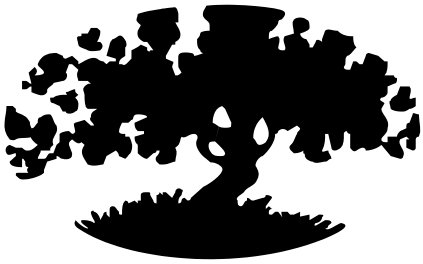
FUNGICIDES, BACTERICIDES, BIOCONTROLS, AND NATURAL PRODUCTS FOR DECIDUOUS TREE FRUIT AND NUT, CITRUS, STRAWBERRY, AND VINE CROPS IN CALIFORNIA 2022



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

James E. Adaskaveg, Professor
University of California, Riverside

Themis Michailides, Plant Pathologist
University of California, Davis/Kearney Agricultural Research and Extension Center

Akif Eskalen, Professor of Cooperative Extension in Plant Pathology
University of California, Davis

Special thanks to **Larry Bettiga**, Farm Advisor, UCCE Monterey Co., for his review of grape fungicides and **Gerald Holmes**, Director of the Strawberry Center, CalPoly, for his review of strawberry fungicides

UC Davis, Dept. of Plant Pathology	**UC Kearney Agricultural Research and Extension Center**
plantpathology.ucdavis.edu	kare.ucanr.edu/programs/Plant_Pathology
UC Statewide IPM Program	**UC Riverside, Dept. of Microbiology and Plant Pathology**
ipm.ucanr.edu	https://cfn-fungicides.ucr.edu

UC Davis, Dept. of Plant Pathology	**UC Kearney Agricultural Research and Extension Center**
plantpathology.ucdavis.edu	kare.ucanr.edu/programs/Plant_Pathology
UC Statewide IPM Program	**UC Riverside, Dept. of Microbiology and Plant Pathology**
ipm.ucanr.edu	https://cfn-fungicides.ucr.edu

TABLE OF CONTENTS

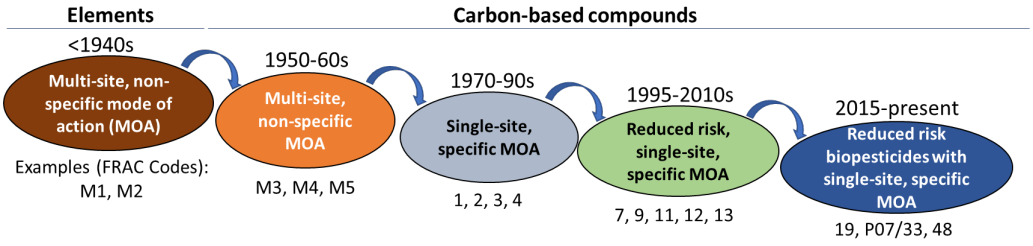
FUNGICIDES, BACTERICIDES, BIOCONTROLS, AND NATRUAL PRODUCTS

fun·gi·cide (ˈfənjə-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 (bī̆ō-kən-trōl̆). 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 natrual 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.

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:



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 http://www.codexalimentarius.net/pestres/data/index.html. In the United States, the website for viewing Global MRLs is https://www.globalmrl.com 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. Chlorpyrifos and other 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 UC-IPM 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).

---

[1] Mussen, E. and Brandi, G. 2010. Relationships of Honey Bees and Pesticides. http://entomology.ucdavis.edu/files/147612.pdf (accessed 12/14/2015)

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. 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.

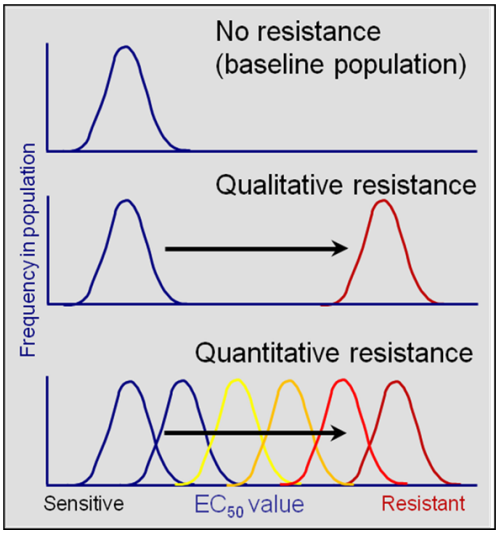


Fig. 1. Frequency distribution of EC_{50} values in fungal populations with no resistance, with qualitative resistance (e.g., MBC fungicides), or with quantitative resistance (e.g., DMI fungicides). Only one population with a distinct baseline range of sensitivities is observed in a sensitive population (no resistance). For qualitative resistance, a shift in fungicide sensitivity is observed by the presence of two distinct populations: a sensitive baseline population 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, frequencies 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)[2].

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 3 1.5	12 6 3	18 9 4.5	High = 1, Medium = 0.5, Low = 0.25
3, 9, 12	Medium = 4	4 2 1	8 4 2	12 6 3	High = 1, Medium = 0.5, Low = 0.25
M1-5, 16.1, P1-7	Low = 1	1 0.5 0.25	2 1 0.5	3 1.5 0.75	High = 1, Medium = 0.5, 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 jaapii, Glomerella cingulata, Phyllosticta citricarpa, Sphaerotheca macularis, Venturia carpophila, V. oleaginea, V. cerasi, V. pirina, Wilsonomyces carpophilus, Colletotrichum, Erysiphe, Neofabraea* spp.	*Alternaria, Botrytis, Plasmopara, Podosphaera* spp., *Venturia inaequalis*	

*- Modified according to Kuck (2005)[3] and FRAC Pathogen Risk List (2019)[4] for 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.

---

[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.

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 (M1)	No	multi-site	low
sulfur	various	Inorganic (M2)	No	multi-site	low
mancozeb	Dithane, Manzate, Penncozeb	Carbamate (EBDC)[2] (M3)	No	multi-site	low
ferbam**	Ferbam	Carbamate (DMDC)[3] (M3)	No	multi-site	low
thiram	Thiram	Carbamate (DMDC)[3] (M3)	No	multi-site	low
ziram	Ziram	Carbamate (DMDC)[3] (M3)	No	multi-site	low
captan	Captan	Phthalimide (M4)	No	multi-site	low
chlorothalonil	Bravo,Chorothalonil, Echo,Equus	Chloronitrile (M5)	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,Iprodione, Nevado	Dicarboximide (2)	Yes	single-site?	medium
difenoconazole	Inspire,Laguna	DMI[5]-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
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	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,Sercadis	SDHI (7)	No	single-site	high[4]
penthiopyrad	Fontelis	SDHI (7)	No	single-site	high[4]
pydiflumetofen	Adepidyn,check	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]

Single active ingredient	Trade name	Class (FRAC number)[1]	Systemic action	Mode of action	Resistance potential
azoxystrobin	Abound	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]
fludioxonil	Scholar,Cannonball	Phenylpyrrole (12)	No	few (multi-site)	medium
quinoxyfen	Quintec	Quinoline (13)	No	single-site	medium
dicloran	Botran/Allisan	Aromatic hydrocarbon (14)	Slight	single-site	medium
fenhexamid	Elevate	Hydroxyanilide (17)	No	single-site	high[4]
fenpyrazamine	Protexio	Hydroxyanilide (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, phosphorous acid	Fungi-Phite, Prophyt	Phosphorous acid and salts (P07,33)	Yes	unknown (multi-site?)	medium
polyphosphite	K-Phite	Polyphosphite (P07,33)	Yes	unknown	low
fosetyl-Al	Aliette,Linebacker, Legion	Ethyl phosphonates (P07,33)	Yes	unknown	low
mandipropamid	Revus	Cell wall synthesis inhibitor (40)	Yes?	single-site	high
fluopicolide	Presidio	Benzamide (43)	Yes?	single-site	high
natamycin	BioSpectra/Zivion S	Polyene-ergosterol binding (48)	No	single-site	low
oxathiapiprolin	Orondis	Oxysterol binding proteins (OSBPI) (49)	Yes	single-site	high
fluoxapiprolin	To be annouced	OSBPI (49)	Yes	sngle-site	high
pyriofenone	Prolivo	Actin disrupter (50)	No	single-site	high
metrafenone	Vivando	Actin disrupter (50)	No	single-site	high?
dodine	Syllit	Guanidine (U12)	Yes	unknown	medium
flutianil	Gatten	Thiazolidine (U13)	No	unknown	high?

