Evaluation of Organic Pest Controls and Fruit Thinning on Multiple Apple Cultivars

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Abstract: Disease and insect control strategies suitable for organic farmers were evaluated in an apple variety block that contained 15 different cultivars. The organic treatments were compared to similar sets of trees that received either standard pest management treatments or were left unsprayed. Effectiveness of pest control programs and their impact on productivity was evaluated for 33 different parameters on each of the 15 cultivars. Due to the high insect and disease pressure in this orchard, neither the standard nor the organic treatments provided commercially acceptable levels of pest control. Insect damage was found on 41 to 53% of fruit at harvest, but the organic and standard programs were comparable for most of the insect pests evaluated. However, the standard program was more effective for controlling black rot, bitter rot, and lenticel spotting caused by *Botryosphaeria* species. Pesticides plus application costs totaled \$650/A for the standard program as compared to \$1,173/A for the organic program. Total yield per acre (including fruit damaged by pests) was 209, 409, and 861 bushels per acre for the unsprayed, organic, and standard treatments, respectively. Pest control costs per bushel were \$2.98 for fruit from the organic block compared to \$0.76 for the standard. Results from this trial show that pest-free apples can be produced organically in New York, but organic producers will likely need at least a 400% sales premium compared to standard growers due to the high costs and reduced yield associated with organic pest control. Further research may lead to cost reductions and improved productivity for organic systems, but farmers currently considering a switch to organic apple production should verify that their prospective produce buyers will be willing to pay a significant premium for organic fruit.

Background and Justification: Over the past decade, availability of new products such as kaolin clay particle film (Surround) and spinosad (Entrust), along with the use of lime-sulfur plus fish oil to adjust crop load, have increased the feasibility of organic apple production under NY conditions. However, the best available technologies have rarely (if ever) been combined in full-season, multi-disciplinary evaluations across multiple cultivars. This trial provided a unique opportunity to determine how different apple cultivars respond to organic pest control strategies.

Objectives:

1. Evaluate a full-season organic spray program consisting of sulfur, liquid lime-sulfur with crop oil, kaolin clay, spinosad, and BT for effectiveness in adjusting crop load (fruit thinning) and in controlling diseases, insects, and mites on 15 apple cultivars.
2. Determine if the products applied for pest control cause unacceptable fruit russetting on some cultivars.
3. Project evaluation: Using data from the objectives above, generate an economic analysis of the organic spray program, publish final results, and improve recommendations for organic pest control in the Cornell Tree Fruit Management Guide.

Procedures:

Organic insect and disease control strategies were assessed in a 7-yr-old planting at the Hudson Valley Lab that was established as part of the NE-183 multistate project on evaluation of new apple cultivars. The planting contained five single-tree replicates for each of 28 different cultivars arranged in a randomized block design, but only 15 cultivars were used for data collection in this trial. The planting consisted of three long rows with rows on 14 ft centers and trees spaced 8.3 ft apart within rows. The southern row paralleled an overgrown orchard that was abandoned nearly 30 years ago whereas the northern row paralleled other research plots that were minimally sprayed during 2006. Woodlots framed both the eastern and western ends of the test block. Insect and disease monitoring over the past five years has shown that this block is exposed to moderately high but uniform pressure from immigrating plum curculio, apple maggot, and cedar rust spores.

This planting was established in 1999 to evaluate differences among cultivars and therefore did not lend itself to a fully replicated evaluation of the three treatments (unsprayed, organic, standard) that were of interest in this trial. Treatments in this trial were applied to complete replicates that existed within the initial design, but that did not allow for normal replication of treatments. However, treatment effects were assessed by assuming that most of the variability among replications was attributable to differences in the pest control treatments that were imposed on the various replications. For each parameter evaluated, the Super ANOVA statistical program was used to analyze for differences among cultivars across all five of the replications and differences among replications were then attributed to effects of the pest control treatments. Fisher's Protected LSD ($P \leq 0.05$) was used to detect significant differences among treatment means.

Organic pest control products were applied in three of the five original cultivar replications. Each of these three replicates occupied a single row starting from the western edge of the planting. The northern row was sprayed only from the north side to avoid cross contaminating of the adjoining research plot with "blow-through" from the airblast sprayer. As a result, one replication of the organic treatment was consistently sprayed from one side only. The replication in the middle row was sprayed from both sides and received blow-through deposits from both sides when the adjacent rows were sprayed. The southern row was also sprayed from both sides, but, being the outer row, it received blow-through deposits from only one side.

The fourth replication of 15 varieties was distributed evenly among all three rows, and all trees were sprayed from both sides using standard commercial pesticides. The fifth replication was left as a completely untreated control. Buffer trees (cultivars not used for data collection) occurred at the ends of each row and separated the sections within rows that received different treatments. All trees were trained using the vertical axe system and were supported with conduit stakes attached to a high wire. Trickle irrigation was installed in this block but was not used during the 2006 growing season.

All of the test materials were applied with a 3-pt hitch Bean airblast sprayer calibrated to deliver 100 gal of spray solution per acre at a travel speed of 2.5 miles per hour. Treatments were generally applied early in the morning under calm conditions.

Standard orchard maintenance practices (fertilizers, herbicides, pruning) were applied across the entire block both to minimize variables that might affect results and to reduce costs for this one-year project. In several cases, we also included in the organic pest control program products that were not approved for organic farmers but which we believed would perform similarly to equivalent products that have OMRI labels. Specifically, COCS and Spintor (neither of which

Table 1. Products used for disease and insect control in the 2006 field trial at the Hudson Valley Laboratory, Highland, NY.

