# FUNGICIDES, BACTERICIDES, BIOCONTROLS, AND NATURAL PRODUCTS FOR DECIDUOUS TREE FRUIT AND NUT, CITRUS, STRAWBERRY, AND VINE CROPS IN CALIFORNIA

# 2025

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|---|---|---|
| *ALMOND* | *GRAPE* | *PLUM* |
| *APPLE* | *KIWIFRUIT* | *POMEGRANATE* |
| *APRICOT* | *PEACH* | *PRUNE (DRIED PLUM)* |
| *CHERRY* | *NECTARINE* | *STRAWBERRY* |
| *CITRUS* | *PEAR* | *WALNUT* |
| | *PISTACHIO* | |


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## FUNGICIDES, BACTERICIDES, BIOCONTROLS, AND NATURAL PRODUCTS

***fun·gi·cide*** ('fənjə-sīd). n. A chemical that inhibits, prevents, or stops fungal growth.
***bac·te·ri·cide*** (bak-tîrə -sīd). n. A chemical that inhibits, prevents, or stops bacterial growth.
***bi·o·con·trol*** (bī′ō-kən-trōl′). n. Short for biological control. The use of living organisms to control plant diseases and other pests.
***nat·u·ral prod·uct*** (nat´u`ral prod´uct). n. A chemical substance produced by a living organism, often a plant or microorganism in a fermentation process.

Fungicides, bactericides, biocontrols, and natural products prevent or mitigate damage caused by microorganisms, typically fungi and bacteria, to other living organisms such as people, animals, plants including agricultural crops, as well as physical structures such as buildings and plant products (e.g., wood). Biological controls are living organisms, whereas natural products are derived from natural sources. Fungicides and bactericides may be developed from natural products, or they are chemically synthesized but most newer products are heterocyclic, carbon-based compounds that are degradable in the environment. In general, pesticides used in modern agriculture need to have high efficacy and have a critical role in the development of our society by improving crop yields and reducing labor needed to produce food. This enables society to diversify and endeavor into activities other than food production. Overall, the benefits of pesticides such as fungicides and bactericides far outweigh the risks associated with using them, especially when they have been thoroughly evaluated and characterized by regulatory agencies, universities, and private testing labs.

Fungicides can be grouped in various ways. Currently, in the most widely used system, they are categorized according to their mode of action by FRAC 2022, an agrochemical industry work group focusing on fungicide resistance management. Each fungicide is assigned a FRAC Code, and the list of Codes is updated annually. Compounds with the same Code have the same molecular mode of action (the same target site in the fungal pathogen) and are at risk for cross-resistance. Target sites within the pathogen include the cytoskeleton, respiration, synthesis of amino acids, proteins, the cell wall, and lipids, nucleic acid metabolism and other target. Code numbering is based on the temporal introduction of a new mode of action. Thus, the methyl benzimidazoles that were the first single-site mode of action fungicides introduced were assigned Code 1. Currently, more than 50 FRAC Codes have been described for single-site mode of action fungicides. For multi-site mode of action fungicides such as copper, the Code is preceded by the letter “M,” copper being M 01, and there is currently a total of 12 FRAC Codes for multi-site compounds. Biological treatments are given Code BM 01 (plant extracts) or BM 02 (biocontrols). Codes for compounds that are considered to induce host plant defenses are preceded by the letter “P”, whereas compounds with unknown modes of action have the letter “U”. A key aspect in fungicide resistance management is to avoid application of fungicides with the same FRAC Code repeatedly on the same crop lot without rotating or mixing with another FRAC Code. The FRAC Code of a fungicide is stated on the commercial container on the fungicide label, but also can be found on various online resources. Knowing the FRAC Code of a fungicide to be applied is the basis of designing fungicide programs that minimize resistance development, but also provide maximum disease management efficacy.

Still, although the mode of action among fungicides of the same FRAC Code is the same, members of a Code may have different spectra of activities (i.e., toxicity against a specific range of fungi) or degree of toxicity (that is commonly measured as the effective concentration to inhibit growth of a fungus by 50 percent, i.e., the $EC_{50}$ value). This is because active ingredients may have different affinities to certain fungal target sites. This is evident among succinate dehydrogenase inhibitors (FRAC Code 7) and especially among the demethylation inhibitors (DMIs; FRAC Code 3). For example, while the DMI propiconazole is highly effective against the sour rot pathogen

*Geotrichum citri-aurantii*, imazalil has low efficacy, whereas other Code 3 fungicides (not registered on citrus) may be more efficacious.

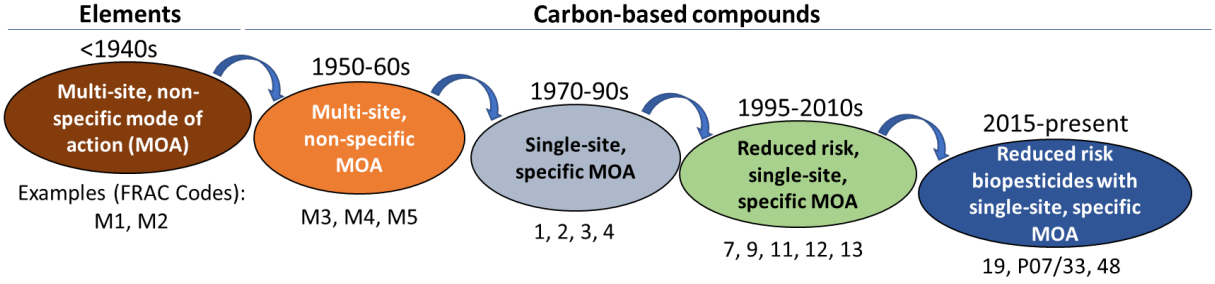
FRAC Codes also vary in their potential to develop resistance in fungal target populations, and this risk determines how prudently they should be used in respect to the number of applications per season and proper timing.

Uptake by plant tissues is another important characteristic of fungicides to be considered in their use. For example, in field applications after an infection event (e.g., rainfall) or in post-harvest applications where infections initiated some time before treatment need to be stopped, a fungicide with locally systemic action can reach the cell layers of the host that the pathogen has colonized at this timepoint. To reduce the risk of resistance development, but also to increase the spectrum of activity, some active ingredients are only marketed as pre-mixtures with another mode of action. Alternatively, single active ingredient fungicides may be mixed manually.

## THE EVOLUTION OF FUNGICIDES

In the last 50 years, there has been a dramatic change in conventional fungicide properties to improve their overall safety, performance, and targeted activity. In general, acute and chronic toxicities to humans and other non-target organisms have been dramatically reduced, and much higher amounts per body weight are required to cause damage in mamalian test subjects. The amounts needed to be toxic are so high that they are generally considered unattainable over a lifetime. Environmental persistence has been reduced in favor of shorter half-lives by designing them without metal ions, and thus, fungicides have less opportunity to contaminate waterways or adjacent ecosystems through air, water, or soil movement beyond the intended treatment area. Fungal pathways have been selected as biochemical target sites of fungicides that are highly specific to these organisms, resulting in lower amounts of active ingredients needed to manage plant diseases. Furthermore, different modes of action (MOA) allow rotations that prevent overuse of any one MOA and the selection of resistant sub-populations. An illustration of major steps in the evolution of agricultural fungicides for disease management is shown below.

**Figure 1. Evolution of agricultural fungicides**




## REGULATION OF PESTICIDES IN THE UNITED STATES

In the United States, the Environmental Protection Agency (EPA) oversees and regulates all pesticides including fungicides and bactericides. In accordance with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the Federal Food, Drug, and Cosmetic Act (FFDCA), and the Food Quality Protection Act (FQPA), the EPA regulates the manufacturing, transport, and use of all pesticides in the United States to protect humans and the environment from potential adverse effects that may be associated with pesticide exposure. In California and several other states, additional laws and government agencies are involved in the regulation and oversight of pesticides. Federal and state laws establish the legal authority of pesticide labels to prohibit the use

of these materials that is inconsistent with the instructions and general guidelines provided on such labels.

The EPA is responsible for determining the “risk” associated with pesticides and for establishing limits or “tolerances” on the amount of pesticide residues that may remain on food marketed in the United States to meet safety standards with “reasonable certainty of no harm” to the general population. A ‘safe risk’ is defined as a reasonable certainty that no harm will result from exposure to a pesticide residue from all anticipated dietary or other potential sources over a human lifetime based on reliable scientific information. Thus, FQPA established an “aggregate risk” assessment to take into account pesticide exposure from all possible sources: food, drinking water, and structural sources including buildings, public facilities, and landscaping. Additionally, FQPA established the evaluation of “cumulative risk” or exposure to a pesticide within a chemical class of materials that have the same toxic effect or a common mode of action. The law also established a 10-fold safety factor to account for pre- and post-natal toxicity, as well as to ensure completeness of pesticide toxicology information to account for pesticide exposure of infants and children.

When all three components - safe, aggregate, and cumulative risks - are put together, this determines the amount of a pesticide that can be used each year in the United States or “the risk cup”. Safer materials inherently have a larger cup (i.e., can be used more) while less safe materials have a smaller cup (i.e., should be used less). Some materials such as those that are derived from natural sources or are known to be generally safer than others are classified as “reduced risk”. These materials generally have a lower toxicity to humans and non-target organisms, have a lower environmental impact (e.g., are non-persistent in soil or water), and/or enhance integrated pest management (IPM) practices.

## MAXIMUM RESIDUE LIMITS (TOLERANCES) OF PESTICIDES ON AGRICULTURAL FOOD COMMODITIES

Residue tolerances are established for all pesticides registered on agricultural commodities. For synthetic pesticides and materials that are produced by fermentation and which are concentrated and/or reformulated, maximum residue limits (i.e., tolerances) have been established by national (country-based) and international regulatory agencies. In the United States, the Environmental Protection Agency (EPA), along with the Food and Drug Administration (FDA) are involved in establishing limits on agricultural food commodities for all registered products including those designated as “exempt” (an EPA designation) or “generally regarded as safe” or GRAS (an FDA designation). Use limits are set for the latter materials, whereas all other materials must have analytical procedures available to measure chemical residues on the commodity. Internationally, the United Nations World Health Organization (WHO) and Food and Agricultural Organization (FAO) created the CODEX Alimentarius Commission to develop food standards, guidelines, and practice codes.

The main goal of national and international agencies is to protect the health of consumers, ensure fair practices in food trade, and promote coordination of food standards. The process of registering a pesticide on a food commodity is rigorous and requires numerous evaluations ranging from toxicity to environmental persistence and chemical fate studies. The limits of a pesticide residue on each commodity are established as a maximum residue level or limit (MRL) which is considered an absolute minimal risk to the consumer. Most countries use the term MRL, but U.S. regulations refer instead to "tolerances". Both terms indicate the amount of pesticide residue that is permitted to remain on a plant commodity. Generally, the MRL level is two or more times higher than what is expected for a residue under labeled pesticide usage. The *CODEX Alimentarius* as part the World Health Organization (WHO) and the Food and Agricriculture Organization (FAO)

provides users with a list of MRL tolerances by commodity, pesticide, or functional class of the database at https://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/en/. In the United States, the website for viewing Global MRLs is https://www.fas.usda.gov/maximum-residue-limits-mrl-database and is provided by Bryant Christie Inc. Registered pesticide MRLs for many markets around the world may be searched by commodity, pesticide, and market. Global MRLs is designed for users in the United States. It provides MRL information from a U.S. viewpoint. **This means that other countries' MRLs are only included if there is a U.S. MRL established for the commodity/active ingredient combination.** This also means that the active ingredient and commodity menus available to search are limited to those listed in the U.S. Code of Federal Regulations (CFR) Title 40 CFR 180 Subpart C for pesticide specific tolerances.

Three rules of the Global MRL Database should be noted:

1. U.S. general, Section 18, regional, and time-limited pesticide MRLs for raw commodities that are currently in force for U.S. Environmental Protection Agency (EPA) registered active ingredients as listed in the U.S. Code of Federal Regulations (CFR) Title 40 CFR 180 Subpart C, and corresponding in force MRLs for other countries.
2. U.S. tolerances specifically designated in the CFR as import tolerances or without current U.S. registrations
3. Processed commodity MRLs

The Global MRL Database exclusively reflects maximum residue levels that have been established on a permanent basis under domestic US legislation according to the US CFR. The following types of MRLs are **not** included in the database:

- Other markets' MRLs in cases where there is no U.S. MRL established
- U.S. tolerances for indirect or inadvertent pesticide residues
- Pending and proposed MRLs that are not yet officially in force
- Active ingredients that are exempt from the requirement of a tolerance in the U.S.
- Exemptions in other countries
- MRLs for animal feed (except almond hulls and alfalfa), goat, horse, fish, shellfish, aquatic plants & algae (except seaweed)

Individuals who require more comprehensive MRL data may obtain premium subscriptions of the Global MRL Database. Access to more information and features include pending and proposed MRLs, regulation names and effective dates, the ability to save queries, and an MRL change report with email notifications.

## FUNGICIDE PERFORMANCE

Fungicides are registered and labeled for agricultural use only after numerous trials and years of testing and disease evaluations that demonstrate the activity of the product. In California and in some other states, efficacy data has to be submitted as part of the registration process. Most fungicides perform generally well under environmental conditions that occur in California. Still, their performance is dependent on many factors including physical and chemical properties of the fungicide, as well as the environmental and biological conditions in the agricultural system where they are used. Factors including deposition (e.g., application methods, rates, intervals, and coverage of plant surfaces) and depletion (rate of degradation from water, sunlight, microbial enzymatic breakdown, volatilization, systemic action, plant growth, etc.) will determine the persistence of fungicides on plant surfaces and contribute to the overall performance.

The disease triangle (the interaction between host, pathogen, and environment) determines the disease pressure in any agro-system. Susceptibility of plant cultivars and the conduciveness of environmental conditions before, during, and after fungicide application will affect disease development and ultimately, the performance of the fungicide. Furthermore, the sensitivity of the pathogen to the fungicide may change or "shift" with usage over time through adaptation or genetic resistance and thus, this greatly influences the success or failure of any fungicide product used under field conditions.

In this document, we rated the performance of conventional fungicides and bactericides, biocontrols, and natural products for managing major diseases caused by fungi and bacteria of temperate fruit (pome and stone fruit) and nut tree (almond, pistachio, and walnut) crops, citrus, grapevines, and strawberries that are major fruit and nut crops in California. For each product, the mode of action is shown and is based on the Fungicide Resistance Action Committee or FRAC Codes. A complete listing of the FRAC codes can be found at: https://www.frac.info/knowledge-database/downloads.

Performance ratings of products listed are based on direct experience from research trials evaluating the performance of the tested products under field conditions. Environmental conditions and pathogen populations may greatly influence the performance of the materials. A numbering system denotes:"0" = ineffective; "1" = minimal and often ineffective; "2" = limited and erratic; "3" = moderate and sometimes variable; "4" good and reliable; and "5" = excellent and consistent. Generally, "4" and "5" are commercially acceptable. Ratings with "1", "2", or "3" represent variability in performance inversely related to pathogen population, favorable environments, or host susceptibility. Thus, the performance ratings are relative in comparison to other products and may change as experience is gained in using the individual products. Attributes or deficiencies of a product are noted where information is available. For example, the resistance potential (presence of resistant pathogen populations in California) and persistence or degradation rate is cited for individual products when this information is known. Most materials are labeled for the management of the diseases for which ratings are presented. However, some products have been tested but are not labeled for managing a specific disease. Always consult the product label to ensure that the fungicide is currently registered for a specific use. This document is not a legal recommendation for using pesticides. When using pesticides, always consult with licenced pest control advisors or qualified pesticide applicators.

## FUNGICIDES AND THEIR EFFECTS ON NON-TARGET ORGANISMS, ESPECIALLY HONEY BEES

Fungicides are currently the "state of the art" tool in the management of flower, foliar, and fruit diseases of many crops worldwide, especially when cultivars with natural host resistance are not available. For example, in almond, stone fruit, grapes, and other fruit and nut crops in California,

some devastating diseases such as brown rot, shot hole, powdery mildew, and anthracnose have been managed using fungicides since these crops were introduced into the state. Furthermore, several fungicide chemistries, i.e., dicarboximides, benzimidazoles, and DMIs with unique modes of action have been used for over 60, 40, and 30 years, respectively. Many of these diseases initiate their disease cycles during host flowering. Thus, without the use of fungicides for managing bloom and foliar diseases, these diseases would be limiting to crop production. One might argue that developing host resistance is the best approach; however, this is very difficult in perennial tree and vine crops and requires many years. Furthermore, crop characteristics selected by the breeder to meet consumer demands often result in higher disease susceptibility of the crop.

In registration processes, all pesticides are extensively evaluated for their efficacy against diseases and their effect against non-target organisms. Toxicity data for new pesticides are required from each registrant and data are evaluated at federal (US Environmental Protection Agency) and sometimes at state (California Department of Pesticide Registration) regulatory agencies. Organisms required to be tested include European honey bees, aquatic invertebrates (e.g., *Daphnia* spp.), aquatic plants, and vertebrates (e.g., fish, birds, and mammals). For honey bees, the tests are directed to determine acute, short-term toxicity levels by contact and ingestion by adults. If a fungicide is found to be toxic to the adult honey bee, then additional tests are required against the brood. If any toxicity to non-target organisms is found, then a warning or prohibition is placed on the label to limit or restrict usage. Currently registered fungicides are either non-toxic or are practically non-toxic to adult honey bees exposed to extremely high levels of the fungicides. All fungicides registered have been approved only after these requirements are met.

Recently, European honey bees have been affected by Colony Collapse Disorder (CCD), where worker bees suddenly disappear, leaving the hive without a sustained source of honey and pollen. The cause of this disorder is still unknown. Numerous factors have come into scrutiny, including exposure to pesticides. With their longstanding regulatory requirements for pesticides to protect beneficial insects such as honey bees, the US-EPA, however, has no data demonstrating that any EPA-registered pesticide used according to the label instructions has caused CCD. Recent research indicates that it is more likely that a combination of factors, including poor nutrition, parasites (e.g., varroa mite), new diseases (e.g., Israeli Acute Paralysis virus, *Nosema* species), and changes in bee management (e.g., insect and mite control with pesticides inside the hives and migratory stress and drought, etc. brought about by anthropogenic movement of honey bees long distances) may be responsible for the disorder (http://www.epa.gov/pollinator-protection/colony-collapse-disorder). Other considerations include changes to honey bee populations due to breeding programs that render hives more susceptible to environmental stress, pests, and pathogens, as well as apicultural practices that place bee hives next to highways with high traffic.

**Insecticides and Fungicides**

More recently, many new insecticides have been introduced that have high toxicity to honey bees and systemic activity in plants. The systemic neonicotinoids and phenylpyrazoles represent two groups that can directly affect honey bee health and may have long residual activity in plants. Although new application methods help to minimize direct exposure of bees to these compounds, the potential negative outcome is that honey bees may instead be exposed to these pesticides over extended periods of time in pollen, nectar, and plant exudates such as water guttation from leaves (http://www.apidologie.org/articles/apido/pdf/2010/03/m09141.pdf). Additionally, the regulatory system governing pesticide use directly in bee hives may also contribute to the problem. Some of the older miticides have become ineffective and thus, new hive-applied pesticides have been recently introduced that may contribute to honey bee management stress.

Chronic exposures to neurotoxic insecticides and their combinations with other pesticides, including fungicides, are known to increase the toxicity of insecticides and elicit reductions in honey bee fitness. Still, no direct association of these pesticide combinations has been shown with

CCD. The following guidelines aim to minimize exposure of bees to fungicides applied during flowering of fruit and nut crops. This information was adapted from Mussen and Brandi, 2010[1], Mussen (U.C. Apiaries Newsletter– Jan/Feb 2012), and combined with current fungicide use strategies.

Current research on colony collapse is focused on four general categories of possible causes. These include:

1. **Pathogens**: Among others, scientists are considering *Nosema ceranae* and *N. apiss* (pathogenic gut fungus), Israeli Acute Paralysis Virus, and possibly unknown pathogens as possible culprits for CCD. USDA-ARS research has indicated that the presence of no one pathogen of any class directly correlates with the majority of CCD incidents. Rather, a higher total pathogen load of viruses and bacteria correlates more directly with CCD than any one specific pathogen. The anthropogenic movement of honey bees especially nationally and internationally is one of the most dangerous practices that have been followed by industry that has led to consequences of introduced pathogens.
2. **Parasites**: Varroa mites are often found in honey bee colonies that are affected by CCD. It is not known if the Varroa mites are directly involved or if the viruses that Varroa mites transmit (similar to the way mosquitoes transmit the malaria virus) are a factor in causing CCD.
3. **Management stressors**: Among the management stressors that are possible contributors to CCD are poor nutrition due to apiary overcrowding and increased migratory stress brought on by the honey bees being transported to multiple locations across the country.
4. **Environmental stressors**: Such stressors include the impact of pollen/nectar scarcity, lack of diversity in pollen/nectar, availability of only pollen/nectar with low nutritional value, and limited access to water or access only to contaminated water. Stressors also include accidental or intentional exposure to pesticides at lethal or sub-lethal levels.

**Use of pesticides during flowering of agricultural commodities**

Insecticides should never be applied with fungicides during the bloom period of tree crops and many other agricultural crops. Acaricides/insecticides (e.g., all neonicotinoids, all pyrethroids) may be synergistic with chlorothalonil and all DMI fungicides and the toxicity of the acaricide/ insecticide to honey bee brood may be increased. For example, mixing a pyrethroid, IRAC Code 3A, with chlorothalonil or a DMI may increase toxicity of the insecticide. Organophosphates (IRAC Code 1B) mixed with SDHI and QoI fungicides FRAC Codes 7 (e.g., boscalid) and 11 (e.g., pyraclostrobin) may increase toxicity of the insecticide to honey bees.

Insecticides are often mixed with fungicides for many tree crops in the growing season. When using systemic insecticides (e.g., neonicotinoids), be aware that they may be long lasting in the plant and may affect honey bees and other insects for several months after application.

Thus, **fungicides are less involved** in honey bee colony collapse than previously considered. Still, for selection and usage, choose fungicides that do not accumulate in honey bee products (e.g., bee bread). Johnson et al. (2010) (http://www.apidologie.org/articles/apido/pdf/2010/03/m09141.pdf) indicated that possible fungicides that may accumulate to high levels in pollen are chlorothalonil, captan, and iprodione. These fungicides can be used after bloom for other foliar and fruit diseases during the season.

Follow Almond Board of California Honey Bee Best Management Practices for Almonds (http://www.almonds.com/sites/default/files/content/attachments/honey_bee_bmp_practices_quick_guide_for_almonds.pdf). Some important aspects are listed below:

1) Most fungicides are formulated with adjuvants including wetting agents, spreaders, and stickers. Unless a registrant specifically indicates on the product label that an adjuvant should be added, most fungicide products do not need additional adjuvants mixed into the sprayer

tank to improve performance. With few exceptions, adjuvants do not statistically improve the efficacy of fungicides for managing diseases of fruit and nut commodities. Although there is limited information on the interaction of adjuvants and fungicides with honey bees, it is best to follow a conservative approach. Because adjuvants may increase the wettability of bees and subsequently the potential toxicity of fungicides, adjuvants should not be used in fungicide applications during bloom or when there is high honey bee activity in the field.

2) Do not apply fungicides when honey bees are in flight in orchards. Contaminated foraging worker bees will carry the fungicide back to the hive where other worker bees will clean them and contaminate the hive's food supply.
3) Do not apply fungicides when pollen is available. Pollen is released when temperatures reach 13°C (55°F) in the morning and is often removed by honey bees by late afternoon. Thus, from late afternoon until very early the next morning, the amount of fresh pollen available is at the lowest levels of the day.
4) Apply fungicides in the evening or at night or when temperatures are less than 13°C (55°F).
5) Turn off sprayer near hives.
6) Follow UC guidelines and make a single delayed bloom application at 20-30% bloom if environmental conditions are not conducive for disease development, to minimize the total number of fungicide applications during bloom.
7) Follow UC guidelines on fungicide resistance management to limit honey bee exposure to any one fungicide product by following the "RULES" (*see* Fungicide Resistance).

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[1] Mussen, E. and Brandi, G. 2010. Relationships of Honey Bees and Pesticides. https://ucanr.edu/sites/entomology/files/147612.pdf (accessed 3/15/2022)

## FUNGICIDE RESISTANCE

Fungicide resistance is a relative term that describes the reduction in sensitivity to a fungicide in a fungal population beyond natural variation. The natural variation of a fungal pathogen population is described as the baseline sensitivity. Baseline sensitivities are derived from a sample of pathogen individuals that were never exposed to the fungicide. Generally, a normal distribution of variation occurs that may be skewed based on the pathogen and type of chemistry or selection pressure. Resistance is an inheritable genetic trait that is distinguished from adaptation where the same individual reverts back to sensitivity to the fungicide after some period of absence of exposure. Field-resistance (practical resistance) is the reduction in sensitivity in the pathogen that is accompanied by crop losses.

Resistance frequency is the relative incidence of a less sensitive variant within a population of individuals that has the ability to survive under the selection pressure of a fungicide. Variants arise from genetic mutations that are continuously and spontaneously occurring within populations of organisms. Some mutations are detrimental, whereas others may allow survival of individuals under a specific stress such as the presence of a toxicant (i.e., fungicide). Resistance frequencies are generally very low numbers (e.g., 1 in millions) and as such, resistance is a rare event. Still, fungi are able to reproduce in great numbers. Thus, although fungicides may eliminate most of the population, a few survivors can replace the sensitive population in a relatively short time. Once resistance is selected, then the resistance factor or the magnitude of resistance can be calculated as compared to the baseline sensitivity level.

Fungicide resistance can be further characterized into two types: qualitative and quantitative (Fig. 1). Qualitative resistance (monogenic resistance) is when an abrupt change in a sensitive fungal population occurs that results in a distinct sub-population that is resistant to the fungicide at field use rates. The benzimidazoles typically show this type of resistance. Different levels of resistance (i.e., resistance factors) can still occur in individuals reflecting different mutations in the target β-tubulin gene. These changes result in substitutions of different amino acids and subsequent different binding potential of the fungicide to the β-tubulin molecule. Quantitative resistance (polygenic resistance) is when mutations of several genes each contribute to the development of resistance. Fungal populations respond to the fungicide selection pressure in a continuous shift from sensitive to resistant to highly resistant populations. This is because these mutations can be additive, resulting in an increased resistance factor. This results in decreased efficacy over time.

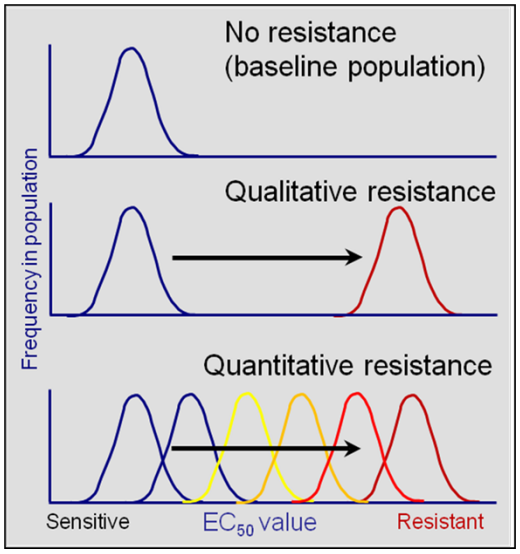


**Figure 2. Frequency distribution of $EC_{50}$ values in fungal poulations with no resistance, with qualitative resistance (e.g., MBC fungicides), or with quantitative resistance (e.g., DMI fungicides).**
Only one population with a distinct baseline range of sensitivities is observed in sensitive population (no resistance). For qualitiative resistance, a shift in fungicide sensitivity is observed by the presence of two distinct populations: a sensitive baselinepopulation and a resistant population. For quantitative resistance, there is a gradual shift to increased $EC_{50}$ values, resulting in a range of sensitivities within the population due to a step-wise accumulation of resistance genes. For both, qualitative and quantitative resistance, frecquencies of resistant isolates as compared to sensitive isolates can vary widely (i.e., heights of each distribution may be different). Modified from Brent and Hollomon (2007).

The DMI fungicides typically show this type of resistance. Both types of resistance, qualitative and quantitative can occur in a single fungal species responding to fungicides with different modes of action. *Monilinia fructicola* and *Podosphaera* (*Uncinula*) *necator* show qualitative resistance to the benzimidazole and quantitative resistance to the DMI fungicides.

Kendall and Holloman (1998)[2] stated that "**Unlike insecticide resistance, with fungicides cross-resistance patterns generally follow modes-of-action, presumably reflecting target site alterations rather than uptake and detoxification changes.**" Thus, the most effective way to combat fungicide resistance is to mix or alternate fungicides with different modes of action (classes of fungicides) and, if possible, at least one rotational mix partner should be a multi-site material. For this reason, the Fungicide Resistance Actin Committee (FRAC) has promoted a number system that is used to group fungicides within the same chemical class and with the same mode of action. This system simplifies resistance management practices to rotating fungicide usage between FRAC Code numbers.

Factors determining the risk of fungicide resistance development in a pathogen population include: 1) fungicide chemistry; 2) fungal species; and 3) the agronomic practices (Table 1). Specific components of these factors can be outlined as follows for a pathogen causing disease on a susceptible host:

1) ***Fungicide Risk***
   - Single-site vs. multi-site mode of action compounds.
   - Selection pressure: number of applications or the exposure frequency.
     - Selection pressure: rate effect may be involved with certain types of fungicide resistance, such as quantitative resistance as opposed to qualitative resistance.
     - Degradation of the fungicide over time under different environments
2) ***Pathogen Risk***
   - Inherent resistance frequency in the population (e.g., $10^{-4}$, $10^{-6}$, etc.)
   - Comparative fitness of sensitive and resistant strains (survival attributes of the resistant population)
     a) Pathogenicity and virulence
     b) Propagation and survival
   - Low efficacy, competition, and slow dispersal *may* help reduce but not prevent the development of resistance.
3) ***Agronomic Risk - an interaction of fungicide, environment, and usage practices***: The stability of the fungicide on the plant and the interaction of the fungicide with the fungus under different environments and agricultural practices including host susceptibility (Fig. 1).
   - Crop susceptibility
   - Application volumes, equipment (air applications, airblast and electrostatic sprayers), frequencies, and methods (mixtures, alternate rows, etc.).

***Conclusion***: Resistance development is a complex process and has to be determined for each Pathogen-Fungicide-Agronomic practice.

