Managing Fungicides to Minimize Fruit and Leaf Injury

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Devising seasonal disease-control programs for apples is increasingly complicated (i) because of uncertainties relating to fungicide resistance in any given orchard, (ii) because mixtures containing multiple fungicides are often needed to ensure effective disease control, and (iii) because complex pesticide mixtures sometimes cause unexpected damage leaves or fruit. Applying fungicides to prevent fungal damage can be counter-productive if fruit end up damaged by a phytotoxic spray mixture.

The most common contributors to phytotoxicity problems in apple orchards are copper, sulfur, liquid lime-sulfur (LLS), and captan. However, other products also cause occasional problems. For example, 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 after bloom can result in development of narrow strap-shaped terminal leaves that look somewhat like glyphosate injury. Some micronutrient products can burn fruit if they are mis-applied. Of course, using off-label products on apples can also cause severe injury, one example being the effects from accidental carry-over of azoxystrobin (e.g., Abound, Quadris) in a sprayer that was previously used to spray stone fruits, grapes, or vegetable crops.

Factors that contribute to phytotoxicity: Pesticide applications that result in fruit and/or leaf injury almost always involve interactions of at least two contributing factors, but the probabilities of injury increase significantly when three, four or five risk factors from the following list occur together:

1. The spray mixture includes at least one product that will kill plant cells if it is carried through the leaf or fruit cuticle and enters epidermal cells. Among fungicides, captan, copper products, sulfur, and LLS are the most common culprits, but none of these will cause phytotoxicity in the absence of at least one additional contributing factors in this list.
2. The spray mixture (or leaf residue persisting from the preceding spray) includes an adjuvant or active ingredient that enhances penetration of pesticide molecules through the waxy cuticular layer on fruit and leaves. Adjuvants can be products that are purposely added to the tank mix, such as oil or spreader-stickers. Or they may simply be carriers present in other pesticide formulations or in micronutrients that are tank mixed with problem fungicides. Urea applied as a foliar spray can enhance penetration of pesticides into leaves. (Note that urea is specifically recommended for tank-mixing with some herbicides because of its ability to improve uptake into plants!)
3. Sprays are applied under slow drying conditions. Slow drying conditions occur when sprays are applied to leaves that are still wet from dew or rain, when sprays are applied under high humidity and low wind conditions at night, or when sprays are applied with enough water to cause leaves to drip.
4. Sprays are applied after a few warm, rainy, windless days sometime between bloom and first cover. Under those conditions, trees are rapidly producing new terminal leaves and fruit are increasing in size, but the new tissues fail to develop the cuticular waxes needed to prevent both desiccation and pesticide penetration because they have not yet been exposed to either direct sunlight or desiccating breezes.
5. For the same reasons noted in #4 above, sprays applied following 10 or more days of cool cloudy weather any time during the year occasionally contribute to leaf or fruit injury. (No one can really predict exactly how many days of cloudy weather and what temperatures are required to enhance injury, but you get the idea!)
6. Hot weather with daytime highs approaching or exceeding 90°F occur the day sprays are applied or within a day or two after sprays have been applied. High temperatures are especially problematic following applications of sulfur or LLS. Trees that are simultaneously exposed to drought stress and high temperatures may be especially at risk for injury.

New recommendations for minimizing phytotoxicity: The first logical step for reducing risks of leaf and fruit injury with fungicides requires that captan be omitted from all sprays between full bloom and second cover. This recommendation has been incorporated into the apple section of Cornell's Tree Fruit Management Guide for 2014. The rational for this recommendation comes from the fact that captan has been involved in most of the recent phytotoxicity-based losses that I have diagnosed over the past five years, and as noted above, the period from petal fall through first cover is the period of greatest risks. Captan incompatibilities during this time period have increased in recent years due to the increasingly complex tank mixtures that are being used at petal fall and first cover (i.e., with foliar nutrients and plant growth regulators). 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 period, thereby eliminating risks of captan injury during the period when most phytotoxicity problems occur in commercial orchards. Flint or some other fungicide can be added to the mancozeb sprays to enhance scab control and to pick up mildew, black rot, and other diseases that must be controlled with sprays at petal fall and first cover.