Program and application dates	Products applied	Rate/A*
Standard fungicide sprays		
3 Apr	COCS	4.0 lb
12 Apr	Dithane	2.3 lb
20, 28 Apr, 8, 15, 24 May, 1, 8 June	Dithane + Rubigan	2.0 lb + 7.67 fl oz
20, 29 June, 11, 20 July, 4, 21 Aug	Topsin M + Captan-80	7.67 oz + 23 oz
Standard insecticide sprays		
15 May	Sevin XLR	2.3 pt
24 May	Imidan	3.83 lb
1, 8, 20, 29 June	Asana	8.4 fl oz
11, 20 July, 4, 21 Aug	Imidan	2.3 lb
Standard fruit thinning spray		
24 May	Fruitone-N	4.6 oz
Organic fungicide sprays		
3 Apr	COCS**	4.0 lb
6 Apr	COCS	2.3 lb
12, 20, 25, 28 Apr, 8, 17, 24 May, 1, 8, 20, 29 June	Microthiol Disperss	11.3 lb
11, 20 July, 4, 21 Aug	Microthiol Disperss	2.3 lb
11, 15 May	Liquid lime-sulfur (LLS)	2.5 gal
Organic insecticide sprays		
6 Apr	Damoil	6.9 gal
20, 25, 28 Apr, 8, 17, 24 May 1, 8 June, 11, 20 July, 4, Aug	Surround WP	38.3 lb
11, 15 May	JMS Stylet Oil	2.0 gal
20 June	DiPel DF	1.53 lb
29 June, 21 Aug	Spintor (instead of Entrust)**	7.67 fl oz
Organic fruit thinning sprays:		
Liquid-lime sulfur plus JMS Stylet Oil applied 11 & 15 May (noted above).		

*Rate/A was calculated based on a tree-row volume of 230 gal/A for dilute sprays.

**COCS and Spintor (neither of which are acceptable in organic programs) were used as substitutes in our trial for Champion WP Copper Hydroxide and Entrust, respectively, due to problems accessing the organically approved products.

are acceptable in organic programs) were used as substitutes for Champion WP Copper Hydroxide and Entrust due to problems accessing the organically approved products.

Spray application dates and products applied for disease and insect control and for fruit thinning are detailed in Table 1. The organic pest control program was devised using the following generalized rules:

- Apply materials at recommended rates with adjustments as appropriate for tree row volume (TRV). We used TRV-adjusted rates of 200 to 230 gal/A depending on stage of growth.
- For apple scab and fire blight, begin with one or two applications of a copper fungicide.

Table 2. Spray dates and intervening weather conditions for the 2006 growing season at the Hudson Valley Lab, Highland, NY

Spray dates: conventional	Spray dates: organic	McIntosh growth stage	Wetting periods: date	start time	duration (hr)	avg. temp (°F)	rainfall (in.)
3 Apr	*3 Apr*	GT	3 Apr	1800	21.25	40.3	0.92
	6 Apr	QIG	7 Apr	1215	21.5	46.4	0.24
12 Apr	*12 Apr*		14 Apr	1315	20.75	53.5	0.35
20 Apr	*20 Apr*	TC	22 Apr	0530	59.5	43	2.35
	25 Apr		25 Apr	1730	4.5		0.08
28 Apr	*28 Apr*	Full Bloom	3 May	1830	13.0	50.9	0.03
8 May	*8 May*		10 May	2315	9.75	54.2	Trace
	11 May	early PF	12 May	0000	36.5	56.6	1.00
15 May	*15 May*	PF-all trees	15 May	1130	4.25	51.9	0.30
			16 May	0145	30.5	50.1	0.41
	17 May		18 May	1615	42.0	50.8	0.54
			21 May	1230	8.5	52.2	0.12
24 May	*24 May*	1st Cover	26 May	1245	21.75	64.7	0.42
			30 May	1915	16.5	63.4	0.36
1 Jun	*1 Jun*	2nd Cover	1 Jun	1445	20.75	66.2	0.23
			2 Jun	2115	38.25	56.6	0.63
			7 Jun	0115	35.5	57.2	1.07
		Accumulations between sprays:			Hr wetting	Rainfall (in.)	
8 June	*8 June*		8 Jun- 19 Jun		79	0.50	
20 Jun	*20 Jun*		20 Jun - 28 Jun		72	3.90	
29 Jun	*29 Jun*		29 Jun -11 Jul		32	0.91	
11 Jul	*11 Jul*		11 Jul - 19 Jul		58	1.61	
20 Jul	*20 Jul*		20 Jul – 3 Aug		84	1.90	
4 Aug	*4 Aug*		4 Aug-21 Aug		79	1.30	
21 Aug	*21 Aug*	harvest dates					
		28 Aug	21 Aug –28 Aug		73	1.76	
		7 Sep	21 Aug – 7 Sep		172	3.57	
		18 Sep	21 Aug – 18 Sep		295	5.94	
		2 Oct	21 Aug – 2 Oct		424	7.42	

- For primary scab and rust diseases, apply sulfur (5 lb/100 gal dilute spray) at least weekly beginning after the second copper spray and continuing to mid-June. Shorten spray intervals to less than 7 days if spray deposits are weathered by rainfall totaling one inch or more within the week after application. Liquid lime-sulfur (LLS) should be applied as an anti-sporulant if primary scab lesions appear on leaves due to coverage failures with wettable sulfur.
- For crop load adjustment, apply two sprays of 2% emulsifiable oil with 2-2.5% liquid lime-sulfur, with the first spray at petal fall and the second 4-5 days later. This strategy is based on previous research done by Dr. Jim Schupp in the Hudson Valley.

