Beyond Strobys and Triazoles: How Do Fungicides Work?

Matt Montgomery and Bruce Paulsrud, University of Illinois Extension

FRAC Group 1 - *Methyl-benzimidazole carbamates*

H

Active ingredient examples: *thiabendazole, thiophanate-methyl*

Mode or site of action on pathogen:
Disrupt "Beta-tubulin assembly." Following the duplication of chromosomes (interphase) and condensation of duplicated chromosomes into transportable packages (prophase), duplicated chromosomes are aligned in a central column (metaphase) and then pulled to either end of the cell (anaphase) in preparation for cell division (telophase). The movement of chromosome packages is accomplished via the work of microtubules. These thread-like structures attach and move packaged chromosomes via adjusting the number of subunits per microtubule. Fungicides in this group disrupt mitosis by binding to the tubulin subunits.

FRAC Group 3 - *Demethylation inhibitors (DMIs)*

Active ingredient examples: *difenoconazole, imazalil, myclobutanil, propiconazole, tebuconazole, tetraconazole, triadimenol*

Mode or site of action on pathogen:
Inhibit enzymes necessary to form sterols (lipids), compounds located between certain phospholipids in the cell membrane that regulate the permeability of the membrane. Inhibited sterol production therefore leads to inadequate filtering by the cell membrane, and allows undesirable material to accumulate in the cell.

Note: All active ingredients listed (except imazalil) belong to the "triazole" subgroup.

FRAC Group 4 - *Phenylamides*

H

Active ingredient examples: *mefenoxam (metalaxyl-M), metalaxyl*

Mode or site of action on pathogen:
Phenylamides disrupt the enzyme RNA polymerase, which is needed to form ribonucleic acid (RNA). Disrupted RNA formation results in a cell incapable of transferring information from the DNA (housed within the nucleus – informing the cell what proteins need to be produced) to the ribosomes (located in the cytoplasm – producing the proteins). This results in disrupted protein formation which inhibits both cellular metabolism and development.

FRAC Group 7 - *Carboxamides*

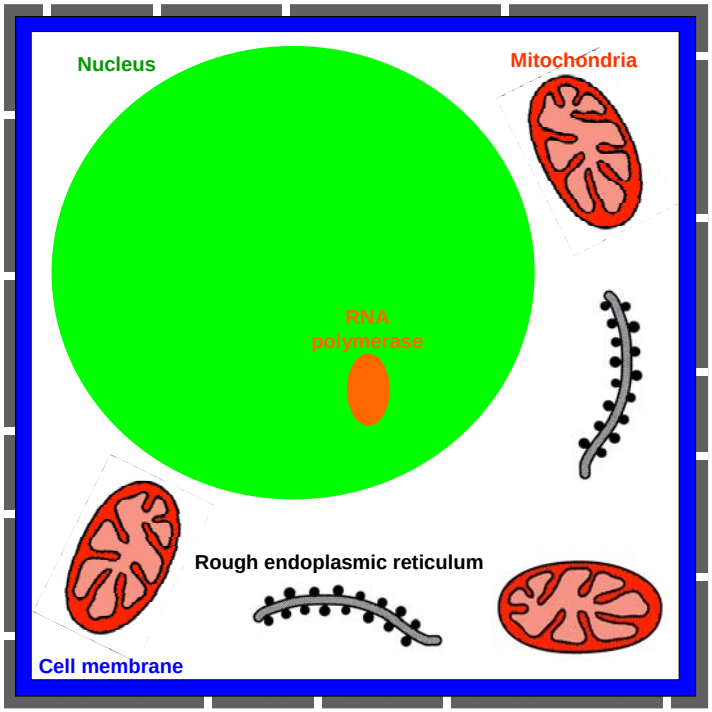
Active ingredient examples: *carboxin*

Mode or site of action on pathogen:
Carboximides inhibit the function of a molecule within mitochondria, termed complex II, necessary to secure energy (via FADH2). During respiration, negatively charged electrons are moved across mitochondrial membranes, dragging with them protons which also accumulate behind the membrane. The protons filter back through the membrane, in an effort to reestablish equilibrium, and turn cellular turbines which generate the energy needed to sustain life. As the function of complex II molecules is inhibited, the cell's ability to transport electrons across the mitochondrial membrane is inhibited as well, also inhibiting proton movement. As a result, the cell cannot harvest energy via FADH2 and energy depletion ensues.

