Update on Pesticide Combinations That Can cause Phytotoxicity

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The economic impact of phototoxicity (damage to fruit and or leaves) can have a tremendous financial impact on farm finances. The economic impact to perennial crop like wine grapes can be even larger. Phytotoxic effects can show a wide range of symptoms; however, a key diagnostic feature is uniformity. The pattern of symptom development typically follows the application method. For example, an eight-row boom sprayer would give a distinctly different pattern than spot applications of an herbicide.

We have identified a few key causes of phytotoxicity, and new ones continue to pop up. One of the biggest problems is a pesticide may be labeled and do an excellent job on one species, but cause damage on a second species. The challenge is that most growers grow multiple crops.

Often, this potential damage is not noted on the label!

Vivando Fungicide -The newest Phytotoxicity Issue

Vivando Fungicide, a newer fungicide from BASF, is labeled on grapes. It turns out that Vivando can cause phytotoxicity on apple leaves and fruit if the same tank is used following a grape application. Note that the Vivando label has no warning about apple sensitivity, and apples are not on the label. For a few years, a NJ grower noticed spots on his apple leaves and fruit but only on a few cultivars, specifically Macoun, Snow Sweet, and Bramley. After searching the BASF website, maker of Vivando Fungicide, he

Figure 1. Vivando foliar injury on Macoun apple, Hunterdon County, NJ.

Figure 2. Vivando foliar injury on Snow Sweet apple, Hunterdon County, NJ.

found a 2015 Product Guide for Apple Safety warning against damage to apples if Vivando was applied.

This grower applied Vivando to his grapes, only a small amount of residue was left in the empty grape spray tank before he mixed a tank with different pesticides for apple. The little bit of residue was enough to cause damage to his Macouns, Snow Sweets (leaf curl), and Bramleys. On Bramley it scarred the fruit at a concentration of less than 1 ppm!

It appears that a residue of a few parts per million of Vivando can cause injury to apple (<1.0 to 25ppm). Since you cannot clean residues and eliminate them perfectly in a commercial airblast sprayer, then Vivando fungicide does not belong on a farm growing apples.

Figure 3. Vivando foliar injury to Bramley Apple, Hunterdon County, NJ.

Sources:
https://agriculture.basf.us/content/dam/cxm/agriculture/crop-protection/products/documents/BASF_ProductGuide_Vivando_AppleSafety_medres.pdf

Review of a Few Tree-fruit Pesticides That Can Cause Phytotoxicity on Apple

Phytotoxicity can show up as spotting on leaves and fruit, unusual growth patterns, blighting leaves or flowers, stunted growth, reduced root growth, as well as complete plant death. Symptoms often develop within a few days of an application although in some cases phytotoxicity may take much longer to develop. We have seen Roundup injury express one to two years after the application was made (in apple, it is absorbed by the plant, stored in the roots,

Figure 4. Vivando fruit injury to Bramley Apple, Hunterdon County, NJ.

and travels up to the foliage the following spring, where it is expressed as injury to the leaves). It is essential to properly diagnose phytotoxicity and make sure that the same mistakes are not made twice. The most telling symptom of phytotoxicity is a uniform distribution. For example, is the entire field affected, is damage limited to the end of the row, or is there any evidence of a uniform pattern? Once this has been established research should be conducted to determine and confirm the cause.

There are various factors that can sometimes mimic phytotoxicity. For example, a frost event can cause uniform damage to one part of a field or just the bottom halves of fruit trees. Soil pH, salt injury or fertilizer burns are other possible factors that might mimic phytotoxicity. Information on the climatic conditions and soil factors are critical in making a diagnosis.

Types of Pesticides

Pesticides are toxins that kill or inhibit the target organism. They are generally considered selective toxins and when used as prescribed by the label will not harm the crop. It is important to note that some pesticides (such as captan and chlorothalonil) are biocidal and will kill any cell into which they gain entry (especially on grape). They are selective because they are formulated so that the target organisms will ingest them, and non-target organisms will not. These surface acting pesticides do not enter the plant cell. Other pesticides target a certain biochemical pathway that is unique to the target organism(s). Often these types of pesticides maybe systemic and be translocated in the plant tissues.