- Use Kaolin clay (Surround) to control most insects by applying on a 7-10 day interval. Begin at tight cluster so as to develop a significant deposit on trees before European apple sawfly (EAS), tarnished plant bug (TPB), and plum curculio (PC) are expected to become active on fruit. Coverage should be renewed at less than 7-day intervals if heavy rains remove residues.
- Spinosad (Entrust) should be applied once during early summer to help with control of internal lepidopteran pests and once in August to help control apple maggot (AM).

Using the above criteria, trees in the standard block received a total of 15 different applications during the growing season whereas trees in the organic block were sprayed 19 times. Spray dates and weather events are detailed in Table 2. Details of data collections are noted in footnotes to the data tables.

Results:

The sulfur-based organic spray program provided excellent control of apple scab but failed to control rust infections on leaves (Table 3A). Control of scab and quince rust with sulfur was unacceptable in the outer row that was sprayed from only one side. The center row that received blow through from both sides had the least disease, but disease incidence in this row and in the outer row sprayed from both sides usually were not significantly different. Although cedar apple rust and hawthorn rust lesions were prevalent on leaves, cedar apple rust infections were relatively uncommon on fruit (data not shown). Only Ambrosia, NJ 90, and Mutsu with 3.2, 1.7, and 2.6%, respectively, had more than 1% of fruit affected.

Table 3A. Effects of fungicide programs on foliar incidence of apple scab and cedar rust diseases and on the incidence of quince rust on fruit at harvest.

	apple scab infection (%)			Rust infection (%)		
				leaves		Quince
	cluster lvs[b] 26 May	terminal lvs[c] 10 July	fruit at harvest[d]	clusters[a] 26 May	terminals[c] 10 July	rust on fruit (hvst)[d]
Control.........................	7.3 b[a]	36 d	39 b	70 d	30 cd	12 d
Standard.......................	0.2 a	1 a	1. a	<1 a	3 a	1 a
Organic-center row sprayed both sides......	1.0 a	4 ab	1 a	53 bc	18 b	2 ab
Organic-outside row sprayed both sides......	0.7 a	8 b	2 a	48 b	23 bc	5 bc
Organic-outside row sprayed one side.........	0.1 a	20 c	6 a	65 cd	35 d	7 cd

[a] Means are from 15 different cultivars evaluated in each of the five blocks. Letter separations indicated significant differences among blocks (rep effects) as determined via ANOVA for the 15 cultivars replicated in the five blocks that were included in the statistical analyses.

[b] Cluster leaf data is from all leaves on 10 clusters per tree collected on 26 May.

[c] Five terminals per tree were collected on 10 July '06 from every cultivar in the study group and all leaves were evaluated for diseases.

[d] Fruit data from 50 fruit (or all available fruit if less than 50) per tree harvested at commercial maturity. Mean number of fruit rated per tree for the entire experiment was 43.

Table 3B. Differences among apple cultivars in the foliar incidence of apple scab and cedar rust diseases and in the incidence of quince rust on fruit at harvest. Cultivars are arranged based on apple scab incidence on fruit.

	apple scab infection (%)[a]			Rust infection (%)[a]		
				leaves		Quince
	cluster lvs	terminal lvs	fruit at	clusters	terminals	rust on
Cultivar	30 May	10 July	harvest	30 May	10 July	fruit (hvst)
NY 79507-49...	0.0 a[b]	<1 a	0 a	23 a	1 a	0.0 a
CQR10T17......	0.0 a	<1 a	0 a	52 cdef	24 c	4.5 abcdef
Sundance.........	0.4 ab	1 ab	0 a	38 abcde	2 ab	7.8 bcdef
Crimson Crisp .	0.0 a	1 ab	0 a	50 bcdef	27 cd	6.3 cdef
NJ 109.............	0.0 a	4 abc	0 a	30 abcd	25 c	10.8 f
Zestar...............	3.9 cd	8 abcd	1 ab	44 abcde	4 ab	0.0 a
BC 8S-26-50	1.6 abcd	1 ab	4 abc	44 bcde	30 cd	10.9 def
NJ 90...............	2.8 bcd	13 cde	7 abcd	30 ab	2 ab	2.0 abcd
Fuji [c]................	1.5 abcd	8 bcd	10 abcd	56 def	27 cd	8.7 ef
Mutsu..............	4.1 cd	13 def	10 abcde	70 f	46 e	14.2 f
Chinook...........	1.4 abc	12 def	15 abcd	57 ef	43 de	3.5 abcd
Delblush...........	0.9 abcd	19 defg	17 bcde	39 abcde	5 ab	2.8 abc
Ambrosia..........	1.8 abcd[y]	19 efg	20 cde	58 ef	32 cd	4.4 abcde
Hampshire........	3.7 d	27 fg	26 de	58 ef	9 b	1.2 ab
Roger's Mac.....	4.4 bcd	27 g	26 e	30 abc	1 a	0.8 a

[a] For details of sampling methods, see footnotes on Table 3a.

[b] Numbers within columns followed by the same small letter do not differ significantly (Fisher's Protected LSD, $P \leq 0.05$). The angular transformation was used for the analysis of data expressed as percentages, but the arithmetic means are shown.

[c] September Wonder strain of Fuji.

Of the cultivars evaluated, the first five listed in Table 3b are virtually or completely scab-resistant, but none of the cultivars are resistant to rust diseases. Where one or more scab lesions were reported on cultivars known to carry the Vf gene for scab resistance (i.e., NY 79507-49, CQR10T17, Sundance, and Crimson Crisp), we did not verify whether the scab lesions reported resulted from misidentifications in the field or from scab that escaped control by the Vf gene.

