Timing Summer Fungicides To Control Flyspeck Disease On Apples

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Flyspeck and sooty blotch (SBFS) are fungal diseases that cause superficial blemishes on apple fruit during summer. Infections can occur anytime during the summer or fall prior to harvest when there is a lapse in fungicide coverage. Effectiveness of summer fungicide sprays can be compromised by heavy summer or fall rains that wash off fungicide residue. The safest approach for preventing flyspeck is to protect apple fruit with fungicides throughout the entire summer.

Flyspeck and sooty blotch (SBFS) are fungal diseases that cause superficial blemishes on apple fruit during summer (Figure 1). These diseases are common wherever apples are grown in non-arid environments. Light infections or infections appearing just prior to harvest can sometimes be removed by treating fruit with chlorine or detergents before fruit are run over brush beds on packing lines (Batzer et al., 2002), but established flyspeck and severe sooty blotch infections can be difficult to remove. Affected fruit are not acceptable for the fresh market. In the Northeast, the need to control SBFS is usually the driving force for fungicide selection and spray timing from June through mid-September even though summer fungicides are also needed to control black rot, white rot, and bitter rot.

Before the 1980's, scientists believed that flyspeck and sooty blotch were caused by *Zygophiala jamaicensis* and *Gloeodes pomigena*, respectively. Johnson et al. (1997) showed that at least four different fungi cause sooty blotch in North Carolina. More recently, researchers in Iowa used molecular biology tools to show that SBFS on apples in the midwestern states is attributable to at least 30 species of fungi (Batzer et al., 2005). So far, these discoveries concerning the etiology of sooty blotch and flyspeck have not had much impact on management strategies.

All of the fungi causing SBFS are favored moderate temperatures (65-80°F) and extended wetting periods. In the Northeastern United States, flyspeck is more difficult to control than sooty blotch because minimal residues of most fungicides suppress sooty blotch whereas higher concentrations of fungicide residues are required to control flyspeck. In unsprayed trees, however, sooty blotch appears on fruit before flyspeck does because sooty blotch has a shorter incubation period. In commercial orchards, sooty blotch may also appear before flyspeck in autumn if a heavy rain (i.e., greater than two inches of rainfall in a single event) removes all fungicide residues, thereby allowing pathogens for both diseases to start growing on fruit at the same time.

The greatest advances in understanding SBFS in commercial orchards have come from research in North Carolina and Massachusetts. Working in North Carolina, Brown and Sutton (1995) reported that after ascospores of the flyspeck fungus land on fruit, the fruit must accumulate 273 hr of wetting before the disease becomes visible on the fruit. In Massachusetts, Cooley et al. (2007) verified that ascospores of the flyspeck fungus mature on wild hosts shortly after apple trees begin blooming in spring. Significant releases of ascospores are initiated near petal fall and continue for three to four weeks thereafter.

In New York, we have spent nearly 20 years studying the impact of fungicide spray timing on development of SBFS on apple fruit. Our objective was to determine the minimum number of summer sprays needed to keep flyspeck from appearing on fruit just to harvest. Initial efforts focused on determining how long different fungicides would suppress flyspeck. In retrospect, our early studies now appear simplistic because we failed to recognize and account for the many interacting factors that affect development of SBFS on fruit. The remainder of this article describes some recent experiments and observations that are relevant to controlling SBFS with fungicides.

Fig. 1. Flyspeck (discrete black spots) and sooty blotch (discolored gray areas) on a Golden Delicious fruit.