Causes of Phytotoxicity

1. **Direct toxicity.** Certain pesticides are simply toxic to a particular crop species or variety. When a pesticide is applied to the crop with the goal of controlling a specific pest, weed or pathogen phytotoxic symptoms develop on the entire treated area. A classic example of this scenario is with the fungicide azoxystrobin (Abound, Quadris) on apple (see the example writeup). In grapes, Concords as well as some other varieties are sensitive to a variety of pesticides including Revus, Pristine, Flint, and sulfur. Many herbicides are selective in toxicity and may cause direct injury to a sensitive crop type.
2. **Overdose.** Pesticides are formulated to be applied at a specific rate or rate range. Overdosing can arise from poor sprayer calibration, lack of uniformity or inaccurate rate calculations. In all cases, overdose levels may be large (i.e. 10 fold) and a variety of problems including phytotoxicity as well as excessive residues may develop. Sprayer calibration can be difficult with airblast sprayers that may reach one to many rows depending on wind conditions. Growers should calibrate and spray at the minimum row interval that is practical. Even if the spray can reach further, by spraying at a tight interval insures a more uniform and accurate application. Non-uniformity can be the result of overlapping sprays, poor guidance systems or calibration for a larger area than the sprayer is capable of reaching in a single swath. Systemic materials such as Ridomil will cause burning along the leaf margins when too high a rate is applied. This symptom develops because the material is translocated with the flow of water

in a plant. Thus, the chemical is translocated and concentrated in the leaf margins and if an excessive rate is used chlorosis and burning will develop.

3. **Mixtures.** Most pesticides are marketed as a formulated product. For example, there are granular formulations, wettable powders, and emulsifiable concentrates to name only a few. These formulations are specifically tailored for maximizing the effect of the individual pesticide. A convenient and economical method for controlling several pest problems at once is through the use of pesticide mixtures. Fungicides and insecticides are commonly used in combination for disease and insect control. Many problems can arise from inappropriate use of mixtures. Chemicals that are physically incompatible form an insoluble precipitate that clogs nozzles and sprayer lines. Other mixtures may be phytotoxic and result in a crop loss. Mixing formulations of diazinon or Danitol with Captan or Captec have caused crop injury in the past. Therefore, diazinon and Captan formulations should **not** be tank-mixed. This type of phytotoxicity results from either a direct interaction of the active ingredients or an interaction of the "inert" ingredients in one formulation that enhances the toxicity of the other one, e.g. Syllit 65WG should not be combined with dormant oil, sulfur, chlorpyrifos or foliar nutirents.

A third type of incompatibility arises when one component of the mixture reduces efficacy of the other component.

When Using Pesticide Mixtures, There Are Several Guidelines to Follow

1. Read the label, and follow the manufacturer directions. A section specifically addressing compatibility is usually included on the label. If you are in doubt, contact the manufacturer or a technical representative.
2. Obtain a compatibility chart, and use it as a guideline only. Compatibility charts are frequently out of date, because new pesticide formulations can alter compatibility. However, they provide useful baseline information.
3. Use a jar test to determine physical compatibility. Jar tests are conducted by mixing chemicals at approximately the same rate as specified on the labels. The volumes are scaled down to fit in a small (1 pint – 1 quart) container. Results are evaluated by observing the mixture for reactions such as formation of larger particles, the formation of layers, or other changes that result in the formation of a precipitate (i.e. sludge at the bottom of the container).
4. Chemicals that are physically compatible may be phytotoxic**.** Note: Captan formulations and Oil are the most obvious, all EC formulations (e.g. Diazinon, Danitol and some fungicides) have oil and should not be used on grapes (See the Example). Therefore, mixtures of new chemicals should always be tested on a small number of plants before being sprayed on a larger area. Phytotoxicity may appear as wilting, spotting, dieback, or other abnormalities in plant growth. The appearance of phytotoxicity may be environmentally controlled. For example, high temperatures may cause more severe expression of phytotoxicity. Environmental variables can play a big role in causing mixtures as well as single component sprays to perform not as predicted.
5. Use of spray additives, such as spreaders, stickers, penetrants, or activators, can greatly complicate chemical compatibility in mixtures. Unless recommended by the manufacturer, these additives should be avoided.
6. For aircraft sprays, apply at least 5 gal/A of spray mix. Use a jar test to check for compatibility of pesticides.

