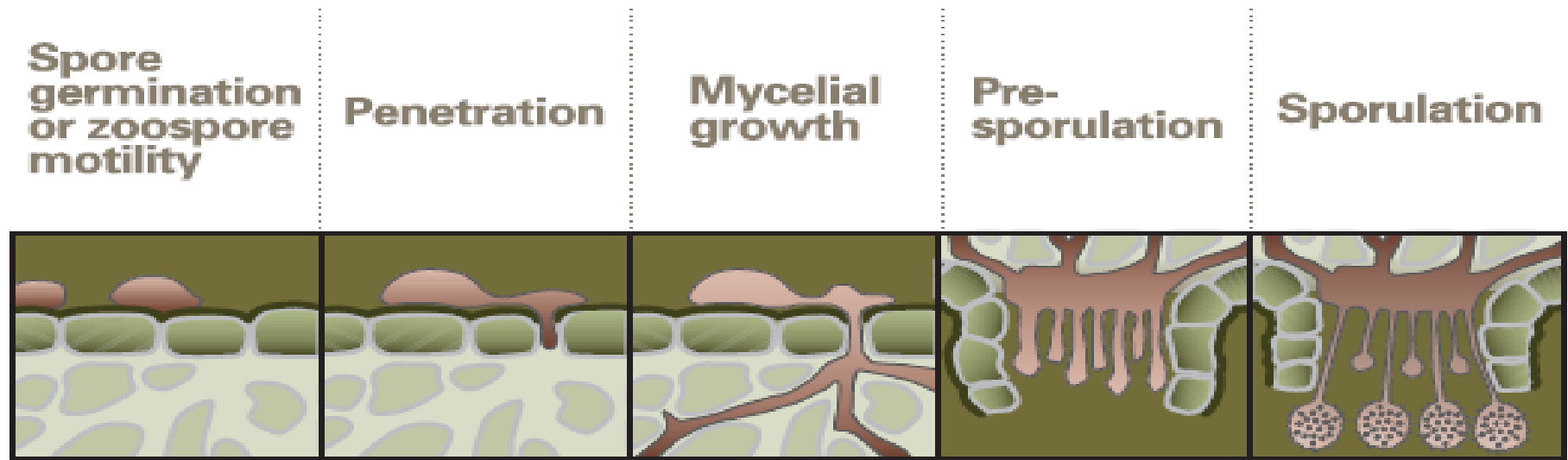
Downy Mildew: Wet weather



Powdery Mildew: Dry weather



We need to know what stage in the pathogens life cycle we are trying to control.



- Crop Rotation

- Tillage

- Weed mngt.

- Assess the risk



ipmPIPE

PEST INFORMATION PLATFORM
FOR EXTENSION & EDUCATION

Spray recommendations are based on all of these components.

Watermelon Fungal Spray Program

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Program starts 1 week after transplanting, then use a 7-10 day schedule (especially with weekly rainfall)

Spray No.	Fungicide/Product	Notes
1	Chlorothalonil (GSB) Copper fungicide/Actigard (BFB)	Preventative spray Copper used prior to fruit set if BFB is an issue
2	Chlorothalonil (GSB) Copper fungicide/Actigard (BFB)	Preventative spray Copper used prior to fruit set if BFB is an issue
3	Chlorothalonil (GSB)* Copper fungicide/Actigard (BFB)	*If disease is present, use a systemic (i.e. Tebuconazole or Inspire super)
4	Chlorothalonil (GSB)* Copper fungicide (BFB)	*Preventative spray, but should consider a systemic if there is disease pressure.
5	Tebuconazole OR Inspire Super (GSB) Copper fungicide (BFB)	Luna experience can be added to this rotation once it becomes available for GSB and PM, and Torino for PM.
6	Mancozeb (GSB + DM) Presidio or Revus (DM or PCAP) Copper fungicide (BFB)	Could spray Cabrio, as well, for Anthracnose control. Remember to watch FRAC and rotate fungicides. Watch for fruit set with copper fungicide spray.
7	Tebuconazole OR Inspire Super (GSB) Quintec or Endura or Procure or Rally (PM)	Luna experience can be added to this rotation once it becomes available for GSB and PM, and Torino for PM.
8	Mancozeb (GSB + DM) Presidio or Revus (DM or PCAP)	Managing Gummy Stem Blight Managing DM and Phytophthora.
9	Tebuconazole OR Inspire Super (GSB) Topsin+mancozeb OR Inspire Super (GSB + ANTH) Presidio or Revus (DM or PCAP)	Luna experience can be added to this rotation once it becomes available for GSB and PM, and Torino for PM.

- Disease management should be part of an integrated program that uses disease free seed/transplants, proper crop rotation, debris removal and resistant varieties.
- Chlorothalonil *can burn the watermelon rind* and sprays should be stopped 21 days before harvest.
- Actigard and copper fungicides are used to manage BFB before it is a disease issue (i.e. high severity or incidence).
- As always, *fungicide labels should be consulted for rates and application instructions* as well as other detailed spray information (PHI, spray limits, etc.).
- Pay attention to preharvest intervals (PHI) for late season sprays as they may be as high as 14 days.
- Sprays can be reduced to 14 day intervals in the spring under dry condition (i.e. no rainfall).

Consult the Vegetable Production Handbook for Florida for more detailed management information.

Disease Acronyms: GSB=Gummy Stem Blight; BFB=Bacterial Fruit Blotch; PM=Powdery Mildew; DM=Downy Mildew; ANTH=Anthracnose; PCAP=Phytophthora crown and fruit rot.

How do we know which fungicide to use or recommend in these programs?



For fungicide recommendations you often hear:

- Rotate the mode of action
- Systemic and contact
- FRAC number

What do these terms mean and how are fungicides active in the plant?

What is a fungicide?

3 names: chemical name, common name
and trade name

Fungicide: chemical/physical agent that
kills/inhibits the growth of fungi

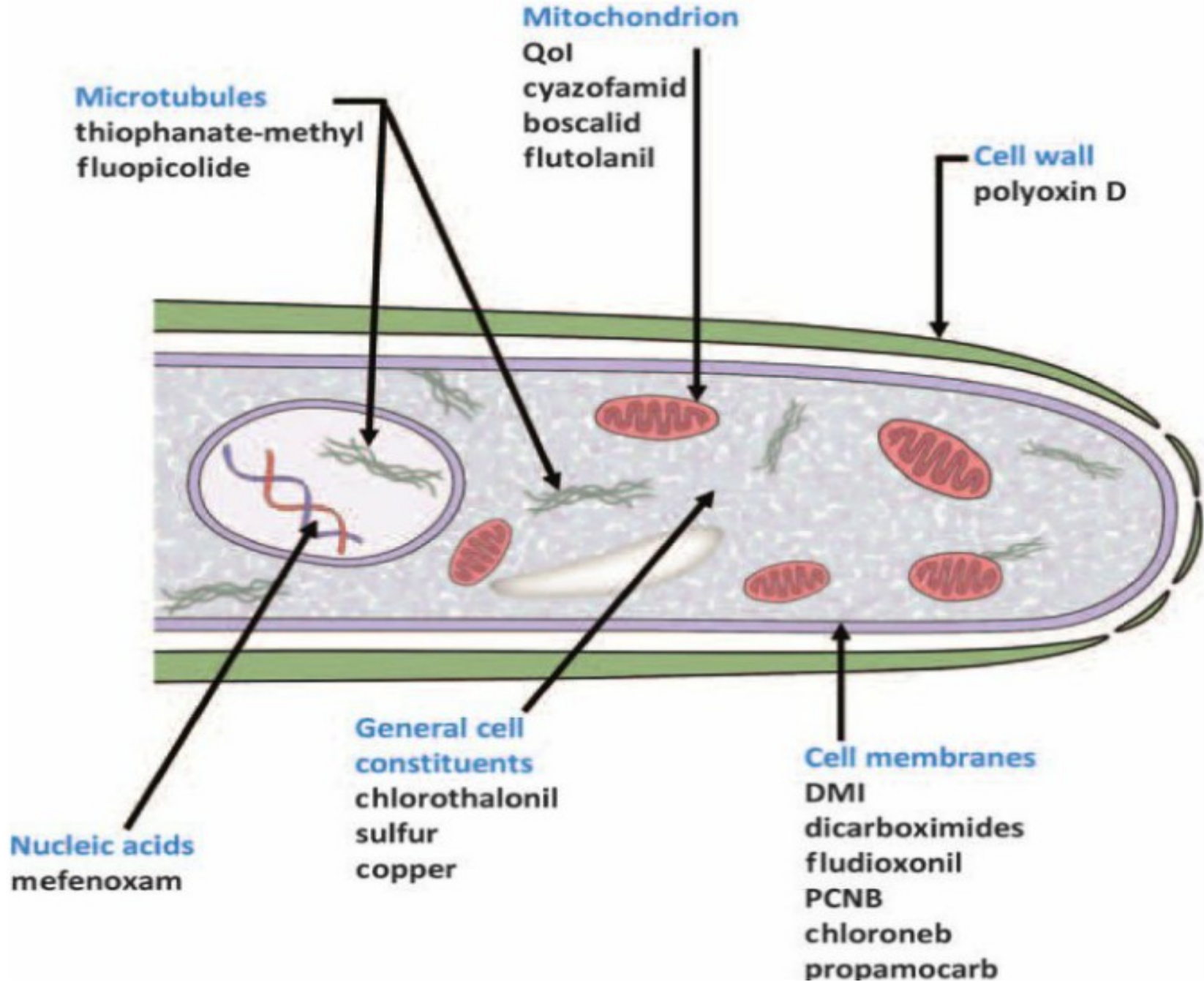
Classified as follows:

1. Mode of action
2. Breadth of activity
3. Mobility within the plant
4. Role in protection
5. Chemical group
6. FRAC Code

1. Mode of action

How the fungicide acts on the target fungus, e.g.

