Great Lakes Fruit, Vegetable & Farm Market EXPO
Michigan Greenhouse Growers EXPO

December 4-6, 2012

DeVos Place Convention Center, Grand Rapids, MI

Apple II

Where: Ballroom D
MI Recertification credits: 2 (1C, COMM CORE, PRIV CORE)
CCA Credits: PM(1.5) CM(0.5)
Moderator: Brett Anderson, EXPO Board, Sparta, MI

2:00 pm — Biology and Control of Apple Powdery Mildew
- David Rosenberger, Hudson Valley Laboratory, Cornell Univ.

2:30 pm — Keeping Up with Managing Fire Blight in 2013
- George Sundin, Plant, Soil and Microbial Sciences Dept., MSU

3:00 pm — Improving Apple Scab Management via Inoculum Reduction, Fungicide Selection, and Spray Timing
- David Rosenberger, Hudson Valley Laboratory, Cornell Univ.

3:30 pm — Solid Set Canopy Delivery System: First year designs and observations
- Matt Grieshop, Entomology Dept., MSU

4:00 pm — Session Ends

Biology and Control of Apple Powdery Mildew

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In eastern United States, controlling apple powdery mildew is becoming more challenging because DMI fungicides are losing effectiveness against mildew in many orchards and because erratic weather patterns (especially warmer winters in more northern areas) may favor survival and/or dissemination of powdery mildew. Apple powdery mildew is caused by the fungus *Podosphaera leucotricha.* The mildew fungus overwinters in infected buds, but infected buds are more sensitive to winterkill than are healthy buds. When infected buds are killed during winter, the fungus in those buds also dies. Winterkill of mildew-infected buds begins as winter temperatures drop below 10 °F, but suppression of mildew by winter cold is more noticeable after temperatures drop below 0 °F. If temperatures drop to –11 °F, then 95 percent of infected buds may be killed, although the timing and duration of the cold periods probably impact the degree of mildew eradication.

If mildew-infected buds are not killed during winter, the mildew fungus will grow out of the buds as buds expand in spring. Signs of powdery mildew that overwintered in infected fruit buds first become evident about the time that buds reach the tight cluster stage (Fig. 1), but these early symptoms are easily overlooked. Overwintering mildew that has colonized terminal shoot buds becomes evident slight later, often during late bloom, when terminal shoots begin to grow rapidly. The shoots that develop from buds that carried mildew through winter appear as completely colonized "flag shoots" (Fig. 2), although some fungicides can suppress sporulation on these shoots, thereby allowing the shoots to grow almost normally. Inoculum from primary infections (Figs. 1 &2) subsequently spreads to other leaves and causes secondary infections (Fig. 3). Secondary spread of mildew continues so long as new leaf tissue is being produced. Mildew does not invade mature leaf tissue, so the spread of mildew ceases when trees stop producing new terminal leaves in early to mid summer.

Powdery mildew can sometimes cause fruit russetting on mildew-susceptible cultivars (Fig. 4), but russetting from mildew is not very common. Published reports suggest that fruit are most susceptible to mildew when trees are at the petal fall stage, and there is no evidence that mildew can cause fruit russetting after first cover even though leaves must be protected until terminal growth ceases.

Some fungicides, if applied at tight cluster and bloom, can eradicate mildew from primary infections that originate from infected buds, and that can help to reduce the inoculum available for infecting new leaves. However, even in orchards where the best fungicides are applied in such a way as to ensure perfect coverage, some primary infections will almost always survive. The main objective in controlling mildew is to prevent secondary infections on new leaves, thereby breaking the disease cycle so that there will not be any mildew available to infect the buds for the next year. Thus, orchards with poor mildew control last year may produce a lot of completely white flag shoots that will persist through the season as a reminder of last year's failure, but those white flag shoots do not indicate that the current season's spray program is a failure because the current season program is primarily designed to prevent secondary spread and reduce or eliminate infections that would lead to primary infections for the next year.

The DMI fungicides, a class that now includes Rally, Procure, Indar, Inspire Super, and Topguard, were exceptionally effective for controlling powdery mildew when the first products in this class were introduced more than 25 years ago. However, observations from both commercial orchards and research plots indicate that many populations of mildew have gradually become less sensitive to these fungicides. Problems developed in some New York orchards in 2010 when growers switched from Rally or Vintage to Inspire Super (Rosenberger, 2011). Although Inspire Super has better activity against apple scab than older DMIs like Rally and Vintage, it is somewhat less effective against mildew (Fig. 5). That difference allows mildew to explode when Inspire Super is applied in orchards where the mildew population has already shifted toward DMI resistance.