The "recipe for resistance development" follows a general procedure in the lab: expose large numbers of propagules of the pathogen, expose the same population repeatedly to the same mode of action, and use low concentrations of the fungicides that may favor quantitative-types of resistance development. In the field, a parallel situation may occur:

**Table 1**. Combined resistance risk diagram based on inherent fungicide, pathogen, and agronomic risks*.

| Fungicide FRAC codes ** | Fungicide risk | Combined risk | | | Agronomic risk |
|---|---|---|---|---|---|
| 1, 2, 4, 7, 11 | High = 6 | 6<br>3<br>1.5 | 12<br>6<br>3 | 18<br>9<br>4.5 | High = 1,<br>Medium = 0.5,<br>Low = 0.25 |
| 3, 9, 12 | Medium = 4 | 4<br>2<br>1 | 8<br>4<br>2 | 12<br>6<br>3 | High = 1,<br>Medium = 0.5,<br>Low = 0.25 |
| M 01-05,<br>16.1,<br>P1-7 | Low = 1 | 1<br>0.5<br>0.25 | 2<br>1<br>0.5 | 9<br>1.5<br>0.75 | High = 1,<br>Medium = 0.5,<br>Low = 0.25 |
| | Pathogen risk | Low = 1 | Medium = 2 | High = 3 | |
| Pathogen groups | | Seed-borne pathogens, Soil-borne pathogens (e.g. *Phytophthora* spp.), rust fungi, *Rhizoctonia*, *Fusarium*, *Sclerotinia* spp. | *Blumeriella jaapli*, *Glomerella cingulate*, *Phyllostica citricarpa*, *Sphaerotheca macularis*, *Venturia carpophila*, *V. oleaginea*, *V. cerasi*, *V. pirina*, *Wilsonomyces carpophilus*, *Colettotrichum, Erysiphe*, *Neofabraea* spp. | *Alternaria*, *Botrytis*, *Plasmopara*, *Podosphaera* spp., *Venturia inaequalis* | |

*Modified according to Kuck (2005) and FRAC Pathogen Risk List (2019) fior fruit and nut crops in California
**Only the most important FRAC Codes and groups are mentioned

1) Highly susceptible varieties under favorable environmental conditions generally support high populations of primary or secondary inoculum of the pathogen.
   a. Improper timing of fungicide application in respect to host stage, environmental conditions, or both.
   b. Application of fungicide after an epidemic occurs (high populations of the pathogen)
   c. Cultural practices that favor increases in pathogen populations (e.g., lack of pruning out cankers or infected tissue).
   d. Cultural practices that create environments that favor disease (e.g., long irrigation sets, irrigation designs that favor wetting of the canopy).
   e. Plant nutrition and fertilizer programs that favor development of susceptible tissue (e.g., high nitrogen fertilization programs).
2) Improper fungicide rate or application timing.
   a. Off-label rates are used or occur due to alternate row applications. This results in pathogen populations that are repeatedly exposed to low fungicide concentrations. This allows for survivors and resistance.
   b. Improperly timed applications due to environmental conditions. (e.g., alternate row 3-day re-application intervals delayed due to rain).
3) Repeated use of the same fungicide mode of action (Using one FRAC Code repeatedly in a growing season).
   a. Lack of awareness of FRAC codes, biological agents, or natural products available
   b. Poor understanding of IPM practices available.
   c. Other modes of action are not available on the commodity.

UC guidelines on fungicide resistance management can be described as following the "RULES" -

a. ***R***otate between different fungicide modes of action as indicated by the FRAC number on each fungicide product (e.g., FRAC 7 should not be followed by FRAC 7; instead use FRAC 7, then follow with FRAC 3 or FRAC 3/11, FRAC 3/9, and FRAC 7/11).
b. ***U***se labeled rates – Fungicide labels often provide a range of rates: use the upper range for high disease pressure and the lower range for low disease pressure. Proper rates include proper coverage to minimize survivors from inadequate exposure to the toxicant.
c. ***L***imit the total use of any single-site mode of action fungicide to ideally one or two per growing season.
d. ***E***ducate yourself about the mode of action, spectrum of activity, recommended rates, and the performance of a fungicide against various diseases. This information is found later in this document.
e. ***S***tart a fungicide spray program with a multi-site mode of action fungicide, pre-mixture, or tank mixture to reduce the total fungal population that is exposed to any single-site mode of action fungicide used later in a sequence of fungicide applications. NOTE: Never use a single-site mode of action fungicide or a pre-mixture when high levels of disease already occur. The possibility of selecting fungicide resistant individuals is more likely to occur when high populations of a pathogen are being exposed to the selection pressure.

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[2] Brent, K. J. and Hollomon, D. W. (1998) Fungicide Resistance: The Assessment of Risk FRAC Monograph No 2, Global Crop Protection Federation, Brussels, 48pp. http://www.frac.info/docs/default-source/publications/monographs/monograph-2.pdf

[3] Kuck, K. H. (2005) Fungicide resistance management in a new regulatory environment. In: Modern fungicides and anti-fungal compounds IV. Dehne, H. W., Gisi, U., Kuck, K. H., Russell, P. E. and Lyr, H. eds. BCPC, Alton UK., 35-43.

[4] FRAC. 2019. Pathogen risk list. https://www.frac.info/docs/default-source/publications/pathogen-risk/frac-pathogen-list-2019.pdf.

[5] FRAC Code List©* 2024: Fungal control agents sorted by cross-resistance pattern and mode of action. https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2024.pdf?sfvrsn=52e14e9a_2

**General Properties of Registered and Experimental Fungicides Used on Deciduous Tree Fruit, Nut, Citrus, Strawberry, and Vine Crops in the United States (sorted by FRAC Code)‡**

| Single active ingredient | Trade name | Class (FRAC number)[1] | Systemic action | Mode of action | Resistance potential |
|---|---|---|---|---|---|
| copper[9] | various | Inorganic (M 01) | No | multi-site | low |
| sulfur | various | Inorganic (M 02) | No | multi-site | low |
| mancozeb | Manzate Pro-Stick, Dithane, Penncozeb | Carbamate (EBDC)[2] (M 03) | No | multi-site | low |
| ferbam** | Ferbam | Carbamate (DMDC)[3] (M 03) | No | multi-site | low |
| thiram | Thiram | Carbamate (DMDC)[3] (M 03) | No | multi-site | low |
| ziram | Ziram | Carbamate (DMDC)[3] (M 03) | No | multi-site | low |
| captan | Captan | Phthalimide (M 04) | No | multi-site | low |
| chlorothalonil | Bravo, Chorothalonil, Echo, Equus | Chloronitrile (M 05) | No | multi-site | low |
| thiabendazole | Mertect | MBC (1) | Yes | single-site | very high[4] |
| thiophanate-methyl | Topsin-M, T-Methyl, Incognito, Cercobin** | MBC (1) | Yes | single-site | very high[4] |
| iprodione | Rovral, Meteor, Iprodione 2F**, Nevado** | Dicarboximide (2) | Yes | single-site? | medium |
| cyproconazole | Alto | DMI[5]-triazole (3) | Yes? | single-site | high |
| difenoconazole | Inspire, Laguna** | DMI-triazole (3) | Yes? | single-site | high |
| fenarimol | Rubigan**,Vintage** | DMI-pyrimidine (3) | Yes? | single-site | high |
| fenbuconazole | Indar, Enable | DMI-triazole (3) | Yes? | single-site | high |
| flutriafol | Rhyme | DMI-triazole (3) | Yes? | single-site | high |
| imazalil | Deccocil, Freshgard 700 | DMI-imidazole (3) | Yes? | single-site | high |
| metconazole | Quash | DMI-triazole (3) | Yes? | single-site | high |
| myclobutanil | Rally, Laredo | DMI-triazole (3) | Yes? | single-site | high |
| propiconazole | Tilt, Bumper**, Mentor, Propimax**, Propicure, Propiconazole | DMI-triazole (3) | Yes? | single-site | high |
| tebuconazole | Orius**, Tebucon, Toledo, Teb, Miresa**, Elite**, Tebuzol**) | DMI-triazole (3) | Yes? | single-site | high |
| tetraconazole | Mettle, Perissim** | DMI-triazole (3) | Yes? | single-site | high |
| triadimefon | Bayleton** | DMI-triazole (3) | Yes? | single-site | high |
| triforine | Funginex** | DMI-piperazine (3) | Yes? | single-site | high |
| triflumizole | Procure, Viticure** | DMI-imidazole (3) | Yes? | single-site | high |
| mefentrifluconazole | Cevya | DMI-triazole (3) | Yes? | single-site | high |
| mefenoxam, | Ridomil Gold, Mefenoxam | Phenylamide (4) | Yes | single-site | high[4] |
| metalaxyl | Metalaxyl** | Phenylamide (4) | Yes | single-site | high[4] |
| benzovindiflupyr | Aprovia | SDHI (7) | No | single-site | high[4] |
| boscalid | Endura | SDHI[6] (7) | No | single-site | high[4] |
| inpyrifluxam | Excalia*, Indiflin | SDHI (7) | No | single-site | high[4] |
| isofetamid | Kenja | SDHI (7) | No | single-site | high[4] |
| fluindapyr | ---- | SDHI (7) | No | single-site | high[4] |
| fluopyram | Luna Privilege, Velum One | SDHI (7) | No | single-site | high[4] |
| fluxapyroxad | Xemium, Tesaris, Sercadis** | SDHI (7) | No | single-site | high[4] |
| penthiopyrad | Fontelis | SDHI (7) | No | single-site | high[4] |
| pydiflumetofen | Adepidyn (tech.), Miravis | SDHI (7) | No | single-site | high[4] |
| pyraziflumid | Parade fungicide | SDHI (7) | No | single-site | high[4] |
| cyprodinil | Vangard | AP[7] (9) | Slight | single-site | high[4] |
| pyrimethanil | Scala, Penbotec | AP (9) | Slight | single-site | high[4] |
| azoxystrobin | Quadris | QoI[8] (11) | Yes? | single-site | high[4] |
| kresoxim-methyl | Sovran | QoI (11) | Yes? | single-site | high[4] |
| mandestrobin | Intuity | QoI (11) | Yes? | single-site | high[4] |
| picoxystrobin | Aproach | QoI (11) | Yes? | single-site | high[4] |
| pyraclostrobin | Cabrio, Headline | QoI (11) | Yes? | single-site | high[4] |
| trifloxystrobin | Flint Extra | QoI (11) | Yes? | single-site | high[4] |

| Single active ingredient | Trade name | Class (FRAC number)[1] | Systemic action | Mode of action | Resistance potential |
|---|---|---|---|---|---|
| fludioxonil | Scholar, Cannonball | Phenylpyrrole (12) | No | single-site | medium |
| proquinazid | Telendo | Quinoline (13) | No | single-site | high |
| quinoxyfen | Quintec | Quinoline (13) | No | single-site | high |
| dicloran | Botran/Allisan | Aroma. hydrocarbon (14) | Slight | single-site | medium |
| fenhexamid | Elevate | Hydroxyanilide (17) | No | single-site | high[4] |
| fenpyrazamine | Protexio** | Amino-pyrazolinone (17) | No | single-site | high[4] |
| polyoxin-D | Ph-D, Endorse**, Oso | chitin synthesis inhibitor (19) | No | single-site | medium |
| cyazofamid | Ranman | QiI (21) | No | single-site | high[4] |
| fluazinam | Omega, Lektivar** | Dinitro-aniline (29) | No | single-site | low |
| potassium phosphite | Fungi-Phite, Prophyt K-Phite | Phosphorous acid or Mono- and dipotassium salts of phosphorous acid (P 07/33) | Yes | unknown (multi-site?) | medium |
| fosetyl-Al | Aliette, Linebacker, Legion** | Ethyl phosphonates (P 07/33) | Yes | unknown | low |
| mandipropamid | Revus | Carboxylic Acid Amides (40) | Yes? | single-site | high |
| fluopicolide | Presidio | Benzamide (43) | Yes? | single-site | high |
| pyriofenone | Prolivo | Actin disrupter (50) | No | single-site | high |
| metrafenone | Vivando | Actin disrupter (50) | No | single-site | high? |
| natamycin | BioSpectra/Zivion S Cerafruta | Polyene-ergosterol binding (48) | No | single-site | low |
| oxathiapiprolin | Orondis | Oxysterol binding proteins (OSBPI)[10] (49) | Yes | single-site | high |
| fluoxapiprolin | To be determined | OSBPI (49) | Yes | single-site | high |
| ipflufenoquin | Axios | DHODHI[11] (52) | No | single-site | high |
| cyflufenamid | Torino | Phenyl-acetamide (U6) | No | unknown | high? |
| dodine | Syllit | Guanidine (U12) | Yes | unknown | medium |
| flutianil | Gatten | Thiazolidine (U13) | No | unknown | high? |

*** Registration pending in California**
**** Not registered, label withdrawn or inactive in California (maybe registered federally).**

## General Properties of Registered and Experimental Fungicides Used on Deciduous Tree Fruit, Nut, Citrus, Strawberry, and Vine Crops in the United States (sorted by FRAC code)‡, Continued

| Multiple active ingredients (Premixtures) | Trade name | Class (FRAC number) [1] | Systemic action | Mode of action | Resistance potential |
|---|---|---|---|---|---|
| captan/fenhexamid | CaptEvate** | Phthalimide (M 04)/ hydroxyanilide (17) | No | multi-site/ single-site | medium |
| chlorothalonil/ postassium phosphite | Catamaran** | chloronitrile (M 05)/ phosphonate (P 07/33) | Yes? | multi-site/ single-site | low |
| thiophanate methyl/ propiconazole | Protocol | MBC (1)/DMI-triazole (3) | Yes? | single-site/ single-site | medium |
| difenoconazole/ benzovindiflupyr | Aprovia Top | DMI-triazole (3)/ SDHI (7) | Yes? | single-site/ single-site | medium |
| difenoconazole/ pydiflumetofen | Miravis Duo | DMI-triazole (3)/ SDHI (7) | Yes? | single-site/ single-site | medium |
| tebuconazole / fluopyram | Luna Experience | DMI-triazole (3)/ SDHI (7) | Yes? | single-site/ single-site | medium |
| flutriafol/ fluindapyr | *Pending* | DMI-triazole (3)/ SDHI (7) | Yes? | single-site/ single-site | medium |
| tebuconazole/ isofetamid | Fervent | DMI-triazole (3)/ SDHI (7) | Yes? | single-site/ single-site | medium |
| mefentrifluconazole/ fluxapyroxad | Mibelya (Elysis, pending) | DMI-triazole (3)/ SDHI (7) | Yes? | single-site/ single-site | medium |
| difenoconazole/ cyprodinil | Inspire Super | DMI-triazole (3)/ AP (9) | Yes? | single-site/ single-site | medium |
| difenoconazole/ azoxystrobin | Quadris Top | DMI-triazole (3)/ QoI (11) | Yes? | single-site / single-site | medium |

| Multiple active ingredients (Premixtures) | Trade name | Class (FRAC number) [1] | Systemic action | Mode of action | Resistance potential |
|---|---|---|---|---|---|
| propiconazole/ azoxystrobin | Quilt Xcel | DMI-triazole (3)/ QoI (11) | Yes? | single-site / single-site | medium |
| tebuconazole /trifloxystrobin | Adament | DMI-triazole (3)/ QoI (11) | Yes? | single-site / single-site | medium |
| tebuconazole / azoxystrobin | Custodia** | DMI-triazole (3)/ QoI (11) | Yes? | single-site/ single-site | medium |
| pydiflumetofen/ fludioxonil | Miravis Prime | SDHI (7)/ Phenylpyrrole (12) | Yes? | single-site / single-site | medium |
| tebuconazole/ phosphite | Viathon | DMI-triazole (3) /phosphonate (P 07/33) | Yes? | single-site multi-site? | medium |
| difenoconazole/ tea tree oil | Regev | DMI-triazole (3) / tea tree oil (BM 01) | Yes? | single-site multisite | medium |
| fluopyram/pyri-methanil | Luna Tranquility | SDHI (7)/AP (9) | Yes? | single-site/ single-site | high |
| fluopyram/ trifloxystrobin | Luna Sensation | SDHI (7)/QoI (11) | Yes? | single-site/ single-site | high |
| pyraclostrobin / fluxapyroxad | Merivon, Priaxor | SDHI (7)/QoI (11) | Yes? | single-site / single-site | high |
| Boscalid/ pyraclostrobin | Pristine | SDHI (7)/QoI (11) | Yes? | single-site / single-site | high |
| cyprodinil/fludioxonil | Switch | AP (9)/Phenylpyrrole (12) | No/ Slight | single-site/ single-site | medium |
| cyprodinil/ ipflufenoquin | Axios Scion* (pending) | AP (9)/DHODHI (52) | No | single-site/ single-site | high |

*** Registration pending in California**

**** Not registered, label withdrawn or inactive in California (maybe registered federally).**

‡ Some of the active ingredients or products listed in this table may not be registered as pesticides or may have had their registration withdrawn. Check with your state pesticide regulatory agency to verify that applications are made in accordance with state and federal laws and regulations.

**?** = Unsure or lacking scientific evidence. For fungicides, a question mark indicates general acceptance of systemic action based on performance data, but may not have been proven experimentally using lab assays (e.g., radioactively labeled compounds).

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (*see* http://www.frac.info/). Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action Code numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action Code number; for fungicides with other Code numbers, make no more than two consecutive applications before rotating to a fungicide with a different mode-of-action Code number.

[2] EBDC = ethylene bisdithiocarbamate.

[3] DMDC = dimethyl dithiocarbamate.

[4] Resistance has been found in California for certain fungicides with a single-site mode of action. To reduce the risk of resistance development, take the mode of action into account when choosing a fungicide. At the beginning of a treatment program, use a fungicide with a multi-site mode of action; for subsequent applications rotate or mix fungicides with different mode of action FRAC numbers. Use labeled rates (preferably the upper range) of the single-site fungicides, and limit the total number of applications per season.

[5] DMI = demethylation (sterol) inhibitor.

[6] SDHI = Succinate dehydrogenase inhibitor.

[7] AP = Anilinopyrimidine.

[8] QoI = quinone outside inhibitor (strobilurin).

[9] Fixed copper (M 01a) bactericides (e.g., Kocide, Badge, Nordox, and ChampION$^{++}$) may cause phytotoxicity (russetting) when applied after full bloom. Other copper products (M 01b) with lower metallic copper equivalent (i.e., MCE) such as copper complexes (e.g., Cueva, Copper Count-N, etc.) and copper sulfate pentahydrate (e.g., CS-2005, Phyton 27AG**, Instill, MasterCop, etc.) have been reported to be less phytotoxic with applications following bloom because of lower MCE (*see* specific registrant label concerning product rates and number of times each material can be applied during the growing season).

[10] OSBPI = oxysterol binding protein homologue inhibition.

[11] DHODHI = dihydroorotate dehydrogenase inhibitor within de novo pyrimidine biosynthesis.

**General Properties of Registered and Experimental Antibiotics, Biologicals, Oils, Salts, and Natural Products Used on Deciduous Tree Fruit, Nut, Citrus, Strawberry, and Vine Crops in the United States (sorted alphabetically)‡**

| Active ingredient | Trade name | Class | Systemic action | FRAC number[1], Mode of action | Resistance potential |
|---|---|---|---|---|---|
| acibenzolar-S-methyl | Actigard | SAR | Yes | P 01 | unknown |
| alcohol ethoxylate | Vintre | natural plant oil | No | NC | low |
| *Ampelomyces quisqualis* | AQ-10 | biological-fungus | No | BM 02 | low |
| *Aureobasidium pullulans* | Botector | biological-fungus | No | BM 02 | low |
| *Aureobasidium pullulans* DSM14940/14941 (used with Buffer Protect) | Blossom Protect | biological-fungus | No | BM 02 | low |
| *Bacillus amyloliquefaciens* D747 | Double Nickel 55 | biological-bacteria | No | BM 02 | low |
| *Bacillus amyloliquefaciens* MBI 600 | Serifel | biological-bacteria | No | BM 02 | low |
| *Bacillus amyloliquefaciens* FZB24 | Taegro 2 | biological-bacteria | No | BM 02 | low |
| *Bacillus amyloliquefaciens* | Stargus | biological-bacteria | No | BM 02 | low |
| *Bacillus pumilis* QST 2808 | Sonata | biological-bacteria | No | BM 02 | low |
| *Bacillus subtilis* QST 713 | Serenade | biological-bacteria | No | BM 02 | low |
| *Bacillus subtilis* IAB/BS03 | Aviv | biological-bacteria | No | BM 02 | low |
| *Bacillus mycoides* isolate J | LifeGard | biological SAR | No | P 06 | low |
| bacteriophages | AgriPhage-Fireblight | bacteriophages | No | BM 02 | low |
| blend of fruit acids, flavonoids, chelators, & wetting agents | Citrox Protect | plant extract | No | BM 01 | low |
| boric acid and latex paint | B-Lock | inorganic salt | No | NC/tree paint | low |
| calcium metalosate | Metalosate Calcium | inorganic salt | No | NC | low |
| capric and caprylic acids | Dart | organic acids | No | NC | low |
| chitosan (poly-D-glucosamine protein) | Amour-Zen | natural product | No | NC | low |
| chlorine dioxide | Virus Shield | inorganic salt | No | NC | low |
| cinnamaldehyde (cinnamon oil) | Cinnacure, Cinnerate, Seican | natural product | No | BM 03 | low |
| cinnamon oil and garlic | Gargoil | natural product | No | BM 01 | low |
| clove, rosemary, peppermint oils | EF-400 | natural plant oils | No | BM 01 | low |
| *Colonostachys rosea* CR-7 | Vectorite | biological-fungal | No | BM 02 | low |
| corn oil | Pure Crop Spray Oil | natural plant oil | No | NC | low |
| essential oils | Vitiseal, Mevalone | natural plant oils | No | BM 01 | low |
| GABA/L-glutamic acid | Auxigro** | SAR2-protein | Yes | NC | unknown |
| harpin | Messenger**, Employ | SAR2-protein | Yes | P unspecified, host resistance | unknown |
| hydrogen peroxide in acetic acid (peroxyacetic acid) | OxiDate 5.0, StorOx, Perasan A, Jet-Ag, Zerotol HC, 2.0 | oxidizer | No | NC | very low |
| kasugamycin | Kasumin | antibiotic | Yes | 24, protein synthesis | high |
| low range oil | Omni Supreme, Purespray | oil | No | various | low |
| *Lupinus albus* | ProBLAD Verde/ Fracture** | natural product | Yes | BM 01 | low |
| mineral oil | JMS Stylet oil | oil | No | NC | low |
| *Muscodor albus* | Arabesque** | biological | No | BM 02 | low |
| natural oil | Timorex (Act, Gold**) | tea tree oil | No | BM 01 | low |
| natural oil blend | Sporatec | oil | No | BM 01 | low |
| neem oil | Trilogy, Rango Terraneem** | natural oil | No | BM 01 | low |
| oxytetracycline | Mycoshield, FireLine | antibiotic | No | 41, protein synthesis | high |
| *Pantoea agglomerans* E/325 | Bloomtime Biological FD** | biological-bacteria | No | BM 02 | low |

**General Properties of Registered and Experimental Antibiotics, Biologicals, Oils, Salts, and Natural Products Used on Deciduous Tree Fruit, Nut, Citrus, Strawberry, and Vine Crops in the United States (sorted alphabetically)‡**

| Active ingredient | Trade name | Class | Systemic action | FRAC number[1], Mode of action | Resistance potential |
|---|---|---|---|---|---|
| petroleum oil | Omni Supreme Spray oil, Purespray | agricultural | No | NC | low |
| pinolene | Vapor Gard, NuFilm-P, -17 | terpenic polymer | No | NC | low |
| plant host defense activator | ProAlexin | plant extract bioflavonoid stimulator | Yes | NC | low |
| plant oils (clove, rosemary, thyme, tea tree, peppermint) | Aleo, EF-400, Guarda, Sporatec, Sporan, Thyme Guard, Thymox, Vitiseal, Timorex-Act, -Gold** | natural plant oils | No | BM 01 | low |
| polyoxin-D zinc salt | Oso | fermentation product | No | 19 | medium |
| potassium bicarbonate | Armicarb, Kaligreen, Milstop | inorganic salt | No | NC | low |
| potassium metalosate | Metalosate Potassium | inorganic salt | No | NC | low |
| potassium salts of fatty acids | M-Pede | inorganic salt | No | NC | low |
| potassium sorbate | All Phase | inorganic salt | No | NC | low |
| prohexadione calcium | Apogee | plant growth regulator | Yes | PGR, inhibitor | low |
| *Pseudomonas chlororaphis* AFS009 | Howler | biological-bacteria | No | BM 02 | low |
| *Pseudomonas fluorescens* | BlightBan | biological-bacteria | No | BM 02 | low |
| Quaternary ammonium compounds | BacStop-OPL, -XL | sanitizer | No | NC | low |
| *Quillaja saponaria* | Quiponin-BS Powder** | natural product | No | BM 01 | low |
| *Reynoutria sachalinensis* | Regalia | natural product | No | P 05 | low |
| sanitizers[3] (Oxidate 5.0, etc.) | various | oxidizer | No | NC | low |
| sodium tetraborohydrate | Prev-am | inorganic salt | No | NC | low |
| *Streptomyces lydicus* | Actinovate AG | biological-bacteria | No | BM 02 | low |
| streptomycin | AgriMycin, FireWall, Ag Streptomycin** | antibiotic | Yes | 25, protein synthesis | high |
| *Swinglea glutinosa* | EcoSwing | natural product | No | BM 01 | low |
| *Trichoderma atroviride* | Vintec | biological-fungus | No | BM 02 | low |
| *Trichoderma harzianum* | Plant Shield | biological-fungus | No | BM 02 | low |
| *Ulocladium oudemansii* | Botry-Zen** | biological-fungus | No | BM 02 | low |
| yeast extract | KeyPlex-350**, -DP** | SAR2-protein | Yes | P 06 | unknown |

**** Not registered, label withdrawn or inactive in California (maybe registered federally).**

‡ Some of the active ingredients or products listed in this table may not be registered as pesticides or may have had their registration withdrawn. Check with your state pesticide regulatory agency to verify that applications are made in accordance with state and federal laws and regulations.

[1] Fungicide Resistance Action Committee (FRAC) Code (FC) numbers are assigned by the according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action Code numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action Code number; for fungicides with other Code numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action Code number. NC = not coded in FRAC.

[2] SAR = Systemic acquired resistance induced in host

[3] Sanitizers such peroxyacetic acid (e.g., Oxidate 2.0, 5.0, Zerotol, Perasan A) or chlorine dioxide (Virus Shield) are oxidizers that act immediately on contact. They are neutralized rapidly by reducing agents and are non-persistent.

## DISEASE AND PATHOGEN NAMES

| Disease | Pathogen(s) | Host(s) |
|---|---|---|
| Alternaria late blight | *Alternaria alternata* and *A. arborescens*[1] | pistachio |
| Alternaria leaf spot | *Alternaria alternata* and *A. arborescens*[1] | almond |
| Alternaria fruit rot | *Alternaria alternata* and *A. arborescens*[1] | pome and stone fruits, citrus, pomegranate |
| Angular leaf spot | *Xanthomonas fragariae* (bacterium) | strawberry |
| Anthracnose | *Colletotrichum acutatum* | almond, peach, strawberry |
| | *Colletotrichum gloeosporioides, C. karsti* | citrus |
| Anthracnose | *Marssonia leptostyla* | walnut |
| Bacterial blast | *Pseudomonas syringae* pathovars (bacterium) | *Prunus* spp. including almond, cherry, peach, etc. |
| Bacterial canker | *Pseudomonas syringae* pathovars (bacterium) | *Prunus* spp. including almond, cherry, peach, etc. |
| Bacterial spot | *Xanthomonas arboricola* pv. *pruni* (bacterium) | *Prunus* spp. including almond, cherry, peach, etc. |
| Band canker | *Botryosphaeria dothidea* (*Fusicoccum* sp.)[2] | almond |
| Botrytis decay (fruit rot) /Gray mold | *Botrytis cinerea* | strawberry, stone and pome fruit, kiwifruit, pomegranate |
| Black foot | *Cylindrocarpon destructans/C. liriodendron* | grapevine |
| Black root rot complex | *Cylindrocarpon destructans, Pythium ultimum, Rhizoctonia* spp. | strawberry |
| Bot canker, Botryosphaeria canker | *Botryosphaeria* spp. (*Fusicoccum* sp. and *Neofusicoccum* sp.)[2] | grapevine, pomegranate, walnut |
| Botryosphaeria panicle and shoot blight | *Botryosphaeria dothidea* (*Fusicoccum* sp. and *Neofusicoccum* sp.)[2] | pistachio |
| Botrytis blossom blight | *Botrytis cinerea* | cherry |
| Botrytis blossom and shoot blight | *Botrytis cinerea* | pistachio |
| Brown rot | *Monilinia fructicola, M. laxa* | almond and other stone fruits |
| Brown spot | *Cladosporium cladosporioides* | grape fruit rot |
| Bunch rot | *Botrytis cinerea* | grapevine |
| Cankers (Eutypa, Cytospora, and Calosphaeria cankers) | *Eutypa lata, Leucostroma persoonii, Calosphaeria pulchella* | cherry |
| Common leaf spot | *Ramularia tulasnii* | strawberry |
| Crown rot | *Phytophthora* spp. | strawberry |
| Dead arm | *Eutypa lata* and *Phomopsis* (*Cyrtosporella*) *viticola* (*see* Bot canker and Phomopisis dieback) | grapevine |

| | | |
|---|---|---|
| Downy mildew | *Plasmopora viticola* | grapevine |
| Esca (Black measles) | *Togninia* spp. (*Phaeoacremonium* spp.), *Phaeomoniella chlamydospora* | grapevine |
| Eutypa dieback | *Eutypa lata* | apricot, grapevine, cherry, almond, apple, blueberry |
| Fire blight | *Erwinia amylovora* (bacterium) | pome fruit (apple, pear, quince, etc.) |
| Gray mold | *Botrytis cinerea* | strawberry, stone and pome fruit, kiwifruit, pomegranate |
| Greasy spot | *Mycosphaerella citri* | citrus |
| Internal (Heart) fruit rot | *Aspergillus niger* or *Alternaria* sp. | pomegranate |
| Jacket rot/Green fruit rot | *Botrytis cinerea, Monilinia laxa*<br>*Monilinia fructicola, Sclerotinia sclerotiorum* | all stone fruits |
| Leaf blight | *Seimatosporium lichenicola* | almond |
| Leaf spot | *Blumeriella jaapii* | cherry |
| Leaf curl | *Taphrina deformans* | peach, nectarine |
| Leather rot | *Phytophthora cactorum* | strawberry |
| Mucor rot | *Mucor piriformis* and other species | pome and stone fruit; strawberry |
| Neofabraea leaf and shoot spot | *Neofabraea kienholzii*<br>and *Phlyctema vagabunda* | olive |
| Olive knot | *Pseudomonas savastanoi*<br>pv. *savastanoi* | olive |
| Olive leaf spot (Peacock spot) | *Venturia oleaginea (syn. Fusicladium oleagineum, Spilocea oleaginea)* | olive |
| Phomopsis blight | *Diaporthe* spp. (*Phomopsis* spp.) | pistachio |
| Phomopsis cane and leafspot and Phompsis dieback (canker phase) | *Diaporthe* spp. (*Phomopsis viticola, Phomopsis* spp.) | grapevine |
| Phomopsis fruit rot and dieback | *Phomopsis amygdali* | almond |
| Phytophthora brown rot | *Phytophthora citrophthora, P. syringae, P. hibernalis, P. parasitica* (*P. nicotianae*) | citrus |
| Phytophthora root rot - citrus | *Phytophthora citrophthora, P. parasitica* (*P. nicotianae*), *P. syringae* | citrus |
| - deciduous trees | *Phytophthora* spp. | pome and stone fruit crops including almond; pistachio, grapevine, strawberry, and walnut |
| Powdery mildew | *Erysiphe* (=*Uncinula*) *necator*<br>*Podosphaera leucotricha*<br>*Podosphaera clandestina*<br>*Podosphaera tridactyla*<br>*Podosphaera* (=*Sphaerotheca*) *macularis*<br>*Podosphaera* (=*Sphaerotheca*) *pannosa* | grapevine<br>almond, apple, peach, nectarine<br>cherry<br>apricot, cherry, plum, prune, peach<br>strawberry<br>apricot, peach, nectarine, plum |

| | | |
|---|---|---|
| Red stele | *Phytophthora fragariae* | strawberry |
| Rhizopus rot | *Rhizopus* spp. | strawberry |
| Rind disorder | Abiotic disorder | citrus |
| Russet scab | Abiotic (rain during bloom) | prune |
| Rust | *Tranzschelia discolor* | almond, nectarine, peach, prune, plum |
| Scab, almond, peach | *Venturia carpolphila (*syn. *Fusicladium carpophilum, Cladosporium carpophilum*) | almond, nectarine, peach |
| Scab, apple | *Venturia inaequalis* | apple |
| Scab, pear | *Venturia pirina* | pear |
| Sclerotinia blight | *Sclerotinia sclerotiorum* | almond, apricot, nectarine, peach, prune, pistachio |
| Septoria spot | *Septoria citri* | citrus |
| Shot hole | *Wilsonomyces carpophilus* | almond, apricot, peach, nectarine |
| Silver leaf | *Chondrostereum purpureum* | pome and stone fruit, including almond |
| Summer rot (sour rot of grape) | *Aspergillus carbonarius, A. niger, Alternaria tenuis, Botrytis cinerea, Cladosporium herbarum, Rhizopus arrhizus, Penicillium* sp., and others | grapevine |
| Walnut blight | *Xanthomonas arboricola* pv. *juglandis* (bacterium) | walnut |
| Wood canker complex | *Botryosphaeria* spp*., Neofusicoccum* spp*., Eutypa lata, Phomopsis* spp*., Phaeoacremonium parasiticum* | grapevines, tree nuts |
| Wood decay complex | Fungi in the Basidiomycota causing brown (*Laetiporus* spp.) and white wood rots (*Ganoderma, Perenniporia, Phellinus, Oxyporus* spp.) | grapevines, tree crops |

[1] These species are members of the taxonomic Section *Alternaria* (e.g., *A. arboricola, A. alternata*) and are the most prevalent in diseases of almond and pistachio. Other closely related species of *Alternaria*, however, may also be involved.

