Organic Apple and Grape Performance in the Midwestern U.S.

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Abstract

Since 1999, there has been a resurgence of interest in grape and organic fruit production in the Midwestern U.S. state of Iowa. With the new U.S. federal rules governing organic production becoming effective in October 2002, any products sold as "organic" in the U.S. must be grown without synthetic fertilizers, pesticides, genetically modified seeds or ingredients, antibiotics or hormones for a period of 3 years, but "wine made with organic grapes" may contain 100 ppm sulfur dioxide. In an Organic Grape Vineyard Survey, conducted in 2002, and at the Organic Grape Vineyard Demonstration, viticulturists reported planting *Vitis labrusca* or *V. labrusca* hybrids with inherent disease-tolerance as their most important method for managing diseases. Integrated weed management, using cover crops, mulching and mowing, offered the option for weed control. Successful organic apple production relies on insect mating disruption and integrated pest management, including apple scab disease-resistant cultivars and non-synthetic pesticides, such as kaolin clay particle film. Research conducted in a certified organic apple (*Malus* H *domestica* Borkh.) orchard in 2000 determined that kaolin particle film was effective in lowering codling moth and plum curculio insect damage in Redfree and Jonafree apples during the growing season and in Jonafree apples at harvest. Beneficial insects were not harmed by the kaolin clay treatments. Apple productivity and yields were not affected by pest management treatments. In postharvest examinations, washing significantly reduced yeast and mold populations on kaolin particle film-treated apples. Organic fruit production will become a viable niche market in the Midwestern U.S. as producer and consumer demand for less pesticides in the environment increases and pest management technology is advanced through cooperative efforts between universities and private industry.

INTRODUCTION

The U.S. organic industry was listed as an $8 billion industry in 2001, with an annual growth rate exceeding 20% (Greene et al., 2001). According to the Organic Farming Research Foundation, there were 16,000-20,0000 organic farmers in U.S. in 1997 (Walz, 1999). Among these growers, there were 145 organic apple orchards on 1,111 ha and 86 organic vineyards with 2,906 ha of grapes. The Midwestern state of Iowa has an active organic farming community, with 500 farmers farming 60,000 ha (IDALS, 2001). Since 1999, there has been a resurgence of interest in grape and organic fruit production in Iowa. Governmental support for organic fruit research and development since 1999 has included funds for the new state viticulturist and organic crops specialist at Iowa State University.

Iowa was the sixth largest producer of grapes in the U.S. in early 1900s with 24,000 ha under production (Pirog, 2000). The rapid expansion of petrochemicals post-World War II led to the decline of many vineyards. The sensitivity of grapes to 2,4-D herbicide and the replacement of vineyards with commodity-supported corn and soybean acreage reduced the total vineyard size in Iowa to 28 ha in 2001. The rapid increase in organic production since 1990 has been driven by consumer demand. Many organic growers and organic consumers have chosen to avoid pesticides in their crops and food because of the following concerns:

- Herbicide damage to crops (with particular sensitivity in grapes)

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- Problems of resistance, residues, and resurgence of secondary pests. More than 600 insect pests have developed resistance to insecticides, and many fungi have also evolved immunity to certain fungicides, rendering these products useless for pest management. Pesticide residues can be detrimental to human health and are restricted by law. A resurgence of secondary pests (aphids, leafhoppers, mites) following insecticidal spraying of natural enemies (predators and parasitic wasps) of these once-minor pests has become more commonplace.
- Direct effect of accidental exposure, ranging from dermatitis to death, depending on the pesticide and exposure time.