In the absence of resistance, DMI fungicides controlled mildew not only by protecting new foliage, but also by eradicating incubating infections before they can appear on leaves and by suppressing sporulation of older infections. Because of their post-infection and anti-sporulant activity, DMI fungicides provided effective control of powdery mildew even when the first mildewcide spray was delayed until petal fall (Fig. 6). None of the other mildew fungicides provide an equivalent level of post-infection activity against mildew. Therefore, they must be applied earlier in the season, beginning no later than tight cluster, so as to protect new leaves against secondary infections and thereby limit the amount of inoculum that can come from new infections if sprays are delayed until petal fall.

Because DMI-resistant mildew is emerging in many orchards, a non-DMI mildewcide should now be included in sprays starting at half-inch green if sulfur will be the primary mildewcide or at tight cluster if Flint or Luna Sensation will be used for mildew control. This is true even where DMI fungicides are still working against mildew because including a non-DMI mildewcide at tight cluster and pink will reduce further selection pressure for DMI-resistance. Except for orchards where oil is being applied at tight cluster or pink, the best approach for controlling mildew before bloom might be to include 3 to 5 lb of sulfur per acre in all prebloom scab sprays. This low rate of sulfur will suppress mildew and provide some assistance with scab control, but higher rates of sulfur (e.g., 15 to 20 lb/A) are required if sulfur alone is being used to control scab.

Sulfur can be especially useful in programs where captan or captan-mancozeb mixtures are being used for scab control. Neither captan nor mancozeb will control mildew. (Dodine, Vangard, and Scala also lack mildew activity, and Fontelis is only fair against mildew). Sulfur fungicides that are formulated with bentonite clay generally provide better residual activity than other sulfur products. One advantage of sulfur is that mildew will not develop resistance to it. A second advantage of using sulfur in prebloom sprays is that, at this application timing, temperatures are usually low enough to eliminate concerns about sulfur phytotoxicity. Sulfur will sometimes burn leaves and even fruit if temperatures exceed 80 F during the three to five days after sulfur has been applied. Sulfur can also be used for mildew control in petal fall and cover sprays, but the high temperatures that contribute to sulfur burn are more likely to occur after bloom.

The strobilurins (Flint, Sovran, Cabrio) provide effective protection against mildew so long as the mildewcide programs are initiated before bloom. The strobilurin fungicides can be used for both prebloom and post-bloom control of mildew, but they may provide suboptimal mildew control if they are applied at petal fall in orchards where no mildewcides were applied prior to the petal fall spray. Unlike DMI fungicides, the strobilurins cannot eradicate pre-existing infections, so they must be used in programs that include prebloom applications of mildewcides.

Label restrictions allow only four applications per year for any combination of strobilurin fungicides. Those wishing to use Flint or Pristine in late summer to control summer diseases will need to preserve one or two of those four applications for the late-summer timing.

Luna Sensation is an excellent option for prebloom mildew control in states where it is registered and available, and in orchards where Flint is still active against apple scab. Luna Sensation is a packaged mixture of Flint plus the new SDHI fungicide fluopyram. This mixture provides two modes of action against both scab and mildew. However, this combination may not be cost-effective where scab is already resistant to Flint. Luna Tranquility is a packaged mixture of Scala plus the SDHI fungicide that can be used for scab control where scab is resistant to Flint. However, this mixture will provide less protection against mildew than does Luna Sensation because Scala is not a mildewcide.

Where DMI fungicides are still working, they are especially useful during the period immediately after bloom because they will provide both post-infection and protectant activity, not only against mildew, but also against rust diseases. Among the DMI fungicides, Rally and Topguard are the best choices for mildew control. If Inspire Super will be used for scab control after bloom, then it should probably be supplemented with sulfur at 3 to 5 lb/A to ensure that mildew will be controlled during this critical period.

Protection against powdery mildew is especially important from petal fall through the second cover spray because the rapid growth of terminal leaves during this period provides a constant supply of new mildew-susceptible tissue. Failure to control mildew during this critical period can result in devastating levels of mildew by late June and an abundance of inoculum for infecting the buds that will carry mildew through winter into the next growing season. By the time mildew appears on terminal leaves in mid to late June, it will be too late to implement effective control measures. Thus, mildew control must be integrated into scab sprays during the entire period from tight cluster through at least second cover. Mildew protection may be required all the way through mid-summer on non-bearing trees where terminal growth continues long after bearing trees have set terminal buds.