- damage cell membranes
- inactivates critical enzymes/proteins
- interferes with respiration



2. Breadth of activity

Single-site:

- active against only one point in one metabolic pathway in a fungus, OR against a single enzyme or protein needed by the fungus

Multi-site:

- affects a number of different metabolic sites within the fungus

Mitochondria

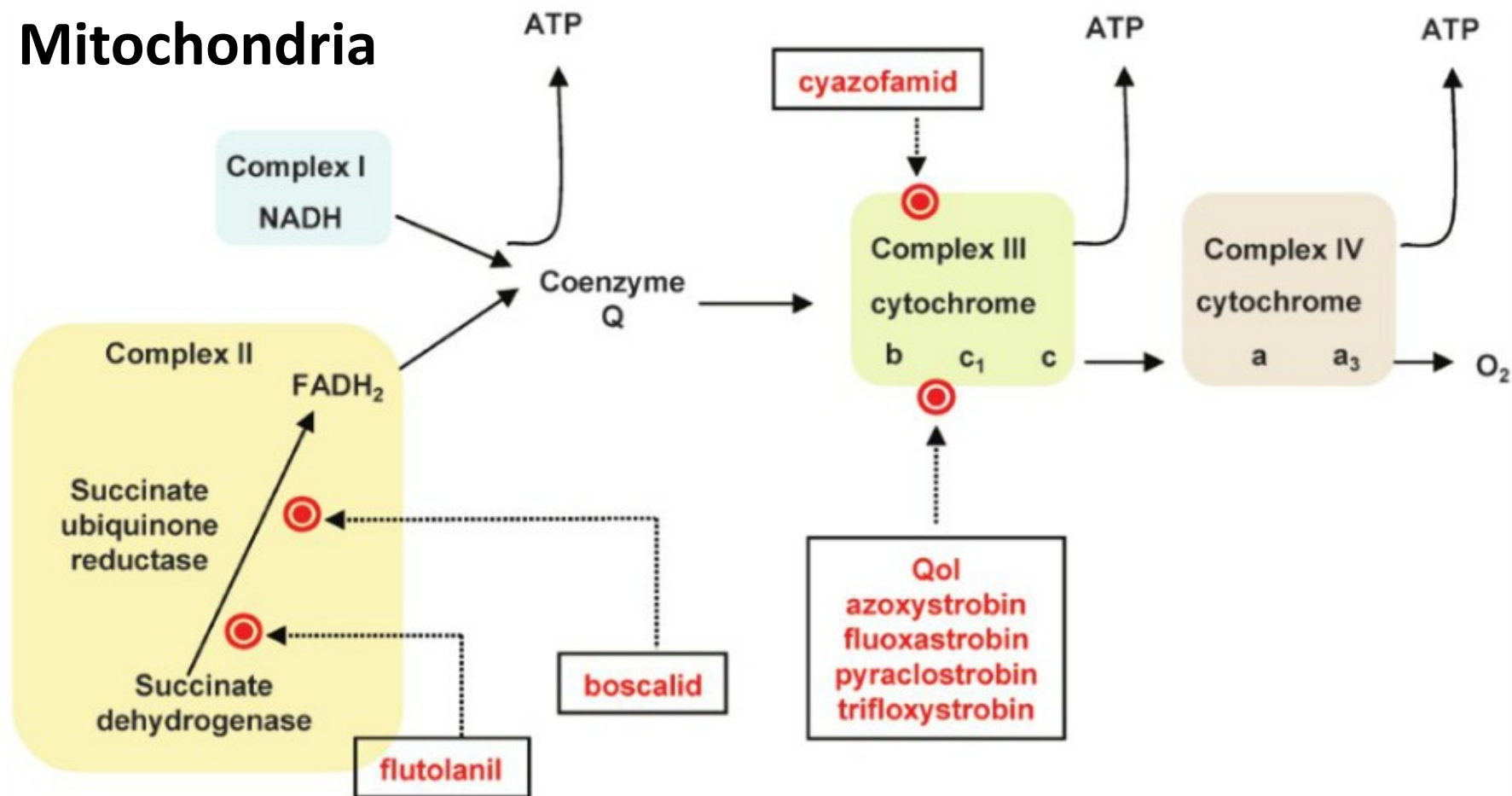


Fig. 2.7. The respiratory electron transport chain occurs within mitochondria. It generates energy in the form of adenosine triphosphate (ATP) to fuel other cell functions. Two of the four complexes in the chain are targeted by fungicides used for turf disease control. Carboxamide fungicides (boscalid and flutolanil) disrupt electron transport at Complex II. Q_iI (quinone inside inhibitor) fungicide (cyazofamid) and Q_oI (quinone outside inhibitor) fungicides (azoxystrobin, fluoxastrobin, pyraclostrobin, and trifloxystrobin) interrupt the chain at Complex III.

Cytoplasm

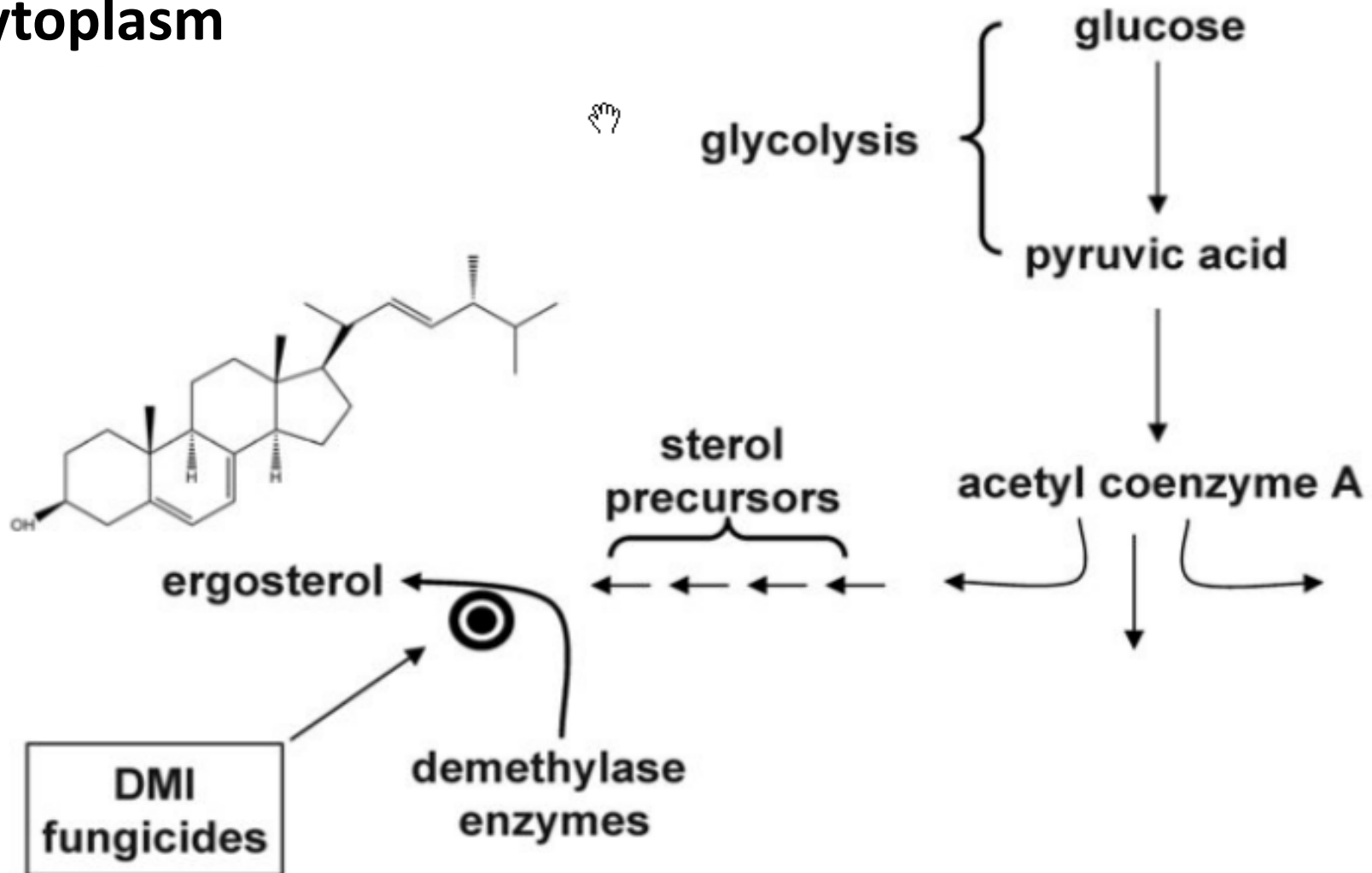
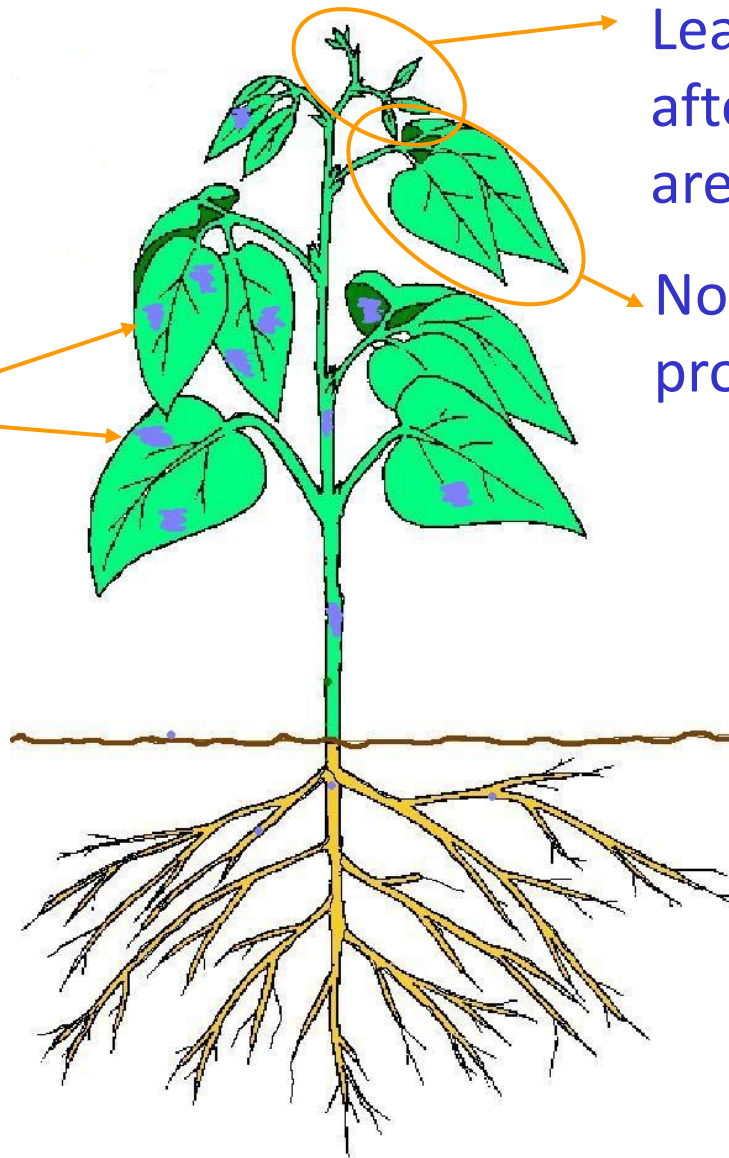


