LEAF SPOTTING: CAUSES AND SOLUTIONS

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Introduction

Leaf spots on apples can be caused by fungal pathogens, air pollution, viruses, or injury from pesticides or foliar nutrients. Determining the causes of leaf spots is often difficult because the spotting caused by different pathogens or injuries looks very much alike. In some cases, leaf spots develop as a result of interactions among multiple factors, any one of which would not cause leaf spotting on its own. Following is a brief description of the most common causes of leaf spotting in apples in the Northeast, along with comments on how to minimize damage from leaf spotting.

Leaf Spots Caused by Fungi

Many fungi can cause spots on apple leaves. Apple scab, cedar apple rust, hawthorn rust, and powdery mildew cause spots on leaves although they are not usually classified as "leaf-spotting fungi." Frog-eye leaf spot caused by Botryosphaeria obtusa exemplifies the more stereotypical leaf spot disease in that its nondescript brown leaf spots are very similar to those caused by many other fungi and by non-pathogenic agents that damage leaf tissue.

Frog-eye leaf spots are usually round dark brown spots, 2-5 mm in diameter, with an almost black border and a tan center. The leaf spots become irregular in shape as they age because of irregular growth at the lesion margins and secondary invasion by other pathogens. Individual leaves may have a single spot or as many as 30 to 50 spots.

In sprayed orchards, frog-eye leaf spots are usually concentrated in the vicinity of mummified fruitlets that were retained after fruit thinning the previous year or beneath twigs and branches that were killed by fire blight during the previous season. Fruitlet mummies and blight-killed wood are rapidly colonized by B. obtusa and then provide inoculum for infecting the leaves the following season. Spores are dispersed by splashing rain during extended wetting periods from about tight cluster through second cover. Frog-eye leaf spot can usually be differentiated from other kinds of leaf spots by its non-random distribution and its association with nearby inoculum sources.

Frog-eye leaf spot is most common on apple cultivars that retain fruitlets after chemical thinning. These include Cortland, Northern Spy, and Honeycrisp, among others. However, all cultivars may retain thinned fruit in years when weather conditions following fruit thinning fail to promote rapid abscission of thinned fruitlets.

Severe frog-eye leaf spot may cause some premature leaf drop, but most infections cause little more than cosmetic damage to the foliage. The same fungus that causes frog-eye leaf spot also causes black rot fruit decay, but there is no evidence that leaf spots contribute to fruit infection. Instead, the inoculum for fruit infection comes from the same fruit mummies and blighted wood that contributes the inoculum for leaf infection. Thus, frog-eye on leaves can be viewed as an indicator for conditions that may have favored infection of fruit, but the leaves themselves do not contribute directly to the development of black rot on fruit. Black rot infections in fruit may remain quiescent until fruit ripen because green fruit contain inhibitors that prevent fungal growth.

Frog-eye leaf spot is easily controlled by including captan, Flint, Sovran, Benlate, or Topsin M in scab control programs, although Benlate and Topsin M are no longer recommended for scab control because many orchards contain scab strains that are resistant to these fungicides. The SI fungicides do not provide good control of frog-eye leaf spot. Polyram, thiram, and the mancozeb fungicides provide adequate control of frog-eye when applied at rates of 6-8 lb/A, but they are only marginally effective at 3 lb/A.

Apple scab, rust diseases, and powdery mildew may cause obscure leaf spots when their normal symptom development is arrested by fungicides. Syllit, Benlate, and Topsin M were used for many years to arrest apple scab epidemics because these fungicides could stop fungal growth and/or spore production in developing lesions. Scab spots arrested by these fungicides were often a rusty, red-brown color instead of the typical olive-brown of normal scab lesions, but these spots were still recognizable as apple scab because they were still the usual size and shape of normal scab spots.

The SI fungicides (Rubigan, Nova, and Procure) and the strobilurin fungicides (Sovran and Flint) can arrest development of apple scab earlier in the infection process. When these fungicides are applied more than 96 hours after the start of a wetting period, only "ghost lesions" or other aberrant scab spots may develop on leaves. Ghost lesions are indistinct pale spots 2-3 mm in diameter that develop where the scab fungus disrupted normal cell functions before the fungus was arrested by the fungicide.