Preventative & Curative **Preventative**

H = High Resistance Concern

Fungicide Resistance Action Committee (FRAC) Groups are color coded to match the site or organelle affected in this simplified fungal cell. (Brown = other or nondescript mode of action)



FRAC Group 11 - *Quinone outside inhibitors*

H H

Active ingredient examples: *azoxystrobin, pyraclostrobin, trifloxystrobin*

Mode or site of action on pathogen:
Like carboximides, QOI fungicides kill the targeted pathogen via inhibiting the cell's ability to harvest energy in the mitochondria thus killing the cell via energy depletion. However, the mechanism at work is somewhat different. Whereas carboximides only inhibit the harvest of energy via FADH2, QOIs inhibit the harvest of energy via both FADH2 and NADH. This is accomplished by inhibiting a molecule (Complex III) needed to transport electrons across the mitochondrial membrane.

Note: Future additions to this Group may not belong to the "strobilurin" subgroup.

FRAC Group 12 - *Phenylpyrroles*

Active ingredient examples: *fludioxonil*

Mode or site of action on pathogen:
Phenylpyrroles disrupt osomotic signal transduction via inhibiting MAP kinase proteins. In the cell, signal transduction proteins are used to monitor intracellular and extracellular conditions and allow the cell to respond appropriately in response to those conditions. MAP kinase proteins monitor and regulate osmotic pressure within the cell. Disruption of MAP kinase proteins results in erratic, and possibly non-existent, osmotic pressure regulation, which dehydrates or ruptures the cell.

FRAC GROUP 14 - *Aromatic hydrocarbons (nitroanilines)*

Active ingredient examples: *PCNB*

Mode or site of action on pathogen:
The exact mode of action at work in such materials is unclear, but some references suggest that these materials affect lipids via lipid peroxidiation. If correct, a free radical reacts with a lipid by removing an electron, which results in the formation of additional free radicals. The free radical-lipid reaction eventually would cause severe damage to the cell membrane possibly resulting in lysis (rupture of the cell).

FRAC GROUP M3 - *Dithiocarbamates*

Active ingredient examples: *mancozeb, maneb, thiram*

Mode or site of action on pathogen:
Most references state that such materials have "multi-site" activity. Dithiocarbamates thus likely inhibit a host of processes in the cell including oxygen uptake, enzyme function, amino acid synthesis, respiration, etc.

FRAC Group M4 - *Phthalimides*

Active ingredient examples: *captan*

Mode or site of action on pathogen:
Most references state that such materials have "multi-site" activity. Phthalimides thus likely inhibit a host of processes in the cell including enzyme function, amino acid synthesis, cellular metabolism, etc.

FRAC Group M5 - *Chloronitriles/Phthalonitriles*

Active ingredient examples: *chlorothalonil*

Mode or site of action on pathogen:
Chlorothalonil reacts with thiols, which are sulfur and hydrogen containing compounds. The chlorothalonil-thiol reaction disrupts various processes within the cell including enzyme production. This likely disrupts amino acid synthesis, protein synthesis, cellular metabolism, etc. Sulfur containing enzymes also are tied to various parts of the respiration process, including the "Complexes" that procure energy from NADH and FADH2 thus indicating that such materials likely also disrupt respiration.

References

- Brent, Keith, J. "Fungicide Resistance in Crop Pathogens: How can it be managed?" Fungicide Resistance Action Committee. April 1995. (http://www.frac.info/publications.html). Accessed October, 2004.
- Bretthauer, Scott, et al. "Report on Plant Disease 1002: Characteristics of Fungicides Used in Field Crops." University of Illinois. September 2005. (http://www.ag.uiuc.edu/~vista/abstracts/a1002.html). Accessed March, 2006.
- "FRAC Fungicide List 1 (arranged by FRAC Code)." Fungicide Resistance Action Committee. (http://www.frac.info/publications.html). Accessed October, 2004.
- Locke, Tom, et. al. "Fungicide Resistance." Fungicide Resistance Action Group – UK. August 2001. (http://www.pesticides.gov.uk/uploadedfiles/Web_Assets/RAGs/FRAG_UK_leaflet.pdf). Accessed October, 2004.
- "Fundamentals of Biochemistry." Voet, Voet, and Pratt. Wiley (New York), 1999.
- "Asking About Cells." Tobin and Morel. Harcourt Brace (Fort Worth), 1997.