Fig. 2.8. Target site of demethylation inhibitors (DMI fungicides).

3. Mobility within the plant

Contact

Droplets spread out and remain on the surface where applied; do not move inside



Leaves produced after the application are not protected

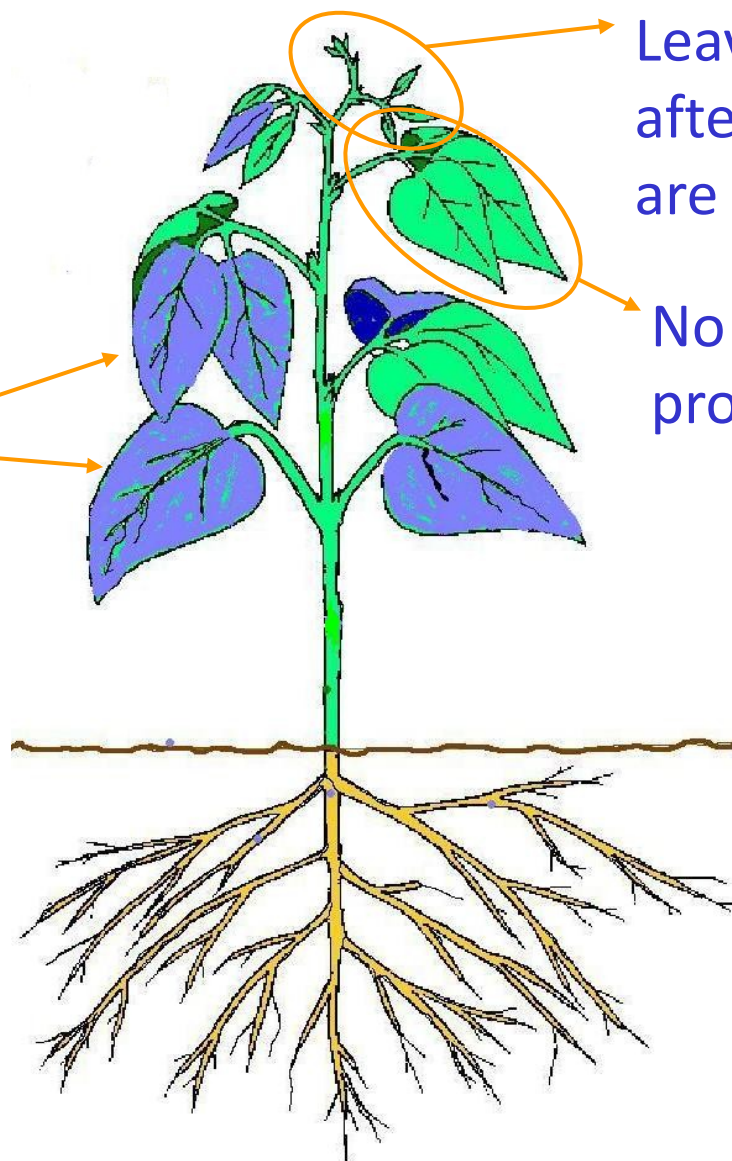
No chemical = no protection

3. Mobility within the plant

Systemic:

(i) Locally / translaminar

Droplets spread out
and are absorbed by
plant tissue



Leaves produced
after the application
are not protected

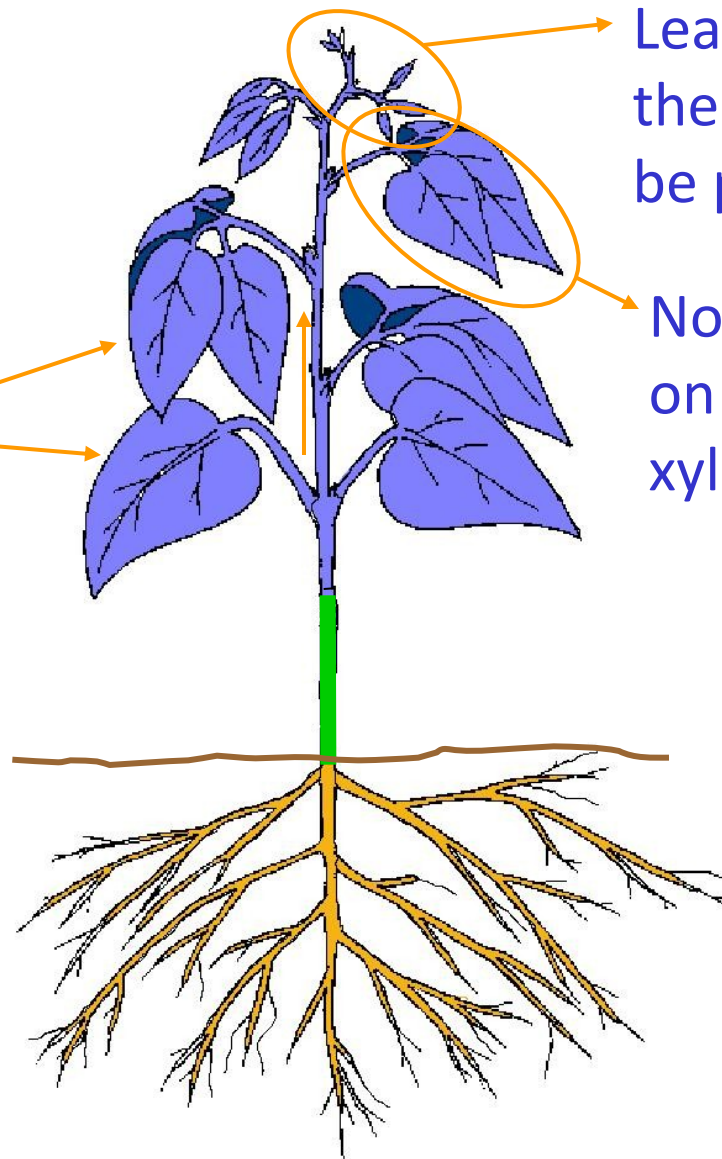
No chemical = no
protection

3. Mobility within the plant

Systemic:

(ii) acropetal

Droplets spread out and are absorbed by leaf tissue. Fungicide moves upwards in the xylem to edge of leaves and new growth



Leaves produced after the application MAY be protected

No chemical = rely on fungicide via xylem

Table 1.3. Phytomobility of active ingredients in turf fungicides

Fungicide	Phytomobility classification	Movement throughout the plant	Movement among cells
chlorothalonil	Contact	...	...
mancozeb	Contact	...	...
thiram	Contact	...	...
PCNB	Contact	...	...
chloroneb	Contact	...	...
etridiazole	Contact	...	...
iprodione	Local penetrant	Translaminar	Uncertain
vinclozolin	Local penetrant	Translaminar	Uncertain
trifloxystrobin	Local penetrant	Translaminar	Apoplastic
pyraclostrobin	Local penetrant	Translaminar	Apoplastic
cyazofamid	Local penetrant	Translaminar	Apoplastic
fludioxonil	Local penetrant	Translaminar	Apoplastic
polyoxin D	Local penetrant	Translaminar	Apoplastic
azoxystrobin	Acropetal penetrant	Xylem mobile	Apoplastic
fluoxastrobin	Acropetal penetrant	Xylem mobile	Apoplastic
fenarimol	Acropetal penetrant	Xylem mobile	Apoplastic
metconazole	Acropetal penetrant	Xylem mobile	Apoplastic
myclobutanil	Acropetal penetrant	Xylem mobile	Apoplastic
propiconazole	Acropetal penetrant	Xylem mobile	Apoplastic
tebuconazole	Acropetal penetrant	Xylem mobile	Apoplastic
triadimefon	Acropetal penetrant	Xylem mobile	Apoplastic
triticonazole	Acropetal penetrant	Xylem mobile	Apoplastic
flutolanil	Acropetal penetrant	Xylem mobile	Apoplastic
boscalid	Acropetal penetrant	Xylem mobile	Apoplastic
mefenoxam	Acropetal penetrant	Xylem mobile	Apoplastic
thiophanate-methyl	Acropetal penetrant	Xylem mobile	Apoplastic
propamocarb	Acropetal penetrant	Xylem mobile	Apoplastic
fluopicolide	Acropetal penetrant	Xylem mobile	Apoplastic
fosetyl aluminum	Systemic penetrant	Ambimobile	Symplastic
phosphonic acids	Systemic penetrant	Ambimobile	Symplastic

4. Role in protection

Preventative:

- acts as a protective barrier
- prevents spore germination and infection
- contact and systemic fungicides

Early infection (“curative”) activity:

- systemic
- stops pathogen in plant tissues (24-72h after infection)
- most effective when applied before infection

4. Role in protection

Eradication:

- stop disease development after symptoms developed
- VERY FEW fungicides

Anti-sporulant activity:

- prevent spores being produced
- disease continues to develop

A visual depiction of fungicide's role in protection.