In addition, we advise using caution when captan is included in later summer sprays because subjective observations suggest that liquid calcium products and spray adjuvants may carry Captan into fruit lenticels during late summer. Captan carried into lenticels may produce lenticel spots that appear after just before harvest, but I suspect that captan in lenticels may also cause sublethal injury around the lenticel that later develops into lenticel spotting during storage.

Risks from copper injury can be reduced by applying copper (for fire blight suppression) only up until green tip. 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. Organic farmers or others wishing to use copper to control fire blight during bloom should use one of the low rate copper products (e.g., Phyton, Mastercop, Cueva, or Magnabon) and should apply the copper products using low volumes of water to treat dry foliage under rapid-drying conditions. Applied in this way, copper may still cause some fruit russet, but the level of injury will be less than if copper is applied to wet foliage under slow drying conditions.

Neither sulfur nor LLS should be applied to trees when either temperatures at the time of application or predicted high temperatures for the next four days will exceed 90°F. Organic growers who choose to use low rates of LLS during summer to control summer diseases should instead substitute low-rate copper products during hot summer weather. The low-rate copper sprays applied during summer may still cause some fruit russet and/or blackened lenticels on fruit, but they will not cause the fruit burn and resultant increased susceptibility to fruit decays that occurs when sulfur and LLS are applied in hot weather.

Impacts of fungicides on development of fruit russet: Fruit russet can be caused by frost, powdery mildew infections that occur between bloom and first cover sprays, chemical phytotoxicity (e.g., from copper or LLS), or by *Aureobasidium pullulans*, a yeast-like fungus that is the most common epiphyte on apple trees. In many cases, the russet on fruit does not become apparent until many weeks after it was initiated, and that is especially true for light, net-like russetting. Because russetting triggered by any of the factors mentioned above can be virtually identical in appearance, determining the actual cause of the russet after it appears is almost impossible in situations where more than one factor could plausibly be involved as a contributing factor.

Field trials conducted over many years have clearly shown that contact fungicides such as mancozeb, captan, and Polyram can suppress fruit russet on russet-susceptible cultivars like Golden Delicious. Thus, unsprayed check trees that receive no fungicide very often have more fruit with russet and more severe russet on affected fruit than occurs on trees that received contact fungicides during bloom. Spray trials at the Hudson Valley Lab have shown that Flint can also suppress russet (although it may be slightly less effective than the contact fungicides listed above) whereas Inspire Super has no suppressive effects on fruit russet. Because the incidence and severity of fruit russet are heavily impacted by fungicide choices and timing, it seems probable that much of russet suppression achieved with fungicides is attributable to the suppression of *A. pullulans* by the fungicides that are applied at bloom, petal fall, and perhaps first cover.

A proprietary mixture of two strains of *A. pullulans* was recently registered in the U.S. under the trade name "Blossom Protect" as a biocontrol to prevent blossom infections by *Erwinia amylovora*, the fire blight pathogen. Blossom Protect (BP) has been used successfully both Europe and in the Pacific

