Tutorial on Fungicides

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Pesticides can be described by their time of "invention"; by their mode of action (MOA), their descriptors which include mobility, function, and time of use, or their chemical class. Often all this becomes a tangled mess and confusion (even among the most knowledgeable) can set in. It's no small wonder that novel (or even veteran) grape growers would feel a bit overwhelmed. Added to all the names, dates, amounts, preharvest intervals, restricted entry levels, tank mixes, etc, etc, etc is the issue that has us all shaking in our spray boots – resistance development! But how do we know how to delay resistance development if we don't understand the pesticide chemistries? Topping it all off, how do you pick the chemical with the best bang for the buck without knowledge of the brand names in each chemical class?

Whoa…let's not get ahead of ourselves. In fact, let's go back to square one and introduce one component of chemical control: the fungicides.

What is a fungicide: The definition of a fungicide is a chemical that kills fungi. The cide portion of the word comes from Latin meaning *to kill*. By contrast certain fungistatic materials may inhibit but not kill fungi. High temperature, for example, can be fungistatic (and may even be fungicidal if high enough). Other terms used to classify fungicides (which I call descriptors) relate to mobility, function, and time of use.

Mobility
- Residual – resides on surface of the leaf and provides protection
- Systemic – moves into leaf and provides protection

Function
- Protectant – protects from disease infection
- Curative – cures the disease

Time of Use
- Prophylactic – used before infection occurs
- Eradicant – used after infection has occured

Classes of fungicides: Fungicides can also be described based on class. To fully understand the "class system" it's best to go back to the early years. Pesticides, of some fashion, have been used since the early days of mankind. Researchers have found many historical works describing pest control methods, some surprisingly useful, others quite laughable. Those early trials, however primitive, paved the way for many of the agricultural practices used today.

From an article titled "Caesar's Wars":

> "Many modern pest controls began in Socrates' garden. The ancient Greeks and Romans excelled at more endeavors than just philosophy, architecture, orgies, and war – they pioneered many of the agriculture practices used today, and developed many forms of pest control that are still used as the foundation for today's battle against pests."
>
> -Agrichemical Age

There are four major eras of pesticide development, including the period of Socrates:

I. Sulfur – before 1882

References to sulfur use are found in the Bible, as well as Greek and Roman literature. After the introduction of powdery mildew into France in the 1840s, it was noted that when a mixture of powdered lime and sulfur was applied to vines, leaves and berries were significantly protected from powdery mildew infection.

Class name: Sulfur

- Spectrum of activity (target): Powdery mildew
- Descriptors: Protectant/Residual/slightly Systemic?
- Mode of Action: Inhibits spore germination and mycelial growth (FRAC code M2)
- Advantages: Low cost, Organic production
- Disadvantages: Limited spectrum of activity, phytotoxic at high temperatures (>85°F), large quantities needed
- Example product names (common names):
  - Microthiol Disperss
  - Kumulus
  - flowable liquid sulfur
  - wettable sulfur
  - Sulfur Spray
  - Kocide 404S (sulfur + copper)

II. Copper – 1882 to 1934

In 1878, grapevine leaves in some French vineyards began to show symptoms of downy mildew. Downy mildew spread rapidly until French Botany professor Pierre Alexis

Millardet while walking through a vineyard noticed that vines next to the road had a bluish film on their leaves and significantly less downy mildew. When questioning the owner of the vineyard, he found the bluish film was actually bluestone (copper sulfate) mixed with hydrated lime (to aid in sticking to the leaves). The farmer used this mixture to give passer-byers the impression the vines were poisonous so they would not eat his fruit. After testing various copper sulfate and hydrated lime formulations what we now know as Bordeaux mixture was born. This began the Copper Era.