Mixtures provide an economical and efficient method for applying different classes of pesticides. Mixtures can provide enhanced activity through synergism and in some cases reduce the chance of resistance developing in the target population. Some chemical companies market pesticides premixed. Thus, appropriate use of mixtures **requires** preliminary research to determine the compatibility.

Incompatible spray schedules. A related topic to mixtures is incompatible spray schedules. In this case use one product such as a crop oil followed by another product such as sulfur or captan will cause phytoxicity. The pesticide labels will generally give a recommended interval to avoid problems.

Excessive concentrations. If a pesticide is applied at a specific rate to an agricultural field it must be applied in a specific volume of water. Some pesticides are safe to the crop if applied at a high enough dilution. Also, the pH of the water used can affect both pesticide activity and phytotoxicity. An example of this situation occurred with some phosphite fungicides. These materials were found to be phytotoxic when used in less than 50gallons/acre of water if the pH of the water was less than 5.5.

Climate and Phytotoxicity. Pesticide applications should be made under "ideal" climate conditions. However, this is often impractical. Understanding the implications of various climate conditions can help minimize possible negative effects.

Application during windy periods can lead to drift. This is particularly important when applying herbicides near sensitive crops. For example, Roundup applied to Roundup resistant crops may drift to sensitive neighbors. Also, herbicides applied to the ground may be carried into the sensitive canopy during windy conditions.

Plants growing in cool overcast seasons are often more sensitive to phytotoxicity. It is likely that these plants have a more easily penetrated cuticle and are more sensitive to the biocidal chemicals.

Temperature can greatly affect pesticide related phytotoxicity. Compounds such as sulfur, chlorothalonil and captan can become phytotoxic at high temperatures. A good rule of thumb is to avoid spraying when temperatures exceed 85F.

Examples of Phytoxicity

The Captan Conundrum: Scab Control vs. Phytotoxicity

Dave Rosenberger, Professor Emeritus, Cornell

Captan is a cornerstone fungicide for apples because it is very effective against apple scab and also controls summer fruit rots. Captan has long been noted for its ability to prevent scab on fruit even when scab control on leaves is less than perfect. In fungicide tests in replicated plots where we purposely used lower than recommended rates, Captan 50W at 3 lb./A has usually provided better control of apple scab than mancozeb fungicides applied at the same rate.

Fungi do not become resistant to captan because it blocks multiple biochemical pathways (i.e., it is a multi-site inhibitor). Resistance to captan can occur only if fungi develop simultaneous mutations for all of the blocked pathways, something that has not happened in the 60 years since captan was introduced.

Captan kills spores that it contacts whereas many of our newer fungicides kill fungi or arrest fungal growth only after germ tubes emerge from the spores. As a result, when captan is applied in combinations with other fungicides in protectant sprays, captan usually does 90 to 99% of the work by killing spores on contact, thereby reducing selection pressure for fungicide resistance to the other product in the tank mix. We use tank mixes with other fungicides (dodine, benzimidazoles, DMIs, strobilurins, SDHIs) to expand the spectrum of disease control and/or to control/suppress the small amount of scab that may have escaped control from the last spray. Captan does not control powdery mildew or rust diseases, so tank mixes are needed to control those diseases even when captan alone might suffice for controlling apple scab.