Most fungal spores require water for germination, but powdery mildew spores can germinate and infect tissue anytime that relative humidity is between 70 and 100 percent with temperatures between 50 and 80° F. Optimum infection conditions are 96 to 100 percent relative humidity and 68 to 72° F. Rain actually deters mildew by washing spores off of primary infections and by slowing spore germination. Because mildew thrives in dry weather, mildew problems are often more severe in years that have extended periods with little or no rain between tight cluster and second cover. Thus, mildew sprays may still be required during dry periods when there is little risk from apple scab.

Summary:

Most mildew control failures result from (i) starting mildew control programs too late in the season; (ii) using fungicides that are not effect or that lost effectiveness due to fungicide resistance; (iii) stretching spray intervals during dry periods when no scab sprays are needed; or (iv) poor spray coverage. For effective mildew control, mildewcides should be included in all sprays from at least tight cluster through second cover. Inspire Super is not a reliable mildewcide, and other DMIs may also prove ineffective, especially if used at reduced rates, because the mildew populations in most orchards are now more resistant to DMI fungicides than when that class of fungicides was first introduced. Flint, Sovran, Cabrio, and Luna Sensation should provide excellent mildew control, but they may not be cost-effective where orchards contain QoI-resistant apple scab. Sulfur at 3 to 5 lb/A may be the best option for mildew control where resistance limits the usefulness of DMI and QoI chemistries.

Literature cited:

Rosenberger, D. 2011. Selecting apple fungicides for controlling scab and mildew. Scaffolds Fruit Journal 20(2):5-7. Online at http://www.scaffolds.entomology.cornell.edu/2011/110404.pdf.

Figure 1. Author's ranking of DMI fungicide activity against three common apple diseases for products that are currently registered or that were previously registered on apples. Rankings are based on observations and test results from orchards where scab and mildew populations have shifted toward resistance to the DMI chemistry.

Fungicide	powdery mildew activity	apple scab activity	SBFS* activity
Topguard (flutriafol)	(most)	(least)	(least)
Rally (myclobutanil)	↑		
Procure (triflumazole)			
Vintage (fenarimol)			
Indar (fenbuconazole)		↓	↓
Inspire (difenoconazole)	(least)	(most)	(most)

* SBFS = sooty blotch and flyspeck

Figure 2. Overwintering mildew visible as a white powder on a stunted fruit bud (cluster shown on the right) compared to a healthy bud from the same tree (shown on the left).

Figure 3. Overwintering mildew on a terminal shoot. These infections are sometimes called primary infections, and the infected shoots are sometimes called flag shoots because of their completely white foliage. Even the best fungicide programs often fail to eliminate mildew on these flag shoots.

Figure 4. A secondary mildew infection showing the white patch of mildew that appears on the underside of leaves and that often causes the leaf edge to curl upward and become distorted. Mildewcide sprays are aimed at preventing these secondary infections.

