Project Report to the NYS IPM Program, Agricultural IPM 2002

Title:
AN ORGANIC APPLE PRODUCTION SYSTEM FOR NEW YORK

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Throughout the Northeast

Abstract:
Several NY apple growers have indicated they see a marketing opportunity for NY grown organic apples (both fresh and processed products) and have requested a Cornell University led effort to develop a system of organic apple production for NY. In 2002 we studied apple maggot management, fruit thinning, and weed control tactics that are organically approved. We have evaluated an organic approved insecticides (Surround) for apple maggot control using 2 application methods. We also evaluated an experimental antagonist for apple maggot control. Surround showed gave very good control of apple maggot regardless of application method. With organic approved thinning agents we had excellent success. The Fish Oil/Lime Sulfur combination gave excellent thinning efficacy and a wide window of application (full bloom to post petal fall). NC-99 also gave significant thinning but gave more phytotoxicity. Both products also resulted in a small improvement in fruit size. We successfully modified and improved a weed flaming unit that gave promising results in 2001 and 2002 for cost effective weed control in organic apple orchards. The use of a shroud allowed faster travel times and more effective weed suppression. This method should allow organic apple growers to limit weed competition and improve tree growth, yield and fruit size.

Background and Justification:
Organic apple production in NY has remained small and limited to a few farms due to the intense disease and insect problems encountered with organic apple production in the NY climate. Several NY apple growers have indicated they see a marketing opportunity for NY grown organic apples (both fresh and processed products) and have requested a Cornell University led effort to develop a system of organic apple production for NY. Two grants

(Cornell Organic Farming Grants Program and Organic Farming Research Foundation in California) in 2000 and 2001 allowed a multidisciplinary project at Cornell University to begin to develop a system of organic apple production for the eastern US. Grants from the NYS IPM program in 2001 and 2002 have allowed us to continue the work.

In NY state, a large number of both native and introduced insect and mite species attack apples grown in commercial apple orchards. Control of this pest complex without common pesticides is particularly challenging, because apple orchards in NY are commonly in close proximity to semi-wooded areas with an abundance of wild apple and hawthorn species that can harbor fairly large populations of certain apple insect pests. Controlling apple diseases with fungicides approved for use in organic food production involves old and well-documented technology. Sulfur and lime-sulfur are effective for controlling most diseases if they are applied correctly (Burrell, 1945).

A second major management problem in organic apple orchards is the lack of suitable approaches to thin the crop. Fruit thinning is essential to control biennial bearing in apples. It also increases fruit size in the current season while increasing return bloom in the next season. In conventional orchards fruit thinning is accomplished by the use of growth regulating chemicals; however, in organic blocks hand thinning which is expensive is the only current approach.

A third major problem with organic apple production in NY is weed control. In conventional orchards, weeds are controlled with an early spring application of residual herbicides followed with 2-3 spray applications of contact herbicides. The few existing organic apple orchards in NY control weeds by mowing and limited hand weeding around trees. However, the competition from weeds severely reduces trees growth of young trees and reduces yield, and fruit size in older trees. Propane flamers could become an economical method of weed control for organic farmers, providing a non-chemical method of controlling weeds and pests.

Objectives:

1. Develop an organically approved arthropod management system that will lead to the production of apples suitable for the fresh and processed organic fruit market.
2. Develop alternative chemical fruit thinning approaches for use in certified organic apple orchards that will result in annual cropping and large fruit size.
3. Develop alternative weed control approaches for use in certified organic apple orchards that will result in similar tree growth, yield, fruit size and leaf nutrient levels as conventional herbicides.

Procedures:

OBJECTIVE 1. ORGANIC ARTHROPOD MANAGEMENT.

A field trial was established in a western New York apple orchard which has been in organic production for several years to study apple maggot control with organic methods. The block was selected for use in this trial because high levels of apple maggot damage was observed in fruit harvested during the previous season. A Durand-Wayland airblast sprayer calibrated to deliver 200 GPA and two treatments were applied using the kaolin particle film Surround on a weekly basis. These two treatments varied in the respect that different nozzles were used for each application. Tee Jet hollow cone nozzles (Model D4 disc with DC45 whirl plate) as well as Tee Jet air induction nozzles (Model AI11004VS, Spraying Systems Company, North Avenue, Wheaton Illinois 60188) were tested to determine the effectiveness of droplet size with this material. A volatile bait containing Spinosad was applied with a MeterJet™ spray gun (Model 2362, Spraying Systems Company, North Avenue, Wheaton Illinois 60188) connected to a CO^2 backpack sprayer at 40 psi, also on a weekly basis at the rate of 1.0 gal/A.

