Precision Application of Pesticides in Orchards – Adjusting Liquid Flow

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This work supported in part by the New York Apple Research and Development Program

The application of pesticides has been of concern for many years, particularly methods of reducing drift and improving deposition. There are many inter-related factors which affect spray application depending upon the target, the efficacy of the spray, the attitude of the operator, the standard of management, the weather etc. The operation of the canopy sprayer often leaves much to be desired in orchards. Most growers know that there are three factors which affect application rate: forward speed, nozzle size and system pressure but often overlook the factors which help get the spray onto the target:

- airflow
- liquid flow
- forward speed
- canopy structure

Adjusting forward speed, air and liquid flow to match the growing canopy as the season progresses is the key. Knowing how much spray has been applied is very useful for farm management purposes, to ensure every row has been sprayed and also for traceability to ensure no rows are double-dosed.

We have been developing a system of real-time liquid flow adjustment based on canopy volume as a means to improve deposition and reduce drift. This paper describes our progress to date.

Canopy sensing

For vegetation detection, the sensing system is based on an array of ultrasonic sensors that are capable of detecting the tree canopy, similar to the system proposed by Solanelles and Gil in their studies (Solanelles et al., 2002; Gil et al., 2007).

For this study, one array of 6 sensors was mounted on a vertical mast with 27 inches (70cm) between the sensors to ensure no interference between the sensor signals. With this configuration the system could detect vegetation up to a height of 11.5 feet (3.5 m).

An outdoor-use and low cost ultrasonic sensor was used to sense the canopy, (model MB7052 MatBotix Inc.). To protect the electric connections a sensor body was constructed with PVC fittings and a cable connector used to protect the sensor under field conditions.

The process was controlled by a DAQ (Data Acquisition) system mounted on the sprayer; an Arduino Board (Open Source I/O Interfacing, Model Arduino Uno, Arduino, Italy) has used to control the system using software developed at Cornell University. A Global Positioning System (GPS) provided location information for the sprayer.

Liquid flow

The canopy of fruit trees changes in size and density as the growing season progresses. The amount of spray needed to adequately cover the target is often a point of discussion, but all agree that good coverage is essential and the amount of spray required varies due to many horticultural factors such as variety, trellis design and growth stage. As many orchards have different size crops, growth stages and row widths, changing liquid flow rate to match the varying parameters is very important. In order to adjust liquid flow rate for the canopy, current practice is to change tractor forward speed, adjust sprayer pressure or change nozzles. Chang-

Figure 1. Diagram of the fully automatic precision orchard sprayer.
ing forward speed is simplest but also affects air penetration. Changing pressure only has a minor effect on output so changing nozzles is the preferred method. Unfortunately changing nozzles is time-consuming, exposes the operator to potentially dangerous pesticide residues and is regarded as a chore by most operators.

The selection of the correct nozzles to ensure good coverage is essential for precision spraying if sprays are to provide effective treatment of pests and diseases. Modern nozzle catalogues contain information on spray quality to allow growers to select the correct nozzles to match label recommendations on spray quality. Air induction nozzles reduce drift considerably and provide good coverage in the canopy, (Landers and Schupp 2001). Grower experiences of air induction (a.i) nozzles, on both herbicide sprayers (flat fan a.i) and canopy sprayers (hollow cone a.i) confirm our trials.

In an attempt to automate nozzles to provide variable flow according to the tree canopy, we conducted field trials over 3 seasons in citrus trees located at Southern Gardens Citrus, Florida using a combination of Wilger COMBO-RATE® nozzles with the Capstan Synchro® system. This pulsing nozzle system allows for a wide range of continuous flow rates from the Wilger nozzle while holding the spray pressure at a constant 10 bar (150psi). A total of 20 Wilger nozzles and Capstan Synchro valves were installed on a Durand Wayland® axial fan canopy sprayer. Wilger Capstan nozzles installed on an autonomous tractor and automatic sprayer proved to be extremely quick, reliable and allowed for individual nozzle flow rate changes on the move, Landers et al (2012).

Following on from our citrus research we are currently conducting research on apples at Cornell University to develop methods which allow adjustment of liquid flow for an orchard sprayer (Llorens et al, 2013). Adjustment of liquid flow is made via information provided by a sensing system that scans the vegetation, and by the use of one multiple array of ultrasonic sensors. In general this project aims to follow the principles of variable rate technology (VRT). We have fitted an air-assisted sprayer, John Bean Redline Tower sprayer (Durand Wayland, La Grange, GA, USA) with a Lechler VarioSelect® system for proportional liquid application (Lechler USA, Franklin, TN, USA). The mounted system is based on thirteen blocks (at five different heights or manifolds) each with space for up to four nozzles. Every manifold and combination of nozzles is activated in groups by a pneumatic system mounted on the sprayer. These nozzles can be operated individually or in groups, and the system permits the use of the best combination of three nozzles. This sprayer was prepared only for applying on the right side and was equipped with three flat fan nozzles (Position A:110-01 Orange Position B: 110-015 Green and Position C: 110-02 Yellow). Every manifold and combination of nozzle was activated in groups by a pneumatic system mounted on the sprayer. Figure 4 represents the capacity of adjusting the volume rate of the VarioSelect system.

**Field trials**

Deposition on the fruit and leaves was measured by adding a determined quantity of Tartrazine into the sprayer tank. Quality of application was measured by picking leaves and fruit from specific areas of the trees. The extraction of deposited tracer on the fruit, leaves and pipe cleaners was determined by rinsing them with de-ionised water and the rinsate collected and then analysed for concentration. Results were expressed in terms of deposition per area of leaf surface (micrograms/cm²) and expressed by normalizing in a way that permits the comparison of results between treatments. Full details of the procedures used can be found in the reference Landers (2012).
Results

These preliminary results show that the variable application rate system on the orchard sprayer is able to attain different flow rates depending on what combination of nozzles are working. This wide range of flow rate (from 0.026 to 6.6 gpm at 60 psi, (0.1 to 25 L/min at 4 bar), permits an adjustment of the volume applied according to the canopy detected. In Table 1 we can see the basic parameters used during the testing of the system. When the sensing system detects the canopy we can save 22.7 % of the volume rate applied compared to the conventional sprayer. These savings are the result of adjusting the flow rate for each point of the application. Figure 7 shows these adjustments. This adjustment can be very important when trees are absent or when the target is very small. The conventional application (represented with the red line in Figure 7), always applies a constant amount of liquid.

In terms of product deposition (yellow tracer in the trials) on the leaves, the general results show no differences in normalized deposition between the two methods (Figure 8), indicating that the volume reduction method, using information obtained with the ultrasonic sensors, performed really well. These results are very encouraging and indicate that continuing this research using new technologies will improve spray application.

Discussion

The ultrasonic sensors are mounted and configured for an accurate reading of vegetation in fruit trees. The electronic system is based on an Arduino board that is able to control the different sectors and nozzles of the Lechler VarioSelect system. The same system is also able to operate the position of the actuator on the air adjusting louver system as described by Landers (2011). The electronic system can register data from all the systems via a serial port operating at a maximum frequency of 2 Hz.

Conclusions

Precision application of pesticides in orchards provides the grower with better crop protection, less environmental pollution and better use of resources. Our field trials show that the use of mechanical and electrical techniques can significantly improve deposition and reduce drift.
Acknowledgements
The authors wish to acknowledge funding for this project from The New York Apple Research and Development Program. We would also like to thank Lechler USA, for providing a complete VarioSelect system and Durand Wayland for supplying the sprayer.

Literature Cited

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