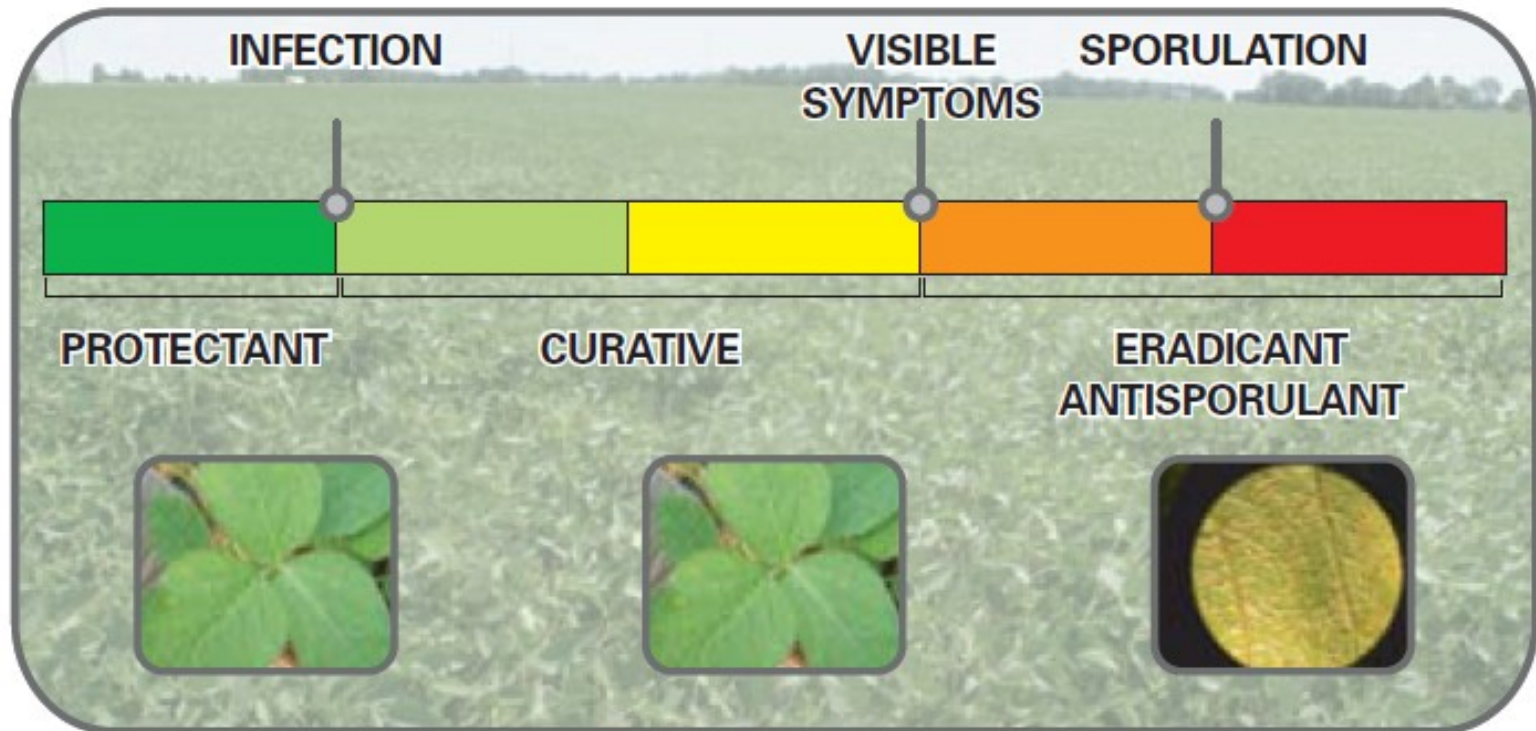


Figure 7.1. Schematic representation of fungicide activity in relation to soybean rust development.

5. Chemical groups

- A group of chemicals that share a common biochemical mode of action
- May / may not have similar **chemical structure**
 - Demethylation Inhibitor (DMI) (includes triazoles)
 - QoI (includes strobilurins)
 - Methyl Benzimidazole Carbamates (MBC)
 - Carboxamides
 - Chloronitriles

Qol fungicides

Examples:

- azoxystrobin (Quadris®)
 - pyraclostrobin (Headline®)
 - trifloxystrobin (Stratego YLD®)
 - fluoxastrobin (Evito®)
-
- **single site activity** – quinol outer binding site of cytochrome bc1 complex

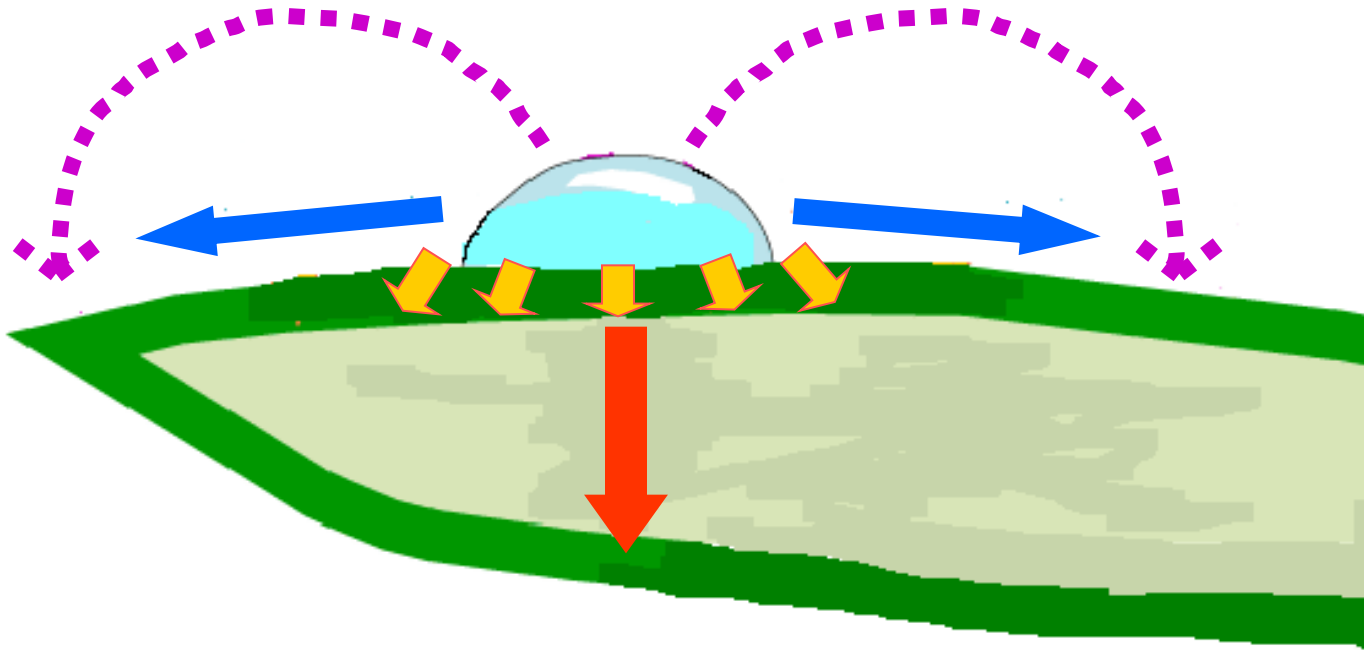
Qol fungicides

- **Mode of action:**
 - prevent energy production by the fungus by inhibiting mitochondria respiration
 - Stop spore germination and early mycelium growth (infection)
- **Role in protection:** Preventative / early infection activity
- **Other information:**
 - Residual period up to 21 days
 - mostly locally systemic (translaminar)*
 - prone to resistance

*Two strobilurin fungicides currently on the marketplace can move thru the xylem (azoxystrobin (a.i. in Quadris – or one of the a.i.s in Quilt and Quilt Xcel) and fluoxastrobin (Evito).

