FIRE BLIGHT FACT SHEET

Host range and significance. Fire blight is caused by *Erwinia amylovora*, a bacterial plant pathogen that infects apple, crabapple, pear, Asian pear and quince. It also infects decorative landscape or forest plants such as hawthorn, Callery pear, firethorn (aka *Pyracantha*), raspberry (*Rubus* spp.), mountain ash, serviceberry (*Amelanchier* spp.), *Cotoneaster spp.*, loquat, *Chaenomeles spp.* (Maule's quince), and other Rosaceae family species. Losses caused by fire blight depend on how conducive the weather conditions during bloom each year are. However, in some years, fire blight unexpectedly occurs on shoots for the first time in the season. In an epidemic in Michigan in 2000, fire blight caused losses of $42 million due to removal of around 350,000-400,000 apple trees. In 2014, an epidemic in Nova Scotia, Canada, affected 90% of apple orchards and was spread by a hurricane Arthur causing estimated $20 million damage due to removal of 45-90,000 trees. In USA alone, fire blight losses and management costs are estimated to more than $100 million per year. We estimate that in northern New York in 2016, fire blight caused losses of between $10-14 million due to tree death, crop loss, labor costs for pruning removal of blighted plant parts, and summer fire blight sprays.

Disease cycle and symptoms. Fire blight bacteria survive through the winter between the cells of apple cortical parenchyma in the bark around and below fire blight cankers formed after infections in previous years. Pathogen emergence on edges of overwintered cankers usually occurs during late bloom and petal fall. With warm temperatures in spring, some fire blight cankers exude orange ooze droplets on the surface of cankers edges consisting of exopolysaccharide sugars and multiplying fire blight bacterial cells (Fig. 1). The orange ooze protects bacteria from unfavorable weather conditions and is the main form in which bacteria spread in the orchard to reach flowers and shoots. Bacteria in sticky ooze droplets are dispersed to flowers in rain droplets i.e. aerosol or disseminated with insects that

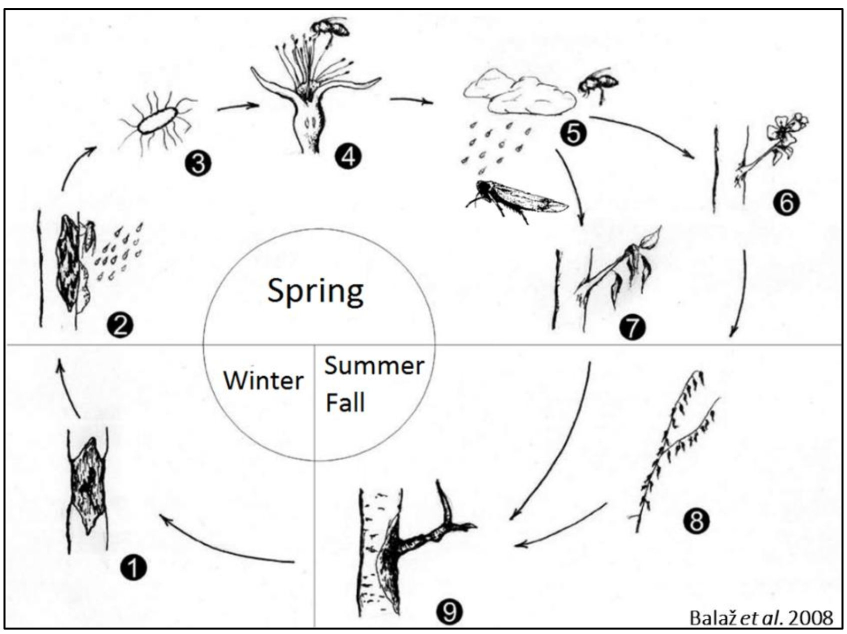

Figure 1. Life cycle of fire blight bacterium *Erwinia amylovora*: 1. Overwintering in cankers on wood, 2. Emergence of bacteria on the bark surface at canker edges (oozeless colonies, ooze droplets, dry ooze strands), 3. Dissemination of bacteria on flowers by insects, rain and wind, 4. Bacterial population growth on flowers and insect vector exposure, 5. Further dissemination of bacteria to flowers and shoots by rain, wind and insects, 6. Blossom blight development, 7. Shoot blight development, 8. Branch death, 9. Formation of new cankers and overwintering. From: Balaž, et al. 2008. Bacterial fire blight (*Erwinia amylovora*) of pome fruit species and ornamental plants.

touch the ooze. In some cases, dry ooze strings or particles exuded from lenticels on the bark can break off and land on flowers or shoots by wind or with insects. In low relative humidity conditions, fire blight bacteria can survive in dry ooze for even more than a year. It is still investigated which insects commonly disperse the fire blight pathogen from cankers to flowers, but it is known that the species vary depending on the region of the world. It is known that flies can be attracted to ooze but are rarely observed on apple flowers. It seems that bees do not visit ooze droplets on cankers in spring and probably do not spread the bacteria from cankers to flowers. However, the closer the oozing cankers are physically to any open flowers, the higher is the chance for bacteria to reach flower by previously mentioned ways.

