Apple Scab Management Options for High-Inoculum Orchards

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Apple scab emerged as an expensive problem in apple orchards throughout the Northeastern United States in 2009. Experienced growers who had managed scab effectively for many years found themselves spraying throughout summer to control scab that kept appearing on new leaves. The effort required to protect fruit from scab during summer increased production costs and represents a "loss" to apple scab even where no scab was present on fruit at harvest.

> **"For many apple growers in 2010, scab control problems will be compounded by high levels of carry-over inoculum and the presence of fungicide-resistant scab populations. Control strategies will need to be adjusted based on inoculum levels, fungicide resistance issues, and cultivar susceptibility."**

Given the prevalence of scabby leaves in orchards at the end of 2009, the average New York apple orchard may be carrying more over-wintering scab inoculum in spring of 2010 than at any other time in the past 40 years. If spring weather favors scab development, these high inoculum levels could contribute to massive scab control failures and significant crop loss in the coming year. As always, there are big discrepancies among orchards even within rather small geographic areas. Where no scab was present on leaves last season, spray programs used in previous years can probably be used again in 2010. However, where scab was a problem in 2009, control strategies may need to be adjusted for the 2010 season.

What Contributed to Scab Control Failures in 2009?

A unique aspect of control failures in 2009 was that scab problems often did not become evident until mid-June or even later. In many areas of the state, weather conditions from green tip to bloom were not particularly challenging in terms of scab control. Infection periods were spaced so that fungicides could be applied between rains, and most regions in New York did not have lengthy wetting periods with heavy rains that sometimes remove fungicide coverage and leave trees unprotected in the middle of extended wetting periods.

So what went awry in June? First, it is important to note that scab lesions that appear on terminal leaves in June are almost always secondary infections initiated by conidia from primary infections that occurred sometime between green tip and first cover. Those primary infections may be very few in number and therefore escape detection. Just 10 primary scab lesions per acre can produce as many spores per acre as all of the over-wintering leaf litter in a clean orchard that had less than 10 scab lesions per 100 terminal shoots at the end of the previous year. Thus, a few uncontrolled primary infections can set up an orchard for a major scab problem during summer if other factors fall into place as they did in 2009.

A variety of factors may have enabled scab to become established early and then explode during June last year. First, in some regions the prebloom weather in 2009 was rather dry and many growers used extended spray intervals because there seemed to be no point in spraying when no rains were predicted. However, those extended spray intervals may have left trees with less cumulative fungicide residues available to protect leaves during critical infections periods as compared to years when weekly fungicide applications are required to protect against more regular wetting events with moderate rainfall.

The rainfall patterns near petal fall may have also inhibited effectiveness of some of the protectant fungicide programs in 2009. During some critical wetting periods, rainfall in some regions may have been insufficient to redistribute fungicide residues to new leaves that emerged during week-long wetting periods. In those cases, spray intervals of less than seven days or use of a fungicide with greater post-infection activity at the end of the rain period might have eliminated the scab problem.

A major factor contributing to summer scab problems in 2009 was the near total lack of hot dry periods during summer. Daytime temperatures above 85° F for several consecutive days cause a decrease in the number of conidia produced in scab lesions. At the same time, heat may slow tree growth, thereby leaving trees with less susceptible tissue since each new leaf is susceptible to scab for only a few days. The absence of heat to shut down scab during summer in 2009 would have been less important if we still had fungicides with the kind of "eradicant" scab activity that the DMI fungicides had before that fungicide class was compromised by resistance issues.

Fungicide Resistance

Fungicide resistance undoubtedly contributed to some of the scab problems noted in 2009. From 1965 through 2005, apple growers could rely on a sequence of various fungicides (first dodine, then Benlate or Topsin M, and finally the DMI fungicides) for presymptom and antisporulant activity. Those fungicides provided a safety net for minor failures in early-season scab programs. As a result, growers could opt to omit one or two sprays after green-tip, use alternate row sprays, or apply post-infection sprays at the end of rain periods because the "safety net" fungicides would arrest scab development if initial control sprays were not completely effective. Many orchards now contain scab populations that are resistant to all of these "safety net" fungicides, so that small lapses in pre-bloom scab control now can trigger a major scab outbreak that ultimately requires high rates of captan throughout summer to keep scab off of fruit.

