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CONTROL OF INSECTS AND MITES ON TRUNKS: IMPLICATIONS OF SPRAYER TYPE AND TECHNOLOGY FOR HIGH-COVERAGE APPLICATIONS

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Introduction

In the publication, "Using Smart Apply Variable-Rate Technology to Improve Air-Assisted 'Air-blast' Sprayer Pesticide Application Efficiency in Nurseries and Orchard Crops," we examined air-assisted sprayers and explored the advantages sprayers equipped with variable-rate spray technology offer over conventional air-blast sprayers. Variable-rate sprayers emit significantly less pesticide and provide a more targeted application with less off-target drift than conventional sprayers. In experiments conducted in several nursery production systems and orchards in Tennessee and across the US, these sprayers controlled a variety of foliar insects, mites and diseases as effectively as conventional sprayers. Variable-rate technology provides additional economic benefits to growers by reducing both the labor associated with spraying as well as the fuel required to spray crops. In our earlier publication, we report research by Manandhar (2018) who calculated that a 200-acre field nursery using this technology could save $406-$504 per acre due to reduced pesticide use, fuel use and labor costs.

Arthropods include insects, spiders, mites, and crustaceans

While foliar pests are a major concern for Tennessee nursery owners, there are many nursery pests that inhabit or damage tree trunks. Using a contact insecticide to control pests on tree trunks traditionally involves either multiple sprays with an air-blast sprayer, which is imprecise and wasteful, or manual applications using a spray gun or a backpack sprayer, which is a more precise but labor-intensive process. Research is ongoing with the goal of determining the effectiveness of using variable-rate spray technology to make high-coverage applications of contact insecticides to tree trunks for the treatment of trunk boring insects and arthropods that overwinter on tree trunks. The purpose of this publication is to educate growers and Extension personnel about 1) the implications of trunk damage and common trunk pests encountered in nurseries in Tennessee and surrounding states, 2) the methods used to prevent and control trunk pests, and 3) examine the opportunity that intelligent, variable-rate spray technology may have for ornamental nurseries for controlling these pests. Many of these pests infest not only the trunk but also the lower branches of a tree. For simplicity, we will just refer to the trunk throughout the publication.

Tree trunks as resources for arthropods and implications of trunk-inhabiting arthropods

Depending on the species, an arthropod may overwinter as an adult, as a single egg or in a mass of eggs on tree trunks. During the spring and summer, some arthropods may inhabit tree trunks as immature life stages or as adults. While foliar pests are common and their damage more immediately apparent due to obvious discoloration of foliage at eye level, trunk boring insects are often more cryptic and could have a more significant effect on plant health. While photosynthetically active leaf areas can be reduced by arthropod damage, this damage often has a limited impact on carbohydrate production unless trees are repeatedly defoliated. Therefore, the management goal for foliar pests is to maintain aesthetic value. In contrast, arthropods that damage the trunk may damage the **phloem** and/or the **xylem**, the tree's vasculature, greatly limiting water and nutrient movement through

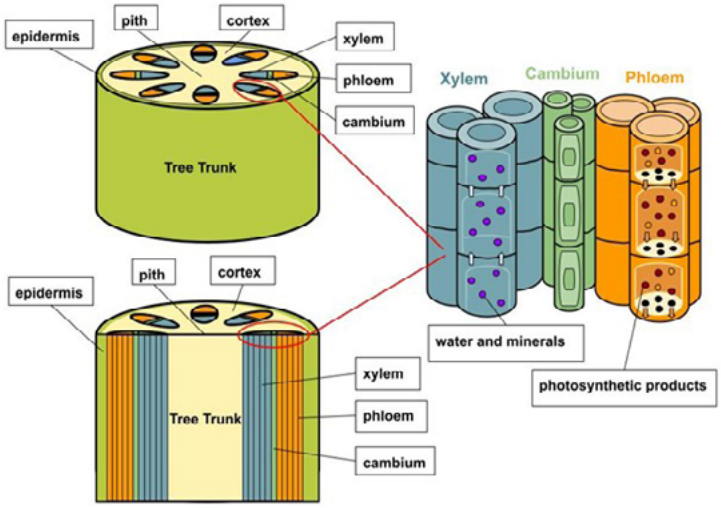


Figure 1. *The anatomy of a tree's vascular system. Graphic Credit: Karl McKim.*

the plant and often negatively impacting plant health and its structural strength (Figure 1).

