

Current Progress in Development of a Fixed-Spray Pesticide Application System for High-Density Apple Plantings

Arthur Agnello and Andrew Landers

Department of Entomology
Cornell University, NYSAES, Geneva, NY

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The method of application of pesticides to fruit throughout the world, gives rise to concern, primarily due to inaccurate application, which often results in high residues and environmental pollution. Inaccuracy, due to over- or under-application, may result in high levels of disease or insect activity. Air and water pollution resulting from pesticide drift is a major concern. There is also a growing concern for food safety and accountability among consumers who purchase fruit. Surveys of New York fruit growers, based upon stakeholder input, show that evalua-

tion of sprayers, sprayer management and fruit coverage issues are a research priority in tree fruits and apples in particular.

Orchard Trials with Fixed Spray Systems

In 1998, a fixed spraying system was devised at the NYSAES in Geneva, and preliminary trials were conducted to measure its efficiency in applying pesticides and controlling insects and diseases. Spray lines were fixed to metal conduit poles at three different heights and fitted with microsprinkler nozzles. Preliminary

Spraying an entire orchard using a fixed system could have several advantages that would justify initial establishment costs. Spray drift would be minimized without sacrificing adequate crop protection. Pesticide application could be achievable in a fraction of the time of tractor spraying, during shorter windows of acceptable spraying conditions, and at times of the year (i.e., early season) when ground conditions may make it impractical to drive through the orchard.

trials were conducted in two blocks each of Red Delicious and Empire apples on M.9 dwarfing stock located in a research orchard. Tracer solutions, using micronutrients, were used to monitor spray deposition, and a conventional airblast sprayer was connected, via a hose, to the spray lines passing through the trees. The fixed line system orchard blocks were compared with blocks treated using a conventional airblast sprayer. The scope of these preliminary trials was small, but results over two years showed control of diseases and insect pests was equal to that obtained with a conventional airblast sprayer, although engineering constraints prevented its practical implementation in commercial-scale plantings.

In 2005, a similar pesticide application system was devised, similar to a fixed irrigation system, in a larger-scale, 0.9-acre block of dwarf super-spindle Gala apple trees in a cooperating grower's orchard (Fowler Farms in Wolcott, NY). Two 3/4-inch plastic pipes (laterals) were positioned in-row through the canopy of the apple trees, following the top support wire at 8 feet and the bottom wire at 3.5 feet above the ground (Figure 1).



Figure 1. Arrangement of lateral lines in tree rows



Figure 2. Spray profile from a microsprinkler nozzle



Figure 3. Connection of upper lateral lines to main supply pipes



Figure 4. Main spray input point at one side of the block

Small emitters, Netafim DAN 7000 series, with an 8 mm orifice and a flat pattern spreader (Netafim, Fresno, CA) were installed at 6-foot intervals along the length of the pipe (Figure 2). As so many emitters are required, traditional sprayer nozzles and nozzle bodies would be prohibitively expensive. Micro-emitters are used in greenhouse irrigation systems and produce small droplets. Droplet size was a concern, so the micro-emitters were tested at OARDC (Wooster, OH) using an Aerometrics PDPA 1-D laser system. The volume mean diameter at 4 bar was 310 microns. This is larger than might have otherwise been selected, but is the smallest emitter available. Initial field trials over the 1998-99 seasons showed extremely good pest control with these emitters. The laterals were attached to a central 2-inch main pipe, which was run perpendicular to the rows at a height of eight feet. Because of pump capacity limitations, the system was divided into two individual main+laterals sections (Figure 3), and each was run separately to spray either the north or south halves of the rows. The mains both terminated in a central filling position at one side of the planting (Figure 4). Pipe diameters and pump requirements were calculated based upon a hydraulic analysis computer program devised by W. Shayya (Natural Resource Engineering, SUNY-Morrisville) for irrigation purposes.

In 2005, the system's original design employed direct pesticide injection. Injection sprayers eliminate tank rinsing and allow rapid changes in dose rate. The main tank of the sprayer holds clean water only. Pesticide is injected into the water flow via a piston or a peristaltic pump and the resulting mix flows through the pipes to the nozzles. A manual or electronic controller adjusts the pesticide injection pump according to changes in operating requirements; e.g., changes in application rate and pesticide required. Because the capacity of the tubing system was greater than the amount of pesticide solution that would be applied during a spray treatment, our intended procedure was to first charge the system by fully filling the main and lateral lines with clean water, then injecting the pesticide concentrate into the flow for sufficient time to obtain the appropriate amount of finish spray solution (e.g., 50 gal per acre). Pesticide injection was then shut off, and water was pumped until the pesticide solution was purged out of all the laterals and into the trees, thus leaving the system filled with water.