Post-infection application of the SIs and strobilurins can also cause "burned out" mildew and rust spots on leaves. Mildew lesions arrested by fungicides may appear as large but indistinct chlorotic lesions on the upper leaf surface or as more sharply-defined red blotches on the lower surface of leaves. Portions of the leaf compromised by mildew may be more susceptible to subsequent invasion by other leaf spotting pathogens.

Rust infections arrested by the SI fungicides often produce small 1-2 mm diameter tan or brown leaf spots, sometimes with a tiny orange fleck in the center of the leaf spot. Similar lesions can appear on McIntosh, Liberty, and other rust-resistant cultivars if trees are subjected to high levels of rust inoculum in the absence of fungicide protection. On the rust-resistant cultivars, fungal development is arrested by the genetic resistance of the host, but leaf cells damaged by the initial infection still die and produce leaf spots similar to those that occur when rust infections on susceptible cultivars are arrested by fungicides.

Rust-induced leaf spots develop when fungi such as Botryosphaeria, Alternaria, or Phomopsis invade cells killed or damaged by failed rust infections. These fungi move from the dead or dying cells to adjacent healthy tissue, thereby enlarging the leaf spots until they are indistinguishable from frog-eye leaf spots. Thus, trees of rust-resistant cultivars such as McIntosh may suddenly develop what appears to be a severe outbreak of frog-eye leaf spot when the infection was actually initiated by cedar apple rust spores attacking a non-susceptible host. However, rust-induced leaf spots are usually uniformly distributed throughout tree canopies, whereas frog-eye leaf spots are clustered near inoculum sources. Sometime the original orange-yellow rust lesion remains visible in the center of rust induced leaf spots whereas frog-eye leaf spots never have orange centers.

Rust-induced leaf spotting is most common on terminal leaves that develop during the spring growth flush between petal fall and second cover, but it can also occur on cluster leaves. Rust-induced leaf spotting can be prevented by protecting trees from rust infections during the interval between tight cluster and second cover. Captan, Syllit, Benlate, and Topsin M do not control rust diseases. Flint and Sovran have only marginal rust activity. The SIs and carbamate fungicides (mancozeb, Polyram, Ferbam, and Thiram) are very effective against rust diseases.

Alternaria leaf spot looks very similar to frog-eye leaf spot. Alternaria can be isolated from leaf spots in many orchards, especially in late summer, but Alternaria leaf spot is not known to cause economic damages in the northeast. In North Carolina and Virginia, a severe form of Alternaria leaf spot known as Alternaria blotch spreads rapidly during summer and causes premature defoliation of affected trees. Delicious is particularly susceptible. The strain of Alternaria mali that causes defoliation in the southeast may be different from the common Alternaria mali present in northeastern orchards.

During the past 20 years, I have encountered three cases where an unknown leaf spot caused extensive late-summer defoliation to apple trees in "hot spots" within managed orchards. In all three situations, the leaf spotting affected multiple cultivars including cultivars that have been reported as relatively resistant to Alternaria blotch. In all three cases, an Alternaria species was isolated from the leaf spots, but we never proved that Alternaria actually caused the defoliation. Alternaria is common on leaf surfaces and rapidly invades damaged tissue on leaves, so proving the cause-and-effect relationship is especially important when attempting to

separate cases where Alternaria causes leaf spots from those where Alternaria only acted as a secondary invader. Lacking evidence to the contrary, we believe that Alternaria leaf spot remains an insignificant problem in the northeastern United States. None of our fungicides is very effective for preventing Alternaria leaf spot or Alternaria blotch.

Other fungi that can cause apple leaf spots in the Northeast include Phoma pomorum, the cause of Phoma leaf and fruit spot, Phyllosticta solitaria, the cause of apple blotch, Colletotrichum gloeosporioides, cause of apple bitter rot, and Phomopsis mali, the cause of Phomopsis canker and Phomopsis fruit decay. None of these fungi is an important cause of leaf spotting in commercial orchards in the northeast.