Infestations of trunk-inhabiting arthropods are often treated by applying contact insecticides to tree trunks. When applying contact insecticides, it is important to fully coat tree trunks, and it is critical to appropriately time applications to effectively target pests during their vulnerable life stage(s). Some arthropods inhabit the trunk's exterior only during the egg stage, whereas others bore into trunks to feed, complete development or lay eggs. Maple spider mites (*Oligonychus aceris*), for example, are foliar pests that overwinter as small reddish-orange round eggs in bark crevices. Eggs hatch the following spring, and larvae move to the undersides of leaves where they develop and live as adults. Scale insects often inhabit trunks as adults where they feed, overwinter and lay eggs. Some mature scale insect species, such as white peach scale (*Pseudaulacaspis pentagona*), have thick, armor-like waxy layers that protect both adults and their eggs underneath. These waxy protective layers make it difficult to effectively treat infestations of these pests with contact insecticides. To be effective, contact applications must be timed against the immature crawler stage. Japanese maple scale (*Lopholeucaspis japonica*) crawlers begin forming their waxy coating just a few days after hatching, underscoring how critical it can be to monitor for pests and properly time insecticide applications. Trunk boring insects bore into the interior of tree trunks and create tunnels. Granulate ambrosia beetles (*Xylosandrus crassiusculus*), for example, are generalist pests which bore into the trunks of many tree species. These beetles lay eggs in their tunnels and inoculate tunnel walls with symbiotic fungi. Both adults and newly hatched larvae feed on these fungi. It is not uncommon to find granulate ambrosia beetles of every life stage living in a single tunnel.

Vascular System

Phloem-The layer of bark in which the compounds made in leaves during photosynthesis are transported throughout a plant. Damage to this layer can prevent the distribution of nutrients. For example, insect infestation or the girdling of a trunk by twine or wire, can damage a significant portion of a tree's phloem and slowly lead to tree death.

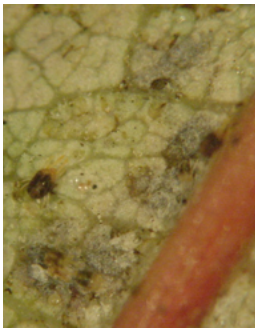
Xylem (sapwood)-Woody tissue through which water and ions move from roots to leaves. As with inadequate irrigation, damage to the xylem of a tree can cause water stress, as water is unable to move through the plant despite its presence in the root zone. Xylem damage directly or indirectly interferes with many processes including photosynthesis and transpiration. If prolonged, it can restrict tree growth, and, if severe, it can quickly lead to tree death.

As with a foliar infestation, a trunk infestation may cause unsightly damage, rendering the plant aesthetically unsalable. More importantly though, trunk infestations damage a tree's vascular system, disrupting its nutrient cycle and compromising its structure, which can lead to tree mortality. Larvae of species in the flatheaded borer (FHB) complex, for example, feed beneath the bark, creating long serpentine channels in the phloem and causing visible damage to tree trunks (Figure 2). The damage caused by a single FHB larva can girdle and kill a young tree in a single season. Because trunk boring insects inhabit the inside of tree trunks for at least some amount of time, a specialized approach is needed to effectively control them with contact insecticides. Table 1 contains images and descriptions of common Tennessee nursery pests that inhabit tree trunks at some point in their life cycle as well as common techniques and preventative measures to monitor and control each pest.

Figure 2. *Trees damaged by flatheaded borers are characterized by winding channels created by the larval stage of this insect and the resultant callous roll that develops (left). Flatheaded borer infestations can also be recognized by the flat, plate-like frass (left, center). When the frass is removed, D-shaped openings made by emerging adult are visible (right). Image credit: Amy Fulcher.*

Table 1. *Select nursery arthropod pests inhabiting trunks in Tennessee and surrounding states.*