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

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 (M4)/ hydroxyanilide (17)	No	multi-site/single-site	medium
chlorothalonil/ tebuconazole	Catamaran	chloronitrile (M5)/ DMI-triazole (3)	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 (3)/SDHI (7)	Yes?	single-site/ single-site	medium
difenoconazole/ pydiflumetofen	Miravis Duo	DMI-triazole (3)/ SDHI (7)	Yes?	single-site/ single-site	medium
fluopyram/ tebuconazole	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
isofetamid/ tebuconazole	Fervent	DMI-triazole (3)/ SDHI (7)	Yes?	single-site/ single-site	medium
fluxapyroxad/ mefentrifluconazole	Mibelya (pending) (formerly 752)	DMI-triazole (3)/SDHI (7)	Yes?	single-site/ single-site	medium -site/ -site
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
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 (P07,33)	Yes?	single-site multi-site?	medium
difenoconazole/ tea tree oil	Regev	DMI-triazole (3) / tea tree oil (46)	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
pyraclostrobin / boscalid	Pristine	SDHI (7)/QoI (11)	Yes?	single-site / single-site	high
cyprodinil/ fludioxoni	Switch	AP (9) / Phenylpyrrole (12)	No/ Slight	single-site/ single-site	medium

‡ 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 this characteristic may not have been proven experimentally using more rigorous assays (e.g., radioactively labeled compounds).

[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.

[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 (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, Phyton 27AG, 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).

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
agriphages	AgriPhage-Fireblight	biological - bacteriophages	No	BM 02, parasites	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	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	BM 02	low
blend of fruit acids, flavonoids, chelators, & wetting agents	Citrox BC	plant extract	No	BM 01	low
boric acid and latex paint	B-lock	inorganic salt	No	NC	low
calcium metalosate	Metalosate Calcium	inorganic salt	No	BM 01	low
capric and caprylic acids	Dart	organic acids	No	BM 01	low
cinnamaldehyde	Cinnacure	natural product	No	BM 01	low
cinnamaldehyde	Valero	natural product	No	BM 01	low
cinnamon oil + potassium oleate	Cinnerate	natural product	No	BM 01	low
clove, rosemary, peppermint oils	EF-400	natural plant oils	No	BM 01, membrane disruption	low
Colonostachys rosea CR-7	BVT-CR-7	biological-fungal	No	BM 02	low
essential oils	BacStop	natural plant oils	No	BM 01	low
essential oils	Vitiseal	natural plant oils	No	BM 01	low
essential oils	Mevalone	natural plant oils	No	BM 01	low
cinnamon oil and garlic	Gargoil	oil	No	BM 01	low
GABA/L-glutamic acid	Auxigro	SAR2-protein	Yes	BM 01, host resistance	unknown
glucosamine protein	Elexa	SAR2-protein	Yes	BM 01, host resistance	unknown

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
harpin	Messenger, Employ	SAR2-protein	Yes	P unspecified, host resistance	unknown
hydrogen dioxide in acetic acid (peroxyacetic acid)	OxiDate, StorOx, Perasan	oxidizer	No	oxidation	very low
Kasugamycin	Kasumin	antibiotic	Yes	24, protein synthesis	high
low range oil	Omni Supreme	oil	No	various	low
low range oil	Purespray	oil	No	various	low
Lupinus albus	ProBLAD Plus/ Fracture	natural product	Yes	BM 01	low
mineral oil	JMS Stylet oil	oil	No	various	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, Terraneem, Rango	natural oil	No	BM 01	low
orange oil	Vintre	natural plant 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
petroleum oil	oil		No	various	low
pinolene	Vapor Gard, NuFilm-P, -17	terpenic polymer	No	film-forming	low
plant host defense activator	ProAlexin	plant extract	Yes	BM 01, bioflavonoid stimulator	low
plant oils (clove, rosemary, thyme, tea tree)	Aleo, BacStop, EF-400, Gargoil, Sporan, 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/ sodium lauryl sulfate	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

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
Quillaja saponaria	Quiponin	natural product	No	BM 01	low
Reynoutria sachalinensis	Regalia	natural product	No	BM 01, P 05	low
sanitizers[3] (Oxidate, etc.)	various	oxidizer	No	oxidizer	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 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	BM 01, P 06	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.

[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.

[2] SAR = Systemic acquired resistance induced in host

[3] Sanitizers such peroxyacetic acid (e.g., Oxidate, Zerotol, Perasan A) 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* *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* and *Phlyctema vagabunda*	olive
Olive knot	*Pseudomonas savastanoi* 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* *Podosphaera leucotricha* *Podosphaera clandestina* *Podosphaera tridactyla* *Podosphaera* (=*Sphaerotheca*)	grapevine almond, apple, peach, nectarine cherry apricot, cherry, plum, prune, peach strawberry

	macularis *Podosphaera* (=*Sphaerotheca*) *pannosa*	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

‡ 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.
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
BlightBan	*Pseudomonas fluorescens* A506	J.R. Simplot/Plant Health Tech.	contact	BM 02
Bio-Tam 2.0	*Trichoderma asperellum* (ICC 012), *T. gamsii* (ICC 080)	Isagro USA	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
CR-7	*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	BM 02, 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

Taegro	*Bacillus amyloliquefaciens* FZB24	Syngenta Crop Protection	contact	BM 02
Theia	*Bacillus subtilis* AFS032321	AgBiome Innovations	contact	BM 02
Vintec	*Trichoderma atroviride* SC1	AMVAC Chemical Corp.	contact	BM 02

‡ 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.

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
All-Phase	potassium sorbate and sodium lauryl sulfate	Circadian Crop Sciences	contact	NC
Aleo	garlic oil	Brandt Consolidated, Inc.	contact	BM 01
Armicarb	sodium bicarbonate	Helena Chemical Co.	contact	NC
Armour-Zen	chitosan	BotryZen	systemic	P-unspecified
B-Lock	boric acid and latex paint	Nutrient Technologies	contact	NC/paint
Bac-Stop	clove, rosemary, peppermint and thyme oils	MarVista Resources	contact	BM 01
Cinnacure	cinnamaldehyde	Pro-Guard, Inc.	contact	BM 01
Cinnerate	cinnamon oil+ potassium oleate	Sym Agro	contact	BM 01
Citrox BC	plant extract	Citrox Limited	contact	BM 01
Dart	capric/caprylic acid	Westbridge Ltd.	contact	BM 01
EcoSwing	*Swinglea glutinosa*	Gowan Company	contact	BM 01
EF400	clove, rosemary, peppermint oils	USAgriTech, Inc.	contact	BM 01
Gargoil	cinnamon oil and garlic	Westbridge Ltd.	contact	BM 01
JMS Stylet Oil	mineral oil	JMS Flower Farms	contact	oil
Kaligreen	potassium bicarbonate	Toagosei/UPL OpenAg	contact	NC
Metalosate Calcium	calcium metalosate	Albion Laboratories	contact	NC
Metalosate Potassium	potassium metalosate	Albion Laboratories	contact	NC
Mevalone	essential oils	K&NE Earth Matters	contact	BM 01
Milstop	potassium bicarbonate	BioWorks	contact	NC
M-Pede Insecticidal Soap	potassium salts	Dow AgroSciences	contact	NC
Omni Supreme	low range oil	Helena Chemical	contact	oil
Prev-am	sodium tetraborohydrate	ORO Agri. Inc.	contact	NC
ProAlexin	plant extract	Citrox Limited	systemic	BM 01
ProBLAD Verde	*Lupinus albus*	Sym Agro	contact	BM 01
Procidic	citric acid	Greenspire Global, Inc.	contact	BM 01
Purespray	mineral oil	PetroCanada	contact	oil
Quiponin	*Quillaja saponaria*	Nor-Natur	contact	BM 01
Regalia	*Reynoutria sachalinensis*	Marrone Bio Innovations	contact	BM 01, P 05
Saf-T-Side, Omni Supr.	petroleum oil	Brandt Consolidated, Inc.	contact	oil
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
Timorex (Act, Gold)	tea tree oil	Summit Agro, USA	contact	BM 01
Trilogy, Terraneem, Rango	neem oil/cold pressed neem oil	Certis USA/Terramera	contact	BM 01
Vitiseal	essential oils	Emerson	contact	BM 01