Figure 5. Mobile pesticide pumping unit

A trailed application unit (Figure 5) was constructed using a 300-gal water tank and a gasoline-driven centrifugal pump producing a flow of 90 gallons/minute at 36 psi. Two Dosmatic proportional injection pumps (Dosmatic USA, Carrollton, TX) were fitted into the water flow line after the pump. The pumps dispense pesticide at a known rate into the water stream in the spray pipeline, the injection rate being adjustable from 0.2–2.5% or 1:500 to 1:40. The resultant mix was then pumped along the main pipe to the laterals within the tree canopy. This arrangement was used to apply the grower's standard mixture of insecticides and fungicides in July-Aug 2005 for the final three-crop protectant sprays of the season.

Although the system was functional (Figures. 6 and 7), a number of engineering challenges and anomalies were encountered that needed to be addressed in order to optimize and improve system performance, and to facilitate grower acceptance and implementation on a commercial scale. The operating characteristics of the injection pumps were not suitable to the system's requirements, as it was difficult to accurately regulate the amount and rate of product uptake. Also, the grower typically wanted to apply several products in a single spray, which would necessitate the unwise practice of mixing concentrate products together. In the spring of 2006, the two Dosmatic pumps were removed and a Mazzei venturi was fitted along

with a 12 gallon pesticide/water premix tank. A butterfly valve allowed a pressure differential of up to 20 psi across the venturi. This arrangement allowed more precision and control over the amounts of pesticide being injected, and circumvented the problem of mixing chemical concentrates. Additionally, 10-psi check valves were installed on each nozzle, to prevent dripping of pesticide solution both before the system was up to operating pressure and after the spray was finished.

Flow tests were conducted, using blue dye as a tracer, to determine the uniformity of pesticide concentrations from nozzle to nozzle and along the extent of the lateral tubes, as well as the system response time during filling and application of products. These tests revealed an unacceptably long period of time for the dye to begin appearing at the farthest nozzles and to finish leaving the laterals after the dye had been switched off. Depending on how well the dye simulated actual pesticide flow, spray amounts of 500–800 gal per acre of solution would be required to ensure that all the injected pesticide had been sprayed out on to the trees, which was clearly not a practical option. As a result, it was decided to forego the pesticide injection approach entirely for the remainder of the season, and simply combine pesticide products with water directly in the main tank. This solution was sprayed through the system into the orchard, using a flow meter to determine the length of time necessary to achieve the desired amount per acre.

The grower's regular schedule of insecticides and fungicides (i.e., Captan, Imidan, Flint, Dipel, Thionex, Sovran, Provado, Topsin) was applied to half of the 0.9-acre block using this system during July and August 2006, with the same products being applied by the grower to



Figures 6 and 7. System in operation showing spray profile in tree rows

the other half of the block using a conventional airblast sprayer. Applications were made on 6 July (300 gpa), 4 and 17 August (both 320 gpa), which were still higher than preferred spray volumes, but were needed to ensure adequate pesticide sprayout and distribution using the current design. On each date, the duration of the entire application process (system operating time) ranged from 2–3 minutes. As this procedure resulted in the system remaining filled with pesticide solution after the trees were sprayed, clean water was used to flush the tubing on the day following each application date. It was assumed that by this time, the pesticide products would have had sufficient opportunity to effect their respective biological activity on their targets, and would not be appreciably washed off by a nominal water spray.

Because this period of the summer does not correspond exactly with the period of occurrence of a large number of apple insects and diseases, only limited field evaluations were made on the relative efficacy of these pesticide applications. On 19 July, foliar terminals were inspected for incidence of obliquebanded leafroller infestations by examining three replicates of 100 terminals (10 on each of 10 trees per replicate) in both the fixed-spray and airblast halves of the block. These samples revealed zero percent infestation in all cases. Just prior to harvest on 12 September, fruits were randomly sampled for insect and disease damage by inspecting five replicates of 100 fruits (10 from each of 10 trees per replicate) in both the fixed-

spray and airblast halves of the block. Each 100-fruit sample was taken from a separate interior row of each plot. Results are shown in Table 1. With the exception of plum curculio, there were no significant differences in fruit quality between the two treatments. Although all visible damage was rated, plum curculio scars would have resulted from insect activity that occurred before the fixed-spray treatment was implemented, so this cannot be attributed to the application method. It is possible to say only that, over the period from midsummer to harvest, applications using the fixed-spray system appeared to protect the fruit as well as those applied with an airblast sprayer.

Future Research Plans

Below are some of the specific objectives we intend to address in the coming season to improve the operation of this system on a commercial scale:

1. Assess the use of compressed air to purge the spray lines rather than having to rinse with water on a subsequent day.
2. Refine and improve the engineering aspects of the fixed spray line using accepted procedures to optimize:
 - The deposition characteristics of the emitters, employing computer-aided image analysis of deposition patterns on water-sensitive cards.
 - The uniformity of pesticide concentrations from nozzle to nozzle, using tracer dyes and individual catch tubes on sequential nozzles

to obtain comparative samples of solution all along the length of the spray line.