Pest name	How to monitor to schedule application of contact insecticides – trap type and lure	Life stage that inhabits the trunk	Part of plant damaged, symptoms	Life stage, how and when to control[1]
Dogwood borer (*Synanthedon scitula*)  Image credit: James Solomon, USDA Forest Service, Bugwood.org	Suspend wing traps baited with dogwood borer pheromone 4 to 6 feet above ground. Use these traps to estimate peak flight in mid-May and again in August.	Eggs are laid on bark. Newly hatched larvae seek wounds or cuts to enter inner layers of bark where they feed and overwinter.	Larvae bore through bark on tree trunks and feed on inner cambium. Signs of infestations include loose bark, reddish brown sawdust-like frass at entrance holes and pupal casings at exit holes. Damage from dogwood borers causes leaves to turn red prematurely and can cause branch dieback.	Nematode sprays during larval stage (often in late August) and multi-year mating disruption using pheromone dispensers can be effective. Preventative trunk applications can be timed with adult emergence/flight in late-April, mid-July, early September, or as indicated by traps.
Flatheaded borer (*Chrysobothris femorata*)  Image credit: Amy Fulcher	Monitor newly infested trees for D-shaped openings beginning in February for adult emergence. Columnar purple sticky traps are thought to mimic tree trunks and can be installed in the late spring to monitor for adult emergence.	Eggs are laid in the outer layers of bark. Newly hatched larvae chew directly through bark and feed on cambium. Larvae develop in phloem and emerge as adults in the spring.	Damage occurs to inner layers of tree trunks (cambium, phloem, xylem). Symptoms include cracked, peeling bark and winding tunnels under bark containing sawdust-like boring dust and plate-like frass under which are D-shaped exit holes.	Preventative trunk applications should be timed with adult emergence/flight. Wounded or stressed trees appear to be more susceptible, including first year liners and other recently transplanted trees. Prevent moisture and other stress to young trees. Monitor trees closely if the cutback stub faces southeast or southwest as these appear to be more susceptible to adult selection for laying eggs or egg/larva survival. Consider cutback orientation when lining out susceptible crops to potentially prevent or reduce flatheaded borer infestation.
Granulate ambrosia beetle (*Xylosandrus crassiusculus*)  Image credit: Amy Fulcher	Traps can be made using two-liter bottles and baited with ethanol. Set traps in February or March to monitor for active adults.	Eggs, larvae, pupae and adults can be found inhabiting tunnels under bark.	Damage to xylem vessels results in leaf wilt, branch and trunk dieback. Look for toothpick-like protrusions of sawdust-like frass on the trunks of infected trees.	Preventative trunk applications of pyrethroids timed with adult activity in traps can be effective. Prune out heavily infested branches and remove heavily infested trees several weeks after attack to minimize damage to healthy trees.

Japanese maple scale (*Lopholeucaspis japonica*)  Image credit: Mollie Wyatt	Monitor for crawlers using petroleum jelly-coated electrical tape wrapped around infested limbs beginning in May.	Eggs, larvae and adults inhabit trunk and branches.	Destruction of plant cells results in branch dieback, leaf yellowing and loss.	Conserve and promote natural predators such as lady beetles, lacewings and parasitic wasps. Dormant oil treatments in the winter and horticultural oils or systemic or insect growth-regulator (IGR) insecticides should be applied during nymphal or crawler stage.
Lesser peachtree borer (*Synanthedon pictipes*)  Image credit: Carroll E. Younce, USDA Agricultural Research Service, Bugwood.org	Red paper or plastic delta traps or wing traps baited with species specific pheromone lures should be set in early April at a height of 4-5 feet. Monitor lower branches and trunk for frass and sap.	Eggs are laid in cracks near wounds in the bark between ground level and eight feet high. Larvae burrow under bark and feed on cambium layer inside trunks and lower branches.	Damages cambium layer of lower trunk and limbs. Frass resembles coarse sawdust and when mixed with sap can appear as soft, sticky, brown gum on trunks and infested limbs. Leaf wilt and branch dieback can occur in mid-to-late-summer.	Make preventative trunk applications before egg hatch approximately 7 to 14 days after adult emergence/flight between May and September. Treat the trunk and lower limb scaffold of ornamental trees and shrubs. Multi-year mating disruption using pheromone dispensers can be effective.
Lilac Borer (*Podosesia syringae*)  Image credit: James Solomon, USDA Forest Service, Bugwood.org	Wing traps baited with lilac borer pheromone lures to monitor adult activity should be set in mid-April.	Eggs are laid on bark. Larvae feed under bark on phloem and outer sapwood as well as the cambium and overwinter in tunnels created in trunks and large limbs.	Damage to phloem, results in branch dieback and leaf wilt.	Apply preventive sprays before larvae chew into bark typically in early to mid-May. Nematode sprays on gallery entrances can help control larvae. Prune out infected branches and destroy clippings before emergence.
Maple spider mite (*Oligonychus aceris*)  Image credit: Paul Bachi and Amy Fulcher	Scout wrinkled bark in the branch collar for brick-red eggs in the winter and for hatched eggs (clear) early in the season.	Eggs and adults overwinter in bark crevices, adults inhabit the underside of leaves.	Foliar damage includes stippling on leaves and leads to premature leaf drop.	Choose less susceptible maple cultivars. Dormant oil sprays in the winter and horticultural oil applied during the larval stage can be effective. In some studies, repeated use of broad-spectrum insecticide sprays for other pests have doubled maple spider mite populations.