Class name: Copper

- Spectrum of activity (target): Downy mildew, some powdery mildew, some black rot, and bacteria
- Descriptors: Protectant
- Mode of Action: Works at cell surface causing membrane damage (FRAC code M1)
- Advantages: Many formulations, Organic production
- Disadvantages: Phytotoxic to many plants
- Example product names (common name):
    - Bordeaux mixture (copper sulfate + lime)
    - Kocide 404S (copper + sulfur)
    - Kocide 101 (copper hydroxide)
    - Tenn-Cop 5E (copper salts)
    - Champ 4L (copper hydroxide)
    - BCS-Copper Fungicide (copper oxychloride)
    - C-O-C-S (copper oxychloride-copper sulfate)

III. Organic (compounds containing Carbon) – 1934 to 1964

After WWII, organic chemistries became the fore-front of chemical research resulting in the release of inexpensive, highly effective, and very popular pesticides such as DDT, BHC, aldrin, dieldrin, endrin, and 2,4-D. Users applied these pesticides liberally. Soon pests developed resistance, non-target organisms were harmed, and residues appeared in unexpected places. In 1962, Rachel Carson published Silent Spring, alerting the public to the downfalls of pesticide use. As a result pesticide research was redirected toward more pest-specific chemistries and the most harmful pesticide chemistries were phased out of use. It was during the organic period that broad spectrum fungicides such as captan and mancozeb were released.

Class name: Dithiocarbamates (EBDC) – monoalkyldithiocarbamates*

- Spectrum of activity (target): Phomopsis, downy mildew, black rot, late-season rots
- Descriptors: Protectant/Residual
- Mode of Action: Inactivation of cellular thiol groups (FRAC code M3)
- Advantages: Broad spectrum

- Disadvantages: Broad spectrum (may harm non-targets)
- Example product names (common name):
    - Dithane M45, F45, DF (mancozeb)
    - Manzate 200, 200 DF (mancozeb)
    - Penncozeb (mancozeb)
    - Manex II (mancozeb)

Note: "Mancozeb" is the generic name for these proprietary products. The generic name derives from manganese co-ordinated with zinc and ethylenebis(dithiocarbamate).

Class name: Dithiocarbamates – dialkyldithiocarbamates

- Spectrum of activity (target): Phomopsis, black rot, downy mildew, late-season rots
- Descriptors: Protectant/Residual
- Mode of Action: Inhibits cellular respiration (FRAC code M3)
- Advantages: Broad spectrum
- Disadvantages: Broad spectrum (may harm non-targets)
- Product names (common name): Ziram (ziram)

Class name: Phthalimides

- Spectrum of activity (target): Phomopsis, downy mildew, black rot, late-season rots
- Descriptors: Protectant/Residual
- Mode of Action: Interferes with cellular respiration and glycolysis (FRAC code M4)
- Advantages: Broad spectrum
- Disadvantages: No activity against powdery mildew, may harm non-targets
- Product names (common name):
    - Captan (captan)
    - Captec (captan)

IV. Modern – 1964 to present

The shift from broad spectrum to more organism- or site-specific chemistries, led to many of the chemicals in use today. The modern era represents a time of realization, an exploration of environmentally sound yet effective chemistries. Researchers are continuously improving pesticide chemistries while also looking at other avenues of pest control such as biological and cultural control. Integrated pest management programs have been developed to improve the effectiveness or reduce the overall use of pesticides by incorporating components of multiple disciplines including plant pathology, horticulture, entomology, microbiology, ecology, herbology, and economics among others.

Class name: Dicarboximides

- Spectrum of activity (target): Botrytis
- Descriptors: Protectant and Curative/Systemic
- Mode of Action: Interferes with membrane function (FRAC code 2)
- Advantages: Organism specific
- Disadvantages: Resistance an issue, limited applications per season, little activity against other late-season rots
- Product names (common name): Rovral (iprodione)

Class name: Ergosterol biosynthesis inhibitors (DMIs or SIs)*

- Spectrum of activity (target): Powdery mildew, black rot
- Descriptors: Protectant and Curative/Systemic
- Mode of Action: Inhibits 3 steps in ergosterol biosynthesis (ergosterol is a component of the cell membrane) (FRAC code 3).
- Advantages: Very effective
- Disadvantages: Resistance an issue, no activity on downy mildew, should not spray onto a full blown powdery mildew infection, limited applications per season
- Product names (common name):
    - Nova (myclobutanil)
    - Elite (tebuconazole)
    - Rubigan (fenarimol) – powdery mildew only
    - Procure (triflumizole)
    - Bayleton (triadimefon)