Leaf Spots Caused by Spray Injury

Many pesticides can injure leaves if the pesticides are applied at inappropriate rates, under unusual environmental conditions, or in untested mixtures with other pesticides. It is impossible to list all of the potential materials or mixtures that might cause phytotoxicity because no one can evaluate all of the combinations that fruit growers might mix in a spray tank or duplicate all of the host and environmental conditions that occur in orchards. However, some of the more common culprits or phytotoxicity should be mentioned.

Captan is a potent fungicide on leaf surfaces, but captan is phytotoxic when it moves inside leaves or fruit. Most growers know that captan, if applied within 7 to 10 days of an oil spray, can cause severe leaf spotting, especially on Delicious. This captan-induced leaf spotting occurs because oil deposits on leaves carry captan into the leaf cells. Captan penetrates leaves more easily when leaves have developed under extended periods of cloudy weather because sunlight and dry conditions are required to stimulate development of thick cuticle layers that prevent captan from reaching leaf cells.

Captan-injury can also occur when captan is tank mixed with other products that are formulated with special wetting agents or penetrants. The captan label specifically states “The use of spreaders that cause excessive wetting is not advised.” In 1998, liquid calcium chloride products that were tank-mixed with captan caused extensive injury on Empire fruit in the Hudson Valley. The calcium chloride was formulated to optimize absorption, but the adjuvants in calcium formulation also allowed captan to pass through the fruit cuticle.

Over the past 20 years, I have seen cases of leaf spotting that have been traced to applications of various other pesticides including Sevin XLR, Lorsban, and Asana. In some cases, these products had been applied in mixtures with captan whereas other cases involved other pesticides. None of these incidents resulted in serious leaf damage, and they are cited here only to illustrate that many different pesticides may cause phytotoxic leaf spotting under certain conditions.

Among the new fungicides, note that the Flint label contains the following warning: “Do not apply Flint in combination with organo-silicate surfactants to apples or pears or crop injury may occur.” I have not yet seen any injury from Flint, but label warnings should be heeded.

Another strobilurin fungicide, azoxystrobin, is extremely phytotoxic to McIntosh, Gala, and a few other apple cultivars. Concentrations of azoxystrobin as low as 5 parts per billion have been reported to cause a leaf spotting on McIntosh that is indistinguishable from frog-eye leaf spot. Higher concentrations will cause damage similar to that observed with paraquat. Azoxystrobin is labeled as “Abound” for use on grapes and stone fruits and as “Quadris” for use on corn, soybeans, small grains, vegetables, and Christmas trees. The large number of labeled uses for azoxystrobin raises the probability that apple growers in the northeast will experience occasional problems due to off-site drift of azoxystrobin. Azoxystrobin injury due to off-site drift should be easy to diagnose because the leaf spotting will appear suddenly, will be evenly distributed throughout the canopy, and will occur only on McIntosh, Gala, and a few other Mac-related cultivars whereas adjacent cultivars will be completely unaffected. The latter is the most distinguishing characteristic because no other pesticide or fungal pathogen that might cause leaf spotting on apples is so distinctly delimited by cultivar.

Leaf Spots Caused by Air Pollution

Air pollutants can cause or contribute to leaf spotting diseases in several ways. In one incident that I witnessed in the Hudson Valley, oily particulates ejected from an electrical power plant smoke stack caused severe leaf spotting on leaves and fruit in orchards within several miles of the plant. The cause of the leaf spotting was never fully proven, although we later learned that it could have been proven had we collected fresh samples for chemical analyses by regulatory agencies. Rather, the cause of this leaf-spotting incident was deduced from the limited locale in which it occurred and from the observation that similar spotting also occurred in leaves in adjacent wood lots and shade trees.

