Organic Farming Research Foundation

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Organic farming research project report submitted to the Organic Farming Research Foundation:

Project Title:

Insect management and fruit thinning in commercial organic apple production systems in New York

FINAL PROJECT REPORT

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Funding provided by OFRF: $15,000

Funding awarded: Spring 2000 ($10,000) and Fall 2001 ($5,000)

Project period: 2000-2002

Report submitted: July 2003

EXECUTIVE SUMMARY:

Two grants from the Organic Research Farming Foundation in 2000 and 2002 provided matching funds for 2 grants from Cornell University and 2 grants from the NY state IPM program for the development of a system of organic apple production for the eastern US. We collaborated with two N.Y. growers: Jim Bittner, Singer Farms, Barker, NY who is currently producing apples commercially for the organic processing market, and Steve Clarke, Milton, NY, who established a new fresh market organic apple orchard for this project. They allowed us to evaluate a variety of pest management, fruit thinning and weed control tactics that would be compatible with the organic certification requirements in their orchards.

Our work focused on insect control, fruit thinning and weed control. For insect control we evaluated pheromone mating disruption, kaolin particle film sprays, Bacillus thuringiensis, horticultural mineral oils, an organic approved insecticide (Aza-Direct) and whole tree insect exclusion cages. Our results showed considerable promise with kaolin clay and pheromone microsprayers for mating disruption. They both provided moderate pest control but less than half of the fruit was free from insect damage. Handgun treatments were better than airblast treatments. Fruit insect damage results were generally higher than acceptable for the fresh market but adequate for the organic juice market. We believe much better fruit quality is attainable with more effective implementation of our treatment protocols. Both of the products showed some promise but organic growers will still have to accept considerably more insect damage than with conventional pest management products. In 2002 we focused our studies on apple maggot management with the organic approved insecticide (Surround) using two application methods. We also evaluated an experimental antagonist for apple maggot control. Surround gave very good control of apple maggot regardless of application method but the antagonist was ineffective.

For fruit thinning we evaluated two organically approved thinning agents (NC-99, a calcium/magnesium brine solution, and fish oil plus lime sulfur, FOLS). Our results show that both NC 99 and FOLS show promise as organic thinners for apple. 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 was only tested at full bloom. Both products also resulted in improved fruit size. There were some phytotoxic effects of both products and a small amount of fruit russetting from multiple applications of fish oil/lime sulfur. The NC-99 brine gave more phytotoxicity than the FOLS.

In our weed control work we evaluated mechanical tillage and weed flaming. We successfully modified and improved a weed flaming unit that gave promising results 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. The mechanical tillage implement which was imported from Germany gave good weed control in young apple blocks where there was not established sod in the tree rows. However, in mature blocks the sod was too thick to allow adequate weed control with the tillage implement.

The combination of Surround for insect control, Fish oil/lime sulfur for fruit thinning and the shrouded flame weeder for weed control are three important pieces to organic apple production in the eastern US. These 3 pieces, coupled with new disease resistant varieties and rootstocks and the newly

approved spinosad insecticide Esteem, which we are testing in 2003 should allow a viable production system for organic apples.

INTRODUCTION

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 while organic apple production in the western US and Canada has increased significantly in the last few years. Marketing opportunities for NY-grown organic apples (both fresh and processed products) have prompted several NY apple growers to request research by Cornell University to develop a system of organic apple production for NY. In 2000 and 2002 we obtained funding from the Organic Farming Research Foundation and in 2000 and 2001 from the Cornell Organic Farming Program and in 2001 and 2002 and from the NY state IPM program.

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.

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 tree growth of young trees and reduces yield, and fruit size in older trees.

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). However, both of these products can cause phytotoxicity. Sulfur is especially phytotoxic if applied to trees at or near the same time that spray oils or other products with an oil-based carrier are applied to foliage. Producers of organic apples must learn to use these products without causing fruit russetting or other phytotoxicity.

Our objective in this project was to develop an integrated organic apple production protocol for NY that can be used with existing disease susceptible apple orchards and one that can be used with new orchards using disease resistant apple varieties and rootstocks. Our work has focused on insect control, fruit thinning and weed control. The project utilized existing certified organic apple blocks of both disease susceptible and disease resistant varieties at a commercial apple farm (Jim Bittner in Niagara County) and a conventional orchard at Steve Clark’s (Ulster County). We also established a new planting with disease resistant varieties and rootstocks for future work at Steve Clark's farm.

PROJECT OBJECTIVES

1. Develop an integrated, sustainable arthropod management system that will allow the production and marketing of certified organic apples.

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.

OBJECTIVE 1. ORGANIC ARTHROPOD MANAGEMENT SYSTEM.

Leaders: A. Agnello, and H. Reissig, Department of Entomology, NYSAES, Geneva, NY 14456

INTRODUCTION

In the past, very few growers in the Northeast have attempted to produce apples organically without using conventional, broad-spectrum pesticides, because of the practical difficulties involved in controlling insects and mites in this region. However, during the last 10–15 years, extensive studies have been conducted to develop management programs that can replace current strategies that rely primarily on pesticide applications. For example, recent studies have shown that a predaceous mite species, *Typhlodromus pyri* (Scheuten), which is native to apple production regions in Western NY, can successfully control populations of the key mite pest species, European red mite [*Panonychus ulmi* (Koch)], in commercial apple orchards, so that no applications of miticides are required for seasonal control. Recent experiments in NY and elsewhere have also shown that pheromones can be deployed in apple orchards to disrupt mating of key lepidopterous species, such as the codling moth [*Cydia pomonella* (L.)], oriental fruit moth [*Grapholita molesta* (Busck)], and leafroller species, and thereby substantially reduce (but not eliminate) fruit damage from this complex of pests. Improved lures and traps have also been developed during the last decade for another key indigenous insect species infesting apples throughout the northeast, the apple maggot [*Rhagoletis pomonella* (Walsh)], and these devices have been used successfully in commercial apple plantings to virtually eliminate fruit infestations from this pest. In addition to some of these newer types of organically compatible insect control technology, traditional control methods such as selective fruit thinning, pruning, sanitation (frequent removal of dropped apples infested with internal insect pests), removal of wild hosts near apple plantings, and exclusion of insect and mite pests with biological or physical barriers near or around trees, have also been shown to reduce populations of many types of insect and mite pests in Northeast apple plantings.

MATERIALS AND METHODS

Year 2000 Studies.

In 2000 all work was conducted in nonreplicated plots set up in two orchards owned by Singer Farms, Niagara Co. The first (Orchard P1) was a 10-acre mixed planting of 'McIntosh', 'Cortland', and 'Red Delicious' on a vigorous rootstock, approximately 20 years old. This orchard, located on a lakeshore site, had no history of problems with mites or leafrollers, but did have endemic populations of apple maggot, codling moth, oriental fruit moth, and some plum curculio [*Conotrachelus nenuphar* (Herbst)]. The second (Orchard G11) was 11 acres of 'Taylor Rome' trees on a semi-dwarfing rootstock, approximately 15 years old, and located a mile inland and bordered by woods to the south. Plum curculio pressure was traditionally higher in this block, with less codling moth and apple maggot. All trees received an early season disease control spray program consisting of the following applications: 17 April and 1 May: COCS + Oil; 10 and 17 May: Sulfur.

Pheromone Mating Disruption Block. No further sprays were applied in Orchard P1. On 11 May, automated pheromone microsprayer dispensers were hung in the trees at a rate of 5 per acre. These prototype units, obtained through a collaborative research arrangement from Michigan State University, consisted of an aerosol canister fitted with a battery-driven timer circuit that released a short burst of pheromone mixture into the tree canopy every 3–4 minutes, operating continuously for 120 days. The mixture, which was intended to simulate the mating pheromones of codling moth (CM), oriental fruit moth (OFM), and obliquebanded leafroller, *Choristoneura rosaceana* (Harris) (OBLR), consisted of: (Z) 11-14 OAc (8%); (Z) 11-14 OH (0.1%); (Z) 8-12 OAc (4.7%); (E,E) 8,10-12 OH (7%); and ethanol (80.3%). At this density, the release rates of the individual pheromone blends was calculated to be: OFM, 600 mg/acre/day; CM, 900 mg/acre/day; and OBLR, 1038 mg/acre/day. The units were hung near the top of the tree canopy (~9 ft height), and spaced throughout the planting in a regular grid pattern. Wing-type pheromone traps (Pherocon) baited with commercial lures (Trécé) were hung at head height in the central interior section of the orchard. Three traps were hung per species, at spacings of 50–100 yd; these were checked 2–3 times per week from 30 May until 7 September.