Unfortunately, captan also has a dark side: it is toxic to plant cells if it penetrates into leaf or fruit tissue. Spray oil and other spray adjuvants that act as penetrants allow captan to move through the protective wax cuticle on leaf surfaces. When that occurs, we see captan-induced leaf spotting, usually on the two or three leaves on each terminal that were just unfolding at the time trees were sprayed. It takes time for cuticular waxes to develop on new leaves, so young unfolding leaves are the most susceptible to spray injury. The leaf cells directly killed or injured by captan provide entry sites for other leaf spotting fungi such as *Phomopsis, Alternaria,* and *Botryosphaeria* than can enlarge the spots. It may take five or 10 days for the injury to become visible, and by that time the injured leaves may be 5 or 6 nodes below the growing point on terminal shoots.

Captan injury on apples usually appears during the three weeks after petal fall because during that time period terminal shoots are growing very rapidly (i.e., producing lots of new leaves), and spray mixtures used at petal fall and in first and second cover sprays commonly include insecticides, growth regulators, foliar nutrients, and spray adjuvants. Captan applied alone almost never causes leaf spotting on apples. Rather, it is the other products in the tank that sometimes enhance captan uptake and trigger the resultant phytotoxicity. Increasing the number of products that are included in a tank mixture increases the probabilities that the mixture will enhance captan absorption and result in injury to leaves.

Sensitivity of Apple Cultivars to Azoxystrobin Fungicide

Norman Lalancette, Win Cowgill, Jeremy Compton, and Kathleen Foster

Three Strobilurin fungicides became labeled for growers in the late 1990's: azoxystrobin (Abound), kresoxim-methyl (Sovran), and trifloxystrobin (Flint). With respect to tree-fruit crops, Abound is available for use on stone fruit, while both Sovran and Flint are labeled for pome fruit; all three are registered for use on grape as well as various other crops. Each of the three registered strobilurins has some level of phytotoxicity to another crop. For azoxystrobin, certain apple cultivars –particularly McIntosh – have been found to be particularly sensitive. This phenomenon complicates usage by orchardists who have both stone and pome fruit. Many growers in both NJ and Massachusetts have both. Research in NJ in 1999-2000 evaluated 96 strains and variety of apple to test sensitivity of apple to azoxystrobin. Tables 2, 3 show the results.

Table 2. Apple cultivars and strains moderately sensitive to azoxystrobin fungicide

Braeburn	Slight leaf curl, possible stunting; No necrosis or drop
Luster Elster	2% leaf necrosis / browning
Red Delicious, Dulcet	2% leaf necrosis / browning
Shamrock	10% stippling
Suncrisp	20% basil leaf drop on 2-year wood; uninjured 1-year wood; browned fruit
Sunrise	10% leaf drop; 10% scorch

Highly sensitive cultivars. A total of 33 cultivars and strains were found to be highly sensitive to azoxystrobin sprayed at the indicated concentration. Leaves on treated shoots initially became necrotic (uniformly brown), with 100% defoliation eventually occurring on many of the cultivars. However, treated lateral buds on shoots remained green and the majority of the terminal buds began to grow and produce new foliage later in the summer.

Table 3. Apple cultivars and strains highly sensitive to azoxystrobin fungicide

Akane	Gala, Stark Ultra Red	Northwest Greening
Britemac	Gravenstein	Pink Lady
Cortland	Keepsake	Raritan
Cox Orange Pippin	Liberty	Red Cort
Fameuse	Macoun	Redfree
Gala	McIntosh, Millers	Red Haralson
Gala, Royal	McIntosh, Rodgers Red	Spartan
Gala, Imperial	McShay	Spire, Scarlett
Gala, Lydia's Red	Mollies Delicious	Vista Bella
Gala, Scarlet	Northern Lights	Wealthy
Gala, Stark Galaxy	Northern Spy	William's Pride

Wine Grape Phytotoxicity to Captan 80WDG + Danitol 2.4EC in NJ

Win Cowgill

At the Rutgers Snyder Farm in 2010, Captan and Danitol 2.4 EC were applied twice in midseason on standard IPM-based pest control program. The right weather conditions, warm 80's and humid, created the perfect conditions for the oil in the Danitol to pull the Captan into the plants, killing some of the more sensitive grape cultivars in the variety trial. No warning is found on either label, but they should not be combined together on wine grapes.