- The uniformity of pesticide concentrations with changes in dose level, by running a series of pesticide injection trials employing different initial input concentrations and assessing readings in the final effluent.
 - The system response time during filling and application of products, through repeated time trials using a range of pesticide materials representative of the grower's typical spray program.
3. The reliability of the components of the fixed spray line system over a number of seasons will be evaluated by observing the system's performance throughout the course of this project.
 4. Determine the physical aspects of spray deposition and distribution patterns in the tree canopy achieved, as well as pesticide drift and off-target deposition compared with a conventional airblast sprayer.
 5. Evaluate pest control efficacy and economics of use with each type of application method used throughout the entire season.

To assess the relative economics of using a fixed spray system for applying pesticides, a budget will be drafted that takes into consideration the set costs and the variable per-acre construction costs of the equipment (Table 2). Estimates will be made of time and labor requirements for system construction and individual

Table 1

Percent fruit damage at harvest by insects and disease in Gala apple block receiving July-August pesticide sprays applied using either a fixed-spray or airblast method, 2006.

| Treatment | Rep | Sting ¹ | Tarnished plant bug | Plum curculio | Apple Scab | % Clean fruit |
|-------------|------|--------------------|---------------------|---------------|------------|---------------|
| Fixed-Spray | 1 | 2 | 0 | 0 | 1 | 97 |
| | 2 | 1 | 0 | 0 | 1 | 98 |
| | 3 | 0 | 0 | 0 | 0 | 100 |
| | 4 | 0 | 1 | 0 | 0 | 99 |
| | 5 | 0 | 0 | 0 | 0 | 100 |
| | Avg. | 0.6 | 0.2 | 0.0 | 0.4 | 98.8 |
| Airblast | 1 | 0 | 0 | 0 | 0 | 100 |
| | 2 | 0 | 0 | 0 | 0 | 100 |
| | 3 | 0 | 1 | 1 | 0 | 98 |
| | 4 | 3 | 0 | 1 | 0 | 96 |
| | 5 | 3 | 0 | 2 | 0 | 95 |
| | Avg. | 1.2 | 0.2 | 0.8 | 0.0 | 97.8 |

¹ Indeterminate damage caused by either larval Lepidoptera feeding (e.g., codling moth, oriental fruit moth, or obliquebanded leafroller) or unsuccessful apple maggot oviposition puncture.



spray sessions, and an estimated cost will be formulated for both the expense of constructing this system and the costs of use for each application and on a season-long basis. This will be compared against the set material and labor costs of operating a conventional tractor-pulled airblast sprayer. Costs of both application methods will be amortized over a best estimate of the respective equipment life on a commercial scale.

Potential of Fixed Spray Systems

While this system would not be intended for all planting systems, it could be used in many of the newer high-density blocks where airblast sprayers are not the most suitable, or required, application method. Because drift and off-target deposition would be reduced with this method, adjacent properties and their occupants would benefit secondarily from lowered risk.

Spraying an entire orchard using a fixed system could have several advantages that would justify initial establishment costs and reduce pesticide-associated risks. Spray drift would be minimized without sacrificing adequate crop protection. Pesticide application could be a much more efficient process, achievable in a fraction of the time of tractor spraying, during shorter windows of acceptable spraying conditions, and at times of the year (i.e., early season) when ground conditions may make it impractical to drive through the orchard. Because multiple sprays and re-sprays would be much easier, this enhanced efficiency would make it more

| Table 2 | | |
|--|--|------------------|
| Economics of the components of a prototype fixed-spray system. | | |
| Mobile Pumping Unit | Chassis | (donated) |
| | 300 gal tank, saddle & straps | \$491 |
| | frame & plate for engine/pump; welding | \$572 |
| | flow meter | \$450 |
| | 5-hp gasoline pump | \$340 |
| | fittings | \$228 |
| | Total fixed costs | \$2283 |
| Orchard Structure | | <u>Cost/acre</u> |
| | 3/4" polyethylene tubing, lateral lines (@\$0.10/ft) | \$648 |
| | Microsprinkler nozzles, 1 every 6 ft (@\$0.65 ea) | \$702 |
| | PVC pipe, 2" Schedule 80 (\$1.50/ft); 1" (\$0.20/ft) | \$325 |
| | PVC elbows, tees, caps; clamps, etc. | \$250 |
| | cable ties for lateral lines; 2160 needed @ \$0.07 | \$151 |
| | 2x4s, weatherized; hardware, U-bolts, etc. | \$100 |
| | Total per-acre cost | \$2176 |

practical to use lower rates of pesticides and a more "least-toxic" alternative or organically approved materials that have relatively short residual effectiveness, such as botanicals, microbials, oils, soaps, or insect growth regulators. To the extent that alternative pest management programs would provide more realistic options in such plantings, such a system could favor growing fruit profitably for organic or niche specialty markets in selected blocks.

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Art Agnello is an extension and research professor who leads Cornell's fruit extension entomology program at Cornell University.

Andrew Landers is an Extension Associate who specializes in pesticide application and leads a statewide program in sprayer research.