Fungicide resistance monitoring conducted in the Cox lab at Geneva from 2007 through 2009 included samples from 93 orchards in 12 different states including NY, VT, WV, NH, MA, ME, RI, MI, OH, IN, PA, and CT. Fungicide resistance assessments are completed by testing 50 scab isolates from each orchard against a single discriminatory dose of the test fungicide. For each isolate, growth rates are determined on unamended agar and on agar containing the discriminatory dose. Fungicide sensitivity for each isolate is then expressed as "relative growth" (RG) which is the percentage of growth on amended compared to unamended agar. The higher the level of resistance in any given isolate, the higher the RG-value for that isolate will be. Some highly resistant isolates may even grow faster on amended agar than on unamended agar, so RG-values can actually exceed 100.

The mean RG-values for all 50 isolates are then compared to the mean RG-value from baseline populations of apple scab collected from isolated trees never exposed to the test fungicide. On the graphs in Figure 1, the green line toward the left side of the graph shows the mean RG for baseline populations. The red line indicates RG-values from "resistant" orchards where using the test fungicide resulted in a control failure. The vertical axis shows the percentage of tested orchards that have mean RG-values falling between numbers listed on the horizontal axis. Bars to the right of the graphs indicate higher levels of resistance.

Results show that DMI-resistant populations of apple scab now predominate in a majority of the sampled orchards. Seventy-eight percent of the 93 orchards tested for DMI resistance over the past three years contained scab populations that would no longer be controlled by myclobutanil, the active ingredient in Rally (formerly sold as Nova). This suggests that the majority of orchards with control problems (i.e., orchards from which samples were collected) have scab populations that no longer respond to myclobutanil.

It is important, however, to note that data in Figure 1 do NOT represent an assessment from randomly selected orchards. Growers experiencing scab control problems are more likely to submit samples for analysis than are those who can still control scab with DMI fungicides. Thus, results shown in Figure 1 almost certainly overstate the prevalence of DMI resistance within northeastern United States.

Scab populations that are resistant to Rally are also cross-resistant to Rubigan and Procure. However, the new fungicide Inspire Super contains difenoconazole, a DMI fungicide with greater intrinsic activity against the apple scab pathogen. Based on comparisons of baseline sensitivity, the labeled rate for Inspire Super would require Rally to be used at more than 16 oz/A to achieve a similar level of toxicity to the scab pathogen, but higher rates of Rally were never feasible because they caused phytotoxicity. Sensitivity to difenoconazole was measured only for scab isolates collected in 2009, so only 33 orchards have been tested for sensitivity to this product (Figiure 1B). We don't yet know what level of resistance will result in a field control failure with this fungicide, so there is no red line on the difenoconazole graph in Figure 1. However, testing to date shows that the sensitivity