Kaolin Particle Film Block. In Orchard G11, a spray program using Surround 95WP (kaolin clay) was started shortly after fruit set. Applications were made in one-third of the block (5 rows) using 50 lb/100 gal/acre on 19 and 23 June, 14 and 20 July, and 11 August. No other pesticides were applied to these trees.

Bacillus thuringiensis and Oil Block. In another 5 rows of Orchard G11, a spray program was tested using Dipel 10.3DF (B.t.; 1 lb/acre) plus Omni Supreme (highly refined horticultural mineral oil, 1%) at 100 gal/acre, also starting shortly after fruit set. Applications were made on 19 and 27 June, 14 and 20 July. No other pesticides were applied to these trees.

Whole-Tree Exclusion Cages. Some apple producers serving certain specialty and international markets go to the trouble of bagging individual fruits to protect them from insect damage without the use of chemical pesticides. The idea of caging entire trees was proposed as a less labor-intensive, if somewhat less effective, alternative to this practice. A local tentmaker (Warder's Awnings and Tentworks, Geneva) was contracted to produce large sewn fabric bags in the shape of a sack 10 ft high and 10 ft diam, with a drawstring closure. Four cages were made using each of four different commercial screening or netting products:

- ABC Netting Inc., Mississauga, ONT (product #K1-1001)
- Fablok Mills Inc., Murray Hill, NJ (product #3149)
- Lumite, Synthetic Industries, Gainesville, GA (product #C20W)
- Solargard 40% Black Weathershade, Griffin Greenhouse Supplies, Auburn, NY (product #78-3025)

On 26 May, after the pollination period, one interior row of Orchard G11 was selected, and the cages were placed over individual trees along the length of the row. The openings were cinched tightly against the trunks at ground level, and no further sprays were applied to these trees for the remainder of the season. Cages were removed at harvest.

Wing-type pheromone traps (Pherocon) baited with commercial lures (Trécé) were hung at head height in the central interior section of Orchard G11 as well, to serve as a Check against the catches in the pheromone disruption block. Three traps each were hung for CM, OFM, and OBLR, at spacings of 50–100 yd; these were checked 2–3 times per week from 30 May until 7 September.

On 30 August, light readings were taken inside and outside each of the cages to measure the degree of reduction in photosynthetic light caused by each of the cage materials. One reading was taken at 11:00 am on the interior and exterior edges of each cage using a photometer (LI-170, Lambda Instruments) with the probe held at a height of approximately 7 ft; a second reading was taken at 3:00 pm the same day. The relative difference for each set of measurements was converted to a percent reduction, and an ANOVA plus lsd test was performed on the arcsine square root-transformed data to separate treatment means.

Pre-harvest fruit samples were evaluated for insect damage just before the respective harvest dates of each of the varieties in these two orchards: 'McIntosh', 24 August; 'Cortland' and 'Red Delicious', 19 September; and 'Rome', 5 October. In each of the treatment plots described, as well as in a 5-row section of Orchard G11 left as an untreated Check, 100 fruits were sampled randomly from each of 5 trees and inspected for damage caused by any of the major or minor direct apple pests commonly encountered in commercial plantings. Percent fruit damage was recorded for each class of pest in nonexclusive categories (i.e., each fruit may have exhibited more than one type of damage), and treatment means were separated using ANOVA plus an lsd test on arcsine square root-transformed data. 100 fruits were also sampled from each caged tree in Orchard G11; in addition to the pest damage evaluation, these fruits were first run through a commercial fruit grading line with a video camera and computerized digital color scanner to separate them into five different categories based on percent-red measurements: <25, 25–33, 33–50, 50–75, and >75% red. These were compared against the fruits taken from the untreated Check trees.

<u>Year 2001 Studies.</u>

In 2001 a field trial was established in a certified organic apple orchard in western NY where two season-long insect control programs with organic approved insecticides were compared. Sprays were applied by the grower with a FMC airblast sprayer (300 psi) using 100 GPA. Applications of organic approved insecticides started at petal fall (5 May) and continued until the final cover spray (14 Aug). The orchard was divided into two treatments: 1) Surround WP (50.0 lbs. form/A) applied weekly for all sprays (13 applications); 2) Surround WP (50.0 lbs. form/A) applied weekly for five applications and then Aza-Direct EC (32.0 oz form/A) applied weekly for the remainder of the cover sprays (8 applications). Surround is a formulation of kaolin clay, which is a slurry of clay particles that is intended to form a barrier film that acts as a broad spectrum agricultural crop protectant against insects and mites. Azadirachtin (commercial formulation GWN 1535) is a chemical extracted from the Neem tree that has provided control of many of the key apple insect pests such as second generation of codling moth and apple maggot. All of the orchard received applications of one of the two treatments; thus there was no untreated control, and there was no replication of treatments. The use of Surround in both treatments for the petal fall and early cover sprays was intended for the control of plum curculio. The plot that received the Aza-Direct cover sprays was converted to this spray regime only after 340 degree days (Base 50o) was reached, after which PC is no longer ovipositing. Harvest evaluations were conducted by randomly selecting 500 fruit on 10 September from each treatment and inspecting them for damage. Data was subject to analysis by SuperAnova 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.

Economic aspects--such as the cost of these materials, marketability of the fruit and labor intensity--were also taken into consideration upon the final overview of the project. Also in this orchard, two rows were excluded from these treatments and put into another trial to test the efficacy of other insecticides against apple maggot and the internal lepidoptera complex (oriental fruit moth, codling moth and lesser apple worm). These applications were made with a handgun (450 psi) and used both of the materials applied with an airblast sprayer in the rest of the orchard. This allowed us to compare the results of efficacy between application methods.

Year 2002 Studies.

A field trial was established in 2002 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 was 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.

RESULTS

Year 2000 Results.

Pheromone Disruption Although the two test orchards had somewhat different moth population pressures and histories, the pheromone trap catches in the microsprayer plot showed a reduction over the non-disrupted Check that was impressively close to complete (Fig. 1). A comparison of total moth catch over the entire season shows a trap catch reduction of 97.6% for CM, 99.4% for OFM, and 95.5% for OBLR, indicating that the microsprayers were evidently very efficient at disrupting chemical communication of these pest species.

Light Reduction by Whole-Tree Cages Results of the light measurements show that all of the cage materials were generally comparable in the reduction of photosynthetic light they caused inside the cages. Most readings were in the range of 25–40%; however, the Fablok Mills material appears to be most uniformly on the lower end of this range (Table 1). The skies were a bit more overcast during the 11:00 am reading, so these conditions may have served to emphasize the difference among the materials, as seen in the more complete separation of the treatments during that reading.

Harvest Evaluations Insect pest pressure was relatively high in both orchards, but with some differences in population pressure of relative species (Table 2). In Orchard P1, plum curculio and apple maggot accounted for the greatest proportion of the damage, a reasonable result considering that the pheromone treatment would not be expected to protect against these pests. Injury varied by fruit variety, with 'Red Delicious' showing less than the other two, particularly in the case of apple maggot. Treatment effectiveness against the target species was not complete, but all the damage categories resulting from attack by these lepidopterous pests — Internal Lep, Sting, Early OBLR, and Late Lep — was considerably less than would normally be expected in an unsprayed orchard in this situation, as indicated by the check trees in the other orchard.

The fruit damage in the Orchard G11 treatments show some interesting trends, and the same untreated check fruits were used as comparisons in the two trials—B.t./Oil vs. Kaolin, and the cage tree test (Table 2). The only significant difference seen in the alternative materials comparison is the effect of the kaolin treatment on reducing plum curculio damage to roughly half of the levels seen in the B.t./Oil and check plots. Much of the damage in this category was actually not a result of early season oviposition scarring (which none of the treatments would have affected, as they weren't started until after this activity was finished), but instead represents the late season feeding injury caused by adults returning to the trees near the end of the summer; kaolin residues apparently were better at preventing this feeding damage than the B.t./Oil applications. There did turn out to be more apple scab and sooty blotch/flyspeck injury in the treated trees than in the checks, but the reason for this is not known. Levels of clean fruit were highest in the kaolin treatment, although the 24% reading was still not significantly different from the check. It should be noted that maintaining adequate residual coverage of any sprayed material was especially difficult because of the frequency and volume of rainfall received this season (Fig. 2).