On flower stigmas bacteria multiply rapidly only when temperatures are favorable. Fire blight bacteria multiply slowly below 70ºF, moderately between 70º - 75ºF, and rapidly between 75º - 93ºF (Smith 2017). The most favorable population growth occurs in the range of 82º - 90ºF. Above 95ºF, population growth severely decreases and number of bacteria declines at temperatures more than 99ºF (Smith 2017). Presence of bacteria on flowers does not always lead to infections. After colonizing the flower, bacteria only have few days to grow their numbers to at least 100,000 or 1 million live bacteria before a possible infection event that can be triggered by rain, dew, or hail. In the meantime, before the moisture is available to facilitate the infection, bees can spread the bacteria from contaminated flowers to newly opened flowers and contaminate them. This spread to new flowers continues pathogen population increase. Even though the role and lasting of high relative air humidity (RH 85% and above) in pathogen development and infection onset is weakly investigated, it seems that it significantly contributes to the development of unprecedented fire blight epidemics. With moisture in the form of rain, dew or hail, and probably the RH of 90% or higher, pathogen is washed down into the nectar glands and infects the flowers.

Figure 2. Blossom blight on flower cluster with apple shoot declining from internal infection spreading (Photo by Aćimović S. G., 2016)

During the infection incubation, i.e. before the blossom blight symptoms are visible, small white to yellow or orange droplets of bacterial ooze are exuded from infected green flower parts. If moisture is available and insect activity is high, this ooze is spread from flowers to other rattail flowers and actively growing green shoots across the whole orchard. Since symptoms are not visible yet, this is a recipe for successful outbreak and an epidemic, if the antibiotic spray/s were not applied during bloom and guided by the outputs of fire blight prediction models (NEWA's EIP, Maryblyt, RIMpro, Cougarblight). Blossom blight is visible as dead, black or brown flower clusters looking like fire burned them, often with more orange droplets of bacterial ooze exuding and dripping from the calyx, receptacle, or the flower pedicels (Fig. 2). Shoot blight infections are visible as black or brown strikes, like fire burned them and the typical fire blight sign of shepherd's crook on the shoot tip (Fig. 3). Fire blight cankers on woody tissues are usually formed from the established blossom and shoot blight infections, through disease progress form the succulent, current year tissues into the perennial tissue (Fig. 4). However, it can also form around a pruning cut when pruning tool is contaminated with the fire blight bacteria (Fig. 4).

In years when weather conditions are marginally favorable for flower infections, fire blight is often limited to low incidence blossom or shoot blight, with spotty i.e. "hot-spot" dispersal across orchards with susceptible cultivars (Fig. 3). These hot-spots are hard to find in big orchards but should be noted and recorded by tractor drivers during air-blast sprays for later removal. They usually form late in the summer when weather is warm i.e. conditions for fire blight become conducive and hidden fire blight cankers start to ooze. These hot-spots sometimes lead to a surprise shoot blight outbreak out of nowhere. The hot-spots form around the (few) trees which still hold fire blight cankers remaining on large limbs from past years when fire blight outbreak occurred. Pruning removal of infected tree parts or entire trees in these "hot-spots" usually yields good control results. However, no matter how meticulous the pruning crews are in removing cankers during the summer or winter after a major outbreak or in in these hot-spots in orchards, some cankers always remain undetected and unpruned on old branches or the trunk (Fig. 4).

Figure 3. Fire blight "hot-spot" with one tree of 'Rome' showing shoot blight and containing fire blight cankers from previous years (Photo by Aćimović S. G. 2017).

If left undetected and removed, hot-spots will enlarge in area size from year to year, encompassing more trees, especially on susceptible cultivars. Carried over into the following growing seasons, any fire blight cankers pose a constant threat as sources for infection for development of new outbreaks and regional epidemics. If infection sources are present in a form of active fire blight cankers and the weather conditions during bloom are favorable, fire blight bacteria can spread fast, develop into an epidemic and can destroy apple orchards, especially if they are younger than 8th leaf and with highly susceptible apple varieties and/or rootstocks. The most susceptible apple cultivars to fire blight are 'Gala', 'Pink Lady', 'Ginger Gold', 'Fuji', 'Idared', 'Rome', 'Jonathan', 'Jonagold', 'Mutsu', 'RubyFrost', and 'SnapDragon'. The most susceptible apple rootstocks are all M.9 clones and M.26. Due to unknown reasons, not all the overwintered fire blight cankers in the orchard are active i.e. exuding ooze with bacteria in spring. Some reports find that from all the previous-season developed cankers, only 10-12% exude ooze with bacteria and even less exude ooze during bloom period. However, this does not mean that there is less chance for infection onset during bloom, if conditions are conducive. Early literature claims that only 1-4 active cankers per 2.5 acres are enough to propel an epidemic when weather conditions favor pathogen development. In other words, if you even had a limited fire blight outbreak, anytime in the past, pathogen is

Figure 4. Fire blight canker around a pruning cut on 'Rome' apple limb with damp bacterial ooze emerging from the canker edge in the lower left corner (Photo by Aćimović S. G. 2016).

most certainly than not surviving somewhere in an undetected leftover canker(s) in the orchard over all those years. It is easy to omit cankers for removal during summer or fall pruning since some of them are small in diameter and formed deep within or high up in the canopy. In comparison to the fire blight strikes, this makes them difficult to find. Finding both strikes and cankers to remove during winter pruning is even more difficult due to absence of leaves. Hence summer pruning is a better option, when finding these is easier. At these times though, care should be taken to avoid excessive pruning which could promote renewed tree growth and thus prevent proper preparation of trees for dormancy.

