NEW FUNGICIDES AND RESISTANCE IN SCAB AND MILDEW

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Apple Scab and Powdery Mildew in NY during the 2013 season

The 2013 growing season came at the usual time of year in the early April, but the heavy infection periods didn't really start until bloom. The majority of ascospores were released during several large infection periods that occurred just after bloom. The weather turned cool throughout bloom and into petal fall. This weather was good for suppressing fire blight, but favorable to apple scab development. From petal fall to first cover, there was an extended period of cool wet weather, which was favorable for any secondary apple scab infections from conidia or remaining ascospores that truly were not released in early May.

The warm dry weather prior to bloom likely favored the development of powdery mildew inoculum, and the high humidity during the weather following petal fall further promoted the development of powdery mildew. By the end of season, powdery mildew seemed unstoppable in the drier areas of western NY particularly in plantings along the lakefront.

Efforts to manage apple scab during the extended period slow drying weather following petal fall lead to problems with tank mixes for thinning, disease, and insect management. Operations throughout the NY/New England region suffered considerable damage from chemical applications made during this period. To make matters worse, many production operations suffered losses to apple scab from despite a lack of apparent of infection periods. Due to the prevalence of chemical injury in the region, extension scientist have started to the re-think the use of protectant fungicides mixes from bloom to $1^{st}/2^{nd}$ cover.

Overview of key fungicide chemistries registered and used for apple disease management

Numerous fungicide chemistries ranging from protectants to single target site-specific systemic fungicides with antisporulant activity are registered for diseases of apples in the United States. Below is a brief list of the fungicide chemistries and the diseases of apple for which they are labeled to control. Several of the new chemistries mentioned have pending 24(c) SLN labels pending for NY. Luna Sensation will not have a NYDEC label in 2014.

Multi-site inhibitors: Mode of Action (MOA): multi-site contact inhibition

Multi-site inhibitor fungicides are generally inexpensive, have good protectant activity, are low risk for resistance development due to non-specific modes of action, but have little or no post-infection activity.

Inorganic: FRAC Codes: M1, M2;

Fungicides in this group include copper and sulfur-based products. These fungicides are inorganic in that they contain no carbon, but confusion may arise as fungicides in this group are labeled for organic production, and hence may be vernacularly referred as organic fungicides. This group includes the copper hydroxide, copper salt, and copper sulfate products, and the

liquid lime-sulfur and wettable sulfur products. These fungicides are widely labeled for diseases in apple.

Organic: FRAC Codes: M3, M4 M5;
Fungicides in this group include ziram and thiram (dithiocarbamates), captan (phthalimide), and chlorothalinil (chloronitrile). These have multi-site non-specific action and are at low risk for resistance, hence their persistence in the industry for several decades. Formulated products of these fungicides.

Single-site inhibitors
Single-site inhibitor fungicides are generally newer and therefore more expensive, have both protectant and post-infection activity, and have propensity for resistance development due to highly specific modes of action.
Thiophanate-methyl (thiophanates); FRAC Code: 1; MOA: Cell division
These fungicides include generics of Topsin-M, which is labeled apple scab, and summer fruit rots including gray mold and a few foliar diseases. They are benzimidazoles in terms of chemistry, which are high risk for resistance development. Benzimidazole resistance is widely prevalent in regional populations of *Venturia*, *Alternaria*, and in *Botrytis*.

Cyprodinil, Pyrimethanil (Anilinopyrimidines); FRAC Code: 9; MOA: Amino acid biosynthesis Scala and Vanguard are formulations of pyrimethanil and cyprodinil labeled primarily for apple scab and *Botrytis* diseases. Despite excellent activity against botrytis in the lab and the field, these AP fungicides are less effective against apple scab except in the early season when the weather is cooler. All of these fungicides have a propensity for resistance development.

Myclobutanil, Fenbuconazole, Flutriafol, Fenarimol, Difenoconazole (Demethylation Inhibitors); FRAC Code: 3; MOA: Sterol biosynthesis inhibition
Sterol demethylation inhibiting (DMII) fungicides are considered to be fairly potent fungicides with good post-infection activity. Rally 40WSP (Myclobutanil) has been the DMI mainstay for the management of apple scab, powdery mildew, rusts, and other fungal foliar diseases. Flutriafol (Topguard) is similar in efficacy to myclobutanil, and as such, is highly effective on powdery mildew and rust diseases. Indar 2F (Fenbuconazole) and Inspire Super (difenoconazle) contain highly potent DMIs and are effective again DMI resistant *V. inaequalis* populations in the region.