The whole-tree cages did result in significantly higher levels of clean fruit than were seen in any of the other treatments, although they were not successful in excluding all of the direct fruit pests (Table 2). Injury from internal Lepidoptera, apple maggot, and plum curculio was substantially reduced on these trees compared with the Checks; however, once again in the case of plum curculio this derives primarily from the exclusion of late season adult feeding, as the cages were not placed until much of the oviposition damage already had been done. The cages had no effect on late Lep feeding damage, presumably because the larval forms responsible for this injury were already on the tree when the cages were installed. The type of damage noted in this category was not typical of the feeding injury normally caused by the most common tortricid pest in N.Y. apple orchards, OBLR, but rather resembled that of another species in this family, probably lesser appleworm [*Grapholita prunivora* (Walsh)] or even redbanded leafroller [*Argyrotaenia velutinana* (Walker)]. Finally, incidence of both apple scab and the sooty blotch/flyspeck summer disease complex was higher inside the cages than on uncaged Check trees. This may point to a microhabitat difference inside the cages that favored disease development.

Fruit Color Effects Following the determination that each of the tree cage materials caused a marked reduction in the transmission of light to the interior, it was not unexpected to see poorer fruit color in all of the cages than was produced on uncaged Check trees (Table 3). Of all the materials used, the Fablok-caged trees had the highest proportion of fruits in the reddest categories, in agreement with the results of the light meter readings taken during the summer. This effect was intensified by the fact that these fruits are 'Taylor Romes', a particularly red strain of the 'Rome' variety. This can be seen by comparing the values against those from one of the Check trees that happened to be a different strain of 'Rome' that is less red than the others. Although still redder than the fruits in the tree cages, the difference is less extreme for this variety, and it could be argued that color differences could go virtually unnoticed for other varieties that are not so highly colored.

Year 2001 Results

The insect control programs with Surround or Surround/Aza-Direct gave only partial control of direct fruit pest but not complete control as with conventional pesticides (Table 4). Very few significant differences were found between the treatments when compared for insect damage. The Surround only program controlled internal lepidoptera significantly better than the combination program of Surround and Aza-Direct. Although the remainder of the insect categories were not significantly different from each other, overall the Surround only treatment had a significantly higher percentage of clean fruit. This is due to the accumulation of damage from each of the different pests, because in most cases the combination treatment of Surround and Aza-Direct had slightly higher percentages of damage. The one exception to this is occurrence of apple maggot where Aza-direct resulted in a lower damage level than Surround. This was due to the poor coverage of Surround when applied with an airblast sprayer. In contrast when Surround was applied with a handgun sprayer perfect apple maggot control was obtained, as well as significantly better efficacy against internal worms (Table 5). When Aza-Direct was applied by handgun, activity against internal lepidotera was better than by airblast sprayer but was poorer for apple maggot. This is probably due to a varietal difference because the handgun plots were set up on ‘Cortland’ trees, and the data taken from the airblast plot was on "Delicious’. Knowing that coverage from hand applied treatments is significantly better than from airblast applications indicates that Aza-Direct is not very ineffective for AM control, especially with a susceptible variety like ‘Cortland’.

The organically approved insecticides we used are about five to six times more expensive than conventional insecticides. An increased number of applications, combined with the problem of increased labor involved with these applications, especially if applied by handgun, makes organic insecticide application a very expensive insect control program (Table 6). Our estimates of insecticide costs show that the two treatments we evaluated would cost 5-7 times as much as conventional insecticides.

Year 2002 Results

A field trial in a certified organic apple orchard which has had high apple maggot (AM) pressure was conducted in 2002. We found that in 2002 the AM pressure 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 7). 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 8). 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 analysis of variance (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 dispensers. 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.

Table 1. Light readings in whole-tree cages, (Aug. 30, 2000) (Microeinsteins/m^2/sec x 0.1 Watts/m^2 x 10 Lux; full sun = 2000)

	11:00 AM			3:00 PM		
Cage Material	Outside	Inside	% Reduction	Outside	Inside	% Reduction
Fablok	553	427	22.6 a	1540	1148	25.6 a*
ABC	548	320	41.7 b	1550	1030	33.7 ab
Lumite	546	320	41.4 b	1494	1118	25.2 a
Solargard	585	335	42.7 b	1453	915	37.1 b

*Values in the same column followed by the same letter are not significantly different (*P* = 0.05, Fisher's protected lsd test).

Table 2. Harvest evaluation of fruit insect damage in blocks of apples managed using various organically approved pest management techniques, Singer Farms, Niagara Co., NY. (2000)

Treatment	Clean Fruit	Int. Lep[1]	Sting[2]	Early OBLR	Late Lep	Tarnished Plant Bug	Plum Curculio	Apple Maggot	Apple Scab
Orchard P1 Microsprayer									
McIntosh	1.4 a	12.0 a	7.6 a	0.4 a	10.0 a	1.8 a	78.8 a	77.2 a	—
Cortland	0.0 a	22.8 b	1.0 b	1.0 a	11.6 a	1.8 a	93.2 a	21.8 b	—
Red Delicious	35.0 b	8.8 a	0.0 c	1.4 a	6.6 a	1.0 a	47.0 b	0.2 c	—
Orchard G11 (Rome)			Sooty Blotch/ Flyspeck						
Kaolin	24.0 b	38.7 a	6.7 a	1.6 ab	17.4 a	1.0 a	31.5 a	6.1 a	3.4 b
Bt + Oil	7.4 a	53.4 b	6.1 a	3.2 b	15.1 a	2.0 a	53.0 b	2.6 a	7.9 c
Check	15.3 ab	30.6 a	3.0 a	0.0 a	16.8 a	1.3 a	64.8 b	3.0 a	0.4 a
Tree Cages									
ABC	47.2 b	1.0 a	0.0 a	15.7 c	24.2 a	2.5 c	10.5 a	0.0 a	10.0 c
Fablok	41.3 b	4.0 a	0.8 a	11.2 bc	19.2 a	0.5 a	27.8 bc	0.8 ab	3.5 b
Lumite	46.7 b	1.0 a	0.0 a	8.6 b	31.7 b	1.6 bc	19.0 ab	0.0 a	1.2 ab
Solargard	38.8 b	3.3 a	0.3 a	8.0 b	23.9 a	0.8 ab	39.1 c	0.0 a	0.5 a
Check	15.3 a	30.6 b	3.0 b	0.0 a	16.8 a	1.3 ab	64.8 d	3.0 b	0.4 a

Values given are percent fruit inspected in non-exclusive pest damage categories. Values are mean % damage to 400–500 total apples per variety or treatment in each orchard (100 from each of 5 trees, except for 100 from each of 4 trees for ABC, Fablok & Lumite tree cages).
ANOVA done individually for each damage type within each plot; mean separation on arcsine square root-transformed values. Within each orchard and plot, values followed by same letter not significantly different ($P = 0.05$; Fisher's protected least significant difference test.)

[1] Complex of internal Lepidoptera including codling moth, oriental fruit moth, and possibly lesser appleworm.

[2] Superficial injury to fruit skin caused by either nominal caterpillar feeding or apple maggot oviposition probe.

Table 3. Fruit color grades from trees in whole-tree exclusion cages throughout the summer. (2000)

	Percent-red category				
Cage Material	0-25%	26-33%	34-50%	51-75%	76-100%
Check	0.0 a	0.0 a	0.0 a	0.0 a	100.0 a
ABC	22.4 c	12.5 c	26.4 b	32.3 bc	6.5 a
Fablok	7.1 b	5.9 b	20.8 b	44.7 c	21.6 b
Lumite	22.5 c	11.0 c	26.2 b	33.7 c	6.7 a
Solargard	32.4 c	14.5 c	27.5 b	21.7 b	4.1 a
Check (non-red strain)	3.4	5.7	6.8	67.0	17.0

Values in the same column followed by the same letter are not significantly different (P = 0.05, Fisher's protected lsd test).

