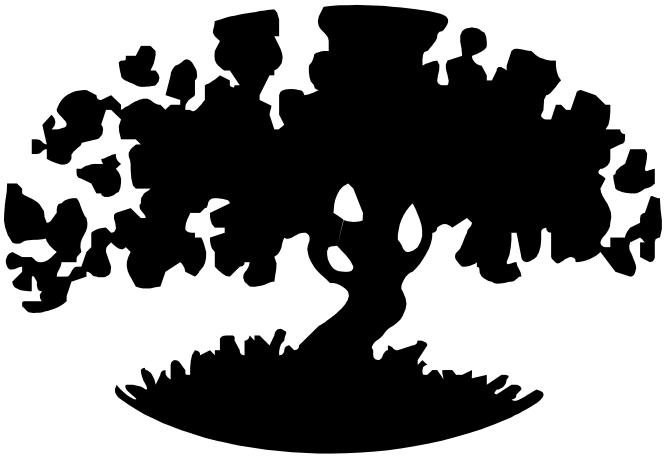
FUNGICIDES, BACTERICIDES, AND BIOLOGICALS FOR DECIDUOUS TREE FRUIT, NUT, STRAWBERRY, AND VINE CROPS 2017



ALMOND	***PEAR***
APPLE	***PISTACHIO***
APRICOT	***PLUM***
CHERRY	***POMEGRANATE***
GRAPE	***PRUNE***
KIWIFRUIT	***STRAWBERRY***
PEACH/NECTARINE	***WALNUT***

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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. 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.

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 group numbers.

Factors determining the risk of fungicide resistance development in a pathogen population include: 1) fungicide chemistry; 2) fungal species; and 3) the interaction of the pathogen and the

fungicide in the disease triangle. Specific components of these factors can be outlined as follows for a pathogen causing disease on a susceptible host:

1) *Fungicide*
   - 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.
2) *Pathogen*
   - 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) *Interaction:* The stability of the fungicide on the plant and the interaction of the fungicide with the fungus under different environments.
   - *Degradation of the fungicide over time*
   - *Changes in concentrations and the effect on selection pressure.*

Conclusion: Resistance development is a complex process and has to be determined for each Pathogen-Fungicide combination in the disease triangle.

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:

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)
2) Improper fungicide rate is applied. Off-label rates are used or occur due to alternate row applications. These may be improperly timed because environmental conditions prevent 3-day re-application intervals. This results in pathogen populations that are repeatedly exposed to low fungicide concentrations. This allows for survivors and resistance.
3) Repeated use of the same fungicide mode of action (Using one FRAC group repeatedly in a growing season).

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

a. ***R***otate between different fungicide modes of action as indicated by the FRAC number on each fungicide product (e.g., FRAC 7 should not be followed by FRAC 7; instead use FRAC 7, then follow with FRAC 3 or FRAC 3/11, FRAC 3/9, and FRAC 7/11).
b. ***U***se labeled rates – Fungicide labels often provide a range of rates: use the upper range for high disease pressure and the lower range for low disease pressure. Proper rates include proper coverage to minimize survivors from inadequate exposure to the toxicant.
c. ***L***imit the total use of any single-site mode of action fungicide to ideally one or two per growing season.

d. ***E***ducate yourself about the mode of action, spectrum of activity, recommended rates, and the performance of a fungicide against various diseases. This information is found later in this document.

e. ***S***tart a fungicide spray program with a multi-site mode of action fungicide, pre-mixture, or tank mixture to reduce the total fungal population that is exposed to any single-site mode of action fungicide used later in a sequence of fungicide applications. NOTE: Never use a single-site mode of action fungicide or a pre-mixture when high levels of disease already occur. The possibility of selecting fungicide resistant individuals is more likely to occur when high populations of a pathogen are being exposed to the selection pressure.

