Selecting Fungicides to Minimize Resistance Development and Avoid Phytotoxicity and Fruit Finish Problems

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Devising seasonal disease-control programs for apples is increasingly complicated because of concerns about fungicide resistance, because some tank mixtures can burn leaves or fruit, and because fungicide mixtures are often needed to cover the full spectrum of apple diseases.

Selecting fungicides for resistance management: All fungicides are classified by the Fungicide Resistance Action Committee (FRAC: see http://www.frac.info/) into groups wherein products with similar modes of action have the same FRAC group number (Table 1). All of the newer fungicides are "at risk" for development of resistance. Managing fungicides to delay resistance requires an integrated program evolving from the following considerations:

1. Keep inoculum levels as low as possible. For apple scab, this involves using fall or spring urea sprays and/or leaf chopping to reduce ascospore numbers in blocks that had scab last year, and using contact fungicides (mancozeb, Polyram, Captan) in combinations with all at-risk fungicides. Contact fungicides kill spores before they germinate whereas most at-risk fungicides kill fungi only after spore germination is initiated. Therefore, when the contact fungicides are applied in combinations with the at-risk fungicides, the contact fungicides act first by killing spores they contact, thereby reducing the amount of inoculum that must be managed by the at-risk fungicide.
2. Use different classes of fungicides (products with different FRAC numbers, Table 1) in rotations during the season. Labels for many of the newer products indicate that after the product has been applied twice it cannot be used again until after a different chemistry group has been applied at least one time. If a program that was historically effective on your farm begins to break down, shift to a different program immediately so as to avoid both the economic losses and the inoculum buildup that occur when fungicide resistant populations are ignored as they first begin to appear.
3. For any given disease, reserve the most effective at-risk fungicide for the period of peak risk for the disease being targeted. The peak risk period for primary scab is usually pink through petal fall whereas the peak risk period for mildew is petal fall through second cover. (Sprays before the peak risk period are also important, but the greatest amount of primary inoculum usually becomes available during the peak periods indicated.) In selecting the most effective fungicide, one must consider both the intrinsic activity of the fungicides and any suspected or known shifts toward resistance in the pathogen population for the specific orchard in question.
4. Use full label rates of the at-risk fungicides, and avoid extended spray intervals. When an infection period occurs during the latter part of an extended spray interval, the pathogen will encounter a much-reduced concentration of the fungicides, thereby increasing the selection pressure for resistance development. Remember that resistance management strategies for

plant pathogens is more akin to strategies used in human medicine than it is to strategies used by entomologists. Using reduced rates of at-risk fungicides is like stopping an antibiotic regimen prescribed by your doctor as soon as you feel a bit better. In both plant pathology and human medicine, using the full dose is a critical for resistance management.

5. Use programs that will simultaneously reduce resistance risks for both apple scab and for powdery mildew. If fungicides selected to control scab at tight cluster or pink do not have activity against mildew (e.g., mancozeb plus Syllit, Scala, or Vangard), then add sulfur to the mix so as to prevent early infections of mildew that, left uncontrolled, would result in more inoculum at petal fall. If sulfur cannot be used because of pre-bloom oil sprays, then the pre-bloom scab program should be changed to include some other mildewcide.
6. Three-way mixtures of fungicides in the same tank are becoming essential for managing multiple pathogens (e.g., scab, mildew, black rot) while simultaneously contending with resistance issues even though this approach seems inconsistent with previous IPM strategies. An effective three-way mixture applied at critical junctures in the primary scab season can eliminate scab control failures that might otherwise necessitate summer-long applications of high rates of Captan. Effectively managing primary scab and mildew also eliminates the selection pressure that occurs if at-risk fungicides are used in June to arrest these pathogens after lesions appear on leaves. Thus, three-way mixtures of fungicides can make sense both economically and as a long-range IPM strategy.

Avoiding phytotoxicity problems: Perfect disease control is of little value if fruit are marred due to phytotoxicity from one of the products applied to manage pests. The most common contributors to phytotoxicity in apples are copper, sulfur, and Captan, but other products may also cause occasional problems. For example, I recently became aware that Topguard applied to drip under cool conditions may cause leaf spotting and/or leaf edge burn, especially on Braeburn. Repeated applications of full rates of phosphite fungicides can result in development of narrow strap-shaped terminal leaves that look somewhat like glyphosate injury.