Class name: Phenylamides*

- Spectrum of activity (target): Downy mildew
- Descriptors: Curative/Systemic
- Mode of Action: Inhibits rRNA synthesis (FRAC code 4 + M3)
- Advantages: Active after haustoria penetration for curative effective
- Disadvantages: Resistance may develop, limited applications per season
- Product names (common name):
    - Ridomil Gold Copper (mefenoxam + copper)
    - Ridomil Gold MZ (mefenoxam + mancozeb)

Class name: QoI Inhibitors (Strobilurins)*

- Spectrum of activity (target): Powdery mildew, downy mildew, black rot, Phomopsis, Botrytis, late-season rots
- Descriptors: Protectant & slightly Curative/Residual & Systemic
- Mode of Action: Inhibits spore germination, mycelial growth, suppresses sporulation, inhibits respiration (FRAC code 11)

- Advantages: Very effective
- Disadvantages: Resistance an issue, recommended maximum of 2 seasonal sprays in Virginia, should not spray on full blown powdery mildew or downy mildew infection (consult label)
- Product names (common name):
    - Sovran (kresoxim-methyl)
    - Abound (azoxystrobin)
    - Flint (trifloxystrobin)
    - Pristine (pyraclostrobin + boscalid) (FRAC code 11 + 7)

Class name: Anilinopyridimines*

- Spectrum of activity (target): Botrytis
- Descriptors: Protectant and Curative/Systemic
- Mode of Action: Mechanism of action not clear (FRAC code 9)
- Advantages: Very effective
- Disadvantages: Limited spectrum of activity, resistance may develop, limited applications per season
- Product names (common name):
    - Vangard (cyprodinil)
    - Scala (pyrimethanil)

Class name: Benzimidazoles & Thiophanates

- Spectrum of activity (target): Botyrtis, black rot, bitter rot, Phomopsis, powdery mildew
- Descriptors: Curative/Systemic
- Mode of Action: Affect mitotic spindle formation in cell division (FRAC code 1)
- Advantages: Broad spectrum
- Disadvantages: Resistance development common
- Product names (common name): Topsin M (thiophanate-methyl)

Others:

There are other fungicides that have either been recently invented or do not belong in an established class (their modes of action do not fit with any other class). We call them *others* but perhaps in the future they will form a class all their own.

Class name: Others

Hydroxyanilides (a group of sterol biosynthesis inhibitors)

- Spectrum of activity (target): Botrytis
- Descriptors: Protectant

- Mode of Action: unknown 3-keto reductase, C4-demethylation (FRAC code 17)
- Advantages: Organism specific
- Disadvantages: Resistance development, limited applications per season
- Product names (common name): Elevate (fenhexamid)

Carboxamides

- Spectrum of activity (target): Botrytis, powdery mildew
- Descriptors: Protectant and Curative
- Mode of Action: unknown inhibit succinate dehydrogenase (respiration) (FRAC code 7)
- Advantages: Organism specific
- Disadvantages: Limited applications per season
- Product names (common name): Endura (boscalid)

Quinolines

- Spectrum of activity (target): Powdery mildew
- Descriptors: Protectant
- Mode of Action: Unknown, may affect cell signaling (FRAC code 13)
- Advantages: Organism specific
- Disadvantages: Should not apply to existing powdery mildew infections
- Product names (common name): Quintec (quinoxyfen)

* Fungicides and formulations in these classes may have different efficacy on the target organism(s). Consult pest management guides for more information about the individual fungicides.

Additional information on diseases and fungicide applications is available on my homepage and the 2006 Pest Management Guide. A table listing fungicides, FRAC Codes, and information on resistance development can be found at http://www.frac.info/frac/publication/anhang/FRAC_Code_List2.pdf.

References:

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"Caesar's Wars". 1987. Agrochemical Age. Dec: p24.