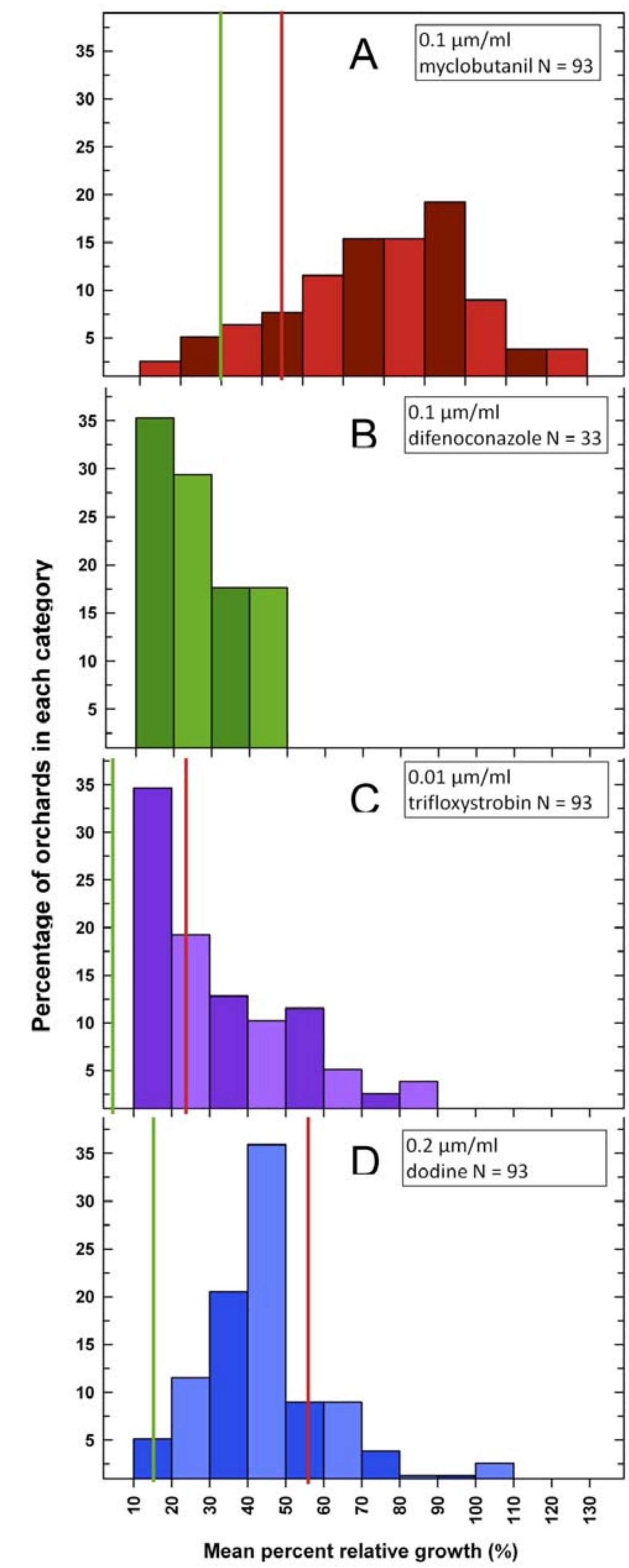

Figure 1. Frequency distributions for orchards with varying levels of resistance to (A) myclobutanil, the active ingredient in Rally, (B) difenoconazole, one component of Inspire Super, (C) trifloxystrobin, the a.i. for Flint, and (D) dodine, the a.i. for Syllit. Green lines in the graphs indicate the mean relative growth (RG) for scab isolates from baseline orchards where the test fungicide was never used and red lines indicate the mean RG for orchards where the test fungicide no longer controls scab.

distribution is still more compact (i.e., with less resistance) that that for myclobutanil.

Unfortunately, a significant number of orchards now have scab populations that are also resistant to trifloxystrobin, the active ingredient in Flint (Figure 1C). Populations resistant to Flint will also be resistant to other strobilurin fungicides such as Sovran and Pristine. With strobilurin fungicides, the gradual shift toward resistance that is occurring in many orchards is often followed by a genetic mutation (known as the G143A mutation) that makes the population totally immune to this fungicide class. Populations with the G143A mutation were recently found in a dozen orchards in Michigan and in several orchards in New York (Cox et al., 2009; Lesniak et al., 2009). Thus, the strobilurin fungicides may have limited utility in the future.

Surprisingly, the majority of the 93 orchards evaluated over the past three years have scab populations that should still respond to dodine (Figure 1D). Although the majority of orchards have populations that are above baseline, it appears that dodine might still prove useful in a carefully managed program in many of these orchards.

Inoculum Reduction Strategies for Problem Orchards

Risks of scab control failures in 2010 can be reduced if inoculum-reduction treatments are applied to orchards that had scab in 2009. The objective of inoculum reduction is to eliminate a large proportion of the ascospores that would otherwise be produced in overwintering leaves. Fungicides applied in spring will be more effective when applied in low-inoculum as compared to high-inoculum orchards.

Inoculum reduction strategies have no value in orchards that did not have apple scab last year. Thus, the need for inoculum reduction must be assessed on a block-by-block basis and in some cases may be needed only for scab-susceptible cultivars within a block. Ascospore reduction strategies will be beneficial for treated blocks even if the neighboring block is not treated because studies have shown that effects of ascospore dissemination from large inoculum sources are usually visible only on those trees located within 100 feet of the inoculum source (Gomez et al., 2007; MacHardy, 1996).

Four approaches for inoculum reduction have proven effective in controlled studies in commercial orchards:

a. Urea sprays (40 lb urea/A) applied to fallen leaves in autumn or spring (Sutton et al., 2000).
b. Shredding of leaf litter with a flail mower (Sutton et al., 2000).
c. Application of dolomitic lime (2.5 ton/A) over fallen leaves in autumn (Spotts et al., 1997).
d. Removing leaf litter by raking, sweeping, or vacuuming leaves and removing them from the orchard (Gomez et al., 2007).

None of these approaches will eliminate 100% of the ascospores, but any one of them can reduce inoculum production by 80% or more.

