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/under application, may result in high levels of disease or insect activity. Air and water pollution is a major concern due to pesticide drift. 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. Priorities developed by members of the Northeastern IPM Fruit Working Group include sprayer and pesticide application resources (evaluations, calibration, best use patterns, etc.).

Direct injection sprayers have been developed by many researchers for boom sprayers in conventional field crops, but only one paper, Tennes et al. (1976) has been published in their application to fruit crops where they used four direct injection pumps inside a trailed tunnel sprayer. Direct injection sprayers offer the operator many advantages, including reduced environmental pollution and operator contamination (Landers 1992, 1997). 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 resultant 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.

A fixed spraying system was devised at NYS Agric. Expt. Station, Geneva, and preliminary trials were conducted to measure its efficiency at applying pesticides and controlling insects and diseases. Spraylines were fixed to metal conduit poles at three different heights and fitted with Netafim DAN 7000 sprinkler 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 at this experiment station (Agnello et al. 1999). Tracer solution, using micronutrients, was used to monitor spray deposition and a conventional airblast sprayer was connected, via a hose, to the spraylines passing through the trees. The fixed line system orchard blocks were compared with blocks treated with a conventional airblast sprayer. The scope of the preliminary trials was small, but results over two years showed control of diseases and insect pests such as plum curculio was equal to that obtained with a conventional airblast sprayer.

In 2005, a 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 in Wolcott, NY. Two 3/4-inch plastic pipes (laterals) were positioned 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 emitters, Netafim DAN 7000 series, with an 8 mm orifice and flat pattern spreader (Netafim, Fresno, CA) were installed at 6-foot intervals along the length of the pipe. A 2-inch main pipe was run along the junction of the rows to a central filling position. Pipe diameters were calculated based upon a hydraulic analysis computer program devised by W. Shayya for irrigation purposes.

A trailed application unit 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 A80-2.5% proportional injection pumps (Dosmatic USA, Carrollton, TX) were fitted into the water flow line after the pump. The water-driven pumps were fitted with super corrosive transfer (SCT) kits to avoid damage to the pump seals from solvents in the pesticides. 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, a number of engineering challenges and anomalies were encountered that need to be addressed to optimize and improve system performance in order to facilitate grower acceptance and implementation on a commercial scale.

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

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.

The engineering challenges in this project have been numerous, but not unsurmountable. To prevent excessive pressure loss in this larger scale trial, we minimized pipe runs and branch points, and opted for a high and low lateral line, with careful analysis of the hydraulic flows provided by an irrigation engineer, W. Shayya, SUNY-Morrisville. Another hydraulic concern was overcome by using a mobile pumping unit. Originally, we had intended to use a central pumping station, but hydraulic flow limitations and costs were a concern. The mobile unit can be transported from one block of trees to another.

A conventional airblast sprayer, used as the pumping station, suffers from a tank of mixed pesticide and water, plus operating at too a high pressure. To overcome the problems of tank rinsing and pump pressures, we chose a direct injection unit. A water-driven injection pump and gasoline-powered centrifugal water pump allows the system to be independent of tractors and PTO drive lines. The unit could, if desired, be pulled and operated with a pick-up truck. A 12 volt electricity supply is required for the pesticide mixing reservoir fitted below the intake of the injection pump.

The large internal volume of a mains/lateral pipeline system through a block of apple trees presents many problems, such a filling and emptying the pipe. The direct injection pump allows us to fill the pipes with clean water for one minute, then inject pesticides for one minute and then purge the pesticide laden water out with a clean water for a further minute.
As so many emitters are required, traditional sprayer nozzles, nozzle bodies and anti-drip check valves would be prohibitively expensive. Micro-emitters are used in greenhouse irrigation systems and produce small droplets. Droplet size was of concern, so the micro-emitters were tested at OARDC (Wooster, OH) using an Aerometrics PDPA 1-D laser system. The VMD at 4 bar was 310 micron (Downer 2004). This is larger than we might choose, but is the smallest emitter available. Initial field trials over two seasons have shown extremely good pest control with these emitters.

Specific goals of the trial in refining and improving the engineering aspects of the fixed sprayline will involve 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 sprayline
- 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
- The use of a purge mode to rinse the sprayline, comparing the relative merits of a water rinse as opposed to an alternative using compressed air
- The injection pump characteristics, consisting of examining the pump's operational limits under a testable range of candidate injection rates and spray durations.

The reliability of the components of the fixed sprayline system over a number of seasons will be evaluated by observing the system's performance throughout the course of this project, which was initiated during the 2004 season.

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.

At different times during the growing season, physical measurements of the spray deposition and distribution patterns within the orchard canopy and via off-site drift will be taken using water-sensitive cards and strips located at set distances from the trees. The strips and cards will be analyzed using a scanner and computer software program to calculate the proportion of the target areas contacted by the spray.

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

The seasonal standard pesticide schedule of sprays will be applied through this system in one-half of the orchard, and, for comparison, the remaining half will be managed using the same pesticide schedule, materials and rates, but applied by the grower cooperator using a standard orchard airblast sprayer. Because some time will be needed at the start of the spray season to
complete the system's design and operational improvements, it may be necessary to start the pest control efficacy comparison with the petal fall sprays; this will miss the apple scab primary infection period, which occurs pre-bloom, but will still allow enough time to assess management levels of secondary scab, plus all the remaining diseases and arthropod pests normally present during the growing season. Pest incidence and damage will be assessed in multiple randomly selected orchard sites throughout the season and at harvest, using standard research-based sampling procedures (Agnello et al. 1999) to evaluate both direct (fruit-feeding or -attacking) and indirect (foliar) pests, including insects, mites, and disease pathogens.

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 (i.e., mobile pumping unit: tank, primary pump, pesticide injection pump, flowmeter, mixing reservoir, etc.) and the variable per-acre construction costs (supply mains, lateral lines, nozzles, support hardware, etc.) of the equipment. Records will be kept 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.

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 secondarily benefit 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 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.

References Cited