[2] Other species of *Botryosphaeria* and their anamorphs have been recently identified in addition to *B. dothidea*.

## BACTERICIDES, BIOCONTROLS, NATURAL COMPOUNDS, ELEMENTS, AND SARS LISTED BY CHEMICAL CLASS

### ANTIBIOTICS‡

| Trade name | Common name | Company | Activity | FRAC code |
|---|---|---|---|---|
| Ag Streptomycin** | streptomycin | Makhteshim Agan | systemic | 25 |
| AgriMycin | streptomycin | NuFarm | systemic | 25 |
| FireLine | oxytetracycline, terramycin | AgroSource, Inc./Advan LLC | contact | 41 |
| FireWall | streptomycin | AgroSource, Inc./Advan LLC | systemic | 25 |
| Kasumin | kasugamycin | UPL OpenAg | systemic | 24 |
| Mycoshield | oxytetracycline | NuFarm | contact | 41 |

**Mode of action**: all are protein synthesis inhibitors but with specifically different modes of action.
**Resistance risk**: high
**Growth effects:** inhibits protein production and growth.

### BIOLOGICALS‡ - microorganisms (bacteria and fungi)

| Trade name | Common name | Company | Activity | FRAC code |
|---|---|---|---|---|
| Aviv | *Bacillus subtilis* IAB/BS03 | Summit Agro, USA | contact | BM 02 |
| Actinovate AG | *Streptomyces lydicus* WYEC 108 | Natural Industries, Inc. | contact | BM 02 |
| AQ10** | *Ampelomyces quisqualis* M-10 | Ecogen Inc. | contact | BM 02 |
| Agriphage-Fireblight | bacteriophage | Certis USA, L.L.C. | contact | BM 02 |
| Arabesque** | *Muscodor albus* QST 20799 | Bayer CropScience | contact | BM 02 |
| Bio-Tam 2.0 | *Trichoderma asperellum* (ICC 012), *T. gamsii* (ICC 080) | Isagro USA | contact | BM 02 |
| BlightBan | *Pseudomonas fluorescens* A506 | J.R. Simplot/Plant Health Tech. | contact | BM 02 |
| Bloomtime Biological FD** | *Pantoea agglomerans* | Northwest Ag Prod. | contact | BM 02 |
| Blossom Protect | *Aureobasidium pullulans* DSM 14940; DSM 14941 | Westbridge Ltd. | contact | BM 02 |
| Botector | *Aureobasidium pullulans* DSM 14940; DSM 14941 | Westbridge Ltd. | contact | BM 02 |
| Botry-Zen** | *Ulocladium oudemansii* U3 | BotryZen Ltd. | contact | BM 02 |
| Vectorite | *Clonostachys rosea* CR-7 | BVT | contact | BM 02 |
| Double Nickel 55 | *Bacillus amyloliquefaciens* D747 | Certis USA, L.L.C. | contact | BM 02 |
| Howler | *Pseudomonas chlororaphis* AFS009 | AgBiome Innovations | contact | BM 02 |
| LifeGard | *Bacillus mycoides* J | Certis USA, L.L.C. | systemic | P 06 |
| Plant Shield HC** | *Trichoderma harzianum* T-22 | BioWorks, Inc. | contact | BM 02 |
| Serenade | *Bacillus subtilis* QST 713 | Bayer CropScience | contact | BM 02 |
| Serifel | *Bacillus amyloliquefaciens* MBI 600 | BASF Corp. | contact | BM 02 |
| Sonata | *Bacillus pumilis* QST 2808 | Bayer CropScience | contact | BM 02 |
| Stargus | *Bacillus amyloliquefaciens* F727 | Marrone Bio Innovations | contact | BM 02 |
| Taegro 2 | *Bacillus amyloliquefaciens* FZB24 | Novozyme BioAg, Inc. | contact | BM 02 |
| Theia | *Bacillus subtilis* AFS032321 | AgBiome Innovations | contact | BM 02 |
| Vectorite | *Colonostachys rosea* CR-7 | Bee Vectoring Technology | contact | BM-02 |
| Vintec | *Trichoderma atroviride* SC1 | AMVAC Chemical Corp. | contact | BM 02 |

*** Registration pending in CA**
**** Not registered, label withdrawn or inactive in California (maybe registered federally).**

**Mode of action**: Possible mechanisms: antibiosis, antagonism, mycoparasitism, and/or site exclusion
**Resistance risk**: low
**Growth effects:** growth inhibition of pathogen by antibiosis, antagonism, or mycoparasitism.

## NATURAL COMPOUNDS/OILS/INORGANIC SALTS‡

| Trade name | Common name | Company | Activity | FRAC code |
|---|---|---|---|---|
| AgriMycin | streptomycin | NuFarm | systemic | 25 |
| All-Phase | potassium sorbate | Circadian Crop Sciences | contact | NC |
| Aleo | garlic oil | Brandt Consolidated, Inc. | contact | BM 01 |
| Armicarb** | potassium bicarbonate | Helena Chemical Co. | contact | NC |
| Armour-Zen | chitosan | BotryZen | systemic | NC |
| B-Lock | boric acid and latex paint | Nutrient Technologies | contact | NC/paint |
| Bac-Stop | clove, rosemary, peppermint and thyme oils | GreenFurrow Organics | contact | BM 01 |
| Cinnacure | cinnamaldehyde | Pro-Guard, Inc. | contact | BM 03 |
| Cinnerate | cinnamon oil | Sym Agro | contact | BM 03 |
| Citrox Protect | plant extract | Citrox Biosciences LTD | contact | BM 01 |
| Dart | capric/caprylic acid | SAN Agrow | contact | NC |
| EcoSwing | *Swinglea glutinosa* | Gowan Company | contact | BM 01 |
| EF400 | clove, rosemary, peppermint oils | USAgriTech, Inc. | contact | BM 01 |
| FireLine | oxytetracycline | AgroSource, Inc. | contact | 41 |
| FireWall | streptomycin | NuFarm | systemic | 25 |
| Gargoil | cinnamon oil and garlic | SAN Agrow | contact | BM 01 |
| Guarda | thyme oil | BioSafe Systems | contact | BM 01 |
| JMS Stylet Oil | mineral oil | JMS Flower Farms | contact | NC |
| Kaligreen | potassium bicarbonate | Toagosei/UPL OpenAg | contact | NC |
| Kasumin | kasugamycin | UPL OpenAg | systemic | 24 |
| Metalosate Calcium | calcium metalosate | Albion Laboratories | contact | NC |
| Metalosate Potassium | potassium metalosate | Albion Laboratories | contact | NC |
| Mevalone | essential oils | Sipcam Agro | contact | BM 01 |
| Milstop | potassium bicarbonate | BioWorks | contact | NC |
| M-Pede | potassium salts | Dow AgroSciences | contact | NC |
| NuFilm P, -17 | pinolene | Miller Chemical | contact | NC |
| Omni Supreme | low range mineral oil | Helena Chemical | contact | NC |
| Mycoshield | oxytetracycline | Nufarm | contact | 41 |
| Oso | polyoxin-D zinc salt | Certis USA | contact | 19 |
| Prev-am | sodium tetraborohydrate | ORO Agri. Inc. | contact | NC |
| ProAlexin | plant extract | Gronn Gjodsel | systemic | P 07/33 |
| ProBLAD Verde | *Lupinus albus* | Sym Agro | contact | BM 01 |
| Procidic | citric acid | Greenspire Global, Inc. | contact | NC |
| Purespray | mineral oil | Suncore Energy, Inc. | contact | NC |
| Quiponin BS Powder** | *Quillaja saponaria* | Nor-Natur | contact | BM 01 |
| Regalia | *Reynoutria sachalinensis* | Marrone Bio Innovations | contact | P 05 |
| Saf-T-Side** | petroleum oil | Brandt Consolidated, Inc. | contact | NC |
| Seican | cinnamaldehyde | Summit Agro | contact | BM 03 |
| Sporan EC[2] | plant oils | KeyPlex | contact | BM 01 |
| Sporatec | natural oil blend | Brandt Consolidated, Inc. | contact | BM 01 |
| Thymox Control | thyme oil | Kemin Industries, Inc. | contact | BM 01 |
| Thyme Guard | thyme oil | Agro Research International | contact | BM 01 |
| Timorex (Act, Gold**) | tea tree oil | Summit Agro, USA | contact | BM 01 |
| Trilogy, Rango, Terraneem** | neem oil/cold pressed neem oil | Certis USA/Terramera | contact | BM 01 |
| Vapor Gard | pinolene | Miller Chemical | contact | NC |
| Vitiseal | essential oils | Emerson | contact | BM 01 |
| Virus Shield | chlorine dioxide | Virus Shield Biosciences | contact | NC |

**Mode of action**: various
**Resistance risk**: low
**Growth effects:** various

## ELEMENTS‡

| Trade name | Common name | Company | Activity | FRAC code |
|---|---|---|---|---|
| Copper | various | various | contact | M 01 |
| Sulfur | various | various | contact | M 02 |
| Lime sulfur | various | various | contact | M 02 |

**Mode of action**: both are multi-site inhibitors: copper inactivates numerous enzyme systems; sulfur inhibits respiration
**Resistance risk**: low
**Growth effects:** inhibit spore germination: sulfur also inhibits mycelial growth of powdery mildews
**Sporulation:** no effect

## SYSTEMIC ACQUIRED RESISTANCE (SAR) STIMULATORS‡

| Trade name | Common name | Company | Activity | FRAC code |
|---|---|---|---|---|
| Actigard | acibenzolar-S-methyl | Syngenta Crop Protection | systemic | P 01 |
| Apogee | prohexadione calcium | BASF | systemic | Plant growth regulator) |
| KeyPlex-350, -DP | yeast extract | KeyPlex Co. | systemic | P 06 |
| LifeGard | *Bacillus mycoides* | Certis USA, L.L.C. | systemic effect | P 06 |
| Messenger**, Employ | harpin | Eden Bioscience | systemic | P unspecified |
| Aliette, ProPhyt, others | Fosetyl-AL, Potassium phosphite | Bayer Crop Science, Luxemburg Industries Ltd. | | P 07/33 |
| ProAlexin | plant host defense activator | Gronn Gjodsel | systemic | P 07/33 |

**Mode of action**: host resistance
**Resistance risk**: unknown
**Growth effects:** unknown
**Sporulation:** unknown

‡ Some of the active ingredients or products listed in this table may not be registered as pesticides or may have had their registration withdrawn. Check with your state pesticide regulatory agency to verify that applications are made in accordance with state and federal laws and regulations.

# FUNGICIDES LISTED BY CHEMICAL CLASS:
# CONVENTIONAL CHEMISTRIES – sorted by FRAC code (FC)
**(*Single Active Ingredients*)**

### METHYL BENZIMIDAZOLE CARBAMATES (MBC) (FC 1)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Mertect, Alumni*** | thiabendazole (TBZ) | Syngenta Crop Protection | systemic (local) |
| Cercobin** | thiophanate-methyl | FMC Corp. | systemic (local) |
| T-Methyl | thiophanate-methyl | UPL OpenAg | systemic (local) |
| Topsin-M | thiophanate-methyl | UPL OpenAg | systemic (local) |
| Incognito | thiophanate-methyl | ADAMA Agricultural Solutions Ltd. | systemic (local) |

***Postharvest use only**
**Mode of action:** FRAC[1] Code 1; single-site inhibitors that interfere with β-tubulin assembly and mitosis (nuclear division disruption)
**Resistance risk:** high; levels of resistant populations do not decline in the absence of fungicide use; to reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** inhibits mycelial growth
**Sporulation:** inhibits

### DICARBOXIMIDES (FC 2)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Iprodione** | iprodione | UPL OpenAg | systemic (local) |
| Meteor | iprodione | UPL OpenAg | systemic (local) |
| Nevado** | iprodione | ADAMA Agricultural Solutions Ltd. | systemic (local) |
| Rovral | iprodione | FMC Corp. | systemic (local) |

**Mode of action:** FRAC[1] Code 2; osmotic signal transduction (MAP / histidine kinase (os-1, Daf1)
**Resistance risk:** low with low frequency of application; none reported in California; where resistance occurs, no crop losses reported on stone fruits; resistant populations are less fit and decline in absence of fungicide use.
**Growth effects:** inhibits mycelial growth and to a lesser extent spore germination
**Sporulation:** inhibits

### DEMETHYLATION (ERGOSTEROL OR STEROL BIOSYNTHESIS) INHIBITORS (DMI OR SBI) (FC 3)‡

| Trade name | Common name | Subclass | Company | Activity |
|---|---|---|---|---|
| Alto | cyproconazole | Triazole | Syngenta | systemic (local) |
| Bayleton** | triadimefon | Triazole | Taminco | systemic (local) |
| Bumper** | propiconazole | Triazole | ADAMA Agric. Sol. Ltd. | systemic (local) |
| Cevya, Provysol** | mefentrifluconazole | Triazole | BASF | systemic (local) |
| Deccozil*** | imazalil | Imidazole | UPL Open Ag | systemic (local) |
| Elite** | tebuconazole | Triazole | Bayer CropScience | systemic (local) |
| Fungaflor*** | imazalil | Imidazole | Janssen Pharmaceutica | systemic (local) |
| Indar (Enable) | fenbuconazole | Triazole | Dow AgroSciences | systemic (local) |
| Inspire | difenoconazole | Triazole | Syngenta Crop Protection | systemic (local) |
| Laguna** | difenoconazole | Triazole | Wilbur-Ellis Co. | systemic (local) |
| Marazo** | propiconazole | Triazole | AgBiome Innovations | systemic (local) |
| Mentor*** | propiconazole | Triazole | Syngenta Crop Protection | systemic (local) |
| Mettle | tetraconazole | Triazole | Sipcam Agro USA | systemic (local) |
| Miresa** | tebuconazole | Triazole | AgBiome Innovations | systemic (local) |
| Orius** | tebuconazole | Triazole | ADAMA Agric. Sol. Ltd. | systemic (local) |
| Perissim** | tetraconazole | Triazole | AgBiome Innovations | systemic (local) |
| Procure,Viticure** | triflumizole | Imidazole | UPL OpenAg | systemic (local) |
| Propiconazole | propiconazole | Triazole | Adama | systemic (local) |
| Propicure | propiconazole | Triazole | Direct AgSource | systemic (local) |
| Quash | metconazole | Triazole | Valent USA | systemic (local) |
| Rally (Laredo) | myclobutanil | Triazole | Dow AgroSciences | systemic (local) |
| Rubigan**,Vintage** | fenarimol | Pyrimidine | Gowan Co. | systemic (local) |
| Toledo | tebuconazole | Triazole | Rotam North America | systemic (local) |
| Teb | tebuconazole | Triazole | Willowood, Inc. | systemic (local) |
| Tebucon | tebuconazole | Triazole | Repar Corp. | systemic (local) |

| | | | | |
|---|---|---|---|---|
| Tebuzol** | tebuconazole | Triazole | UPL OpenAg | systemic (local) |
| Tilt | propiconazole | Triazole | Syngenta Crop Protection | systemic (local) |
| Rhyme | flutriafol | Triazole | FMC Corp. | systemic (local) |

*****Postharvest use on fruit only**

**Mode of action:** FRAC[1] Code 3; single-site inhibitors; inhibit demethylation and other processes in sterol biosynthesis; most are absorbed quickly and move up but not down in the plant; all have little effect on spore germination, but interfere with other early developmental processes; all inhibit mycelial growth and may stop lesions from sporulating; many have "kick-back" activity against brown rot, rust, perhaps scab, and apple and pear scab. Systemic action was determined in leaves of annual plants. The requisite tests using radioactive labeled compounds on flowers, fruit, and leaves of tree crops have not been conducted.
**Resistance risk:** high
**Growth effects:** inhibits mycelial growth
**Sporulation:** suppresses

## PHENYLAMIDES (FC 4)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Mefenoxam | mefenoxam | ADAMA Agricultural Solutions Ltd. | contact, systemic |
| Metalaxyl** | metalaxyl | ADAMA Agricultural Solutions Ltd. | contact, systemic |
| Ridomil Gold | mefenoxam | Syngenta Crop Protection | contact, systemic |

**Mode of action:** FRAC[1] Code 4; interferes with activity of a nuclear RNA polymerase I.
**Resistance risk:** high; to reduce the risk of resistance development start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of application per season.
**Growth effects:** inhibits mycelial growth, sporangial development, and zoospore viability
**Sporulation:** reduces

## SUCCINATE DEHYDROGENASE INHIBITORS (SDHIs) (FC 7)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Aprovia | benzovindiflupyr | Syngenta Crop Protection | contact |
| Endura | boscalid | BASF | contact |
| Fontelis | penthiopyrad | Corteva Agriscience | contact |
| Indiflin, Excalia* | inpyrfluxam | Valent USA | contact |
| Kenja | isofetamid | Summit Agro, USA | contact |
| Luna Privilege, Velum One | fluopyram | Bayer CropScience | contact |
| Miravis (Adepidyn Tech.) | pydiflumetofen | Syngenta Crop Protection | contact |
| Parade | pyraziflumid | Nichino Co. | contact |
| Xemium, Tesaris, Sercadis** | fluxapyroxad | BASF | contact |

*** Registration pending in California**

**Mode of action**: FRAC[1] Code 7; single-site; blocks respiration by interfering with complex II (succinate dehydrogenase). Several subcodes have different activity and resistance potential. Examples include: pyridine-carboxamides (boscalid), pyrazole-4-carboxamides (penthiopyrad, fluxapyroxad, isopyrazam), and pyridinyl-ethyl benzamides (fluopyram).
**Resistance risk:** high
**Growth effects:** reduced mycelial growth
**Sporulation:** unknown

## ANILINOPYRIMIDINES (AP) (FC 9)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Penbotec (Pyrimethanil)*** | pyrimethanil | Janssen Pharmaceutica (Dist. by UPL, Decco, Pace International, JBT, etc.) | contact, systemic on some crops |
| Scala | pyrimethanil | Bayer CropScience | contact, systemic on some crops |
| Vangard | cyprodinil | Syngenta Crop Protection | contact, systemic on some crops |

*****Postharvest use only**

**Mode of action:** FRAC[1] Code 9; single-site, methionine biosynthesis inhibitor (protein disruption); has "kick-back" activity against apple and pear scab and stone fruit fungi.
**Resistance risk:** high; to reduce the risk of resistance development start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** APs inhibits mycelial growth and suppresses spore germination. More effective in spring (lower temperatures) than summer (higher temperatures)
**Sporulation:** no effect

## STROBILURINS or QUINONE OUTSIDE INHIBITORS (QoIs) (FC 11)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Aproach | picoxystrobin | Corteva Agriscience | contact and systemic |
| Cabrio,Headline | pyraclostrobin | BASF | contact and systemic |
| Dexter | azoxystrobin | UPL OpenAg | contact and systemic |
| Evito* | fluoxastrobin | UPL OpenAg | contact and systemic |
| Flint Extra | trifloxystrobin | Bayer CropScience | contact and systemic |
| Intuity | mandestrobin | Valent USA | contact and systemic |
| Mazolin** | azoxystrobin | AgBiome Innovations | contact and systemic |
| Quadris, (Abound = discontinued trade name) | azoxystrobin | Syngenta Crop Protection | contact and systemic |
| Sovran | kresoxim methyl | FMC Corp. | contact and systemic |

**Mode of action:** FRAC[1] Code 11; single-site; blocks respiration by interfering with cytochrome bc1 (ubiquinol oxidase) at Qo site.
**Resistance risk:** high; to reduce the risk of resistance development start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** inhibits spore germination
**Sporulation:** no effect

**PHENYLPYRROLES (FC 12)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Scholar*** | fludioxonil | Syngenta Crop Protection | contact (except cherry-systemic) |
| PacRite FDL*** | fludioxonil | Pace International | contact (except cherry-systemic) |
| Cannonball WG | fludioxonil | Syngenta Crop Protection | contact |

*****Postharvest use only**
**Mode of action:** FRAC[1] Code 12; single-site; interferes with regulatory enzymes of oxidation and osmotic signal transduction (MAP / histidine kinase (os-2, HOG-1)).
**Resistance risk:** high
**Growth effects:** inhibits mycelial growth and germination
**Sporulation:** reduces

**AZA NAPHTHALENES (FC 13)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Quintec | Quinoxyfen | Gowan | contact |
| Talendo* | Proquidazid | Corteva Agriscience | contact |

**Mode of action**: FRAC[1] Code 13; probably single-site inhibitor; disrupts early cell signaling events (signal transduction).
**Resistance risk:** medium
**Growth effects:** suppresses spore germination, early germ tube development and/or appressorium formation
**Sporulation:** no effect

**AROMATIC HYDROCARBONS (FC 14)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Botran, (Allisan)[2] | dicloran | Gowan | Contact/systemic? |

**Mode of action:** FRAC[1] Code 14; mechanism unclear, but lipid peroxidation (disruption of membrane integrity) was proposed. Mostly a contact fungicide for protecting wounds on fruit; uptake by roots in lettuce and tomato.
**Resistance risk:** medium
**Growth effects:** inhibits mycelial growth, little effect on spore germination
**Sporulation:** little effect

**KRI-fungicides (Keto Reductase Inhibitors) (FC 17)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Elevate | fenhexamid | UPL OpenAg | contact |
| Protexio | fenpyrazamine | Valent USA | contact |

**Mode of action:** FRAC[1] Code 17; unknown, probably single-site and related to sterol biosynthesis inhibition.
**Resistance risk:** high; to reduce the risk of resistance development start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** inhibits spore germination and mycelial growth
**Sporulation:** no effect

[2] Allisan was for postharvest use only - label changed to Botran Flowable

**POLYOXINS (FC 19)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Ph-D, Endorse** | polyoxin-D | UPL OpenAg | contact |
| Oso | polyoxin-D | Certis USA | contact |

**Mode of action**: FRAC[1] Code 19; single-site inhibitor of chitin synthase (disruption of cell wall biosynthesis).
**Resistance risk:** medium
**Growth effects:** inhibits spore germination and mycelial growth.
**Sporulation:** no effect

**QUINONE INSIDE INHIBITORS (FC 21)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Ranman | cyazofamid | Summit Agro USA (ISK) | contact |

**Mode of action**: FRAC[1] Code 21; single-site inhibitor; blocks respiration by interfering with cytochrome bc1 (ubiquinol oxidase) at Qi site.
**Resistance risk:** medium-high
**Growth effects:** suppresses spore germination, early germ tube development and/or appressorium formation.
**Sporulation:** no effect

*** (FC 22)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Elumin*, Intego Solo | ethaboxam | Valent USA | contact |

*** Registration in process through IR-4 program**
**Mode of action**: FRAC[1] Code 22; single-site; blocks β-tubulin assembly in mitosis.
**Resistance risk:** low to medium
**Growth effects:** reduced mycelial growth
**Sporulation:** unknown

**DINITROANILINES (FC 29)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Lektivar | fluazinam | AgBiome Innovations | contact |
| Omega | fluazinam | Syngenta, ISK | contact |

**Mode of action**: FRAC[1] Code 29; single-site; uncouples oxidative phosphorylation.
**Resistance risk:** low
**Growth effects:** reduced mycelial growth
**Sporulation:** unknown

**PHOSPHONATES (FC P 07/33)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Aliette | fosetyl-aluminum | Bayer CropScience | systemic |
| Fungi-Phite | potassium phosphite | Plant Protectants, LLC | systemic |
| K-Phite | potassium phosphite | Plant Food Systems, Inc. | systemic |
| Legion | fosetyl-aluminum | ADAMA Agricultural Solutions Ltd. | systemic |
| Linebacker | fosetyl-aluminum | Tessenderlo Kerley, Inc. (NovaSource) | systemic |
| ProPhyt | potassium phosphite | Helena Chemical Company | systemic |

**Mode of action:** FRAC[1] Code P 07/33; reports indicate variable effects on both plant and organism physiology.
**Resistance risk:** medium (resistance detected in some crops)
**Growth effects:** may inhibit phosphorus deficiency signaling in the plant and fungus; direct toxicity in inhibiting mycelial growth.
**Sporulation:** suppresses sporulation of *Phytophthora* spp.
**Note:** K-phite is reported to be active against fungal and bacterial diseases (e.g., *Xanthomonas* spp,) at higher rates registered than other phosphonates, and is compatible with copper.

**CARBOXYLIC ACID AMIDES (FC 40)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Revus | mandipropamid | Syngenta Crop Protection | contact, systemic |

**Mode of action:** FRAC[1] Code 40; interferes with cellulose synthase and cell wall biosynthesis
**Resistance risk:** high; to reduce the risk of resistance development start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per eason.
**Growth effects:** inhibits conidial germination and mycelial growth
**Sporulation:** reduces

**BENZAMIDES (FC 43)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Presidio | fluopicolide | Valent (Bayer CropScience) | systemic (local) |

**Mode of action**: FRAC[1] Code 43; delocalization of cellular spectrin-like proteins resulting in disruption of cell division.
**Resistance risk:** high; the fungicide should be used following FRAC guidelines and used in mixtures and rotations with other fungicides effective against target plant pathogens; to reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action, use labeled rates (preferably the upper range), and limit the total number of applications per season (less than 4).
**Growth effects:** inhibition of mycelial growth, and lysis of zoospores.
**Sporulation:** inhibits

**POLYENE MACROLIDE (FC 48)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| BioSpectra/Zivion S | natamycin | Pace International/DSM | contact |
| Cerafruta | natamycin | Ceradis | contact |
| Uniguard** | natamycin | Janssen PMP | contact |

**Mode of action**: FRAC[1] Code 48; ergosterol binder, inhibiting transport membrane proteins from functioning properly.
**Resistance risk:** low
**Growth effects:** inhibits mycelial growth.
**Sporulation:** no effect

**PIPERIDINYL-THIAZOLE-ISOXAZOLINES (FC 49)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Orondis | oxathiapiprolin | Syngenta Crop Protection | Contact (fruit) / local systemic (roots) |
| To be announced | fluoxapiprolin | Bayer CropScience | Contact |

**Mode of action:** FRAC[1] Code 49; oxysterol binding protein (OSBP) inhibition.
**Resistance risk:** high
**Growth effects:** inhibits mycelial growth.
**Sporulation:** inhibits sporangia, oospore, and chlamydospore formation

**BENZOPHENONE (FC 50)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Vivando | metrafenone | BASF | contact |
| Prolivo | pyriofenone | Summit Agro USA (ISK) | contact |

**Mode of action:** FRAC[1] Code 50 (formerly U8); single-site; proposed mechanism is actin disruption.
**Resistance risk:** high?; to reduce the risk of resistance development start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), follow protective application schedule, and limit the total number of applications per season.
**Growth effects:** abnormal spore germination, appressorium formation, and secondary hyphal growth (prevents plant infection).
**Sporulation:** inhibition of spore formation occurs if mycelium on leaf surfaces is treated

**DIHYDROOROTATE DEHYDROGENASE INHIBITION (DHODHI) (FC 52)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Axios | iopflufenoquin | UPL | Contact (fruit) / local systemic (roots) |

**Mode of action:** FRAC[1] Code 52; dihydroorotate dehydrogenase inhibition (DHODHI) within de novo pyrimidine biosynthesis.
**Resistance risk:** high, rotation and mixtures are recommended
**Growth effects:** inhibits mycelial growth and spore germination.

**Copper (FC M 01)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Various | copper | various | contact |

**Mode of action**: FRAC[1] Code M 01; multi-site inhibitor that complexes with enzymes resulting in cellular disruption.
**Resistance risk:** low in fungi
**Growth effects:** inhibits spore germination and fungal growth
**Sporulation:** no effect

**Sulfur (FC M 02)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Various | sulfur | various | contact |

**Mode of action**: FRAC[1] Code M 02; multi-site inhibitor that forms sulfuric acid when mixed with water.
**Resistance risk:** low in fungi
**Growth effects:** inhibits spore germination and fungal growth
**Sporulation:** contact disruptor

### DITHIOCARBAMATES AND RELATIVES (FC M 03)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| *Ethylene bisdithiocarbamates (EBDC)* | | | |
| Dithane (coordinated product) | mancozeb | Dow AgroSciences | contact |
| Manzate (coordinated product) | mancozeb | Corteva Agriscience | contact |
| Penncozeb (coordinated product) | mancozeb | UPL OpenAg | contact |
| *Dimethyl dithiocarbamates (DMDC)* | | | |
| Ferbam** | ferbam | Taminco | contact |
| Thiram | thiram | Taminco | contact |
| Ziram | ziram | UPL OpenAg | contact |

**** Not registered, label withdrawn or inactive in California**
**Mode of action**: FRAC[1] Code M 03; multi-site inhibitors that complex with enzymes probably inhibiting respiration.
**Resistance risk:** low
**Growth effects:** inhibits spore germination
**Sporulation:** no effect

### PHTHALIMIDES (FC M 04)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Captan | captan | various | contact |

**Mode of action**: FRAC[1] Code M 04; multi-site inhibitor that complexes with enzymes probably inhibiting respiration.
**Resistance risk:** low
**Growth effects:** inhibits spore germination
**Sporulation:** no effect

### CHLORONITRILES (FC M 05)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Bravo | chlorothalonil | Syngenta Crop Protection | contact |
| Chlorothalonil | chlorothalonil | UPL OpenAg | contact |
| Echo | chlorothalonil | Sipcam Agro USA | contact |
| Equus | chlorothalonil | ADAMA Agric. Sol. Ltd. | contact |

**Mode of action:** FRAC[1] Code M 05; multi-site inhibitor affecting various enzymes and other metabolic processes.
**Resistance risk:** low
**Growth effects:** inhibits spore germination
**Sporulation:** unknown

## HOST PLANT DEFENCE INDUCTION

### PHOSPHONATES (FC P 07/33)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Aliette | fosetyl-aluminum | Bayer CropScience | systemic |
| Fungi-Phite | potassium phosphite | Plant Protectants, LLC | systemic |
| K-Phite | polyphosphite | Plant Food Systems, Inc. | systemic |
| Legion | fosetyl-aluminum | ADAMA Agricultural Solutions Ltd. | systemic |
| Linebacker | fosetyl-aluminum | Tessenderlo Kerley, Inc. (NovaSource) | systemic |
| ProPhyt | potassium phosphite | Helena Chemical Company | systemic |

**Mode of action:** FRAC[1] Code P 07 (formerly FC P 07/33); reports indicate variable effects on both plant and organism physiology.