Peachtree borer (*Synanthedon exitiosa*)  Image credit: Wendell Snow, USDA Agricultural Research Service, Bugwood.org	Red paper or plastic delta traps or wing traps baited with species specific pheromone lures should be set in early April. Monitor lower trunk and large exposed roots for frass and sap between ground level and 6 inches high.	Eggs are laid around trunk base. Larvae feed on cambium under bark at the base of tree trunks and on larger roots 0-6 inches from the ground.	Damage is inflicted to cambium layer on lower trunk and large roots. Look for wet spots on bark. Frass resembles coarse sawdust and when mixed with sap, it can appear as soft sticky, brown gum around tree base. Branch dieback and leaf wilt can occur in mid to late summer.	Apply preventative trunk applications timed with adult emergence and flight in late-May and in mid-July. Treat any exposed roots, the trunk and lower limb scaffold of ornamental trees and shrubs. Multi-year mating disruption using pheromone dispensers can be effective.
White peach scale (*Pseudaulacaspis pentagona*)  Image credit: Frank Hale	Monitor for crawlers using double-sided tape or electrical tape coated with petroleum jelly wrapped above infested areas in early-May, late July-August and early-September.	Eggs, larvae and adults inhabit trunks and branches.	Infestations occur on trunks and woody branches. Symptoms include leaf yellowing and dieback and tree death.	Conserve and promote natural predators such as lady beetles, lacewings and parasitic wasps. Dormant oils applied over the winter as well as horticultural oil and insecticide applications timed for crawler or nymphal stage can be effective. Heavy pruning of infected branches can help reduce infestations.

[1]For more information on resistant and susceptible cultivars, please see "Scouting and monitoring pests of deciduous trees during nursery production" in the additional resources and literature cited section.

Approaches to trunk applications

To protect trees and treat current infestations, many growers spray conventional insecticides or horticultural oils several times a year. Unlike with foliar pests, it is assumed that complete coverage of the trunk with a contact insecticide is necessary to control many arthropod pests; however, this has not been tested and likely varies across pest species. Applications of contact insecticides often involve either manually spraying trunks with spray guns or backpack sprayers equipped with a wand or making calendar-based sprays with a broad-spectrum insecticide several times a year using an air-blast sprayer. Spraying trunks with conventional air-blast sprayers is an indiscriminate process that can result in off-target spray landing in unintended areas in tree canopies, on the ground within production blocks and in air and soil outside the intended spray zone. Additionally, using broad-spectrum insecticides can affect numerous non-target organisms such as beneficial insects or human beings. Studies have shown that applying insecticides to tree trunks with an air-blast sprayer requires considerably less labor than manual trunk applications. However, manual applications consistently achieve high coverage (>95 percent) use less insecticide than air-blast sprayers and reduce drift to off-target areas (Frank and Sadof 2011).

