

Fungicide Resistance Problems in Almond and Other Stone Fruits

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Several important diseases of almond and other stone fruits are developing resistance to our fungicides. Almond scab began showing widespread resistance to the strobilurin class of fungicides (e.g., Abound[®], Flint[®], Gem[®]) in 2006. This means Pristine[®] is no longer effective against scab in resistant orchards because Pristine[®] is a combination of a strobilurin fungicide and Boscalid[®] (Boscalid[®] is not effective against scab).

Alternaria leaf spot, a real problem on almonds in certain areas of Kern, Butte, Glenn and Tehama counties, developed resistance to the strobilurin class of fungicides beginning in 2003. This disease is now also showing resistance to carboxamide fungicides (e.g., boscalid[®]) in many locations. This means that Alternaria is now showing resistance to Pristine[®]. In 2007 we had our first confirmation that brown rot is becoming resistant to anilinopyrimidine fungicides (Scala[®], Vanguard[®]) in prunes. Resistance most likely developed due to overuse and/or improper use of these materials.

Be smart when choosing your fungicide program. Use a particular fungicide only once per year. In fact, use a particular CLASS of fungicides only once per year if possible. Study the charts below and apply the fungicides which are most appropriate for the bloom / disease period. For instance, a pink bud or early bloom spray is primarily a brown rot spray. There are many fungicides listed as very good or excellent against brown rot. Not all of them work as well on later season diseases (jacket rot, shot hole, anthracnose, scab, rust, etc.). It doesn't make sense to use broad spectrum materials like Pristine or Adament for a brown rot spray and then be unable to use them later in the season when fungicide choices are more limited.

How does resistance to a fungicide (or insecticide, or antibiotic, etc.) develop? Whenever you have a population of living organisms, there are always a few individuals within the population that survive. If a grower continually uses the same class of materials, he/she will kill most of the susceptible individuals within the population, but the resistant ones will survive and multiply. Pretty soon the whole population is resistant to this chemical class. Poor spray coverage will increase the rate of resistance development.

Growers need to follow the important resistance management strategies listed below.

- If possible, begin the season with a multi-site mode of action fungicide. Many popular fungicides control a fungus by acting only on one site of a particular biochemical pathway. The potential for resistance development to these types of fungicides is high. Multiple-site mode of action fungicides kill an organism in more than one way. Resistance potential is low for these fungicides.
- Use fungicides from the same "class" only once per season if possible, especially fungicides with a single-site mode of action. Fungicides within the same class have the same mode of action. If an organism becomes resistant to a fungicide,

it is also resistant to all other fungicides in the same class (example: Rally/Laredo and Elite). Fungicide classes are identified by a FRAC (Fungicide Resistance Action Committee) number. Do not use fungicides with the same FRAC number more than once in the same season (see table below).

- Use label rates (not below label rates). For strobilurins (examples include Abound, Flint and Gem), use upper label rates.
- Make sure you have good spray coverage. This includes:
 - Do not use alternate row spray applications
 - Use enough spray volume to achieve good coverage
 - Drive slowly enough to achieve good spray coverage
 - Do not use airplane applications, especially at full canopy

The table on the next page lists the fungicides labeled for use on almonds, other stone fruits, and grapes, their modes of action, their FRAC number and resistance potential. Please study this list, as well as the table on the following page, before planning your fungicide program this year. Almond growers may choose to hold off on using materials like Pristine and Abound at bloom so they can be used later in the season for diseases like scab, anthracnose, and Alternaria leaf spot if necessary. Please note that rotating between Pristine and Abound, Flint or Gem is not a good resistance strategy (they all share FRAC number 11). Also note that Adament, Elite, Indar, Inspire Super, Orbit and Quash share the same FRAC number (3), meaning only one of these fungicides should be used in a season.

We are fortunate to have several very effective fungicides registered for use in almonds, other stone fruits, and grapes. There is no need to use the same fungicide more than once in the same season. If resistance develops against a fungicide class, this class may be lost for ever as a management tool. Generally, it takes the chemical industry and researchers years to develop new products with unique modes of action. If we all follow the resistance management guidelines, we will be able to maintain the effectiveness of the currently registered fungicides for many seasons to come.