A new antagonistic method of chemical repellency was also incorporated into this trial by using 12 dispensers hung in the center tree of a 3x3 tree plot. This new technology was developed by Dr. Wendell Roelofs, New York State Agricultural Experiment Station, Geneva New York, and is still in a preliminary testing phase as this was the first trial conducted in a field setting. Treatments including an untreated control were replicated four times and arranged in a RCB design. All applications were started on 25 Jul and continued on 2 Aug, 8 Aug, 14 Aug and 21 Aug. The dispenser vials for the repellant were hung on 20 Jul. Red sphere traps with volatile bait were hung in four trees surrounding the center tree in both the repellant trial and the untreated check. Weekly counts were taken from these traps to determine whether the flies had any repellant action away from the treated tree. These counts were compared to one another to determine any effectiveness. Fruit was harvested on 9 Sept. by randomly selecting 200 fruit from the center tree in each replication. A sub-sample was taken from the harvest sample from the check plot and the repellant block, and examined in the laboratory to determine if a reduction in punctures from AM had occurred in these plots. Damage from AM was measured upon fruit inspection and was subjected to an AOV with SuperAnova (Abacus concepts). Means were separated with Fisher's Protected LSD Test ($P<0.05$). Data was transformed Arcsin (Sqrt X) prior to analysis.

OBJECTIVE 2 DEVELOPMENT OF ORGANIC THINNING STRATEGIES

Studies were conducted in Modena, NY, Geneva, NY and at Barker, NY to evaluate organically acceptable blossom thinners. In addition we tested lime sulfur as an alternative to carbaryl in conventional thinning programs.

Experiment 1: Timing Study (Hudson Valley) This experiment was conducted on McIntosh and Empire trees on M.26 rootstock to determine the application time that produces the best thinning response to fish oil + lime sulfur sprays. Fish oil was applied at 2% (vol:vol), and LS was applied at 2.5%. All treatments were applied by high-pressure handgun. Fruit set, yield, fruit size, fruit color and russet were evaluated. Fruit growth was measured periodically throughout the growing season. Leaf damage was rated, and photosynthesis was measured periodically, to evaluate the effect of the treatments on tree physiology.

Experiment 2: Alternative to Carbaryl in Thinning Combinations (Hudson Valley) This experiment was conducted on Gala/M.9 trees to determine if combinations of Fish Oil and Lime Sulfur could be used instead of carbaryl in thinning programs. Fish oil was applied at 2% (vol:vol), and LS was applied at 2.5%. Carbaryl was applied at 1 pt. / 100 gallons and Accel was applied at 53 oz. / 100 gallons. All treatments were applied with an air-blast sprayer. Leaf damage, fruit set, yield, fruit size, fruit color and russet were evaluated.

Experiment 3: Effect of Surfactants on Effectiveness of Lime Sulfur as a Chemical Thinner. (Geneva) This was conducted at the New York State Agricultural Experiment Station in an 12 year old block of Empire/M.9 apple trees with a spacing of 6' X 12' and trained to a vertical axis system. The trial compared the effectiveness of lime sulfur with various surfactants. The treatments also included and unthinned control and a NAA+Sevin treatment and a BA+Sevin treatment as commercial standards. A randomized complete block experiment was used with blocking done based on location in the field. There were 5 single tree reps per treatment. Each test tree had a guard tree on each side. Tree row volume for a dilute spray was 200 gal/acre. Trees were sprayed with an airblast sprayer at 100 gal/acre using a 2.0X concentration of thinning chemicals. The surfactants (oils, Regulaid and Silwet) were not concentrated. Sprays were applied on May 16, 2002 at petal fall. Fruit set was measured on two tagged limbs per tree where the number of flower cluster and number of fruits harvested were recorded. Plot were harvested and fruit number and yield were recorded. A sample of fruit was collected for analysis of fruit quality and seed number. Fruit samples have not yet been analyzed.