Spraying with an air-blast sprayer reduces labor costs as it is faster than manual applications, but when done on a calendar or repetitive basis has environmental costs that can be difficult to quantify and can reduce the effectiveness and efficiency of a grower's pest management program. While intended to control a variety of pests,

Manual vs. mechanized application

In a study conducted at two container nurseries in North Carolina, researchers compared the effectiveness and efficiency of using an air-blast sprayer and manual backpack sprayers to prevent granulate ambrosia beetles. When using a battery-operated backpack sprayer equipped with two full-cone spray nozzles angled to coat tree trunks in a single pass, the **manual application of contact insecticides emitted five-fold less insecticide than application with an air-bast sprayer yet required 12 times more labor**. Additionally, there was less **off-target insecticide movement into areas** such as tree canopies with the backpack sprayer, which led to **50 percent more natural enemies and 50 percent fewer spider mites** in blocks treated with the manual sprayer versus those treated with the air-blast sprayer (Frank and Sadof 2011).

calendar sprays of broad-spectrum insecticides can harm non-target beneficial arthropod species. Beneficial insects often feed on or parasitize nursery pests, keeping pest populations at such a low level that the pests do not impact crop quality or health. The unintended elimination of beneficial insects through calendar spraying (Figure 3) allows pest populations to increase in the absence of natural enemies, often leading to secondary outbreaks of pests which the grower may not have known were present in the nursery due to the control provided by beneficial insects. This results in increased labor and insecticide use, as the grower must treat each new outbreak (Raupp 2001).