Northwest. A field trial was conducted in 2013 at the Hudson Valley Lab to determine if spraying BP during bloom might artificially boost populations of *A. pullulans* in orchards enough to exacerbate fruit russetting under the warm damp conditions that often persist during bloom in eastern United States. Treatments were applied as shown in Table 1, but similar treatments were combined for analysis of data as shown in Table 2. A rainy period starting on 8 May began about 3 hr after the 8 May treatments had been completed and provided 41 hr of intermittent leaf wetting and 0.98 inches of rain with a mean temperature of 62 °F. Much of the russet that occurred on Golden Delicious fruit apparently developed during that wetting period because treatments where BP was applied on 8 May had the more russet than treatments were BP was applied only in earlier timings (trts 5 & 6). The good news was that applications of Blossom Protect did not cause any russetting on Jerseymac or Redcort apples that were included in the spray plots, so adding *A. pullulans* via BP sprays does not generate russet on cultivars that rarely show russet anyway. BP treatments generally resulted in russet on Golden Delicious similar to or only slightly greater than that observed in the control plots, but the level of russet on Golden Delicious in the BP and control plots was not commercially acceptable. Mancozeb applications during late bloom (or applications of other products that suppress *A. pullulans)* are essential for minimizing fruit russet on some apple cultivars, but mancozeb is not compatible with BP. No fire blight developed in our research plots, so we could not assess effectiveness of the treatments for suppressing blight. However, it seems likely that after mid-bloom, achieving fire blight control with BP and russet suppression with mancozeb may be mutually exclusive objectives for russet-prone apple cultivars grown under the wet, humid conditions that commonly occur during bloom in eastern United States.

Table 1: Timing of Blossom Protect and fungicide sprays during bloom in 2013.

Treatments (italics indicate copper treatments)	3 May 10% BL	6 May 40% BL	7 May airblast	8 May 80%BL	15 May airblast	15 May Petal fall
1. Control: no blight or russet suppression			V*		V-R	
2. Control: no russet suppression		FW*	V		V-R	
3. Manzate + Fire Wall standard trt		Mz+FW*	V		V-R	Mz
4. Manzate + Fire Wall standard trt		Mz+FW	V		V-R	Mz
5. BP (2-sprays) // Manzate (2 sprays)	**BP***	**BP**	V	Mz*	V-R	Mz
6. BP (2 sprays)	**BP**	**BP**	V		V-R	
7. BP (4 spring sprays)	**BP**	**BP**	V	**BP**	V-R	**BP**
8. BP (3-sprays)	**BP**	**BP**	V	**BP**	V-R	
9. BP (3-sprays) // Manzate (1 spray)	**BP**	**BP**	V	**BP**	V-R	Mz
10. Manzate (1 spray) // BP (2 sprays)		Mz	V	**BP**	V-R	**BP**

* V = Vangard 50W 5 oz/A, V-R = Vangard 5 oz/A plus Rally 40WSB 6 oz/A, InsSup = Inspire Super 2.83EW 12 fl oz/A, FW = Fire Wall 17WP 8 oz/100 gal, Mz = Manzate 75DF 1 lb/100 gal, BP = Blossom Protect, X = the listed product was applied.

Table 3. Impact on fruit russet on Golden Delicious when comparing five pairs of similar treatments.

Material and rate of formulated product per 100 gal of spray	Fruit (%) with russetting that exceeded standards for USDA Extra Fancy grade[z]	Golden Delicious fruit affected by russet: Fruit (%) with russet[y] Stem end	Calyx end	Russetted area (%)[x] Stem end	Calyx end
Controls: no Manzate or BP (Trts 1 & 2)	31.3 bc[w]	14.9 ab	34.3 bc	4.4 ab	11.3 bc
Manzate on 6 May, no BP (Trts 3 & 4)	13.1 a	10.1 a	17.4 a	2.7 a	4.6 a
BP on 3 & 6 May only (Trts 5 & 6)	19.1 ab	11.9 a	26.8 ab	3.2 a	8.1 ab
BP on 8 May; no Manzate (Trts 7 & 8)	37.7 cd	20.9 b	45.1 c	6.8 b	15.7 cd
BP on 8 May + one Manzate (Trts 9 & 10)	43.6 d	24.3 b	45.7 c	7.7 b	16.6 d

[z] Percentage of fruit with more russet than allowed within USDA Extra Fancy grade.

[y] Percentage of fruit that, when viewed from either stem end or calyx end, had visible russet.

[x] Estimated percentage of the fruit surfaces covered with russet when fruit were viewed from either end.

[w] Means followed by the same letter are not significantly different (Fishers Protected LSD, $P \leq 0.05$).