PennState Extension

Specialty Crop Innovations: Intelligent Spraying Systems

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Figure 1. An air blast sprayer in operation at the Fruit Research and Extension Center (FREC) orchards in Biglerville, PA. Photo: Long He, Penn State

Pennsylvania is the fourth-largest apple producing state in the country, and also produces an abundance of other tree-fruit crops including peaches, nectarines, pears, and cherries. Recent economic impact analysis of the fruit belt in Adams County by the Adams Economic Alliance revealed that the fruit industry contributed as much as $580 million to the local economy in 2016.

The success of the tree fruit industry in Pennsylvania is due to favorable geologic and climatic conditions, particularly in the Piedmont region where Adams County is located. The steep slopes of the Appalachian Mountains and rolling foothills give rise to fertile loams well-suited for agriculture, and aid with both drainage and frost protection.

This region receives, on average, over 40 inches of rain each growing season. The abundant rainfall and resulting humidity foster higher disease and insect pressures than observed in the arid fruit growing regions of the Pacific Northwest. Consequently, producers of horticultural crops rely on pesticides and other chemical inputs to control these problems and ensure a consistent, high-quality harvest.

The Problem with Existing Air Blast Sprayers

For tree fruit producers, the spraying of chemical inputs is a regular occurrence beginning before bud-break and lasting until shortly before harvest. Air blast sprayers are a common piece of orchard machinery used to apply these sprays due to their effectiveness and ease of use (Figure 1).

Unfortunately, measurements performed in orchards using conventional, constant-rate air blast sprayers have demonstrated significant chemical losses due to the indiscriminate nature of how the nebulized liquids are applied. Less than 30% of the active compounds may actually be deposited on target trees, the rest being lost to the ground or evaporative drift. Current air blast sprayers are inefficient partially because they are not able to adjust spray volumes based on individual, per-tree variations such as the growth stage, size, shape, or canopy density. Nor can these sprayers account for differences in the in-row spacing of orchard trees, which typically varies from orchard to orchard (Figure 2).

Figure 2. Examples of variation among tree canopies in fruit orchards. Photo: Long He, Penn State

In addition to the economic loss due to waste, pesticides may adversely – if inadvertently – impact non-target beneficial biocontrol organisms and pollinators, or drift to contaminate adjacent crops or habitats outside of the orchard. Reducing pesticide use for both economic and environmental reasons is a priority for all producers of intensively sprayed agricultural systems, and particularly in orchards.

The Development of Intelligent Spraying Systems

Recent innovations in computer vision and real-time spatial analysis technologies have given rise to a new branch of agricultural engineering: "intelligent" or "smart" spraying systems. The objective of all intelligent spraying technologies is to identify suitable spray targets within the row and to apply sprays only to the regions where the spray is necessary. This reduces economic losses due to non-target misapplications and the collateral environmental impact associated with current equipment.