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

GRAPEVINE: FUNGICIDE EFFICACY – Conventional Chemistry

Fungicide	Resistance risk (FRAC#)[1]	Powdery mildew	Downy mildew	Rot		Phomopsis cane and leaf spot	Eutypa dieback	Bot Canker	Dead Arm (*Phomopsis* sp.)
				Botrytis bunch rot	Summer rot				
Abound	high (11)[2]	++++	++++	+	----	+++	NR	----	----
Flint[3]	high (11)[2]	++++	+++	++	++	++	NR	----	----
Inspire Super	medium (3/9)	++++	----	++++	++	----	NR	NR	NR
Kenja	high (7)	++++	NR	NR	NR	NR	NR	NR	NR
Luna Experience	medium (3/7)	++++	----	++++	++	----	NR	NR	NR
Luna Tranquility**	medium (7/9)	++++	----	+++	++	----	NR	NR	NR
Merivon (wine+raisin)	medium (7/11)	++++	----	++++	++	----	NR	NR	NR
Mettle	high (3)	++++	----	----	+	----	+++	----	----
Orius,Tebucon,Toledo,Tebuconazole, Elite, (Tebuzol)**	high (3)	++++	----	++	++	----	NR	----	----
Pristine	medium (7/11)[2]	++++	++++	++++	+++	+++	NR	----	----
Procure	high (3)	++++	----	----	----	----	NR	----	----
Quadris Top	high (3/11)	++++	+	++	++	++	NR	----	----
Quintec	high (13)	++++	----	----	----	----	NR	----	----
Rally	high (3)	++++	----	----	----	----	+++	++	++
Rally+Topsin-M[5]	high (1+3)	++++	----	----	----	++++	++++[6]	++++	++++
Revus Top	medium (3/40)	++++	++++	++	++	++	NR	----	----
Rhyme	high (3)	++++	----	----	----	----	NR	----	----
Rubigan**, Vintage**	high (3)	++++	----	----	----	----	NR	----	----
Sovran	high (11)[2]	++++	++++	++	++	++++	----	NR	++++
Sulfur	low (M2)	++++	----	----	----	----	NR	----	----
Topsin-M,T-Methyl,Incognito	high (1)[2]	++++	----	++	++	+	++++	++++	++
Torino	high (U6)	++++	----	----	----	----	----	----	----
Vivando	high (U8)	++++	----	----	----	----	----	----	----
Luna Privilege	High (7)	+++	----	+++	+	----	++	----	----
Bayleton**	high (3)	++	----	----	----	----	NR	----	----
Copper	low (M1)	++	+++	++	+++	----	----	----	----
Elevate	high (17)[2]	++	----	++++	++	----	NR	----	----
Ph-D	medium (19)	++	----	+++	+++	ND	NR	----	----
Scala	high (9)[2]	++	----	++++	++	----	NR	----	----
Switch	low (9/12)	++	----	++++	+++	----	----	----	----
Vangard	high (9)[2]	++	----	++++	++	----	NR	----	----
Botran	medium (14)	----	----	+++	----	----	----	----	----
Captan	low (M4)	----	+	+++	+++	+++	NR	----	----
CaptEvate**	low (M4/17)	----	+	+++	+++	+	----	----	----
Dithane,Manzate, Penncozeb	low (M3)	----	----	++	----	+++	----	----	----
Presidio**	high (43)	----	++++	----	----	----	----	----	----
Revus	high (40)	----	++++	----	----	----	----	----	----
Ridomil Gold, (Mefenoxam**)	high (4)	----	++++	----	----	----	----	----	----

Rovral,Iprodione, Nevado	low (2)	----	----	+++	----	----	----	----	----
Ziram	low (M3)	----	++	+	+	+++	----	----	+++
Laguna	high (3)	ND	ND	ND	ND	ND	ND	ND	ND
Aprovia*	medium (7/11)[2]	NR	NR	NR	NR	NR	NR	NR	NR
Rovral + Oil[4]	low (2)	NR	----	++++	----	----	NR	----	----
Oso	medium (19)	NR	----	+++	+++	ND	NR	----	----

Rating: ++++ = excellent and consistent, +++ = good and reliable, ++ = moderate and variable, + = limited and/or erratic, +/- = minimal and often ineffective, ---- = ineffective; ND = no data and NR = not recommended.