Qol fungicides

- Mobility



1. Surface redistribution

2. Penetrate waxy cuticle

3. Translaminar activity

4. Vapor movement & reabsorption

Adapted from: Vincelli, 2002
<http://www.apsnet.org/>

Leaf tip

Leaf base

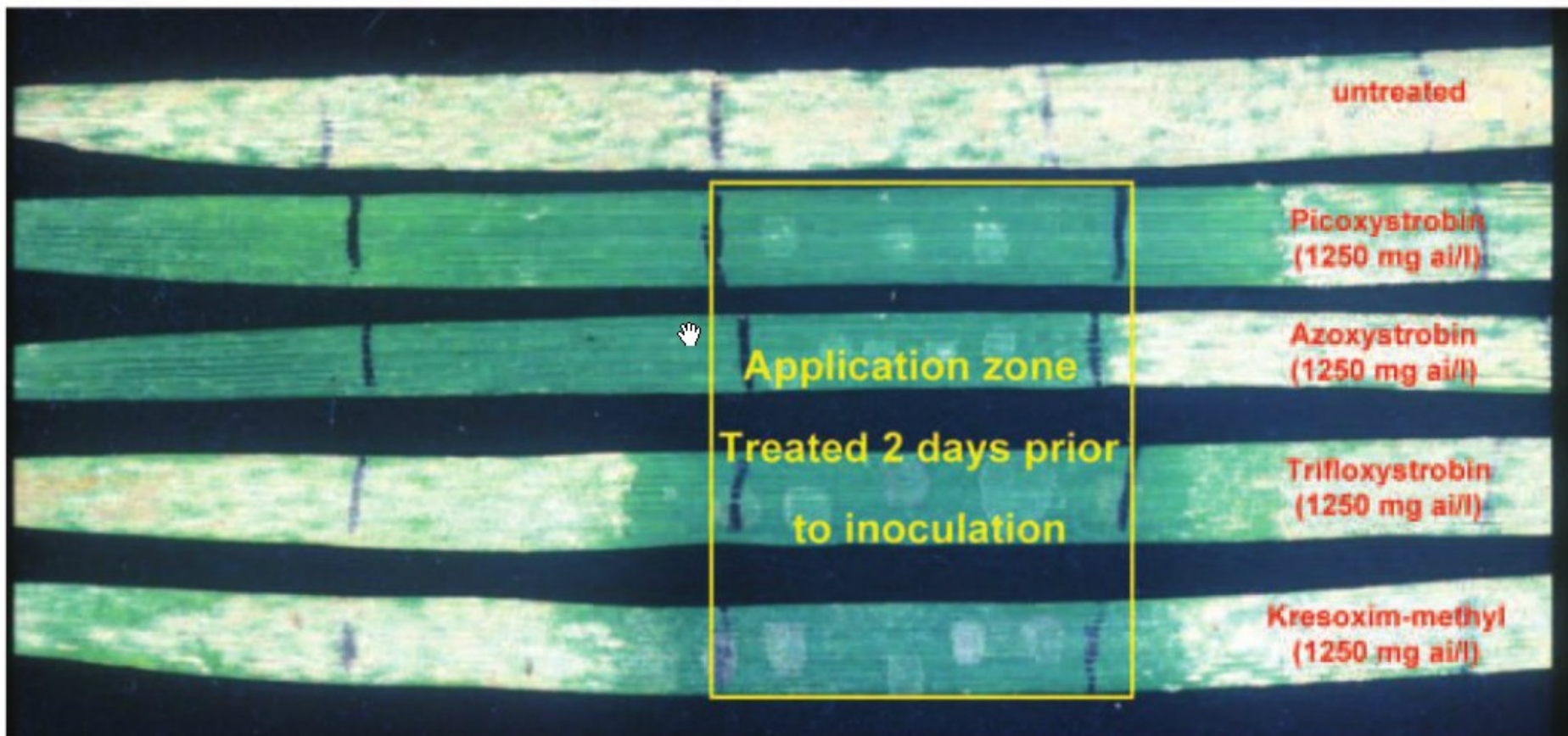


Fig. 1.8. Movement of acropetal and local penetrant fungicides. Fungicides were applied to the bases of wheat leaves prior to inoculation with the powdery mildew pathogen. (Adapted from Bartlett et al., 2002)

Triazole fungicides

Demethylation Inhibitor (DMI) fungicides

Examples:

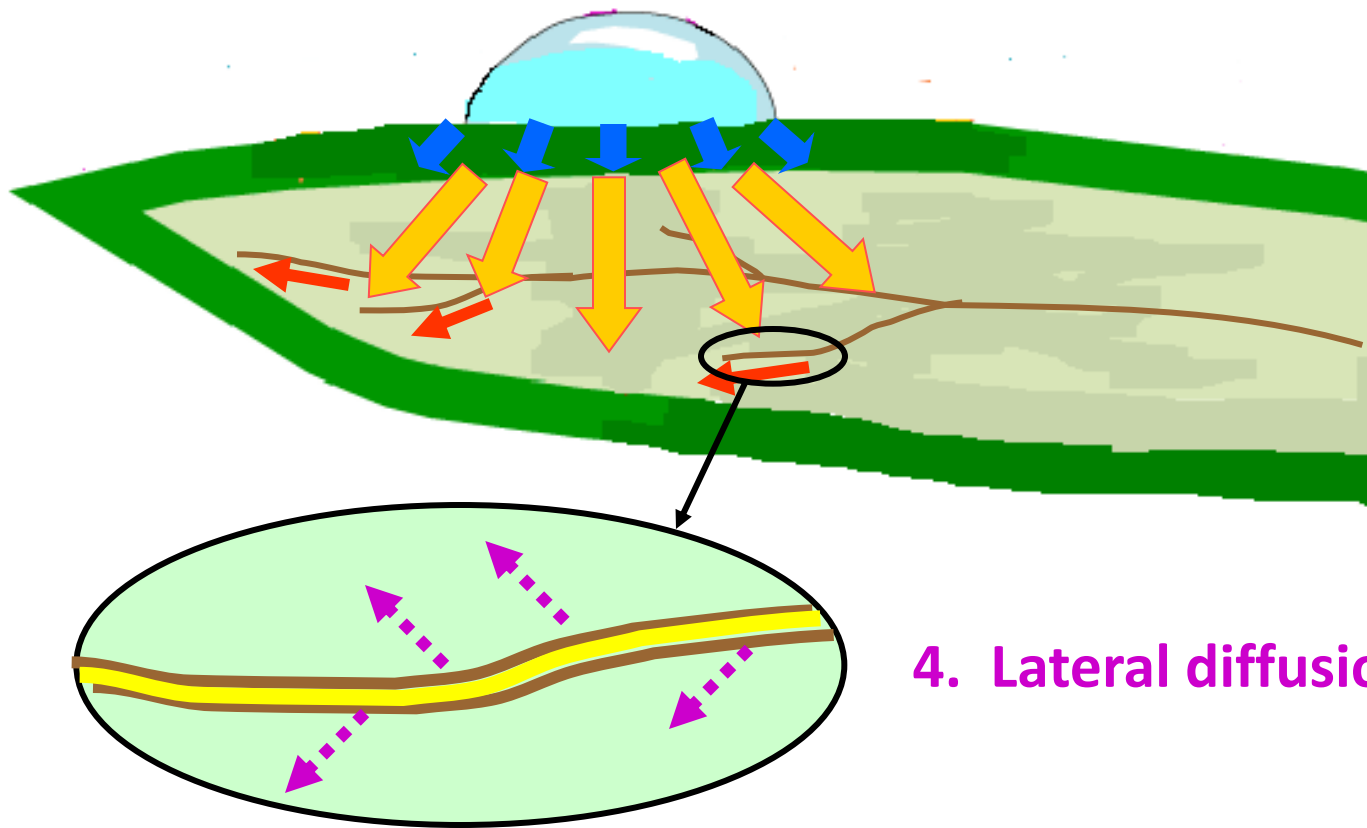
- tebuconazole (TebuStar, Monsoon)
 - propiconazole (Tilt[®], Quilt, Quadris Xtra)
 - prothioconazole (Proline[®])
 - metconazole (e.g., Headline Amp[®])
 - tetraconazole (Domark[®])
-
- **single site activity** – inhibit C14-demethylase

Triazole fungicides

- **Mode of action:**
 - prevent sterol production by the fungus
 - sterols = building blocks of membranes
 - result in abnormal fungal growth and eventual death
- **Role in protection:** preventative / early infection activity / anti-sporulant
- **Other information:**
 - Residual period ~ 14 days
 - locally systemic (typically more mobile than QoI fungicides)
 - prone to resistance

