GROWING KNOWLEDGE

Series content is coordinated by Dr. Lloyd Nackley, associate professor of nursery production and greenhouse management at Oregon State University in Corvallis, Oregon.

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View from the tractor seat looking down a row of maple trees in a field-grown tree nursery. The rearview mirror reflects an orange air blast sprayer equipped with the Intelligent Spray System (ISS), which is being towed by the tractor. This setup highlights the integration of advanced spray technology in a practical field application. PHOTO BY LLOYD NACKLEY

Precision in pest control

Researchers evaluate trunk spray effectiveness of air-blast sprayers with sensors to target Pacific flatheaded borer

BY LLOYD NACKLEY, BRENT WARNEKE, AND JAY PSCHEIDT

In the evolving landscape of agricultural technology, sensor-controlled air-blast sprayers have emerged as a significant innovation. These advanced systems utilize sensors to enhance the precision and efficiency of pesticide and fertilizer applications, offering a promising solution to many challenges faced by modern farmers.

Intelligent Sprayer project history

The Intelligent Sprayer project was initiated in 2009 by agricultural engineer Dr. Heping Zhu (USDA-ARS). Dr. Zhu's team designed and tested prototypes and concept models of the Intelligent Spray System, with the primary objective of developing two advanced and affordable spray systems.

These systems aim to continuously match operating parameters to crop characteristics, insect/disease pressures, and microclimatic conditions during pesticide applications. In collaboration with Robin Rosetta, former Oregon State University nursery IPM specialist, the USDA and Oregon State University have been collaborating with Oregon Association of Nurseries growers over these past 15 years to refine and improve the sprayer systems (**TinyURL.com/OSUSprayers**).

The project's advanced sprayers include several key modules: (a) a data acquisition and control unit with laser scanning sensors to characterize crop shape, canopy density, and plant volume; (b) an expert subsystem that considers real-time microclimatic conditions and pest prediction models; (c) an off-target recovery unit to trap non-target sprays; (d) a direct in-line injection unit to eliminate leftover disposal problems; and (e) an air-assisted spraying system with multi-jet nozzles for tree crops and hydraulic boom spraying systems for other plants.

While the new spray systems may be more expensive than conventional ones, the increased efficiency and more than 50% reduction in pesticide use can offset the initial investment, providing significant cost savings and reducing environmental risks.

Following successful demonstrations, the focus shifted to developing Intelligent Spray System retrofit kits that can be added to any sprayer designed for specialty crops (**TinyURL.com/OSUSprayRetro**). These kits have been installed across the the country, with researchers in various states using them to manage pests and diseases in region-specific crops. Cooperating universities — including Washington State University, the University of California, the University of Tennessee, Texas A&M, and Clemson University — have implemented these systems in crops such as wine grapes, pecans, apples, hazelnuts, berries, peaches, and nurseries. The recent commercialization of the Intelligent Spray System allows it to be purchased by the public, further expanding its accessibility and impact (**TinyURL.com/OSUComSpray**).

Close-up view of the base of maple trees in a field-grown nursery, focusing on the stubbing and grafting wounds at the base of the trunks. These wounds are preferred locations for Pacific flatheaded borer (PFB) infestation, making them critical targets for trunk spray applications. PHOTO BY LLOYD NACKLEY

Sensor technologies: the basics

Sensor-controlled sprayers integrate various sensor types to optimize spray applications. At the core of these systems are ultrasonic and LiDAR (light detection and ranging) sensors, which help detect the presence and density of plant canopies.

Ultrasonic sensors, known for their affordability and effectiveness, measure the distance to objects by emitting sound waves and timing their return. This data allows the sprayer to adjust its output based on the canopy's thickness, ensuring that plants receive the appropriate amount of spray.

LiDAR sensors, although more costly, offer superior accuracy by using laser beams to create detailed three-dimensional maps of the canopy. These maps provide precise information about the shape and size of each plant, enabling even more accurate spray targeting. The ability of these sensors to differentiate between plant material and gaps in the canopy helps reduce chemical use and prevents overspray, contributing to both cost savings and environmental protection.

Recent research trunk sprays

In the Pacific Northwest, particularly Oregon's Willamette Valley, the Pacific flat-headed borer (PFB) (*Chrysobothris mali*) has become a growing concern for nursery and orchard growers. This pest is particularly problematic in hazelnut orchards, where young trees, which are most vulnerable to PFB damage, are increasingly planted. As hazelnut acreage expands, often in areas with challenging growing conditions, PFB infestations have become more common. Infected trees can suffer severe damage, including up to 35% tree loss in some cases.