A smart sprayer generally includes two components: a target detection system and the spraying system proper. The targeting sensor forms the foundation of the precision spraying system. The quality of the intelligent spraying system is only as good as its ability to accurately identify suitable targets and to make automated decisions about when and where to spray. Three sensor technologies commonly used in intelligent sprayer prototypes are ultrasonic sensors, digital cameras, and laser scanning sensors (Figure 3A and 3B). Each has its strengths and weaknesses.
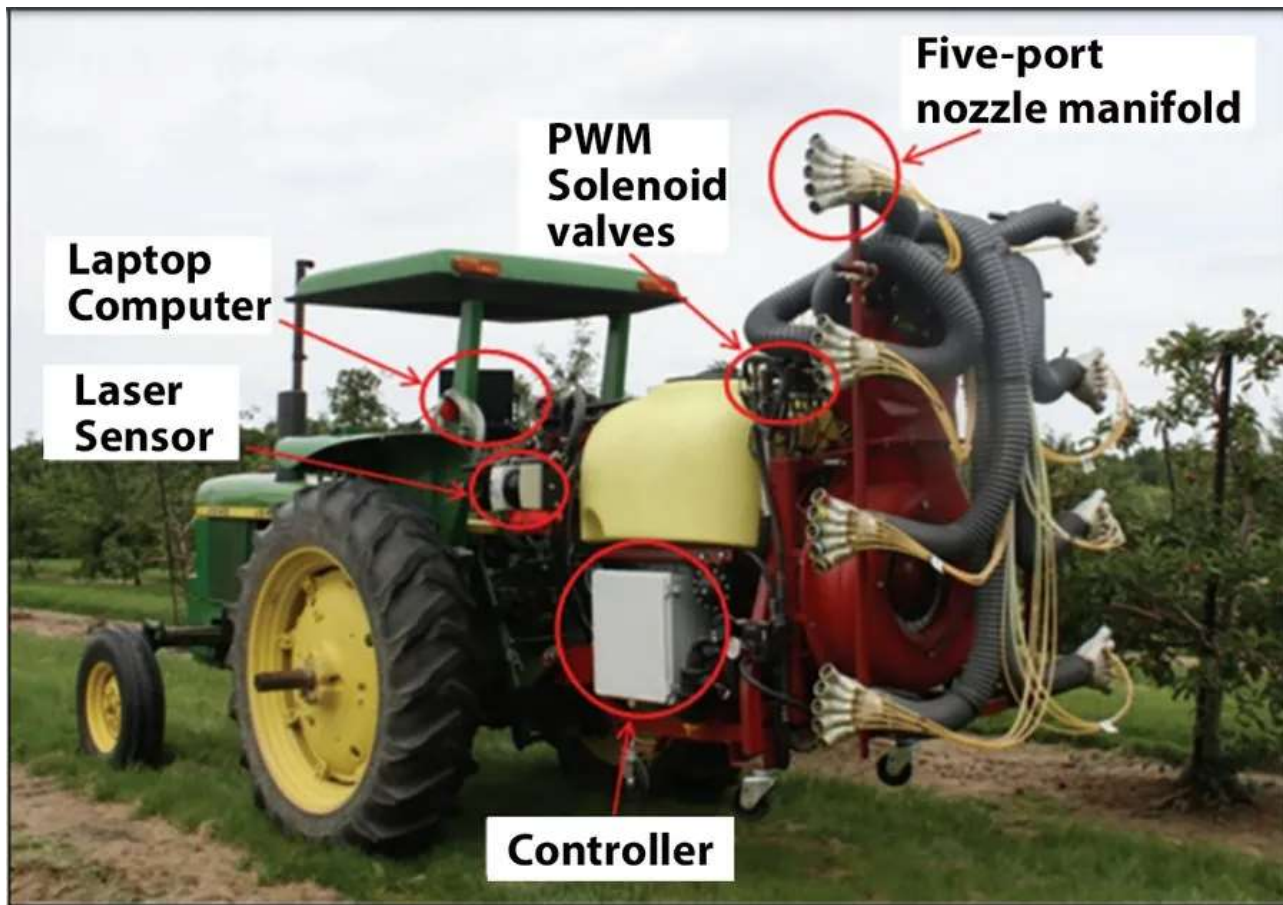
Figure 3A

Figure 3B

Figures 3A & 3B. Two of the three common sensor types: (3A) an ultrasonic sensor-based targeted spraying system (Stajnko et al., 2012), and (3B) a Lidar (Light Detection and Ranging) sensor-based intelligent spraying system (Chen, Zhu, & Ozkan, 2012).

Two of these technologies have been utilized with some limited success in the tree fruit and small fruit industries. While effective under stable conditions, the ability of ultrasonic sensors to detect tree canopy structure accurately may be negatively affected by temperature, humidity, ground speed, and detection distance (Rosell & Sanz, 2012). Reduced sensitivity to canopy structure results in increased imprecision during spray application, thereby reducing overall effectiveness. Digital cameras have been used to detect diseases on strawberry leaves and to adjust spray outputs by toggling individual nozzles on and off to maintain proper application rates (Esau et al., 2014). However, current technological limitations prevent digital cameras from providing more than two-dimensional crop surface images, and their performance is sensitive to lighting conditions.