A high percentage of fruit from both standard and organic treatments were out-of-grade due to sooty blotch and flyspeck (SBFS, Table 4A). Some of the disease recorded may have developed after harvest because all fruit from this block was harvested on the dates indicated and then held in cold storage at 36-38 °F until they could be rated in late October. Losses to SBFS would have been much lower if another fungicide treatment had been applied in early September. The first five cultivars listed in Table 4B were all harvested during August or the first week of September, and for these cultivars the mean percent fruit out-of-grade due to SBFS was only 8.8% for those receiving standard treatment and 10.9% for the two rows that received organic sprays from both sides. Disease incidence increased with cultivars that were harvested later in the season due to the large accumulation of wetting hours that occurred after the last spray was applied on 21 August (Table 2).

The percentage of fruit out-of-grade due to surface russetting was higher in two of the three blocks receiving organic spray treatments and was inversely related to the expected level of spray coverage among those three blocks (Table 4A). Thus, it seems probable that some of the russetting in the organic block was attributable to pesticides applied in that block. The LLS applied for fruit thinning is the most likely culprit.

The organic treatments failed to control black rot and appeared to exacerbate problems with bitter rot and lenticel spots caused by *Botryosphaeria* species (Table 4A). Ambrosia, Delblush, and Mutsu were especially susceptible to lenticel spotting (Table 4B). Ambrosia was harvested 28 August, almost a month before normal maturity, because fruit in the organic plots were beginning to drop due to the severity of lenticel spotting even though fruit were still too immature to be edible. We suspect that lenticel spotting resulted when *B. obtusa* or *B. dothidea* invaded lenticels that had been damaged by sulfur sprays applied during summer. Cultivars that showed high levels of lenticel spotting may be especially sensitive to sulfur injury.

The organic plots had smaller fruit size than the standard and unsprayed plots when king fruits and side fruits were measured on 26 May (Table 5A). This size differential presumably was attributable in large part to the LLS thinning sprays that were applied in mid-May. The larger size may of the side fruit from the standard spray program apparently were more attractive to early plum curculio damage. Cultivars with larger fruit on 26 May also tended to have more PC damage (Table 5B). Differences in plum curculio between the organic and the standard programs disappeared by harvest. The high incidence of plum curculio damage at harvest was attributable to extremely heavy pressure (94% in control plots), a delayed peak in PC activity in the 2006 season, and perhaps failure to reapply insecticides after the rains on 2 June (Table 2).

The organic program was equivalent to the standard program for controlling EAS and TPB on king fruit and provided better control than the standard program on side fruit (Table 6A). Control of PC, EAS, and TPB in the standard program might have been better if an insecticide had been applied at pink. The proportion of fruit showing no insect damage (clean fruit) was still quite high in the organic blocks on 26 May, but it dropped considerably due to later damage from PC (right column, Tables 5A&B).

Evaluations of fruit at harvest showed that the organic program was more effective than the standard program for protecting fruit from EAS and TPB, was less effective than the standard program against external lep damage (XLEP), and was comparable (statistically, though not numerically) for controlling San Jose scale (SJS), internal leps (ILEP) and apple maggot (AM) (Table 7A).

Total harvested crop weight per tree was lowest in unsprayed plots, intermediate in organic plots, and highest in standard plots (Table 8A). Disease and insect damage to fruits and fruit stems undoubtedly caused fruit to drop from the trees throughout the season in the unsprayed control plots. The reason for greater preharvest drop (i.e., fully-sized fruit on the ground at harvest) in the organic plots compared to the standard plot is not known. The LLS+oil thinning sprays were very effective and reduced crop load to a lower number of fruit per tree than did the standard thinning treatment (Table 8A). Thus, the increased level of preharvest drop in the organic block is not attributable to "push-offs" that might have occurred if the trees were over-cropped.

(Text continues after Table 8.)

Table 4A. Effects of fungicide program on fruit grade and disease incidence at harvest.

	% fruit affected				
	out-of-grade due to:[b]		black	lenticel	bitter
	SBFS	russet	rot	spots[c]	rot
Control	100 c[a]	20 a	28 b	8 ab	1 a
Standard	41 a	20 a	12 a	6 a	<1 a
Organic-center row sprayed both sides	31 a	32 c	32 b	20 bc	4 b
Organic-outside row sprayed both sides	40 a	29 bc	30 b	22 c	6 b
Organic-outside row sprayed one side	72 b	22 ab	24 ab	16 abc	4 b

See footnotes below table 4B.

Table 4B. Differences among apple cultivars in fruit grade and disease incidence at harvest. Cultivars are arranged based on harvest date to illustrate that late-harvested cultivars were generally more affected by sooty blotch and flyspeck (SBFS).

		% fruit affected				
	Harvest	out-of-grade due to:[b]		black	lenticel	bitter
Cultivar	date	SBFS	russet	rot	spots[c]	rot
Ambrosia	28 Aug	44.0 bc[a]	0 a	17.7 abc	55.2 d	3.2 bcd
NJ 109	28 Aug	49.7 bc	1 ab	15.5 abc	11.5 bc	3.0 abcd
Zestar	28 Aug	0.5 a	30 ef	31.2 bcd	4.3 ab	1.6 abcd
Roger's Mac	31 Aug	28.4 b	5 abc	17.8 abc	10.3 bc	0.0 a
NY 79507-49	7 Sep	42.0 bc	18 cde	13.2 ab	0.0 a	1.6 abcd
Fuji[d]	7 Sep	51.3 bc	19 de	36.9 cd	0.0 a	5.2 cd
NJ 90	12 Sep	42.4 bc	8 bcd	19.2 abc	0.0 a	0.0 a
BC 8S-26-50	18 Sep	61.0 cde	70 g	46.7 d	0.8 ab	6.0 d
Crimson Crisp	18 Sep	48.4 bc	22 de	38.4 cd	0.0 a	1.0 abc
CQR10T17	18 Sep	61.8 cde	7 bcd	74.3 e	20.0 a	0.8 e
Hampshire	18 Sep	54.0 cd	18 cde	19.2 abc	0.0 a	0.8 abcd
Chinook	2 Oct	81.2 def	49 f	5.5 a	0.0 a	0.4 ab
Sundance	2 Oct	83.5 ef	88 h	24.5 abcd	21.8 c	0.5 abc
Delblush	9 Oct	92.4 f	38 f	11.6 abc	60.5 d	0.0 a
Mutsu	9 Oct	92.5 f	14 cde	7.3 ab	52.7 d	1.9 abcd