Copper that is applied or redistributed onto flower parts or fruit after tight cluster will frequently cause fruit russetting. Copper applied in summer sprays can cause blackened lenticels. Risks from copper injury can be reduced by applying copper (for fire blight suppression) only up until green tip. Organic farmers or others wishing to use copper to control fire blight during bloom should use one of the low rate copper products (Table 1) and apply it with low volumes of water to dry foliage under rapid-drying conditions.

Neither sulfur nor Captan will cause leaf or fruit spotting if they are applied alone and well separated from applications of oil or urea (except that sulfur applied in hot weather can burn fruit). Urea, oil, solvents in pesticides formulated as ECs, and spray adjuvants that enhance leaf penetration will increase the probability of leaf and fruit injury if they are tank-mixed with Captan or sulfur because the latter two fungicides kill cells if they penetrate fruit or leaf tissue.

Leaves and fruit are especially susceptible to spray injury during the period from late bloom through first cover. Tank mixes used during that period often include several fungicides, plant growth regulators (i.e., Apogee and thinners), insecticides, foliar nutrients, and miracle products promoted by suppliers. Given the combination of highly susceptible tissue and the complexity of the tank mixes, I believe that growers should completely avoid any use of Captan between full bloom and second cover. Mancozeb fungicides, which can be applied seven times at the rate of 3 lb/A with a 77-day PHI, can effectively substitute for Captan during that time, thereby significantly reducing risks of spray injury during the period when most phytotoxicity problems

occur in commercial orchards. In addition, complex mixtures with Captan should be avoided in late-summer when liquid calcium products and spray adjuvants may carry Captan into fruit lenticels. Captan carried into lenticels may produce lenticel spots that appear some after spraying as well as sub lethal damage that appears only during storage.

Table 1. Mode-of-action groups and risk factors for fungicides registered on apples

Trade name(s)	Fungicides or fungicide groups	FRAC group code	Resis-tance risk*	Phytotoxicity risk	Comments
Basicop, Badge, Champ, COCS, Cuprofix, Kocide, Nordox, etc	Fixed copper fungicides	M-1	L (none?)	L at silver tip or green tip; H after green tip (GT)	Applications after green-tip may cause fruit russetting.
Mastercop, Phyton 27AG, CS2005,	Copper sulfate (label limits = low Cu^{++} rates)	M-1	L (none?)	M-H (after GT)	Label limitations make these unsuitable for green-tip sprays.
(various)	sulfur	M-2	L (none?)	H (with oil or penetrants)	Organic farms or mildew; High rates reduce yield.
Captan	Captan	M-4	L (none?)	H (with oil or penetrants)	Phytotoxic if mixed with the wrong products.
Dithane, Penn-cozeb, Manzate, Polyram	Mancozeb, metiram	M-3	L (none?)	L	Best contact fungicides for tank mixes, especially bloom to 2nd cover.
Ziram	Ziram	M-3	L (none?)	L	Captan work-around for oil sprays in summer.
Syllit	Dodine	U-12	L-M	L	New label restriction: apply only between green tip and pink bud.
Topsin M	Thiophanate-methyl	1	H	L	Used with captan for summer diseases/rots.
Vangard, Scala	AP	9	M	L	Prebloom with mancozeb
Flint, Sovran	QoI	11	H	L	Resistance in scab (and mildew?) increasing.
Indar, Nova, Pro-cure, Topguard	DMI	3	M	L (except Topguard ??)	Resistance to scab/ mildew widespread
Inspire Super	DMI + AP	3 + 9	M†	L	Weak on mildew
Fontelis	SDHI	7	M-H	??	Phyto with captan ?
Pristine	SDHI + QoI	7 + 11	M†	L	Questionable for scab control where QoI-resistance is already present.
Merivon**	SDHI + QoI	7 + 11	M†	??	
Luna Sensation**	SDHI + QoI	7 + 11	M†	L-??	
Luna Tranquility**	SDHI + AP	9 + 11	M†	L-??	Weak on rust diseases?
Omega**	fluazinam	29	L	L-??	Captan substitute?
Phosphorous acids	Phosphonates	33	L	L-M	For Phytophthora (and with Captan, for SBFS).

*Resistance risk listed on FRAC website except that combination products (†) are estimated from the component fungicides and anticipated use strategies on apples. Abbreviations: L = low, M = moderate, H= high risk; Question marks indicate some uncertainty.

** Not yet labeled in NY