*** Registration pending in California.**
**** Not registered, label withdrawn or inactive in California.**
***** Registered only on wine grapes in California.**

GRAPEVINE: FUNGICIDE EFFICACY – Soft Chemistry (Biological and Natural Products)

Fungicide	Resistance risk (FRAC#)[1]	Powdery mildew	Downy mildew	Bunch rot		Phomopsis cane and leaf spot	Eutypa dieback	Bot Canker	Dead Arm (*Phomopsis* sp.)
				Botrytis	Summer				
Cinnacure	low	+++	----	----	----	----	----	----	----
Elexa**	low	+++	----	----	----	----	----	----	----
Fracture	low	+++	----	++	----	----	----	----	----
JMS Stylet oil4	low	+++	----	+++	++	----	NR	----	----
Kaligreen	low	+++	----	----	----	----	----	----	----
Milstop	low	+++	----	----	----	----	----	----	----
Purespray	low	+++	----	----	----	----	----	----	----
Regalia	low	+++	-----	----	----	----	-----	----	----
Serenade	low (44)	+++	----	++	+	----	----	----	----
Sonata	low	+++	----	++	NR	----	----	----	----
Taegro**	low	+++	----	++	+	----	----	----	----
Vintre	low	+++	----	----	----	----	----	----	----
Actinovate	low	++	-----	----	----	----	-----	----	----
Employ*	low	++	----	----	----	----	----	----	----
HiPeak*	low	++	----	----	-----	-----	-----	----	----
Prev-am *[4]	low	++	----	----	----	----	++	----	----
Sporan	low	++	----	----	----	----	----	----	----
Timorex* [4]	low	++	----	----	----	----	----	----	----
VigorCal*	low	++	----	----	----	----	----	----	----
VigorK*	low	++	----	----	----	----	----	----	----
Double Nickel	low	+	----	+	NR	----	----	----	----
Sporatec	low	+	----	----	----	----	----	----	----
B-Lock*	low	----	---	----	-----	-----	++++	++	NR
Vitiseal	low	----	----	----	----	----	++++	----	----
Botector	low	ND	----	+	----	----	----	----	----

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

Rating: ++++ = excellent and consistent, +++ = good and reliable under low to medium disease pressure (high disease pressure will result in reduced efficacy with a rating of +/++), ++ = moderate and variable, + = limited and/or erratic, +/- = minimal and often ineffective, ---- = ineffective; and NR = not recommended.

[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/). Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action Group numbers 1, 4, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action Group number; for fungicides with other Group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action Group 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/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.

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)	+++	----	----	----	----	----
Botrytis Bunch Rot	+++[2]	----	+++[1]	+++[1]	+++[1]	+++[1]
Brown spot	----	----	----	+++	+++	+++
Dead arm	+++	+++	----	----	----	----
Downy mildew	----	+++	+++	----	----	----
Esca (Black measles)	+++[2]	----	----	----	----	----
Eutypa Dieback	+++	----	----	----	----	----
Powdery mildew	+++[2]	+++[3]	+++[3]	+++[4]	----	----
Phomopsis	+++	+++	----	----	----	----
Summer bunch rot (sour rot)	----	----	----	----	+++[1]	+++[1]

Rating: +++ = most effective, ++ = moderately effective, + = least effective, and ---- = 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 FUNGICIDE FRAC[1] GROUPS

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 groups 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 groups. *Numbers separated by slashes are premixtures, whereas numbers grouped by pluses are tank mixtures.* If several diseases need to be managed, select a group that is effective against all diseases. Refer to fungicide efficacy table for fungicides belonging to each FRAC group. Group numbers are listed in numerical order within the suggested disease management program.
3) Rotate groups for each application within a season and, if possible, use each group only once per season, except for multi-site mode-of-action materials or natural products/biological controls (i.e., M2, NP/BC).

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

[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/). Group numbers are listed in numerical order within the suggested disease management program. Fungicides with a different group number are suitable to alternate in a resistance management program. Refer to the fungicide efficacy table for fungicides belonging to each FRAC group.

[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] NP/BC = Natural Products/Biological Controls such as B-Lock, Sonata, Serenade, Kaligreen, Cinnacure, etc.

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