A more common air pollutant that contributes to leaf spotting is ozone. Ozone injury appears as irregular purple mottling on the lower surface of apple leaves. It may sometimes be confused with symptoms typically associated with aging mildew lesions. Ozone injury occurs most commonly during late summer and is usually found on the bottom sides of cupped leaves that are positioned in such a way that a portion of the lower leaf surface faces upwards. The economic importance of ozone injury on apples is not known, but leaves compromised by ozone injury may be more prone to infection by weak fungal pathogens that cause late-season leaf spotting.

Leaf Spots Caused by Virus Diseases

Apple mosaic virus can cause a yellow mottling or spotting on leaves of apple trees that carry this “latent virus.” Apple mosaic spreads only via infected propagation material. It is present in many trees planted before the mid 1970’s and in some later plantings that were derived from non-certified stock. Infected trees often show symptoms only in years with a cool, prolonged spring. Thus, trees may remain symptomless for many years, then one year they may suddenly develop distinct yellow mottling on leaves during early June. There is no cure for affected trees and no danger that the virus will spread to adjacent trees. Apart from the occasional flush of leaf symptoms, the virus has no visible effect on tree health.

Leaf Spots from Unknown Causes

Necrotic leaf blotch is a disease that occurs primarily on Golden Delicious trees. Leaves develop irregular brown spots that may encompass 10-20% of the individual leaf surface. The first symptoms usually appear in early August. Affected leaves soon turn yellow and drop from the tree. Affected trees may lose more than 50% of their leaves during August and early September, and the yellowing of the affected leaves makes this a very noticeable disease. Although necrotic leaf blotch does not cause fruit drop or fruit blemishes, it may have adverse effects on fruit size and quality.

Dr. Turner Sutton in North Carolina studied necrotic leaf blotch in the early 1970’s, but he was unable to identify the cause of the disease. Sutton showed that the disorder is not caused by a fungus, bacterium, or air pollution and that it is not related to foliar nutrient levels. Symptoms and subsequent leaf drop frequently occur in distinct "waves" in mid to late summer. In controlled environment tests, Sutton showed that the disorder failed to develop on leaves of trees held at 86/79/F. day/night temperatures, whereas 33% of leaves on trees held at 79/72 or 72/64 day/night temperatures developed leaf blotch. He also showed that potted trees watered every day had roughly three times more leaves affected than did similar trees watered only every second or third day. The results suggest that necrotic leaf blotch is favored by relatively cool, wet weather in late summer.

Sutton found that mancozeb fungicides applied during summer suppressed necrotic leaf blotch whereas Captan, Benlate, and Topsin M were ineffective. Mancozeb fungicides can no longer be applied during summer, so there is currently no fungicide program available for reducing the severity of this disorder.

Late-season leaf spotting is a term used to describe nondescript small (1-3 mm diameter) leaf spots that become apparent in unsprayed or poorly sprayed orchards during late summer. In one study at the Hudson Valley Lab, late-season leaf spotting developed during September on Liberty trees that were left unsprayed throughout summer whereas trees that received summer fungicides did not develop leaf spots. Unsprayed trees defoliated 15 days earlier in October and had weaker flower buds the following spring. Isolations made from the leaf spots on unsprayed Liberty trees yielded a variety of obscure fungi, and the cause of the late-season leaf spotting remains unknown.

Since this study, similar late-season leaf spotting has been noted in various commercial orchards, especially where summer fungicide programs were terminated early. Late-season leaf spotting can degrade foliage quality in autumn, but further study is required to determine both the cause(s) of this disease and its economic importance.

Conclusions

With the exception of well-known leaf diseases like apple scab, powdery mildew and rust, most leaf spotting diseases of apple that occur in northeastern United States cause little if any direct economic damage. Causes of leaf spots can sometimes be deduced from disease patterns within the orchard, the time of symptom appearance, and characteristics of the individual leaf spots. However, causes for many leaf spot outbreaks cannot be easily determined. Where phytotoxicity from pesticide sprays or foliar nutrients is a probable cause, growers should carefully note the mixtures, spray conditions, and stage of host growth so that similar injury can be avoided in the future.