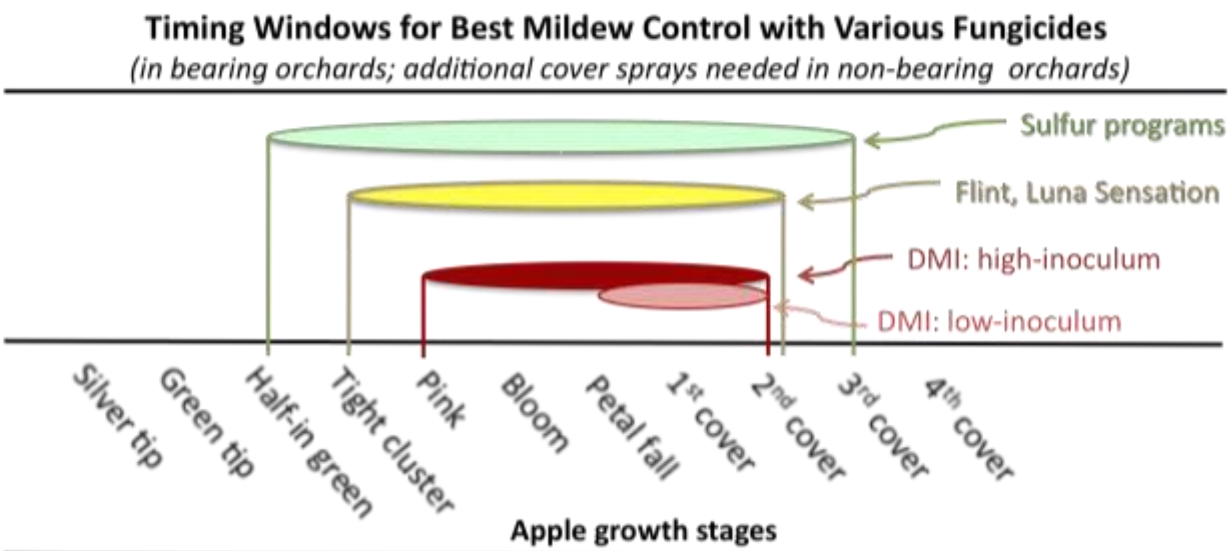

Figure 5. Schematic showing the critical windows for controlling powdery mildew on apples with various fungicides. When DMI fungicides were introduced, they were so effective against mildew that nearly all orchards became low-inoculum orchards and three applications (at petal fall, 1st cover, and 2nd cover) often provided complete control of mildew. In high-inoculum orchards (i.e., where mildew was a problem the previous year) or when other fungicides are used to control mildew, spray programs for mildew must now be started earlier in the season and more sprays per season are necessary to achieve acceptable control of mildew.

Improving Apple Scab Management
via Inoculum Reduction, Fungicide Selection, and Spray Timing

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In apple orchards where scab is poorly controlled in any given year, growers will need to adjust spray programs the following spring to compensate for the five curses of high-inoculum, as described below:

1. Expect more ascospores: Using data from a study by Gadoury and MacHardy (1986), New Hampshire orchards that had less than 1% leaf scab in autumn produced an estimated 888,000 ascospores/A as compared to 6.1 billion spores/A for an orchard with 20% leaf scab (Table 1). These data suggest that orchards with 20% leaf scab may produce nearly 7,000 times more ascospores than orchards that had less than 1% leaf scab. Thus, orchards with a lot of scabby leaves in fall are indeed "high-inoculum" orchards.

2. Expect more ascospores at green-tip: This is a logical corollary to the previous item. However, it is noted separately because the spores that are discharged early in the season pose the greatest risk for generating economic losses in commercial orchards. If ascospores initiate infections at green tip, then the first generation of conidia will become available about the time that trees are in bloom, and that is a period when fruit and leaves are at maximum susceptibility. Also, fungicide protection sometimes lapses toward the end of bloom if a fungicide spray is delayed with the objective of combining the fungicide with petal fall insecticides. Thus, having more ascospores at green tip escalates the risk of getting green-tip infections that will produce conidia before petal fall, which in turn ratchets up the risk of fruit scab.

3. Conidia may overwinter in buds: Work by Holb et al. (2005) in the Netherlands showed that when scab incidence in autumn exceeded 40% of terminal leaves, then small numbers of viable conidia would often survive through winter inside bud scales. The numbers of conidia surviving in buds under the worst-case scenarios reported by Holb are dwarfed by the numbers of ascospores that would be produced in those orchards, but the conidia in buds are perfectly positioned to cause infections as buds begin to grow in spring. Thus, conidia in buds can be expected to have much greater infection efficiency than ascospores since the majority of ascospores released at green tip will never find tissue where they can cause infections. Incidentally, viable spores have been found inside buds on at least several occasions in New York, so it seems probable that the results reported by Holb from studies in the Netherlands are also applicable to high-inoculum orchards in northeastern United States.

4. Expect more infections from marginal infection periods: In low-inoculum orchards, relatively small numbers of ascospores are released during any given wetting period, and only a few of those released will be deposited on host tissue and complete the infection process in the minimum time listed for infections in the revised Mill's table. As the duration of wetting increases, more and more spores can be deposited on host tissues, so the severity of infection periods increases with time at any given temperature. In high-inoculum orchards, the total spore contingent is much higher (perhaps 7000 times higher as pointed out in #1 above), so many more spores will succeed in completing the infection process during short or "marginal" infections periods.

5. Fungicides will seem less effective: If one assumes that 2% of the total season's ascospores could be released at green tip, that only 1% of those released will succeed in causing infections in unsprayed orchards, and that a green-tip fungicide spray will be 99.9% effective (which may be optimistic), then one might expect only 0.18 scab infections/A for orchards that had less than 1% leaf scab last year whereas orchards with 20% leaf scab last year might see 1,218 infections per acre. The only options for changing the odds are to (i) improve fungicide efficacy via higher rates, shorter intervals, and better spray coverage; and/or (ii) to implement inoculum reduction practices in the high-inoculum orchards.