Rootstock blight - the killer of trees. Rootstock infections start either via diseased root suckers or through fire blight pathogen transfer downward from the crown through the trunk xylem. Especially in young and small trees in high-density plantings, internal fire blight infections from flowers and shoots can spread via xylem into the tree trunk and then rootstock, because fruiting limbs are much shorter and thinner in comparison to thick old limbs of classic training systems. The resulting cankers on small diameter trunks and visible or latent fire blight infections of rootstock, can lead to tree death due to rootstock collapse. It is not known how important the infected rootstocks as sources of inoculum for infection renewal in spring are. It is known that infected rootstocks, with or without visible cankers, can exude fire blight ooze in the current or the following season (Fig. 5). In some cases, it is possible that when rootstock is moderately resistant to fire blight, infection might not lead to canker formation or can produce atypical symptom that is not readily associated with fire blight. Even though infected rootstocks can provide copious amounts of ooze with bacteria in spring and summer, their role in providing inoculum might depend on year-specific weather conditions and insect vector activity. Hence, their role as sources of inoculum may be less important in some years and more important in the other.

Figure 5. Rootstock blight symptoms: far left – fire blight ooze exuding from latent infection; middle – canker before and after bark shaving showing perennial xylem infection of the rootstock wood; and far right: tree collapse due to rootstock death due to fire blight infection (Photos by Aćimović S. G. and Wallis A. E. 2017).

Fire blight management. The delayed dormant spray of copper is the first pillar of fire blight management. Copper ions released from different copper products kill fire blight bacteria on plant surfaces in the spring. Copper is applied late in tree dormancy which ranges from green tip up to 1/4- to 1/2-inch green bud stage, if the pesticide label permits. The goals of copper spray are to reduce fire blight bacteria emerging from overwintered cankers on the tree surface, provide enough copper residue on tree surface to last until bacteria emerge from cankers with warm weather, and avoid phytotoxic effects of copper on green tissue and the base of the flower buds that will develop into fruit. The second pillar of fire blight management is reduction of bacterial inoculum by pruning. Fire blight cankers on trunk and branches are the main places where viable bacterial ooze or colonies emerge in spring to enable flower infections (Fig. 4). Removing cankers, as the main sources of disease for flower infections, can significantly reduce the chance for fire blight outbreaks in the future. Some cankers always remain unpruned on branches or the the trunk. Carried over into the future growing seasons, cankers pose a constant threat for development of new epidemics.

The most important period for fire blight management starts from when the first flower opens in the orchard and ends when the last terminal buds set on shoots. Terminal bud set is a growth stage when the current year vegetative growth stops, and a bud is formed at the end of the shoot. Terminal bud set usually occurs during July varying somewhat among different apple cultivars. Once terminal bud set is done, there is reduced danger of fire blight infections unless hail injury occurs on a tree providing new entry points for infection. Majority of spray recommendations with antibiotics (streptomycin, kasugamycin) are for bloom period because if you spray protective materials at the right time and blossom blight control is good, there will be minimal chance for infections of shoots. This is true unless you had a history of fire blight in the orchard and some hidden cankers are present in the orchard. Cankers can serve as inoculum sources during summer for unexpected shoot infections. Hence, shoot blight management might be needed in these orchards (Apogee, low-rate copper sprays). Antibiotics for management of fire blight during bloom should be applied only when fire blight prediction models like NEWA's EIP, Maryblyt, RIMpro, of Cougarblight indicate there will be/was an infection event. Take into account the periods of ≥85% relative air humidity on top of the predictions reported by these models. If the risk for fire blight infection is high or extreme, treat the predicted ≥85% relative air humidity period(s) the same as a rain event(s) that is/are predicted by model to trigger infection. Apply streptomycin plus Regulaid surfactant just before or within 24 h after the rain event that is/was predicted to trigger the infection. After bloom is over, to avoid antibiotic-resistance development in pathogen populations, antibiotics should not be used during summer unless a hail-storm event occurs, when spray should be done just before or 24 h after the hail. To prevent shoot blight in orchards with fire blight history, use Apogee starting at 1-3" shoot growth stage (late bloom). Do not apply Apogee in Empire. Total of three applications at mid- to high-rate are needed, each 14-21 days apart. Apogee reduces shoot growth and thickens cell walls thus reducing their susceptibility to fire blight infections. In addition, low-rate copper sprays of up to 2-3 oz of metallic copper equivalent can reduce surface fire blight populations and prevent new infections on uninfected shoots (avoid applying at slow drying conditions to prevent fruit russet).

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