PennState Extension

Spray Based on Canopy Density Can Reduce Chemical Usage and Drift

Conventional orchard spraying systems typically spray with a fixed spraying rate, which can lead to a huge amount of agrochemical waste every year.

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LiDAR sensor data acquisition. Photo: Long He, Penn State

Introduction

Excessive use of agrochemicals also increases production costs and potentially causes serious human health hazards and environmental contamination. In response to the critical need to reduce chemical usage and enhance the apple industry's profitability, precise control of pesticide application is needed. Therefore, it is desirable to develop a variable-rate spraying system to apply agrochemicals as needed to the target trees to reduce off-target deposition of the spray droplets.

Concept of Precision Spraying

Precision spraying means applying agrochemicals to the crop with precise control over when and where sprays are applied, with the overall aim of reducing chemical usage. A precision spraying system includes a sensing unit to detect the crop, a detection algorithm to process the crop information, and a control system to adjust the nozzle flow rate, as shown in Figure 1. Normally, cameras, ultrasonic sensors, or LiDAR (Light Detection and Ranging) sensors can be used to detect the tree canopy. The canopy information measured by the sensor can then be processed by certain algorithms (mathematical and logical statements developed to provide information on the 3D environment). The output of these algorithms is the control signal to the solenoid valves to adjust the flow rate of the nozzles, especially closing the nozzle when there is no canopy. Previous studies indicated that the LiDAR sensor is an effective and efficient canopy measurement sensor for precision spraying in orchard environments.

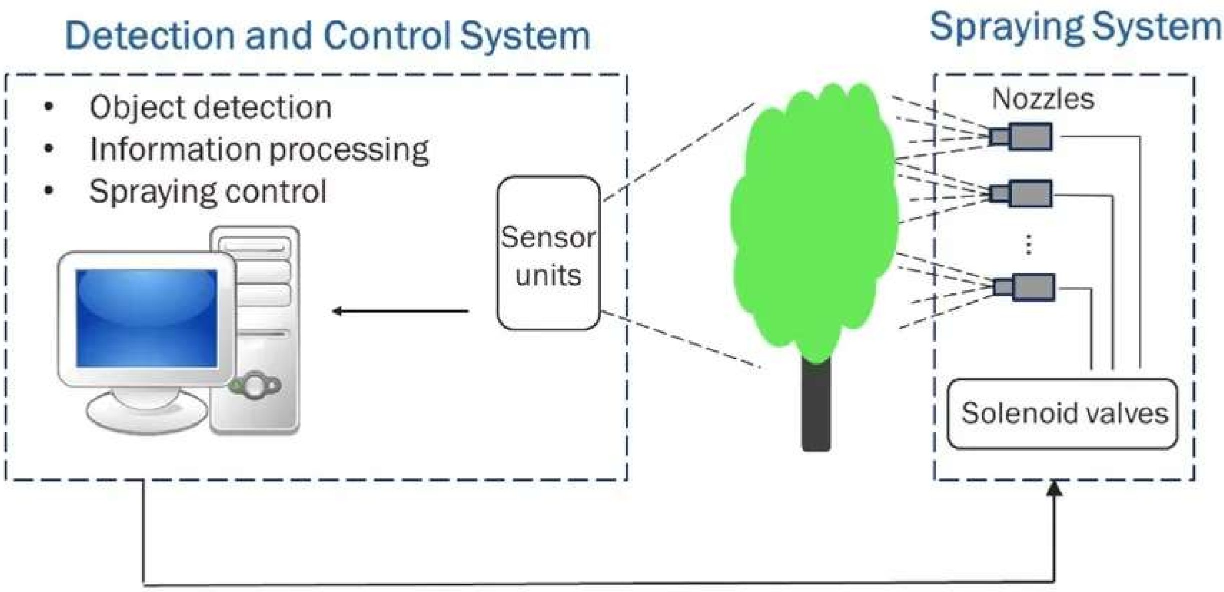

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Figure 1. Illustration of the concept of precision spraying for fruit trees. Image: Long He, Penn State

Tree Canopy Measurement Using LiDAR Sensor

Orchard spraying can be heavily affected by tree canopy structure and density. Even in planar orchard systems, trees grow differently. Quantified inputs – measurements that have numerical data associated with the spatial positioning of the tree canopy, such as the distance from the tree canopy to the spray nozzles or the density of the canopy section for the corresponding nozzles, are necessary for achieving precise control of spraying. Therefore, measuring the canopy at the individual tree level is essential. A light detection and ranging (LiDAR) sensor imaging system was developed to estimate the main canopy specifications with point cloud data, where each point represents the 3D position of where the light emitted by the LiDAR system bounced off some part of the tree canopy and was detected by the light sensor (Figure 2). An algorithm was then developed to calculate the canopy density based on the point cloud data density. A map of the canopy created from the distribution of points in the point cloud images is then used to target the emission of spray to the tree canopy and not the airspace between the branches.