Triazole fungicides

- Mobility



1. Moves into epidermis

2. Rapidly penetrates leaf tissue

3. Transported in vascular system

4. Lateral diffusion

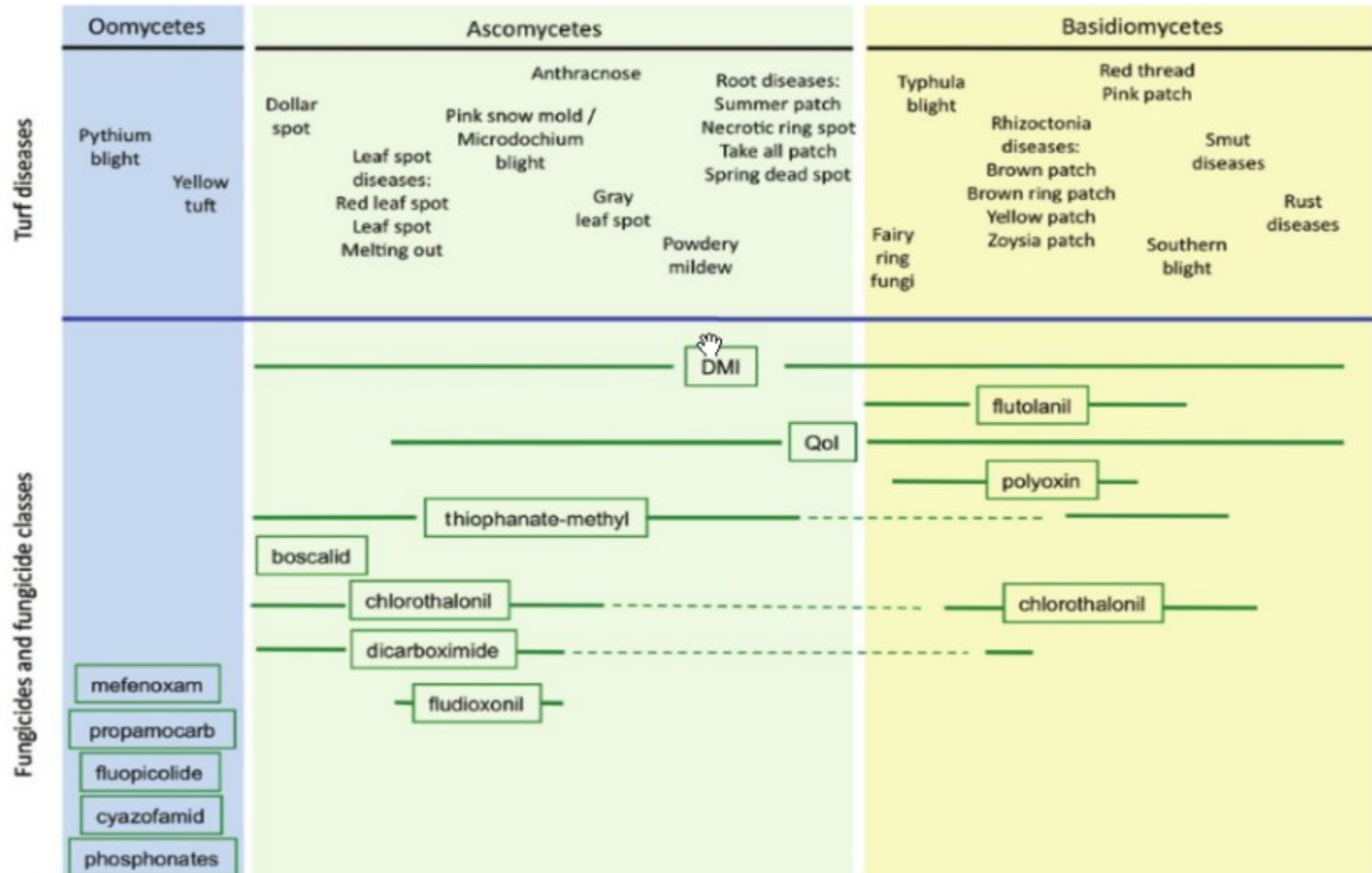
SDHI fungicides

Succinate Dehydrogenase Inhibitor (SDHI) Fungicides

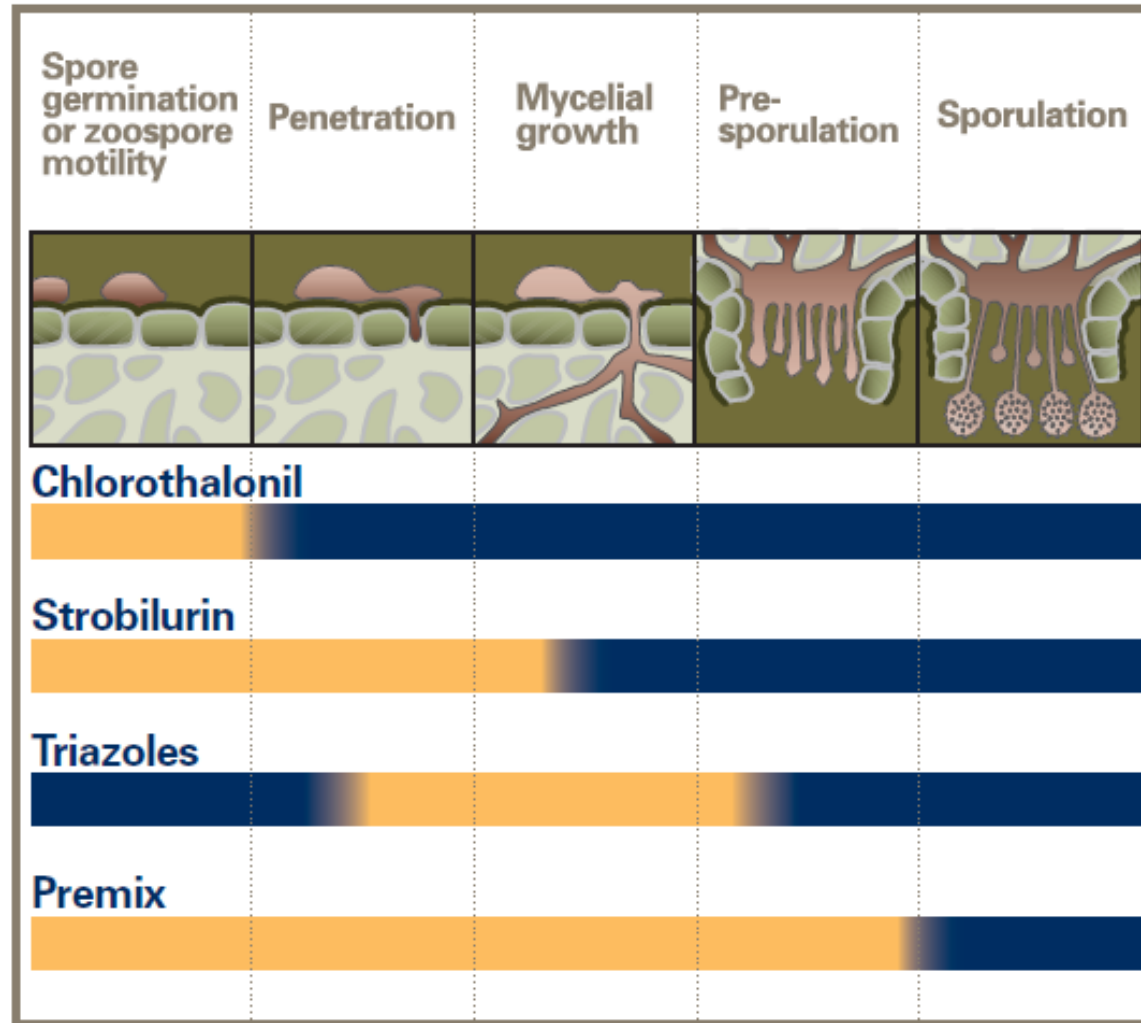
Mode of action: SDHI fungicides inhibit fungal respiration (similar to QoI fungicides).

Mobility in plants: Locally systemic. Movement is translaminar and upward.

The classes of fungicide will affect fungal types differently.



A example of how to use fungicide classes to control a fungus.



Highly Effective



Little or no effect

A summary comparison of a contact versus penetrant fungicides.

Contact	Penetrant
Must be applied before infection	Applied soon after infection
Prevents spore germination	Ineffective once fungus begins reproduction
No effect after infection	Limited “curative” effect
Low risk for resistance	Higher risk for resistance

Remember common penetrant movement:

- Translaminar
- Acropetal



6. FRAC code

- The FRAC code represents the mode of action of the fungicide.
- Alternate numbers to manage fungicide resistance

Quadris®

Flowable Fungicide

Broad spectrum fungicide for control of plant diseases

GROUP **11** FUNGICIDES

Active Ingredient:

Azoxystrobin: methyl (E)-2-{2-[6-(2-cyanophenoxy)
pyrimidin-4-yloxy]phenyl}-3-methoxyacrylate* 22.9%

Other Ingredients: 77.1%

Total: 100.0%

FRAC Code on the Quadris label

Fungicide resistance

- **Resistance risk varies by pathogen and fungicide class**
 - DMI (triazole; FRAC 3) – Medium Risk – slower, more gradual development
 - SDHI (FRAC 7) – Medium Risk – > 10 mutations
 - QoI (Strobilurin; FRAC 11) – High Risk – One common mutation (G143A) but others have been detected
 - Some pathogens will not survive the G143A mutation (lower risk)
- **Resistance management strategies**
 - Good agronomic practices
 - Restriction in spray number
 - Use of a diversity of fungicide modes of action

<http://www.frac.info/index.htm>

FRAC # are a simple way to know which fungicide you are using.

A list of common fungicides labeled for watermelon disease control

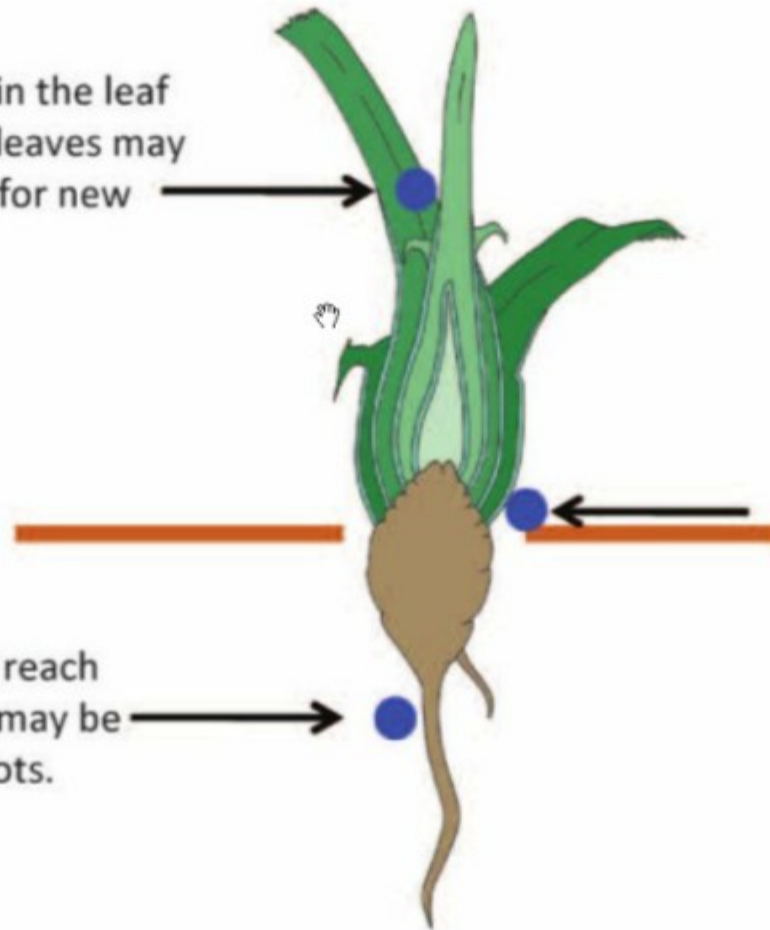
A more extensive list of pesticides can be found in the Vegetable Production Handbook for Florida (2011-2012). As always, it is important to consult the label for detailed information about spray applications and managed pests. This list is designed to encompass many diseases that attack watermelons during the growing season in Florida and is only meant to support the resources like those stated above. Always rotate fungicide products (i.e. different FRAC groups) when implementing a disease spray program.