Urea works by stimulating microbial breakdown of overwintering leaves. When using urea for inoculum reduction, each acre of orchard should be sprayed with 40 lb of urea fertilizer dissolved in 100 gallons of water. It may be necessary to dissolve the urea prills in hot water before dumping them into a sprayer because the prills may dissolve slowly in ice water pumped from a pond in late fall or early spring. Springtime applications should be made as early as possible to allow for leaf degradation prior to green tip, but applications as late as green tip can still reduce the numbers of ascospore available during peak discharge periods between tight cluster and bloom. The urea spray can be applied either with air blast sprayers that have the upper nozzles turned off or with boom sprayers rigged to spray both the sodded row middles and the areas beneath the trees. Effectiveness of the spray will be largely dependent on achieving thorough coverage of the entire orchard floor. Spreading urea prills with a fertilizer spreader will NOT accomplish the same thing because the prills will not allow for uniform and thorough coverage of the leaf litter. Urea should not be applied just prior to predicted rains because rainfall might wash urea from leaves into the soil before the leaf litter can absorb it. For similar reasons, urea applications may be more effective if temperatures during the days immediately following application remain above freezing so that microbes that utilize the urea can start the leaf breakdown process before the urea can be washed into the soil.

Urea fertilizer contains 46% actual nitrogen in a highly soluble form. The portion of the urea spray that falls within the herbicide strip beneath the tree canopy (or inside the drip-line) will ultimately contribute somewhat to nitrogen fertilization of the trees whereas the portion of the spray that is applied to the sodded row middles will be utilized primarily by the ground cover. Nitrogen fertilizer rates may need to be adjusted accordingly for orchards where urea is applied in spring. Where the addition of nitrogen is undesirable for horticultural reasons, leaf shredding with a flail mower may be a better option for reducing scab inoculum. Using urea at less than 40 lb/A may have some effect on inoculum reduction, but benefits of lower rates of urea have not been adequately researched.

Shredding leaf litter with a flail mower can reduce inoculum in several ways. First, it provides more "edges" in the leaf litter for invasion by the microflora that cause the leaves to decay. Second, if flail mowing is done in spring, the chopping action will result in re-orientation of most leaf pieces on the orchard floor and many ascospores will discharge into the soil rather than into the air. Effective leaf shredding can be accomplished only with a flail mower that is set so low that it nearly scalps the sod in the row middles. Effectiveness is also dependent on having a level orchard floor and on being able to shred most of the leaves beneath the tree canopy. If the flail mower cannot be offset to reach beneath trees, leaves beneath trees must be moved into the sodded row middles by using a blower or a paddle-type of brush rake. If prunings are normally windrowed in the row middles and shredded with a flail mower, then brush disposal and leaf shredding can be performed as a single operation so long as pruning and brush removal is completed several weeks before green-tip and the flail mower is set low enough to engage the leaf litter.

Dolomitic lime has not been widely tested as an inoculum reduction technique, but it was effective in Oregon when it was applied after leaf drop in autumn at 2.5 ton/A. Lime presumably works by raising the pH of fallen leaves so that they are suitable for invasion by bacteria and yeasts. Effectiveness of lime applied in springtime has not been evaluated, and effectiveness of autumn applications may also be reduced in areas where leaves remain frozen or covered with snow through most of the winter.

Leaf removal by raking or vacuuming leaves is being practiced in commercial orchards in Europe. Specialized equipment is required. This approach is more feasible for high-density manicured orchards than for older orchards with wide tree canopies. Removing leaves from orchards may be the most effective option for organic orchards because, if done carefully, it can reduce ascospore availability to almost zero.

Fungicide Options for 2010

Given the high scab inoculum levels that are prevalent throughout the state, apple growers should be especially careful to apply protectant fungicides at the first sign of bud break in 2010. Even though only a small proportion of ascospores will be ready to discharge at the green tip bud stage, that “small proportion” can translate into a large spore discharge in orchards with high inoculum levels. In orchards where DMIs, strobilurins (QoIs), and/or Syllit are no longer effective, failure to protect against green-tip infections almost guarantees a scab problem through summer.