‡ Some of the active ingredients or products listed in this table may not be registered as pesticides or may have had their registration withdrawn. Check with your state pesticide regulatory agency to verify that applications are made in accordance with state and federal laws and regulations.

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action Code numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action Code number; for fungicides with other Code numbers, make no more than two consecutive applications before rotating to a fungicide with a different mode-of-action Code number.

‡ Some of the active ingredients or products listed in this table may not be registered as pesticides or may have had their registration withdrawn. Check with your state pesticide regulatory agency to verify that applications are made in accordance with state and federal laws and regulations.

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action Code numbers 1, 4, 9, 11, or 17 before

**Resistance risk:** medium (resistance detected in some crops)
**Growth effects:** may inhibit phosphorus deficiency signaling in the plant and fungus; direct toxicity in inhibiting mycelial growth.
**Sporulation:** suppresses sporulation of *Phytophthora* spp.
**Note:** K-Phite is reported to be active against fungal and bacterial diseases (e.g., *Xanthomonas* spp,) at higher rates registered than other phosphonates, and is compatible with copper.

**TERPENE HYDROCARBONS (FC BM 01)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Timorex Act, Timorex Gold** | tea tree oil | Summit Agro USA | contact |

**Mode of action**: FRAC[1] Code BM 01; cell membrane disruption.
**Resistance risk:** low
**Growth effects:** inhibits mycelial growth.
**Sporulation:** no effect

## UNKNOWN MODES OF ACTION

**PHENYL-ACETAMIDES (FC U6)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Torino | cyflufenamid | Gowan | contact |

**Mode of action**: FRAC[1] Code U6; unknown mechanism.

**GUANIDINES (FC U12)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Syllit | dodine | UPL OpenAg. | systemic (local) |

**Mode of action:** FRAC[1] Code U12; membrane disruption.
**Resistance risk:** high

**THIAZOLIDINES (FC U13)‡**

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Gatten | flutianil | Nichino America | Mostly contact |

**Mode of action:** FRAC[1] Code U13; unknown.
**Resistance risk:** high

rotating to a fungicide with a different mode-of-action Code number; for fungicides with other Code numbers, make no more than two consecutive applications before rotating to a fungicide with a different mode-of-action Code number.

# MULTIPLE ACTIVE INGREDIENTS IN PREMIXTURES

### COPPER/MANCOZEB (FC M 01 and M 03)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Mankocide | Copper/mancozeb | Kocide | contact |

**Mode of action:** FRAC[1] Codes M 01 and M 03; both milti-site modes of action.
**Resistance risk:** low
**Growth effects:** both inhibit mycelial growth and germination
**Sporulation:** reduction

### MBC/DMI (FC 1 and 3)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Protocol | thiophanate methyl/ propiconazole | Loveland Products | systemic |

**Mode of action:** FRAC[1] Codes 1 and 3; both single-site, MBC (thiophanate methyl) binds to beta–tubulin; DMI single-site inhibitors (propiconazole) target demethylation and other processes in sterol biosynthesis.
**Resistance risk:** medium to high (if MBC resistance already exists)
**Growth effects:** MBCs inhibit germination; whereas DMIs inhibit mycelial growth
**Sporulation:** reduction

### MBC/PHENYLPYRROLE (FC 1 and 12)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Scholar Max MP*** | TBZ/fludioxonil | Syngenta Crop Protection | contact/slightly systemic |

***Postharvest use only**

**Mode of action:** FRAC[1] Codes 1 and 12; both single-site, MBC (TBZ) binds to beta–tubulin; phenylpyrroles (fludioxonil) interfere with regulatory enzymes of oxidation, osmoregulation, and possibly respiration.
**Resistance risk:** medium to high (if TBZ resistance already exists)
**Growth effects:** both inhibit mycelial growth and germination
**Sporulation:** reduction

### DMI/SDHI (FC 3 and 7)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Aprovia Top | difenoconazole/benzovindiflupyr | Syngenta Crop Protection | contact and systemic |
| Fervent | tebuconazole/isofetamid | Summit Agro USA (ISK) | contact and systemic |
| Luna Experience | tebuconazole/fluopyram | Bayer CropScience | contact and systemic |
| Miravis Duo/ MiravisTop** | difenoconazole/pydiflumetofen | Syngenta Crop Protection | contact and systemic |
| Mibelya/Elysis | mefentrifluconazole/ fluxapyroxad | BASF | contact and systemic |

**Mode of action:** FRAC[1] Codes 3 and 7; DMI single-site inhibitors (tebuconazole) target demethylation and other processes in sterol biosynthesis; whereas SDHI fungicides inhibit succinate dehydrogenase (fluopyram). Most DMI fungicides most are absorbed quickly and move up but not down in the plant; all have little effect on spore germination, but interfere with other early developmental processes; all inhibit mycelial growth and may stop lesions from sporulating; many have post-infection or "kick-back" activity against brown rot, rust, perhaps scab, and apple and pear scab.
**Resistance risk:** medium to high; rating is a result of only partial overlap in the spectrum of activity of the two active ingredients. To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** unknown for SDHI; DMI inhibits only mycelial growth
**Sporulation:** unknown for SDHI; DMI inhibits sporulation.

### DMI/ANILINOPYRIMIDINE (AP) (FC 3 and 9)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Inspire Super | difenoconazole/cyprodinil | Syngenta Crop Protection | contact and systemic |

**Mode of action:** FRAC[1] Codes 3 and 9; both single-site inhibitors; DMIs (e.g., tebuconazole) inhibit demethylation and other processes in sterol biosynthesis pathway; whereas AP fungicides are methionine inhibitors (e.g., cyprodinil).

**Resistance risk:** medium; rating is a result of only partial overlap in the spectrum of activity of the two active ingredients. To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** APs inhibit mycelial growth and suppresses spore germination; DMIs inhibit mycelial growth.
**Sporulation:** APs have no effect; DMIs suppress sporulation.

### DMI/STROBILURIN (QoI) (FC 3 and 11)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Adament | tebuconazole/trifloxystrobin | Bayer CropScience | contact and systemic (local) |
| Avaris 2XS | propiconazole/azoxystrobin | Helena Chemical Co. | systemic (local) |
| Quadris Top | difenoconazole/azoxystrobin | Syngenta Crop Protection | contact and systemic (local) |
| Quilt Xcel | propiconazole/azoxystrobin | Syngenta Crop Protection | contact and systemic (local) |
| Custodia** | tebuconazole/azoxystrobin | Adama | contact and systemic (local) |
| Xiphosin** | propiconazole/azoxystrobin | AgBiome Innovations | systemic (local) |

**Mode of action:** FRAC[1] Codes 3 and 11; both single-site inhibitors; DMIs (difenoconazole, propiconazole, tebuconazole) inhibit demethylation and other processes in sterol biosynthesis; strobilurins (azoxystrobin, trifloxystrobin) block respiration by interfering with cytochrome b.
**Resistance risk:** medium to high; rating is a result of only partial overlap in the spectrum of activity of the two active ingredients. To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** DMIs inhibit mycelial growth; strobilurins inhibit spore germination.
**Sporulation:** DMIs suppress sporulation; strobilurins have no effect.

### DMI/PHENYLPYRROLE (FC 3 and 12)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Academy*** | difenoconazole/fludioxonil | Syngenta Crop Protection | contact |
| Chairman*** | propiconazole/fludioxonil | Syngenta Crop Protection | contact and systemic |

***Postharvest use only**

**Mode of action:** FRAC[1] Codes 3 and 12; both single-site inhibitors; DMIs (e.g., difenoconazole, propiconazole) inhibit demethylation and other processes in sterol biosynthesis pathway; phenylpyrroles (fludioxonil) interfere with regulatory enzymes of oxidation, osmoregulation, and possibly respiration.
**Resistance risk:** medium; rating is a result of only partial overlap in the spectrum of activity of the two active ingredients. To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** APs inhibit mycelial growth and suppresses spore germination; DMIs inhibit mycelial growth.
**Sporulation:** APs have no effect; DMIs suppress sporulation.

### DMI/Phosphonate (FC 3 and P 07/33)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Viathon | tebuconazole/phosphite | Luxembourg | contact and systemic |

**Mode of action:** FRAC[1] Codes 3 and P 07/33; both single-site inhibitors; DMIs (e.g., tebuconazole) inhibit demethylation and other processes in sterol biosynthesis pathway; whereas phosphonate fungicides have an unknown mode of action.
**Resistance risk:** medium; rating is a result of only partial overlap in the spectrum of activity of the two active ingredients. To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** DMIs inhibit mycelial growth; whereas phosphonates affect many aspects of fungal growth.
**Sporulation:** DMIs suppress sporulation.

### DMI/ESSENTIAL OILS (FC 3 and BM 01)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Regev | Difenoconazole/ tea tree oil | SummitAgro | systemic (local) |

**Mode of action:** FRAC[1] Codes 3 and 46; both single-site inhibitors; DMIs (e.g., difenoconazole) inhibit demethylation and other processes in sterol biosynthesis pathway; whereas essential oils are cell membrane disruptors.
**Resistance risk:** medium; rating is a result of only partial overlap in the spectrum of activity of the two active ingredients. To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different

mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** DMIs inhibit mycelial growth; whereas essential oils affect many aspects of fungal growth.
**Sporulation:** DMIs suppress sporulation.

### SDHI/ANILINOPYRIMIDINE (AP) (FC 7 and 9)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Luna Tranquility | fluopyram/pyrimethanil | Bayer CropScience | contact and systemic |

**Mode of action:** FRAC[1] Codes 7 and 9; Succinate dehydrogenase inhibitors possibly multi-site; whereas APs are single-site. The SDHI fungicides inhibit succinate dehydrogenase (boscalid, fluopyram, penthiopyrad, fluxopyroxad) whereas AP fungicides are possibly methionine inhibitors (e.g., pyrimethanil).
**Resistance risk:** medium to high; rating is a result of only partial overlap in the spectrum of activity of the two active ingredients. To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** SDHIs and APs inhibit mycelial growth
**Sporulation:** APs have no effect; unknown for SDHI.

### SDHI/STROBILURIN (QoI) (FC 7 and 11)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Merivon, Priaxor | fluxapyroxad/pyraclostrobin | BASF | contact and systemic |
| Luna Sensation | fluopyram/trifloxystrobin | Bayer CropScience | contact and systemic |
| Pristine | boscalid/pyraclostrobin | BASF | contact and systemic |

**Mode of action:** FRAC[1] Codes 7 and 11; Succinate dehydrogenase inhibitors possibly multi-site; whereas QoIs are single-site. The QoIs (pyraclostrobin, trifloxystrobin, picoxystrobin) block respiration by interfering with cytochrome b; SDHI fungicides inhibit succinate dehydrogenase (boscalid, fluopyram, penthiopyrad, fluxopyroxad, pyraziflumid, pydiflumatofen).
**Resistance risk:** medium to high; rating is a result of only partial overlap in the spectrum of activity of the two active ingredients. To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** strobilurins inhibit spore germination; SDHIs inhibit mycelial growth.
**Sporulation:** no effect for strobilurins; unknown for SDHI

### SDHI/PHENYLPYRROLE (FC 7 and 12)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Miravis Prime | pydiflumetofen/fludioxonil | Syngenta Crop Protection | contact and systemic |

**Mode of action:** FRAC[1] Codes 7 and 12; both single-site, Succinate dehydrogenase inhibitors possibly multi-site; phenylpyrroles (fludioxonil) interfere with regulatory enzymes of oxidation, osmoregulation, and possibly respiration.
**Resistance risk:** medium to high
**Growth effects:** both inhibit mycelial growth and germination
**Sporulation:** reduction from fludioxonil, unknown from SDHI

### ANILINOPYRIMIDINE (AP)/PHENYLPYRROLE (9 and 12)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Switch | cyprodinil/fludioxonil | Syngenta Crop Protection | contact/slightly systemic |

**Mode of action:** FRAC[1] Codes 9 and 12; both single-site, anilinopyrimidines (cyprodinil) inhibit methionine; phenylpyrroles (fludioxonil) interfere with regulatory enzymes of oxidation, osmoregulation, and possibly respiration.
**Resistance risk:** high
**Growth effects:** both inhibit mycelial growth and germination
**Sporulation:** reduction

### PHOSPHONATE/CHLORONITRILE (FC P 07/33 and M 05)‡

| Trade name | Common name | Company | Activity |
|---|---|---|---|
| Catamaran | phosphonate/chlorothalonil | Luxembourg | contact and systemic |

**Mode of action:** FRAC[1] Codes P 07/33 and M 05; phosphonate fungicides have an unknown mode of action; whereas chloronitrile fungicides are multi-site inhibitors that affect different metabolic sites.
**Resistance risk:** medium; rating is a result of only partial overlap in the spectrum of activity of the two active ingredients. To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
**Growth effects:** DMIs inhibit mycelial growth; whereas chloronitriles affect many aspects of fungal growth.
**Sporulation:** DMIs and chloronitriles suppress sporulation.

‡ Some of the active ingredients or products listed in this table may not be registered as pesticides or may have had their registration withdrawn. Check with your state pesticide regulatory agency to verify that applications are made in accordance with state and federal laws and regulations.

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action Code numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action Code number; for fungicides with other Code numbers, make no more than two consecutive applications before rotating to a fungicide with a different mode-of-action Code number.

## ALMOND: FUNGICIDE EFFICACY - CONVENTIONAL

| Fungicide | Resistance risk (FRAC)[1,7] | Brown rot | Jacket rot | Anthrac-nose | Shot hole | Scab[3] | Rust[3] | Leaf blight | Alternaria leaf spot [3] | PM-like[5] | Hull rot[16] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Adament | medium (3/11) | 5 | 4 | 4 | 5 | 4 | 5 | ND | 4 | 4 | 4 |
| Axios | high (52)[7] | 5 | 4 | ND | 4 | 3 | ND | ND | 3 | ND | 4 |
| Bumper**, Tilt, Propicure, Propiconazole[4] | high (3) | 5 | 1 | 5 | 3 | 3 | 4 | ND | 3 | 4 | 3 |
| Cevya | high (3) | 5 | 1 | 5 | 5 | 3/4 | 4 | ND | 4 | ND | 4 |
| Fontelis[3] | high (7)[7] | 5 | 5 | 3 | 5 | 3 | 3 | ND | 4 | ND | 0 |
| Kenja[4] | high (7)[7] | 5 | 5 | 3 | 5 | 4 | 0 | ND | 4 | ND | 0 |
| Parade* | high (7)[7] | 5 | 5 | ND | 5 | 3 | ND | ND | 3 | ND | 1 |
| Indar | high (3) | 5 | 1 | 4 | 3 | 3 | NL | ND | 2 | ND | 0 |
| Inspire | high (3) | 5 | 3 | 5 | 3 | 4 | 5 | ND | 5 | ND | 4 |
| Regev | high (3/BM 01) | 5 | 3 | 4 | 3 | 4 | 4 | ND | 4 | ND | 4 |
| Protocol[2] | med.-high (1/3) | 5 | 5 | ND | 4 | 4 | 5 | ND | 3 | ND | 2 |
| Inspire Super[4] | medium (3/9) | 5 | 5 | ND | 4 | 4 | 5 | ND | 5 | ND | 4 |
| Luna Experience[3] | medium (3/7) | 5 | 4 | 5 | 4 | 5 | 5 | ND | 5 | 4 | 4 |
| Fervent | medium (3/7) | 5 | 4 | 5 | 4 | 5 | 5 | ND | 5 | 4 | 4 |
| Luna Sensation[3] | medium (7/11) | 5 | 5 | 5 | 5 | 5 | 5 | ND | 5 | 4 | 4 |
| Miravis Duo | medium (3/7) | 5 | 4 | 5 | 4 | 5 | 5 | ND | 5 | 4 | 4 |
| Miravis Prime | medium (7/12) | 5 | 4 | 5 | 5 | 5 | 5 | ND | 5 | 5 | 4 |
| Merivon[3] | medium (7/11) | 5 | 5 | 5 | 5 | 5 | 4 | ND | 5 | 5 | 4 |
| Pristine[3] | medium (7/11) | 5 | 5 | 5 | 5 | 5 | 4 | ND | 4 | 4 | 4 |
| Quadris Top[3] | medium (3/11) | 5 | 5 | 5 | 4 | 5 | 5 | ND | 4 | 4 | 4 |
| Quilt Xcel, Avaris 2XS[3] | medium (3/11) | 5 | 4 | 5 | 4 | 5 | 5 | ND | 4 | 4 | 4 |
| Quash[4] | high (3) | 5 | 3 | 5 | 4 | 4 | 5 | ND | 5 | 4 | 4 |
| Rovral + oil[8, 9] | low (2) | 5 | 5 | 0 | 4 | 1 | 3 | ND | 4 | ND | 0 |
| Scala[3, 10] | high (9)[7] | 5 | 5 | ND | 3 | 0 | ND | ND | 2 | 0 | 0 |
| Tebucon,Toledo, Teb, Tebuconazole** | high (3) | 5 | 1 | 4 | 3 | 3 | 4 | ND | 2 | ND | 3 |
| Viathon | medium (3, P 07/33) | 5 | 1 | 4 | 3 | 3 | 4 | ND | 2 | ND | 3 |
| Topsin-M, T-Methyl, Incognito, Cercobin**[2,6,8] | high (1)[7] | 5 | 5 | 0 | 0 | 4 | 2 | 4 | 0 | 3 | 0 |
| Vangard[3, 7,9, 10] | high (9) | 5 | 5 | ND | 3 | 0 | ND | ND | 2 | 0 | 0 |
| Quadris, (Abound discontinued) | high (11)[7] | 4 | 2 | 5 | 4 | 5 | 5 | 4 | 4 | 4 | 4 |
| Aproach[3,4] | high (11)[7] | 4 | 2 | 5 | 4 | 5 | 5 | 4 | 4 | 4 | 4 |
| CaptEvate** | low (M 04/17) | 4 | 4 | 4 | 4 | 4 | 0 | 4 | 2 | 0 | 0 |
| Elevate[7] | high (17) | 4 | 5 | 0 | 2 | ND | ND | ND | ND | ND | 0 |
| Gem[3,4] | high (11)[7] | 4 | 0 | 5 | 4 | 5 | 5 | 4 | 4 | 4 | 4 |
| Laredo, Rally[13] | high (3) | 4 | 0 | 3 | 3 | 0 | 2 | 4 | 0 | 4 | 0 |
| Luna Privilege** | high (7)[7] | 4 | 3 | 3 | 3 | 4 | 4 | ND | 4 | 3 | 3 |
| Rovral[9], Meteor[9], Iprodione**, Nevado** | low (2) | 4 | 4 | 0 | 4 | 0 | 0 | ND | 3 | 0 | 0 |
| Rhyme | high (3) | 4 | 1 | ND | 2 | 3 | ND | ND | 3 | ND | ND |
| Bravo, Chlorothalonil, Equus, Echo[11, 12, 15] | low (M 05) | 3 | NL | 4 | 4 | 4 | 5 | NL | NL | 0 | 0 |
| Captan[4, 6, 12] | low (M 04) | 3 | 3 | 4 | 4 | 3 | 0 | 4 | 2 | 0 | 0 |
| Mancozeb | low (M 03) | 3 | 3 | 4 | 4 | 3 | 4 | 4 | 2 | 0 | 0 |
| Ph-D | medium (19) | 3 | 4 | 0 | 3 | 4 | 4 | ND | 5 | ND | 4 |
| Ziram | low (M 03) | 3 | 2 | 4 | 4 | 4 | 0 | 3 | 2 | 0 | 0 |
| Syllit | medium (U 12) | 2 | 0 | ND | 4 | 5 | ND | ND | 2 | ND | 0 |
| Copper[14,15] | low (M 01) | 1 | 1 | 0 | 2 | 2 | 0 | 0 | ND | 0 | 0 |
| Lime sulfur[12,15] | low (M 02) | 1 | NL | 0 | 1 | 3 | 3 | NL | NL | 0 | 0 |
| Sulfur[4,12] | low (M 02) | 1 | 1 | 0 | 0 | 3 | 3 | 0 | 0 | 4 | 0 |
| Copper + oil[14,15] | low (M 01) | ND | ND | 0 | 2 | 4 | 0 | 0 | ND | 0 | 0 |

## FUNGICIDE EFFICACY - PHYTOPTHORA ROOT AND CROWN ROT (PRCR) USING CONVENTIONAL TREATMENTS

| Fungicide | Resistance risk (FRAC code)[1] | PRCR |
|---|---|---|
| Orondis | high (49) | 5 |
| Revus* | high (40) | 5 |
| Presidio | high (43) | 4 |
| Elumin* | high (22) | 4 |
| Ridomil**, Metalaxyl** | high (4) | 3 |
| Ridomil Gold, ProPhyt, Mefenoxam*** | high (4) | 4 |
| Aliette***, Fungi-Phite, K-Phite | low-medium (P07/33) | 4 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

*** Registration pending in California.**
****Not registered, label withdrawn or inactive in California.**
***** - 12-month PHI**

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-actions (MOA) with high resistance risk before rotating to a fungicide with a different MOA (Code number); for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different MOA (Code number).

[2] Strains of the brown rot fungi *Monilinia laxa* and *M. fructicola* resistant to Topsin-M and T-Methyl have been found in some California almond orchards. MBC-resistant strains of the jacket rot fungus, *Botrytis cinerea* and powdery mildew fungi, have been reported in California on crops other than almond and stone fruits and may have the potential to develop in almonds with overuse of fungicides with similar chemistry. MBC-resistant strains of the scab fungus, *Venturia* (*Fusicladium, Cladosporium*) *carpophila*, have been found in California.

[3] Field resistance of *Alternaria* sp. and *Fusicladium carpophilum* to QoI and SDHI fungicides has been detected in almond orchards. AP-resistant populations of *Monilinia* spp. have been found on other stone fruit crops in California.

[4] Of the materials listed, only sulfur, Captan (FRAC Code M 02, M 04), Kenja (FRAC Code 7), Aproach, Gem, Quadris (FRAC Code 11), and some of the DMI fungicides (FRAC Code No. 3) are registered for use in late spring and early summer when treatment is recommende.

[5] PM-like refers to a powdery mildew-like disease on almond fruit. Information suggests an *Acremonium* species is involved.

[6] Excellent control obtained when combinations of Topsin-M or T-Methyl and Captan are used.

[7] To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.

[8] Oils recommended include "light" summer oil, 1-2% volume/volume.

[9] Do not use later than 5 weeks after petal fall.

[10] Efficacy reduced at high temperatures and relative humidity.

[11] Bravo Ultrex, Bravo WeatherStik, Echo, and Chlorothalonil are currently registered.

[12] Dormant applications with oil are highly effective against scab, Do not use in-season combinations with oil or shortly before or after oil treatment.

[13] Efficacy is better in concentrate (80–100 gal/acre) than in dilute sprays.

[14] The low rates necessary to avoid phytotoxicity in spring reduce the efficacy of copper.

[15] "Burns out" scab twig lesions when applied at delayed dormant. (Chlorothalonil can be applied with dormant oil during tree dormancy).

[16] Hull rot ratings are for the disease caused by *Rhizopus stolonifer*. Ratings for the disease caused by *Monilinia* or *Aspergillus* spp. will be provided in the future.

[17] PlantShield is best used for wood-exposing wounds to prevent silverleaf and wood decay.

## ALMOND: FUNGICIDE EFFICACY - BIOCONTROLS AND NATURAL PRODUCTS

| Trade name | Biocontrol or natural product (FRAC code)[1,6] | Brown rot | Jacket rot | Anthrac -nose | Shot hole | Scab | Rust | ALS[2] | Hull rot[3] | PM-like[4] | Silver leaf | Bac. Spot, Bac. Blast |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Botector | *Aureobasidium pullulans* (BM 02) | 3 | 2 | NL | NL | NL | NL | NL | NL | NL | NL | NL |
| Double Nickel 55 | *Bacillus amyloliquefaciens* D747 (BM 02) | 2 | 2 | ND | 2 | NL | NL | NL | NL | NL | NL | 2 |
| Serifel | *B. amyloliquefaciens* MBI600 (BM 02) | 2 | 2 | NL | 2 | 2 | 1 | 1 | 1 | ND | ND | 2 |
| Sonata | *B. pumilis* QST2808 (BM 02) | 2 | NL | NL | NL | NL | NL | NL | NL | NL | NL | NL |
| Serenade | *B. subtilis* QST 713 (BM 02) | 3 | 3 | 2 | 2 | 1 | 1 | 1 | NL | ND | NL | 3 |
| Aviv | *B. subtilis* IAB/BS03 (BM 02) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Theia | *B. subtilis* AFS03232 (BM 02) | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Dart | capric and caprylic acids (BM 01) | 3 | 2 | ND | 2 | 1 | 1 | 2 | 2 | ND | 0 | 3 |
| Cinnacure, Seican, Cinnerate | Cinnamaldehyde/Cinnamon oil (BM 03) | 1 | 1 | NL | NL | NL | NL | NL | NL | NL | NL | 2 |
| EF400 | clove, rosemary, peppermint oils (BM 01) | 1 | 2 | 1 | NL | ND | NL | NL | NL | NL | NL | NL |
| Vectorite | *Clonostachys rosea* CR-7 (BM 02) | 4 | 2 | ND | 2 | ND | ND | ND | ND | ND | ND | ND |
| BacStop-OPL,-XL | quaternary ammonia (NC-sanitizer) | 1 | 1 | 1 | NL | ND | NL | NL | NL | NL | NL | 3 |
| Employ | harpin (P unspecified) | NL | 1 | NL | NL | NL | NL | NL | NL | NL | NL | NL |
| Kasumin* | kasugamycin (24)[1] – Section 18 registr. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| ProBLAD Verde | *Lupinus albus* (BM 01) | 3 | 2 | NL | NL | NL | NL | NL | NL | NL | NL | NL |
| Timorex (Act, Gold) | natural oil (BM 01) | 1 | 1 | 2 | 1 | 2 | 2 | 1 | ND | 2 | NL | NL |
| Trilogy, Rango | neem oil (BM 01) | 1 | 1 | 1 | 1 | 1 | 2 | 1 | ND | 2 | NL | NL |
| Oxidate 5.0 | peroxyacetic acid (NC) | 1 | 2 | 1 | 1 | NL | NL | 1 | ND | ND | NL | 2 |
| Milstop | potassium bicarbonate (NC) | NL | NL | NL | NL | 1 | NL | NL | ND | 3 | NL | NL |
| All Phase | potassium sorbate (NC) | NL | NL | NL | NL | 2 | NL | NL | NL | NL | NL | NL |
| Howler | *Pseudomonas chlororaphis* strain AFS009 (BM 02) | 2 | 1 | NL | NL | NL | NL | NL | NL | NL | NL | 3 |
| Regalia | *Reynoutria sachalinensis* (P 05) | 2 | 2 | 1 | 1 | 1 | 1 | 1 | ND | 2 | NL | 3 |
| Actinovate AG | *Streptomyces lydicus* (BM 02) | 1 | 1 | NL | NL | NL | NL | NL | NL | 1 | NL | 2 |
| EcoSwing | *Swinglea glutinosa* (BM 01) | 3 | 2 | NL | NL | 1 | NL | 1 | NL | ND | NL | ND |
| PlantShield** | *Trichoderma harzianum* (BM 02) | NL | NL | NL | NL | NL | NL | NL | NL | NL | 4 | 0 |
| Vintec | *Trichoderma atroviride* (BM 02)[5] | NL | NL | NL | NL | NL | NL | NL | NL | NL | 4 | 0 |
| Procidic | citric acid (NC) | ND | ND | ND | NL | NL | NL | ND | NL | NL | NL | NL |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

*** Registration pending in California.**

**** Not registered, label withdrawn or inactive in California.**

[1] Alphabetically arranged organic treatments. Note that kasugamycin is a fermentation (natural) product, but not an organic treatment. FRAC Codes are also provided as BM-, NC, or P-number codes. NC = not coded in FRAC. In general, sulfur compounds are fungicidal and may affect applications of fungal biocontrols (e.g., Botector); whereas copper may affect applications of bacterial biocontrols (e.g., Actinovate, Double Nickel 55, and Serenade). Rotations must consider these factors.

[2] ALS = Alternaria Leaf Spot caused by *Alternaria alternata* and *A. arboresscens*.

[3] Hull rot ratings are for the disease caused by *Rhizopus stolonifer*.

[4] PM refers to a powdery mildew disease.

[5] Labeled for *Eutypa* sp., *Botryosphaeria* sp., *Cytospora* sp., and other trunk diseases of almond.

[6] Sodium laruryl sulfate is not organically approved for crop production (synthetic substance approved for noncrop areas); All Phase is not organic. Cinnacure, PlantShield and Vintec do not have OMRI/WSDA certification and do not claim to be compliant, but their active ingredients are allowed for organic production.

## ALMOND: TREATMENT TIMING

**Note: Not all indicated timings may be necessary for disease control.**

| | | Bloom | | | Spring[1] | | Summer | |
|---|---|---|---|---|---|---|---|---|
| **Disease** | **Dormant** | **Pink bud** | **Full bloom** | **Petal fall** | **2 wks** | **5 wks** | **May** | **June/ July** |
| Alternaria | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 |
| Anthracnose[2] | 0 | 2 | 3 | 3 | 3 | 3 | 3 | 2 |
| Bacterial spot | 1 | 0 | 2 | 3 | 3 | 2 | 1 | 0 |
| Brown rot | 0 | 2 | 3 | 1 | 0 | 0 | 0 | 0 |
| Green fruit rot | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 |
| Hull rot[7] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Leaf blight | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 |
| Rust | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 1[6] |
| Scab[3] | 2 | 0 | 0 | 2 | 3 | 3 | 1 | 0 |
| Shot hole[4] | 1[5] | 1 | 2 | 3 | 3 | 2 | 0 | 0 |

| **Disease** | **At planting** | **Spring root flush** | **Summer** | **Fall root flush** |
|---|---|---|---|---|
| Phytophthora root and crown rot | 3 | 3 | 2 | 3 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective

[1] Two and five weeks after petal fall are general timings to represent early postbloom and the latest time that most fungicides can be applied. The exact timing is not critical but depends on the occurrence of rainfall.

[2] If anthracnose was damaging in previous years and temperatures are moderate (63°F or higher) during bloom, make the first application at pink bud. Otherwise, treatment can begin at or shortly after petal fall. In all cases, application should be repeated at 7- to 10-day intervals when rains occur during periods of moderate temperatures. Treatment should, if possible, precede any late spring and early summer rains. Rotate fungicides, using different fungicide classes, as a resistance management strategy.