Experiment 4: Evaluation of Lime Sulfur Rate and Lime Sulfur and Fish Oil Ratio. (Barker, NY) A second field study was conducted at the farm of James Bittner in Barker NY in an 6 year old block of Enterprise/M.9 and Goldrush/M.9 apple trees with a spacing of 7' X 12.5' and trained to a slender spindle system. The trial compared the effectiveness of lime sulfur, fish oil and NC-99 (a proprietary product containing a brine of Ca+Mg). The treatments also included and unthinned control. A randomized complete block experiment was used with blocking done based on location in the field. There were 5 single tree reps per treatment. Each test tree had a guard tree on each side. Tree row volume for a dilute spray was 125 gal/acre. Trees were sprayed with an airblast sprayer at 100 gal/acre but thinning chemicals were not concentrated. Sprays were applied on May 8, 2002 at full bloom. Fruit set, fruit number and yield were recorded. A sample of fruit was collected for analysis of fruit quality and seed number. Fruit samples have not yet been analyzed

OBJECTIVE 3. DEVELOPMENT OF ALTERNATIVE WEED CONTROL APPROACHES.
A prototype shrouded flame weeder developed by Ian Merwin and Kevin Bittner was tested for effectiveness at Singer Farms in Barker NY, and at the Cornell Orchards Research Farm in Ithaca, NY. The prototype flame burner was built from components that included the tank, valve assembly, two burners, control solenoids, and a skid mounted steel shroud. A plate was welded to a set of rear pallet forks for the tank to sit on. The burners were put on the end of a weed sprayer bar that was mounted to a bracket for a Muller rototiller and brush sweeper. A shroud built over the burners to contain the heat (Fig. 1). This allowed the burners to float freely upon the ground surface. The Muller bracket has its own single action hydraulics for lifting and allows the shroud to float over clumps of sod and groundhog holes (Figs. 1-4). This bracket arrangement also allowed a width adjustment for different orchard or vineyard tree spacings. The burners were then bolted to the back of the shroud facing inward. A hinge previously welded onto the shroud allowed the burners to be adjusted for angle. Roundstock skids were then made up to assist the shroud in floating over any rough areas as well as provide replaceable wear points. For use around larger trees the right side of the shroud can be unbolted and the burners can be angled towards the trees, enabling control of weeds in between the trees. All the electronics and valves were located inside the cab of a tractor, to protect them from the weather and tree branches. Protecting these components should help extend the life of the machine. For all practical purposes this flamer was set up to be adjustable for diverse planting densities of trees, ranging from dwarf blocks to semi dwarf trees.
During the initial year of testing (2000) we operated the machine in empty lots during the dormant season, and determined that everything operated effectively. During the summer of 2001 and 2002 we tested the flamer under different field conditions. Tests in 2001 were completed in a commercial ten acre tart cherry block of Montmorency on Mahleb rootstock that was uniform and already had good weed control established. In 2002 tests were done in a high-density Liberty/M.9 apple orchard at Cornell orchards. We used the flamer at different speeds and pressures and shrouded and unshrouded as well as shrouded with one side missing or a door to allow the flames to get between the trees.
The measurements consisted of weed height before and a few days after each application, visual estimation of % ground covered with weeds, and the types of weeds. Prior to the treatment with the flamer, the weeds were mowed to three inches high. The flame and paraquat treatments were then applied. A week later the percent of foliage remaining was estimated visually.

Results and Discussion:

OBJECTIVE 1. ORGANIC ARTHROPOD MANAGEMENT SYSTEM.
AM pressure in the test orchard was moderate to high as indicated by the damage levels found in the untreated check plots and by high trap catches of flies throughout the season. The weekly applications of Surround provided good control of AM damage regardless of which nozzle was used (hollow cone-2.4%, air induction-3.3%) (Table 1). The exact mode of action of this material against AM is not known. However, the coverage of kaolin reduces visual stimuli, and may affect the ability of the flies to recognize and orient to apples. Also, the buildup of clay on the apple may act as a deterrent to females attempting to oviposit. The spinosad bait also