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

Mode of action: various

Resistance risk: low

Growth effects: various

ELEMENTS‡

Trade name	Common name	Company	Activity	FRAC Code
Copper	various	various	contact	M1
Sulfur	various	various	contact	M2
Lime sulfur	various	various	contact	M2

‡ 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.
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	--- (Growth Regulator)
KeyPlex 350 DP	yeast extract	Morse Enterprises	systemic	BM 01, P 06
LifeGard	*Bacillus mycoides*	Certis USA, L.L.C.	systemic effect	BM 02, P 06
Messenger, Employ	harpin	Eden Bioscience	systemic	P unspecified
Aliette, ProPhyt, others	Potassium phosphite	Bayer Crop Science, Luxemburg Industries Ltd.		33, P 07
ProAlexin	plant host defense activator	Citrox Limited	systemic	P unspecified

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

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

‡ 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.

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	Sub-class	Company	Activity
Bayleton	triadimefon	Triazole	Taminco	systemic (local)
Bumper	propiconazole	Triazole	ADAMA Agricultural Solutions Ltd.	systemic (local)
Cevya, Provysol	mefentrifluconazole	Triazole	BASF	systemic (local)
Deccocil***	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 Agricultural Solutions 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
Adepidyn, Miravis	pydiflumetofen	Syngenta Crop Protection	contact
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
F4406-1*	fluindapyr	FMC Corp.	contact
Xemium	fluxapyroxad	BASF	contact

Mode of action: FRAC[1] Code 7; single-site; blocks respiration by interfering with complex II (succinate dehydrogenase). Several sub-Codes 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
*** Registration pending in California**

ANILINOPYRIMIDINES (AP) (FC 9)‡

Trade name	Common name	Company	Activity
Penbotec (Pyrimethanil)***	pyrimethanil	Janssen Pharmaceutica (Dist. by Cerexagri, Pace International, JBT, etc.)	slightly systemic (on most crops)
Scala	pyrimethanil	Bayer CropScience	slightly systemic (on most crops)
Vangard	cyprodinil	Syngenta Crop Protection	slightly systemic (on most 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 INSIDE INHIBITORS (QoIs) (FC 11)‡

Trade name	Common name	Company	Activity
Abound	azoxystrobin	Syngenta Crop Protection	contact and systemic
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
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

QUINOLINES (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)[1]	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
[1]- Allisan was for postharvest use only - label changed to Botran Flowable

HYDROXYANILIDES (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

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

THIAZOLE CARBOXAMIDE (FC 22)

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

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	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 P07/33)‡

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 P07/33; 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

Copper (FC M1)‡

Trade name	Common name	Company	Activity
Various	copper	various	contact

Mode of action: FRAC[1] Code M1; 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 M2)‡

Trade name	Common name	Company	Activity
Various	sulfur	various	contact

Mode of action: FRAC[1] Code M2; 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 M3)‡
CARBAMATES

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

Mode of action: FRAC[1] Code M3; multi-site inhibitors that complex with enzymes probably inhibiting respiration.
Resistance risk: low
Growth effects: inhibits spore germination
Sporulation: no effect
**** Not registered, label withdrawn or inactive in California.**

PHTHALIMIDES (FC M4)‡

Trade name	Common name	Company	Activity
Captan	captan	various	contact

Mode of action: FRAC[1] Code M4; multi-site inhibitor that complexes with enzymes probably inhibiting respiration.
Resistance risk: low
Growth effects: inhibits spore germination
Sporulation: no effect

CHLORONITRILES (FC M5)‡

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 Agricultural Solutions Ltd.	contact

Mode of action: FRAC[1] Code M5; 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 P07/33)‡

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 P07 (formerly FC P07,33); 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.

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 46; 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

MULTIPLE ACTIVE INGREDIENTS IN PRE-MIXTURES

‡ 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.

COPPER/MANCOZEB (FC M1 and M3)‡

Trade name	Common name	Company	Activity
Mankocide	Copper and mancozeb	Kocide	contact

***Postharvest use only

Mode of action: FRAC[1] Codes M1 and M3; 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 3/7)‡

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/Top	difenoconazole/pydiflumetofen	Syngenta Crop Protection	contact and systemic
Mibelya	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 3/9)‡

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 3/11)‡

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 3/12)‡

Trade name	Common name	Company	Activity
Academy***	difenoconazole/fludioxonil	Syngenta Crop Protection	contact
Chairman***	propiconazole/fludioxonil	Syngenta Crop Protection	contact and systemic
Miravis Prime	difenoconazole/pydiflumetofen	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 3/33, P 07)‡

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

Mode of action: FRAC[1] Codes 3 and 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/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.

DMI/ CHLORONITRILE (FC 3/M5)‡

Trade name	Common name	Company	Activity

Catamaran	tebuconazole/chlorothalonil	Luxembourg	contact and systemic

Mode of action: FRAC[1] Codes 3 and M5; single-site and multi-site inhibitors; DMIs (e.g., tebuconazole) inhibit demethylation and other processes in sterol biosynthesis pathway; whereas chloronitril fungicides effect many 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.

SDHI/Anilinopyrimidin (AP) (FC 7/9)‡

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 7/11)‡

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).
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 7/12)‡

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/PHENYLPYRROLE (9/12)‡

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

ALMOND: FUNGICIDE EFFICACY - CONVENTIONAL

Fungicide	Resistance risk (FRAC)[1]	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	5	5	5	5	ND	5	4	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)	5	5	3	5	3	3	ND	4	ND	0
Kenja[4]	high (7)	5	5	3	5	4	0	ND	4	ND	0
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
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[3,7]	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[3,7]	medium (7/11)	5	5	5	5	5	4	ND	5	5	4
Pristine[3,7]	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, 7, 10]	high (9)	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/ P07,33)	5	1	4	3	3	4	ND	2	ND	3
Topsin-M, T-Methyl, Incognito, Cercobin[2,6,7,8]	high (1)	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
Abound	high (11)	4	2	5	4	5	5	4	4	4	4
Aproach[3,4,7]	high (11)	4	2	5	4	5	5	4	4	4	4
CaptEvate*	low (M4/17)	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, 7]	high (11)	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)	4	3	3	3	4	4	ND	4	3	3
Rovral, Iprodione, Nevado[9]	low (2)	4	4	0	4	0	0	ND	3	0	0

Regev	high (3/BM 02)	5	2	4	3	4	4	ND	4	ND	4
Rhyme	high (3)	4	1	ND	2	3	ND	ND	3	ND	ND
Bravo, Chlorothalonil, Echo[11, 12, 15] (Equus**)	low (M5)	3	NL	4	4	4	5	NL	NL	0	0
Captan[4, 6, 12]	low (M4)	3	3	4	4	3	0	4	2	0	0
ProBLAD Verde	low (BM 01)	3	2	0	0	0	0	0	0	0	0
Mancozeb	low (M3)	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 (M3)	3	2	4	4	4	0	3	2	0	0
Syllit	medium (U12)	2	0	ND	4	5	ND	ND	2	ND	0
Copper[14,15]	low (M1)	1	1	0	2	2	0	0	ND	0	0
Lime sulfur[12,15]	low (M2)	1	NL	0	1	3	3	NL	NL	0	0
Sulfur[4,12]	low (M2)	1	1	0	0	3	3	0	0	4	0
PlantShield[17]	low (BM 02)	0	0	0	0	0	0	0	0	0	0
Copper 2 oil[14,15]	low (M1)	ND	ND	0	2	4	0	0	ND	0	0

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

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.