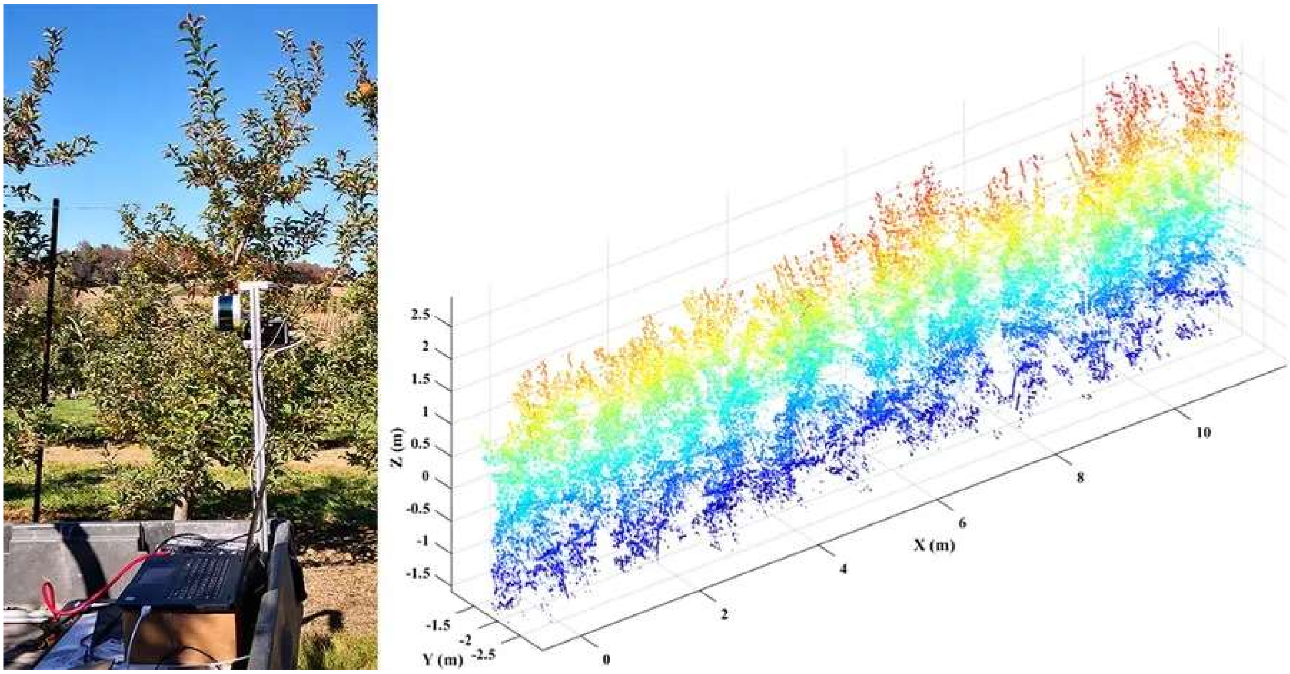

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Figure 2. LiDAR sensor data acquisition and the recorded point cloud data for apple trees. Image: Long He, Penn State

A LiDAR Sensor Guided Precision Sprayer

Figure 3 shows a LiDAR-guided precision sprayer attached to a tractor PTO with a three-hitch point. The sprayer was originally proposed by USDA ARS scientist Dr. Heping Zhu's research group, and recently it was commercialized by Smart Apply(https://smartapply.com/). The sprayer is guided with a laser sensor and can independently control individual nozzles' outputs to match tree canopy size, shape, and leaf density. It includes a universal intelligent spray control system as a retrofit for existing sprayers. A variable flow rate nozzle kit can be installed on the base of the original nozzle. A GPS is installed for recording the geo-location of the sprayer. Smart Apply's software (mobile APP) provides tools that can assist in operating the sprayer and checking and analyzing the spray reports.

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Figure 3. A LiDAR-guided precision sprayer attached to a tractor. Image: Long He, Penn State

Disease Management with the Precision Sprayer

A series of field tests were conducted in the 2021 season for apple scab control. We evaluated the potential of the precision spraying technology to reduce excessive agrochemical applications by considering tree canopy variabilities for spray application decisions. Both conventional mode and intelligent mode (precision spraying) were used in the test. (The sprayer can be switched from intelligent mode back to the conventional mode.) Additionally, a control set was used by spraying water only to compare the disease control performance with fungicides. Two apple blocks were chosen for the test (only some trees in the blocks were used for the tests); both are 'Gala,' but one block has a conventional tree structure (Orchard #1), while the other is trained for high-density production (Orchard #2). Figure 4 shows the precision sprayer operating in the apple orchards.

