The Development of a Spray Monitoring System as an Aid to Orchard Management and Traceability

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The ever-increasing price of spray materials is a very important input cost that requires farm managers to know exactly where and how much pesticide is being applied. orchards come in all sizes and with variable financial means of support and levels of investment. Many growers choose to invest in quality spraying equipment using the most recent controls to adjust application rate and air volume; others choose not to.

On fruit farms 99% of growers have no way of recording actual spray volumes applied other than manually via pen and paper. Owners and managers rely upon themselves or an operator to spray acre upon acre of apple trees without missing a row or driving along a row for a second time; some would suggest it is a tedious job to say the least. When disease or insect activity occurs within a row, the first question should be “has this row been sprayed?” At the end of the season the grower has to spend countless hours filling in pesticide records, with data entry being yet another tedious job. If only there was an easier method of recording sprayer output, the products applied and their location, thus providing a simple, fast and easy alternative to tedious form filling.

Monitoring which sprays were applied, when, where and in what quantities, is becoming more important, and even critical, every year as processors and consumers require this information in the name of traceability. Along with farm and food industry representatives the USDA is very quick to remind consumers that the government sets allowable pesticide residue limits and that the use of Alar which wasn’t even a pesticide.

Traceability also serves to raise the awareness and importance of safe spraying practices on the farm.

To help growers with monitoring and traceability, we have developed a spray application-recording device to monitor and document the actual spray application. The device is a cost effective recording and documentation system that can be retrofitted to almost any sprayer. An attempt was made to find the least-costly system that could be used reliably as well as middle-of-the-road and high-end systems. The system allows the farm manager to easily download the spraying data at the end of a day’s work for analysis and use in the compilation of spraying reports.

Materials and Methods

This research was undertaken at Cornell University’s New York Agricultural Experiment Station in Geneva, New York and at Singer Farms, Appleton, NY. The criteria for choosing the equipment are as follows:

- 3 levels of cost (low, medium and high)
- Proven equipment and/or rugged and reliable design for use in agriculture
- Able to be retrofitted to most sprayers
- Output easily produced and understood by the user
- Could be commercially produced

Outline of basic system components:

1. Data logger including software
2. Flow meters
3. GPS system for location and tractor speed (Figure 1)
4. Either a standard laptop computer or a PDA for data download and analysis
5. Output software for data analysis

**Data Logger.** The logger selected was a Campbell Scientific model CR800 (Logan, Utah) with 12vdc input. This rugged logger allowed the integration of the GPS and flow meter readings while time stamping all of these readings together. Software used to acquire the data was PC400 programming software (Campbell Scientific 2009). The datalogger is stored inside the waterproof box on the sprayer (Figure 2).

**Flow Meters.** Flow meters come in an array of designs and styles. In keeping with the criteria of low cost and proven agri-
cultural usage, the Raven Model RFM-15P was chosen. This is a turbine type flow meter with a pulse output that could be read by the data logger. It is simple in construction and is repairable. The flow range of this model is 0.3 to 15 gallons per minute and an accuracy of 1.5% of reading. The pressure rating of the unit is 175 psi.

GPS Systems. We investigated three GPS systems:
1. A simple entry-level data recording system that allows the farm manager to download data at the end of the operator’s shift and take it back to his office to analyze.
2. A more expensive system using a more accurate GPS receiver but still no operator interface.
3. A full featured RTKGPS system that allows the operator to see all data being recorded in the cab of the tractor.

There is a diverse array of GPS designs, and GPS is a large part of the overall cost of the system. There are many package systems available on the market that do everything from simple location plotting to steering tractors, controlling implements and creating an output of the day’s work. Large field-crop farms in the Midwest USA have been the driving force and the test-bed for the more sophisticated systems. These have been under development for many years and are now becoming accepted as being quite functional. Ease-of-use has greatly improved and capital costs of these systems have come down. Comparatively little GPS technology has been used in the New York fruit industry with the exception of tree planters on a few farms.

After investigation, it was determined that “pass to pass” accuracy is the key and you get what you pay for. Day-to-day and year-to-year accuracy used to create latitude and longitudinal position is also an important consideration, which can be affected by satellite position. We chose to test three GPS systems: 1. Garmin GPS16X-HVS Antennae - $130. WAAS corrected, accuracy of <3metres 2. Raven Invicta 115 Smart Antennae - $1250. WAAS corrected, accuracy of <1metre 3. Leica mojoRTK system, $12-14,000. CORS Cellular network for position correction centimeter static, pass-to-pass, day-to-day and year-to-year accuracy

In our low-cost and mid-price systems, day-to-day and year-to-year repeatability is important only to the extent that a row or part of a row can be located and sprayed if it has been missed and is determined as needed by the farm manager. If “pass-to-pass” accuracy is reliable and repeatable, then the manager will be able to find the row and direct the operator to resolve the problem. The accuracy of the Leica mojoRTK system is sub centimeter and has stable day-to-day as well as year-to-year accuracy. The goal is to pinpoint the tractor/sprayer location within this row spacing, pass-to-pass, and day-to-day.