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

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

Almond: Fungicide Efficacy, continued

[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, Abound, Gem, and some of the DMI fungicides (FRAC Code No. 3) are registered for use in late spring and early summer when treatment is recommended.

[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] Not registered for use later than 5 weeks after petal fall.
[10] Efficacy reduced at high temperatures and relative humidity.
[11] Bravo Ultrex, Bravo WeatherStik, Echo, Echo Ultimate, 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	Biological or natural product (FRAC Code)[1]	Brown rot	Jacket rot	Anthrac-nose	Shothole	Scab	Ru	ALS	Hull rot	PM-like	Silver leaf	Bac. Spot
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
Taegro 2**	*B. amyloliquefaciens* FZB (BM 02)	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL
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
Dart*	capric and caprylic acids (BM 01)	3	2	ND	2	1	1	2	2	ND	0	3
Cinnacure	cinnamaldehyde (BM 01)	1	1	NL	NL	NL	NL	NL	NL	NL	NL	NL
EF400	clove, rosemary, peppermint oils (BM 01)	1	2	1	NL	ND	NL	NL	NL	NL	NL	NL
BVT CR-7	*Clonostachys rosea* CR-7 (experimental)	4	2	ND	2	ND	ND	ND	ND	ND	ND	ND
BacStop	essential oils (BM 01)	1	1	1	NL	ND	NL	NL	NL	NL	NL	3
Messenger**	harpin (P unspecified)	NL	1	NL	NL	NL	NL	NL	NL	NL	NL	NL
Kasumin	kasugamycin (24)[1]	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, Perasan	peroxyacetic acid (oxidizer)	1	2	1	1	NL	NL	1	ND	ND	NL	2

Armicarb**, Milstop	potassium bicarbonate (NC)	NL	NL	NL	NL	1	NL	NL	ND	3	NL	NL
All Phase	potassium sorbate/sodium lauryl sulfate (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, BM 01)	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 atroverde* (BM 02)[6]	NL	NL	NL	NL	NL	NL	NL	NL	NL	4	0
Procidic	citric acid	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.

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

[3] PM refers to a powdery mildew disease.

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

[5] 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.

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

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

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

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

[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., M2).

Disease	Dormant	Bloom			Spring		Summer	
		Pink bud	Full bloom	Petal fall	2 weeks	5 weeks	May	June/July
Alternaria	----	----	----	----	----	2	3, 3/7, 3/9, 3/11, 3/33, 7, 7/11, 11, 19	3, 3/7, 3/9, 3/11, 3/33, 7, 7/11, 11, 19
Anthracnose	----	3, 3/7, 3/9, 3/11, 3/33, 7	3, 3/7, 3/9, 3/11, 3/33, 7, 7/11, 11	3, 3/9, 3/7, 3/11, 3/33, 11, M3, M4, M5	3, 3/9, 3/11, 3/7, 3/33, 7, 7/11, 11, M3, M4, M5	3, 3/7, 3/9, 3/11, 3/33, 7, 7/11, 11 M3, M4, M5	3, 3/7, 3/9, 3/11, 3/33, 7, 7/11, 11, M4	3, 3/7, 3/9, 3/11, 3/33, 7, 7/11, 11, 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, 3/33, 9	1[2], 2 +oil, 3, 3/7, 3/9, 3/11, 3/33, 7, 7/11, 9, 11, 19	1[2], 2 +oil, 3/11, 3/33 7, 7/11, 9, 19	----	----	----	----
Jacket rot	----	----	1[2], 2 +oil, 3/7, 3/9, 3/11, 7, 7/11, 9, 19	1[2], 2 +oil, 3/7 3/9, 3/11, 7, 7/11, 9, 19	----	----	----	----
Hull rot[5]	----	----	----	----	----	----	3, 3/7, 3/9, 3/11, 7/11, 11, 19	3, 3/7, 3/9, 3/11, 7/11 11, 19
Leaf blight	----	----	1[2], 2, 3, 3/7, 3/9, 3/11, 3/33, 11	1[2], 2, 3, 3/7, 3/9, 3/11, 3/33, 11, M3, M4, M5	3, 3/7, 3/9, 3/11, 3/33, 11, M3, M4, M5	----	----	----
Rust	----	----	----	----	----	3, 3/7, 3/11,3/33[1], 7, 7/11, 11, 19 M3	3, 3/7, 3/11, 3/33, 7, 7/11, 11, 19	3, 3/7, 3/11, 3/33, 7, 7/11, 11, 19

Disease	Dormant	Bloom			Spring		Summer	
		Pink bud	Full bloom	Petal fall	2 weeks	5 weeks	May	June/July
Scab[4]	M1+oil, M2[3], M5+oil	----	----	1[2], 3/7, 3/9, 3/11, 3/33, 7, 7/11[2], 11[2] M3, M4, M5	1[2], 3/7, 3/9, 3/11, 3/33, 7, 7/11[2], 11[2] M3, M4, M5	3, 3/7, 3/9, 3/11, 3/33, 7, 7/11[2], 11[2] M2[3], M3, M4	M2[3], M4	----
Shot hole	M1	2, 3, 3/7, 3/9, 3/11, 7, 9, 11	2, 3, 3/7, 3/9, 3/11,7, 7/11, 9, 11, 19	2, 3, 3/7, 3/9, 3/11, 7, 7/11 9, 11, 19	7, 7/11, 11, 19, M3, M4, M5	7, 7/11,11, 19, 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.

[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, BM 02, oxidizer	BM 01, BM 02, oxidizer	BM 01, BM 02, oxidizer
Anthracnose	**----**	BM 01, BM 02, P 05, oxidizer	BM 01, BM 02, P 05, oxidizer	BM 01, BM 02, P 05, oxidizer	BM 01, BM 02, P 05, oxidizer	BM 01, BM 02, P 05, oxidizer	BM 01, BM 02, P 05, oxidizer	BM 01, BM 02, P 05, oxidizer

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

[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
Sercadis**	high (7)	5	3	4
Luna Sensation	medium (7/11)	5	3	5
Inspire Super	medium (3/9)	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
Cevya	high (3)	4	3	5
Captan[6]	low (M4)	4	0	0
Dithane, Manzate, Penncozeb[6]	low (M3)	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 (3/33, P07)	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 (M1)	3[7]	0	0
Lime sulfur[6,8]	low (M2)	3	5[8]	4[9]
Ph-D, Oso	high (19)	3	0	4
Sulfur[7]	low (M2)	3	0	5
Ziram[6]	low (M3)	3	0	0
Gatten	high (U13)	0	0	4

APPLE AND PEAR: FUNGICIDE EFFICACY – BIOCONTROLS AND NATURAL PRODUCTS

Fungicide	Resistance risk (FRAC#)[1,13]	Scab		Powdery mildew (apple only)
		Protectant	Eradicant	
Lime sulfur	low, M2	3	0	4
Sulfur[7]	low, M2	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, BM 01, 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, M1	2/3	0	2
Procidic	low, BM 01	ND	0	ND