[a] Means separations are based on Fisher's Protected LSD (*P* ≤0.05) from ANOVA for 15 cultivars in five blocks. The angular transformation was applied to incidence data, but the arithmetic means are shown. Means in the upper table represent "block" effects where most of the differences were attributable to spray programs. Means in the lower table represent cultivar effects as measured across all five blocks.

[b] Fruit with sooty blotch and/or flyspeck (SBFS) or surface russetting that would exclude it from USDA Extra Fancy grade.

[c] Lenticel spots were presumably attributable to small infections by *Botryosphaeria* species.

[d] September Wonder strain of Fuji.

Table 5A. Effects of spray programs on fruitlet size as measured on 26 May for king fruit and side fruit and on incidence of plum curculio damage on 26 May and at harvest.

REPS	Fruitlet diameters[b] king	Fruitlet diameters[b] sides	% plum curculio[b] fruitlets king	% plum curculio[b] fruitlets sides	% plum curculio[b] Harvest
Control	15.9 b[a]	11.2 c	17 b	10 c	94 b
Standard	15.8 b	11.0 c	6 a	4 b	26 a
Organic-center row sprayed both sides	14.5 a	8.4 a	5 a	1 a	25 a
Organic-outside row sprayed both sides	14.1 a	9.0 b	6 a	2 ab	31 a
Organic-outside row sprayed one side	14.4 a	9.0 b	2 a	2 a	45 a

See footnotes below table 5B.

Table 5B. Differences among apple cultivars in fruitlet size as measured on 26 May for king fruit and side fruit and in incidence of plum curculio damage on 26 May and at harvest. Cultivars are ordered based on the mean size of king fruits.

Cultivar	Fruitlet diameters[b] king	Fruitlet diameters[b] sides	% plum curculio[b] fruitlets king	% plum curculio[b] fruitlets sides	% plum curculio[b] Harvest
Ambrosia	12.3 a[a]	8.1 ab	0 a	2 ab	41 ab
Delblush	12.8 ab	9.6 cde	3 a	3 ab	35 ab
BC 8S-26-50	13.3 b	8.3 b	0 a	0 a	40 ab
NJ 90	13.4 b	9.2 c	6 ab	2 ab	80 ab
Chinook	13.5 b	7.5 a	4 ab	0 a	47 b
Fuji	14.4 c	10.1 ef	7 ab	5 bc	5 b
Crimson Crisp	14.7 cd	9.5 cd	4 ab	5 bc	33 ab
Hampshire	14.9 cde	10.7 fg	3 a	2 ab	45 ab
NY 79507-49	15.3 def	8.7 b	3 a	2 ab	38 ab
Mutsu	15.3 def	9.7 cde	7 ab	6 bc	38 ab
Sundance	15.5 efg	12.5 h	19 cd	13 d	51 b
CQR10T17	15.9 fg	10.8 g	10 abc	3 ab	46 ab
Roger's Mac	16.3 g	10.7 fg	7 ab	6 bc	42 ab
NJ 109	16.3 g	9.4 c	13 bc	4 abc	39 ab
Zestar	20.3 h	12.5 h	23 d	7 c	28 a

[a] Means separations are based on Fisher's Protected LSD ($P \leq 0.05$) from ANOVA for 15 cultivars in five blocks. The angular transformation was applied to incidence data, but the arithmetic means are shown. Means in the upper table represent "block" effects where most of the differences were attributable to spray programs. Means in the lower table represent cultivar effects as measured across all five blocks.

[b] Fruitlet evaluations were based on all fruitlets from 10 clusters per tree collected 26 May before effects of fruit thinners had caused thinned fruitlets to abscise

Table 6A. Effects of spray programs on incidence of undamaged fruitlets and incidence of European apple sawfly (EAS) and tarnished plant bug (TPB) on king fruitlets and on side fruitlets from 10 clusters per tree that were collected on 26 May.

	% damage				% clean fruit 26 May (no insect damage)	
	EAS		TPB			
REPS	king	sides	king	sides	king	sides
Control	21.5 c[a]	14.0 c	17 b	7 c	46 a	68 a
Standard	7.2 b	5.8 b	4 a	4 b	83 b	86 b
Organic-center row sprayed both sides	1.5 a	0.7 a	0 a	<1 a	94 c	98 c
Organic-outside row sprayed both sides	2.0 ab	0.9 a	0 a	1 a	92 c	97 c
Organic-outside row sprayed one side	4.0 ab	2.7 a	1 a	<1 a	94 c	95 c

See footnotes below table 6B.

Table 6B. Difference among apple cultivars in incidence of undamaged fruitlets and incidence of European apple sawfly (EAS) and tarnished plant bug (TPB) on king fruitlets and on side fruitlets from 10 clusters per tree that were collected on 26 May.