General Model of Flyspeck Development

The discovery that flyspeck requires roughly 273 hr of accumulated wetting (hr-AW) between infection and appearance of symptoms has been validated repeatedly in our studies in the Hudson Valley. Brown and Sutton (1995) ignored wetting periods of less than 4 hr when they derived the 273 hr-AW incubation period for flyspeck, and they initiated their model at 10 days after petal fall. In the Hudson Valley, we have found we can reasonably predict flyspeck development when we begin summing hr-AW beginning from petal fall and including all wetting hours (even short dew periods) as recorded on our DeWitt leaf wetness recorders. We have also rounded the duration of the incubation period to 270 hr. Other researchers have shown that measurements of wetting duration are highly variable depending on sensors used and where they are placed within tree canopies. Thus, variability among sensors probably introduces more error into calculations of accumulated wetting hours than does inclusion or omission of shorter wetting periods or a few days difference in starting time for disease predictions.

Our current understanding of flyspeck development is outlined in Figure 2. Relatively few ascospores released during late bloom and petal fall land on apple fruit, and most of these are killed by fungicides used to control apple scab. Ascospores are important, however, for initiating infections in wild hosts. Primary infections initiated by ascospores on non-orchard hosts begin producing conidia after completing the incubation periods of 270 hr-AW counting from petal fall (hr-AWPF). The conidia produced on non-orchard hosts are blown into apple orchards and cause the majority of infections that appear on apple fruit during late summer. However, another 270 hr-AW are required before flyspeck infections become visible on apple fruit. Thus, in orchards where fungicide protection is discontinued in early June, flyspeck infections on fruit should become visible at about 540 hr-AWPF. In control plots that received no summer sprays, we have repeatedly documented that a logarithmic increase in flyspeck occurs somewhere close to 540 hr-AWPF.

Timing the Last Spray

In orchards receiving summer sprays, flyspeck problems usually develop in September or October, long after the orchards have passed the threshold of 540 hr-AWPF for appearance of conidial infections on unsprayed apple fruit. Losses to flyspeck usually develop after late summer rains remove fungicide protection, thereby allowing fruit infection and exposure to 270 hr-AW prior to harvest. Under those conditions, flyspeck can suddenly appear on a high proportion of fruit within a few days.

This scenario is illustrated by results from a 2004 field trial at the Hudson Valley Lab that was conducted in a small orchard surrounded by woodlots. The orchard contained seven-year-old trees on MM.111 rootstock with M.9 interstems. The control trees used for this experiment did not receive any fungicides all year. All other trees in the block were sprayed with contact fungicides (Penncozeb, Polyram, Microthiol Disperss, and/or Captan) from 16 Apr through 24 May to control apple scab, rust diseases, and powdery mildew. Fungicide treatments were applied June 8, and 24, July 15, 29 and August 17. Development of flyspeck was monitored by examining twenty-five arbitrarily selected Golden Delicious fruit per tree on August 23 and September 3, 14, 22 without removing the fruit from the trees. Fifty Golden Delicious fruit were harvested from each tree on September 27 and were held at ambient temperature