APPLE AND PEAR: BACTERICIDE EFFICACY – CONVENTIONAL

Bactericide	Resistance risk	Fire blight[11]		Phytotoxicity[1,5]	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 (M4)	3	0	0	0
Copper[7]	low (M1)	3	0	2	0
Dithane, Manzate, Penncozeb[6]	low (M3)	3	0	0	0
Actigard[12]	low (P 01)	0	2	0	2
Apogee[11]	low (PGR)	0	2/3	0	3

APPLE AND PEAR: BACTERICIDE EFFICACY – BIOCONTROLS AND NATURAL PRODUCTS

Bactericide	Resistance risk (FRAC Code)[1,13]	Fire blight[11]		Phytotoxicity[1,5]	Plant Growth Regulator/SAR
		Contact	Systemic		
AgriPhage	low (BM 02)	2/3	0	0	0
Blossom Protect	low (BM 02)	4	0	1	0
Copper[7]	low (M1)	3	0	4	0
Actinovate	low (BM 02)	2/3	0	1	0
BacStop	low (BM 01)	2	0	1	0
Blight Ban	low (BM 02)	2/3	0	1	0
Dart	low (BM 01)	2/3	0	0	0
Double Nickel 55	low (BM 02)	2/3	0	1	0
Regalia	low (P 05, BM 01)	2/3	0	1	0
Sanitizers[14]	low	2/3	0	0	0
Serenade	low (BM 02)	2/3	0	1	0
LifeGard	low (P 06, BM 02)	2	2	0	2
Lime sulfur/sulfur[8]	low (M2)	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/). 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 (SAR = systemic acquired resistance).

[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] Labeled on pear but not apple.

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

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

[13] 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.

[14] Sanitizers such peroxyacetic acid (e.g., Oxidate, Zerotol, Perasan A) are oxidizers that act immediately on contact. They are neutralized rapidly by reducing agents and are non-persistent. Note: Zerotol is registered only on apple, but not on pears. Perasan A is for postharvest use in sanitizing fruit only.

[15] Higher numbers of 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., M2) or natural products/biological controls (BM 01, BM 02, NC, P).

Disease	Fall	Delayed dormant	Bloom			Spring
			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, P 01, P 05, P 06	M1[1], 24, 25, 41, BM 01, 02, P 01, P 05, P 06	M1[1], 24, 25, 41, BM 01, 02, P 01, P 05, P 06, PGR[5]
Scab	----	M2	M1[1], M2, M3, 1, 3, 7, 9, 3/9, 7/11, 19, U12, U12+M1-3, BM 01, 02, 03, P 01, P 05, P 06	M1[1], M2, M3, 1, 3, 7, 9, 3/9, 7/11, 19, U12, U12+M1-3, BM 01, 02, 03 P 01, P 05, P 06	M1[1], M2, M3, 1, 3, 7, 9, 3/9, 7/11, 19, U12, BM 01, 02, 03, P 01, P 05, P 06	M1[1], M2, M3, 1, 3, 7, 9, 3/9, 7/11, 19, BM 01, 02, 03, P 01, P 05, P 06
Powdery mildew			M2, 1, 3, 7, 9, 3/9, 7/11, 19, BM 01, 02, P 01, P 05, P 06	M2, 1, 3, 7, 9, 3/9, 7/11, 19, BM 01, 02, P 01, P 05, P 06	M2, 1, 3, 7, 9, 3/9, 7/11, 19, BM 01, 02, P 01, P 05, P 06	M2, 1, 3, 7, 9, 3/9 7/11, 19, BM 01, 02, 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, Phyton 27AG, 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] - M2 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 (3/33, P07)	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	high (3)	5	5	5	4	4	0
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
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] 2 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, Iprodione, Nevado[5]	low (2)	4	NL	4	0	4	0
Abound	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 (M5)	3	3	3	0	4	0
Captan[10,11]	low (M4)	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 (M1)	1	0	0	0	3	0
Ziram	low (M3)	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/). 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]		Botrytis Blossom / Fruit	Powdery mildew[2]	Eutypa
		Blossom	Fruit			
Adament**	high (3/11)	5	5[12]	3	3	4
Bumper,Tilt	high (3)	5	5	0	4	4
Cevya	high (3)	5	5[12]	2	5	ND
Orius, Teb, Toledo, Tebucon, Tebuconazole	high (3)	5	5[12]	3	3	3
Viathon	med. (3/33, P07)	5	5[12]	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
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] 2 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]
Abound	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
Procure[8]	high (3)	4	4	0	5	0
Rally[8]	high (3)	4	4	0	5	4
Rovral, Iprodione, Nevado[6]	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 (M5)	3	NL	3	0	0
Captan[10]	low (M4)	3	3	3	0	0
Ph-D, Oso	high (19)	3	3	4	4	0
Copper	low (M1)	1	0	0	0	0
Sulfur[10]	low (M2)	1	0	0	4	0
Ziram	low (M3)	1	NL	0	0	0
Vitiseal	low (?)	0	0	0	0	5
Quintec	high (13)	NL	NL	NL	5	0
Vivando	high (50)	NL	NL	NL	5	0
Gatten	high (U13)	NL	NL	NL	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, 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, 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/). 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

		Brown rot				
Trade name[1]	**Biological or natural product (FRAC Code)[2]**	**Blossom**	**Fruit**	**Botrytis Blossom/Fruit**	**Powdery mildew**	**Eutypa**
Oso	polyoxin-D	3	3	4	4	NL
Problad Verde **	low (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, BM 01)	2	2	2	2	NL
Taegro 2	*B. amyloliquefaciens* FZB (BM 02)	2	1	2	1	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 (BM 01)	2	1	NL	NL	NL
Cinnacure	cinnamaldehyde (BM 01)	1	1	1	NL	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 (M2)	1	0	0	4	0
Kaligreen, Milstop	potassium bicarbonate (NC)	NL	NL	NL	4	NL

Copper[3]	copper (M1)	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	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.

[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.

[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	2-3 weeks later	Preharvest 1-10 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 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 (i.e., FRAC Codes M2, BM 01, BM 02, NC).

Disease	Dormant	Prebloom	White Tip /Popcorn	Full bloom	Petal fall	2-3 weeks later	Preharvest 1-10 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	2+oil, 3/7, 7, 7/11, 17, 19	----	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	1[3], 3, 7, 3/7 3+17, 3/11 7/11, 17, 19	----	----	3, 3/7, 3/11, 7, 7/11, 17, 19
Powdery mildew	M2[2]	M2[2]	2+oil, 3	1[3], 3, 3/7, 3/11, 7, 7/11, 13, 19, BM 01, BM 02, NC	3, 3/7, 7, 7/11, 11, 13, 19, M2[2], BM 01, BM 02, NC	3, 3/7, 3/11, 7, 7/11, 11, 13, 19, M2[2], BM 01, BM 02, NC	3, 3/7, 3/11 3+17, 7/11, 11, 19, BM 01, BM 02, 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/). 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 amyloliquefaciens* Strain QST 713 (e.g., Serenade – FC BM 02). In general, sulfur compounds (FC M2) 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]		Septoria Spot	Anthrac -nose	Alter-naria Rot	Greasy Spot	Rind Disorder
		Brown Rot	Root Rot					
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	high (4)	NL	3	0	0	0	0	0
Copper	low (M1)	4	0	4	3	1	3	0
Aliette, ProPhyt, Fungi-Phite, K-Phite	low-medium (P07, 33)	4	4	3	3	1	ND	0
Luna Sensation	medium (7/11)[5]	NL	0	5	5	2	4	0
Priaxor	medium (7/11)[5]	NL	0	5	5	2	4	0
Mibelya*	medium (3/7)[5]	NL	0	5	5	2	4	0
Switch[4]	medium (9/12)	0	0	5	5	2	4	0
Miravis Prime**[4]	medium (7/12)	0	0	5	5	2	4	0
Pristine	medium (7/11)[5]	NL	0	4	4	2	4	0
Quadris Top	medium (3/11)	NL	0	5	5	3	4	0
Abound	high (11)[5]	NL	0	4	4	2	4	0
Flint Extra	high (11)[5]	NL	0	4	4	2	4	0
Headline	high (11)[5]	NL	0	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 (M3)	NL	NL	0	3	0	0	0
Sulfur	low (M2)	0	0	0	0	0	3	0
Vapor Gard	anti-transpirant	0	0	0	0	0	0	5

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/Deccocil/Fungaflor, Graduate/FDL, GraduateA+, Azoxy, Mentor, Penbotec/Pyrimethanil, and Alumni/Decco Salt No. 19/TBZ.**

[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] 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	0	0	0	0	0	3
Alternaria rot	0	0	0	0	0	1/2
Greasy spot	0	0	0	0	0	3
Rind disorder[4]	0	0	3	2	1	0

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

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

[3] 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).