	% damage[b]				% clean fruit 26 May (no insect damage)[b]	
	EAS		TPB			
Cultivar	king	sides	king	sides	king	sides
CQR10T17	2.1 a[a]	1.5 ab	4 ab	2 abc	83 bcd	92 def
NJ 90	2.1 a	3.9 abcde	2 ab	2 abc	89 cd	92 ef
Mutsu	2.2 a	2.8 abcd	4 ab	0 a	87 cd	91 cdef
Ambrosia	2.5 a	1.4 ab	5 ab	3 abcd	93 d	92 def
Delblush	2.6 ab	5.2 bcdef	10 bc	5 bcd	85 bcd	88 bcde
NJ 109	4.9 ab	7.0 def	5 ab	3 abc	77 bc	87 bcde
Fuji	5.6 ab	2.6 abc	7 ab	3 abc	82 bcd	90 cdef
Roger's Mac	7.3 ab	7.9 efg	4 ab	1 a	82 bcd	86 abcd
NY 79507-49	8.5 ab	0.0 a	9 b	3 abc	81 bcd	95 f
Crimson Crisp	10.4 abc	3.3 abcd	8 ab	7 d	77 bc	87 bcde
BC 8S-26-50	10.5 abc	6.8 cdef	18 c	5 cd	71 b	89 cdef
Sundance	11.6 abc	5.1 bcdef	0 a	1 a	70 b	81 ab
Hampshire	12.7 bc	9.2 fg	3 ab	3 abc	82 bcd	86 abc
Chinook	20.4 cd	9.0 fg	4 ab	2 abc	71 b	88 bcde
Zestar	23.0 d	11.8 g	2 ab	1 ab	56 a	80 a

[a] Means separations are based on Fisher's Protected LSD ($P \leq 0.05$) from ANOVA for 15 cultivars in five blocks. The angular transformation was applied to incidence data, but the arithmetic means are shown. Means in the upper table represent "block" effects where most of the differences were attributable to spray programs. Means in the lower table represent cultivar effects as measured across all five blocks.

[b] For details of sampling methods, see footnotes on Table 3A.

Table 7A. Effects of spray programs on the incidence of insect damage on apple fruit at harvest: EAS = European apple sawfly, TPB = tarnished plant bug, SJS = San Jose scale, XLEP = external feeding damage by lepidoptera, ILEP = internal feeding damage by lepidoptera, AMT = apple maggot tunnels in fruit flesh, CLEAN = fruit with no insect damage.

	% damage to fruit at **HARVEST** [a]						% clean
Rep	EAS	TPB	SJS	XLEP	ILEP	AMT	(no insect damage)[a]
Control	5 b [a]	8 b	2 a	5 b	26 c	3.2 a	1 a
Standard......................	7 b	12 c	3 ab	2 a	4 a	0.8 a	52 bc
Organic-center row sprayed both sides.....	1 a	2 a	7 abc	2 a	6 ab	2.1 a	59 c
Organic-outside row sprayed both sides.....	1 a	2 ab	10 bc	5 b	6 ab	2.4 a	53 bc
Organic-outside row sprayed one side........	1 a	2 ab	10 c	5 b	9 b	1.1 a	47 b

See footnotes below table 7B.

Table 7B. Differences among apple cultivars in incidences of insect damage on apple fruit at harvest

	% damage to fruit at **HARVEST** [a]						% clean (no
Cultivar	EAS	TPB	SJS	XLEP	ILEP	AMT	insect damage
Ambrosia	<1 a [a]	3 ab	10 a	4 bcde	9 b	0.0 a	43 bcdef
BC 8S-26-50	2 abcd	4 ab	1 a	2 abc	8 ab	1.2 abc	49 cdef
Chinook	8 d	5 ab	1 a	1 a	10 b	0.4 ab	38 abcd
Sundance	3 abcd	17 c	0 a	1 a	30 c	8.3 c	30 abc
Crimson Crisp	3 abcd	2 ab	0 a	4 abcde	12 b	1.4 ab	54 def
CQR10T17	2 abcd	2 ab	0 a	4 abcde	12 bc	0.0 a	39 abcde
Delblush	3 bcd	6 ab	48 c	4 abcde	11 ab	0.8 ab	23 a
Hampshire	4 cd	4 ab	0 a	3 abcd	7 ab	2.4 abc	47 bcdef
Fuji	1 ab	3 ab	<1 a	4 e	8 ab	1.2 abc	43 bcdef
Roger's Mac	1 abc	12 bc	2 a	1 abc	7 ab	0.8 ab	50 cdef
NJ 109	3 abcd	6 ab	0 a	3 cde	8 ab	6.0 abc	48 bcdef
NJ 90	<1 a	5 ab	0 a	2 ab	7 ab	0.4 ab	49 cdef
NY 79507-49	4 abcd	2 a	0 a	1 abcde	2 a	0.0 a	56 ef
Zestar	3 abcd	1 a	0 a	2 de	9 ab	4.6 bc	57 f
Mutsu	6 d	7 ab	33 b	2 abcd	16. b	3.0 abc	25 ab

[a] Means separations are based on Fisher's Protected LSD ($P \leq 0.05$) from ANOVA for 15 cultivars in five blocks. The angular transformation was applied to incidence data, but the arithmetic means are shown. Means in the upper table represent "block" effects where most of the differences were attributable to spray programs. Means in the lower table represent cultivar effects as measured across all five blocks.

[b] For details of sampling methods, see footnotes on Table 3A.

Table 8A. Effect of spray program on incidence of preharvest drop, fruit size, and productivity.