reduced damage found at harvest (12.8%), however it was not significantly different from the check (24.6%). The repellant plots (20.3%) also were not statistically different from the untreated check plot (Table 2). The pressure found in this orchard is many times greater than that found in the average commercial block. Because of this, the constant presence of flies in the orchard was probably too high a population for the weaker programs to control. The sub-sample set inspected for punctures provided little insight into the efficacy of the repellant plot. The untreated check plot yielded a mean result of 1.3 punctures per apple and the repellent had a mean of 1.04 punctures per apple. When analyzed and subjected to AOV, the two treatments were not statistically different from each other. Trap catches taken over the duration of the trial seemed to indicate that some repellency was being exhibited from the dispenser's. A mean of 7.6 flies per trap were caught in the untreated check plot, while a mean of 12.3 flies per trap were caught in the repellent block. When subjected to an AOV these two treatments were not significantly different from each other. Therefore the damage found in these blocks at harvest adequately represents these findings.

Apple maggot control programs with Surround gave excellent control and close to what is achieved with conventional pesticides. Our previous works showed that Surround also controlled internal lepidoptera and had a significantly higher percentage of clean fruit than other organic approved treatments. Our results show that the best organic apple production protocol presently available is a Surround program. However, results are much poorer than conventional pesticides.

Most of the organic apples sold in NY are sold for processing, but there are small niche markets that have limited amounts of fresh fruit. In both markets fruit generally sells for twice the amount of conventional grown products. The Surround spray program results in a relatively high percentage of clean fruit, but this may still not be enough to make the system economically feasible. The organically approved insecticides we used are about five to six times more expensive than conventional insecticides. Our estimates of insecticide costs show that the two treatments we evaluated would cost 5-7 times as much as conventional insecticides. Competition for the organic market is small and consumers concerned about the pesticides being used for conventional growing are probably willing to pay considerably more for certified organic products.

OBJECTIVE 2. ORGANIC THINNING STRATEGIES

Timing Study: All timings resulted in thinning of McIntosh, with later timings tending to remove more fruit (Table 3). Empire fruit set was not significantly reduced by FOLS in this study (data not presented). All timings resulted in larger McIntosh fruit, the 5 DAPF timing resulting in the greatest amount of fruit of three inches diameter or greater, compared to single applications at 15 or 21 DAPF. Double applications thinned the most fruit and resulted in the greatest proportion of large fruit.

The mode of action of FOLS is not limited to desiccation of flower parts, as shown by the efficacy of the post-bloom treatment. This finding has great value, as the timing of true blossom thinners requires great precision, which contributes to frequent failure of the thinning sprays, limits the number of acres that can be effectively treated, and contributes to grower stress. It now appears that the effective timing window of these thinners is much broader than originally thought. Further studies are planned to determine the actual mode(s) of action, as an understanding of how these chemicals cause fruits to thin would be of great value in assessing their safety and reliability as thinners.

Carbaryl Alternatives Study: A killing frost occurred in this orchard during bloom, which reduced fruit set of all trees. The blocks were arranged by location in the field, and replicate 5 in the lowest row was dropped from the study to eliminate those trees most affected by the frost. The effects of thinning treatment of the remaining trees were still negatively impacted by the adverse weather, so it is difficult to draw firm conclusions from this single year of data.

FOLS at PF followed by Accel at 8 mm fruit diameter and the FOLS/Accel or carbaryl/Accel tank mixes applied at 8 mm resulted in the fewest fruit per tree at harvest (Table 4). None of the treatments had a significant effect on fruit size, fruit shape, seed number or russet rating in this year of frost-induced light cropping.
Carbaryl alternatives may become necessary, as a result of future FQPA rulings, and because of export restrictions imposed by buyers in the United Kingdom. Further research is needed to evaluate the use of organic thinners in combination with conventional post-bloom materials.