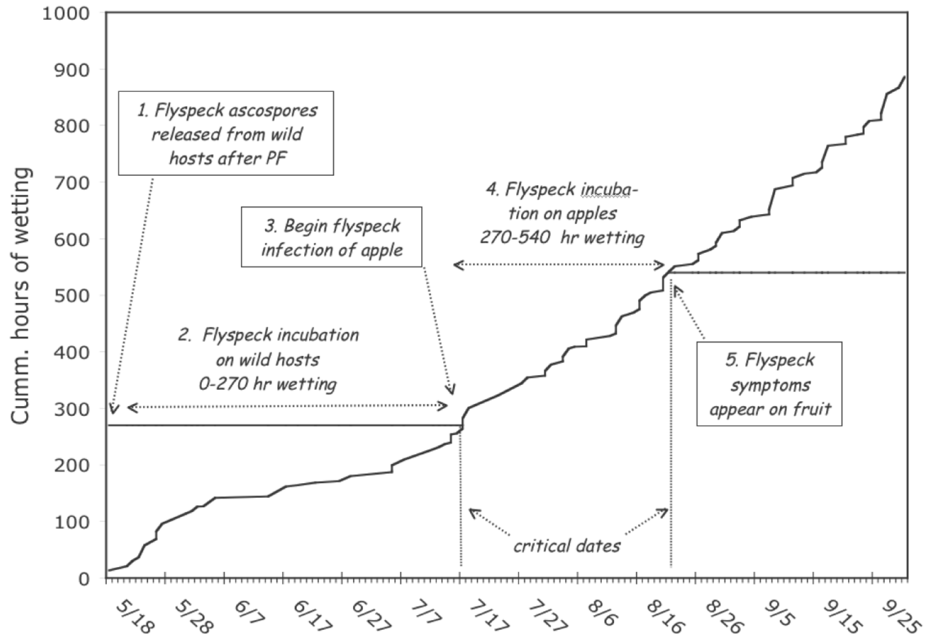

Fig. 2. General chronology for flyspeck development in trees left unsprayed after mid-June. The cumulative hours of wetting shown in this example were based on hours of wetting measured after apple trees reached petal fall at the Hudson Valley Lab in Highland, NY in 2004.

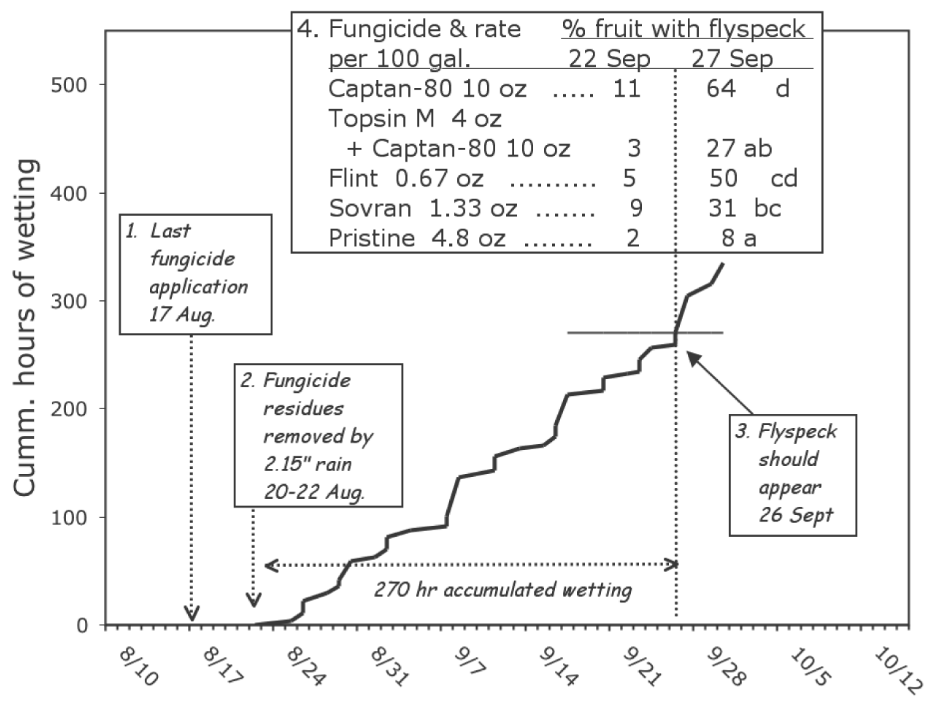

Fig. 3. Chronology of flyspeck development in fungicide test plots at the Hudson Valley Lab following the last fungicide application on 17 August 2004.

until the final disease evaluation was completed on September 29. Rainfall during a storm on 21-22 Aug totaled 2.15 in. and presumably removed most of the fungicide residues remaining from the August 17 spray. Total hr-AW counting from August 22 were 164, 233, and 270 hr for the observations made on September 14, 22, and 27, respectively.

On September 22, less than 10% of fruit had flyspeck and most of the lesions observed were small inconspicuous infections in stem-cups or calyx ends of fruit. Five days later, and after exactly 270 hr-AW counting from the fungicide wash-off date of August 22, incidence of flyspeck jumped to more than 27% in all except the Pristine plots (Figure 3). This trial showed that none of our fungicides (with the possible exception of Pristine) could withstand more than two inches of rain, and the results further verified the validity of using 270 hr-AW as the incubation period for flyspeck.