Specific strategies for managing scab in high-inoculum orchards:

First, reduce the risk by using some form of sanitation to reduce the inoculum load in the orchard. There are four proven strategies for reducing over-wintering inoculum in apple orchards that had a lot of scab last year:

A. Treat orchards in either late fall or early spring by applying 40 lb/A of urea dissolved in water and sprayed over the orchard floor (Sutton et al., 2000). This is probably the most fool-proof approach except for orchards where 40 lb/A of urea will stimulate excessive growth. Remember, however, that only the urea that is deposited within the drip-line of the trees will contribute significantly to tree nutrition because the grass in the sodded row middles will utilize the urea that is deposited in the row middles.

B. Chop leaf litter in early spring to speed leaf degradation (Sutton et al., 2000). This works well only if the leaf litter beneath trees can be swept out into the row middles where it can be chopped with the flail mower that is set low enough to literally scalp the surface of the sod in the row middles, thereby accessing all of the leaves that have been beaten down by winter rains and snows. On hillside orchards, scalping the sod in late fall or early spring may reduce traction for spraying operations if the early spring has a lot of rain.

C. Apply dolomitic lime to the orchard floor at the rate of 2.25 tons/A (Spotts et al., 1997). This is useful if lime is also needed to adjust soil pH.

D. Rake or vacuum the leaf litter and remove it from the orchard. This is feasible primarily for small orchards, although it is being used commercially in some larger orchards in Europe.

More details on methods for urea treatment or flail mowing can be found in a Scaffolds article published in 2009 (Rosenberger, 2009).

Second, begin fungicide applications at silver tip or green tip. Having a fungicide in place before the first infection period after bud break is absolutely essential, especially in orchards where the DMI fungicides are no longer effective. As noted above, failure to control early infections vastly increases the risks of economic losses.

Third, use higher rates of fungicides or fungicide combinations: In low-inoculum orchards, the scab risk at green tip can be adequately addressed with a copper spray (as applied to suppress fire blight) or by using mancozeb at 3 lb/A. Either of these options will provide about seven days of protection against apple scab. Even in low inoculum orchards, however, we know that higher rates of fungicide are needed as we approach tight cluster because 3 lb/A of mancozeb used alone is not adequate to control scab during the period of peak ascospore discharge between tight cluster and petal fall. In high-inoculum orchards, high numbers of ascospores may be released at green tip, especially when warm rains (i.e., >50 °F) occur at green tip. Therefore, we suggest that high inoculum orchards should be treated with a combination of either mancozeb at 3 lb/A plus copper. Or mancozeb at 3 lb/A can be combined with Syllit (in orchards where dodine is still working) or with Scala or Vangard. Syllit, Scala, and Vangard all seem to work better in early sprays and/or cold conditions as compared to sprays later in the season.

Fourth, consider using combinations of captan plus mancozeb for controlling scab in orchards where the DMI and QoI fungicides are no longer reliable due to fungicide resistance. Captan is intrinsically more active against scab than is mancozeb, but mancozeb is more rain-fast than captan and therefore may provide better scab control during periods of heavy and extended rainfall. Dr. Mike Szkolnik at the

Geneva Experiment station ran greenhouse trials for many year wherein he sprayed potted trees with fungicides, exposed them to two inches of simulated rainfall, then inoculated the trees with apple scab conidia and held them in the greenhouse with no further leaf wetting until disease severity could be assessed. His results clearly showed that mancozeb had better residual activity than captan (Table 2). Note that rates shown in Table 2 and subsequent tables are rates per 100 gal of dilute spray. These rates must be multiplied by 3 to arrive at the comparable rate per acre for medium to large-size trees. The trials summarized in Table 2 were conducted before the development of the newer rain-fast formulations of mancozeb, so the differences might be even greater if those tests were run again with our current formulations of mancozeb.

However, if mancozeb has more residual activity than captan, then a logical corollary is that captan will redistribute better than mancozeb during rain events. Redistribution of fungicides results in improved disease control during periods of rapid leaf expansion when newly unfolded leaves must be protected via redistribution of residues from older leaves and from bark surfaces. The ability of a fungicide to redistribute is especially important when periods of rapid leaf expansion (i.e., the growth flush that starts near petal fall) coincide with periods misty light rain that provide extended wetting periods with minimal rain fall. Under those conditions, new foliage can be protected from scab only if the fungicide residues remaining on older leaves can be easily moved about in the light rains that are creating the wetting periods.