Azoxystrobin & Pyraclostrobin (Quinone outside Inhibitors); FRAC Code: 11; MOA: Respiration inhibition
Quinone outside Inhibitors (QoI) (a.k.a. Strobulurins, Strobys) are newer fungicides and are considered slightly less potent than the SIs, but also have good systemic and post-infection activity. Kresoxim-methyl (Sovran) was one of the first QoI fungicides available and is labeled for numerous apple diseases including, apple scab, powdery mildew, and fruit rots. Flint WG (trifloxystrobin), and Pristine WG {Pyraclostrobin & boscalid (Dicarboximides; FRAC Code 2)} are some of the newer QoI fungicides and are widely labeled for apple diseases. Unfortunately, qualitative resistance to QoI fungicides has emerged in *V. inaequalis* populations in MI, NY, and

several New England States. At the sites in which it occurs, these fungicides are no longer effective.

New! Fluxapyroxad, Penthiopyrad, & Fluopyram, (Succinate Dehydrogenase Inhibitors); FRAC Code: 7; MOA: Respiration inhibition

Succinate Dehydrogenase Inhibitors (SDHIs) are a group of newly developed fungicides in a chemistry previously available on apples in the form of boscalid. The new chemistries are much more potent than the previously available boscalid and are also systemic with post-infection activity. Fluxapyroxad is premixed with pyraclostroin in the product Merivon, which has strong activity against all apple diseases. Similarly, fluopyram is mixed with trfloxystrobin or cyprodinil in Luna Sensation or Luna Tranquility, respectively. Interestingly, pethiopyrad is formulated singly allowing flexibility of tank mixing for resistant managment. Currently, we have only been able to test pethiopyrad and fluxapyroxad singly. Alone, these fungicides work well on apple scab and some activity on powdery mildew. Qualitative resistance to SDHI fungicides has emerged in *Botrytis* and *Alternaria* populations in strawberries and stone fruit, but *V. inaequalis* populations are still fairly baseline.

Fungicide resistance concerns for apple scab and powdery mildew in NY

Apple scab causes extensive crop loss in all production regions in the northeastern US. The development of durable and appealing scab-resistant cultivars to reduce reliance on fungicides has been a major goal of apple management programs for decades. Cultivars fully resistant to scab have been introduced, but both grower and consumer acceptance has been limited to organic production operations due to fruit quality concern. In the absence of durable host resistance and because of emerging fungicide resistance, producers make considerable applications of protectant fungicides to avoid losses. Apple scab is managed with up to 15 fungicide applications per season. The SI (e.g. Rally 40 WSP, Vintage SC, Indar 2F, and Inspire Super) and QoI (Flint WG and Sovran) fungicides are some of the safest and most effective fungicides for use against apple scab. However, because of their specific mode of action, many apple scab populations throughout NY and the Northeastern United States have developed a moderate to high level of resistance to all, but the most these highly effective chemistries in these fungicides.

Compared to diseases such as apple scab and fire blight, powdery mildew, caused by *Podosphaera leucotricha,* is not a devastating disease of apples in the eastern United States. However, this disease can cause considerable foliar damage on highly susceptible apple cultivars including ‘Cortland’, ‘Idared’, ‘Gingergold’, and ‘Jonagold’ to name a few. Symptoms of infection include a powdery white blight of young leaves and shoots in addition to fruit russeting. Severe mildew infections can lead to reduced yields from aborted blossoms, poor return bloom, and compromised shoot growth. Powdery mildew infection can occur in the absence of free moisture; hence the disease will be a problem during periods of dry weather or during extended periods of high humidity and light rain. Apple powdery mildew is managed by fungicide programs applied during apple scab infection periods because susceptible phenological stages for both diseases often overlap. The sterol biosynthesis inhibitor (SI) fungicides with high solubility have excellent activity against powdery mildew, and the widespread use of SIs in apple scab fungicide programs in NY has likely kept powdery mildew in check. However, SI resistance in NY apple scab populations has also raised concerns regarding SI resistance in mildew

populations. Field trials in NY and West Virginia suggest that SI applications at lower label rates are becoming insufficient to control mildew in the region. Moreover, some the newer SI fungicides that are more effective against SI resistant apple scab appear to be less effective against powdery mildew.