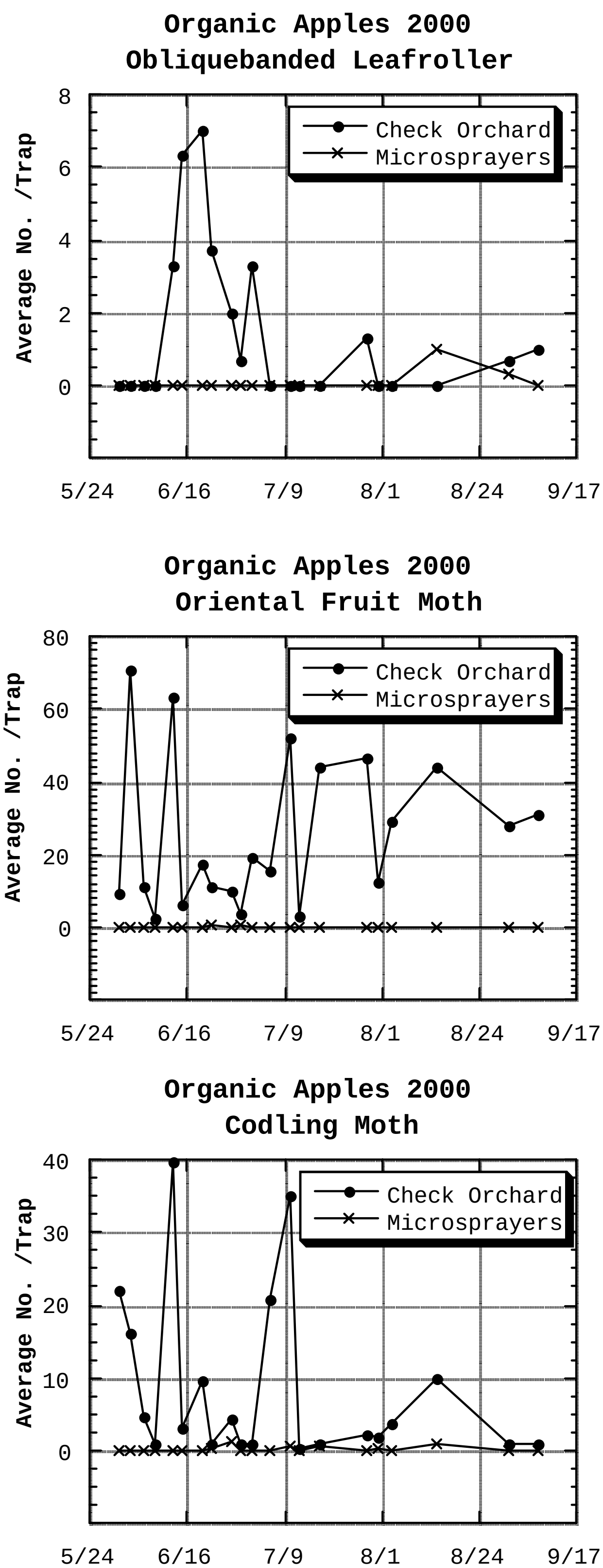

Fig. 1. Pheromone trap catches in an orchard permeated with a multi-species pheromone blend, compared with those in a non-disrupted block. Niagara Co. (2000)

Fig. 2. Rainfall accumulation in Appleton during the summer 2000 season.

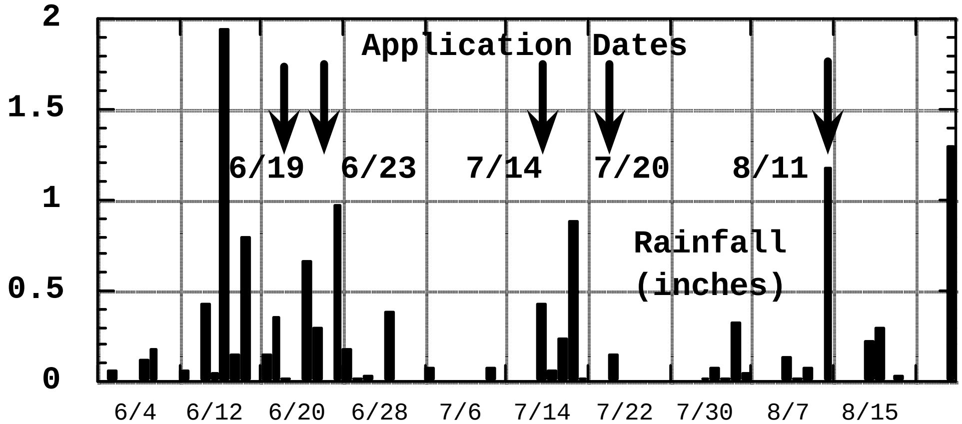

Table 4. Fruit Damage of two Organic Insecticide Programs. (2001)

Pest	Mean % Fruit Damage	
	Surround	Surround/Aza-Direct
Internal Lepidoptera	20.4 a	34.0 b
Spring OBLR	0.2 a	0.4 a
Summer OBLR	5.0 a	8.0 a
Apple maggot	9.0 a	3.6 a
Plum curculio	25.4 a	32.8 a
Tarnished plant bug	0.4 a	0.8 a
Clean	44.6 b	29.2 a

Means within a row followed by the same letter are not significantly different (Fisher's Protected LSD Test, P<0.05). Data transformed Arcsin (Sqrt X) prior to analysis.

Table 5. Comparison of Handgun vs. Airblast Application Method on Efficacy of Two Organic Insecticides (2001).

Treatment	% Internal Lepidoptera	% Apple Maggot
Surround Handgun*	3.5 a	0.0 a
Aza-Direct Handgun*	6.9 a	42.0 c
Surround Airblast**	20.4 b	9.0 b
Aza-Direct Airblast**	34.0 c	3.6 ab

* - Data taken from 'Cortland' trees
** - Data taken from 'Delicious' trees
Means within a column followed by the same letter are not significantly different (Fisher's Protected LSD Test, P<0.05). Data transformed Arcsin (Sqrt X) prior to analysis.

Table 6. Pesticide Cost Analysis of Organic Insecticide Programs (2001).

Material	Rate/A	Cost	Cost/A/ Application	Cost/A/Season
Guthion 50	1.5 lbs./A	$8.13 lb.*	$12.20	$85.40 (7 applications)
Surround WP	50.0 lbs./A	$0.65/lb.*	$32.50	$422.50 (13 applications)
Aza-Direct EC	32.0 oz/A	$1.48/oz*	$47.36	$615.68 (13 applications)

* Prices quoted from UAP Northeast 10/19/01

Table 7. 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 8. 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.

DISCUSSION

Results from our studies show that the best organic apple production protocol presently available results in less than half of the fruit being free of insect damage when the control treatments are applied by conventional airblast equipment. Few alternative insecticides or application equipment exist to these materials. The relatively poor insect control levels achieved are a detriment to organic apple production in NY. Application technology for these particular products has not yet been perfected, but recent studies have shown that hand application of Surround results in better coverage. This may be a viable option for those looking to increase the amount of insect free fruit produced by their organic orchards.

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, organic fruit generally sells for twice the amount of conventionally grown products. By increasing the percentage of clean fruit growers could also increase gross returns, but this may still not be enough to make the system economically feasible. The new spinosad insecticide Esteem may provide improved insect control. We are testing this product in 2003.

The evaluations of tactics in these trials provide an indication of their efficacy under fruit growing conditions commonly encountered in the Northeast. Although this research consisted of a variety of insect control methods that could be applicable to organic apple production in NY, it did not represent a complete organic pest management program for all of the major species present, nor were the tactics necessarily implemented in the most effective or optimal manner to obtain the desired results. For example, organizational and logistical details prevented the spray programs from starting earlier in the season, and the unusually wet spring weather proved to be an unexpected complication in maintaining a reasonable treatment schedule. Under different circumstances, overall fruit damage would be expected to be lower than observed here. Likewise, the approach of enclosing trees in cages would be more practical for smaller trees than those used in this test. This might even allow placement early in the season, so that cages could be removed or raised temporarily during bloom for pollination to take place, and re-installed afterward. Further investigation would be needed to address the need for early season apple scab control, and fruits should ideally be evaluated also for overall quality (e.g., soluble solids content), in view of the reduced light levels inside of caged trees.

Furthermore, suspension of all or most protectant sprays could likely encourage the development of pests that are not normally encountered in most conventionally managed apple orchards. For example, both of the orchards in this study developed rather serious infestations of apple leaf curling midge [*Dasineura mali* (Kieffer)], an established pest species that generally goes unnoticed because it is easily killed by any of the toxicants routinely used during the season in standard commercial apple orchards. This midge, which has three generations per year, lays its eggs in the rolled margins of undeveloped leaves; larvae feed on the surface leaf tissue, which prevents the leaf from unrolling and stunts shoot growth. Although fruits are not affected, young trees may suffer developmental setbacks. There are doubtless several other insect species present in most Northeast apple orchards that could present unforeseen pest management challenges under production regimens devoid of conventional crop protectants.