[4] 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		Phomop-sis 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
Abound	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. (3/33, P07)	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 (M2)	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 (U6)	5	0	0	0	0	0	0	0
Vivando	high (50)	5	0	0	0	0	0	0	0
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? (U13)	4	NL	NL	NL	NL	NL	NL	NL
Bayleton**	high (3)	3	0	0	0	0	NL	0	0
Copper	low (M1)	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 (M4)	0	2	4	4	4	NL	0	0
Dithane, Manzate, Penncozeb	low (M3)	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/M1)	0	5	0	0	0	0	0	0
Rovral,Iprodione, Nevado	low (2)	0	0	4	0	0	0	0	0
Ziram	low (M3)	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.**
***** Registered only on wine/raison grapes in California.**

GRAPEVINE: FUNGICIDE EFFICACY – BIOCONTROLS AND NATURAL PRODUCTS

				Bunch rot					
Fungicide	**Resistance risk (FRAC Code)[1]**	**Powdery mildew**	**Downy mildew**	**Botrytis**	**Summer**	**Phomopsis cane and leaf spot**	**Eutypa dieback**	**Bot Canker**	**Phomopsis dieback**
Bio-Tam 2.0	low (BM 02)	NL	NL	NL	NL	NL	4	4	4
Cinnacure	low (BM 01)	4	NL	NL	NL	NL	NL	NL	NL
Elexa**, Armour-Zen	low (P-unspecified)	NL (4)	NL	ND	NL	NL	NL	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 (BM 01)	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 CS	low (BM 01)	NL (4)	ND	3	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 (NC)	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 (BM 01)	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/). 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.

GRAPEVINES: 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., M2, BM 01, BM 02, NC).

Disease	Dormant	Bud break	Full bloom	Pre-close	Veraison	Preharvest
Botryosphaeria canker	BM 01[1], BM 02, 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, 4, 21, 40, 43	4, 21, 40, 43	----	----	----
Esca	BM 01[1], BM 02, M2 (lime sulfur)[3]	----	----	----	----	----
Eutypa	BM-01[1], BM-02, 1, M2	----	----	----	----	----

Powdery mildew[4,5]	BM-01[1], 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[1], BM-02[1], 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 - B-Lock, Cinnacure), BM 02 (Biological Controls - Sonata, Serenade,), and NC (Kaligreen, 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)[2]	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.

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

[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]			Postharvest
			14 day	7 day	1 day	
Botrytis fruit rot	0	1-2[2]	2	2	3	3

Rating: +++ = most effective, ++ = moderately effective, + = least effective, and ---- = 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] Blossom	Brown rot[2] Fruit	Powdery mildew[2]	Scab	Rust	Leaf curl	Shot hole
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 (3/33, P07)	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
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
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]2 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, Iprodione, Nevado[5]	low (2)	4	NL	0	0	0	0	0
Abound	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 (M5)	3	0	0	4	2	4	4
Captan[9]	low (M4)	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 (U12)	2	0	0	4	0	3	4
Copper	low (M1)	1	0	0	0	0	4	4
Sulfur[9]	low (M2)	1	1	4	4	4	0	0
Thiram[11]	low (M3)	1	0	0	4	0	5	4
Ziram	low (M3)	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/). 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

		Brown rot						
Trade name[1]	**Biological or natural product (FRAC Code)[2]**	**Blossom**	**Fruit**	**PM[3]**	**Scab**	**Rust**	**Leaf curl**	**Shot hole**
Oso	polyoxin-D (19)	3	3	3	ND	NL	NL	NL (2)
Botector	*Aureobasidium pullulans* (BM 02)	2	2	NL (3)	NL	NL	NL	NL
ProBlad Verde*	*Lupinus albus* (BM 01)	2	2	2	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 (BM 01)	3	2	NL (2)	NL	NL	NL	NL
Cinnacure	cinnamaldehyde (BM 01)	2	1	NL	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	potassium bicarbonate (NC)	NL	NL	3	NL	NL	NL	NL
Regalia	*Reynoutria sachalinensis* (P 05, BM 01)	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 (BM 01)	NL	NL	ND	ND	ND	NL	NL
Copper	copper (M1)	1	1	1	2	2	4	4
Sulfur	sulfur (M2)	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] Organic treatments arranged by performance on brown rot.

[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.

[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		3-6 weeks postbloom	Preharvest[1]	
		20-40%	80-100%		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., M2, BM 01, BM 02, NC, P).

Disease	Dormant	Bloom		3-6 weeks postbloom	Preharvest	
		20-40%	80-100%		3 weeks	1 week
Brown rot	----	1[3], 2+oil, 3, 3/7, 3/9, 3/11, 7, 9, 19	1[3], 2+oil, 3[4], 3/7, 3/9, 3/11, 7/11, 9, 17, 19	3, 3/7, 3/11, 7/11, 17	3, 3/7, 3/11, 7/11, 17, 19	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	1[3], 3, 3/7, 3/11, 7/11, 13, U8	3, 7, 3/7, 7/11, 11, 13, 19, M1, M2[2], U12, BM 01, BM 02, 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, M3, M4, M5, U12	1[3], 3, 3/9, 3/11, 7/11, M3, M4, M5, U12	1[3], 3, 3/9, 3/11, 7/11, 11, 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/). 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 M1 - copper, M2 - sulfur, BM 01 - Natural products, BM 02 - Biological controls (*Streptomyces lydicus* - Actinovate AG, *Bacillus pumilus* - Sonata, *Bacillus subtilis* - Serenade, Aviv), or NC (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
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	ND	5[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 (3/33, P07)	5	2	5[5]
Abound	high (11)[2,3]	4	0	4
Cabrio	high (11)[2,3]	4	0	4
Flint Extra	high (11)[2,3]	4	0	4
Ph-D	medium (19)	4	5	4
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 (M5)	3	0	3
Bumper,Tilt	high (3)	3	2	3[5]
Scala	high (9)[3]	3	4	4[6]
Inspire Super	medium (3/9)	3	4	4/5
Topsin-M, T-Methyl, Incognito, Cercobin[7]	high (1)	0	3	3
Elevate	high (17)[3]	ND	5	ND
K-Phite	low (33)	ND	ND	4/5
Organic treatments				
Actinovate	low (BM 02)	3	5	4
Regalia	low (BM 01)	3	0	3/4[8,9]
Copper	low (M1)	2	0	0
Liquid lime sulfur[8]	low (M2)	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/). 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 Abound 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 within 60 days of harvest, Quash within 25 days of harvest, or tebuconazole fungicides (Tebucon/Teb/Toledo/Viathon) within 35 days before harvest.
[6] Under low and moderate disease pressure.
[7] Registered for bloom treatment only.
[8] Dormant treatments and/or delayed dormant
[9] Tested only under low disease pressure.