Following the development of molecular tools for apple scab, we were able to look for the mutation in cyt b gene in powery mildew, which is responsible for QoI fungicide resistance. At research blocks in Geneva, more than 50% of the copies of the cyt b gene have the mutation for resistance, but oddly enough, the QoI fungicide flint continues to provide a high level of powdery mildew control.

2013 trial results from Geneva indicated that:

1. Fungicide products containing difenoconazole (Inspire Super) or fenbuconzaole (Indar 2F) are still more effective against SI-resistant apple scab on susceptible cultivars and less effective against powdery mildew. These provide a level of control comparable to a QoI fungicide. These differences in control only become apparent toward the season's end.
2. In an orchard with an apple scab population with both QoI and DMI resistance, both Mervion and Luna Sensation provide a level of control comparable to, or greater than that of Fontelis, a non-premix SDHI fungicide for two years in a row. The efficacy of the Mervion and Luna Sensation was not affected by the development of multiple resistance to fungicides in the apple scab population.
3. Fungicide products containing flutriafol (Topguard) or myclobutanil (Rally 40WSP) are weaker against SI-resistant apple scab, but are still some of the most effective fungicides against powdery mildew, especially on susceptible cultivars. At the newly increased maximum rate of 8 oz/A, Rally 40WSP performs much more like Inspire Super, but with increased mildew control.
4. Interestingly, the addition of mixing partner such as captan or mancozeb to a strong mildew fungicide (Topguard, Rally 40WSP, or Merivon, or Luna Sensation) often seemed to diminish the ability of the fungicide to manage powdery mildew compared to programs where the fungicides were applied alone.
5. Treatment programs that received Inspire Super, Merivon, or Pristine during summer covers had a similar to lower severity of mildew at harvest compared to those receiving a highly effective fungicide such as Topguard or Rally 40WSP in the primary scab season, but only received captan in the summer covers.
6. Generalizations about the new SDHI fungicide products are complicated by formulation paradigms used by different agrichemical companies. Fontelis SC by DuPont provides a high level of control against apple scab, and although it'll not likely be marketed for mildew, it provides > 50% control of mildew on highly susceptible varieties. Luna Sensation by Bayer and Merivon by BASF are premixes that contain a SDHI fungicide formulated with a QoI fungicide. As formulated, Luna Sensation and Merivon provide exceptional of control apple scab and a high level of mildew control even in research orchards with resistant populations.

Preparing for apple scab and powdery mildew in 2014

In 2014 growers should be poised to deal with preseason apple scab inoculum, powdery mildew carry over inoculum in buds, and variable seasonal weather. The level of powdery

mildew inoculum and apple scab inoculum will vary from site to site depending on the success of the 2013 program. Regardless, growers along the great lakes with endemic powdery mildew problems should begin proactively managing powdery mildew. Although the newer fungicide chemistries/products will not be available in NY in 2013, growers will need to address both apple scab and powdery mildew with the products currently available. To manage both diseases in 2013, consider matching the fungicide program to either variety susceptibility or seasonal weather. If the acreage is primary planted to scab susceptible varieties such as those with a 'McIntosh' background, use an SI or newer SDHI material with a strong activity against scab that still provides some mildew control at bloom to 1st cover. On varieties that are highly susceptible to mildew, consider using an SI or newer SDHI material with strong activity against mildew mixed with an appropriate rate of protectant from bloom to 1st. If your operation is along the great lakes, consider including sulfur in each application from tight cluster to pre-harvest if there is no modern fungicide product with mildew activity in the tank. Finally, when you do choose to use a SI or QoI product, bear in mind that a single application will not likely provide the desired the results. The successes of the products in research trials are often contingent using the labeled maximum number of applications allowed for a season (i.e. 4 applications).

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