[3] Early treatments (during bloom) have minimal effect on scab; the 5-week treatment usually is most effective. Treatments after 5 weeks are useful in northern areas where late spring and early summer rains occur. Dormant treatment with liquid lime sulfur improves efficacy of spring control programs.

[4] If pathogen spores were found during fall leaf monitoring, apply a shot hole fungicide during bloom, preferably at petal fall or when young leaves first appear. Reapply when spores are found on new leaves or if heavy, persistent spring rains occur. If pathogen spores were not present the previous fall, shot hole control may be delayed until spores are seen on new leaves in spring.

[5] Dormant copper treatment seldom reduces shot hole infection but may be useful in severely affected orchards and must be followed by a good spring program.

[6] Treatment in June is important only if late spring and early summer rains occur.

[7] Make application at 1 to 5% hull split to manage hull rot caused by *Rhizopus stolonifer*; use earlier June timings for hull rot caused by *M. fructicola.* Apply a second application, mid-way through hull split especially if hull split is progressing slowly.

## ALMOND: SUGGESTED DISEASE MANAGEMENT PROGRAMS BY FRAC[1] CODES - CONVENTIONAL GROWERS

**Note: Not all indicated timings may be necessary for disease control (*see* Treatment Timing Table). If treatments are needed based on host phenology, weather monitoring, inoculum models, or environmental-disease forecasting models, suggested fungicide Codes are listed for each timing.**

How to use this table:

1) Identify the disease(s) that need(s) to be managed. Know the disease history of the orchard, especially from the last season.
2) Select one of the suggested fungicide Codes. *Numbers separated by slashes are pre-mixtures, whereas numbers separated by pluses are tank mixtures.* If several diseases need to be managed, select a Code that is effective against all diseases. Refer to the fungicide efficacy table for fungicides belonging to each FRAC Code. Code numbers are listed in numerical order within the suggested disease management program.
3) Rotate Codes for each application within a season and, if possible, use each Code only once per season, except for multi-site mode-of-action materials (e.g., M 02).

| Disease | Dormant | Bloom | | | Spring | | Summer | |
|---|---|---|---|---|---|---|---|---|
| | | Pink bud | Full bloom | Petal fall | 2 weeks | 5 weeks | May | June/July |
| Alternaria | ---- | ---- | ---- | ---- | ---- | 2 | 3, 7, 11, 19, 3/7, 3/9, 3/11, 3+P 07/33, 7/11, 52, 3/BM 01 | 3, 3/7, 7, 3/9, 3/11, 3+P 07/33, 7/11, 11, 19, 52, 3/BM 01 |
| Anthracnose | ---- | 3, 3/7, 3/9, 3/11, 3+P 07/33, 7, 3/BM 01 | 3, 3/7, 3/9, 3/11, 3+P 07/33, 7, 7/11, 11, 3/BM 01 | 3, 3/9, 3/7, 3/11, 3+P 07/33, 11, 3/BM 01 M3, M4, M5 | 3, 3/9, 3/11, 3/7, 7, 7/11, 3+P 07/33, 11, 3/BM 01 M3, M4, M5 | 3, 3/7, 3/9, 3/11, 3+P 07/33, 7, 7/11, 11, 3/BM 01 M3, M4, M5 | 3, 3/7, 3/9, 3/11, 3+P 07/33, 7, 7/11 11, 3/BM 01, M4 | 3, 3/7, 3/9, 3/11, 3+P 07/33, 7, 7/11, 11, 3/BM 01, M4 |
| Bacterial spot | M1, M1+M3 | ---- | M1, M1+M3 | M1, M1+M3 | M1, M1+M3 | M1, M1+M3 | M1 | ---- |
| Brown rot | ---- | 1[2], 2+oil, 3, 3/7, 3/9, 3/11, 3+P 07/33, 9, 52, 3/BM 01 | 1[2], 2+oil, 3, 3/7, 3/9, 3/11, 3+P 07/33, 7, 7/11, 9, 11, 19, 52, 3/BM 01 | 1[2], 2+oil, 3/11, 3+P 07/33, 7, 7/11, 9, 19, 52, 3/BM 01 | ---- | ---- | ---- | ---- |
| Jacket rot | ---- | ---- | 1[2], 2 +oil, 3/7, 3/9, 3/11, 7, 7/11, 9, 19, 52, 3/BM 01 | 1[2], 2+oil, 3/7, 3/9, 3/11, 7, 7/11, 9, 19, 52, 3/BM 01 | ---- | ---- | ---- | ---- |
| Hull rot[5] | ---- | ---- | ---- | ---- | ---- | ---- | 3, 3/7, 3/9, 3/11, 7/11, 11, 19, 52, 3/BM 01 | 3, 3/7, 3/9, 3/11, 7/11 11, 19, 52, 3/BM 01 |
| Leaf blight | ---- | ---- | 1[2], 2, 3, 3/7, 3/9, 3/11, 3+P 07/33, 11, 3/BM 01 | 1[2], 2, 3, 3/7, 3/9, 3/11, 3+P 07/33, 11, 3/BM 01, M3, M4, M5 | 3, 3/7, 3/9, 3/11, 3+P 07/33, 11, 3/BM 01, M3, M4, M5 | ---- | ---- | ---- |
| Rust | ---- | ---- | ---- | ---- | ---- | 3, 3/7, 3/11, 3+P 07/33[1], 7, 7/11, 11, 19, 3/BM 01, M3 | 3, 3/7, 3/11, 3+P 07/33, 7, 7/11, 11, 19, 3/BM 01 | 3, 3/7, 3/11, 3+P 07/33, 7, 7/11, 11, 19, 3/BM 01 |
| Scab[4] | M1+oil, M2[3], M5+oil | ---- | ---- | 1[2], 3/7, 3/9, 3+P 07/33, 3/11, 7, 7/11[2], 3/BM 01, 11[2] M3, M4, M5 | 1[2], 3/7, 3/9, 3+P 07/33, 3/11,7, 7/11[2], 3/BM 01, 11[2] M3, M4, M5 | 3, 3/7, 3/9, 3/11, 3+P 07/33, 7, 7/11[2], 3/BM 01, 11[2] M2[3], M3, M4 | M2[3], M4 | ---- |
| Shot hole | M1 | 2, 3, 3/7, 3/9, 3/11, 7, 9, 11, 52, 3/BM 01 | 2, 3, 3/7, 3/9, 3/11,7, 7/11, 9, 11, 19, 52, 3/BM 01 | 2, 3, 3/7, 3/9, 3/11, 7, 7/11 9, 11, 19, 52, 3/BM 01 | 7, 7/11, 11, 19, 52, 3/BM 01, M3, M4, M5 | 7, 7/11,11, 19, 52, 3/BM 01, M3, M4, M5 | ---- | ---- |

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Code numbers are listed in numerical order within the suggested disease management program.

Fungicides with a different Code number are suitable to alternate in a resistance management program. Refer to the fungicide efficacy table for fungicides belonging to each FRAC Code. Note: FC 33 is currently P 07 but it is indicated as P 07/33.

[2] Strains of *Monilinia fructicola* and *M. laxa* resistant to Topsin-M and T-Methyl are present in some California almond orchards. Resistant strains of the jacket rot fungus, *Botrytis cinerea*, and powdery mildew fungi have been reported in California on crops other than almond and stone fruits and may have the potential to develop in almond with overuse of fungicides with similar chemistry.

[3] Use liquid lime sulfur in dormant applications and wettable sulfur at and after pre-bloom.

[4] Apply petal-fall treatments based on twig-infection sporulation model.

[5] Effective hull rot management is dependent on integrated strategies including dust control, reduced irrigation, and limiting nitrogen fertilization prior to and during hull split, as well as ensuring adequate air circulation (appropriate pruning or hedging practices) in the orchard.

## ALMOND: SUGGESTED DISEASE MANAGEMENT PROGRAMS BY FRAC[1] CODES - ORGANIC GROWERS

**Note: Not all indicated timings may be necessary for disease control (*see* Treatment Timing Table). If treatments are needed based on host phenology, weather monitoring, inoculum models, or environmental-disease forecasting models, suggested fungicide Codes are listed for each timing.**

How to use this table:

1) Identify the disease(s) that need(s) to be managed. Know the disease history of the orchard, especially from the last season.
2) Select one of the suggested fungicide Codes. If several diseases need to be managed, select a Code that is effective against all diseases. Refer to the fungicide efficacy table for fungicides belonging to each FRAC Code. Code numbers are listed in numerical order within the suggested disease management program.
3) Rotate Codes for each application within a season and, if possible, use each Code minimally per season.

| Disease | Dormant | Bloom | | | Spring | | Summer | |
|---|---|---|---|---|---|---|---|---|
| | | Pink bud | Full bloom | Petal fall | 2 weeks | 5 weeks | May | June/July |
| Alternaria | ---- | ---- | ---- | ---- | ---- | BM 01, -02, -03,oxidizer | BM 01, -02, -03,oxidizer | BM 01, -02, -03,oxidizer |
| Anthracnose | ---- | BM 01, -02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer |
| Bacterial spot | M1 + BM 01 (oil) | ---- | BM 01,-02, -03, M1, oxidizer | BM 01,-02, -03, M1, oxidizer | BM 01,-02, -03, M1, oxidizer | BM 01,-02, -03, M1, oxidizer | BM 01,-02, -03, M1, oxidizer | ---- |
| Brown rot | ---- | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | ---- | ---- | ---- | ---- |
| Jacket rot | ---- | ---- | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | ---- | ---- | ---- | ---- |
| Hull rot[2] | ---- | ---- | ---- | ---- | ---- | ---- | ---- | BM 01,-02, -03, |
| Leaf blight | ---- | ---- | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | ---- | ---- | ---- |
| Rust | ---- | ---- | ---- | ---- | ---- | BM 01,-02, -03, P 05, M2 | BM 01,-02, -03, P 05, M2 | BM 01,-02, -03, P 05, M2 |
| Scab[3,4] | M1 + BM 01 (oil), M2 | ---- | ---- | BM 01,-02, -03, P 05, NC | BM 01,-02, -03, P 05, NC | BM 01,-02, -03, P 05, NC | BM 01,-02, -03, P 05, NC | ---- |
| Shot hole | M1 + BM 01 (oil) | M1+BM 01 (oil) | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | BM 01,-02, -03, P 05, oxidizer | ---- | ---- |

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Code numbers are listed in numerical order within the suggested disease management program. Fungicides with a different Code number are suitable to alternate in a resistance management program. Refer to the fungicide efficacy table for fungicides belonging to each FRAC Code. NC = not coded in FRAC.

[2] Effective hull rot management is dependent on integrated strategies including dust control, reduced irrigation, and limiting nitrogen fertilization prior to and during hull split, as well as ensuring adequate air circulation (appropriate pruning or hedging practices) in the orchard.
[3] Use liquid lime sulfur in dormant applications and wettable sulfur at and after pre-bloom.
[4] Apply petal-fall treatments based on twig-infection sporulation model.

## APPLE AND PEAR: FUNGICIDE EFFICACY – CONVENTIONAL

| Fungicide*** | Resistance risk (FRAC#)[1] | Scab | | Powdery mildew (apple only) |
|---|---|---|---|---|
| | | protectant | eradicant | |
| Adament** | medium (3/11)[3] | 5 | 5 | 5 |
| Flint Extra[2] | high (11)[3] | 5 | 5 | 5 |
| Aprovia | high (7) | 5 | 3 | 4 |
| Excalia[5] | high (7) | 5 | 3 | ND |
| Fontelis | high (7) | 5 | 3 | 3 |
| Kenja | high (7) | 5 | 3 | 4 |
| Tesaris, Sercadis** | high (7) | 5 | 3 | 4 |
| Luna Sensation | medium (7/11) | 5 | 3 | 5 |
| Inspire Super | medium (3/9) | 5 | 5 | 5 |
| Regev | medium (3/BM 01) | 5 | 5 | 5 |
| Merivon | medium (7/11) | 5 | 3 | 5 |
| Pristine | medium (7/11) | 5 | 0 | 4 |
| Procure[4] | high (3) | 5 | 5 | 5 |
| Rally[5] | high (3) | 5 | 3 | 5 |
| Rubigan**, Vintage**,[4] | high (3) | 5 | 5 | 4 |
| Rhyme | high (3) | 5 | 3 | 5 |
| Axios | high (52) | 4 | 4 | 5 |
| Cevya | high (3) | 4 | 3 | 5 |
| Captan[6] | low (M 04) | 4 | 0 | 0 |
| Dithane, Manzate, Penncozeb[6] | low (M 03) | 4 | 0 | 0 |
| Omega, Lektivar**,[5] | medium (29) | 4 | 2 | NL |
| Scala | high (9)[3] | 4 | 4 | 2 |
| Sovran | high (11)[3] | 4 | 4 | 4 |
| Syllit | medium (U12) | 4 | 4 | 0 |
| Viathon[5] | medium (3, P 07/33) | 4 | 4 | 0 |
| Tebucon,Toledo, etc. | high (3) | 4 | 4 | 4 |
| Topsin-M, T-Methyl, Incognito, Cercobin**[3] | high (1)[3] | 4 | 4 | 4 |
| Vangard | high (9)[3] | 4 | 4 | 4 |
| Copper[6] | low (M 01) | 3[7] | 0 | 0 |
| Lime sulfur[6,8] | low (M 02) | 3 | 5[8] | 4[9] |
| Ph-D, Oso | high (19) | 3 | 0 | 4 |
| Sulfur[7] | low (M 02) | 3 | 0 | 5 |
| Ziram[6] | low (M 03) | 3 | 0 | 0 |
| Torino | high (U 6) | NL | NL | ND |
| Gatten[5] | high (U 13) | 0 | 0 | 4 |

## APPLE AND PEAR: FUNGICIDE EFFICACY – BIOCONTROLS AND NATURAL PRODUCTS

| Fungicide | Resistance risk (FRAC#)[1,12] | Scab | | Powdery mildew (apple only) |
|---|---|---|---|---|
| | | protectant | eradicant | |
| Lime sulfur | low, M 02 | 3 | 0 | 4 |
| Sulfur[7] | low, M 02 | 3 | 0 | 5 |
| Actinovate | low, BM 02 | 2/3 | 0 | 2/3 |
| Blight Ban** | low, BM 02 | 2/3 | 0 | 2/3 |
| Blossom Protect | low, BM 02 | 2/3 | 0 | 2/3 |
| Double Nickel 55 | low, BM 02 | 2/3 | 0 | 2/3 |
| Gargoil | low, BM 01 | 2 | 0 | 3 |
| Regalia | low, P 05 | 2/3 | 0 | 2/3 |
| Serifel[5] | low, BM 02 | 2/3 | 0 | 2/3 |
| Serenade | low, BM 02 | 2/3 | 0 | 2/3 |
| Copper[7] | low, M 01 | 2/3 | 0 | 2 |
| Procidic | low, BM 01 | ND | 0 | ND |

## APPLE AND PEAR: BACTERICIDE EFFICACY – CONVENTIONAL

| Bactericide | Resistance risk | Fire blight[10] | | Phytotoxicity[14] | Plant growth regulator/SAR |
|---|---|---|---|---|---|
| | | contact | systemic | | |
| Ag Streptomycin**, Agri-Mycin, Firewall | very high (25) | 5 | 4 | 1 | 0 |
| Kasumin | high (24) | 5 | 5 | 1 | 0 |
| MycoShield, FireLine | high (41) | 4 | 4 | 1 | 0 |
| Captan[6] | low (M 04) | 3 | 0 | 0 | 0 |
| Copper[7] | low (M 01) | 3 | 0 | 2 | 0 |
| Dithane, Manzate, Penncozeb[6] | low (M 03) | 3 | 0 | 0 | 0 |
| Actigard[11] | low (P 01) | 0 | 2 | 0 | 2 |
| Apogee[10] | low (PGR) | 0 | 2/3 | 0 | 3 |

## APPLE AND PEAR: BACTERICIDE EFFICACY – BIOCONTROLS AND NATURAL PRODUCTS

| Bactericide | Resistance risk (FRAC code)[1,12] | Fire blight[10] | | Phytotoxicity[14] | Plant growth regulator/SAR |
|---|---|---|---|---|---|
| | | contact | systemic | | |
| AgriPhage-Fireblight | low (BM 02) | 2/3 | 0 | 0 | 0 |
| Blossom Protect | low (BM 02) | 4 | 0 | 1 | 0 |
| Copper[7] | low (M 01) | 3 | 0 | 4 | 0 |
| Actinovate | low (BM 02) | 2/3 | 0 | 1 | 0 |
| BacStop-OPL,-XL | low (NC-sanitizer) | 2 | 0 | 1 | 0 |
| Blight Ban | low (BM 02) | 2/3 | 0 | 1 | 0 |
| Cinnerate, Seican, Cinnacure | low (BM 03) | 2/3 | 0 | 0 | 0 |
| Dart | low (NC) | 2/3 | 0 | 0 | 0 |
| Double Nickel 55 | low (BM 02) | 2/3 | 0 | 1 | 0 |
| Regalia | low (P 05) | 2/3 | 0 | 1 | 2 |
| Sanitizers[13] | low | 2/3 | 0 | 0 | 0 |
| Serenade | low (BM 02) | 2/3 | 0 | 1 | 0 |
| LifeGard | low (P 06) | 2 | 2 | 0 | 2 |
| Lime sulfur/sulfur[8] | low (M 02) | 2 | 0 | 4 | 0 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective.

*** Registration pending in California.**

**** Not registered, label withdrawn or inactive in California.**

***** Postharvest fruit registrations in California include: Academy, Alumni/TBZ, BioSpectra/Cerafruta, Penbotec/Pyrimethanil and Scholar/FDL.**

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). NC = not coded in FRAC. Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-actions (MOA) with high resistance risk before rotating to a fungicide with a different MOA (Code number); for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different MOA (Code number).

[2] High resistance potential to trifloxystrobin for apple and pear scab pathogen populations.

[3] To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season. Cercobin is registered only on apples.

[4] On pear, use only **before** white bud and **after** full bloom.

[5] Labeled on apple only in California (not pear).

[6] These materials show some efficacy and should be used in mixtures with antibiotics as a component of resistance management programs. Captan is registered on apples, whereas Dithane is registered on apples and pears.

[7] Though copper may be effective for scab and blight control under low disease pressure, copper products may cause fruit scarring or russeting.

[8] "Burns out" scab twig lesions when applied at delayed dormant and disrupts pseudothecial (or ascostroma) development when applied to leaves in fall. **CAUTION:** Lime Sulfur is incompatible with most other pesticides when used after budbreak. Check before use. Sulfur products are also used to thin flowers because of their phytotoxicity and indirectly control fireblight.

[9] In-season application eradicates powdery mildew.

[10] Plant growth regulators (PGR) such as prohexadione calcium (Apogee) can be used in an integrated approach to reduce host susceptibility but do not have direct activity against fire blight.

[11] Acibenzolar-S-methyl (FRAC P1) is a host plant defense or systemic acquired resistancc (SAR) inducer known to stimulate the salicylic acid pathway.

[12] Biologicals: FRAC Codes are provided as BM-No. or P-No. codes. In general, sulfur compounds are fungicidal and may affect applications of fungal biocontrols (e.g., Blossom Protect); whereas copper may affect applications of bacterial biocontrols (e.g., Actinovate, Bloomtime Biological**, Blight Ban, Double Nickel 55, and Serenade). Rotations must consider these factors.

[13] Sanitizers such peroxyacetic acid (e.g., Oxidate 5.0, Zerotol HC, Perasan A) are oxidizers that act immediately on contact. They are neutralized rapidly by reducing agents and are non-persistent. Perasan A is for postharvest use in sanitizing fruit only.
[14] Higher numbers indicate higher phytotoxicity.

## APPLE AND PEAR: TREATMENT TIMING

**Note: Not all indicated timings may be necessary for disease control.**

| Disease | Fall | Delayed dormant | Green tip /White bud | Pink bud/ Full bloom | Petal fall/ Cover sprays |
|---|---|---|---|---|---|
| Fire blight | 0 | 1 | 2 | 3 | 3[4] |
| Powdery mildew[3] | 0 | 0 | 1 | 3 | 3 |
| Scab[1] | 2[2] | 2[2] | 3 | 3 | 3 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective

[1] Protection of early tissue is important. Additional applications should be made according to infection periods as determined by the Mills table.
[2] Disruption of pseudothecial (ascostroma) development (fall) and inactivation of overwintering twig lesions (delayed dormant); effects of these treatments on disease control is uncertain.
[3] Early applications are most effective; additional applications are made if mildew continues.
[4] Start management program at the beginning of bloom and continue through bloom including "rat-tail" bloom throughout spring. Several models are available for forecasting infection periods and treatment timing. Models include: Maryblyt, Cougar Blight, etc.

## POME FRUIT: SUGGESTED DISEASE MANAGEMENT PROGRAMS BY FRAC[1] CODES - CONVENTIONAL AND ORGANIC GROWERS

**Note: Not all indicated timings may be necessary for disease control; whereas additional applications may be necessary under favorable conditions for disease (*see* Treatment Timing Table). Suggested fungicide bactericide, biological, and natural product Codes are listed for each timing based on host phenology, weather monitoring, inoculum models, or environmental-disease forecasting models.**

How to use this table:

1) Identify the disease(s) that need(s) to be managed. Know the disease history of the orchard, especially from the previous season.
2) Select one of the suggested fungicide Codes. *Numbers separated by slashes are pre-mixtures, whereas numbers grouped by pluses are tank mixtures.* If several diseases need to be managed, select a Code that is effective against all diseases. Refer to the fungicide efficacy table for fungicides belonging to each FRAC Code. Code numbers are listed in numerical order within the suggested disease management program.
3) Rotate Codes for each application within a season and, if possible, use each Code only once per season, except for multi-site mode-of-action materials (e.g., M 02) or natural products/biological controls (BM 01, BM 02, NC, P).

| | | | Bloom | | | Spring |
|---|---|---|---|---|---|---|
| Disease | Fall | Delayed dormant | Green tip / White bud | Pink bud/ Full bloom | Petal fall (PF) | Cover sprays |
| Fire blight | M1 | M1 | M1, 24, 25, 41, P 01[3] | M1, M2[2,4], 24, 25, 41, BM 01,-02, -03, P 01, P 05, P 06 | M1[1], 24, 25, 41, BM 01,-02, -03, P 01, P 05, P 06 | M1[1], 24, 25, 41, BM 01, 02, -03, P 01, P 05, P 06 PGR[5] |
| Scab | ---- | M2 | M1[1], M2, M3, 1, 3, 7, 9, 3/9, 7/11, 19, 52, U12, U12+M1-3, 3/BM 01, BM 01, -02, -03, P 01, P 05, P 06 | M1[1], M2, M3, 1, 3, 7, 9, 3/9, 7/11, 19, 52, U12, U12+M1-3, 3/BM 01, BM -01, -02, -03, P 01, P 05, P 06 | M1[1], M2, M3, 1, 3, 7, 9, 3/9, 7/11, 19, 52, U12, 3/BM 01, BM -01, -02, -03, P 01, P 05, P 06 | M1[1], M2, M3, 1, 3, 7, 9, 3/9, 7/11, 19, 52, 3/BM 01, BM-01, -02, -03, P 01, P 05, P 06 |
| Powdery mildew | | | M2, 1, 3, 7, 9, 3/9, 7/11, 19, 52, 3/BM 01, BM 01,-02, -03, P 01, P 05, P 06 | M2, 1, 3, 7, 9, 3/9, 7/11, 19, 52, 3/BM 01, BM 01,-02, -03, P 01, P 05, P 06 | M2, 1, 3, 7, 9, 3/9, 7/11, 19, 52, 3/BM 01, BM 01,-02,-03, P 01, P 05, P 06 | M2, 1, 3, 7, 9, 3/9, 7/11, 19, 52, 3/BM 01, BM 01,-02, -03, P 01, P 05, P 06 |

[1] Fixed copper (M1a) bactericides (e.g., Kocide, Badge, Nordox, and ChampION[++]) may cause phytotoxicity (russetting) when applied after full bloom. Other copper products (M1b) with lower metallic copper equivalent (i.e., MCE) such as copper complexes (e.g., Cueva, Copper Count-N, etc.) and copper sulfate pentahydrate (e.g., CS-2005-only apples in CA, Phyton 27AG**, Instill, MasterCop, etc.) have been reported to be less phytotoxic with applications following bloom because of lower MCE (*see* specific registrant label concerning product rates and number of times each material can be applied during the growing season).
[2] M 02 fungicides (e.g., liquid lime sulfur) that are registered for scab control have been used to thin-flowers in Washington state (Section 24c label) with one to two applications between 20-and 80% full bloom and subsequently have reduced the total number of flowers and potential infections sites for fire blight (indirect effects on disease). **No label is available in CA for this usage.**

[3] Acibenzolar-S-methyl (FRAC P 01) is a host plant defense inducer known to stimulate the salicylic acid pathway.

[4] In general, sulfur compounds are fungicidal and may affect applications of fungal biocontrols (e.g., Blossom Protect); whereas copper may affect applications of bacterial biocontrols (e.g., Actinovate, Bloomtime Biological**, Blight Ban, Double Nickel 55, and Serenade). Rotations must consider these factors.

[5] Plant growth regulators (PGR) such as prohexadione calcium (e.g., Apogee) reduce shoot growth and thus, indirectly reduce the number of infections sites for fire blight (indirect effects on disease).

## APRICOT: FUNGICIDE EFFICACY - CONVENTIONAL

**Note: Do not use sulfur at any time on apricot trees or use captan preharvest on apricot fruit.**

| Fungicide*** | Resistance risk (FRAC code)[1] | Brown rot[2] | | Jacket rot | Powdery mildew[2] | Shot hole | Eutypa |
|---|---|---|---|---|---|---|---|
| | | blossom | fruit | | | | |
| Adament** | medium (3/11) | 5 | 5 | 3 | 4 | 4 | 0 |
| Bumper**,Tilt, Propiconazole | high (3) | 5 | 5 | 0 | 4 | 1 | 4 |
| Cevya | high (3) | 5 | 5 | 3 | 5 | 4 | ND |
| Tebucon, Teb, Tebuconazole** | high (3) | 5 | 5 | 2 | 2 | 2 | 0 |
| Viathon | medium (3, P 07/33) | 5 | 5 | 2 | 2 | 2 | 0 |
| Quash | high (3) | 5 | 5 | 3 | 4 | 3 | 0 |
| Rhyme | high (3) | 5 | 5 | 3 | 4 | 3 | 0 |
| Indar | high (3) | 5 | 5 | 0 | ND | 0 | 0 |
| Inspire Super | medium (3/9) | 5 | 5 | 5 | 4 | 4 | 0 |
| Regev | medium (3/BM 01) | 5 | 5 | 3 | 4 | 3 | NL |
| Protocol[3] | med.-high (1/3) | 5 | 5 | 4 | 4 | 4 | ND |
| Miravis Duo | medium (3/7) | 5 | 5 | 3 | 4 | 4 | 0 |
| Luna Experience | medium (3/7) | 5 | 5 | 3 | 4 | 4 | 0 |
| Luna Sensation | medium (7/11)[4] | 5 | 5 | 4 | 4 | 5 | 0 |
| Merivon | medium (7/11)[4] | 5 | 5 | 4 | 4 | 5 | 0 |
| Pristine | medium (7/11)[4] | 5 | 5 | 4 | 4 | 5 | 0 |
| Fontelis | high (7) | 5 | 4 | 5 | 5 | 5 | 0 |
| Kenja | high (7) | 5 | 4 | NL | NL | NL | NL |
| Parade* | high (7) | 5 | 4 | 4 | 4 | 4 | ND |
| Quadris Top | medium (3/11) | 5 | 5 | 2 | 4 | 4 | 0 |
| Quilt Xcel, Avaris 2XS | medium (3/11) | 5 | 5 | 3 | 4 | 4 | 0 |
| Vangard[7] | high (9)[3,4] | 5 | 4[7] | 4[8] | ND | 3 | 0 |
| Rovral[5] + oil[6] | low (2) | 5 | NL | 5 | 0 | 4 | 0 |
| Scala[7] | high (9)[3,4] | 5 | 4[7] | 4[8] | ND | 3 | 0 |
| Topsin-M, T-Methyl, Incognito, Cercobin**[3] | high (1)[4] | 5 | 5 | 5 | 4 | 0 | 5 |
| Elevate | high (17)[4] | 4 | 3 | 4 | 3 | 2 | 0 |
| Rally | high (3) | 4 | 4 | 0 | 4 | 0 | 4 |
| Rovral[5], Meteor[5], Iprodione**,Nevado** | low (2) | 4 | NL | 4 | 0 | 4 | 0 |
| Quadris (Abound discontinued) | high (11)[4] | 3 | 2 | 0 | ND | 4 | 0 |
| Botran** | medium (14) | 3 | 3 | 4 | ND | ND | 0 |
| Bravo, Chlorothalonil, Echo, Equus[9,10] | low (M 05) | 3 | 3 | 3 | 0 | 4 | 0 |
| Captan[10,11] | low (M 04) | 3 | 0[11] | 3 | 0 | 4 | 0 |
| Flint Extra | high (11)[4] | 3 | 2 | 0 | ND | 4 | 0 |
| Ph-D, Oso | high (19) | 3 | 3 | 4 | 4 | 2 | 0 |
| Copper | low (M 01) | 1 | 0 | 0 | 0 | 3 | 0 |
| Ziram | low (M 03) | 1 | 0 | 2 | 0 | 5 | 0 |
| Quintec | high (13) | 0 | 0 | 0 | 5 | 0 | 0 |
| Vivando | high (50) | 0 | 0 | 0 | 4 | 0 | 0 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

*** Registration pending in California.**

**** Not registered, label withdrawn or inactive in California.**

***** Postharvest fruit registrations in California include: BioSpectra/Uniguard*, Chairman, Mentor, Penbotec/Pyrimethanil*, and Scholar/FDL.**

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). NC = not coded in FRAC. Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-actions (MOA) with high resistance risk before rotating to a fungicide with a different MOA (Code number); for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different MOA (Code number).

[2] Do not use fungicides with the same FRAC number and high resistance risk more than twice in one year.
[3] Strains of *Monilinia fructicola* and *M. laxa* resistant to Topsin-M and T-Methyl have been reported in some California apricot orchards. Resistant strains of the jacket rot fungus, *Botrytis cinerea*, have been reported in California on crops other than almond and stone fruits and may have the potential to develop in apricots with overuse of fungicides with similar chemistry. Sub-populations of both *Monilinia* spp. have been shown to be resistant to AP (FRAC 9) fungicides on prune in CA.
[4] To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of application per season.
[5] Blossom blight only; not registered for use after petal fall.
[6] The oil is a "light" summer oil, 1-2% volume/volume.
[7] High summer temperatures and relative humidity reduce efficacy.
[8] Has not been tested on apricot but is effective against the jacket rot pathogens.
[9] Do not use after jacket (shuck) split.
[10] Do not use in combination with or shortly before or after oil treatment.
[11] Causes fruit browning or staining as a preharvest spray.