Apple maggot control programs with Surround gave excellent control and close to what is achieved with conventional pesticides. Our previous work 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.

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 DEVELOPMENT OF ORGANIC THINNING STRATEGIES

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INTRODUCTION

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 and is not feasible in some areas due to labor shortages and/or high cost. Our goal was to develop alternative chemical thinning strategies that are based on chemicals that have organic approval.

MATERIALS AND METHODS

Year 2000 Studies.

Studies were conducted in Modena, NY and at Olcott, NY to evaluate organically acceptable blossom thinners. In addition we evaluated fish oil plus lime sulfur as a post-bloom thinner. Mature Gala trees on M.9 rootstock in the Hudson Valley were thinned with 4 % vol.: vol. NC-99, a calcium/magnesium brine solution (Genesis Agri Products, Inc., Union Gap, WA); 2% fish oil (Crocker's Fish Oil, Quincy, WA), tank-mixed with 2.5 % liquid lime sulfur (FOLS); or 3 pt. per 100 gal. Wilthin (AMADS, Entek Corp., Brea, CA), and were compared to an un-thinned control. All thinners were applied as a single spray at 80% bloom (May 4). NC 99 and FOLS were also applied as a double application, with one spray at 20% bloom (May 3), plus a second spray at 80% bloom. FOLS was also applied as a double application at petal fall and at petal fall plus seven days. Treatments were applied with an air blast sprayer calibrated to deliver 150 gallons per acre and the chemical thinners in this study were measured to deliver the dilute equivalent.

In the western NY trial, mature Rome and Delicious trees on MM.111 rootstock were sprayed with 4 % NC-99 (v/v); 2.5% Crocker's fish oil tank mixed with 2% liquid lime sulfur (FOLS); or 3 % Ammonium Thiosulfate (ATS) and were compared to an un-thinned control. All thinners were applied as a single spray at 80% bloom (May 13). FOLS was also applied as a double application at petal fall and at petal fall plus seven days. Treatments were applied with an air blast sprayer calibrated to deliver 100 gallons per acre and the chemical thinners were applied at 100 gallons/acre.

With both experiments, fruit set, yield and fruit size were measured. Repeat bloom was measured in the spring of 2001.

Year 2001 Studies

Hudson Valley Study. This study was conducted on mature Delicious/ M.7 trees in a commercial orchard in Modena NY. The trees had a calculated tree row volume of 240 gallons per acre. The experimental design was a randomized complete block with 4 replications and two trees per replicate. Buffer trees on either side guarded the test trees in each replicate. Blocking was done by location. The treatments were:

1) NC-99, a calcium/magnesium brine solution developed as an organic blossom thinner by G. S. Long Co., Yakima, WA. The dilute rate was 4 gallons per 100 gallons.
2) Fish oil + lime sulfur (FOLS). Crocker's fish oil (G. S. Long, Yakima, WA) at a dilute rate of 2.5 gallons / 100 gallons, was tank mixed with liquid lime sulfur (Miller Chemical) at a dilute rate of 2 gallons / 100 gallons.

Treatments were applied with an air blast sprayer calibrated to deliver 120 gallons per acre and the chemical thinners in this study were concentrated to deliver the dilute equivalent. Timings were at 80% bloom, or a double application, with one spray at 20% bloom plus a second spray at 80% bloom. Bloom advanced very rapidly in 2001, due to unusually warm temperatures, and the actual dates of application were 2 May for 20% bloom and 5 May for 80% bloom.

<u>Western NY Study</u> A similar thinning study was conducted in a certified organic apple orchard (certified since 1995) at Singer Farms in Appleton NY. The study compared the effectiveness of FOLS and NC 99 to a conventional blossom thinning chemical, Ammonium Thiosulfate. Unsprayed trees served as controls.

The experiment was done on three apple varieties: McIntosh, Cortland and Delicious. The experimental design was a randomized complete block with 4 replications and 1 tree per replicate. Buffer trees on either side guarded the test tree in each replicate. Blocking was done by location.

The trees were 25 years old and were on seedling rootstock. They had a spacing of 20 X 30 feet and a height of 18 ft. The trees had a calculated tree row volume of 300 gallons per acre and were sprayed with an airblast sprayer at 100 gal/acre. Chemicals were not concentrated to account for tree row volume in this part of the experiment. Sprays were applied on 8 May, when McIntosh and Cortland trees were at 80-100% bloom, and Delicious trees were at 50-80% bloom.

Flower cluster numbers were recorded at bloom on two scaffold branches, one on the east and one on the west side of the tree. Fruit numbers on those branches were recorded on July 13, 2000. Fruit set was calculated from the limb data. Plots were harvested and fruit number and yield were recorded. The McIntosh were harvested on Aug. 29, the Cortland were harvested on Sept. 20 and the Delicious were harvested on Oct. 9. A sample of fruit was collected for analysis of fruit quality and seed number. Fruit samples have not yet been analyzed for western NY.

<u>Year 2002 Studies</u>

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.

<u>Timing Study</u> (Modena NY) 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.

Alternative to Carbaryl in Thinning Combinations (Modena NY) 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 lime sulfur 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.

Effect of Surfactants on Effectiveness of Lime Sulfur as a Chemical Thinner. (Geneva, NY) 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 an 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. Plots 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.

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 an 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

RESULTS

Year 2000 Results

2000 Hudson Valley Study. All thinners caused petal browning and mild leaf spotting. The leaf damage was more noticeable when two applications were made than with one. Although some phytoxicity was observed on Delicious, the amount of damage was not enough to cause concern. Parts of an adjacent row of Cortland trees were also treated with each of the blossom thinners at 80% bloom, applied from one side only to avoid over-spray or drift on to the experimental trees. It was observed that the amount of leaf spotting on these trees was much greater than on Delicious.

FOLS reduced fruit set compared to untreated controls (Table 9). NC-99 also showed a tendency to thin, but the results were not significant. All thinning protocols appeared to reduce yield, but only the yield resulting from FOLS applied at 80% bloom was significantly less than the untreated control (Table 9).

Both organic thinners increased fruit size; however double applications were no better than a single spray at 80% bloom (Table 9). Overall, there was little difference between a single spray and a double spray in this study.

The gap in time between the two applications was only three days, due to unusually warm temperatures, which hastened bloom development. In the past, it was suggested that the reduction in fruit set caused by lime sulfur was due to a reduction in photosynthesis for several days after it was applied (Burrell, 1945). If this mode of action explains some of the activity of lime sulfur in causing fruit thinning, then timing the two sprays further apart would be expected to result in a longer period of reduced assimilation, and perhaps greater thinning.

Fruit russet was rated "1" for all treatments, including the control (Table 9). This rating corresponds to raised lenticels. The time of application of these materials may be early enough that there is little risk to fruit finish due to the minimal amount of tissue that is exposed at the time of application. The effects of the thinning treatments on return bloom will be evaluated in spring, 2001.

2000 Western NY study Foliar damage was not observed in this study where less active ingredient per acre was applied. Also, the foliage in this organic block had leaf spotting from a number of biotic causes, which made it difficult to attribute spots to any particular cause.

Both of the organic blossom thinning chemicals caused a significant reduction in fruit set while ATS treatment did not (Table 10). The NC-99 Ca/Mg brine product caused the most thinning while FOLS resulted in slightly less thinning. Despite significant thinning neither of the organic thinning products improved fruit size. It appeared that NC-99 reduced fruit size while FOLS and ATS had similar size as the controls. It should be noted that the level of fruit set on the untreated trees was relatively low. The light crop on the control trees, combined with the adequate moisture throughout the 2000 season may explain the lack of treatment effects on fruit size.

The reduction in fruit number and yield caused by the thinning treatments was not statistically significant due to the relatively few replications and significant variability in tree size in this experiment (Table 10). Nevertheless the numeric reduction was about 25%, which is likely a real effect. Similar reductions in fruit number and yield have been observed with traditional blossom thinning chemical in NY.

There was greater preharvest drop with the FOLS and the ATS treatments than the control but the increase was not large (Table 10).