Alternatives to Fish Oil Study: In 2002 the weather at Geneva during bloom and for 10 days after petal fall was cool. This resulted in a protracted bloom and slow fruit growth after bloom. Fruit set and fruit number per tree on untreated trees was high (83% and 414 respectively) (Table 5). Lime sulfur alone did not significantly reduce fruit set or fruit numbers compared to the controls. However, the addition of either fish oil or ultra fine spray oil did result in significant thinning. Neither the addition of Regulaid or Silwet to lime sulfur sprays improved the thinning effectiveness of lime sulfur. The thinning effectiveness of the lime sulfur + oil sprays was not as great as the traditional thinning treatments of NAA + Carbaryl or BA + Carbaryl. None of the lime sulfur treatments significantly improved fruit size although the lime sulfur + oil sprays were numerically larger. The two commercial standard treatments than thinned more did improve fruit size with the BA + Carbaryl treatment improving size more than the NAA + Carbaryl treatment (Table 1).
The fruit size improvement due to the thinning chemicals was largely due to reductions in cropload. When fruit size was adjusted for cropload BA + Carbaryl gave the greatest size improvement followed by the NAA + Carbaryl treatment (Table 1). Although none of the lime sulfur treatments had larger adjusted fruit size than the control trees there was a trend toward adjusted fruit size from the lime sulfur + Ultra Fine oil.
This research shows that ultrafine spray oil is equally effective as Fish oil in thinning sprays. Fish oil is malodorous and relatively expensive. Horticultural oils may be more cost effective and less offensive to use.

Lime Sulfur and Fish Oil Ratio Study. When Fish Oil was not tank mixed with Lime Sulfur it still provided some thinning at the high rate but Lime Sulfur alone did not give any thinning with Enterprise and Goldrush apple trees(Table 6). The combination of Fish Oil and Lime Sulfur (FOLS) gave similar thinning regardless of the rate of Fish Oil or the rate of Lime Sulfur. NC-99 gave the most thinning in this trial.
Fruit size was improved with either Fish Oil, Lime Sulfur, FOLS or NC-99. The best size was obtained with the low rate of Lime Sulfur (1.5 gal/100) or NC-99. When the rate of Lime Sulfur was increased to 2.5 gal/100 then fruit size increase was less. Cropload adjusted fruit size was improved by the low rate of Lime Sulfur or NC-99 but not by any of the other treatments.
Both NC 99 and FOLS caused petal browning but NC-99 caused much more marginal leaf burn than either Fish Oil or Lime Sulfur or the combination of FOLS. These materials have been applied during warm, dry bloom periods in both 2000 and 2001 but in 2002 they were applied under cool conditions. Additional experience applying these thinners in more typical wet seasons is needed before we can be confident that the damage to fruit or foliage isn't economically harmful. We can conclude at this point that organic growers who use these chemicals as thinners will have to accept a noticeable amount of leaf burn resulting from their use but that commercially acceptable fruit thinning can be achieved.

OBJECTIVE 4. DEVELOPMENT OF ALTERNATIVE WEED CONTROL APPROACHES.
Results from our weed control project with the flamer were encouraging. There were nine treatments.
1. paraquat
2. shrouded flamer at 2 mph and 25 psi.
3. shrouded flamer at 4 mph and 25 psi

4. shrouded flamer at 2 mph and 40 psi
5. shrouded flamer at 4 mph and 40 psi
6. unshrouded flamer at 2 mph and 25 psi
7. unshrouded flamer at 4 mph and 25 psi
8. unshrouded flamer at 2 mph and 40 psi
9. unshrouded flamer at 4 mph and 40 psi.

