The best/worst time for pathogens

New, weather-driven risk models indicate when box blight and apple scab are more likely to spread

Figure 1. Box blight shows many symptoms on boxwood, including leaf spots (top), as well as defoliation and blighted foliage (bottom). PHOTOS BY BJORN GEHESQUIERE

By Leonard Coop

Certain weather conditions can greatly increase the chance that plants will become infected when exposed to certain diseases. In this article, we will review temperature and moisture requirements and how to predict them for two fungal diseases that have been seen in nurseries recently.

The first disease is apple scab (*Venturia inaequalis*). This is a classic disease of apple and ornamental crab-apple, and is not to be confused with pear scab, which is a different pathogen that attacks pear trees.

The second disease is boxwood blight (*Calonectria pseudonaviculata*, synonym *Cylindrocladium buxicola*), also known as box blight. This invasive pathogen attacks boxwoods (*Buxus* spp.). It was first seen in Oregon in 2011, and could become a huge problem if it becomes established in various parts of the United States.

Boxwood blight has been in Europe for more than 10 years, and in the U.K. for almost 20 years. It now seems to be firmly established in some parts of the eastern U.S.

Inoculum for this disease can survive up to several years. The pathogen produces thousands of microsclerotia per leaf, so any place where this disease has been diagnosed is contagious, and should be kept under quarantine. This means that no boxwood varieties should be grown in ▶

An ongoing series provided by Oregon State University in collaboration with the United States Department of Agriculture and in partnership with OAN these locations, and soils where symptoms were seen should not be transported elsewhere or used for container plantings.

Blight symptoms appear as early as seven days after infection occurs (Figure 1). One should refer to the *Pacific Northwest Plant Disease Management Handbook* (available at http://pnwhandbooks.org/plantdisease) for more information on symptoms, diagnosis and management options for box blight and apple scab.

Factors of risk

Infection risk for many plant diseases is determined by three major factors:

1. Local inoculum levels,
2. Host plant susceptibility, and
3. Environmental conditions.

Of these three factors, growers can have some control over the first two through the use of best management practices. These include using certified planting stock, choosing resistant varieties, practicing good sanitation, and if available, using spore traps or local information networks to estimate local and regional inoculum levels.

One should note that for boxwood, true resistance to box blight has not yet been described, though researchers have documented a wide range of susceptible selections. Most *Buxus sempervirens* cultivars are moderately to very highly susceptible to box blight. Most Asiatic species (*B. microphylla*, *B. sinica* and *B. harlandii*) cultivars range from low to moderate susceptibility. *B. microphylla* var. *japonica* 'Morris Midget', however, tested as very highly susceptible.

Charts of degree of susceptibility are available online (http://www.shemin.net/assets/ncsu_boxblight_tolerance.pdf). Beware that some boxwood varieties of supposed "low susceptibility" may appear to be symptomless, but they can still carry the disease.

Monitoring conditions

When disease inoculum is suspected or known to be present, and no resistant varieties are available, then one must closely monitor current

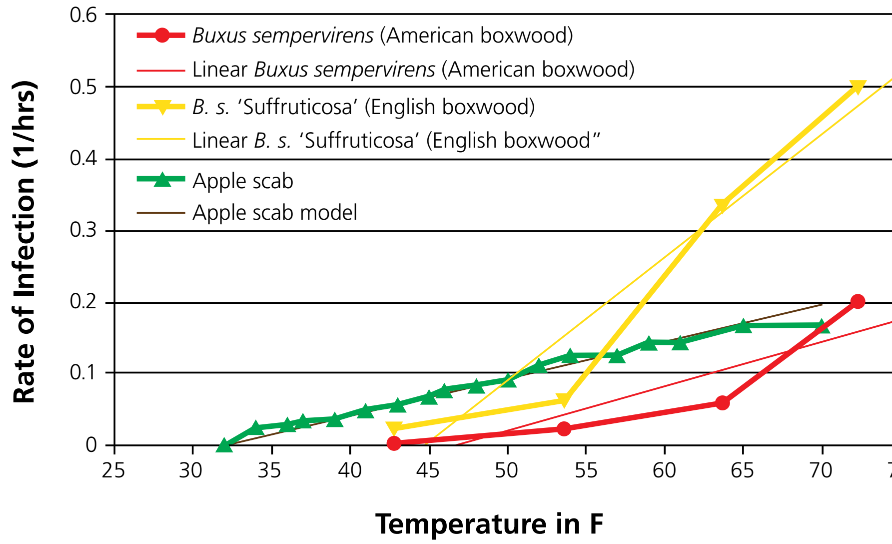

Figure 2. With apple scab as well as boxwood blight, there's a consistent relationship between higher temperatures and infection rates, provided there is sufficient moisture. However, plants are susceptible to apple scab (represented by the green line) over a greater range of temperatures than box blight (represented by the yellow and red lines). As shown in the graph, English boxwood (yellow line) infection rates skyrocket above roughly 55 degrees. The response rate for moderately susceptible American boxwood and apple scab, meanwhile, is more constant. SOURCE: GEHESQUIERE ET AL

