**Northeastern IPM Center Partnership Grant Final Report**

## A. Grant Data

*Title*: Optimization of a fixed spraying system for commercial high-density apple plantings
*Type*: IWG Priority
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*State*: New York
*Funding Year*: 2006
*Funding Amount*: $20,000

## B. Nontechnical Summary

A pesticide application system was devised, similar to a fixed irrigation system, in a 0.9-acre block of Gala apple trees in a cooperating grower's orchard in Wolcott, NY. Two 3/4-inch plastic tubes 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.

Small greenhouse-style microsprinklers were installed at 6-foot intervals along the length of the tubes. These tubes were attached to a central 2-inch main pipe, which was run perpendicular to the rows at 8-foot height. Because of pump capacity limitations, the system was divided into two individual sections, 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. Pipe diameters and pump requirements were calculated based upon a hydraulic analysis computer program devised for irrigation purposes.

A trailed application unit was constructed using a 300-gal water tank and a gasoline-driven pump. This arrangement was used to mix and apply the grower's typical range of pesticide products during part of the growing season, and various assessments of and improvements to the unit's operation were made during the course of the 2006 field tests.

## C. Introduction

The application of pesticides to fruit throughout the Northeastern US, as in the rest of 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 fruit growers of New York, based upon stakeholder input, show that evaluation of sprayers, sprayer management and fruit coverage issues are a research priority in tree fruits and apples in particular. Diseases such as apple scab in tree fruit are top priorities, along with arthropod pests such as obliquebanded leafroller, internal feeding caterpillars, and mites.

Apple production in the eastern United States is a high value crop, approaching an annual farm-gate value of $450 million with production on 6,582 farms. According to NASS (2006) in 2005, the area planted to apples in NY was 45,000 acres, in PA 21,800 acres and in MA 4,100 acres. Projected yields for the 2006 season in NY: 1,120 mil lbs, Pa: 450 and MA: 31 mil lbs.

In 1998, a fixed spraying system was devised at the NYSAES in Geneva, and preliminary trials were conducted to measure its efficiency at 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 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.

**D. Objectives**

1. Refine and optimize the engineering elements of a pesticide application system of tubing and nozzles fixed into the canopy of high-density apple trees.

- Work during the first half of the growing season focused on improving the performance and precision of the pesticide injection system that allowed us to fill the main tank with clean water and pump only as much pesticide as needed into the flow stream, so as to eliminate tank rinsing and allow quick changes in dose rate. Unfortunately, there were too many engineering complications encountered to refine this specific aspect of the operation, so it was decided to revert to a conventional tank-mixed pesticide solution in order not to spend the entire summer application period perfecting complicated design changes.

2. Determine the physical aspects of spray deposition and distribution patterns in the tree canopy achieved, as well as pesticide drift and off-target deposition, using a fixed spray system, compared with a conventional airblast sprayer.

- A number of trials were conducted to determine the flow characteristics of the pesticide solution through the tubing and onto the trees. Although the system was functional, a number of engineering challenges and anomalies were encountered that needed to be addressed to optimize and improve system performance. An acceptable level of operation was attained to use the system to apply pesticide sprays during the last two months of the season.

3. Evaluate pest control efficacy and economics of use with each type of application method.

- Because the last half of the summer does not correspond exactly with the period of occurrence of a large number of apple insects and diseases, limited field evaluations were made on the relative efficacy of these pesticide applications. Nevertheless, it was possible to conduct a representative comparison of the two methods of applying crop protectants against several of the key insect and disease pests of concern to commercial growers of the region.

**E. Approach, Progress, & Results**

*Obj. 1*: Two Dosmatic proportional injection pumps had been 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 that season.

Although this approach appeared to have promise for incorporation into this application method, 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.

*Obj. 2*: 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 onto 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.

*Obj. 3*: 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 using a conventional airblast sprayer. These comprised applications 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 being left 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 3 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 5 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 ascribed 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.

Because of the developmental nature of the engineering aspects of this project, work will continue on these objectives during 2007, in order to be able to test a more fully operational system throughout the entirety of a growing season. Following are some of the specific objectives we intend to address in the coming year 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.

**F. Impacts**

*1. Innovations*

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. Fowler Farms, where this work is being conducted, comprises hundreds of acres of new and planned plantings of high-density, planar canopy trees that would be optimally suited to such an application system. The farm's owners have expressed great interest in seeing this method explored and developed for particular application to their planting systems, and have repeatedly conveyed their desire to support our efforts, even after the funding period of this project has ended.

*2. Safeguarding human health and the environment*

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 and off-target deposition would be minimized without sacrificing adequate crop protection, and adjacent properties and their occupants would secondarily benefit from lowered risk. 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 practical to use lower rates of pesticides and 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 be more realistic options in such plantings, such a system could favor growing fruit profitably for organic or niche specialty markets in selected blocks.

*3. Ecomonic benefits*

To assess the relative economics of using a fixed spray system for applying pesticides, a budget will be constructed to take 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 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.

It is anticipated that, despite the costs of initially establishing such a system, the long-term economics of the relatively durable components of the spraying infrastructure would compare favorably with the high operating, maintenance, and labor costs associated with towing a sprayer up and down the rows of an orchard multiple times during the year, and the overall efficiency of the spray application process would avoid many shortfalls of more conventional methods.

*4. Implementation of IPM*

Details on the development and testing of this system have already been presented to various audiences:

• New England, New York, Canadian Fruit Pest Management Workshop, Burlington, VT, October, 2005. Audience: 50

• Great Lakes Fruit Workers Meeting, E. Lansing, Michigan, November, 2005. Audience: 35

• Cumberland Shenandoah Fruit Workers Conference, Winchester, VA, November, 2005. Audience: 35.

• Lake Ontario Summer Fruit Tour & Equipment Show, Wayne Co, August, 2006. Audience: 150

• Québec Apple Growers Meeting, St. Rémi, QC, scheduled for December, 2006.

Also, an article on this project is scheduled to appear in the Winter 2006 NY Fruit Quarterly.

**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.

**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 |
| | | Cost/acre |
| **Orchard Structure** | 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 |

## Acknowledgments

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## G. Appendix

See the PowerPoint file "Fixed_Spray_2006.ppt" appended to this report