## APRICOT: TREATMENT TIMING

**Note: Not all indicated timings may be necessary for disease control.**

| Disease | Fall/ Dormant | Red bud | Popcorn | Full bloom | Until pit hardening | Preharvest 1 to 3 weeks |
|---|---|---|---|---|---|---|
| Brown rot[1] | 0 | 3 | 3 | 3 | 0 | 3 |
| Eutypa | 1[4] | 0 | 0 | 0 | 0 | 0 |
| Jacket rot | 0 | 0 | 0 | 3 | 0 | 2 |
| Powdery mildew | 0 | 0 | 0 | 3 | 3[2] | 0 |
| Shot hole[3] | 0 | 0 | 0 | 2 | 3 | 0 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective

[1] Begin at red bud, add one or two more sprays if weather favors disease.
[2] Repeated treatment at 7- to 14-day intervals may be necessary; earlier treatments are most effective.
[3] If pathogen spores were found during fall leaf monitoring, apply a shot hole fungicide during bloom, preferably at petal fall or when young leaves first appear. Re-apply when spores are found on new leaves or if heavy persistent spring rains occur. If pathogen spores were not present the previous fall, shot hole control may be delayed until spores are seen on new leaves.
[4] Applications are made to pruning cuts.

## CHERRY: FUNGICIDE EFFICACY - CONVENTIONAL

| Fungicide*** | Resistance risk (FRAC code)[1] | Brown rot [2,3] | | Botrytis blossom/fruit | Powdery mildew[2] | Eutypa |
|---|---|---|---|---|---|---|
| | | blossom | fruit | | | |
| Adament** | high (3/11) | 5 | 5 | 3 | 3 | 4 |
| Bumper**,Tilt | high (3) | 5 | 5 | 0 | 4 | 4 |
| Cevya | high (3) | 5 | 5 | 2 | 5 | ND |
| Orius**, Teb, Toledo, Tebucon, Tebuconazole** | high (3) | 5 | 5 | 3 | 3 | 3 |
| Viathon | med. (3, P 07/33) | 5 | 5 | 3 | 3 | 3 |
| Fontelis | high (7)[4] | 5 | 4 | 5 | 5 | 0 |
| Kenja | high (7) | 5 | 4 | NL | NL | NL |
| Indar | high (3) | 5 | 4 | 0 | 4 | 0 |
| Protocol[4] | med.-high (1/3) | 5 | 5 | 3 | 4 | ND |
| Inspire | high (3) | 5 | 5 | 3 | 4 | 0 |
| Regev | medium (3/BM 01) | 5 | 5 | 3 | 4 | ND |
| Luna Experience | medium (3/7) | 5 | 5 | 4 | 5 | 0 |
| Luna Sensation | medium (7/11)[5] | 5 | 5 | 4 | 5 | 0 |
| Merivon | medium (7/11)[5] | 5 | 5 | 4 | 4 | 0 |
| Miravis Duo | medium (3/7) | 5 | 5 | 4 | 5 | 0 |
| Pristine | medium (7/11)[5] | 5 | 5 | 4 | 4 | 0 |
| Quash | high (3) | 5 | 5 | 3 | 4 | 0 |
| Quadris Top | medium (3/11) | 5 | 5 | 3 | 4 | 0 |
| Quilt Xcel, Avaris 2XS, | medium (3/11) | 5 | 5 | 3 | 4 | 0 |
| Rovral[6] + oil[7] | low (2) | 5 | NL | 5 | 3 | 0 |
| Topsin-M,T-Methyl, Incognito, Cercobin**[4] | high (1)[5] | 5 | NL | 5 | 4 | 5[4] |
| Quadris (Abound discontinued) | high (11)[5] | 4 | 2 | 0 | 3 | 0 |
| Cabrio | high (11)[5] | 4 | 3 | 0 | 3 | 0 |
| Elevate | high (17)[5] | 4 | 4 | 5 | 2 | 0 |
| Flint Extra | high (11)[5] | 4 | 3 | 0 | 3 | 0 |
| Luna Privilege** | high (7) | 4 | 4 | 4 | 4 | 0 |
| Parade* | high (7) | 4 | 4 | 4 | 4 | ND |
| Procure[8] | high (3) | 4 | 4 | 0 | 5 | 0 |
| Rally[8] | high (3) | 4 | 4 | 0 | 5 | 4 |
| Rovral[6], Meteor[6], Nevado**, Iprodione** | low (2) | 4 | NL | 4 | 0 | 0 |
| Rubigan**, Vintage** | high (3) | 4 | 4 | 0 | 5 | 0 |
| Rhyme | high (3) | 4 | 4 | 0 | 5 | ND |
| Botran | medium (14) | 3 | 3 | 4 | 0 | 0 |
| Bravo, Chlorothalonil, Echo, Equus[9,10] | low (M 05) | 3 | NL | 3 | 0 | 0 |
| Captan[10] | low (M 04) | 3 | 3 | 3 | 0 | 0 |
| Ph-D, Oso | high (19) | 3 | 3 | 4 | 4 | 0 |
| Copper | low (M 01) | 1 | 0 | 0 | 0 | 0 |
| Sulfur[10] | low (M 02) | 1 | 0 | 0 | 4 | 0 |
| Ziram | low (M 03) | 1 | NL | 0 | 0 | 0 |
| Vitiseal | low (NC, BM 01) | 0 | 0 | 0 | 0 | 5 |
| Quintec | high (13) | NL | NL | NL | 5 | 0 |
| Vivando | high (50) | NL | NL | NL | 5 | 0 |
| Gatten | high (U 13) | NL | NL | NL | 4 | 0 |
| Torino | high (U 6) | NL | NL | NL | ND | 0 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

*** Registration pending in California.**
**** Not registered, label withdrawn or inactive in California.**
***** Postharvest fruit registrations in California include: BioSpectra/Zivion F/Cerafruta**/Uniguard**, Chairman, Mentor, Penbotec/Pyrimethanil, and Scholar/FDL.**

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). NC = not coded in FRAC. Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-actions (MOA) with high resistance risk before rotating to a fungicide with a different MOA (Code number); for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different MOA (Code number).

[2] Do not use the same fungicide or fungicides with similar chemistry more than twice in one year.

[3] Shot hole and leaf spot occur infrequently on cherry in California; control usually is not necessary.

[4] Strains of *Monilinia fructicola* resistant to Topsin-M and T-Methyl are present in some California cherry orchards. Resistant strains of the jacket rot fungus, *Botrytis cinerea*, and powdery mildew fungi have been reported in California on crops other than almond and stone fruits and may have the potential to develop in sweet cherry with overuse of fungicides with similar chemistry.

[5] To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.

[6] Blossom blight only; not registered for use after petal fall

[7] Oil to use is a "light" summer oil, 1-2% volume/volume.

[8] More effective when applied as a concentrate (80-100 gal/acre) than as a dilute spray.

[9] Do not use after jacket (shuck) split.

[10] Do not use in combination with or shortly before or after oil treatment.

## CHERRY - FUNGICIDE EFFICACY - BIOCONTROLS AND NATURAL PRODUCTS

| Trade name[1] | Biological or natural product (FRAC code)[2] | Brown rot | | Botrytis | Powdery | Eutypa |
|---|---|---|---|---|---|---|
| | | blossom | fruit | blossom/fruit | mildew | |
| Oso | polyoxin-D | 3 | 3 | 4 | 4 | NL |
| ProBLAD Verde** | *Lupinus albus* (BM 01) | 3 | 2 | 2 | 0 | NL |
| Botector | *Aureobasidium pullulans* (BM 02) | 3 | NL | NL | NL | NL |
| Double Nickel 55 | *Bacillus amyloliquefaciens* D747 (BM 02) | 2 | 1 | NL (+) | 2 | NL |
| Serifel | *B. amyloliquefaciens* MBI600 (BM 02) | 2 | 2 | 1 | 2 | NL |
| Regalia | *Reynoutria sachalinensis* (P 05) | 2 | 2 | 2 | 2 | NL |
| Sonata | *B. pumilis* QST2808 (BM 02) | 2 | 0 | 1 | 1 | NL |
| Serenade | *B. subtilis* QST 713 (BM 02) | 2 | 0 | 1 | 2 | NL |
| Aviv | *B. subtilis* IAB/BS03 (BM 02) | 2 | 0 | 1 | 1 | NL |
| Gargoil | cinnamon oil and garlic (BM 01) | 2 | 0 | 0 | 2 | NL |
| Dart | capric and caprylic acids (NC) | 2 | 1 | NL | NL | NL |
| Cinnacure, Seican, Cinnerate | cinnamaldehyde (BM 03) | 1 | 1 | 1 | 4 | NL |
| EF400 | clove, rosemary, peppermint oils (BM 01) | NL | NL (0) | NL (0) | 3 | NL |
| Trilogy, Rango, Terraneem** | neem oil (BM 01) | 1 | 1 | 1 | 1 | NL |
| Oxidate, Perasan | peroxyacetic acid (oxidizer) | 1 | 2 | ND | 2 | NL |
| Sulfur[3] | sulfur (M 02) | 1 | 0 | 0 | 4 | 0 |
| Kaligreen, Milstop | potassium bicarbonate (NC) | NL | NL | NL | 4 | NL |
| Copper[3] | copper (M 01) | 1 | 0 | 0 | 0 | 0 |
| Actinovate AG | *Streptomyces lydicus* (BM 02) | 1 | 0 | 0 | 1 | NL |
| EcoSwing | *Swinglea glutinosa* (BM 01) | NL (2) | NL (1) | 1 | 2 | NL |
| PlantShield | *Trichoderma harzianum* (BM 02) | NL | NL | NL | NL | 4 |
| Procidic | citric acid (NC) | NL | NL | NL | ND | NL |

**** Not registered, label withdrawn or inactive in California.**

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

[1] Organic treatments arranged by performance on brown rot. Some products are not OMRI approved (e.g., Cinnacure, Plant Shield). Check the labels.

[2] FRAC Codes are also provided as BM- or P-number codes. NC = not coded in FRAC. In general, sulfur compounds are fungicidal and may affect applications of fungal biocontrols (e.g., Botector); whereas copper may affect applications of bacterial biocontrols (e.g., Actinovate, Double Nickel 55, and Serenade). Rotations must consider these factors.

[3] In general, sulfur compounds are fungicidal and may affect applications of fungal biocontrols (e.g., Blossom Protect*); whereas copper may affect applications of bacterial biocontrols (e.g., Actinovate, Double Nickel 55, and Serenade). Rotations must consider these factors

## CHERRY: TREATMENT TIMING

**Note: Not all indicated timings may be necessary for disease control.**

| Disease | Late budbreak/ Pre-bloom | Popcorn | Full bloom | Petal fall | 2 to 3 weeks later | Preharvest 1 to 10 days[1] |
|---|---|---|---|---|---|---|
| Botrytis | 0 | 3 | 3 | 2 | 0 | 3 |
| Brown rot[2] | 0 | 3 | 3 | 2 | 0 | 3 |
| Jacket rot/Green fruit rot | 0 | 0 | 3 | 2 | 0 | 0 |
| Powdery mildew | 2[3] | 2 | 3 | 3 | 3 | 1 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective

[1] Select broad-spectrum fungicides (or combinations) that have activity against both brown rot and Botrytis fruit rots.
[2] Begin at popcorn and repeat every 10 to 14 days through bloom if rains continue.
[3] Use sulfur at late bud break and other fungicides for later treatment. Treat immediately if mildew is found on shoots or leaves on inner scaffolds.

## CHERRY: SUGGESTED DISEASE MANAGEMENT PROGRAMS BY FRAC1 CODES - CONVENTIONAL AND ORGANIC GROWERS

**Note: Not all indicated timings may be necessary for disease control (*see* Treatment Timing Table). If treatments are needed based on weather monitoring or environmental monitoring models, suggested fungicide Codes are listed for each timing.**

How to use this table:

1) Identify the disease(s) that need(s) to be managed. Know the disease history of the orchard especially from the previous season.
2) Select one of the suggested fungicide Codes. *Numbers separated by slashes are pre-mixtures, whereas numbers grouped by pluses are tank mixtures.* If several diseases need to be managed, select a Code that is effective against all diseases. Refer to fungicide efficacy table for fungicides belonging to each FRAC Code. Code numbers are listed in numerical order within the suggested disease management program.
3) Rotate Codes for each application within a season and, if possible, use each Code only once per season, except for multi-site mode of action materials or natural products/biological controls (i.e., FRAC Codes M 02, BM 01, BM 02, NC).

| Disease | Dormant | Prebloom | White tip /Popcorn | Full bloom | Petal fall | 2 to 3 weeks later | Preharvest 1 to 10 days |
|---|---|---|---|---|---|---|---|
| Botrytis blossom blight/Gray mold fruit decay | ---- | ---- | 1[3], 2+oil, 3[4] | 1[3], 2+oil, 3[4], 3/7, 3/11 3+17, 7/11, 17, 19, 3/BM 01 | 2+oil, 3/7, 7, 7/11, 17, 19, 3/BM 01 | ---- | 3[4], 3/7, 3+17 7/11, 17, 19, |
| Brown rot blossom blight/Fruit rot | ---- | ---- | 1[3], 2+oil 3, 3/11, 7, 19, 3/BM 01 | 1[3], 3, 7, 3/7 3+17, 3/11 7/11, 17, 19, 3/BM 01 | ---- | ---- | 3, 3/7, 3/11, 7, 7/11, 17, 19, |
| Powdery mildew | M2[2] | M2[2] | 2+oil, 3, 3/BM 01 | 1[3], 3, 3/7, 3/11, 7, 7/11, 13, 19, 3/BM 01, BM 01, -02, -03, NC | 3, 3/7, 7, 7/11, 11, 13, 19, 3/BM 01, M2[2], BM 01, -02, -03, NC | 3, 3/7, 3/11, 7, 7/11, 11, 13, 19, 3/BM 01, M2[2], BM 01,-02,-03, NC | 3, 3/7, 3/11 3+17, 7/11, 11, 19, BM 01,-02,-03, NC |

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). NC = not coded in FRAC. Code numbers are listed in numerical order within the suggested disease management program. Fungicides with a different Code number are suitable to alternate in a resistance management program. Refer to the fungicide efficacy table for fungicides belonging to each FRAC Code. FRAC Codes for soft chemistries: potassium bicarbonate (e.g., Kaligreen, Milstop FC NC), fermentation product (FC 19 – e.g., Oso), *Streptomyces lydicus* (e.g., Actinovate AG – FC BM 02), *Bacillus amyloliquefaciens* Strain MBI 600 (e.g., Serifel – FC BM 02), and *Bacillus subtilis* Strain QST 713 (e.g., Serenade – FC BM 02). In general, sulfur compounds (FC M 02) are fungicidal and may affect applications of fungal biocontrols (e.g., Blossom Protect); whereas copper may affect applications of bacterial biocontrols (e.g., Actinovate, Double Nickel 55, and Serenade). Rotations of products must consider these factors.
[2] Use liquid lime sulfur in dormant applications and wettable sulfur at and after prebloom.
[3] Strains of *Monilinia fructicola* resistant to Topsin-M, and T-Methyl are present in some California cherry orchards. Resistant strains of the jacket rot fungus, *Botrytis cinerea*, and powdery mildew fungi have been reported in California on crops other than almond and stone fruits and may have the potential to develop in sweet cherry with overuse of fungicides with similar chemistry.
[4] **Among the Code 3 fungicides, Elite/Orius and Quash have some activity against *Botrytis cinerea*.**

## CITRUS: FUNGICIDE EFFICACY - CONVENTIONAL

| Fungicide*** | Resistance risk (FRAC code)[1,5] | Phytophthora[2] brown rot | Phytophthora[2] root rot | Septoria spot | Anthrac-nose | Alter-naria rot | Greasy spot | Rind disorder |
|---|---|---|---|---|---|---|---|---|
| Orondis | high (49) | 5 | 5 | 0 | 0 | 0 | 0 | 0 |
| Revus | high (40) | 5 | NL | 0 | 0 | 0 | 0 | 0 |
| Presidio | high (43) | NL | 5 | 0 | 0 | 0 | 0 | 0 |
| Ridomil**, Metalaxyl** | high (4) | NL | 3 | 0 | 0 | 0 | 0 | 0 |
| Ridomil Gold, Mefenoxam[3] | high (4) | NL | 3 | 0 | 0 | 0 | 0 | 0 |
| Copper | low (M 01) | 4 | 0 | 4 | 3 | 1 | 3 | 0 |
| Aliette[3], ProPhyt, Fungi-Phite, K-Phite | low-medium (P 07/33) | 4 | 4 | 3 | 3 | 1 | ND | 0 |
| Luna Sensation | medium (7/11)[5] | NL | NL | 5 | 5 | 2 | 4 | 0 |
| Cevya | high (3) | NL | NL | 4 | 5 | 5 | 4 | 0 |
| Priaxor | medium (7/11)[5] | NL | NL | 5 | 5 | 2 | 4 | 0 |
| Mibelya* | medium (3/7)[5] | NL | NL | 5 | 5 | 2 | 4 | 0 |
| Switch[4] | medium (9/12) | 0 | 0 | 5 | 5 | 2 | 4 | 0 |
| Miravis Prime* | medium (7/12) | NL | NL | 5 | 5 | 2 | 4 | 0 |
| Pristine | medium (7/11)[5] | NL | NL | 4 | 4 | 2 | 4 | 0 |
| Quadris Top | medium (3/11) | NL | NL | 5 | 5 | 3 | 4 | 0 |
| Quadris (Abound discontinued) | high (11)[5] | NL | NL | 4 | 4 | 2 | 4 | 0 |
| Flint Extra | high (11)[5] | NL | NL | 4 | 4 | 2 | 4 | 0 |
| Headline | high (11)[5] | NL | NL | 4 | 4 | 2 | 4 | 0 |
| Ph-D, Oso | high (19) | NL | NL | 4 | 4 | 1 | 0 | 0 |
| Bumper**,Tilt[3] | high (3) | 0 | 0 | NL | NL | NL | 4 | 0 |
| Enable | high (3) | 0 | 0 | NL | NL | 1 | 4 | 0 |
| Scala[4] | high (9) | 0 | 0 | NL | NL | 1 | NL | 0 |
| Ferbam** | low (M 03) | NL | NL | 0 | 3 | 0 | 0 | 0 |
| Sulfur | low (M 02) | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Vapor Gard | anti-transpirant | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Agricultural oils | anti-transpirant | 0 | 0 | 0 | 0 | 0 | 0 | 4 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

*** Registration pending in California.**

**** Not registered, label withdrawn or inactive in California.**

***** Postharvest fruit registrations in California include: BioSpectra/Cerafruta/Uniguard**, Imazalil**/Deccozil/Fungaflor/Freshgard 700, Graduate/FDL, GraduateA+, Azoxy, Mentor, Penbotec/Pyrimethanil, and Alumni/Decco Salt No. 19/TBZ. Postharvest sanitizers include: Storox and Perasan A.**

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). NC = not coded in FRAC. Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-actions (MOA) with high resistance risk before rotating to a fungicide with a different MOA (Code number); for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different MOA (Code number).

[2] Do not use the same fungicide or fungicides with similar chemistry more than twice in one year.

[3] Only for non-bearing citrus.

[4] Only federally registered on lemons and/or limes (check label).

[5] To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.

## CITRUS: TREATMENT TIMING

**Note: Not all indicated timings may be necessary for disease control.**

| Disease | Spring root flush | Fall root flush | Oct./Nov. | Jan./Feb. | March | 5 to 1 wk PHI |
|---|---|---|---|---|---|---|
| Phytophthora brown rot | 0 | 0 | 3 | 3 | 2 | 1 |
| Phytophthora root rot | 3 | 3 | 0 | 0 | 0 | 0 |
| Septoria spot | 0 | 0 | 3 | 3 | 1 | 0 |
| Anthracnose[a] | 0 | 0 | 0 | 0 | 0 | 3 |
| Alternaria rot[b] | 0 | 0 | 0 | 0 | 0 | 1/2 |
| Greasy spot | 0 | 0 | 0 | 0 | 0 | 3 |
| Rind disorder | 0 | 0 | 3 | 2 | 1 | 0 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective

[a] Anthracnose and greasy spot management is generally high (+++) with preharvest applications before warm, wet weather.

[b] Alternaria fruit rot management with fungicides is generally low (+) with preharvest fungicide applications before wet weather (the current understanding of the epidemiology of the disease is limited).

[c] Management of rind disorder especially on early-season mandarins (e.g., Satsuma) is generally high (+++) provided that fruit are harvest within 6 to 8 weeks of color break. Other mid- and late-season cultivars have less problems unless high rainfall is observed. Treatment timing should be at color break. Repaeat applications may be necessary.

## GRAPEVINE: FUNGICIDE EFFICACY – CONVENTIONAL

| Fungicide | Resistance risk (FRAC code)[1] | Powdery mildew | Downy mildew | Rot | | Phomopsis cane and leaf spot | Eutypa dieback | Bot canker | Phomopsis dieback |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Botrytis bunch rot | Summer rot | | | | |
| Pristine | medium (7/11)[2] | 5 | 5 | 5 | 4 | 3 | NL | 0 | 0 |
| Merivon | medium (7/11) | 5 | 0 | 5 | 4 | 4 | NL | NL | NL |
| Miravis Prime | medium (7/12) | 5 | 0 | 5 | 4 | 4 | NL | NL | NL |
| Aprovia Top | medium (3/7) | 5 | 0 | 4 | 3 | 4 | NL | NL | NL |
| Adament** | high (3/11) | 5 | 0 | 3 | 3 | 0 | NL | 0 | 0 |
| Luna Sensation | medium (7/11) | 5 | 0 | 5 | 3 | 0 | NL | NL | NL |
| Quadris (Abound discontinued) | high (11)[2] | 5 | 5 | 2 | 0 | 4 | NL | 0 | 0 |
| Flint Extra[3] | high (11)[2] | 5 | 4 | 3 | 3 | 3 | NL | 0 | 0 |
| Inspire Super | medium (3/9) | 5 | 0 | 5 | 3 | 0 | NL | NL | NL |
| Kenja | high (7) | 5 | NL | 5 | NL | NL | NL | NL | NL |
| Luna Experience | medium (3/7) | 5 | 0 | 5 | 3 | 0 | NL | NL | NL |
| Fervent | medium (3/7) | 5 | 0 | 5 | 3 | 0 | NL | NL | NL |
| Cevya[7] | high (3) | 5 | 0 | NL | NL | 4 | NL | NL | NL |
| Mettle | high (3) | 5 | 0 | 0 | 2 | 0 | 4 | 0 | 0 |
| Orius**,Tebucon, Toledo, Elite** | high (3) | 5 | 0 | 3 | 3 | 0 | NL | 0 | 0 |
| Viathon | med. (3, P 07/33) | 5 | 0 | 3 | 3 | 0 | NL | 0 | 0 |
| Procure,Viticure** | high (3) | 5 | 0 | 0 | 0 | 0 | NL | 0 | 0 |
| Quadris Top | high (3/11) | 5 | 2 | 3 | 3 | 3 | NL | 0 | 0 |
| Quintec | high (13) | 5 | 0 | 0 | 0 | 0 | NL | 0 | 0 |
| Rally | high (3) | 5 | 0 | 0 | 0 | 0 | 4 | 3 | 3 |
| Rally+Topsin-M[5] | high (1+3) | 5 | 0 | 0 | 0 | 5 | 5[6] | 5 | 5 |
| Ranman** | high (21) | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Revus Top | medium (3/40) | 5 | 5 | 3 | 3 | 3 | NL | 0 | 0 |
| Rhyme | high (3) | 5 | 0 | 0 | 0 | 0 | NL | 0 | 0 |
| Rubigan**, Vintage** | high (3) | 5 | 0 | 0 | 0 | 0 | NL | 0 | 0 |
| Sovran | high (11)[2] | 5 | 5 | 3 | 3 | 4 | 0 | NL | 5 |
| Sulfur | low (M 02) | 5 | 0 | 0 | 0 | 0 | NL | 0 | 0 |
| Topsin-M, T-Methyl, Incognito | high (1)[2] | 5 | 0 | 3 | 3 | 2 | 5 | 5 | 3 |
| Torino | high (U 6) | 5 | NL | NL | NL | NL | NL | NL | NL |
| Aprovia | medium (7) | 5 | 0 | 3 | 0 | 3 | NL | NL | NL |
| Luna Privilege**, Velum One** | high (7) | 4 | 0 | 4 | 2 | 0 | 3 | 0 | 0 |
| Prolivo | high (50) | 4 | NL | NL | NL | NL | NL | NL | NL |
| Vivando | high (50) | 4 | NL | NL | NL | NL | NL | NL | NL |
| Gatten | high? (U 13) | 4 | NL | NL | NL | NL | NL | NL | NL |
| Bayleton** | high (3) | 3 | 0 | 0 | 0 | 0 | NL | 0 | 0 |
| Copper | low (M 01) | 3 | 4 | 3 | 4 | 0 | 0 | 0 | 0 |
| Intuity | high (11) | 3 | NL | 4 | 3 | NL | NL | NL | NL |
| Elevate | high (17)[2] | 3 | 0 | 5 | 3 | 0 | NL | 0 | 0 |
| Ph-D, Oso | medium (19) | 3 | 0 | 4 | 4 | ND | NL | 0 | 0 |
| Scala | high (9)[2] | 3 | 0 | 5 | 3 | 0 | NL | 0 | 0 |
| Switch | low (9/12) | 3 | 0 | 5 | 4 | 0 | 0 | 0 | 0 |
| Vangard | high (9)[2] | 3 | 0 | 5 | 3 | 0 | NL | 0 | 0 |
| Botran** | medium (14) | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| Captan | low (M 04) | 0 | 2 | 4 | 4 | 4 | NL | 0 | 0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Dithane, Manzate, Penncozeb | low (M 03) | 0 | 0 | 3 | 0 | 4 | 0 | 0 | 0 |
| Presidio** | high (43) | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| Revus | high (40) | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ridomil Gold/Copper | high (4/M 01) | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rovral, Meteor, Iprodione**, Nevado** | low (2) | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| Ziram | low (M 03) | 0 | 3 | 2 | 2 | 4 | 0 | 0 | 4 |
| Laguna** | high (3) | ND | ND | ND | ND | ND | ND | ND | ND |
| Rovral + Oil[4] | low (2) | NL | 0 | 5 | 0 | 0 | NL | 0 | 0 |
| Oso | medium (19) | NL | 0 | 4 | 4 | ND | NL | 0 | 0 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

*** Registration pending in California.**
**** Not registered, label withdrawn or inactive in California.**

## GRAPEVINE: FUNGICIDE EFFICACY – BIOCONTROLS AND NATURAL PRODUCTS

| Fungicide | Resistance risk (FRAC code)[1] | Powdery mildew | Downy mildew | Bunch rot | | Phomopsis cane and leaf spot | Eutypa dieback | Bot canker | Phomopsis dieback |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Botrytis | Summer | | | | |
| Bio-Tam 2.0 | low (BM 02) | NL | NL | NL | NL | NL | 4 | 4 | 4 |
| Cinnacure, Seican, Cinnerate | low (BM 03) | 4 | NL | NL | NL | NL | NL | NL | NL |
| Armour-Zen | low (NC) | 4 | ND | ND | ND | ND | ND | NL | NL |
| ProBlad Verde | low (BM 01) | 4 | NL | 3 | NL | NL | NL | NL | NL |
| JMS Stylet oil[4] | low | 4 | NL | 4 | 3 | NL | NL | NL | NL |
| Kaligreen | low (NC) | 4 | NL | NL | NL | NL | NL | NL | NL |
| Milstop | low (NC) | 4 | NL | NL | NL | NL | NL | NL | NL |
| Purespray | low | 4 | NL | NL | NL | NL | NL | NL | NL |
| Regalia | low (P 05) | 4 | ND | 3 | 2 | NL | NL | NL | NL |
| Serenade | low (BM 02) | 4 | ND | 3 | 2 | 4 | 4 | NL (4) | ND |
| Sonata | low (BM 02) | 4 | ND | 3 | 2 | ND | ND | NL | NL |
| Taegro 2 | low (BM 02) | 4 | ND | 3 | 2 | NL | NL | NL | NL |
| Mevalone | low (BM 01) | 4 | ND | 5 | NL | NL | NL | NL | NL |
| Actinovate | low (BM 02) | 3 | NL | 2 | NL | NL | NL | NL | NL |
| Prev-am [4] | low (NC) | 3 | ND | 3 | 2 | NL | 3 | NL | NL |
| Sporan EC[2] | low (BM 01) | 3 | ND | ND | NL | NL | NL | NL | NL |
| Timorex (Act, Gold)[4] | low (BM 01) | 3 | ND | 3 | ND | NL | ND | NL | NL |
| Double Nickel 55 | low (BM 02) | 2 | ND | 2 | ND | ND | ND | NL | NL |
| Sporatec | low (BM 01) | 2 | ND | ND | NL | NL | NL | NL | NL |
| B-Lock | low | NL | NL | NL | NL | NL | 5 | 3 | NR |
| Vitiseal | low (BM 01) | NL | NL | NL | NL | NL | 5 | NL | NL |
| Botector | low (BM 02) | NL | NL | 2 | ND | NL | NL | NL | NL |
| Vintec[8] | low (BM 02) | NL | NL | NL | NL | NL | 4 | 4 | 4 |
| Procidic | low (NC) | ND | ND | ND | ND | NL | NL | NL | NL |
| Rango | low (BM 01) | ND | NL | ND | ND | NL | NL | NL | NL |

*** Registration pending in California.**
**** Not registered, label withdrawn or inactive in California.**

**Rating:** 5 = excellent and consistent, 4 = good and reliable under low to medium disease pressure (high disease pressure will result in reduced efficacy with a rating of +/++), 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0= ineffective; and NL = not on label; ND = No data.

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). NC = not coded in FRAC. Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-actions (MOA) with high resistance risk before rotating to a fungicide with a different MOA (Code number); for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different MOA (Code number).

[2] To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.

[3] Causes severe phytotoxicity on Concord grape.

[4] Phytotoxic if used within 2 weeks of Captan or sulfur.

[5] Tank mixture applied post-pruning (dormant or delayed dormant).

[6] Apply at two-week intervals during rain events.

[7] Different use restrictions for 'Table and Raisin' and 'Wine' grape. Please read the label carefully.

[8] Labeled for *Eutypa* sp., *Botryosphaeria* sp., *Cytospora* sp., and other trunk diseases of grape.

## GRAPEVINE: TREATMENT TIMING

**Note: Not all indicated timings may be necessary for disease control.**

| Disease | Dormant | Bud break | Full bloom | Pre-close | Veraison | Preharvest/ Postharvest |
|---|---|---|---|---|---|---|
| Botryosphaeria canker (Bot canker) | 3 | 0 | 0 | 0 | 0 | 0 |
| Botrytis Bunch Rot | 2[2] | 0 | 3[1] | 3[1] | 3[1] | 3[1] |
| Brown spot | 0 | 0 | 0 | 3 | 3 | 3 |
| Phomopsis dieback | 3 | 0 | 0 | 0 | 0 | 0 |
| Downy mildew | 0 | 3 | 3 | 0 | 0 | 0 |
| Esca (Black measles) | 1[2] | 0 | 0 | 0 | 0 | 0 |
| Eutypa Dieback | 3 | 0 | 0 | 0 | 0 | 0 |
| Powdery mildew | 2[2] | 3[3] | 3[3] | 3[4] | 0 | 0 |
| Phomopsis | 3 | 3 | 0 | 0 | 0 | 0 |
| Summer bunch rot (sour rot) | 0 | 0 | 0 | 0 | 3[1] | 3[5] |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective.

[1] Apply only if rain is forecasted.