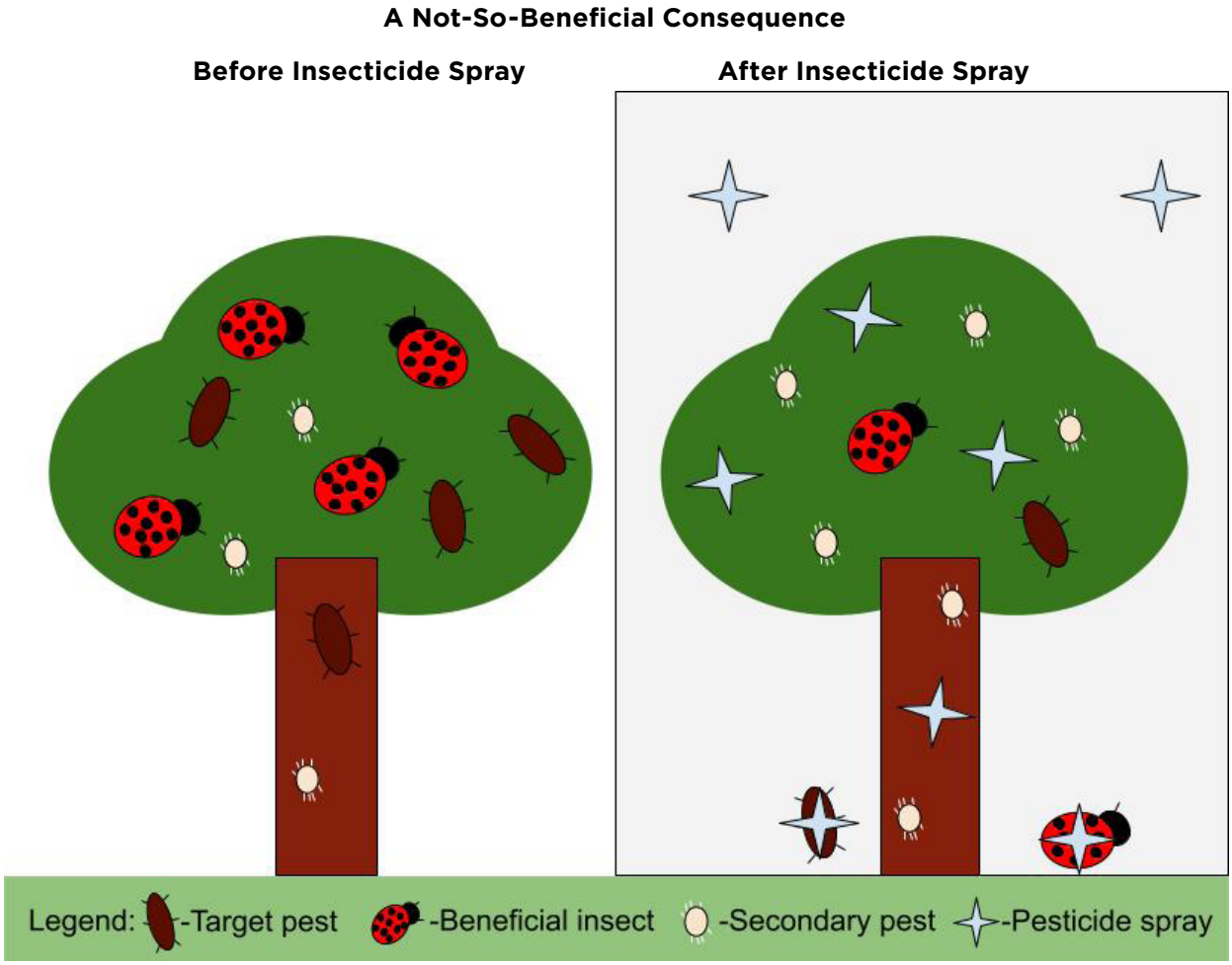


Figure 3. *Secondary outbreaks may occur after calendar spraying with a broad-spectrum insecticide as populations of beneficial insects, such as lady beetles, can be unintentionally reduced by these sprays (left). The absence of natural predators allows pest populations to increase and can lead to outbreaks of pests previously controlled by their natural enemies (right). Graphic credit: Karl McKim.*

Spray Adjuvants

Many arthropods and plants have waxy surfaces which naturally repel water, making it difficult to achieve complete coverage when applying insecticides. Because insecticides are dissolved in water, an adjuvant is often added to insecticide solutions to overcome this interaction and aid in adhesion and absorption. **Adjuvants** are spray-tank additives that alter the physical properties of the liquid in the tank. Adjuvants can increase a liquid's dispersal, adhesion, and emulsification, thereby, influencing the performance of applied pesticides. For instance, the applied volume of a selected herbicide can be reduced up to five-fold when the appropriate adjuvant is selected in a tank mix (Tu and Randall 2003). Additionally, the absorption of a fungicide (azoxystrobin; Gent et al. 2003) or the residuality of some insecticides (chlorpyrifos and cyhalothrin; Abdelgaleil et al. 2015) can be increased with the use of selected adjuvants.

Surfactants are the most common type of adjuvant used in the horticultural industry. Surfactants reduce the surface tension of spray droplets, allowing them to better adhere to and spread across surfaces (Figure 4). This increases coverage on plants and can lead to higher absorption of the spray solution. **Penetrants** allow pesticides to enter the spaces between epidermal cells, whereas, **stickers** can increase a pesticide solution's adhesion to the trunk surface and improve residuality.

Adjuvants may also play a role in the treatment and control of trunk-dwelling pests by increasing the residual efficacy of insecticides, making their applications longer-lasting, and thereby increasing the likelihood that pests come into contact with residue. However, there is limited research on how the performance of specific insecticides is influenced by the addition of adjuvants when controlling trunk-dwelling pests. Control of emerald ash borer (McCullough et al. 2011) and shot hole borers (Eatough et al. 2018) was not improved by the addition of an adjuvant, while research on the addition of adjuvants to pyrethroids to prevent granulate ambrosia beetle is ongoing (Del-Pozo, unpublished data). Additionally, many labels suggest that complete coverage with contact insecticides is required to successfully prevent or control arthropod pests inhabiting tree trunks. Even with sufficient coverage, some pests will have limited opportunity for exposure to insecticide residue due to their life cycle, making timing equally important. When using adjuvants, be sure to follow all instructions on product labels, as using the wrong additive or spraying at too high of a rate can damage plants.