Data Download and Analysis Hardware. The CR800 Campbell Scientific data logger has an RS 232 9-pin connection on the logger. In the case of our simple system, a laptop with the standard 9-pin serial cable or USB to serial was used to download the data. A software program was written using Campbell Scientific PC400 software (Campbell Scientific 2009) to create the data logging protocol for the instrumentation.

Analysis and Mapping Software. Our data was downloaded and saved as an Excel spreadsheet. The lat.-long. data was then imported into Google Earth to compare the tracks that were traveled with the three GPS systems. The final application map including the time stamped, lat.-long., and flow readings, was created using a custom software program developed by Agrinetix LLC, Rochester, N.Y. This program can also be used to flag problem areas/locations and further document...
the spraying runs, with output used in reports to certification agencies and buyers requiring application data.

**Results and Discussion**

All three GPS systems investigated used the same flow meters, data logger and software and download devices. The only variables were the GPS devices used to gather lat.-long., and speed data and the analysis/mapping software.

The first two GPS systems (Garmin and Raven) were inaccurate, particularly run-to-run and day-to-day repeatability. This is because the unit may pick up different satellites when run at different times, and small variations in location may show up as large variations. The variation between the three test tracks was 1.5 meters (worst case), but the variation was all the same way and the lines were straight. These two systems could possibly be used for row and positional location if a farmer couldn’t afford a more expensive system or wanted to try GPS without investing too much money into it. It was determined that a custom software analysis software would be required to fully utilize the information gathered by this system.

Figure 3 shows a GPS map showing the drive pattern of a sprayed orchard at Singer Farms created using the mojoRTK system. Figure 4 shows the flow reading from the tractor and a positional recording of application volume for each row. This is the pictorial output of the logger data that would allow a farm manager to quickly review data and see where he may have concerns to correct missed rows or double applications.

MojoRTK - Its Use for Multiple Operations. In trying to justify the cost of an RTK system for a modern orchard, one must weigh the costs of making sequential passes through the same orchard rows with different pieces of equipment. In talking to orchardists who recognize the potential time wasted, a few have tried to accomplish multiple operations at the same time. It was reported that more than two operations at the same time make it almost impossible to both monitor the process and steer the tractor. The mojoRTK system with a self-steering feature would free the operator from the tractor steering operation and allow him/her to possibly monitor a third operation. Three operations that could be done together might be canopy spraying, weed or spot spraying and mowing; see Fig. 5. These are three of the most time intensive jobs done throughout the growing season. Consideration must be given to the number of times these operations are done individually over a multi-year period.

In order to utilize the expensive mojoRTK GPS and reduce driver fatigue, Mr. Bittner, the cooperating grower, decided to fit auto-steer to the tractor; Figures 6 and 7. This system utilizes the GPS signal to drive a small rubber wheel driven by an electric motor next to the steering wheel. The small wheel rotates the steering wheel, thus allowing the tractor to follow the desired track through the orchard. The sprayer driver is able to disconnect the auto-steer system quite easily, if desired, or transfer it to another tractor or picking platform.

Other Observations. In discussion with members of the NY
apple industry, most growers support the need for an automated pesticide traceability system and are willing to accept new technology providing it can reduce costs and time and make business easier. A monitoring system should also reduce risk and/or increase the value of certified produce.

Our current research is studying methods of completing the traceability loop by using a recording system to monitor pesticides used during the filling process, thus providing improved stock control in the pesticide store. Such a system will avoid the use of incorrect pesticides and potentially avoid both the loss of production and damage to the environment from using a non-specified pesticide. Consultants who advise growers on pesticide application play a key role in the adoption of monitoring technology. Scouts then record location of pests/diseases, the consultant creates the spray program, and then electronic instructions are sent to the sprayer operator. After the spray application is made an electronic copy of all the information, recommendation and results, can be downloaded to the office computer. This will save time in record keeping by providing the spray application records electronically.

Monitoring pesticide use from store to application could provide reassurance to the customer that business is being conducted in an orderly and efficient manner.

It is interesting to note that a growing number of large-scale vegetable growers are employing food safety managers to ensure all products leaving the farms are traceable from the field, where it originated, to the consumer. They are using traceability systems, which include manual labeling, satellite mapping, scanners and software, which records every step of production from, start to finish.

Conclusions
1. It is not practical to use a very inexpensive GPS receiver in developing an application map given the resolution and accuracy required for data analysis and certification agency / buyer reports.
2. A Leica mojoRTK system utilizing the CORS correction network is the most affordable RTK system available today. This technology is improving and prices are coming down as time goes on. Further analysis of the added benefits to farming operations efficiency by using RTK GPS will only improve the cost effectiveness of this system.
3. The spray monitoring system developed in this research project fits very well with the requirements of a modern orchard operation to document a very important, time consuming and costly operation.
4. A spray monitoring system will definitely assist farm management concerns and provide traceability evidence for the purchaser or consumer.

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