	% pre-harvest drop [b]	No. fruit/ tree at harvest [b]	Mean fruit wt (g/fruit) [b]	Total harvest-able crop/tree (lb/tree) [b]
Control	29 b [a]	89 a	128 a	23 a
Standard	11 a	203 c	216 c	93 c
Organic-center row sprayed both sides	27 b	114 ab	197 bc	41 ab
Organic-outside row sprayed both sides	31 b	96 a	195 bc	35 a
Organic-outside row sprayed one side	21 b	155 bc	171 b	56 b

See footnotes below table 8B.

Table 8B. Differences among cultivars in incidence of preharvest drop, fruit size, and productivity.

Cultivar	% pre-harvest drop [b]	No. fruit/ tree at harvest [b]	Mean fruit wt (g/fruit) [b]	Total harvest-able crop/tree (lb/tree) [b]
Ambrosia	6 a [a]	193 c	127 ab	55 n.s [c]
BC 8S-26-50.................	7 ab	118 abc	251 gh	57
Chinook......................	18 bcde	289 d	101 a	65
Sundance	32 defg	133 abc	208 efg	70
Crimson Crisp.............	35 efg	42 a	153 bcd	16
CQR10T17	17 bcde	89 ab	234 fgh	44
Delblush	55 h	129 abc	171 bcde	44
Hampshire	8 abc	163 bc	180 cde	66
September Wonder	11 abc	162 bc	165 bcde	58
Roger's McIntosh	14 abcd	114 abc	145 abc	41
NJ 109	13 abcd	111 abc	165 bcde	42
NJ 90	40 fgh	84 ab	175 cde	33
NY 79507-49	24 def	178 c	206 ef	76
Zestar..........................	25 cdef	79 ab	198 def	35
Mutsu	49 gh	84 ab	262 h	48

[a] Means separations are based on Fisher's Protected LSD ($P \leq 0.05$) from ANOVA for 15 cultivars in five blocks. The angular transformation was applied to incidence data, but the arithmetic means are shown. Means in the upper table represent "block" effects where most of the differences were attributable to spray programs. Means in the lower table represent cultivar effects as measured across all five blocks.

[b] Preharvest drop was determined by counting all fully-sized fruit on the ground at harvest and expressing results as the ratio of drops to total crop (drops plus harvestable fruit). Mean fruit weight was determined by weighing 50 fruit per tree (or all available fruit if less than 50) that were harvested at commercial maturity.

[c] No significant differences.

The organic plots had fewer fruit per tree than the standard and fruit size tended to be smaller. The organic row that was sprayed from only one side had more fruit than the other two organic rows, but it also had the smallest fruit size (Table 8A). This suggests that overthinning was not the primary cause of the decreased crop load evident in the organic plots.

In multi-variety plots, it is impossible to pick a single date or application for chemical thinning that will optimize production for all of the cultivars due to differences in timing of bloom and petal fall and differences in fruit growth rate after petal fall. Thus, some cultivars (e.g. Crimson Crisp) were severely overthinned in our plots and others should have had some supplemental hand thinning in June (e.g., Chinook) (Table 8B). However, we opted not to do any hand thinning in these plots. In some cases, crop load might have been close to optimal if all of the preharvest drops had remained on the trees and had been included in the harvest totals.

Costs for the various pesticides used in this trial were estimated by asking four consultants and several company sales representatives to provide price quotes typical of what medium-sized apple growers might have paid for these products in 2006. Prices listed in Table 9 represent adjusted averages from all available data sources. The cost of pesticides alone was $350/A for

Table 9. Prices estimates for products used in this trial and total costs of seasonal spray programs.

Product	Price per unit		total cost /A/yr
Standard program			
COCS	2.00	lb	7.98
Dithane	1.91	lb	31.17
Rubigan	64.58	qt	108.34
Topsin M	13.69	lb	39.38
Captan-80	3.74	lb	32.22
Sevin XLR	25.80	gal	7.42
Imidan	7.17	lb	93.38
Asana	78.62	gal	20.64
Fruitone-N	33.57	lb	9.65
Total cost/A/yr for pesticides			350.17
Application costs ($20/appl X 15 applications)			300.00
TOTAL insect/disease control expenses/A			**$650.17**
Organic program			
Champion WP copper hydroxide	3.00	lb	18.90
Microthiol Disperss	0.68	lb	91.23
Liquid lime-sulfur	8.00	gal	40.00
Damoil	4.71	gal	32.51
Surround WP	0.95	lb	400.24
JMS Stylet Oil	17.00	gal	68.00
DiPel DF	9.45	lb	14.46
Entrust	400.00	lb	127.83
Total cost/A/yr for pesticides			793.16
Application costs ($20/appl X 19 applications)			380.00
TOTAL insect/disease control expenses/A			**$1,173.16**

the standard plots compared to $793/A for the organic program. However, the organic blocks were sprayed 19 times compared to only 15 times for the standard block. If application costs (equipment plus labor) are calculated at $20 per acre per application, then total pest control costs were 80% higher for the organic program than for the standard program.

The higher cost per acre for pest control and the lower productivity of trees in the organic block combined to create large differences in per-bushel costs for pest control (Table 10). The cost of pest control per bushel of harvestable fruit was 76 cents for the standard program compared to $2.98 for the organic program. This difference is based only on the total number of harvestable fruit and does not account for potential differences in the proportion of marketable fruit. Unfortunately, we did not track the total number of marketable fruit in this trial. The data showing percent clean fruit (no insect damage) in Tables 7A&B underestimate the proportion of marketable fruit because many fruit with tarnished plant bug damage and some fruit with PC and external lep damage would still be marketable under USDA grading standards. On the other hand, fruit with black rot, bitter rot, or lenticel spots would not be marketable. Incidence of these diseases was 12-20% greater in the organic block than in the standard block (Table 4A), and that factor alone might have created even greater differences in the economic comparison between organic and standard pest control if we had recorded the final proportion of marketable fruit from each plot.