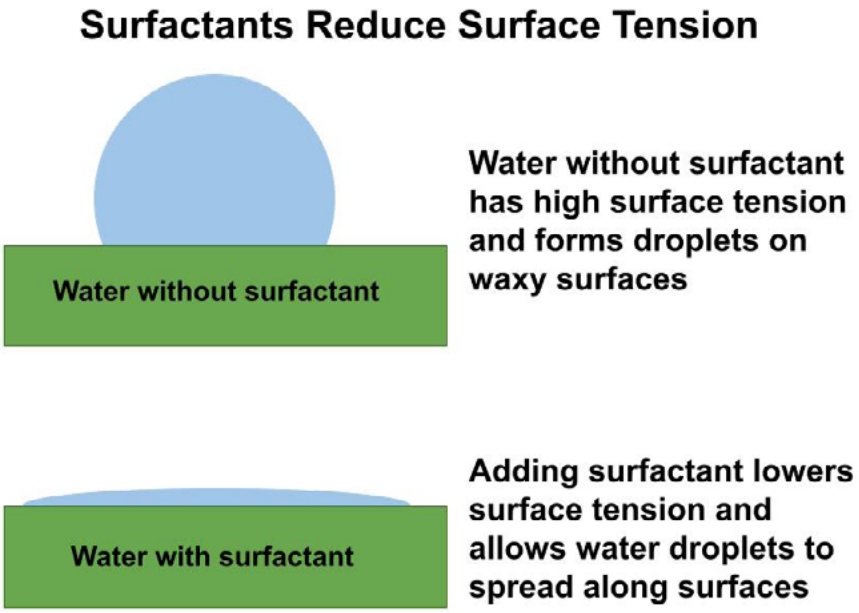


Figure 4. *Surfactants reduce surface tension and allow water droplets to spread out and cover more leaf area surface. Figure adapted from Czarnota and Thomas (2013). Graphic credit: Karl McKim.*

Implications of the use of variable-rate technology to control pests of tree trunks

Carefully timed applications of contact insecticides made with variable-rate spray technology could provide nursery operators with a labor-saving alternative to manual application with spray guns and backpack sprayers and a more product-efficient, environmentally conscious alternative to calendar sprays made with a conventional, constant-rate air-blast sprayer. Variable-rate technology reduced the volume of applied pesticide by 59 to 83 percent at a commercial apple orchard (Fessler et al. 2020) and by 43 to 50 percent at multiple nurseries representing multi-row field and pot-in-pot blocks (Chen et al. 2019; Fessler et al. 2023).

Compared to conventional air-assisted sprayers, sprayers equipped with variable-rate technology (e.g. Smart Apply), (Indianapolis, IN), may allow growers to save money on chemicals, fuel and labor and reduce the likelihood of exposing the applicator to pesticides while maintaining the same level of protection from pests. Smart Apply technology features an on and off delay that modestly increases the target dimensions, which could be useful for narrow trunk applications (Figure 5). Studies that examine the differences between applications made to the trunks of trees using a sprayer operating in conventional, constant-rate mode, the same sprayer using experimental, variable-rate technology and a manual backpack sprayer have been conducted on field-grown maple trees. These studies showed that variable-rate technology reduced the volume of applied pesticide by 30 percent to approximately 21 fl oz per tree. Manual applications reduced this volume by 49 percent (15 fl oz per tree) while generally achieving high levels of coverage (Fessler et al., unpublished data). The ability to use variable-rate technology to treat both canopies as well as trunks could increase the rate of return on a producer's investment and further demonstrate the versatility of variable-rate sprayers. Research is ongoing at the University of Tennessee with the goal of determining the viability of using this technology for trunk applications in nursery production.

Figure 5. *Red dots represent spray application to trunks from variable-rate (left), variable-rate using on/off delay (center), and the same sprayer in constant-rate mode (right). Graphic and Image credit: Karl McKim and Amy Fulcher.*

Conclusions

Nursery crops can be affected by many pests. Foliar pests can affect the salability of crops by feeding on, and thus, damaging leaves. Though primarily aesthetic, damage such as leaf discoloration or visible chewing damage can negatively affect the ability to market a crop. Trunk-dwelling arthropods and trunk boring insects also pose a significant threat to not only the appearance of nursery crops but their health, and treating infestations can be costly and time-consuming for growers. Targeting the trunk with manual applications of contact insecticides requires many hours of labor, while calendar spraying with broad-spectrum insecticides can lead to secondary outbreaks of other pests in the absence of their natural enemies and still may not achieve the coverage needed to provide control of the intended pest. Variable-rate sprayers could offer growers another option for controlling trunk-dwelling arthropods. Variable-rate spray technology has been successful in the control of foliar pests, and research is ongoing to determine the effectiveness of this technology for the application of contact insecticides to tree trunks. Regardless of application method, adjuvants (e.g., stickers or penetrants) can be an important part of successfully using insecticides for trunk-inhabiting pests. A nursery's profitability is greatly influenced by the health and quality of the plants produced; thus, it is critical to prevent damage from trunk pests during production by implementing pest-specific management strategies.

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