RESISTANCE MANAGEMENT – A NECESSITY IN FUNGICIDE USAGE

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Currently, in addition to the inorganic copper and sulfur materials, ten classes of fungicides are registered for preharvest use on peaches and nectarines in California: the pthalimides (e.g., captan); dithiocarbamates (e.g., ziram); dicarboximides (e.g. iprodione); isophthalonitriles (e.g., chlorothalonil); benzimidazoles (e.g., thiophanate-methyl); sterol biosynthesis inhibitors (SBIs; e.g., fenbuconazole, myclobutanil, propiconazole, tebuconazole); strobilurins (QoIs; e.g., azoxystrobin, trifloxystrobin, pyraclostrobin); hydroxyanilides (e.g., fenhexamid); anilinopyrimidines (e.g., cyprodinil, pyrimethanil); and carboxamides (e.g., boscalid, a component of the pre-mixture Pristine®). The first four classes each have a multi-site mode of action, whereas the latter six classes all have a single-site mode of action and thus, target a single site in a specific biochemical pathway of a target organism. Fungicide classes, also referred to as fungicide groups, are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (see http://www.frac.info/). New fungicides introduced in 2008 include two pre-mixtures: tebuconazole-trifloxystrobin (i.e., Adament®) and pyrimethanil-trifloxystrobin (i.e., Distinguish®). Still, several new fungicide classes with unique modes of action are being developed and will be registered in the near future. With an increasing arsenal of fungicides available, using the proper material for good disease control while also keeping the risk of fungicide resistance to a minimum is becoming more difficult and requires an increasing amount of knowledge on the modes of action (fungicide classes), spectrum of activity, efficacy, and best usage strategies.

Resistance development is much more likely against single-site mode of action than against multi-site mode of action materials. In addition to the benzimidazoles, resistance has developed in pathogens of stone fruit crops in California against several of the newer fungicide classes. Thus, in populations of *Alternaria* spp. and *Cladosporium carpophilum*, causing Alternaria leaf spot and scab of almond, respectively, resistance is now widespread against the strobilurin fungicides. In 2007, resistance in *Alternaria* spp. was also common against the carboxamides. In addition, in 2007 we also found for the first time isolates of the brown rot pathogen of stone fruits, *Monilinia fructicola*, that were resistant to the anilinopyrimidines. Furthermore, in other stone fruit growing areas of the country, this latter pathogen has already acquired extensive resistance against the SBI fungicides, a very important class for the management of several stone fruit diseases.

Except for the benzimidazoles, to date resistance is not widespread in fungal pathogens of peach and nectarine in California. Thus, this is a critical time to remember the principles of anti-resistance management that are aimed towards preventing the development and spread of resistance. Resistance development in the field is mainly a selection process where a low fraction of the pathogen population that is naturally resistant multiplies in the presence of the selecting agent, i.e., the fungicide. Because members of a particular fungicide class have the same mode of action, cross-resistance patterns generally follow modes of action making all members of a class ineffective once resistance has developed against this class. Resistance

development is a complex process that depends on characteristics of the pathogen, the fungicide class, and also the host. As a general rule, the risk of resistance development is highest when the following conditions are met:

- A large amount of pathogen propagules is present (e.g., when fungicides are applied when disease is already present – improper timing, especially during conducive environments)
- A low rate of fungicides is applied (e.g., alternate-row applications, air applications that are done at full canopy, or applications at low off-label rates)
- The pathogen is repeatedly exposed to the same chemical class (e.g., when no rotations are being done).

Based on these principles, several anti-resistance strategies have been developed that should be part of an integrated disease management program. The most effective way to combat fungicide resistance is to mix or alternate fungicides with different modes of action (classes of fungicides). If possible, at least one rotational mix partner should be a multi-site material. Because several highly effective classes of fungicides are available for peach, each class should be limited ideally to one and no more than two applications per season in rotation program. The use of fungicide pre-mixtures can be a step in the right direction, but both mixture components should have activity against a particular pathogen, otherwise they will act like single-fungicides in the selection process.

Fungicides are most effective in reducing disease and the amount of pathogen survivors when the environment is less favorable for pathogen infection and when disease pressure is lower. Consequently, planting, cultural, and orchard sanitation practices can be important components in an anti-resistance program. Disease pressure can also be lowered if a management program is started with multi-site mode of action fungicides. This practice will reduce the pathogen population size that is exposed to subsequent treatments with single-site mode of action compounds and the probability of selecting for resistance is reduced. A single-site mode of action fungicide should ***never*** be applied by itself when disease incidence in the orchard is already high.

The following "**RULES**" are a guideline for following fungicide stewardship:

- **R**otate or mix fungicides of different mode of actions. Suggested disease management programs with fungicide groups can be found at http://www.ipm.ucdavis.edu/.
- **U**se labeled rates – for strobilurins, use upper label rates.
- **L**imit the total number of applications of any single-site mode of action fungicide class to ideally one and no more than two per orchard per season in rotation program.
- **E**ducate yourself about fungicide activity, mode of action, and class – as well as resistance management practices. Visit the UC IPM website (http://www.ipm.ucdavis.edu/) to obtain this information.
- **S**tart a fungicide program with multi-site mode of action materials (e.g., Captan, Bravo/Echo, Ziram, Rovral, Sulfur).

Lastly, because fungicide resistance management has to be a large-scale effort due to the general free movement of air-borne pathogen propagules among orchards, it should be taken seriously by everyone.