[2] Use 10 gallons lime sulfur per acre in at least 100 gallons water.

[3] Apply bud break and full bloom treatments every year.

[4] Apply as needed (a disease risk assessment model is available to help determine need for spray).

[5] Preharvest treatments for postharvest decay control.

## GRAPEVINE: SUGGESTED DISEASE MANAGEMENT PROGRAMS BY FRAC[1] CODES - CONVENTIONAL AND ORGANIC GROWERS

**Note: Not all indicated timings may be necessary for disease control (*see* Treatment Timing Table). If treatments are needed based on weather monitoring or environmental monitoring models, suggested fungicide codes are listed for each timing.**

How to use this table:

1) Identify the disease(s) that need(s) to be managed. Know the disease history of the orchard especially from the previous season.
2) Select one of the suggested fungicide Codes. *Numbers separated by slashes are premixtures, whereas numbers grouped by pluses are tank mixtures.* If several diseases need to be managed, select a Code that is effective against all diseases. Refer to fungicide efficacy table for fungicides belonging to each FRAC Code. Code numbers are listed in numerical order within the suggested disease management program.
3) Rotate Codes for each application within a season and, if possible, use each Code only once per season, except for multi-site mode-of-action materials or natural products/biological controls (i.e., M 02, BM 01, BM 02, NC).

| Disease | Dormant | Bud break | Full bloom | Pre-close | Veraison | Preharvest |
|---|---|---|---|---|---|---|
| Botryosphaeria canker | BM 01[1], -02, -03, M2 (lime sulfur)[3] | ---- | ---- | ---- | ---- | ---- |
| Botrytis | ---- | ---- | 3/7, 3/9, 7/11[2], 7/12, 9/12, 9, 17 19, M4 | 3/7, 3/9 7/11[2], 7/12, 9/12, 9, 17, 19 | 3/7, 3/9 7/11[2], 7/12, 9/12, 9, 17, 19 | 3/7, 3/9, 7/11, 7/12, 9/12, 9, 17, 19 |
| Downy mildew | | BM 01, -02, -03, 4, 21, 40, 43 | 4, 21, 40, 43 | ---- | ---- | ---- |
| Esca | BM 01, -02, -03, M2 (lime sulfur)[3] | ---- | ---- | ---- | ---- | ---- |
| Eutypa | BM-01, -02, -03, 1, M2 | ---- | ---- | ---- | ---- | ---- |
| Powdery mildew[4,5] | BM-01, -03, M2 (lime sulfur), Oil | M2, Oil | 3/7, 3/9, 7/11, 7/12, 13, 17+11 19, U8 | 3, 3/7, 3/9, 7/11, 7/12 11, 13, U8 BM-01, -02, -03, M4, NC | 3, 3/7, 3/9, 7/12, 11, 13, 19, U8 M4, NC | ---- |
| Phomopsis cane and leafspot | ---- | 2, 11 M4/M3 | ---- | ---- | ---- | ---- |
| Summer bunch rot (sour rot) | ---- | ---- | ---- | 3/9, 7/11, 7/12, 9, 9/12, Oil, M1 | 3/9, 7/11,7/12, 9, 9/12, M1 | 3/9, 7/11,7/12, 9[6], 9/12, M1[6] |

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Code numbers are listed in numerical order within the suggested disease management program. Fungicides with a different Code number are suitable to alternate in a resistance management program. Refer to the fungicide efficacy table for fungicides belonging to each FRAC Code. FRAC Codes = BM 01 (Natural Products -Timorex, Vitaseal), BM 02 (Biological Controls - Sonata, Serenade), BM 03 (Cinnacure) and not coded in FRAC (NC) (e.g., Kaligreen, B-Lock, etc.)

[2] Apply only if rain is forecasted. When using one class do not follow with the same class.

[3] Use 10 gallons lime sulfur per acre in at least 100 gallons water. Use liquid lime sulfur in dormant applications and wettable sulfur at and after prebloom.

[4] Apply bud break and full bloom treatments every year.

[5] Apply as needed (a disease risk assessment model is available to help determine need for spray).

[6] Apply when insect and bird damage is present or when rainfall is forecasted.

## KIWIFRUIT: FUNGICIDE EFFICACY - CONVENTIONAL

| Fungicide | Resistance risk (FRAC number)[1] | Botrytis fruit rot |
|---|---|---|
| BioSpectra**/Cerafruta**,*** | medium (48) | 3 |
| Scholar*** | high (12) | 4 |
| Oso | medium (19) | 4 |
| Vangard | high (9) | 4 |

**** Not registered, label withdrawn or inactive in California.**

***** For postharvest use only.**

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action Code numbers 9 and 19, before rotating to a fungicide with a different mode-of-action Code number.

## KIWIFRUIT: TREATMENT TIMING

**Note: Not all indicated timings may be necessary for disease control.**

| Disease | Bud break | Full bloom | Preharvest interval[1] 14 day | 7 day | 1 day | Postharvest |
|---|---|---|---|---|---|---|
| Botrytis fruit rot | 0 | 1-2[2] | 2 | 2 | 3 | 3 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective.

[1] Apply as needed. A predictive model BOTMON is available using ONFIT methods for disease detection.

[2] Apply only if rain is forecasted.

## PEACH AND NECTARINE: FUNGICIDE EFFICACY - CONVENTIONAL

| Fungicide*** | Resistance risk (FRAC#)[1] | Brown rot [2] | | Powdery mildew[2] | Scab | Rust | Leaf curl | Shot hole |
|---|---|---|---|---|---|---|---|---|
| | | blossom | fruit | | | | | |
| Adament** | high (3/11) | 5 | 5 | 4 | 3 | 4 | 0 | 3 |
| Bumper**,Tilt | high (3) | 5 | 5 | 4 | 3 | 4 | 0 | 1 |
| Cevya | high (3) | 5 | 5 | 4 | 3 | 4 | 0 | 3 |
| Orius**, Teb, Tebuconazole** | high (3) | 5 | 5 | 4 | 3 | 4 | 0 | 2 |
| Viathon | medium (3, P 07/33) | 5 | 5 | 4 | 3 | 4 | 0 | 2 |
| Fontelis | high (7)[4] | 5 | 4 | 5 | 4 | ND | 0 | 4[10,12] |
| Kenja | high (7)[4] | 5 | 4 | NL | NL | NL | NL | NL |
| Parade* | high (7)[4] | 5 | 4 | 5 | ND | 2 | ND | ND |
| Miravis Duo | medium (3/7) | 5 | 5 | 4 | 4 | 4 | 0 | 4 |
| Indar | high (3) | 5 | 5 | 4 | 3 | ND | 0 | 1 |
| Protocol[3] | med.-high (1/3) | 5 | 5 | 5 | 4 | 5 | 0 | 4 |
| Inspire Super | high (3/9) | 5 | 5 | 4 | 3 | ND | 0 | 1 |
| Regev | medium (3/BM 01) | 5 | 5 | 4 | 3 | ND | 0 | 1 |
| Luna Experience | medium (3/7) | 5 | 5 | 4 | 0 | 4 | 0 | 1 |
| Luna Sensation | medium (7/11)[4] | 5 | 5 | 4 | 4 | 4 | ND | 5[10,12] |
| Merivon | medium (7/11)[4] | 5 | 5 | 4 | 4 | 4 | ND | 5[10,12] |
| Pristine | medium (7/11)[4] | 5 | 5 | 4 | 4 | ND | ND | 5[10,12] |
| Quadris Top | medium (3/11) | 5 | 5 | 4 | 0 | 4 | 0 | 1 |
| Quash | high (3) | 5 | 5 | 4 | ND | 4 | 0 | 4[10,12] |
| Quilt Xcel,Avaris 2XS | medium (3/11) | 5 | 5 | 4 | 0 | 4 | 0 | 1 |
| Rovral[5] + oil[6] | low (2) | 5 | NL | 2 | 2 | 3 | 0 | 3 |
| Scala[7] | high (9)[3,4] | 5 | 4[7] | ND | ND | ND | 0 | 2 |
| Topsin-M,T-Methyl, Incognito, Cercobin** | high (1) [3,4] | 5 | 5 | 4 | 4 | 2 | 0 | 0 |
| Vangard[7] | high (9) [3,4] | 5 | 4[7] | ND | ND | ND | 0 | 2 |
| Elevate | high (17)[4] | 4 | 4 | ND | ND | ND | ND | ND |
| Rally | high (3) | 4 | 4 | 5 | 0 | 0 | 0 | 0 |
| Rhyme | high (3) | 4 | 3 | 4 | ND | ND | 0 | 2[10] |
| Rovral[5], Meteor[5], Iprodione**, Nevado** | low (2) | 4 | NL | 0 | 0 | 0 | 0 | 0 |
| Quadris (Abound discontinued) | high (11)[4] | 3 | 2 | 3 | 5 | 4 | 0 | 3 |
| Botran** | medium (14) | 3 | 2 | ND | ND | ND | ND | ND |
| Bravo, Echo, Equus[8,9] | low (M 05) | 3 | 0 | 0 | 4 | 2 | 4 | 4 |
| Captan[9] | low (M 04) | 3 | 3 | 0 | 4 | 0 | 0 | 4[10,12] |
| Flint Extra | high (11)[4] | 3 | 2 | 3 | 5 | 4 | 0 | 3 |
| Ph-D, Oso | high (19) | 3 | 3 | 3 | ND | NL | ND | ND |
| Syllit | medium (U 12) | 2 | 0 | 0 | 4 | 0 | 3 | 4 |
| Copper | low (M 01) | 1 | 0 | 0 | 0 | 0 | 4 | 4 |
| Sulfur[9] | low (M 02) | 1 | 1 | 4 | 4 | 4 | 0 | 0 |
| Thiram[11] | low (M 03) | 1 | 0 | 0 | 4 | 0 | 5 | 4 |
| Ziram | low (M 03) | 1 | 0 | 0 | 4 | 0 | 5 | 4 |
| Quintec | high (13) | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| Vivando | high (50) | 0 | 0 | 4 | 0 | 0 | 0 | 0 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

*** Registration pending in California.**

**** Not registered, label withdrawn or inactive in California**

***** Postharvest fruit registrations in California include: BioSpectra/Cerafruta/Unigard**, Chairman, Mentor, Penbotec/ Pyrimethanil**, and Scholar/FDL.**

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). NC = not coded in FRAC. Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-actions (MOA) with high resistance risk before rotating to a fungicide with a different MOA (Code number); for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different MOA (Code number).

[2] Do not use fungicides with the same FRAC number and high resistance risk more than twice in one year.

[3] Strains of *Monilinia fructicola* resistant to Topsin-M and T-Methyl are present in some peach and nectarine orchards. Resistant strains of the jacket rot fungus, *Botrytis cinerea*, and powdery mildew fungi have been reported in California on crops other than almond and stone fruits and may have the potential to develop in peach and nectarine with overuse of fungicides with similar chemistry. Sub-populations of both *Monilinia* spp. have been shown to be resistant to AP (FRAC 9) fungicides on prune in CA.

[4] To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
[5] Blossom blight only; not registered for use after petal fall.
[6] Oil is a "light" summer oil, 1-2% volume/volume.
[7] High summer temperatures and relative humidity reduce efficacy.
[8] Do not use after jacket (shuck) split.
[9] Do not use in combination with or shortly before or after oil treatment.
[10] Not effective if used as a dormant treatment.
[11] For use on peach only; not registered on nectarine.
[12] For shot hole management, dormant treatments with copper, ziram, and dodine are highly effective. Petal fall treatments should be used to complement the management program.

## PEACH AND NECTARINE - FUNGICIDE EFFICACY - BIOCONTROLS AND NATURAL PRODUCTS

| Trade name[1] | Biological or natural product (FRAC Code)[2] | Brown rot | | PM[3] | Scab | Rust | Leaf curl | Shot hole |
|---|---|---|---|---|---|---|---|---|
| | | blossom | fruit | | | | | |
| Oso | polyoxin-D (19) | 3 (4) | 3 | 3 | ND | NL | NL | NL (2) |
| Botector | *Aureobasidium pullulans* (BM 02) | 3 | 2 | NL (3) | NL | NL | NL | NL |
| ProBlad Verde* | *Lupinus albus* (BM 01) | 3 | 2 | 3 | NL | NL | NL | NL |
| Double Nickel 55 | *Bacillus amyloliquefaciens* D747 (BM 02) | 2 | 1 | 3 | NL | NL | 2 | 2 |
| Serifel | *B. amyloliquefaciens* MBI600 (BM 02) | 2 | 1 | 3 | NL | NL | NL | 2 |
| Taegro 2** | *B. amyloliquefaciens* FZB (BM 02) | 2 | 1 | 3 | NL | NL | NL | NL |
| Sonata | *B. pumilis* QST2808 (BM 02) | 2 | 1 | 3 | ND | NL | NL | 2 |
| Serenade | *B. subtilis* QST 713 (BM 02) | 2 | 1 | 2 | ND | NL | NL | 2 |
| Aviv | *B. subtilis* IAB/BS03 (BM 02) | 2 | 2 | 3 | ND | ND | NL | 2 |
| Dart* | capric and caprylic acids (NC) | 3 | 2 | NL (2) | NL | NL | NL | NL |
| Cinnacure, Seican, Cinnerate | cinnamaldehyde (BM 03) | 2 | 1 | 3 | NL | NL | NL | NL |
| EF400 | clove, rosemary, peppermint oils (BM 01) | NL | NL | 3 | NL | NL | NL | NL |
| Trilogy, Rango, Terraneem | neem oil (BM 01) | 1 | 1 | 2 | ND | 2 | NL | 1 |
| Oxidate, Perasan | peroxyacetic acid (oxidizer) | 2 | 2 | 2 | NL | NL | 1 | 1 |
| Armicarb**, Milstop (peach only) | potassium bicarbonate (NC) | NL | NL | 3 | NL | NL | NL | NL |
| Regalia | *Reynoutria sachalinensis* (P 05) | 2 | 2 | 3 | ND | ND | NL | ND |
| Actinovate AG | *Streptomyces lydicus* (BM 02) | 1 | 1 | 2 | NL | NL | ND | NL |
| EcoSwing | *Swinglea glutinosa* (BM 01) | 2 | 2 | 3 | NL | NL | NL | NL |
| Procidic | citric acid (NC) | NL | NL | ND | ND | ND | NL | NL |
| Copper | copper (M 01) | 1 | 1 | 1 | 2 | 2 | 4 | 4 |
| Sulfur | sulfur (M 02) | 1 | 0 | 4 | 4 | 2 | 0 | 0 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

*** Registration pending in California.**
**** Not registered, label withdrawn or inactive in California.**

[1] Treatments arranged by performance on brown rot. Some products are not OMRI approved (e.g., Cinnacure). Check the labels to be sure.
[2] FRAC Codes are also provided as BM- or P-number codes. In general, sulfur compounds are fungicidal and may affect applications of fungal biocontrols (e.g., Botector); whereas copper may affect applications of bacterial biocontrols (e.g., Actinovate, Double Nickel 55, and Serenade). Rotations must consider these factors. NC = not coded in FRAC.
[3] PM refers to powdery mildew.

## PEACH AND NECTARINE: TREATMENT TIMING

**Note: Not all indicated timings may be necessary for disease control.**

| Disease | Dormant | Bloom | | 3 to 6 weeks postbloom | Preharvest[1] | |
|---|---|---|---|---|---|---|
| | | 20 to 40% | 80 to 100% | | 3 weeks | 1 week |
| Brown rot | 0 | 2 | 3 | 1 | 2 | 3 |
| Leaf curl[3] | 3 | 1 | 0 | 0 | 0 | 0 |
| Powdery mildew | 0/ND | 2 | 3 | 3[2] | 0 | 0 |
| Rust | 1[4] | 0 | 0 | 3 | 2 | 0 |
| Scab | 0 | 1 | 2 | 3 | 0 | 0 |
| Shot hole[5] | 3 | 1 | 1 | 2 | 0 | 0 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective (ND=No data).

[1] Timing not exact; weather conditions determine need for treatment.
[2] Apply until pit hardening.
[3] Treatment should be made before bud break and preferably before bud swell.
[4] Dormant treatment with liquid lime sulfur.
[5] Fall application before winter rains begin is the most important; additional spring sprays are seldom required but may be needed to protect the fruit if heavy persistent spring rains occur.

# PEACH AND NECTARINE: SUGGESTED DISEASE MANAGEMENT PROGRAMS BY FRAC[1] CODES - CONVENTIONAL AND ORGANIC GROWERS

**Note: Not all indicated timings may be necessary for disease control (*see* Treatment Timing Table). If treatments are needed based on weather monitoring or environmental monitoring models, suggested fungicide Codes are listed for each timing.**

How to use this table:

1) Identify the disease(s) that need(s) to be managed. Know the disease history of the orchard, especially from the previous season.
2) Select one of the suggested fungicide Codes. *Numbers separated by slashes are pre-mixtures, whereas numbers grouped by pluses are tank mixtures.* If several diseases need to be managed, select a Code that is effective against all diseases. Refer to fungicide efficacy table for fungicides belonging to each FRAC Code. Code numbers are listed in numerical order within the suggested disease management program.
3) Rotate Codes for each application within a season and, if possible, use each Code only once per season, except for multi-site mode-of-action materials or natural products/biological controls (e.g., M 02, BM 01, BM 02, NC, P).

| Disease | Dormant | Bloom | | 3 to 6 weeks postbloom | Preharvest | |
|---|---|---|---|---|---|---|
| | | 20 to 40% | 80 to 100% | | 3 weeks | 1 week |
| Brown rot | ---- | 1[3], 2+oil, 3, 3/7, 3/9, 3/11, 7, 9, 19, 3/BM 01 | 1[3], 2+oil, 3[4], 3/7, 3/9, 3/11, 7/11, 9, 17, 19, 3/BM 01 | 3, 3/7, 3/11, 7/11, 17, 3/BM 01 | 3, 3/7, 3/11, 7/11, 17, 19, 3/BM 01 | 3[4], 3/7, 3/11, 7/11, 17, 19 |
| Leaf curl | M1, M3, M5, U12 | M3, M5, U12 | ---- | ---- | ---- | ---- |
| Powdery mildew | M2[2] | 1[3], 2+oil 3, 3/7, 3/11, 3/BM 01 | 1[3], 3, 3/7, 3/11, 7/11, 13, U8, 3/BM 01 | 3, 7, 3/7, 7/11, 11, 13, 19, M1, M2[2], U12, 3/BM 01 BM 01,-02, -03, NC,[5] | ---- | ---- |
| Rust | M2[2] | ---- | ---- | 1[3], 3, 7/11, 11, M2[2] | 3, 7/11, 11, M2[2] | ---- |
| Scab | ---- | 1[3], 3, 3/11, 7/11, 9/11, 3/BM 01, M3, M4, M5, U12 | 1[3], 3, 3/9, 3/11, 7/11, 3/BM 01, M3, M4, M5, U12 | 1[3], 3, 3/9, 3/11, 7/11, 11, 3/BM 01, M2[2], M4, M5, U12 | ---- | ---- |
| Shot hole | M1, M3, M4, M5 | 2, some 3s, M3, M4, M5, U12 | 2, some 3s, 7/11, M3, M4, M5, U12 | 7/11, 11, M4, U12 | ---- | ---- |

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). NC = not coded in FRAC. Code numbers are listed in numerical order within the suggested disease management program. Fungicides with a different Code number are suitable to alternate in a resistance management program. Refer to the fungicide efficacy table for fungicides belonging to each FRAC Code.

[2] Efficacy of liquid lime sulfur in dormant applications has not been determined for powdery mildew. Use liquid lime sulfur in dormant applications and wettable sulfur at and after pre-bloom.

[3] Strains of *Monilinia fructicola* resistant to Benlate (label withdrawn), Topsin-M, and T-Methyl are present in some California peach/nectarine orchards. Resistant strains of the jacket rot fungus, *Botrytis cinerea*, and powdery mildew fungi have been reported in California on crops other than almond and stone fruits and may have the potential to develop in peach/nectarine with overuse of fungicides with similar chemistry. Subpopulations of both *Monilinia* spp. have been shown to be resistant to AP (FRAC 9) fungicides on prune in CA.

[4] Among the Code 3 fungicides, only Teb/Orius and Quash have some activity against *Botrytis cinerea*.

[5] FRAC M 01 - copper, M 02 - sulfur, BM 01 - Natural products, BM 02 - Biological controls (*Streptomyces lydicus* - Actinovate AG, *Bacillus pumilus* - Sonata, *Bacillus subtilis* - Serenade, Aviv), or not coded in FRAC (NC) (e.g., potassium bicarbonate - Kaligreen).

## PISTACHIO: FUNGICIDE EFFICACY - CONVENTIONAL, BIOCONTROLS, AND NATURAL PRODUCTS

| Fungicide | Resistance risk (FRAC#)[1] | Alternaria late blight | Botrytis blossom & shoot blight | Botryosphaeria panicle & shoot blight |
|---|---|---|---|---|
| Fontelis | high (7) | 5 | 5 | 4/5 |
| Luna Experience | medium (3/7) | 5 | 5 | 5 |
| Luna Sensation | medium (7/11)[3] | 5[4] | 5 | 5 |
| Merivon | high (7/11) | 5 | 5 | 5 |
| Mibelya | medium (3/7) | 5 | ND | 4 |
| Miravis Duo | medium (3/7) | 5 | 5 | 5 |
| Miravis Prime | medium (7/12) | 5 | 5 | 5 |
| Pristine | high (7/11)[3] | 5[4] | 5 | 5 |
| Cevya | high (3) | 5 | 5 | 4[5] |
| Quash | high (3) | 5 | 4 | 4[5] |
| Adament | medium (3/11)[3] | 5 | 3 | 4/5 |
| Quilt Xcel, Avaris 2XS | medium (3/11)[3] | 5 | 0 | 4/5 |
| Viathon | medium (3, P 07/33) | 5 | 2 | 5[5] |
| Quadris (Abound discontinued) | high (11)[2,3] | 4 | 0 | 4 |
| Aproach | high (11)[2,3] | ND | 4 | ND |
| Cabrio | high (11)[2,3] | 4 | 0 | 4 |
| Flint Extra | high (11)[2,3] | 4 | 0 | 4 |
| Ph-D | medium (19) | 4 | 5 | 4 |
| Tesaris, Sercadis** | high (7) | 4 | ND | 4 |
| Parade* | high (7) | ND | 4 | ND |
| Quadris Top | medium (3/11)[3] | 4 | 0 | 4/5 |
| Switch | high (9/12)[3] | 4 | 4 | 3 |
| Tebucon, Teb, Toledo, Tebuconazole** | high (3) | 4 | 2 | 4[5] |
| Vangard | high (9)[3] | 4 | 5 | 0 |
| Bravo, Chlorothalonil, Echo | low (M 05) | 3 | 0 | 3 |
| Bumper**,Tilt | high (3) | 3 | 2 | 3[5] |
| Scala | high (9)[3] | 3 | 4 | 4[6] |
| Velum One | high (7) | 3 (NL) | NL | NL |
| Inspire Super | medium (3/9) | 3 | 4 | 4/5 |
| Regev | medium (3/BM 01) | 3 | 3 | 4/5 |
| Topsin-M, T-Methyl, Incognito, Cercobin**[7] | high (1) | 0 | 3 | 3 |
| Elevate | high (17)[3] | ND | 5 | ND |
| K-Phite | low (P 07/33) | ND | ND | 4/5 |
| ***Organic treatments*** | | | | |
| Actinovate | low (BM 02) | 3 | 5 | 4 |
| Regalia | low (P 05) | 2 | 0 | 2[8] |
| Theia | low (BM 02) | 3 | ND | 3 |
| Copper | low (M 01) | 2 | 0 | 0 |
| Liquid lime sulfur[8] | low (M 02) | 0 | 0 | Dormant 1, Delayed Dormant 2 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

*** Registration pending in California.**
**** Not registered, label withdrawn or inactive in California**

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). NC = not coded in FRAC. Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-actions (MOA) with high resistance risk before rotating to a fungicide with a different MOA (Code number); for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different MOA (Code number).

[2] Field resistance of *Alternaria* spp. to Quadris and to other strobilurin fungicides (Flint Extra and Cabrio) is widespread in pistachio orchards.
[3] To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
[4] Resistance to the SDHI (succinate dehydrogenase inhibitor) boscalid has been detected in high levels (80-90%) in some orchards; Pristine should not be applied if resistance to this fungicide is detected in an orchard. Cross-resistance of SDHI fungicides (FRAC Code 7) may occur.
[5] Do not apply Bumper/Tilt (propiconazole) within 60 days of harvest, Quash (metconazole)within 25 days of harvest, Tebucon/Teb/Toledo/Viathon (tebuconazole fungicides) within 35 days before harvest or Cevya (mefentrifluconazole) with 14 day before harvest (PHI intervals).
[6] Under low and moderate disease pressure.
[7] Registered for bloom treatment only.
[8] Dormant treatments and/or delayed dormant

## PISTACHIO: TREATMENT TIMING

| Disease | Dormant | Bloom/terminal shoot ½ to 1 inch (April) | Succulent shoot growth / before shell lignification (May) | Early fruit development / after shell lignification (June)[1] | Fruit development / kernel development (July) | Fruit maturation (August)[2] |
|---|---|---|---|---|---|---|
| Alternaria[3] | 0 | 0 | 0- | 3 | 3[1] | 1? |
| Botryosphaeria[4] | 1?[5] | 3[6] | 3[6] | 3 | 3 | 1? |
| Botrytis | 0 | 3 | 1[7] | 0 | 0 | 0 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective

[1] If only one application is done, the best timing is late June to early July.
[2] Sprays not later than the first week in August.
[3] Three applications during the season are recommended.
[4] Treat once at bloom when the terminals on female trees are 1-2 inches long. Begin summer applications in late May or early June. Treat at 2- to 3-week intervals until mid-August. For resistance management, do not apply consecutive applications of any strobilurin (Flint Extra, Cabrio, or Quadris) or strobilurin-containing fungicides (Pristine, Luna Sensation), and make no more than two applications of a strobilurin or strobilurin-containing fungicide per season.
[5] Liquid lime sulfur: some efficacy in some trials, whereas no efficacy in other trials.
[6] Early season sprays timed before and/or after rains are effective timings in April and May.
[7] Protect young clusters if rain and cool weather occurs.

## PLUM: FUNGICIDE EFFICACY - CONVENTIONAL

**Note: Spring brown rot and shot hole control is not necessary for most plum cultivars in California.**

| Fungicide*** | Resistance risk (FRAC#)[1] | Brown rot | | Powdery mildew[3] | Shot hole[4] |
|---|---|---|---|---|---|
| | | blossom[2] | fruit | | |
| Miravis Duo | medium (3/7) | 5 | 5 | 5 | ND |
| Adament** | medium (3/11)[5] | 5 | 5 | 4 | ND |
| Bumper**,Tilt | high (3) | 5 | 5 | 4 | ND |
| Cevya | high (3) | 5 | 5 | 4 | ND |
| Tebucon[6], Teb, Tebuconazole** | high (3) | 5 | 5[6] | 4 | ND |
| Viathon | med. (3, P 07/33) | 5 | 5 | 4 | ND |
| Fontelis | high (7) | 5 | 5 | 4 | ND |
| Kenja | high (7) | 5 | 5 | NL | NL |
| Indar | high (3) | 5 | 5 | 4 | ND |
| Protocol[10] | med.-high (1/3) | 5 | 5 | 4 | ND |
| Inspire Super | high (3/9) | 5 | 5 | 4 | ND |
| Regev | medium (3/BM 01) | 5 | 5 | 4 | ND |
| Luna Experience | medium (3/7)[5] | 5 | 5 | 4 | ND |
| Luna Sensation | medium (7/11)[5] | 5 | 5 | 4 | ND |
| Merivon | medium (7/11)[5] | 5 | 5 | 4 | ND |
| Pristine | medium (7/11)[5] | 5 | 5 | 4 | ND |
| Quadris Top | medium (3/11)[5] | 5 | 5 | 4 | ND |
| Quash | high (3) | 5 | 5 | 4 | ND |
| Quilt Xcel, Avaris 2XS, | medium (3/11)[5] | 5 | 5 | 4 | ND |
| Rovral[7] + oil[8] | low (2) | 5 | NL | 0 | ND |
| Scala[9] | high (9)[5,10] | 5 | 4[9] | ND | ND |
| Topsin-M, T-Methyl, Incognito, Cercobin**[5] | high (1)[5] | 5 | 5 | 4 | ND |
| Vangard[9] | high (9)[5,10] | 5 | 4[9] | ND | ND |
| Elevate | high (17) | 4 | 4 | 2 | ND |
| Rally | high (3) | 4 | 4 | 4 | ND |
| Rhyme | high (3) | 4 | 4 | 4 | ND |
| Rovral[7], Meteor[7], Iprodione**, Nevado** | low (2) | 4 | NL | 0 | ND |
| Quadris (Abound discontinued) | high (11)[5] | 3 | 2 | ND | ND |
| Botran** | medium (14) | 3 | 3 | ND | ND |
| Bravo, Chlorothalonil, Echo, Equus[11,12] | low (M 05) | 3 | 3 | 0 | ND |
| Captan[12] | low (M 04) | 3 | 3 | 0 | ND |
| Flint Extra | high (11)[5] | 3 | 3 | ND | ND |
| Oso, Ph-D | high (19) | 3 | 3 | 4 | ND |
| Copper | low (M 01) | 1 | 0 | 0 | ND |
| Sulfur[12] | low (M 02) | 1 | 1 | 4 | ND |
| Quintec | high (13) | 0 | 0 | 5 | 0 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

**** Not registered, label withdrawn or inactive in California**

***** Postharvest fruit registrations in California include: BioSpectra/Cerafruta/Uniguard**, Chairman, Mentor, Teb, Penbotec/Pyrimethanil**, and Scholar/FDL.**

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-actions (MOA) with high resistance risk before rotating to a fungicide with a different MOA (Code number); for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different MOA (Code number).

[2] Brown rot blossom blight is seldom observed on most plum cultivars and usually does not require treatment during bloom.

[3] Powdery mildew seldom is observed on most plum cultivars and control usually is unnecessary.

[4] Shot hole disease rarely occurs on plums in California. The small holes often observed on leaves in spring are caused by either a genetic disorder or by other agents including environmental factors.

[5] To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
[6] Registered for pre- and postharvest applications on plum.
[7] Blossom blight only; not registered for use after petal fall.
[8] Oil = "light" summer oil, 1-2% volume/volume.
[9] High summer temperatures and relative humidity reduce efficacy.
[10] Strains of the brown rot fungus *Monilinia fructicola* resistant to Topsin-M and T-Methyl are found in other stone fruit orchards in California. Brown rot is so seldom found in plum orchards that the resistance levels in plum orchards have not been assessed. Subpopulations of both *Monilinia* spp. have been shown to be resistant to AP (FRAC 9) fungicides on prune in CA.
[11] Do not use after jacket (shuck) split.
[12] Do not use in combination with or shortly before or after oil treatment.

## PLUM: TREATMENT TIMING

### Note: Not all indicated timings may be necessary for disease control.

| Disease | Dormant | Green bud | Popcorn | Full bloom | Until pit hardening | Preharvest |
|---|---|---|---|---|---|---|
| Brown rot[1] | 0 | 1 | 2 | 3 | 0 | 1 |
| Powdery mildew | 0 | 1 | 1 | 3 | 3 | 0 |
| Shot hole[2] | 0 | 0 | 0 | 0 | 0 | 0 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective

[1] One early application should suffice; a second treatment should not be needed.
[2] No treatment is recommended for shot hole because the shot holes found on plum leaves only rarely are caused by the shot hole fungus.