The interaction of variety and thinning treatment was not statistically significant. However since thinning is variety specific, the individual variety means are presented in Table 11. The data show that the organic bloom thinning chemicals had a significant effect on Cortland and Delicious fruit set but not on McIntosh. It may be that the optimum application timing for the

McIntosh trees was a day or two earlier since they bloom the earliest. For Delicious, the FOLS treatment resulted in a significant fruit size improvement compared to the controls.

Year 2001 Results

The fruit thinning treatments with the 2 organic approved chemical (FOLS and NC-99) resulted in significant cropload reductions in 2001 (Table 12). NC-99 applied twice and FOLS applied at 80% bloom reduced fruit set, while the non-organic approved blossom thinner, Wilthin, was ineffective (Table 12). Post-bloom FOLS reduced fruit set more than all other treatments. NC-99 reduced yield by a third when applied twice during bloom. FOLS, whether applied once or twice during bloom, also reduced yield by a third, while the post-bloom applications of FOLS reduced yield by 58%. Double applications of both FOLS and NC-99 increased fruit size (Table 13). The largest fruit resulted from the post-bloom FOLS treatment. None of the treatments affected seed number (data not presented).

Both NC-99 and FOLS caused leaf burning and double applications during bloom resulted in the greatest amount of damage (Table 14). Two sprays of FOLS during bloom slightly increased fruit russet.

With the western NY trial in the certified organic block, NC-99 and ATS caused moderate phytotoxicity on Delicious and Rome while FOLS did not (Table 15). FOLS applied twice (petal fall and 1st cover) resulted in the greatest thinning while either FOLS, NC-99 or ATS applied at full bloom were almost as good. The greatest fruit size was with ATS while the organic thinning compounds did not improve fruit size despite significant thinning.

Year 2002 Results

Timing Study*:* All timings resulted in thinning of McIntosh, with later timings tending to remove more fruit (Table 16). 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.

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 17). 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 fruits, respectively) (Table 18). 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.

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 18). 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.

Table 9. Effect of Blossom Thinners on Fruit Set, Fruit Size and Yield of Delicious in the Hudson Valley, NY. (2000)

Treatment	Fruit Set (%)	Fruit Size Weight (g)	Fruit Size Diam. (in.)	Yield/ tree (kg)	Drop weight (kg)	Russet Rating (1-5)
Untreated Control	138 a	157 b	2.77 b	150 a	9.21	.88 b
FOLS @ 80% bloom.	67 bc	200 a	3.02 a	102 b	9.50	1.15 a
FOLS @ 20% bloom + 80% bloom	40 bc	180 ab	2.89 ab	121 ab	6.94	1.06 ab
NC-99 @ 80% bloom.	98 ab	185 a	2.94 a	125 ab	12.06	1.03ab
NC-99 @ 20% Bloom + 80% bloom	106 ab	183 a	2.94 a	141 ab	7.77	1.13 a

Table 10. Main Effect of Blossom Thinners on Fruit Set, Yield and Fruit Size of Cortland, Delicious and McIntosh in a Certified Organic Block. (2000)

Treatment*	Fruit Set (%)	Fruit Size (g)	Fruit Number/ Tree	Fruit Yield/ Tree (kg)	% Fruit Drop
Untreated Control	39.5 a	150.4 a	451 a	63.9 a	18.0 b
2 gal Crocker Fish Oil+2 gal liquid Lime Sulfur per 100 gallons @ 80% Bloom	25.7 bc	144.7 ab	330 a	47.0 a	25.9 a
4 gal NC-99 Calcium/Magnesium Brine per 100 gal @ 80% Bloom	20.1 c	133.7 c	341 a	45.1 a	24.4 ab
1 gal Ammonium Thiosulfate (ATS) per 100 gal @ 80% Bloom	33.3 ab	138.2 bc	333 a	45.9 a	26.5 a
LSD $p \leq 0.05$	9.7	10.9	138.2	19	6.9

*All varieties were sprayed on May 8, 2000 at 8:00am. TRV was 300gpa and the trees were sprayed at 100gpa.

Table 11. Interaction of Variety and Blossom Thinners on Fruit Set, Yield and Fruit Size of Cortland, Delicious and McIntosh in a Certified Organic Block. (2000)

Variety	Treatment*	Fruit Set (%)	Fruit Size (g)	Fruit No./ Tree	Yield/ Tree (kg)	% Fruit Drop
Cortland	Untreated Control	35.9 a	155.6 a	371.0 a	57.3 a	22.2 a
	2 gal Crocker Fish Oil + 2 gal liquid Lime Sulfur per 100 gallons @ 80% Bloom	23.2 ab	146.5 ab	262.9 a	39.6 a	27.4 a
	4 gal NC-99 Calcium/Magnesium Brine per 100 gal @ 80% Bloom	11.7 b	133.7 b	253.4 a	34.7 a	26.1 a
	1 gal Ammonium ThioSulfate (ATS) per 100 gal @ 80% Bloom	26.1 ab	143.3 ab	258.8 a	36.8 a	26.9 a
Delicious	Untreated Control	42.0 a	167.8 b	396.3 a	65.2 a	12.9 a
	2 gal Crocker Fish Oil + 2 gal liquid Lime Sulfur per 100 gallons @ 80% Bloom	26.4 b	185.6 a	311.4 a	58.7 a	15.9 a
	4 gal NC-99 Calcium/Magnesium Brine per 100 gal @ 80% Bloom	20.8 b	169.5 ab	410.8 a	68.1 a	10.9 a
	1 gal Ammonium ThioSulfate (ATS) per 100 gal @ 80% Bloom	45.7 a	175.6 ab	381.3 a	66.2 a	16.9 a
McIntosh	Untreated Control	37.9 a	101.5 a	667.5 a	67.4 a	26.7 a
	2 gal Crocker Fish Oil + 2 gal liquid Lime Sulfur per 100 gallons @ 80% Bloom	27.4 a	101.9 a	416.8 b	42.8 ab	34.4 a
	4 gal NC-99 Calcium/Magnesium Brine per 100 gal @ 80% Bloom	27.8 a	97.9 a	358.6 b	32.5 b	36.2 a
	1 gal Ammonium ThioSulfate (ATS) per 100 gal @ 80% Bloom	28.0 a	95.6 a	359.5 b	34.7 b	35.7 a
	LSD $p \leq 0.05$	15.8	18.1	230.3	31.6	11.5

*All varieties were sprayed on May 8, 2000 at 8:00am. TRV was 300gpa and the trees were sprayed at 100gpa.

Table 12. Effect of organic blossom thinners on fruit set and yield of Gala in the Hudson Valley, NY, 2001.

Treatment	Fruit Set (%)	Yield/tree (lb)
Control	79 a	111 a
NC-99 X 1	62 ab	109 a
NC-99 X 2	47 bc	75 ab
FOLS X 1	52 b	75 ab
FOLS X 2	57 ab	69 ab
FOLS PF + FC	25 c	47 b
Wilthin	76 a	101 a

Table 13. Effect of organic blossom thinners on fruit size of Gala in the Hudson Valley, NY, 2001.

Treatment	Fruit Diameter (in)	Fruit Weight (g)
Control	2.4 b	116 b
NC-99 X 1	2.5 b	126 b
NC-99 X 2	2.8 a	150 a
FOLS X 1	2.5 b	124 b
FOLS X 2	2.8 a	151 a
FOLS PF + FC	2.8 a	167 a
Wilthin	2.4 b	117 b

Table 14. Effect of organic blossom thinners on phytotoxicity to Gala in the Hudson Valley, NY, 2001.

