A PROPOSAL TO THE NORTHEASTERN IPM CENTER INTEGRATED PEST MANAGEMENT PARTNERSHIP GRANTS PROGRAM *IPM WORKING GROUP PRIORITIES FUND*

OPTIMIZATION OF A FIXED SPRAYING SYSTEM FOR COMMERCIAL HIGH-DENSITY APPLE PLANTINGS

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PROJECT DESCRIPTION

A) PROBLEM, BACKGROUND AND JUSTIFICATION:

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.

Apple systems in New York, Pennsylvania and Massachusetts

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 (2004) in 2002, the area planted to apples in NY was 45,000 acres, in PA 28,110 acres and in MA 4,479 acres. Projected yields for the 2005 season in NY: 1,060 mil lbs, Pa: 420 and MA: 35 mil lbs.

Grower priorities: Fruit spraying for insect and disease management

Surveys of fruit growers of New York (NY IPM 2004), 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 and mites. Priorities developed by members of the Northeastern IPM Fruit Working Group include sprayer and pesticide application resources (evaluations, calibration, best use patterns, etc.). They also list evaluation of sprayers and coverage issues, plus spray drift onto neighbors as priorities for research with all tree fruit (Northeastern Pest Management Center 2004). Apple scab and OBLR management, including timing and coverage, are specific priorities.

Similarly, the New England Apple pest management strategic plan 2003 states a priority research area is to continue to evaluate spray application strategies designed to reduce pesticide use with insecticides (Northeastern Pest Management Center 2004). Also included as research priorities are OBLR and mites in apples along with apple scab control.

Who would benefit from this work

A primary beneficiary of this work would be the community of NY apple producers who are continually searching for improved methods of applying pesticides efficiently without sacrificing control efficacy. While the system described in this proposal 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.

Fowler Bros. orchards, Wolcott, NY, where this work is being conducted, is the largest tree fruit producer in the state, with an operation comprising some 2,000 acres of orchards producing 21 varieties of apples for distribution nationwide and overseas. A growing proportion of their acreage is being converted to high density plantings such as the "super-spindle" training style where the fixed spray system is being developed. Co-owner John Fowler has expressed a high interest in this approach to pesticide application because of the improvement it may offer in spray efficiency and effectiveness compared with traditional tractor-drawn airblast methods, which he finds onerous, as well as the potential ability to greatly reduce off-target pesticide drift.

Previous and ongoing work

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.

B) OBJECTIVES AND ANTICIPATED IMPACTS:

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

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.

This project relates to the goals of the National IPM Roadmap by addressing research needs related to improving the efficiency and effectiveness of pest suppression tactics, and incorporating an objective to protect agricultural workers, as this approach seeks to greatly reduce pesticide drift and off-target deposition, while minimizing the applicator's exposure to the pesticide spray materials. This type of technology conforms to the goal of minimizing the adverse effects from pests and related management strategies by reducing off-target impacts and promoting a healthy within-crop environment.

Because this project takes place entirely on a commercial farm as a research demonstration, it will have the highest level of visibility and exposure to the extension audiences who are intended to derive applicable benefits from it. It will incorporate not only functions of the entomology, agricultural engineering and plant pathology disciplines of NYSAES at Geneva, plus the county-based extension staff in the Lake Ontario Fruit Program region, it will also draw significantly on the technical expertise of the agricultural engineering program at a partner institution, SUNY-Morrisville. This multifunctional approach has been shown to be most effective at optimizing the different strengths of a range of collaborators who are all directed towards results in an area of common interest.

This project addresses the Agriculture and Foods Systems priorities relating to innovative horticultural cropping systems, integrated pest management approaches and techniques, and elements of precision agriculture. Also, because it represents a potentially effective way to help minimize pesticide use and risk, it relates to CSREES National Goal 4.1 (sustainable agricultural technologies that ensure ecosystem integrity). One of the research and extension priorities of the Cornell Fruit Program Work Team addresses the development and demonstration of new pesticide application technologies, and this project represents a novel approach to solving some common pesticide application limitations in NY tree fruit systems. Three years of preliminary research have already demonstrated the effectiveness of this technique on a small scale, and the interest shown by a prominent NY grower in adapting it for use in established orchards provides a timely opportunity to give it a more critical evaluation.

C) APPROACH AND PROCEDURES:

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.

Timeline:
<u>Late March–April</u> (dormant to tight cluster bud stage): Tests of nozzle-to-nozzle pesticide concentrations; time trials to adjust filling & application procedures; tests of alternative line purging methods; assessment of injection pump operational limits
<u>Late April–May</u> (pink to bloom bud stage): Initial measurements of spray deposition patterns in canopy; evaluations of pesticide concentrations at different doses
<u>Late June</u> (post-fruit set): Second set of spray deposition measurements at early canopy leaf fill stage of growth; repeated evaluation of nozzle-to-nozzle pesticide concentrations
<u>Late August</u>: Final set of spray deposition measurements with fully mature canopy growth

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 calulate the proportion of the target areas contacted by the spray.