A Newly Commercialized Intelligent Spray System

Considerable research has demonstrated that laser scanning sensors have high accuracy, are independent of environmental conditions, and can be integrated into air blast sprayer systems to achieve variable-rate applications (Liu & Zhu, 2016). The laser sensor-guided system controls the output of individual nozzles independently to match tree canopy size, shape, and leaf density. Because the base spraying system is a commercial air blast sprayer, engineers have developed a universal intelligent spray control system conversion kit which can be used to retrofit existing sprayers (Figure 4). This involves the installation of a variable flowrate nozzle kit onto the base of each original nozzle, in addition to the integration of the Lidar technology. This technology has been commercialized recently by Smart Guided Systems (LLC, n.d.).
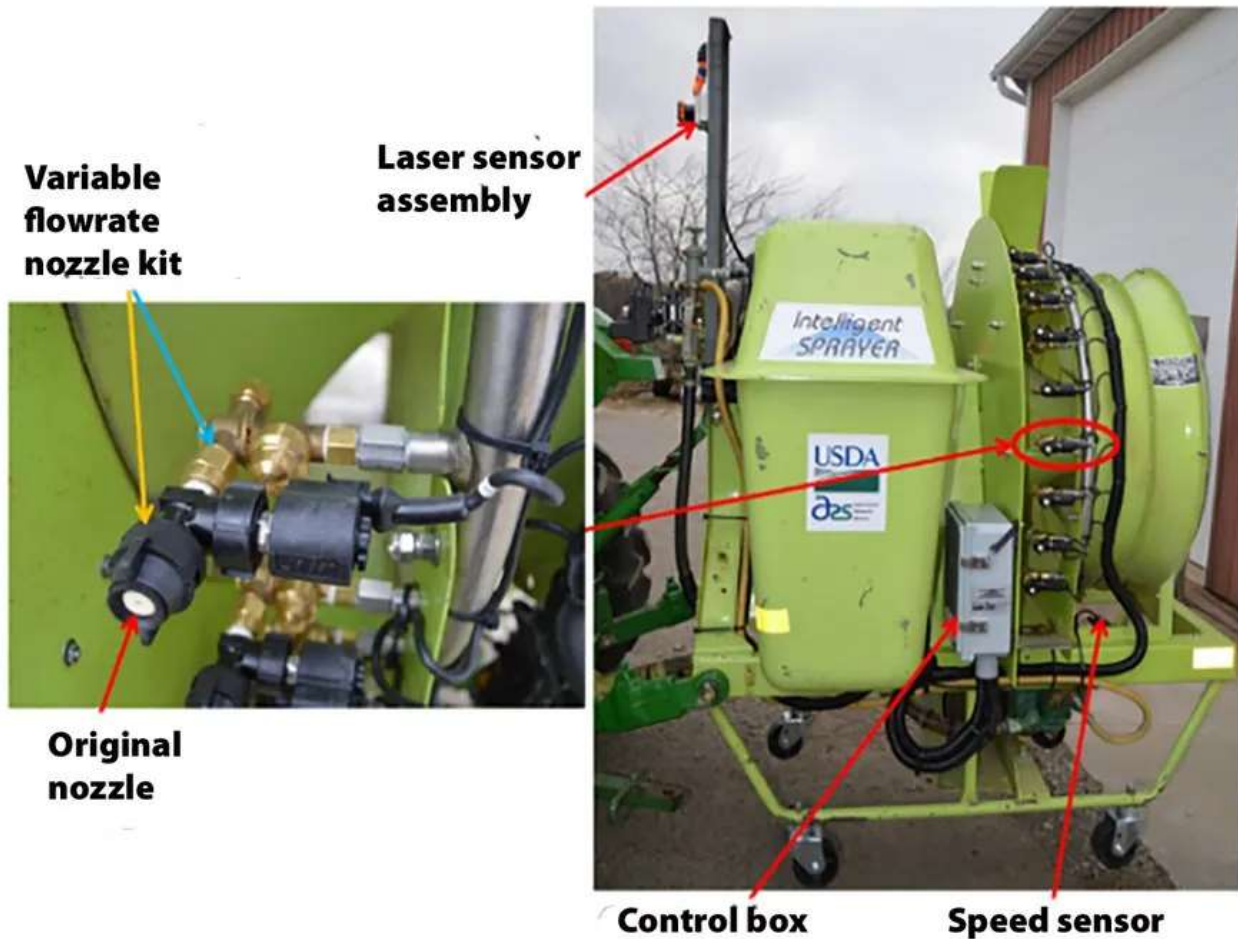
Figure 4: Components of a Lidar-based precision sprayer.

Based on research conducted by the principal engineer, Dr. Heping Zhu, laser-guided sprayers greatly minimized off-target losses. This included a 40-87% reduction in spray loss around the tree canopy, up to an 87% reduction in airborne spray drift, and a 68-93% reduction in spray loss on the ground when compared against conventional sprayers. Use of this intelligent sprayer would, therefore, reduce overall pesticide consumption by 47-70%, which equated to $140-$281 per acre in ornamental nurseries at the time of the study (Zhu, 2018).

While this intelligent spray system has been tested in different regions of the U.S., in the states of California, Ohio, Oregon, Mississippi, and Texas, it has not been tested in Pennsylvania. Due to the differences among cropping systems, terrain, pest pressures, and pest management strategies, the suitability of this technology for Pennsylvania growers remains unknown.

To remedy this situation, Penn State is hosting a brief research trial and public demonstration of this technology in July. This trial is expected to address concerns growers have about the suitability of this technology for the typical orchard terrain, weather conditions (particularly relating to appropriate spray targeting under windy conditions), row spacings, and canopy structures found in Pennsylvanian orchards. Orchards managed under similar conditions throughout the Mid-Atlantic region will benefit from this knowledge as well. Specific concerns about the hardware include the robustness of the sensor and control system, the ease of equipment operation and maintenance, and the level of difficulty in retrofitting existing air blast sprayers with the new technology.

Conclusion

Intelligent spraying technologies have made significant strides in the last decade as more powerful and robust sensing technologies have become readily available. While sensing technologies for disease and pest control have been rapidly maturing for use among many agronomic and horticultural crops, questions remain about their applicability to crops with a significant three-dimensional structure such as

tree fruit.

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