The paraquat treatment resulted in about a 95% foliage kill rate. The shrouded flamer at the slower speed and higher temperature (Treatment 4) had the best results compared with paraquat—around 90 percent weed suppression. The fastest application rate with the shroud (Treatment 3) had the same results as the slowest application rate without the shroud (Treatment 8)—around 55 percent. The shroud nearly doubled the effectiveness of the flamer.
The use of flame weed control is more expensive than traditional residual herbicides which are used by most conventional growers. However the cost of flame weeding is comparable to the cost of multiple applications of contact herbicides. The cost of propane was comparable to that of herbicides depending on the prices of those chemicals and the fuel. It would take about the same number of operator-hours per acre, but the propane leaves no soil or groundwater chemical residue.
With flamers, weeds are usually not burned, rather the operation proceeds at a speed such that surface vegetation is merely scorched, and essential enzymes are denatured, which disables the plants' metabolism. Weeds then wither and succumb over a period of several hours, without actually burning up. This conserves the plant residues as organic matter and ground mulch for the soil. If done properly the weeds still look normal right after flaming, remaining green and still standing. After a few minutes to a few hours they start to wilt and die. Another advantage to using flamers is that soil is not disturbed, so new weed seeds aren't brought to the surface. Potential new weed seeds thus remain buried and dormant, unlike what happens in tilling practices. Cultivation has the disadvantage of bringing dormant weed seeds to the surface, breaking dormancy and recreating weed problems in just a few weeks. Problematic orchard weeds like pigweed (Amaranthus spp.) or lambsquarters (Chenopodium album) are especially prone to regenerate after tillage of cultivation practices, and seeds from these weeds can remain dormant in the soil for decades. Flaming works relatively well for controlling annual weeds, but perennials such as quackgrass (Agropyron repens) may grow back rapidly after flaming or mechanical tillage. Similar problems of weed regrowth also occur with non-residual herbicides such as paraquat, while flaming is usable in organic production and leaves no chemical residue on the crops or in groundwater. Flamers have the disadvantage that they could a ignite and burn mulches or other flammable materials. They are best be used following rain, or when there is dew on the surface vegetation to impede combustion of weeds. Flaming speeds is affected by atmospheric temperatures. On a cold day the flamer must travel more slowly to achieve the necessary minimum temperatures for weed control. It is more difficult to flame after a rain, because heat goes into evaporating the water before it can affect weeds or pests. However, the risk of combustion in weed residues, and smoke generation are also reduced in wet conditions. An advantage of flaming relative to tillage is that flaming is possible when soil is too wet for effective cultivation. The addition of a shroud around a burner can reduce the amount of fuel necessary, as it contains heat so that less escapes and the wind does not dissipate kinetic energy. Inside the shroud the heat is also more uniform and constant. This method should allow organic apple growers to limit weed competition and improve tree growth, yield and fruit size.

Table 1. Comparison of application technology for Apple Maggot control 2002. (Barker, NY)

Treatment	% Fruit with AM Trail	% Fruit with AM Sting
Untreated Controls	24.6 b	4.1 b
Surround WP 200gpa hollow cone nozzles	2.4 a	1.3 a
Surround WP 200gpa air induction nozzles	3.3 a	1.3 a
Spinosad Volatile Bait	12.8 ab	3.6 b
Antagonist Vials	20.3 b	3.1 b

Means within a column followed by the same letter are not significantly different (Fisher's Protected LSD Test, $P \leq 0.05$). Data transformed arcsine (sqrt[x]) prior to analysis.

Table 2. Effect of an antagonist on Apple Maggot fruit punctures and Apple Maggot trap counts 2002. (Barker, NY)

Treatment	Mean Number of Punctures per Apple	Mean Number of Flies per Trap
Antagonist	1.04 a	12.3 a
Untreated Control	1.3 a	7.6 a

Means within a column followed by the same letter are not significantly different (Fisher's Protected LSD Test, $P \leq 0.05$). Data transformed arcsine (sqrt[x]) prior to analysis.

Table 3. Effect of timing of Fish Oil + Lime Sulfur (FOLS) thinning sprays on McIntosh fruit set and size, 2002 (Hudson Valley)

Treatment	Fruit Set (%)	Fruit size(g)	3 in. & up (%)
Control	120 a	164	27
5 DAPF	89 b	180	40
15 DAPF	74 bc	173	35
21 DAPF	83 bc	172	34
5 + 15	69 bc	180	45
15 + 21	55 c	181	44

Table 4.. Effect of Fish Oil + Lime Sulfur (FOLS) thinning sprays or Carbaryl, with and without Accel thinning sprays on Gala fruit set and yield, 2002. (Hudson Valley)

Treatment	Fruit Set (%)	Fruit no./tree	Yield (kg)
Control	55 a	330 a	40
FOLS PF	43 a	217 ab	26
Carbaryl PF	45 a	193 ab	23
FOLS PF + Accel	18 b	175 b	23
Carbaryl PF + Accel	35 ab	228 ab	27
Accel	37 ab	163 ab	23
FOLS+Accel 8 mm	48 a	91 b	12
Carbaryl+Accel 8 mm	44 a	146 b	19