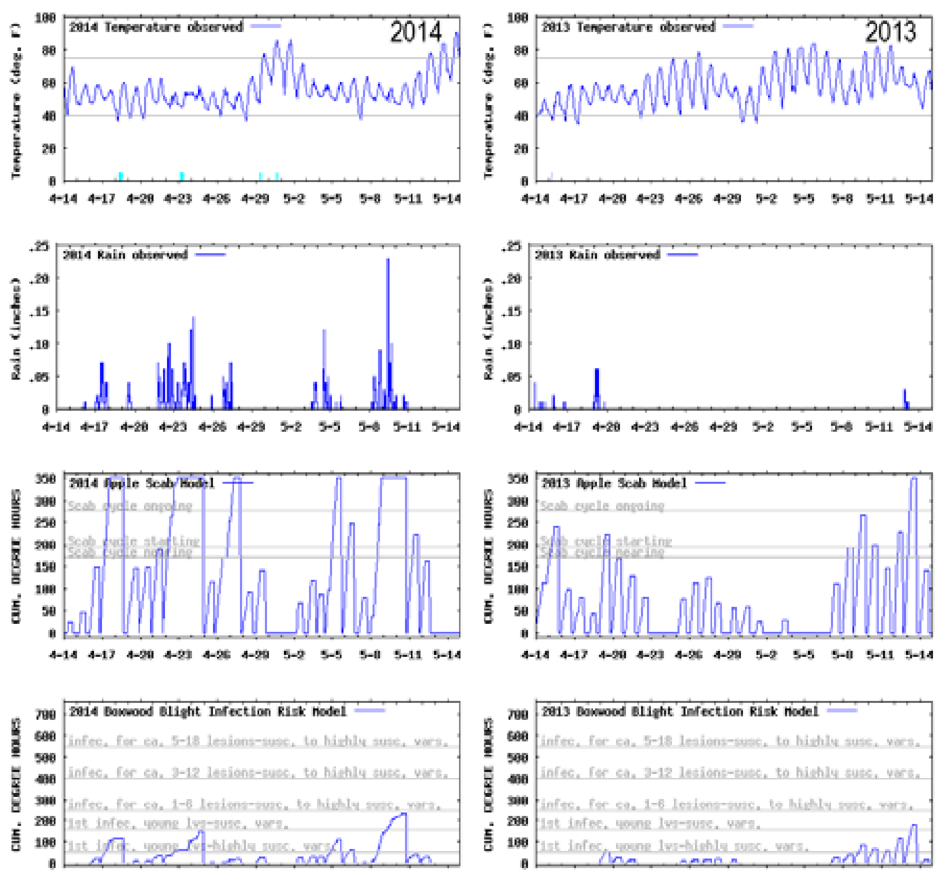

Figure 3. These charts show sample temperature, rain, apple scab model and box blight model outputs from "MyPest Page" during April/May 2013 (right) and 2014 (left), for Agrimet weather station ARAO (Aurora, Oregon, just south of Portland). The charts show relatively higher risk levels during the 2014 interval. The graphs further show risk levels to be much higher for apple scab than for box blight. Temperatures were frequently in the range needed for apple scab infection (horizontal lines drawn at 40 F and 75 F), without being consistently warm enough for high risk of box blight. SOURCE: HTTP://USPEST.ORG/RISK/MODELS

weather conditions. But how?

Special-purpose models tied to local weather stations and forecasts can indicate the degree to which conditions favor a specific disease infection process and provide warning to take preventive actions.

Each plant disease organism has a range of temperature and moisture conditions needed to complete the steps in the infection process. These steps include spore germination, mycelial tube growth (the step often cited to be stopped by fungicides), penetration of host plant tissue, and colonization of plant cells.

The speed of all these activities depends primarily on temperature. Usually, some form of free moisture must also be present on the leaves or other surfaces of a susceptible plant. This can come in the form of high humidity leading to dew formation, or rainfall. The presence of moisture is, as a measurable or estimated factor, known as "leaf wetness."

The warmer the conditions (up to an optimum), the faster the infection rate. When studied in the lab under controlled conditions, we can fit a mathematical model to the relationship between temperature and infection rate (Figure 2).

Once an infection risk model is tested in the field, it can be used as a part of a plant disease infection risk warning system. For example, box blight and apple scab are two diseases that respond somewhat similarly to temperature under conditions of leaf wetness.

They differ in that apple scab responds to much lower temperatures, even below 35–40 F. Box blight, on the other hand, needs at least 46 F for infection of young leaves, while 52–55 F may be the lower threshold for older boxwood leaves. These numbers come from studies done on American and English boxwood; other varieties may differ in response.

Figure 2 also indicates that the higher range of temperature responses for boxwood infection may not be ideally suited for some climates such as the Pacific Northwest, where it is seldom both warm (55–80 F) and wet during the springtime.