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Figure 4. The precision sprayer operating in the test apple orchards. Left: Orchard #1 – conventional structure. Right: Orchard #2 – High-density structure. Images: Long He, Penn State

Five sprays were applied in each orchard block during the season for apple scab control, from tight cluster through first cover. The summer cover sprays beginning at second cover included captan only. Precision spraying saved a significant amount of chemicals for both orchards: savings ranged from 30.6% to 53.6% (Table 1). At the beginning of the season, the chemical saving was higher than at the end of the season. This was due to the canopy density being lower in the early season. Therefore, the spray rate was reduced when using the precision sprayer. The planting distance and training system in use affected spray output. Orchard #1 had slightly higher savings, which can attribute to the gaps between trees.

Table 1. Field evaluation results of the precision spraying system and chemical saving.

Orchards		Orchard #1							Orchard #2						
Date		4/23	5/4	5/18	6/1	6/28	7/13	7/28	4/23	5/4	5/18	6/1	6/28	7/13	7/28
Spraying (Gallons)	Conventional	12.97	13.23	13.06	13.21	13.37	13.66	13.43	12.13	12.2	12.14	12.42	12.59	12.37	13.1
	Precision	6.02	6.19	6.87	7.49	8.45	8.34	8.53	6.10	6.17	7.24	7.56	8.74	8.86	8.81
	Saving (%)	**53.6**	**53.2**	**47.4**	**43.3**	**36.8**	**38.9**	**36.5**	**49.7**	**49.4**	**40.4**	**39.1**	**30.6**	**28.4**	**32.7**

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Apple scab control was evaluated on leaves and fruitlets in mid-June and fruit at harvest in late August. As shown in Tables 2 and 3, disease control for apple scab on leaves and fruit, both in June and at harvest, was statistically similar between the precision sprayer and the conventional sprayer. Although less chemical product by volume was being used by the precision sprayer, it did not impact scab control efficacy, especially since the disease pressure was high in the orchard, as evidenced by the water control data.

Detail results include:

1. The precision sprayer saved 30% to 50% on chemical use during the season.
2. Chemical savings were greater in the early season (less developed canopy to cover) and decreased later in the season.
3. Both precision and conventional sprayers with chemicals had less disease incidence than the control (water).

4. There was no significant difference in apple scab control between precision and conventional sprayers.
5. Spray drift (non-target deposition) was also dramatically reduced with the precision sprayer.

Table 2. Comparison of disease control between conventional and precision sprayer in orchard #1.

Treatments	Early season (mid-June)		Harvest (late August)	
	Apple scab - leaves	Apple scab - fruit	Apple scab - fruit	Ave. # of scab lesions per fruit
Precision sprayer	19.11 bc[1]	18.0 b	32 b	0.99 b
Conventional Sprayer	16.1 c	10.0 b	20 b	0.4 b
Precision sprayer with water (control)	23.9 ab	91.0 a	99 a	18.9 a
Conventional sprayer with water (control)	24.7 a	93.0 a	99 a	18.4 a

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[1]Values within columns followed by different letters are statistically different as determined by ANOVA followed by a Tukey HSD test at α = 0.05.

Table 3. Comparison of disease control between conventional and precision sprayer in orchard #2.

Treatments	Early season (mid-June)		Harvest (late August)
	Apple scab - leaves	Apple scab - fruit	Apple scab - fruit
Precision sprayer	4.7 c[1]	2.0 a	1 ab
Conventional Sprayer	9.9 ab	0.0 a	0 b
Precision sprayer with water (control)	12.6 a	3.0 a	7 ab
Conventional sprayer with water (control)	6.5 bc	10.0 a	10 a

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[1]Values within columns followed by different letters are statistically different as determined by ANOVA followed by a Tukey HSD test at α = 0.05.

Conclusion

Agrochemical application is crucial for crop production to ensure high yield and crop quality. Application with conventional air blast sprayer leads to significant chemical waste and environmental impact. Precision spraying is a solution to address this challenge by applying chemicals precisely to the tree canopy as needed. This research demonstrated that a LiDAR-guided precision sprayer was sufficient for saving chemicals while maintaining similar disease control performance expected from a conventional sprayer. Precision spraying can benefit growers immediately through significant savings via reduced chemical usage.

Further Reading

Specialty Crop Innovations: Intelligent Spraying Systems (https://extension.psu.edu/specialty-crop-innovations-intelligent-spraying-systems)

Lidar technology aims for accurate sprays.(https://www.goodfruit.com/lidar-technology-aims-for-accurate-sprays-video/) Good Fruit Grower, April 1, 2022

Acknowledgments

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