In general, fungicide recommendations remain the same as in previous years. Copper applied at silver tip or green tip to suppress fire blight will also control scab for a week in the same way that one would expect from a mancozeb spray. Copper, mancozeb, and captan cannot stop scab infections once the scab fungus penetrates the leaf tissue, so applications must be made ahead of rains or within 12-18 hr (depending on temperatures) after the start of a rain. Copper should never be applied in the rain because it will wash to the ground too quickly to provide the desired residual protection against fire blight. However, captan and mancozeb applied during a rain can kill germinating spores and protect trees for another day or two following the application.

A prebloom schedule involving a tank-mix of mancozeb at 3 lb/A plus Captan-80 at 1.5 to 3 lb/A has frequently performed better than either product used alone, but Captan cannot be used in combinations with prebloom oil sprays. By using Flint or Sovran with mancozeb for two sprays sometime between tight cluster and petal fall, one gains even more activity against scab (so long as it is not stroby resistant) as well as protection against rust and mildew. Even where DMIs no longer control scab, they are still recommended in combinations with mancozeb or captan for sprays at petal fall and first cover because they still provide the best overall activity against mildew and rust diseases. In cases where a protectant fungicide could not be applied ahead of rains during the prebloom period, Scala or Vangard can provide up to 72 hr of reach-back activity. However, these fungicides do not redistribute well, so they should always be used in combinations with mancozeb or captan. Syllit combined with mancozeb might also prove useful for early-season sprays if resistance testing has shown that the scab population is not fully resistant to dodine.

There is still considerable uncertainty about the usefulness of so-called “second generation” DMIs like Indar and Inspire Super in orchards where Rubigan and Rally are no longer effective. Indar and Inspire Super are definitely more effective than labeled rates of Rally and Rubigan when applied in orchards where the latter products have lost effectiveness. However, regular use of Inspire Super or Indar is expected to cause a continued shift toward greater levels of DMI resistance until even these new products will no longer control scab. We just don’t know how quickly that shift will occur.

Field trials at Geneva in orchards that have DMI-resistant scab populations have shown that Indar and Inspire provide better scab control on cultivars like Empire and Jonagold than on cultivars like McIntosh that are highly susceptible to scab (Figure 2). It is important to note that data shown in Figure 2 were generated