Table 10. Estimated pest control costs per bushel for the two systems evaluated at the Hudson Valley Lab in 2006.

	lb/tree [a]	Bu/A [b]	Pest control costs (dollars per bushel) [c]
Control	23	209	
Standard	93	861	0.76
Organic-center row sprayed both sides	41	384	3.05
Organic-outside row sprayed both sides	35	323	3.63
Organic-outside row sprayed one side	56	519	2.26
Mean for three organic row		409	2.98

[a] lb/tree represents the mean weight of harvested fruit from 15 cultivars in each of the five blocks including apples with disease and pest-related defects but excluding apples that dropped prior to harvest.

[b] Bushels/A were calculated assuming 390 trees/A and 42 lb/bushel.

[c] Pest control costs were derived by dividing total cost/A including application costs for the standard and organic programs (Table 9) by the number of bushels per acre.

Discussion:

As with any field trial, one can see in retrospect things that might have been done differently to improve the outcomes with either the organic, the standard, or both pest control programs. A test orchard with less exposure to cedar rust inoculum and immigrating insects would have allowed more effective pest control than occurred in our trial. Because of the high pest pressure in this orchard, proportions of damaged fruit were unacceptably large for many pests in both the standard and organic blocks. However, our test orchard was not significantly different from many older orchards that new land owners in the Hudson Valley would like to convert to organic production. The difficulty we had in controlling pests in both the standard and the organic blocks illustrates the hurdles that small land-owners are likely to face when attempting to grow apples on small acreages that are surrounded by habitat that supports insect and disease pests.

Scab-resistant apple cultivars are preferable for organic production because they negate the need for many of the sulfur sprays that must otherwise be applied to control apple scab. However, even with scab-resistant cultivars, fungicides are still needed during summer to control SBFS, bitter rot, and diseases caused by *Botryosphaeria* species. More work is needed to determine if LLS or copper can be substituted for sulfur during July and August sprays, but other research at both the Hudson Valley Lab and elsewhere has shown that both LLS and copper can cause phytotoxicity and/or yield reduction. Using LLS plus oil for fruit thinning is preferable to hand-thinning organic blocks, but finding a thinner with fewer adverse effects on fruit size might help to improve the economics of organic apple production.

Results from this trial allow the following conclusions:

1. Surround, Entrust, DiPel, and stylet oil can be used to effectively manage most apple insect and mite pests within organic apple production systems.
2. Sulfur can provide effective control of apple scab and powdery mildew. The latter was not evaluated in this trial because Surround residues made it impossible to rate leaves for mildew. However, effectiveness of sulfur as a mildewcide is well established.
3. Sulfur was not effective for controlling cedar rust lesions on leaves, but it suppressed quince rust infections on fruit.
4. Sulfur applied at 1 lb/100 gal of dilute spray during summer did not provide adequate control of bitter rot, black rot, and *Botryosphaeria*-related lenticel spotting on fruit. Higher rates might be more effective, but even the low rate that we used resulted in severe lenticel spotting on some cultivars. Copper fungicides applied at low rates during summer might provide more effective control of summer fruit rots and should be evaluated as a replacement for sulfur during July and August.
5. Ambrosia, Sundance, Delblush, and Mutsu all developed severe lenticel spotting in our organic plots and may be unsuitable cultivars for organic production where sulfur fungicides will be used during summer. Further testing is required to determine if the lenticel spotting is indicative of unusual sensitivity of the fruit to sulfur injury or whether these cultivars are just more susceptible to invasion of lenticels by *Botryosphaeria.*
6. Using sulfur and LLS in apple production systems results in smaller fruit and reduced production. Our results confirm similar reports from the 1950's (e.g., Palmiter & Smock, 1954).
7. Organic pest control on apples will be more expensive than standard IPM approaches to pest control. Our data suggests that organic growers will need to price their fruit at least four times higher than standard fruit to cover the higher pest control costs and lower production that is currently inherent in organic apple production systems. Before embarking on expensive organic production systems, growers should verify that consumers will be willing to pay a 4X higher price for organic fruit as compared to fruit produced with standard pesticides. Otherwise, organic growers may absorb the costs of a

three-year transition to organic production systems only to find that they cannot sell their fruit at a profit.

8. The organic pest control treatments evaluated in this trial have some disadvantages that are not apparent from the data presented. Both sulfur and LLS are noxious to pesticide applicators and field workers due to their odor and their potential for causing eye irritation. The odor and irritating residue can persist for many weeks after application if the residues are not weathered by rainfall. The chalky residue left by the kaolin clay treatments persists on fruit at harvest and must be removed before fruit can be marketed. In this trial, we removed the visible residues by hand-wiping fruit prior to rating them. It should be possible to remove the residues on a packing line by soaking fruit in commercial detergents, washing them with high-pressure streams of water, and/or running them over brush beds on the packing line. All of those options may add costs that were not included in our cost comparisons.

Results from this trial are most applicable to growers in New York's Hudson Valley, Connecticut, and northern New Jersey where environmental conditions and pest complexes are most similar to those where the experiment was conducted. However, the cost for the two pest control systems that we compared is representative for most of New York and New England and perhaps for the Great Lakes and mid-Atlantic region as well.

This work should be of interest to farmers who are considering organic apple production because it provides an indication of pest control costs and yields that might be anticipated using organic methods. The work reported here suggests that organic apple production is technically feasible with pesticides that are approved for use by organic farmers, but it may not yet be economically practical.

This report, along with additional supporting information, will be made available electronically on the NY State IPM website. The trial may be repeated (with appropriate adjustments) in another year if additional funding can be located to support the project.

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