As of October 21, 2002, any products sold as “organic” in the U.S. must be grown without synthetic fertilizers, pesticides, genetically modified seeds or ingredients, antibiotics or hormones for a period of 3 years, and be certified by an independent third party agency (USDA-AMS, 2000). The term, "organic," may not be used in a product name to modify a non-organic ingredient in the product. With federal rules and oversight, an increased consumer awareness and desire for organic foods is anticipated. Rules governing the labeling of organic grapes, according to the USDA-National Organic Program include the following:

- Grapes, wine or grape-based products sold, labeled, or represented as "100 percent organic" must contain (by weight or fluid volume, excluding water and salt) 100 percent organically produced ingredients.
- Grapes, wine or grape-based products sold, labeled, or represented as "organic" must contain (by weight or fluid volume, excluding water and salt) not less than 95 percent organically produced raw or processed agricultural products. Any remaining product ingredients must be organically produced, unless not commercially available in organic form, or must be nonagricultural substances or non-organically produced agricultural products produced consistent with the National List.
- Grapes, wine or grape-based products sold, labeled, or represented as "made with organic (specified ingredients or food group(s))." Multi-ingredient agricultural product sold, labeled, or represented as "made with organic (specified ingredients or food group(s))" must contain (by weight or fluid volume, excluding water and salt) at least 70 percent organically produced ingredients which are produced and handled pursuant to requirements in subpart C of this part. No ingredients may be produced using prohibited practices. If labeled as containing organically produced ingredients or food groups, such product must be labeled pursuant to § 205.304. “Wine made with organic grapes” may contain 100 ppm sulfur dioxide. (USDA-AMS, 2000).

Successful organic apple production has been documented in Western U.S. using insect mating disruption and integrated pest management (Swezey et al., 2000). Reganold et al. (2001) also demonstrated organic apple production systems with improved profits, soil quality, taste and texture compared with conventional apples in Washington state. With the development of disease-resistant cultivars for apple scab (*Venturia inaequalis* [Cooke]) management, organic apple production in the Midwest has expanded to commercial operations. Insect pests, including codling moth (*Cydia pomonella* [L.]), plum curculio (*Conotrachelus nenuphar* [Herbst]) and apple maggot (*Rhagoletis pomonella* [Walsh]), are considered the most important constraints in humid apple-growing regions (Phillips, 1998). A new certified organic pest management product, kaolin clay, was introduced in 2000 as Surround™ (Engelhard Corp., Iselin, NJ). Kaolin is a natural product that has been used in cosmetic, toothpaste, and food products and is generally recognized as safe. Kaolin particle film consists of 95% kaolin clay and has proven successful in the management of insect pests and some diseases (Puterka et al., 2000; Thomas, 2000). Pests are controlled by visual repellency of the white film protectant and from irritating particles adhering to insect integuments (Glenn et al., 1999). Host ‘masking’ may also be involved when kaolin particle film thwarts insect recognition of the white-coated tree. Protection from heat stress and sunburn and increased photosynthesis rates have also been reported with kaolin particle film. For protection against plum curculio and first generation codling moth, kaolin particle film is applied at petal fall and weekly for 6 to 8 weeks (Earles, 1999). Full coverage of the apple and grape canopy is necessary for optimum protection. Application periods range from every 7 to 10 days, depending on environmental conditions (USDA-ARS, 1999).

Organic apple growers requested information on the efficacy of kaolin clay under Iowa conditions, in addition to the effect on postharvest microbial populations on apples. State and federal organic certification laws prohibit the application of raw manure to a horticultural crop 4 months prior to harvest in order to avoid contamination from pathogenic *Eschereshia coli* (IDALS, 1999; USDA-AMS, 2000). Organic farmers also compost manure to temperatures of 60˚C for at least 3 days to kill pathogenic organisms before applying to fields. Following harvest of kaolin-treated apples, an experiment was conducted to evaluate the effect of washing on microbial organisms in order to comply with USDA food quality regulations.