The problem is exacerbated by the changing climate, with warmer summers and excessive winter rainfall stressing young trees. This stress makes them more susceptible to PFB attacks. Traditionally, hazelnut orchards were not irrigated, but with increasing summer temperatures, irrigation has become more important. However, poorly drained soils during the winter can also stress trees.

To combat PFB, trunk sprays using air-blast sprayers have been proposed as a cost-effective solution. However, conventional sprayers can waste large amounts of pesticide, especially in young orchards where trees are widely spaced. Sensor-controlled sprayers, like the Intelligent Spray System (ISS), offer a solution by applying pesticide only when the tree is directly in line with the sprayer nozzles. This precision can significantly reduce pesticide use and waste.

Recent research has focused on enhancing trunk coverage with sensor-controlled air-blast sprayers, aiming to address the common challenge of uneven pesticide application in orchards.

Trunk coverage trials

Hazelnut Orchard Trial: In this trial, conducted in Corvallis, Oregon, the effectiveness of the sensor-controlled sprayer was evaluated on four-year-old Jefferson hazelnut trees. Using water as the spray mixture, the trial featured individual plots of six trees each, arranged with three trees

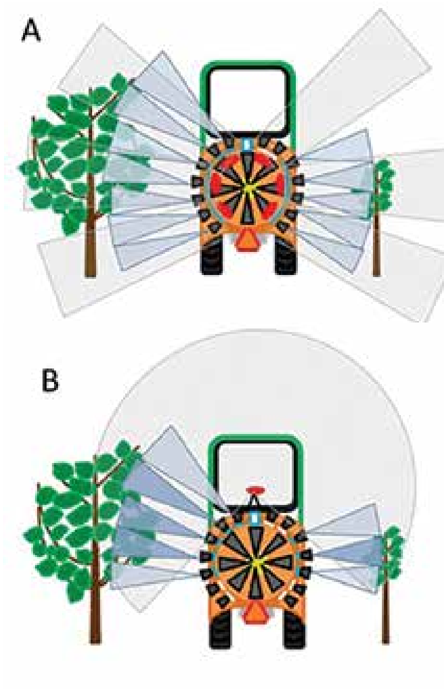

Illustration of on/off sensor sprayers (A) and canopy adapting sensor sprayers (B). Sensors are illustrated with red ovals and sensor field of view illustrated grey shaded washes. FIGURES COURTESYH OF BRENT WARNEKE

in one row and three in an adjacent row. Water-sensitive cards were strategically placed to measure spray coverage:

Trunk Cards: Positioned 6 inches off the ground on the trunks.

PVC Low Cards: Placed 6 inches off the ground on PVC tubes.

PVC High Cards: Positioned 30 inches off the ground on PVC tubes.

Ground Cards: Staked into the ground.

The study tested speeds of 1.9 mph, 3.2 mph, and 6.7 in intelligent mode, and 3.2 mph (5.1 kph) in standard mode as a reference. The trial was randomized with four replications.

Maple Tree Nursery Trial: This trial, conducted at a commercial nursery in Clackamas County, Oregon, assessed spray coverage on *Acer × freemanii* 'Jeffersred' (Autumn Blaze) maples. A 120-gal tower air-blast sprayer, retrofitted with the Intelligent Spray System, was used. The application was conducted with water and the study was organized as a completely randomized design with four replicates. Treatments included:

Speeds: 2 mph, 3 mph, and 4 mph

Modes: Standard spray mode and intelligent spray mode.

Cards were placed on trunks 12 inches off the ground, with two cards per trunk oriented perpendicular to each other.

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Pros and cons of sensors used in sensor-based spraying systems

Sensor type	Measurement method	Pros	Cons
Infrared	Detection of infrared waves emitted or reflected from plants.	Little impact of temperature and humidity on sensing accuracy. Low cost.	Sensing ability impacted by red light intensity and driving speed. Narrow field of view and short sensing distance. Unable to determine plant structure characteristics.
Ultrasonic	Measurement of the distance to objects using sound waves. Uses time of flight concept.	Ability to determine plant structure characteristics. Relatively easy to implement.	Limited resolution of plant structure. Need multiple sensors to detect plant structure.
Plant fluorescense	Detection of near infrared fluorescence from green plant surfaces.	Ability to determine plant structure characteristics. Rapid data acquisition.	Need multiple sensors to detect plant structure. Sensors affected by background lighting, requiring frequent calibration.
LiDAR	Measurement of the distance to objects using laser beams. Uses time of flight concept.	Rich data acquisition capability. Fine resolution of plant structure. High speed of measurement.	Data acquisition affected by tractor bouncing which requires correction. Delicate moving parts inside sensor.