Product Name	Active Ingredient	Group (FRAC)	Type	Target Pest
Bravo, Echo, etc	chlorothalonil	M	C	GSB, DM, PM
Dithane, Penncozeb, etc.	mancozeb	M	C	GSB, DM
Champ, Kocide, etc.	copper hydroxide	M	C	BFB
Topsin M	thiophanate-methyl	1	S	ANTH
Folicur, Tebuzole, etc.	tebuconazole	3	S	GSB, PM
Procure	triflumizole	3	S	PM
Rally	myclobutanil	3	S	PM
Endura	boscalid	7	S	PM
Pristine	boscalid + pyraclostrobin	7 + 11	S	GSB, DM, PM
Inspire Super	cyprodinil + difenoconazole	9 + 3	S	GSB, PM
Switch	cyprodinil + fludioxonil	9 + 12	S + C	GSB, PM
Cabrio	pyraclostrobin	11	S	ANTH
Quintec	quinoxifen	13	C	PM
Ranman	cyazofamid	21	S	DM
Previcur Flex	propamocarb	28	S	DM
Revus	mandipropamid	40	S	DM
Presidio	fluopicolide	43	S	DM
<u>FUTURE PRODUCTS</u>				
Luna Experience (Bayer)	Tebuconazole + Fluopyram	3 + 7	S	GSB, PM
Torino (Gowan Co.)	Cyflufenamid	U6		PM

GSB: Gummy Stem Blight; DM: Downy Mildew; PM: Powdery Mildew; ANTH: Anthracnose; BFB: Bacterial Fruit Blotch. C: contact spray S: "systemic" spray

In general, fungicides either stay where you apply them or move up!

Fungicide deposits in the leaf axil near emerging leaves may provide protection for new leaves.



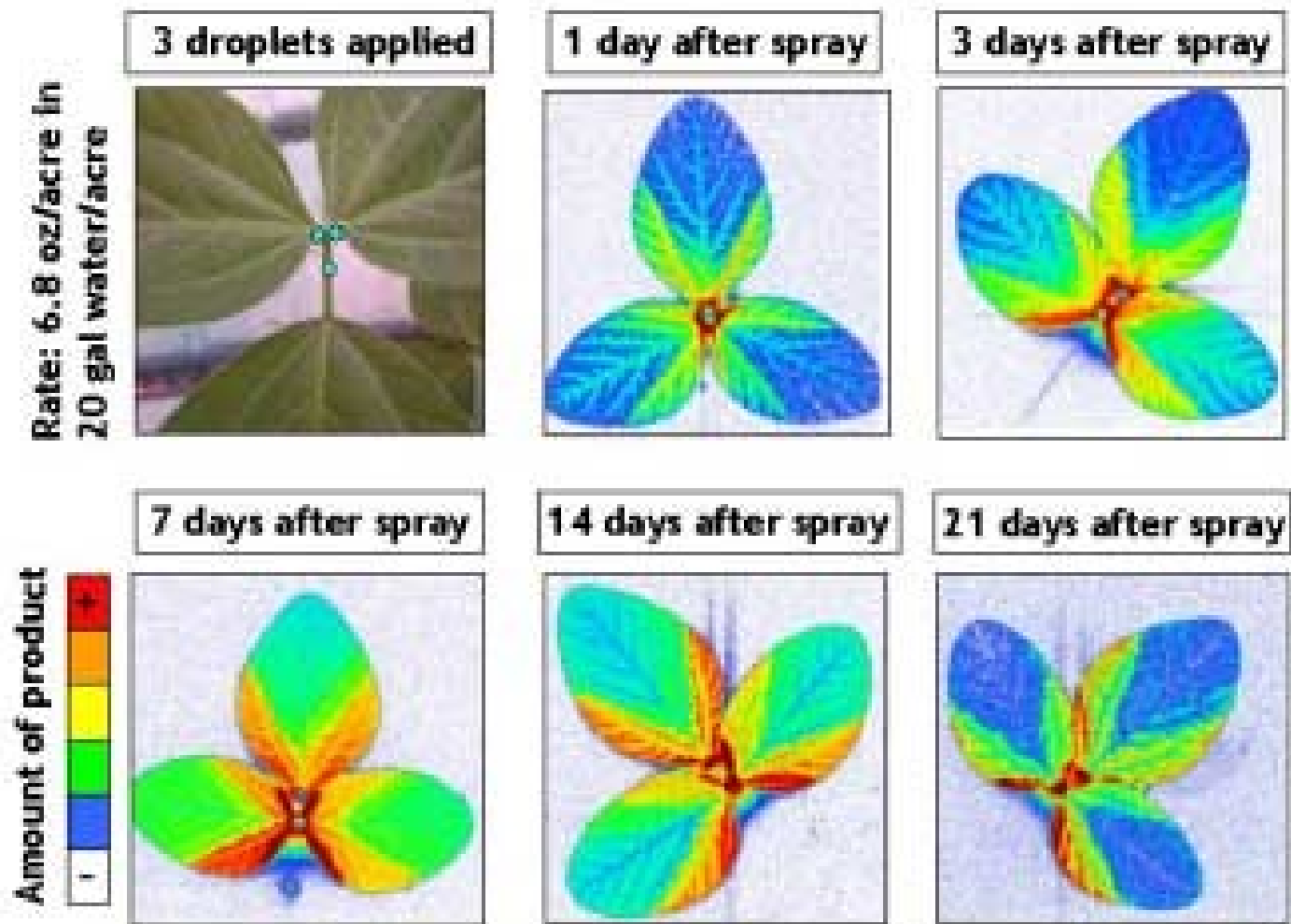
A fungicide deposit close to the crown will protect the oldest leaf sheath from infection, but will not provide protection to new leaves.

Fungicides that reach thatch and soil may be absorbed by roots.

Key spray factors for disease control with fungicides are:

- **Application rates** vary from 15 to 100 GPA
 - Range of rates specified on label
 - Higher rates often better coverage
- **Spray intervals** vary from 7 to 21 days
 - Fungicides breakdown
 - Environment
- **Surface coverage** (spray nozzle type and droplet size)

Spray intervals are based on fungicide residual or plant growth.



Complete coverage (100%) is impossible.

- How much do we need to cover?
 - Late blight: yield increases at 28% coverage
 - Foliar disease can be tolerated
 - Corn: upper 1/3 canopy coverage
 - Legumes: upper 1/3 or so canopy coverage
- Ornamentals and turf more extensive coverage.

Droplet sizes from 200 to 300 microns are best for fungicide applications.

DROPLET SIZE

Category	Symbol	Color code	Approximate VMD (0.5) (microns)*
Very fine	VF	red	<150
Fine	F	orange	150-250
Medium	M	yellow	250-350
Coarse	C	blue	350-450
Very coarse	VC	green	450-550
Extremely coarse	XC	white	>550

*VMD (volume mean diameter) = droplet size where half of the volume has droplets greater than the volume mean diameter, and half the volume has droplets smaller than the volume mean diameter.

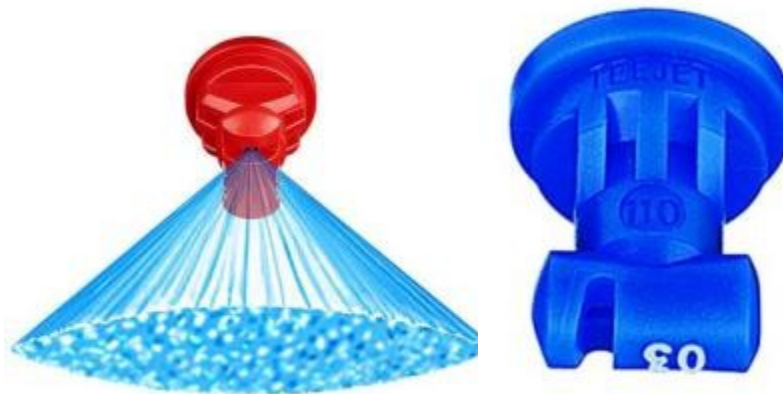
Table 1. Droplet size categories.