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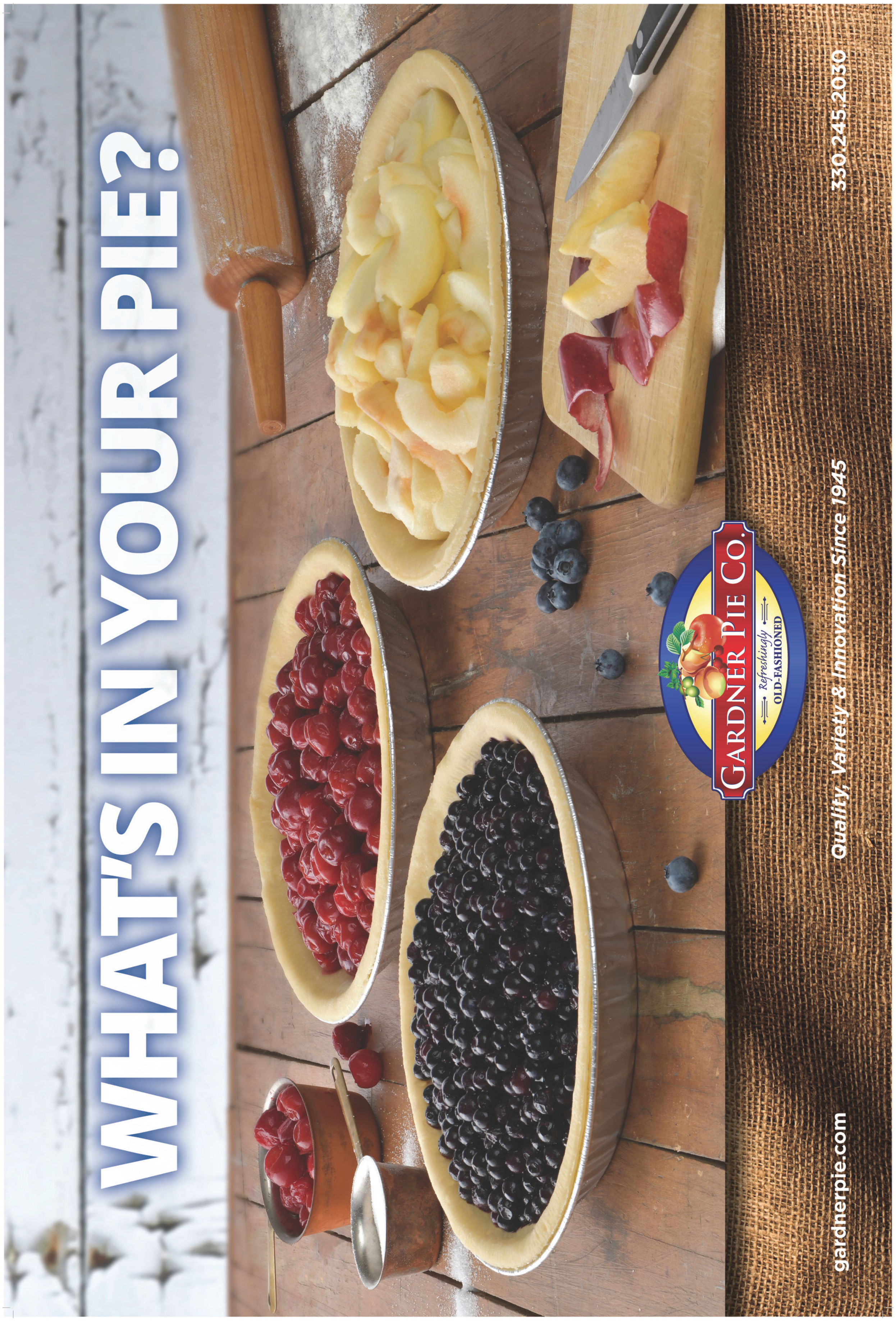
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