Additional cards were placed on the ground to detect off-target spray. After application, cards were analyzed for percent coverage and droplet density using DepositScan.

These trials aim to optimize the precision of pesticide application, focusing on improving coverage of tree trunks and minimizing off-target waste.

Trunk coverage results

Hazelnut Orchard Trial:

Trunk Coverage: In the hazelnut trial, the best trunk coverage was observed with the sprayer traveling at 3.2 mph in standard mode and 1.9 mph (3.1 kph) in intelligent mode. These settings provided significantly better coverage compared to other speeds tested. The 6.7 mph intelligent mode showed lower coverage compared to the 3.2 mph standard mode and the 1.9 mph intelligent mode.

Ground Coverage: At ground level, the 3.2 mph standard mode resulted in the highest coverage, significantly better than all other settings. The 1.9 mph intelligent mode also provided better coverage than the 3.2 mph intelligent mode. The 6.7 mph intelligent mode showed similar coverage to the 1.9 mph intelligent and 3.2 mph intelligent settings.

PVC Low Coverage: Coverage on PVC tubes placed 6 inches off the ground improved as the speed decreased, with the highest coverage observed at 3.2 mph in standard mode. The 6.7 mph intelligent mode had significantly lower coverage than the 3.2 mph intelligent mode.

PVC High Coverage: At 30 inches off the ground, all settings resulted in low and similar coverage, less than 1%.

Pesticide Volume: The amount of pesticide applied in intelligent mode at 1.9 mph, 3.2 mph, and 6.7 mph was 75%, 84%, and 89% lower, respectively, compared to the standard mode at 3.2 mph.

Maple Tree Nursery Trial:

Trunk Coverage: Coverage was highest at 4 mph when the sprayer was facing the first row of trees in both standard and intelligent modes. However, in the second and third rows, the best coverage was achieved at 2 mph in both modes. For the second row, standard mode at 3 mph outperformed intelligent mode at 4 mph. In the third row, there were no significant differences between 3 mph and 4 mph treatments.

Deposit Density: Deposit density inversely mirrored coverage patterns. The lowest deposit densities were found at 4 mph in the first row, and at 2 mph in the second and third rows. Significant differences were found primarily between 4 mph and other speeds, with varying results in each row.

Side Coverage: Coverage on the sides of tree trunks followed similar trends as trunk coverage, with the highest average coverage occurring at 2 mph. Significant differences were noted primarily between 2 mph and 4 mph settings.

Soil Coverage: At soil level, standard mode at 3 mph had higher coverage than intelligent mode at 4 mph and standard mode at 2 mph. For deposit density, standard mode at 2 mph resulted in significantly higher deposits compared to most other settings.

These findings highlight the effectiveness of sensor-controlled sprayers in improving trunk coverage and reducing pesticide use, especially when tailored to specific application speeds and modes.

Applications and industry impact

The results from our trunk coverage trials show that the Intelligent Spray System (ISS) can effectively target trunks and may offer a more cost-efficient alternative to traditional drench treatments for controlling Pacific flatheaded borer (PFB).

PFB is a pest that affects many woody ornamental trees and hazelnuts in the Pacific Northwest. While PFB can cause serious damage, especially in young orchards, infestations are usually sporadic. Because of this, growers often use systemic insecticides that can provide long-term protection but come with high costs.

The ISS, however, can help save money by using 40%-70% less pesticide compared to standard sprayers. In our 2018 hazelnut trunk coverage trial, we found that using the ISS at various speeds resulted in significant savings — up to 84% less pesticide used compared to traditional spraying. This means that for large orchards, switching to the ISS could reduce the cost of trunk sprays, making it a more affordable option than using drenches.

Lower pesticide use not only cuts costs but also makes periodic trunk sprays a viable choice for farms that need occasional pest control without breaking the bank.

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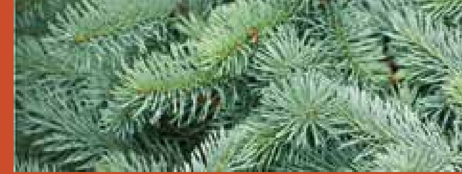
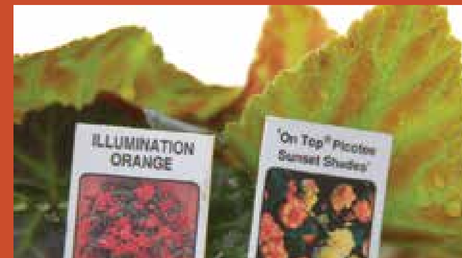

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