## POMEGRANATE: FUNGICIDE EFFICACY - CONVENTIONAL

| Location | Fungicide | Resistance risk (FRAC code) | Alternaria fruit rot | Botrytis fruit rot / Gray mold |
|---|---|---|---|---|
| ***Preharvest*** | Ph-D* | high (19) | 2 | 2 (3) |
| | Merivon | medium (7/11) | 2 | 2 (3) |
| ***Postharvest*** | Penbotec***/Pyrimethanil*** | high (9) | 1 | 4 |
| | Scholar/FDL*** | high (12) | 0 | 4 |
| | BioSpectra***, Cerafruta*** | medium (48) | 0 | 3 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective.

*** Pending registration in California.**
***** In California, postharvest fruit registration only.**

## POMEGRANATE: TREATMENT TIMING

**Note: Not all indicated timings may be necessary for disease control.**

| Disease | Dormant | Early bloom | Mid-bloom | Late-bloom | Preharvest | Postharvest |
|---|---|---|---|---|---|---|
| Alternaria fruit rot | 0 | 1[1] | 1 | 1 | 0 | 0 |
| Gray mold (Botrytis fruit rot) | 0 | ND | ND | ND | 1[2] | 3 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective (ND = No data).

[1] Pomegranates have a long protracted bloom, thus apply when conditions are favorable for disease (i.e., wet conditions).
[2] Preharvest treatments are highly variable in efficacy due to difficulty in fungicide coverage into the fruit "crown".

## PRUNE (DRIED PLUM): FUNGICIDE EFFICACY - CONVENTIONAL

| Fungicide | Resistance risk (FRAC#)[1] | Brown rot | | Russet scab | Rust | Cyto-spora canker |
|---|---|---|---|---|---|---|
| | | blossom | fruit[2] | | | |
| Miravis Duo | medium (3/7) | 5 | 5 | ND | 5 | ND |
| Bumper**, Tilt[2] | high (3) | 5 | 5 | 0 | 4 | ND |
| Cevya | high (3) | 5 | 5 | 0 | 4 | ND |
| Tebucon, Teb, Tebuconazole**, Toledo[2,7] | high (3) | 5 | 5 | 0 | 4 | ND |
| Viathon | med. (3, P 07/33) | 5 | 5 | 0 | 4 | ND |
| Fontelis | high (7) | 5 | 4 | 0 | 4 | ND |
| Kenja | high (7) | 5 | 4 | NL | NL | ND |
| Tesaris, Sercadis** | high (7) | 5 | 4 | NL | NL | ND |
| Indar[2] | high (3) | 5 | 5 | 0 | 4 | ND |
| Protocol[3] | med.-high (1/3) | 5 | 5 | 0 | 5 | ND |
| Inspire Super | high (3/9) | 5 | 5 | 0 | 4 | ND |
| Regev | medium (3/BM 01) | 5 | 5 | 0 | 4 | ND |
| Luna Experience | medium (3/7) | 5 | 5 | ND | 5 | ND |
| Luna Sensation[2] | medium (7/11) | 5 | 5 | ND | ND | ND |
| Merivon | medium (7/11) | 5 | 5 | ND | ND | ND |
| Pristine[2] | medium (7/11) | 5 | 5 | ND | ND | ND |
| Quash [2] | high (3) | 5 | 5 | 0 | 4 | ND |
| Adament** | medium (3/11) | 5 | 5 | ND | 5 | ND |
| Quadris Top, Acadia ESQ[2] | medium (3/11) | 5 | 5 | ND | 5 | ND |
| Quilt Xcel, Avaris 2XS[2] | medium (3/11) | 5 | 5 | ND | 5 | ND |
| Rovral[5], Meteor[5] mixed with oil[2] Iprodione**, Nevado** | low (2) | 5 | NR | 0 | NR | ND |
| Scala[6] | high (9)[3,4] | 5 | 4[6] | 0 | ND | ND |
| Topsin-M, T-Methyl, Incognito, and Cercobin when mixed with oil[2,4] | high (1)[4] | 5 | 5 | 0 | 0 | 5*** |
| Vangard[6] | high (9)[3,4] | 5 | 4[6] | 0 | ND | ND |
| Elevate[2,] | high (17)[4] | 4 | 4 | ND | 0 | ND |
| Rhyme | high (3) | 4 | 4 | 0 | 4 | ND |
| Rovral[5], Meteor, Iprodione**, Nevado** | low (2) | 4 | NR | 0 | NR | ND |
| Topsin-M, T-Methyl, Incognito [2,3] | high (1)[4] | 4 | 1 | 0 | 0 | 5*** |
| Quadris (Abound), Acadia, Arius 250 | high (11)[4] | 3 | 2 | 0 | 4 | ND |
| Botran** | medium (14) | 3 | 3 | ND | ND | ND |
| Bravo, Chlorothalonil, Echo, Equus[7,8,9] | low (M 05) | 3 | 3 | 3 | 0[9] | ND |
| Captan[7,8,9] | low (M 04) | 3 | 3 | 4 | 0 | ND |
| Flint Extra[7] | high (11)[4] | 3 | 2 | 0 | 4 | ND |
| Ph-D, Oso | high (19) | 3 | 3 | 0 | ND | ND |
| Rally[2] | high (3) | 3 | 3 | 0 | 0 | ND |
| Sulfur[9] | low (M 02) | 1 | 1 | 0 | 3 | ND |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data. NR=not registered after bloom.

* **Registration pending in California.**
** **Not registered, label withdrawn or inactive in California**
**** **-2ee label for Topsin-M for management of Cytospora canker.**

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-actions (MOA) with high resistance risk before rotating to a fungicide with a different MOA (Code number); for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different MOA (Code number).

[2] Fruit brown rot treatments for fungicides in FRAC Codes 1, 2, 3, 17, 7/11 are improved with the addition of 1.5% to 2% light summer oil. If applied in summer, fruit will lose their waxy bloom and look red. They will dry to normal color. Use a adjuvant sticker as an alternative to the light summer oil (e.g., NuFilm, Tactic, Adhere)

[3] Strains of *Monilinia fructicola* and *M. laxa* resistant to Topsin-M and T-Methyl have been reported in some California prune orchards. No more than two applications of Topsin-M or T-Methyl should be made each year. Resistant strains of the jacket rot fungus, *Botrytis cinerea*, and powdery mildew fungi have been reported in California on crops other than almond and stone fruits and may have the potential to develop in prune with overuse of fungicides with similar chemistry. Subpopulations of both *Monilinia* spp. have been shown to be resistant to AP (FRAC 9) fungicides on prune in CA.

[4] To reduce the risk of resistance development, start treatments with a fungicide with a multi-site mode of action; rotate or mix fungicides with different mode-of-action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.

[5] Blossom blight only; not registered for use after petal fall.

[6] High summer temperatures and relative humidity reduce efficacy.

[7] Do not use in combination with or shortly before or after oil treatment.

[8] Do not use after jacket (shuck) split.

[9] Do not use sulfur, captan, or chlorothalonil in combination with or shortly before or after oil treatment.

## PRUNE - FUNGICIDE EFFICACY - BIOCONTROLS AND NATURAL PRODUCTS

| | | Brown rot | | | |
|---|---|---|---|---|---|
| **Trade name[1]** | **Biological or natural product (FRAC code)[2]** | **blossom** | **fruit rot** | **Russet scab** | **Rust** |
| Oso | polyoxin-D (19) | 3 | 3 | NL | NL |
| Botector | *Aureobasidium pullulans* (BM 02) | 3 | 2 | NL | NL |
| ProBLAD Verde* | *Lupinus albus* (BM 01) | 3 | 2 | NL | NL |
| EcoSwing | *Swinglea glutinosa* (BM 01) | 3 | 2 | NL | NL |
| Dart | capric and caprylic acids (NC) | 3 | 2 | NL | 3 |
| Guarda[3], Thyme Guard | thyme oil (BM 01) | 2 | 2 | NL | 1 |
| Double Nickel 55 | *Bacillus amyloliquefaciens* D747 (BM 02) | 2 | 0 | NL | NL |
| Serifel | *B. amyloliquefaciens* MBI600 (BM 02) | 2 | 1 | NL | NL |
| Taegro 2** | *B. amyloliquefaciens* FZB (BM 02) | 2 | 1 | NL | NL |
| Sonata | *B. pumilis* QST2808 (BM 02) | 2 | 1 | NL | NL |
| Serenade | *B. subtilis* QST 713 (BM 02) | 2 | 1 | NL | NL |
| Aviv | *B. subtilis* IAB/BS03 (BM 02) | 2 | 1 | NL | NL |
| Oxidate 5, Zerotol HC | peroxyacetic acid (oxidizer) | 2 | 2 | NL | 1 |
| Cinnerate, Seican, Cinnacure | cinnamaldehyde (BM 03)/ cinnamon oil (BM 03) | 2 | 0 | NL | 2 |
| Trilogy, Terraneem** | neem oil (BM 01) | 1 | 1 | 2 | 2 |
| Actinovate AG | *Streptomyces lydicus* (BM 02) | 1 | 1 | NL | NL |
| Sulfur | sulfur (M 02) | 1 | 1 | 0 | 3 |
| Copper | copper (M 01) | 1 | 1 | 0 | 1 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data. NR=not registered after bloom.

*** Registration pending in California.**

[1] Treatments arranged by performance on brown rot. Some products are not OMRI approved (e.g., Cinnacure). Check the labels.

2 FRAC Codes are provided as BM- or P-number codes. NC = not coded in FRAC. In general, sulfur compounds are fungicidal and may affect applications of fungal biocontrols (e.g., Botector); whereas copper may affect applications of bacterial biocontrols (e.g., Actinovate, Double Nickel 55, and Serenade). Rotations must consider these factors.

[3] Not organically approved.

## PRUNE (DRIED PLUM): TREATMENT TIMING

**Note: Timings listed are effective but not all may be required for disease control. Timings used will depend upon orchard history of disease, length of bloom, and weather conditions each year.**

| Disease | Green bud | White bud | Full bloom | May | June | July |
|---|---|---|---|---|---|---|
| Brown rot[1] | 2 | 3 | 3 | 0 | 1 | 2 |
| Russet scab[2] | 0 | 0 | 3 | 0 | 0 | 0 |
| Rust[3] | 0 | 0 | 0 | 1 | 2 | 3 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective

[1] Flowers are susceptible beginning with the emergence of the sepals (green bud) until the petals fall but are most susceptible when open.
[2] A physiological disorder; no pathogens involved.
[3] More severe when late spring rains occur.

## STRAWBERRY: FUNGICIDE EFFICACY - CONVENTIONAL

| Fungicide[1] | Resistance risk (FRAC)[2] | Gray mold | Powdery mildew | Anthrac-nose | Rhizopus/ Mucor rot | Phytophthora diseases[3] | Common leaf spot | Angular leaf spot |
|---|---|---|---|---|---|---|---|---|
| Miravis Prime | medium (7/12) | 5 | 5 | 3 | NL (4) | NL | NL | NL |
| Luna Sensation | medium (7/11) | $5^{R}$ | 5 | $3^{R}$ | 2 | NL | ND | NL |
| Merivon | medium (7/11) | $5^{R}$ | $5^{R}$ | ND | NL (4) | NL | 0 | NL |
| Kenja | high (7) | 5 | 3 | ND | NL (2) | NL | ND | NL |
| Fontelis | high (7) | $5^{R}$ | $4^{R}$ | NL | NL | NL | NL | NL |
| Luna Privilege **(foliar)/ Velum One (soil)[4] | high (7) | 5/NL | 5/3 | NL | ND | ND | ND | NL |
| Pristine | medium (7/11) | $5^{R}$ | $4^{R}$ | ND | NL | NL | 0 | NL |
| Switch[5] | medium (9/12) | $5^{R}$ | 2 | 4 | 4 | NL | NL | NL |
| Cannonball[5] | high (12) | $5^{R}$ | NL | 4 | 4 | NL | NL | NL |
| Elevate | high (17) | $5^{RR}$ | NL (0) | NL (0) | NL | NL | NL (0) | NL |
| Inspire Super | medium (3/9) | $5^{R}$ | 5 | 4 | 5 | NL | ND | NL |
| Regev | medium (3/BM 01) | 3 | 5 | 4 | 5 | NL | ND | NL |
| Luna Tranquility | medium (7/9) | 4 | 5 | NL | 1 | NL | ND | NL |
| Topsin-M, T-Methyl, Incognito, etc.[6] | high (1) | $1^{RR}$ | 4 | 0 | NL | NL | NL (3) | NL |
| Protocol | medium (1/3) | $4^{R}$ | $4^{R}$ | 3 | NL | NL | 4 | NL |
| Captevate** | medium (M 04/17) | $4^{R}$ | NL | 4 | NL | NL | NL | NL |
| Rovral[7], Meteor[7], Iprodione**, Nevado** | high (2) | $4^{R}$ | NL (0) | 0 | NL | NL | 0 | NL |
| Ph-D, Oso | high (19) | 3 | 4 | 3 | NL | NL | NL | NL |
| Intuity | high (11) | $1^{RR}$ | $2^{R}$ | NL | NL | NL | NL (0) | NL |
| Quilt Xcel, Avaris 2XS, etc. | medium (3/11) | NL $(3)^{R}$ | $5^{R}$ | $0^{R}$ | NL (0) | NL | NL | NL |
| Scala | high (9) | 3 | NL (2) | NL | NL | NL | NL | NL |
| Quintec | high (13) | NL (3) | $5^{R}$ | NL ($4^{R}$) | NL (0) | NL | NL (0) | NL |
| Quadris (Abound discont.), Acadia, Arius | high (11) | $1^{RR}$ | $3^{R}$ | $4^{R}$ | NL (2) | NL | NL | NL |
| Evito* | high (11) | $1^{RR}$ | $3^{R}$ | $2^{R}$ | NL | NL | NL | NL |
| Flint Extra | high (11) | $1^{RR}$ | $4^{R}$ | $2^{R}$ | NL | NL | NL | NL |
| Thiram | low (M 03) | 2 | NL (0) | 3 | NL | NL | 0 | NL |
| Captan | low (M 04) | 2 | NL (0) | NL (2) | NL (2) | NL | NL (0) | NL |
| Cabrio | high (11) | $1^{RR}$ | $2^{R}$ | $3^{R}$ | NL (2) | NL | 0 | NL |
| Quadris Top, Acadia ESQ[8] | medium (3/11) | NL $(2)^{R}$ | $5^{R}$ | $4^{R}$ | NL | NL | 3 | NL |
| Bumper**, Tilt, etc. | high (3) | NL (0) | $5^{R}$ | NL (3) | NL (0) | NL | 4 | NL |
| Mettle, Perissim**, etc. | high (3) | NL | $5^{R}$ | NL | NL | NL | ND | NL |
| Procure | high (3) | NL | $5^{R}$ | NL (2) | NL | NL | NL (0) | NL |
| Rally | high (3) | NL (0) | $5^{R}$ | NL (3) | NL | NL | 4 | NL |
| Rhyme[9] | high (3) | NL (0) | $5^{R}$ | NL | NL | NL | NL | NL |
| Torino | high (U 06) | NL | $5^{R}$ | NL | NL | NL | NL | NL |
| Gatten* | high (U 13) | NL | 5 | NL | NL | NL | NL | NL |
| Sulfur | low (M 02) | NL | 4 | NL | NL | NL | NL | NL |

| Fungicide[1] | Resistance risk (FRAC)[2] | Gray mold | Powdery mildew | Anthrac-nose | Rhizopus/ Mucor rot | Phytophthora diseases[3] | Common leaf spot | Angular leaf spot |
|---|---|---|---|---|---|---|---|---|
| Cevya | high (3) | NL | 4[R] | NL | NL | NL | NL | NL |
| Zivion S[5] | low (48) | NL (0) | NL | 4 | NL | NL | NL | NL |
| Fungi-Phite, K-Phite, ProPhyt, etc. | high (P 07/33) | NL | 0 | 0 | NL | 4 | NL | NL (2) |
| Orondis Gold | high (4/49) | NL | NL | NL | NL | 4 | NL | NL |
| Aliette[3,9], Legion** | high (P 07/33) | NL | NL | NL | NL | 4 | NL | NL |
| Ridomil Gold SL, Ultra Flourish, etc.[9] | high (4) | NL | NL | NL | NL | 4 | NL | NL |
| Copper, etc.[10] | low (M 01) | 0 | 0 | 0 | 0 | 0 | 0 | 4[10] |
| Actigard | high (P 01) | NL | NL | NL | NL | NL | NL | 3 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, ND = no data.

[R] Resistance in this pathogen has been documented but performance is not fully compromised.
[RR] High level of resistance documented in this pathogen and performance is significantly compromised.
* Registration pending in California.
** Not registered, label withdrawn or inactive in California.

[1] To reduce the risk of resistance development, start fungicide treatment with a multi-site mode of action; rotate or mix fungicides with different mode of action FRAC numbers for subsequent applications, use labeled rates (preferably the upper range), and limit the total number of applications per season.
[2] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). NC = not coded in FRAC. To minimize resistance, make no more than one application of a fungicide with a "high" or "medium" resistance risk of the same FRAC code before rotating to a fungicide with a different FRAC code. Resistance risk determined based on single-site = high risk; premix = medium risk; multi-site = low risk.
[3] Efficacy rating for soil applied control of Phytophthora crown rot and leather rot of fruit.
[4] Velum One is a fluopyram formulation for chemigation. Soil applications are designed for nematode management but may also suppress powdery mildew.
[5] Apply as a transplant dip after digging/harvesting and prior to cold storage (nursery use) or prior to planting (field use).
[6] Generic products may not be all listed and "etc." indicates that other products may be available that have the same active ingredient.
[7] Apply as preplant dip or foliar spray; do not apply after first fruiting flower.
[8] Not for use in nurseries, on nursery transplants, or greenhouses (check label for details).
[9] Foliar applications provide systemic treatment.
[10] Apply at low rates since phytotoxicity (reddening of older leaves, slow growth and yield reduction) has been documented with repeated sprays.

## STRAWBERRY - FUNGICIDE EFFICACY - BIOCONTROLS AND NATURAL PRODUCTS

| Fungicide trade names | Active ingredient | Resistance risk (FRAC)[1] | Gray mold | Powdery mildew | Anthrac-nose | Rhizopus/ Mucor rot | Phytophthora diseases[2] | Common leaf spot | Angular leaf spot |
|---|---|---|---|---|---|---|---|---|---|
| Oso | Polyoxin D zinc salt | medium (19) | 3 | 4 | 3 | NL | NL | ND | NL |
| Microthiol Disperss, etc.[3] | sulfur | low/ (M 02) | NL | 4 | NL | NL | NL | NL | NL |
| All Phase | potassium sorbate | low (NC) | ND | 4 | ND | NL | NL | ND | ND |
| Serenade ASO, etc.[3] | *Bacillus subtilis* QST 713 | low (BM 02) | 0 | 3 | 0 | NL (0) | NL (0) | NL (0) | NL |
| Sonata | *Bacillus pumilis* QST 2808 | low (BM 02) | NL (0) | 3 | 0 | NL | NL | NL | NL |
| Timorex Act | tea tree oil | low (BM 01) | 0 | 3 | ND | 0 | ND | NL | ND |
| ProBLAD Verde[3] | *Lupinus albus* | low/(BM 01) | 0 | 3 | ND | ND | NL | ND | NL |
| Aviv, BACIX, etc. | *Bacillus subtilis* IAB/BS03 | low (BM 02) | 0 | 3 | ND | NL | ND | ND | NL |
| Kaligreen, MilStop, etc. | potassium bicarbonate | low (NC) | 0 | 3 | NL | NL | NL | NL | NL |
| M-Pede, Des-X, etc.[3] | potassium salts of fatty acids | medium (NC) | NL | 2 | NL | NL | NL | NL | NL |
| Double Nickel | *Bacillus amylo-liquefaciens* D747 | low (BM 02) | 0 | 2 | 0 | NL | 0 | NL | 1 |
| Actinovate | *Streptomyces lydicus* WYEC 108 | low (BM 02) | 0 | 2 | NL | NL | 0 | NL | 1 |
| Serifel | *Bacillus amylo-liquefaciens* MBI 600 | low (BM 02) | 0 | 2 | 0 | NL | 0 | ND | 2 |
| Taegro 2 | *Bacillus amylo-liquefaciens* FZB24 | low (BM 02) | 0 | 2 | 0 | NL | ND | NL | NL (2) |

| Fungicide trade names | Active ingredient | Resistance risk (FRAC)[1] | Gray mold | Powdery mildew | Anthrac-nose | Rhizopus/ Mucor rot | Phytophthora diseases[2] | Common leaf spot | Angular leaf spot |
|---|---|---|---|---|---|---|---|---|---|
| Theia | *Bacillus subtilis* AFS032321 | low (BM 02) | 0 | 2 | 0 | NL | 0 | NL | ND |
| Regalia | *Reynoutria sachalinensis* extract | low (P5) | 0 | 2 | ND | NL | ND | NL | NL |
| Stargus | *Bacillus amylo-liquefaciens* F727 | low (BM 02) | 0 | 1 | ND | NL | NL (1) | NL (1) | NL (1) |
| Copper, etc.[4] | copper | low (M 01) | 0 | 0 | 0 | 0 | 0 | 0 | 4[5] |
| Cinnerate, Seican, Cinnacure | cinnamaldehyde (cinnamon oil) | low (BM 03) | 0 | ND | NL | ND | NL | NL | NL |
| Oxidate 5.0, Jet-Ag, etc. | hydrogen peroxide; peroxyacetic acid | low (NC) | 0 | 0 | NL | NL | NL | NL | 2 |
| Procidic, etc. | citric acid | low (NC) | 0 | NL | NL | NL | 0 | NL | NL |
| Rango | cold pressed neem oil | low (NC) | 2 | ND | ND | NL | 0 | 0 | NL |
| Botector | *Aureobasidium pullulans* DSM 14940; DSM 14941 | low (BM 02) | 0 | NL | ND | NL (1) | NL | NL | NL |
| Howler | *Pseudomonas chlororaphis* AFS009 | low (BM 02) | 0 | NL (2) | NL | NL | ND | ND | 0 |
| Veg'Lys | garlic oil | Low (BM 01) | 0 | NL | 0 | NL | 0 | 0 | ND |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, ND = no data.

[1] Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). NC = not coded in FRAC.
[2] Efficacy rating for soil applied control of Phytophthora crown rot and leather rot of fruit.
[3] Generic products may not be all listed and "etc." indicates that other products are available that have the same active ingredient.
[4] Apply at low rates since phytotoxicity (reddening of older leaves, slow growth and yield reduction) has been documented with repeated sprays.

## STRAWBERRY: TREATMENT TIMING

**Note: Not all indicated timings may be necessary for disease control.**

| | | | At planting | | Preharvest[1] | |
|---|---|---|---|---|---|---|
| Disease | Preplant fumigation[2] | Clean nursery stock | Dips or water washing | Before overhead irrigations | Foliar | Fruit |
| Angular leaf spot | 1 | 3 | 1 | 3 | 1 | 0 |
| Anthracnose[3] | 3 | 3 | 3 | 1 | 1 | 3 |
| Botrytis fruit rot/gray mold[3] | 0 | 3 | 0 | 1 | 2 | 3 |
| Common leaf spot[3] | 1 | 3 | 3 | 3 | 3 | 1 |
| Fusarium wilt | 3 | 2 | 0 | 0 | 0 | 0 |
| Leather rot[4] | 3 | 0 | 0 | 2 | 0 | 2 |
| Macrophomina crown rot | 3 | 2 | 0 | 0 | 0 | 0 |
| Mucor fruit rot | 0 | 0 | 0 | 1 | 1 | 3 |
| Powdery mildew[3] | 0 | 3 | 0 | 0 | 3 | 1 |
| Phytophthora crown rot[4] | 3 | 1 | 0 | 2 | 1 | 0 |
| Red steele | 2 | 2 | 0 | 1 | 2 | 0 |
| Rhizopus rot (Leak) | 0 | 0 | 0 | 0 | 0 | 3 |
| Verticillium wilt | 3 | 2 | 0 | 0 | 0 | 0 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective

[1] Preharvest treatments include applications of fungicides before heavy fog, dews, or rain.
[2] Preplant fumigation includes chloropicrin, 1,3-dichloropropene/chloropicrin or chloropicrin followed by metam sodium or metam potassium. Alternatively, make solitary applications of 1,3-dichloropropene/chloropicrin or chloropicrin.
[3] To reduce risk of fungicide resistance development, use an integrated program that includes a rotation of fungicides with different modes of action.

## WALNUT: BACTERICIDE AND FUNGICIDE EFFICACY – CONVENTIONAL

| | Resistance risk (FRAC#)[1] | Walnut blight[2] | Anthrac-nose | Botryo-sphaeria blight*** | Kernel mold*** |
|---|---|---|---|---|---|
| ***Bactericides*** | | | | | |
| Copper + mancozeb (Manzate, Dithane) | low (M 01 + M 03) | 5 | 5 | 3(2) | 0 |
| Kasumin + copper | low (24 + M 01) | 5 | 0 | 0 | 0 |
| Kasumin + mancozeb | low (24 + M 03) | 5 | 0 | 0 | 0 |
| Syllit + copper | high (U 12 + M 01) | 5 | ND | 0 | 0 |
| Syllit + Kasumin | high (U 12 + 24) | 4 | ND | 0 | 0 |
| Bordeaux[2] | low (M 01) | 4 | 0 | 0 | 0 |
| Fixed coppers[2,3] | medium (M 01) | 4 | 0 | 0 | 0 |
| Zinc sulfate + copper + hydrated lime (Zinc-copper Bordeaux) | low (M 01) | 4 | 0 | ND | 0 |
| Kasumin | high (24) | 4 | 0 | 0 | 0 |
| Copper + mancozeb + surfactant[4] | low (M 01 + M 03) | 2 | ND | ND | 0 |
| | | | | | |
| ***Fungicides*** | | | | | |
| Syllit | high (U 12) | 3 | 5 | ND | ND |
| Luna Experience | medium (3/7) | 0 | 5 | 5 | 3 |
| Luna Experience + Regalia | med. (3/7 + P 05) | 3(2) | 5 | 5 | ND |
| Merivon | medium (7/11) | 0 | 5 | 5 | 3 |
| Pristine | medium (7/11) | 0 | 5 | 5 | ND |
| Quash | high (3) | 0 | 5 | 5 | ND |
| Inspire Super | medium (3/9) | ND | 4 | ND | ND |
| Regev | medium (3/BM 01) | ND | 4 | ND | ND |
| Quilt Xcel | medium (3/11) | 0 | 5 | 5 | ND |
| Luna Sensation | medium (7/11) | 0 | 5 | 5 | ND |
| Quadris Top, Acadia ESQ | medium (3/11) | 0 | 5 | 4 | ND |
| Ph-D | medium (19) | 0 | 5 | 4 | ND |
| K-Phite[3] | low (P 07/33) | 2 | ND | 5 | ND |
| Fontelis | high (7) | 0 | ND | 4 | ND |
| Cevya | high (3) | 0 | ND | 4 | ND |
| Teb, Tebuconzole**, Toledo | high (3) | 0 | ND | 4 | 3 |
| Miravis Prime | medium (7/12) | 0 | ND | 4 | ND |
| Miravis Duo | medium (3/7) | 0 | ND | 4 | ND |
| Viathon | medium (3, P 07/33) | 2 | ND | 4 | ND |
| Rhyme | high (3) | 0 | 5 | 4 | 3 |
| Quadris, Acadia, (Abound discontinued) | high (11) | 0 | ND | ND | ND |
| Luna Privilege** | high (7) | 0 | ND | ND | ND |

## WALNUT: BACTERICIDE EFFICACY – BIOCONTROLS AND NATURAL PRODUCTS

| Organic treatments | FRAC code[1] | Resistance risk | Walnut blight[2] | Botryosphaeria blight*** |
|---|---|---|---|---|
| Actinovate | BM 02 | low | 2 | NL |
| Blossom Protect | BM 02 | low | 3 (2) | NL |
| Bordeaux[2] (organic with approved copper) | M 01 | medium | 4 | 3 (2) |
| Cinnerate, Seican, Cinnacure | BM 01 | low | 3 | ND |
| Fixed coppers[2,3] (organic with approved copper) | M 01 | medium | 4 | 3 (2) |
| Guarda, Thyme Guard | BM 01 | low | 2 | 2 |
| Howler | BM 02 | low | ND | 3 |
| Regalia | BM 01 | low | 2 | 3 |
| Regalia + Copper (organic with approved copper) | BM 01+M 01 | low | 3 (2) | 3 |
| Serenade (organic) | BM 02 | low | 2 | 2 |
| Zinc sulfate + copper + hydrated lime (Zinc Bordeaux) | M 01 | medium | 4 | 2 |

**Rating:** 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label, and ND = no data.

* **Registration pending in California**
** **Not registered, label withdrawn or inactive in California**
*** **Research is ongoing to determine the most efficacious materials and the optimum timing of treatments for management of Botryosphaeria blight and kernel mold of walnut. Fungicides rated for kernel mold may have to be mixed (e.g., Merivon - FC 7/11 and Teb-FC 3) and rotated to another fungicide (e.g., Rhyme - FC-3). This mixture rotation is 4 (good and reliable).**

[1] Code numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions (for more information, see http://www.frac.info/). Fungicides with a different Code number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-actions (MOA) with high resistance risk before rotating to a fungicide with a different MOA (Code number); for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different MOA (Code number).
[2] Copper resistance occurs within sub-populations of *Xanthomonas arboricola* pv. *juglandis*.
[3] Phytotoxicity may occur. For fixed coppers, injury can be reduced by the addition of lime or agricultural oils to the tank mixture.
[4] A single application with a surfactant is not recommended because of an increase in bud populations that may increase disease later in the season or in subsequent years.

## WALNUT: TREATMENT TIMING

| Disease | Catkin emerg-ence | Terminal bud break | 7–10 day intervals | Apr. | May | June | July | Aug. (3-wk before hull split) | Sept. (20–30% hull split) | Oct. | Nov. (1st wk) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Anthracnose[1] | 0 | 0 | 3 | 2[4] | 3 | 2 | 0 | 0 | 0 | 0 | 0 |
| Botryosphaeria blight | 0 | 0 | 3 | 1 | 2 | 3 | 3 | 2 | 0 | 1 | 1 |
| Kernel mold[2] | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Walnut blight [3,4,5] | 2[5] | 3 | 3 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |

**Rating:** 3 = most effective, 2 = moderately effective, 1 = least effective, and 0 = ineffective

[1] Make the first application when the size of the expanding leaves is about half of its final size. This first application stage is critical.
[2] Timing for kernel mold is based on a mixture rotation of Merivon (FC 7/11) and Teb (FC 3) followed by Rhyme (FC-3) at the timings indicated. This mixture rotation is '5' based on the ratings in the efficacy table above.
[3] A temperature-leaf wetness model (e.g., XanthoCast) is available for determining optimum timing of bactericide applications.
[4] Late spring rains are less conducive to disease, provided bloom is not delayed by low chilling.
[5] Male and female flowers are susceptible beginning with their emergence, depending on wetness and temperatures conducive to disease development.