The combination of a mancozeb fungicide at 3 lb/A plus Captan 50W at 1.5 to 3 lb/A has provided excellent scab control when used in protectant programs, probably because it combines the excellent residual activity of mancozeb with the excellent redistribution capabilities of captan. Neither of these products provides true post-infection activity, so they must be in place before infections are established. Where this combination is used continuously through petal fall or first cover, it may be necessary to add 3 to 5 lb/A of sulfur to the mancozeb-captan mixture starting at the pink bud stage in order to control powdery mildew.

Remember that neither captan nor sulfur is compatible with oil! Mancozeb must be combined with something other than captan or sulfur to work around oil sprays. Options include Vangard, Scala, Syllit, Flint, Sovran, Fontelis, Luna Sensation, and Luna Tranquility. The final choice will depend on which chemistries are still working in the orchard to be sprayed. However, among the captan-alternatives just listed, only Syllit, Flint, and Sovran are likely to redistribute as well as or better than mancozeb, so spray intervals may need to be shortened if captan is not included in the spray mixture at petal fall and in the first and second cover sprays where many terminal leaves are being produced between fungicide applications.

The fifth strategy for dealing with high-inoculum orchards, especially where DMI fungicides are no longer working, is to spray in the rain if necessary to ensure that trees are continuously protected with mancozeb, captan, and/or sulfur throughout the entire period between silver tip and first cover, even during periods of extended rains. Most fungicide residues will be completely removed by 2 to 2.5 inches of rain under orchard conditions, and scab spores will continue to mature and be released throughout long wetting periods if temperatures are warm enough to favor scab infections.

Captan, mancozeb, and sulfur fungicides can be applied in light rains and will protect against infections incurred during that wetting period and any that occur over the next day or two. Residual activity from sprays applied in the rain will be less than for sprays that dry before rains begin. Nevertheless, when fungicides residues are removed by rain, then it is imperative to prevent infections even if spray conditions are suboptimal. Spraying in the rain was common in the era when sulfur was the primary protectant against apple scab, but it became unnecessary after we acquired fungicides like benomyl, dodine, and the DMIs that could completely arrest infections even after apple scab was established in leaf tissue. Because of fungicide resistance, we no longer can depend on ANY fungicide to provide post-infection activity against apple scab, so spraying in the rain may be the only way to manage scab in a wet season.

Summary: No single strategy will provide complete scab control in high-inoculum orchards. Given the widespread problem of fungicide resistance, scab control will increasingly depend on using an integrated approach that includes inoculum reduction, spray timing, and fungicide selection to manage scab. Fungicide programs will need to be adjusted for each orchard by taking into account which fungicides are still effective in that particular orchard and by adjusting the total program to compensate for high inoculum during the spring following years when scab was a problem and higher-than-normal inoculum levels would therefore be expected.

Table 1: Effect of inoculum levels on ascospore production based on predicted ascospore doses calculated for New Hampshire orchards by Gadoury and MacHardy (1986).

Scab incidence on leaves in autumn	0.03% to 0.52%	1.1% to 3.5%	4% to 10%	20%
Number of orchards used for the estimate	10	5	3	1
Total ascospores produced/A (X 1000)	888	9,262	242,559	6,090,000
Ascospores/A released at green tip (X 1000)[1]	18	185	4,851	121,812
Potential scab lesions/A from a green-tip infection period[2]	0.18	1.85	48.5	1,218

[1] Assuming that 2% of ascospores are released at green tip. The actual percentage of total ascospore load released at green tip may be much less than 2%, especially under cold conditions.

[2] Assuming 1% of released spores could cause infections but 99.9% of those would be prevented by fungicides applied before the infection period. The actual infection efficiency and fungicide effectiveness are unknown and will vary widely depending on infection conditions and spraying conditions.

Table 2. Results of greenhouse trials conducted by Dr. Mike Szkolnik from 1976-84 showing comparisons of residual activity of Dithane and Captan against apple scab after sprayed trees were exposed to two inches of simulated rainfall.

Rate/100 gal of dilute spray	Number of trials included in the means	Mean percent disease control*
Dithane 80W 1.5 lb	9	99.2
Captan 50W 2 lb	9	91.4
Captan 50W 1 lb	5	78.2
Captan 50W ½ lb	2	68.0

*Data from reports in *Fungicide and Nematicide Tests*, Volumes 31-39.

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