General Properties and Efficacy of Registered and Experimental Fungicides Used on Deciduous Tree Fruit, Nut, Strawberry, and Vine Crops in California

Trade name	Active Ingredient	Class	Systemic action	Mode of action (FRAC number)¹	Resistance potential
various	copper	inorganic	No	Multi-site (M1)	Low
various	sulfur	inorganic	No	Multi-site (M2)	Low
Aliette	fosetyl-aluminum	phosphonate	Yes	Multi-site (33)	Low
Dithane/Manzate	mancozeb	carbamate (EBDC) ²	No	Multi-site (M3)	Low
Maneb/Manex	maneb	carbamate (EBDC) ²	No	Multi-site (M3)	Low
Thiram	thiram	carbamate (DMDC) ³	No	Multi-site (M3)	Low
Ziram	ziram	carbamate (DMDC) ³	No	Multi-site (M3)	Low
Rovral/Iprodione	iprodione	dicarboximide	Yes	Multi-site (2)	Low

Scala/Penbotec ⁴	pyrimethanil	anilinopyrimidine (AP)	Slight	Single-site (9)	High ⁵
Vanguard	cyprodinil	AP	Slight	Single-site (9)	High ⁵
Botran/Allisan ⁴	dichloran	aromatic hydrocarbon	Slight	Single-site (14)	Medium
Bravo/Echo/Chlorothalonil	chlorothalonil	chloronitrile	No	Multi-site (M5)	Low
Benlate**	benomyl	benzimidazole	Yes	Single-site (1)	Very high ⁵
Mertect	thiabendazole	benzimidazole	Yes	Single-site (1)	Very high ⁵
Topsin-M/T-Methyl	thiophanate-methyl	benzimidazole	Yes	Single-site (1)	Very high ⁵
Endura*	boscalid	carboxamide	Yes?	Single-site (7)	High
Syllit***	dodine	guanidine	Yes	Few - multi-site (M7)	Medium/High
Elevate/Judge ⁴	fenhexamid	hydroxyanilide	No	Single-site (17)	High ⁵
Ridomil Gold	mefenoxam	phenylamide	Yes	Single-site (4)	High ⁵
Captan	captan	phthalamide	No	Multi-site (M4)	Low
Captevate	captan/fenhexamid	phthalimide/hydroxyanilide	No	Multi-site (M4)/ Single-site (17)	Low
Quintec	quinoxifen	quinoline	No	Single-site (13)	Medium
Scholar ⁴	fludioxonil	phenylpyrrole	No	Few - multi-site (12)	Medium
Bayleton	triadimefon	DMI ⁶ -triazole	Yes?	Single-site (3)	High
Elite	tebuconazole	DMI-triazole	Yes?	Single-site (3)	High
Eminent*	tetraconazole	DMI-triazole	Yes?	Single-site (3)	High
Funginex**	triforine	DMI-piperazine	Yes?	Single-site (3)	High
Indar/Enable ⁷	fenbuconazole	DMI-triazole	Yes?	Single-site (3)	High
Orbit/Bumper/Mentor ^{4,8}	propiconazole	DMI-triazole	Yes?	Single-site (3)	High
Procure	triflumizole	DMI-imidazole	Yes?	Single-site (3)	High
Rally/Laredo	myclobutanil	DMI-triazole	Yes?	Single-site (3)	High
Rubigan	fenarimol	DMI-pyrimidine	Yes?	Single-site (3)	High
Inspire* ⁸	difenoconazole	DMI-triazole	Yes?	Single-site (3)	High
Abound	azoxystrobin	QoI ⁹	Yes?	Single-site (11)	High ⁵
Cabrio	pyraclostrobin	QoI	Yes?	Single-site (11)	High ⁵
Flint/Gem	trifloxystrobin	QoI	Yes?	Single-site (11)	High ⁵
Sovran	kresoxim-methyl	QoI	Yes?	Single-site (11)	High ⁵
Pristine	pyraclostrobin / boscalid	QoI ⁹ / carboxamide	Yes? Yes?	Single-site (11)/ Single-Site (7)	Medium
Switch	fludioxonil / cyprodinil	phenylpyrrole/ AP	No /Slight	Single-site (12)/ Single-site (9)	Medium

¹ Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of actions. Fungicides with a different group number are suitable to alternate in a resistance management program. For more information, see <http://www.frac.info/>.