Timeline:
Late April: First measurement of spray deposition within orchard sites and at fixed distances downwind of last sprayed rows, at minimal canopy growth
Late June: Second measurement of spray deposition inside orchard at fixed distances downwind, at early canopy fill
Late August: Final measurement of spray deposition inside orchard at fixed distances downwind, at fully mature canopy growth

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.

Timeline:
Plots will be censused both for mites (pest and predator) and insects throughout the season
Pink bud stage: Fruit buds sampled for rosy apple aphid colonies
Bloom: Flower clusters inspected for overwintered generation obliquebanded leafroller larvae
Petal fall: First European red mite sample just prior to petal fall applications. Thereafter, plots will be sampled twice per month. At each sampling period, we will randomly collect 25 leaves from each of 4 trees per treatment and bring them to the laboratory to be brushed, and the mites

will be counted and identified. Fruit clusters will be sampled for 1st generation spotted tentiform leafminer sapfeeding mines, to determine the potential for the 2nd brood population to exceed an acceptable threshold during the summer.
Mid- to late June: Foliar terminals sampled for the presence of green aphids plus cecidomyiid and syrphid predators
Mid- to late July: Fruit and foliar clusters sampled for obliquebanded leafroller foliar infestations
July 15: Sticky red spheres baited with butyl hexanoate volatile lures hung at a rate of 3–5/block, to monitor for ovipositing apple maggot females.
Mid-August: Foliar shoots sampled for nymphs of 2nd generation white apple leafhopper
Harvest: Damage by direct fruit feeders such as plum curculio and apple maggot, as well as obliquebanded leafroller and other secondary pests, evaluated in 100-fruit samples from interior and border row locations of each treatment. Incidence of fruit scab and summer disease (sooty blotch and flyspeck) will also be recorded.

D) EVALUATION PLANS:

Development of the current fixed spray system into a workable, efficient apparatus, the focus of Objective 1, will be a sequential, intuitively motivated endeavor comprising a number of discrete modifications and gradual improvements that should ultimately result in a design and operational profile that we can objectively characterize as optimal for the purposes of the trial being conducted. The engineering progress attending each operational element under review should be self-evident within the context of the system tests we undertake in our efforts to reach this optimal design; our success will be determined by our ability to end up with a mechanically sound method for applying pesticides easily and reliably with this equipment.

The measurements of spray deposition and distribution (Objective 2) will result in quantifiable readings of the percent coverage of numerous, specifically located targets. Aggregate comparisons of thoroughness of coverage in key canopy locations will inform our evaluation of the suitability of this spray application method relative to a conventional airblast sprayer. Similarly, patterns of spray distribution and presence as measured by target strips placed at various distances from the sprayed trees will indicate the extent to which this method reduces the incidence of off-target spray exposure in a realistic agricultural use setting.

Evaluation of pest management efficacy using this approach will be possible primarily by comparing pest populations in-season and fruit quality (damage) levels at harvest with those obtained from the airblast-treated half of the orchard. An economic comparison between these methods will be somewhat speculative, based on the preliminary stage of development of this system, but should be possible at a reasonable enough level to indicate potential applicability of a fixed spray method on a larger commercial scale. Of particular interest will be the willingness of the grower cooperator to consider using this method on an expanded area of his farm.

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Project Summary
IPM Working Group Priorities Project

Northeastern US apple growers apply a number of pesticide sprays to their trees annually. Traditionally they use airblast sprayers, which creates a plume of spray, a variable proportion of which hits the target. The result is often poor distribution within the canopy, leading to ineffective pest control plus off-target drift, leading to environmental pollution and economic inefficiency. Modern orchards comprise numerous planting densities and tree canopies, ranging from dwarf trees on narrow row spacings to large trees in wide rows. Spray application in large scale, high density plantings requires many hours of travel, along miles of tree rows, creating high labor and machinery costs, and affecting the timeliness of application. In such high density plantings, it is possible to construct a fixed arrangement of spray nozzles capable of contacting all portions of the trees with a spray that is maintained for just long enough to completely cover all canopy surfaces. By eliminating the need to contact the target with a uniform spray source travelling past it, some of the intrinsic inefficiencies and drift hazards of contemporary airblast spraying might be overcome. This project will result in the optimization of a fixed spraying system being developed in a high density apple planting on a commercial farm in Wolcott, NY. Preliminary trials have demonstrated the ability to apply a spray solution to the trees using this system. Further work will focus on refining its spray deposition and delivery characteristics, and use of direct pesticide injection to more safely and efficiently handle the pesticides. Also, the economics of using this system and its reliability over time, and its biological effectiveness in controlling insect and disease pests on a seasonal basis will be assessed.