PISTACHIO: TREATMENT TIMING

Disease	Dormant	Bloom/terminal shoot ½-1 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 (Abound, Flint Extra, or Cabrio) 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. (3/33, P07)	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	4
Inspire Super	high (3/9)	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] 2 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, Iprodione, Nevado[7]	low (2)	4	NL	0	ND
Abound	high (11)[5]	3	2	ND	ND
Botran	medium (14)	3	3	ND	ND
Bravo, Chlorothalonil, Echo, Equus[11,12]	low (M5)	3	3	0	ND
Captan[12]	low (M4)	3	3	0	ND
Flint Extra	high (11)[5]	3	3	ND	ND
Oso, Ph-D	high (19)	3	3	4	ND
Copper	low (M1)	1	0	0	ND
Sulfur[12]	low (M2)	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

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
		Blossom	Fruit[2]		
Miravis Duo	medium (3/7)	5	5	ND	5
Bumper, Tilt[2]	high (3)	5	5	0	4
Cevya	high (3)	5	5	0	4
Tebucon, Teb, Tebuconazole, Toledo[2,7]	high (3)	5	5	0	4
Viathon	med. (3/33, P07)	5	5	0	4
Fontelis	high (7)	5	4	0	4
Kenja	high (7)	5	4	NL	NL
Indar[2]	high (3)	5	5	0	4
Protocol[3]	med.-high (1/3)	5	5	0	5
Inspire Super	high (3/9)	5	5	0	4
Luna Experience	medium (3/7)	5	5	ND	5
Luna Sensation[2]	medium (7/11)	5	5	ND	ND
Merivon	medium (7/11)	5	5	ND	ND
Pristine[2]	medium (7/11)	5	5	ND	ND
Quash [2]	high (3)	5	5	0	4
Adament**	medium (3/11)	5	5	ND	5
Quadris Top[2]	medium (3/11)	5	5	ND	5
Quilt Xcel, Avaris 2XS[2]	medium (3/11)	5	5	ND	5
Rovral/Iprodione/Nevado[5] mixed with oil[2]	low (2)	5	NR	0	NR
Scala[6]	high (9)[3,4]	5	4[6]	0	ND
Topsin-M, T-Methyl, Incognito, and Cercobin when mixed with oil[2,4]	high (1)[4]	5	5	0	0
Vangard[6]	high (9)[3,4]	5	4[6]	0	ND
Elevate[2,7]	high (17)[4]	4	4	ND	0
Rhyme	high (3)	4	4	0	4
Rovral/Iprodione /Nevado[5]	low (2)	4	NR	0	NR
Topsin-M, T-Methyl, Incognito [2,3]	high (1)[4]	4	1	0	0
Abound	high (11)[4]	3	2	0	4
Botran	medium (14)	3	3	ND	ND
Bravo, Chlorothalonil, Echo, Equus[8,9,10]	low (M5)	3	3	3	0[9]
Captan[7,8,10]	low (M4)	3	3	4	0
Flint Extra[7]	high (11)[4]	3	2	0	4
Ph-D, Oso	high (19)	3	3	0	ND
Rally[2]	high (3)	3	3	0	0
Sulfur[10]	low (M2)	1	1	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, 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**

[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 2% light summer oil. The oil is "light" summer oil (1-2% vol/vol). If applied in summer, fruit will lose their waxy bloom and look red. They will dry to normal color.

[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] Registered for use on fresh prunes only.

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

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

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

PRUNE - FUNGICIDE EFFICACY - BIOCONTROLS AND NATURAL PRODUCTS

Trade name[1]	Biological or natural product (FRAC Code)[2]	Brown rot		Russet	Rust
		Bloss om	Fruit rot		
Oso	polyoxin-D	3	3	NL	NL
Botector	*Aureobasidium pullulans* (BM 02)	3	2	NL	NL
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
Dart	capric and caprylic acids (BM 01)	3	2	NL	3
Cinnacure	cinnamaldehyde (BM 01)	1	1	NL	NL
ProBLAD Verde*	*Lupinus albus* (BM 01)	3	2	NL	NL
Trilogy, Terraneem	neem oil (BM 01)	1	1	2	2
Oxidate, Perasan	peroxyacetic acid (oxidizer)	2	2	NL	1
Actinovate AG	*Streptomyces lydicus* (BM 02)	1	1	NL	NL
EcoSwing	*Swinglea glutinosa* (BM 01)	3	2	NL	NL
Sulfur	sulfur (M2)	1	1	0	3
Copper	copper (M1)	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] Organic treatments arranged by performance on brown rot.

[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.

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]	3	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	Resistance risk (FRAC)[1]	Powdery mildew	Gray mold	Anthrac - nose	Comm on leaf spot	Rhizopus /Mucor rot	Phyto- phthora diseases	Angular leaf spot
Bumper, Tilt	high (3)	5	NL (0)	NL (3)	4	NL (0)	NL	NL
Luna Privilege (foliar)/ Velum One (soil)[10]	high (7)	5/3	5/2	NL	ND	ND	ND	NL
Luna Sensation[2]	medium (7/11)	5	4	3[R]	ND	2	NL	NL
Luna Tranquility[2]	medium (7/9)	5	4	NL	ND	1	NL	NL
Miravis Prime	medium (7/12)	5	4	3	NL	3	NL	NL
Mettle, Perissim	high (3)	5	NL	NL	ND	NL	NL	NL
Procure	high (3)	5	NL	NL (2)	NL (0)	NL	NL	NL
Quadris Top[8]	medium (3/11)	5	NL (3)[R]	4[R]	0	NL	NL	NL
Quilt Xcel, Avaris 2XS	medium (3/11)	5	3	4[R]	NL	2	NL	NL
Quintec	high (13)	5	NL (0)	NL (0)	NL (0)	NL (0)	NL	NL
Rally	high (3)	5	NL (0)	NL (3)	4	NL	NL	NL
Rhyme	high (3)	5	0	NL	NL	NL	NL	NL
Torino	high (U6)	5	NL	NL	NL	NL	NL	NL
Protocol	medium (1/3)	4	4[R]	3	NL	NL	NL	NL
Abound[2]	medium (11)	4	2[R]	4[R]	NL	NL (2)	NL	NL
Cabrio[2]	medium (11)	4	2[R]	4[R]	0	NL (2)	NL	NL
Gatten*	high? (U13)	4	NL	NL	NL	NL	NL	NL
Evito*[2]	medium (11)	4	2[R]	3[R]	NL	NL	NL	NL
Fontelis	high (7)	4	5[R]	ND	NL	NL	NL	NL
Kenja	high (7)	4	5	ND	ND	NL (2)	NL	NL
Merivon[2,8]	medium (7/11)	5	5	ND	0	NL (4)	NL	NL
Ph-D,Oso	medium (19)	4	3	3	NL	NL	NL	NL
Pristine[2,8]	medium (7/11)	4	5[R]	ND	0	NL	NL	NL
Sulfur	low (M2)	4	NL	NL	NL	NL	NL	NL
Topsin-M, T-Methyl, Incognito[2]	very high (1)	4	4[R]	0	NL (3)	NL	NL	NL
Flint Extra	high (11)	4	2[R]	2[R]	NL	NL	NL	NL
Intuity[2]	medium (11)	2	3[R]	NL	NL (0)	NL	NL	NL
Captan	very low (M4)	NL (1)	4	NL (4)	0	NL (2)	NL	NL
Elevate[2,6]	high (17)	NL (1)	5[6]	NL (2)	NL (0)	NL	NL	NL
Aliette[3, 7], Legion**	low (P07,33)	NL	NL	NL	NL	NL	4	NL
Captevate[2]	medium (M4/17)	NL	4	4	NL	NL	NL	NL
Copper	low (M1)	0	0	0	0	0	0	4[5]
Fungi-Phite, K-Phite, Prophyt	low (P07,33)	NL	NL	NL	NL	NL	4	NL (2)
Ridomil Gold SL[2,4]	high (4)	NL	NL	NL	NL	NL	4[4]	NL
Rovral, Iprodione, Nevado	low (2)	NL (0)	4	0	0	NL	NL	NL
Scala	high (9)	2	3	NL	NL	NL	NL	NL
Switch[7]	high (9/12)	2	5[R]	4	NL	NL (4)	NL	NL
Thiram	low (M3)	NL (0)	2	3	0	NL	NL	NL
Zivion S	low (48)	ND	3	4	NL	3	NL	NL
Actigard	low (P1)	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.