As illustrated by data in Figure 2, the critical decision for controlling flyspeck is deciding when to re-spray orchards if heavy rains in August and September remove fungicide coverage. September of 2003 was one of the wettest Septembers on record at the Hudson Valley Lab, and 270 hr of wetting were accumulated in just 25 days. Applying what we learned from this worst-case scenario, we conclude that fungicides should be re-applied in late August or September if more than two inches of rain have occurred since the last application and if fruit are still more than 25 to 30 days from harvest. This conservative rule of thumb is especially appropriate for orchards adjacent to hedgerows or woodlots that can provide abundant inoculum. As discussed in the next section, flyspeck may show up in even less than 25 days after fungicide residues are depleted if fungicide lapses earlier in the season allowed flyspeck to become established before September.

Do Fungicides Provide Post-infection Activity?

In 2005, an experiment was conducted to determine if the first summer application of Topsin M, Sovran, Flint, or Pristine could be delayed beyond 270 hr-AWPF on the assumption that fungicides with limited systemic activity would eradicate pre-existing infections so long as the fungicides were applied early during the incubation period of the conidial infections that begin accumulating at 270 hr-AWPF. Treatments were replicated four times in the same orchard described for the 2004 trial. The last two scab sprays were Penncozeb 75DF 3 lb/A on 30 May and Captan 80W 2 lb/A on June 8. A total of 2.25 inches of rainfall between June 10 and 18 removed fungicide residues from the June 8 spray before trees reached 270 hr AWPF on June 29. Test plots received their initial spray on July 11 at 337 hr-AWPF and were re-sprayed on July 29 and August 19.

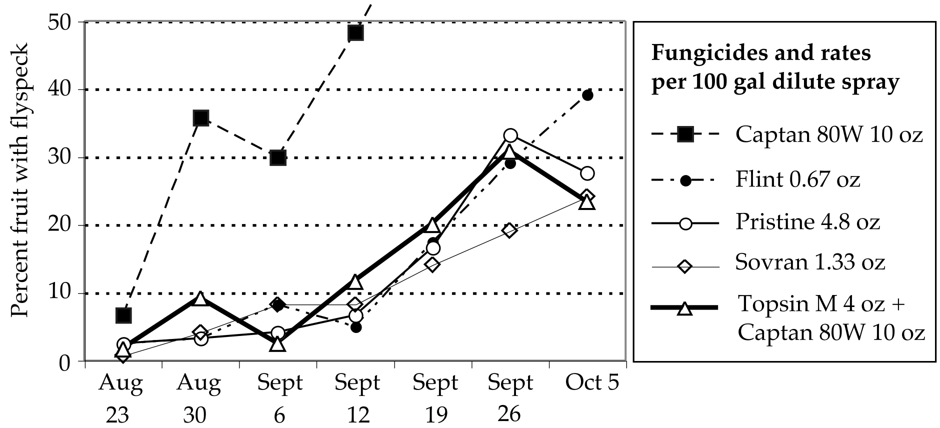

Fig. 4. Development of flyspeck on Golden Delicious fruit in 2005 as affected by fungicides when the first summer spray was initiated after 337 hr of accumulated wetting counting from petal fall. Summer fungicides stopped development of infections that predated the first spray on 11 July, but these infections resumed growth and produced symptoms after fungicide residues were depleted in early September.

Appearance of flyspeck on fruit was monitored during August and September by examining 30 arbitrarily selected Golden Delicious fruit on each tree without removing the fruit from the trees. In control plots that received no summer fungicide sprays, flyspeck incidence jumped from 8.5% of fruit infected on August 15 (516 hr-AWPF) to 46% on August 18 (538 hr-AWPF) and to 77% on August 23 (554 hr-AWPF). As expected, Captan used alone was ineffective. In Captan plots, 48% of fruit had flyspeck by September 12, just 24 days after the last spray.