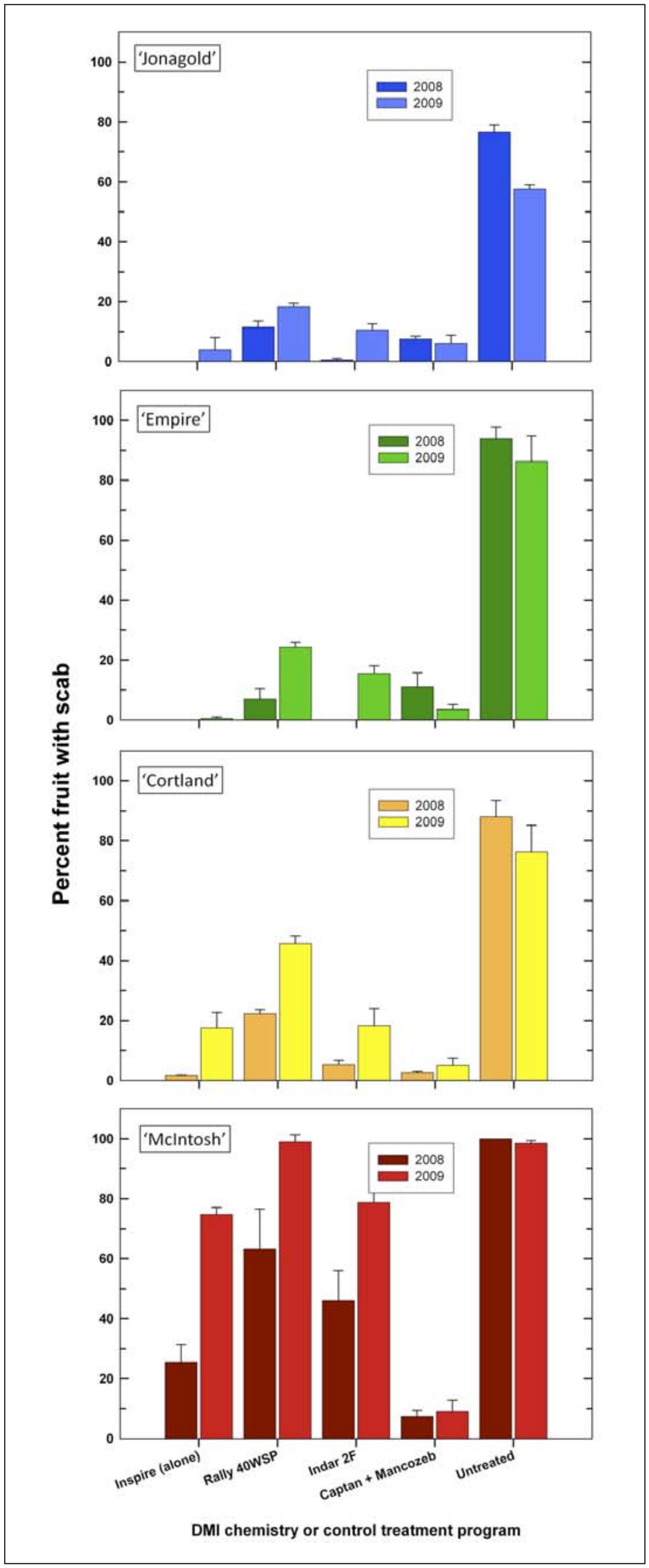

Figure 2. Control of scab on fruit achieved with four different fungicide treatments applied to four cultivars over two years in orchards at Geneva where scab populations were considered resistant to Rally. Results show that Inspire and Indar controlled DMI-resistant scab on cultivars that are only moderately susceptible to scab whereas a Captan-mancozeb combination was more effective for the scab-susceptible McIntosh cultivar.

from trials where Rally, Indar, and the difenoconazole component of Inspire Super were applied alone whereas most growers would use them in combination with mancozeb. With Inspire Super, the tank mix would include both cyprodinil (Vangard), which is the second component of Inspire Super, and mancozeb, which is recommended as a tank-mix partner for Inspire Super. Thus, using Inspire Super plus mancozeb or Indar plus mancozeb in orchards where Rally or Rubigan have failed should produce better results than suggested in Figure 2 where these products were tested without mancozeb. Nevertheless, we suspect that even when used in combinations with mancozeb, Inspire Super and Indar may have less than stellar activity if they are applied to scab-susceptible cultivars like McIntosh in orchards where Rubigan and Rally are no longer effective.

Fungicide Resistance Testing

Apple growers who had scab problems last year are encouraged to submit leaf samples for fungicide resistance testing during 2010 (see details in the side panel). Results from a fungicide resistance analysis are critical for taking corrective action if scab shows up in the orchard during the growing season. Where DMI fungicides or Syllit are still active, these products can arrest a scab epidemic whereas using them against resistant populations can waste time and money.

Summary

Given high-inoculum levels present in many orchards, 2010 could end up being a watershed year for scab control. Control strategies will need to be adjusted based on inoculum levels, fungicide resistance issues, and cultivar susceptibility. Some kind of inoculum reduction strategy should be employed in orchards that had severe scab in 2009, and inoculum reduction is especially critical for high-inoculum orchards with DMI-resistant scab and scab-susceptible cultivars like McIntosh.

Relevant Literature:

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SMOR Resistance Testing

Site-specific management of resistance (SMOR) is a fungicide-resistance testing service offered by the Tree Fruit and Berry Pathology program at Geneva. SMOR testing uses conidia from fresh leaf samples to evaluate sensitivity to three classes of fungicides commonly used to control scab. Growers submitting samples must collect 50-100 young apple leaves with fresh scab lesions sometime during May or early June. Leaves with more than one lesion per leaf are acceptable, but leaves with sheet scab usually lack the discrete lesions required for the test protocol. Samples consisting of at least 75 leaves are preferred because some leaves in any given sample usually lack acceptable numbers of conidia. Samples collected within 10 days after a fungicide application or within several days after a heavy rain may also prove unsuitable due to lack of enough viable conidia.

To ensure availability of a good scab sample, growers should plan ahead by leaving six trees at the opposite corners of an orchard unsprayed until the first scab lesions appear and samples have been collected. An alternative is to place a few potted 'McIntosh' trees within the orchard rows during a rain period near bloom, remove them from the orchard before the next fungicide is applied, and then collect scabby leaves from these potted trees as soon as lesions appear. Potted trees placed in orchards during rains should be kept away from tree canopies where fungicide residues would redistribute downward onto the potted trees.

Instructions for sample submission can be found on-line at http://www.nysaes.cornell.edu/pp/extension/tfabp/smor.htm. Results from samples submitted in May or June generally are not available until the following winter due to time required for completing the tests.

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