Drift is a worry (avoid herbicide mixing)

Common nozzles used for fungicides



Twin Jet Flat Fan



Flat Fan

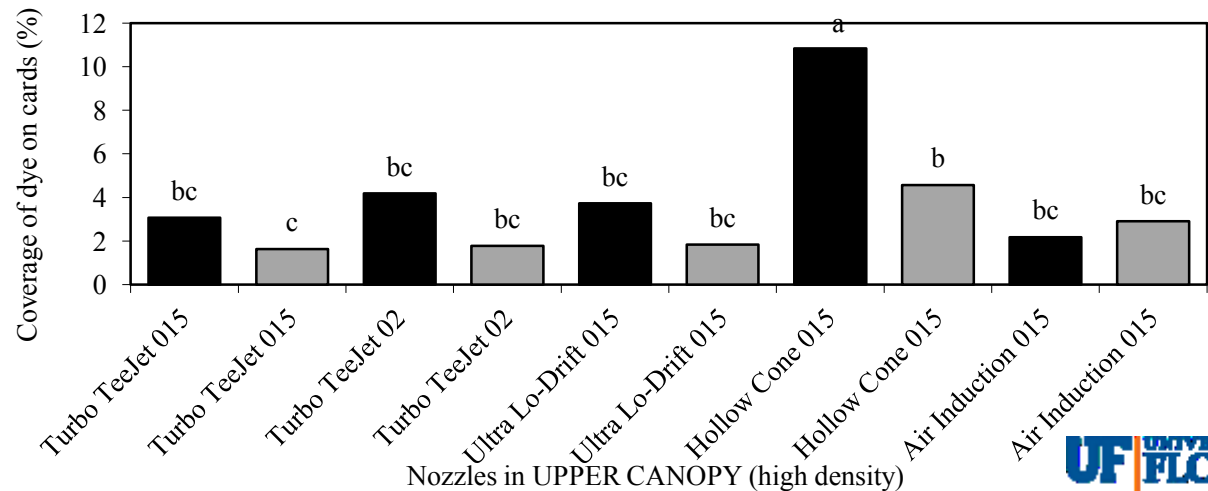
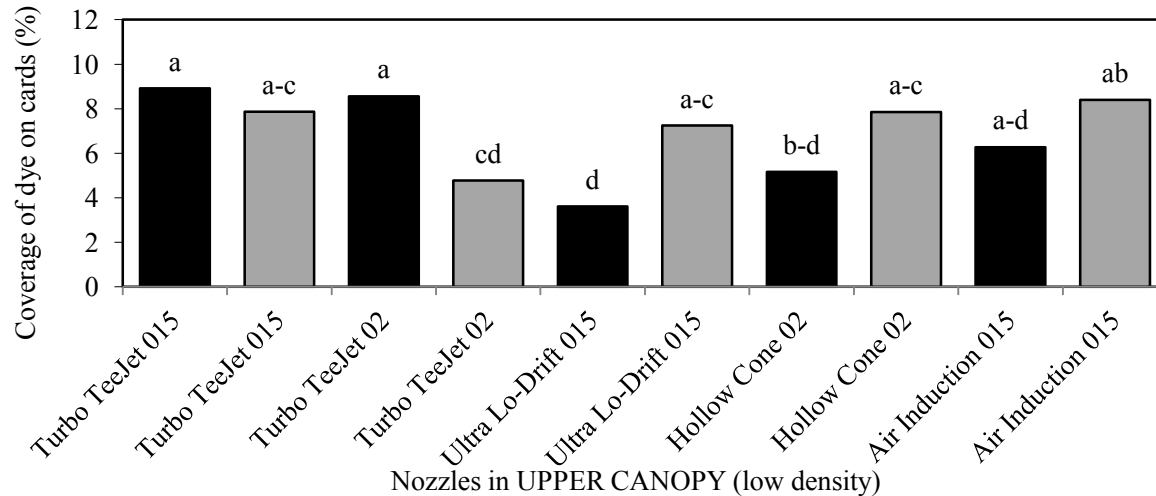


Hollow Cone or Whirling Disc



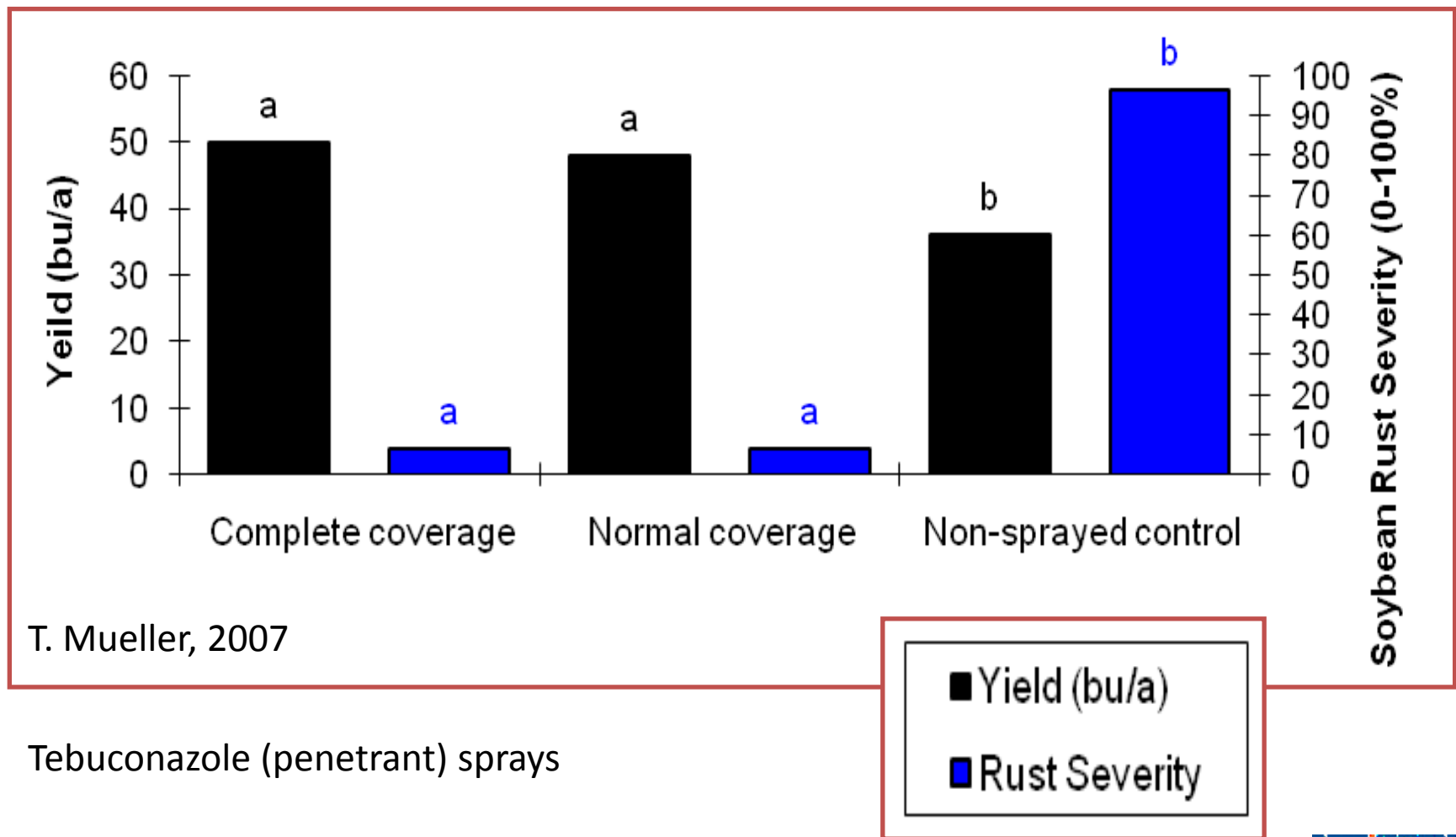
Air Induction Flat Fan

Canopy density important in determining coverage from a nozzle.



T. Mueller
(soybeans),
2006

Fungicide coverage might be less important when using a penetrant.



Spray coverage is important, but it is important to consider the goal.

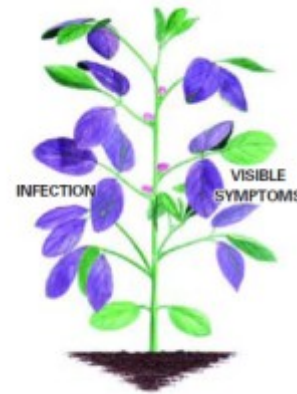
- If it is a preventative (contact) spray then coverage is critical.
- If it is a responsive (penetrant) spray then coverage maybe less critical.



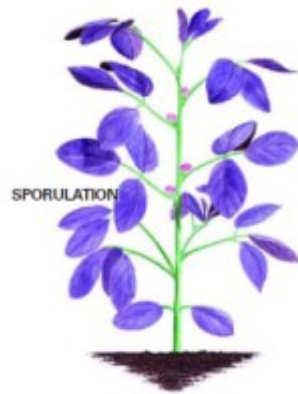
A. Fungicide Applied



B. Contact Fungicide



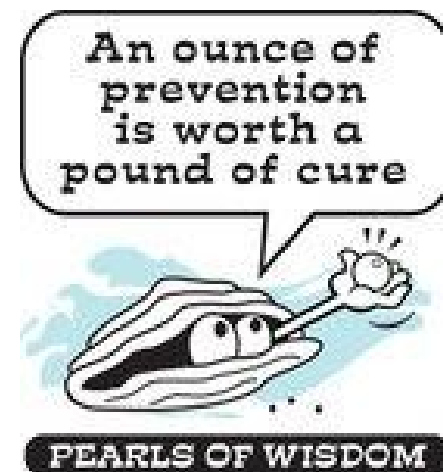
C. Strobilurin mobility



D. Triazole mobility

The basics of a “good” spray program

- **Prevention** is key!
- Be sure to **rotate chemistries**
 - FRAC number
 - Labels for details
- Fungicides will manage diseases, but will not eliminate them.



Questions?



Thank you to Dr. Daren Mueller