Treatment	Leaf Burn	Russett
Control	0 d	1 b
NC-99 X 1	2 b	1 b
NC-99 X 2	3 a	1 b
FOLS X 1	1 c	1 b
FOLS X 2	3 a	2 a
FOLS PF + FC	3 a	2 a
Wilthin	0 d	1 b

Table 15. Effect of Organic Approved Thinners on Fruit Set, Yield and Size of Delicious and Rome Organic Apples (Bittner-2001)

Variety	Thinning Treatment	Phytotoxicity Rating (1-3)	Fruit Set (%)	Fruit No./ Tree	Yield (kg)	Fruit Size (g)	% Fruit Drop
Delicious		0.83	0.35	--	--	--	--
Rome		0.25	0.58	258	44.2	178	67
LSD for Variety (p≤0.05)		0.28	0.16	--	--	--	--
	Untreated Control	0.05	0.62	265	26.2	174	66
	4 gal NC-99/100 gal @ 80% Full Bloom	1.03	0.46	248	23.6	179	68
	2.5 gal Fish Oil + 2 gal Liquid Lime Sulfur @ 80% Full Bloom	0.08	0.46	269	25.7	172	65
	3 gal ATS/100 gal @ 80% Full Bloom	1.44	0.45	232	21.9	199	72
	2.5 gal Fish Oil + 2 gal Liquid Lime Sulfur @ Petal Fall and @ 1st Cover	0.08	0.37	268	24.8	170	66
LSD for Treatment (p≤0.05)		0.26	0.17	8	85.6	21	8
Delicious	Untreated Control	0.00	0.63	--	--	--	--
Delicious	4 gal NC-99/100 gal @ 80% Full Bloom	1.50	0.36	--	--	--	--
Delicious	2.5 gal Fish Oil + 2 gal Liquid Lime Sulfur @ 80% Full Bloom	0.19	0.29	--	--	--	--
Delicious	3 gal ATS/100 gal @ 80% Full Bloom	2.25	0.30	--	--	--	--
Delicious	2.5 gal Fish Oil + 2 gal Liquid Lime Sulfur @ Petal Fall and @ 1st Cover	0.19	0.18	--	--	--	--
Rome	Untreated Control	0.08	0.61	265	43.7	174	66
Rome	4 gal NC-99/100 gal @ 80% Full Bloom	0.65	0.54	248	42.5	179	68
Rome	2.5 gal Fish Oil + 2 gal Liquid Lime Sulfur @ 80% Full Bloom	0.00	0.60	269	46.2	172	65
Rome	3 gal ATS/100 gal @ 80% Full Bloom	0.63	0.61	232	43.9	199	72
Rome	2.5 gal Fish Oil + 2 gal Liquid Lime Sulfur @ Petal Fall and @ 1st Cover	0.00	0.53	268	44.7	170	66
LSD for Variety X Treatment (p≤0.05)		0.04	0.24	--	--	--	--
ANOVA (p≥0.05)							
	Variety	**	*	--	--	--	--
	Thinning Treatment	**	*	NS	NS	**	NS
	Variety X Treatment	***	NS	--	--	--	--

Table 16. 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

DAPF = days after petal fall

Table 17. 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

Table 18. Effect of Oil and Surfactants on Thinning Effectiveness of Lime Sulfur Applied to Empire at Petal Fall 2002. (Geneva, NY)

Chemical Treatment	Timing of Application	Fruit Set (%)	Fruit Number per Tree	Fruit Weight per Tree (kg)	Fruit Size (g)	Cropload Adjusted Fruit Size (g)
Untreated control		83 a[z]	414.3 ab	44.1 ab	110.0 b	112.9 c
2.5 gal Lime Sulfur /100 gal	Petal Fall	72 abc	508.8 a	51.0 a	103.7 b	107.4 c
2.5 gal Lime Sulfur + 2.0 gal Fish Oil plus /100 gal	Petal Fall	50 bcd	320.3 b	35.6 bc	115.0 b	111.5 c
2.5 gal Lime Sulfur + 2.0 gal Ultra Fine oil /100 gal	Petal Fall	44 cd	325.5 b	35.2 bc	116.3 b	118.5 bc
2.5 gal Lime Sulfur + 1 pt Regulaid /100 gal	Petal Fall	71 abc	426.0 ab	44.2 ab	109.3 b	110.0 c
2.5 gal Lime Sulfur + 1 pt Silwet /100 gal	Petal Fall	74 ab	441.9 ab	43.7 ab	104.0 b	109.1 c
75ppm BA (VBC-30001) + 1pt/100gal Sevin XLR	10 mm Fruit Size	40 d	194.1 c	29.2 cd	157.3 a	152.1 a
7.5ppm NAA (Fruitone N) + 1pt/100 gal Sevin XLR	10 mm Fruit Size	23 d	140.1 c	19.1 d	143.2 a	137.3 ab

[z] Mean separation between treatments by Tukey-Kramer Test $p<0.05$.

Table 19. Effect of Organic Blossom Thinners on Cropload and Fruit Size of Enterprise and Goldrush Apples 2002 (Barker, NY).

Thinning Treatment	Cropload (fruit no./cm^2 TCA)	Fruit Size (g)	Cropload Adjusted Fruit Size (g)	Phytotoxicity Rating (0-3 Scale*)
Untreated Control	9.4 ab	98.2 b	103.0 b	0.2 c
1.5 gal Lime Sulfur / 100gal water	9.8 ab	122.3 a	128.3 a	0.7 b
2.5 gal Lime Sulfur / 100gal water	10.1 a	109.4 ab	115.9 ab	0.4 bc
1.0 gal Fish Oil / 100gal water	8.3 abc	113.3 ab	115.0 ab	0.7 b
2.0 gal Fish Oil / 100gal water	6.1 cd	125.8 a	120.8 ab	0.4 bc
1.5 gal Lime Sulfur +1.0 gal Fish Oil / 100gal water	6.4 cd	128.3 a	124.3 ab	0.6 bc
1.5 gal Lime Sulfur +2.0 gal Fish Oil / 100gal water	7.6 bc	112.6 ab	112.1 ab	0.5 bc
2.5 gal Lime Sulfur +1.0 gal Fish Oil / 100gal water	6.5 cd	117.7 ab	114.0 ab	0.8 b
2.5 gal Lime Sulfur +2.0 gal Fish Oil / 100gal water	8.1 abc	114.0 ab	115.2 ab	0.4 bc
4.0 gal NC-99 / 100gal water	5.4 d	129.8 a	123.1 ab	2.4 a
LSD $p<0.05$	2.2	22	22	0.45

*Phytotoxicity Rating Scale: 0=no phytotoxicity, 1=slight spotting or leaf tip burning, 2= spotting and angular lessions, 3=leaf drop.

DISCUSSION

Thinning studies in all 3 years indicate that FOLS and NC 99 appear to be promising products for thinning certified organic orchards. Although yield was not greatly reduced in the Hudson Valley study, both thinners increased fruit size. The lack of improvement in fruit size in western NY was disappointing but the successful reduction in cropload is promising.

In the Hudson Valley, we observed that the amount of leaf spotting on Cortland trees was much greater than on Delicious. This suggests that there are differences in sensitivity among apple cultivars to damage by these thinning materials, and that additional screening of different cultivars to foliar damage is needed before these materials can be generally recommended for use as thinners.

Although there was no benefit to two sprays in 2000, in 2001 there was considerable additional thinning in 2001 from double applications with NC99 in eastern NY and with two applications of FOLS in western NY. In Japan, where lime sulfur is a registered thinner, two applications are typically made, the first at full bloom, and the second at petal fall (Koike and Ono, 1998). Burrell (1945) noted that lime sulfur at petal fall or shortly after caused the greatest reduction in fruit set. Our data from 2002 shows that applications made after petal fall cause more thinning that those made at bloom or petal fall. However, the effects of these thinners on photosynthesis should be evaluated, since it appears that fruit size may be limited by the later applications.

Our preliminary conclusion based upon these results is that both NC 99 and FOLS show promise as organic thinners for apple. In fact, the results of trials in 2000 and 2001 show such potential that we are now considering developing the use of these materials as potential replacements for carbaryl in conventional thinning programs. Lime-sulfur is used in Japan for conventional apple thinning (Koike and Ono, 1998). Its thinning action at bloom or post bloom was recognized in the 1940s (Burrell, 1945). It may find a new niche in both conventional and organic blocks if carbaryl is banned by regulatory action. 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 these thinners in combination with conventional post-bloom materials.

Further research is needed to compare the efficacy of alternatives to fish oil in both organic and conventional production systems. Fish oil is malodorous and relatively expensive. Its contributions to the thinning activity and phytotoxicity are unknown. Our research shows that ultrafine spray oil is equally effective as Fish oil in thinning sprays. Horticultural oils or other penetrants may be more effective, less harmful to the trees, and more cost-effective.

NC 99 and FOLS caused petal browning and a marginal leaf burn, and double applications caused more severe injury than single applications. These materials have been applied during warm, dry bloom periods in 2000, 2001 and 2002. Additional experience applying these thinners in more typical wet cool 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.

The mode of action of these chemicals 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, and additional research is needed to determine the limits of effective timing. 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.

OBJECTIVE 3. DEVELOPMENT OF ALTERNATIVE WEED CONTROL APPROACHES.