*** 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/). 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] Foliar applications provide systemic treatment.

[4] Ridomil Gold SL is the only formulation registered. If the GR formulation is applied to a previous crop that must be removed, it has a 0-day plantback interval.

[5] More than 4 applications cause severe stunting.

[6] Nonpersistent resistant populations of *Botrytis cinerea* to fenhexamid occur with repeated use of FRAC Code 17 fungicides.

[7] Plant dip (nurseries) or foliar spray (field use).

[8] Not for use in nurseries, on nursery transplants, or greenhouses (check label for details).

[9] Bravo is registered under a 24c special local needs for nursery use only on non-bearing plants. It is used as a dip treatment of transplants.

[10] Velum One is a fluopyram formulation for chemigation. Soil applications are designed for nematode management but may also suppress powdery mildew.

[R] Resistant isolates documented in pathogen populations.

STRAWBERRY - FUNGICIDE EFFICACY - BIOCONTROLS AND NATURAL PRODUCTS

Fungicide trade names	Active ingredient	Resis. Risk/ FRAC Code[1]	Powdery mildew[2]	Gray mold	Anthrac - nose	Comm on leaf spot	Rhizopus /Mucor rot	Phytophthora diseases[3]	Angular leaf spot
Actinovate	*Streptomyces lydicus* WYEC 108	low/BM 02	2	0	NL	NL	NL	0	1
Aleo, etc.[4]	garlic oil	low/BM 01	ND	0	0	0	0	0	1
Aviv, etc.	*Bacillus subtilis* IAB/BS03	low/BM 02	3	ND	ND	ND	NL	ND	NL
Botector	*Aureobasidium pullulans* DSM 14940; DSM 14941	low/BM 02	NL	0	ND	NL	1	NL	NL
Cinnerate	cinnamon oil	low/BM 01	ND	0	NL	NL	NL	NL	NL
Copper, etc.[5]	Copper	low/M1	0	0	0	0	0	0	4
Double Nickel	*Bacillus amylo-liquefaciens* D747	low/BM 02	2	0	0	NL	NL	0	1
ProBlad Verde, etc.	Banda de *Lupinus albus* doce	low/NC	3	2	NL	NL	NL	NL	NL
Howler	*Pseudomonas chlororaphis* AFS009	low/BM 02	NL	0	ND	ND	NL	ND	0
Kaligreen, MilStop, etc.	potassium bicarbonate	low/NC	3	ND	ND	NL	NL	NL	NL

Fungicide trade names	Active ingredient	Resis. Risk/ FRAC Code[1]	Powdery mildew[2]	Gray mold	Anthrac - nose	Comm on leaf spot	Rhizopus /Mucor rot	Phytophthora diseases[3]	Angular leaf spot
M-Pede, etc.	potassium salts of fatty acids	medium/28	2	NL	NL	NL	NL	NL	NL
Oso, etc.	Polyoxin D zinc salt	medium/19	4	3	3	NL	NL	NL	NL
Oxidate, Perasan, etc.	Hydrogen peroxide; peroxyacetic acid	low/NC	ND	0	NL	NL	NL	NL	2
Procidic, etc.	citric acid	low/NC	ND	0	NL	NL	NL	0	NL
Rango	cold pressed neem oil	low/NC	ND	2	ND	0	NL	0	NL
Regalia	*Reynoutria sachalinensis* extract	low/P5	1	0	ND	ND	NR	ND	NL
Serenade ASO, etc.	*Bacillus subtilis* QST 713	low/BM 02	3	2	0	NL (0)	NL (0)	NL (0)	NL
Sonata	*Bacillus pumilis* QST 2808	low/BM 02	3	2	0	NL	NL	NL	NL
Stargus	*Bacillus amylo-liquefaciens* F727	low/BM 02	NL	0	ND	NL	NL	NL	NL
Serifel	*Bacillus amylo-liquefaciens* MBI 600	low/BM 02	2	0	0	ND	NL	0	2
Taegro	*Bacillus amylo-liquefaciens* FZB24	low/BM 02	2	0	0	NL	NL	ND	NL (2)
Theia*	*Bacillus subtilis* AFS032321	low/BM 02	2	0	0	NL	NL	0	NL
Timorex Act	tea tree oil	low/BM 01	3	0	ND	NL	0	ND	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.

*** Registration pending in California.**

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

[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/).

[2] Efficacy rating determined with fungicide susceptible populations of pathogen.

[3] Efficacy rating for soil applied control of Phytophthora crown rot.

[4] Generic products may not be all listed and "etc." indicates that other products may be available that have the same active ingredient.

[5] More than 4 applications cause severe stunting

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[3]	0	0	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

Material	Resistance risk (FRAC#)[1]	Walnut blight[2]	Anthrac- nose	Botryo-sphaeria blight***	Kernel mold***
Bactericides					
Copper + mancozeb (Manzate, Dithane)	low (M1 + M3)	5	5	3(2)	0
Kasumin + copper	low (24 + M1)	5	0	0	0
Kasumin + mancozeb	low (24 + M3)	5	0	0	0
Syllit + copper	high (U12 + M3)	4	ND	0	0
Syllit + Kasumin	high (U12 + 24)	4	ND	0	0
Bordeaux[2]	low (M1)	4	0	0	0
Fixed coppers[2,3]	medium (M1)	4	0	0	0
Zinc sulfate + copper + hydrated lime (Zinc Bordeaux)	low (M1)	4	0	ND	0
Kasumin	high (24)	4	0	0	0
Copper + mancozeb + surfactant[4]	low (M1 + M3)	2	ND	ND	0
Fungicides					
Luna Experience	medium (3/7)	0	5	5	ND
Luna Experience + Regalia	medium (3/7 + (BM 01, P 05)	3	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
Quilt Xcel	medium (3/11)	0	5	5	ND
Luna Sensation	medium (7/11)	0	5	5	ND
Quadris Top	medium (3/11)	0	5	4	ND
Ph-D	medium (19)	0	5	4	ND
K-Phite[3]	low (P07, 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 Duo	medium (3/7)	0	ND	4	ND
Viathon	medium (3/P07, 33)	ND	ND	4	ND
Rhyme	high (3)	0	5	ND	3
Abound	high (11)	0	ND	ND	ND
Luna Privilege	high (7)	0	ND	ND	ND

WALNUT: BACTERICIDE EFFICACY – BIOCONTROLS AND NATURAL PRODUCTS

Organic treatments	Resistance risk (FRAC#)[1]	Walnut blight[2]
Bordeaux[2] (organic with approved copper)	low (M1)	4
Fixed coppers[2,3] (organic with approved copper)	medium (M1)	4
Zinc sulfate + copper + hydrated lime (Zinc Bordeaux) (organic with approved copper)	low (M1)	4
Actinovate	low (BM 02)	3
Regalia	low (BM 01, P 05)	3
Regalia + Copper (organic with approved copper)	low (BM 01, P 05 + M1)	3
Blossom Protect	low (BM 02)	2/3
Serenade (organic)	low (BM 02)	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 '+++'.**

[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 build up of populations on buds that may increase disease in subsequent years.

WALNUT: 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 and weather conditions each year.

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	0	2[4]	3	2	0	0	0	0	0
Botryo-sphaeria blight	0	0	0	1	2	3	3	2	0	1	1
Kernel mold[2]	0	0	0	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 '+++' 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.