By September 26, flyspeck had also appeared in all of the other fungicide plots and was evident on 19 to 21% of the fruit (Figure 4). Disease development followed the same pattern for plots treated with Flint, Pristine, Sovran, or the Topsin M plus Captan combination.

In designing this trial, we assumed that, except for Captan, the test fungicides would protect fruit for either 21 days following application or through 1.5 inches of accumulated rainfall. These estimates of residual activity were derived from subjective observations of sprayed plots over many years. Under these assumptions, the summer spray intervals in this trial precluded the possibility that flyspeck that appeared prior to harvest could have originated from infections that occurred between the summer sprays. After August 19, cumulative rainfall did not exceed 1.5 inches until September 17, so residues from the last fungicide spray were not compromised by excessive rainfall during the 21 days following application. The 21-day protection interval counting from the last spray would have extended to September 9. Accumulated hours of wetting from September 9 to October 3 totaled only 186 hr far less than the 270 hr-AW that would have been require to complete the incubation period for flyspeck infections that might have occurred on fruit after residues from the last spray were degraded.

We concluded that symptoms that appeared in and on fruit in September must have resulted from infections that predated the first summer fungicide sprays that were applied on July 11. Thus, fungicides applied during summer suppressed, but did not eradicate those pre-existing infections, and the infections finally resumed growth and became visible after fungicide residues were depleted in September. A similar experiment in 2006 verified the conclusion that none of our fungicides can eradicate flyspeck infections that are established on fruit before the fungicides are applied.

Recommended Practices for Controlling Flyspeck

The following recommendations for controlling flyspeck are derived from our current understanding of both the disease and the limitations of available fungicides.

1. The safest approach for preventing flyspeck is to protect apple fruit with fungicides throughout the entire summer, recognizing that conidia are available to initiate infections at any time after trees have been exposed to 270 hr of accumulated wetting counting from petal fall.
2. If they are applied at labeled rates, Topsin M, Sovran, Flint, and Pristine will protect fruit for about 21 days or through two inches of accumulated rainfall.
3. If fungicide protection is removed by heavy summer rains, the follow-up fungicide spray can be delayed for a few days to allow for better spray conditions or to better integrate fungicide and insecticide spray schedules. Short periods of lapsed coverage are tolerable because the 270 hr-AW incubation period required before conidial infections become visible on fruit can be viewed as a grace period that can be used anytime before harvest. The trade-off, however, is that the portion of the 270 hr-AW grace period used during summer will not be available to get through September if heavy rains in early September remove fungicide residues.
4. If flyspeck infections are present at harvest, the infections can continue to grow on wet fruit surfaces after harvest until fruit are cooled below roughly 45° F. Fluctuations in air temperatures as storage rooms are filled can cause condensation on surfaces of cold fruit already in the room, and that moisture can allow continued growth of flyspeck. We suspect that in some cases, fruit in the center of stacks might be exposed to 70 hr-AW after harvest and before fruit are cooled to below 45° F. Application of a postharvest fungicide drench might suppress growth during the cool-down period after harvest, but no one has investigated this possibility.
5. Effectiveness of late summer fungicide sprays can be compromised by incomplete coverage of fruit surfaces. The best options for improving coverage with late summer sprays include reducing sprayer travel speed, increasing the volume of water applied per acre, and including an effective surfactant to enhance fruit wetting.

Controlling Other Diseases That Infect Fruit During Summer

In the Northeastern United States, spray programs that control flyspeck usually control sooty blotch, black rot, white rot, Brook's spot, and other minor diseases that can appear on unsprayed fruit. However, more stringent fungicide programs may be required to control bitter rot in regions where this disease is prevalent. In northeastern United States, bitter rot can be controlled by using maximum labeled rates of Captan or Pristine.

Acknowledgments

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