The Midwest and eastern U.S. have greater humidity, and thus will be expected to have more frequent and longer infection events. Nurseries in the Pacific Northwest, on the other hand, often create such conditions artificially using shade netting and overhead irrigation systems, which will then more closely emulate ideal infection-conducive conditions. The synoptic mapping system shown in Figure 4 illustrates this point.

On June 27, 2014, high-risk infection conditions existed in many eastern ▶

areas, while the coastal-influenced Pacific Northwest had some high-risk locations, particularly in Oregon's Willamette Valley. This situation was short lived, however, as warm temperature events in the Pacific Northwest tend to be dry.

Rainy periods tend to be a bit too cool for box blight infection, but can be "just right" for apple scab. In fact, 2014 was a very high-risk year for apple scab in the Northwest, as compared to 2013 (using data from Agrimet weather station ARAO in Aurora, Oregon, as an example — see Figure 3). Other than the June 27, 2014 (Figure 4) example, there were practically no high-risk events modeled for box blight. Again, the model runs are based on standard weather shelter microclimate conditions, and do not consider conditions when shade and irrigation are artificially added.

Models such as these provide a convenient tracking system for quantifying the precise environmental conditions that a particular disease infection process requires to reach completion. These models can be linked to weather stations and forecasts to provide early warning systems to inform decision makers about potential high-risk situations where action may be needed.

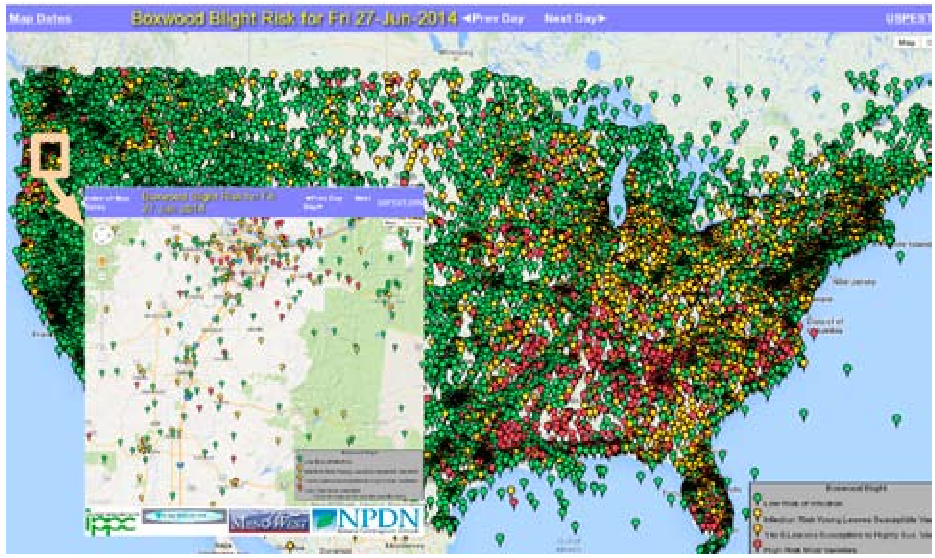

Figure 4. This sample box blight synoptic infection risk map depicts what was a high-risk infection period (June 27, 2014) throughout several portions of the U.S. The inset box focuses on the Willamette Valley, Oregon, which has variable risk levels that, as of early July, were the highest thus far in 2014. The map displays low, moderate and high-risk locations using green, yellow, orange and red pins. On the actual screen, clicking on a pin opened the full "MyPest Page" modeling interface for that location (from which graphs in Figure 3 were derived).

Determining risk

The interpretation of "low," "medium" and "high" risk levels will vary for a given plant disease, model formulation, host plant cultivar, microclimate variability, management practices, and other conditions. In general, the models are designed to trigger the precise time when infection can occur.

If conducive weather conditions continue for longer than this initial threshold, then risk keeps increasing and the relative amount of inoculum required for infection reduces accordingly. Depending on the particular host and disease, such sustained conditions can cause multiple compounding infection cycles, if left unchecked.

One consideration specific to apple scab is that this risk model is used during the springtime primary infection season, caused by the overwintered ascospores. Another model is available to predict the end of this primary infection season. If no scab develops by this time, then no inoculum is likely to be present and no secondary infections are expected to occur. Refer to the *Pacific Northwest Plant Disease Management Handbook* for more information on apple scab.

Besides the strain of box blight already found in North America (G1), a second strain (G2) was recently proposed as a separate species (*Calonectria henricotiae*). It has not yet been seen in the U.S., but is now present in at least five countries in Europe.

Box blight should be closely watched and prevented from establishing wherever possible. The current predictive model does not include any dispersal component. Short-distance dispersal requires either mechanical spread by human or animal movements, most likely only during periods when leaves are wet, such as during rainfall or while dew is present. Alternatively, it can be dispersed by wind-driven rain, as the spores have not been shown to spread through the dry air.

The model is currently being revised to include certain wind and rainfall thresholds that will increase the risk of spread of inoculum and infection. However, current model runs all indicate that whenever high risk develops, rainfall events are already a contributing factor, by bridging nighttime dew periods.

New research results are expected soon. These should improve our understanding and modeling of box blight epidemiology. ©

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