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INTRODUCTION

Weed control in existing organic apple orchards is typically done by mowing with limited hand weeding around trees. However, the competition from weeds severely reduces trees growth of young trees and reduces yield, fruit size and leaf nutrient levels in older trees. Previous research has shown that no alternative weed control system gives equal tree growth and yield as that obtained with conventional herbicides. Nevertheless in an organic system two promising approaches are weed flaming and surface tillage implements that can operate under the trees.

MATERIALS AND METHODS

In 2000 we purchased a specialized tillage implement from Europe. The implement tills a strip 2 feet wide under the tree with a self-indexing system to go around tree trunks. We did trials in young and mature certified organic apple blocks to determine the effectiveness of the tiller in controlling weeds and established sod.

A prototype shrouded flame weeder was developed in 2000 by Ian Merwin and Kevin Bittner. It was tested for effectiveness at Singer Farms in Barker NY in 2001, and at the Cornell Orchards Research Farm in Ithaca, NY in 2002. 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 was built over the burners to contain the heat. 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. 3-6). 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 to 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.

<u>2001 Weed Control Trials</u> From January through May, 2001 we operated the machine in empty lots to ensure proper operation. On July 11, 2001, we tested the flamer under field conditions in a uniform ten acre block of Montmorency tart cherries on Mahaleb rootstock, spaced 22 by 20 ft. In previous years, the block had had rotating paraquat and glyphosate herbicide applications with excellent control of established weeds. Prior to the flame weeder treatments, the ground cover was mowed to three inches in height. 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.

Effectiveness of the treatments was measured by assessing ground cover height before and after each application, making a visual estimation of percentage of treated ground cover affected by flaming, and by observing the types of weeds that recovered the quickest.

During the summer of 2002 we tested the flamer 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.

RESULTS

Tests with the tillage implement showed that it works well where there is minimal sod at the start of the season. With young apple orchards which had minimal sod, this machine provided excellent weed control. Monthly tillage worked exceptionally well and gave complete weed control. However, in mature orchards with heavy sod the mechanical tiller was not adequate for this circumstance and did not provide adequate weed control.

Initial trials with the flame weeder unit in 2000 showed that without a shroud covering the burners the heat dissapated quickly and very slow travel speeds were required for good weed control (~1mph). In 2001 we tested the flame weeder unit with and without the shroud. In these trials Paraquat was the best treatment with 95% of the groundcover area treated killed (Table 20). The next best treatment was the shrouded flamer at 2mph and 40psi.resulting in 90% of treated foliage killed. The shrouded treatment at 4 mph and 20psi was roughly equivalent to the unshrouded treatment at 2mph and 40psi with 60% and 40% respectively of the ground cover treated killed. The unshrouded flamer operated at 20psi and 4mph was ineffective. The shroud was needed to contain the heat and allow faster speeds. The effect of shrouding was significant since the shroud appeared to nearly double the effectiveness of the flamer at equivalent speeds and pressures.

Table 20. Percentage of groundcover killed using various tractor speeds and operating propane pressures.

Weed Control Treatment	Tractor Speed (mph)	Propane Pressure (psi)	Percentage of Groundcover Killed
1 qt Paraquat/Acre (Chemical Standard)			95
Shrouded Flamer	2	20	60
Shrouded Flamer	2	40	90
Shrouded Flamer	4	20	40
Shrouded Flamer	4	40	50
Unshrouded flamer	2	20	30
Unshrouded flamer	2	40	40
Unshrouded flamer	4	20	2
Unshrouded flamer	4	40	20

Figure 3 . Modified flamer mounted on front of tractor.

Figure 4. Front view of unit on tractor. For scale, the tractor is 50 inches wide.

Figure 5. Operator's view of mounted flame weeder from cab of tractor

Figure 6. Flamer raised for easy transport and repairs or adjustments.

DISCUSSION

Mechanical tillage was successful in young orchards but in mature orchards flame weeding was much more successful. The results with the propane weed flamer in 2001 were encouraging. This technique would be particularly valuable in organic fruit production where herbicide use is prohibited. We found that it was desirable to wait a few hours after rains before flame treatments, depending on wind and sun conditions. One of the advantages of flaming relative to tillage is that flaming is possible when soils are too wet for effective cultivation. The addition of a shroud around a burner reduced the amount of fuel necessary, since it contained the heat so that the wind did not dissipate the heat energy. Inside the shroud the heat is also more uniform and constant.

Besides weed control, flaming weeds in orchard crops may also have other positive side effects in pest management resulting in economic benefit for farmers. Secondary pests such as Tarnished Plant Bug and Lygus may be killed (Seifert and Snipes, 1996). In contrast, when weeds are mowed or sprayed with herbicides, insect and mite pests typically move up into the canopy.

Propane flamers could become an economical method of weed control for organic farmers, providing a non-chemical method of controlling weeds and pests. It may also be useful in conventional farming due to its environmental and economical benefits. 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. We found that it takes the same number of operator-hours per acre, but the propane does not create a chemical soil or water residue. The cost of propane was comparable to that of contact herbicides depending on the prices of those chemicals and the fuel. Flaming also has no farmworker hazard, reentry period, or necessity for a pesticide license.

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 or 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 ignite and burn mulches or other flammable materials. They are best used following rain, or when there is dew on the surface vegetation to impede combustion of weeds. Flaming speeds vary greatly, because some applications require slower speeds than others. This is affected by the type of flamer, application rate, and atmospheric temperatures, all of which may vary greatly. 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. 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.

OVERALL CONCLUSIONS:

In our research trials we tested the most promising insect control measures, fruit thinning tactics and weed control methods that could be used in a commercial organic apple orchard in the eastern US. With all three production problems our results were very promising. Nevertheless we still have unsolved insect control problems that limit the viability of organic apple production in the eastern US. The recent introduction of an approved organic spinosad insecticide "Esteem" should help to solve the fruit feeding insect problems. Ultimately it would be most desirable to integrate the most promising insect pest control tactics, fruit thinning strategies and weed control tactics with other crop production methods that also address disease control such as the use of disease-resistant cultivars. However this requires growers to plant new orchards which is very costly.

At the present time the most promising organic apple production system for the northeastern US is:

- Disease resistant varieties and disease resistant dwarfing rootstocks which do not require fungicide or bactericide treatments. Without disease resistant varieties or rootstocks significant effort to control apple scab with sulfur is required. In addition fire blight control with streptomycin is required.
- Suround kaolin clay and Esteem spinosad insecticide to control fruit feeding insect pests such as plum curculio, codling moth and apple maggot.
- Fish oil/lime sulfur sprays at bloom or petal fall to chemically thin the trees to improve fruit size and ensure return bloom.
- Mechanical weed tillage in the first 5 years of an orchard’s life followed by flame weeding of the mature orchard.

Growing apples organically does have other positive aspects as well. 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. This increased effort by both the grower and consumer then prompts not only industry, but also researchers to develop better materials and techniques. Also, most of the organically certified materials tend to be "softer" and offer more of an opportunity for biological control, even further reducing the amount of pesticides needed.

With all aspects of this type of growing system considered, a grower must be completely prepared to make the investment into this market. The increasing interest of organic consumers has had an effect on the number of growers attempting to grow organic produce. With the development and research of efficient materials and techniques, producing a high quality certified organic product may be possible. However, consumers willing to pay premium prices for this type of produce will be the driving factor behind the market.

Finally, a proper evaluation of an alternative production system such as this should take into account the economics of the system. Not only would an examination of costs and market returns be required, an overall assessment of the organic marketing opportunities for a given grower would be invaluable in determining the feasibility of converting an orchard to organic production. The two certified organic orchards used in this study were initially managed conventionally, having been converted in 1995 (Orchard P1) and 1996 (Orchard G11). Their conversion was economically justified by the favorable prices in the organic juice and dried slices market. However, with improved management strategies we believe it is possible to produce apples for the higher priced fresh apple market.

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ACKNOWLEDGMENTS

We wish to acknowledge the contributions of Debby Breth, Steve Hoying and Mike Fargione, Cornell Cooperative Extension, Jim Bittner, Singer Farms and Steve Clarke without whom this study could not have taken place. We are also grateful for support and material received from Barbara Kuhlmann, ExxonMobil Corp.; John Mosko, Engelhard Corp: and G.S. Long and Co.

We are also gratefully acknowledge the financial support of the Organic Farming Research Foundation, Santa Cruz, CA and the Cornell Organic Farming Grants Program under the "Toward Sustainability Foundation" and the NYS IPM program without which the project would not have been undertaken.