MATERIALS AND METHODS

Organic Apple Pest Management

Research was conducted in a certified organic apple orchard in Runnells, Iowa, in 2000 to determine the effect of organic pest management techniques on pest control, apple yields and microbial populations on harvested apples. Scab-resistant apple cultivars, Redfree, Jonafree and Liberty, were planted on dwarf rootstock Malling 9 and B9 in a three-tier trellis wire system on 23 April 1997. Six pest management treatments were applied to the orchard, including a control, double-layer coloring bags (Wilson Irrigation, Yakima, WA), sticky red spheres (Gemplers, Beltsville, WI), kaolin particle film (Surround™, Engelhard Corp., Iselin, NJ), kaolin particle film plus sticky red spheres, and coloring bags plus sticky red spheres. Each treatment was randomly assigned to one row of each cultivar of Redfree, Jonafree and Liberty. Coloring bags were placed on the apples on 6 - 12 June 2000, and removed one month before harvest to allow for sufficient color change of the apples. Plastic red spheres were coated with Tangle-trap™ (Grand Rapids, MI) and were placed on every third tree of the treatment row on 6 June 2000. A mixture of 28 kg ha^{-1} kaolin particle film to 935 l water was applied every two weeks from 15 June 2000 until 2 weeks before harvest, using a backpack CO_2 pressurized sprayer.

Insect and disease data were collected on five randomly selected apples and five randomly selected leaves per five trees of each treatment in each cultivar and were examined every two weeks from 21 June until 30 Aug. The disease rating consisted of 1 = no symptoms; 2 = 1-25% of leaf or apple showing symptoms; 3 = 26-50% of leaf or apple showing symptoms. Insect damage was recorded as number of "strikes”, which were puncture wounds created by pests. Beneficial insects were enumerated in order to determine the impact of kaolin particle film on these insects. Harvest data were collected from five trees each of Redfree and Jonafree cultivars. Data collected included apples per tree, fresh weight of total apples, number of marketable fruit, and plum curculio and codling moth damage.

In order to determine the effect of these organic management practices on regulated, foodborne microbial populations, we examined whole, untreated apples and apples treated with coloring bags or kaolin particle film for coliform, *E. coli*, yeast and mold populations. Standard tests using 3M Yeast/Mold petrifilm and *E. coli*/Coliform petrifilm (3M Microbiology Products, Minneapolis, Minnesota) determined microbial populations on washed and unwashed whole apples. Least significant differences (LSDs) at the 0.05 significance level were calculated (SAS Institute, Cary, N.C.).

Organic Grape Vineyard Demonstration

Among the limited research on organic grape production, Cornell University reported successful organic grape production from 1990-1994 (Pool, 1995). Organic ‘Elvira’ grape yields were equivalent to conventional yields (17.6 Mg/ha) with organic grapes performing better in drier years. Organic ‘Seyval’ grape yields were 30% lower and organic 'Concord' yields were 20% lower, however. Soluble solids were higher in organic Concord and Seyval cultivars, but equivalent concentrations were obtained in the organic and conventional Elvira cultivar.

An Organic Grape Vineyard Demonstration was established at the Iowa State University Neely-Kinyon in Greenfield, Iowa, in Spring 2001. One-year-old vines were planted. All cultivars in the vineyard demonstration planting are *V. labrusca* or *labrusca* hybrids with inherent disease-tolerance. These include Edelweiss, a cold-hardy, white table grape; Frontenac, a cold-hardy, disease-tolerant, red wine and Marechal Foch, a semi-cold-hardy, red wine grape; and Bluebell, a cold-hardy, black table grape. Untreated stakes were used for first- and second-year vines. A bilateral cordon trellis system was created in the second year, using steel posts and wires, per certified organic requirements. Vines were first pruned in 2002. A steel deer fence was also established around the perimeter of the vineyard.

Because weeds were identified as the most important management issue in organic grape production (Pool, 1995), an integrated weed management system was established at the Demonstration Vineyard. Crimson clover (*Trifolium incarnatum* L.) was interseeded at a rate of (112 kg ha^{-1}) on April 19, 2002, as a ground cover in the vine row middles. A 15-cm-deep alfalfa straw mulch was maintained throughout the season in a 1-m perimeter around each vine. Five plants of sweet alyssum [*Lobularia maritima* (L.)] were transplanted in each vine row to serve as attractants for beneficial insects.

Nutrient management in an organic system is based on a recycling of plant and animal residues within the agricultural system. Compost was applied on April 19, 2002 at 8 Mg ha^{-1}. This compost was derived from a hoop-house swine system, which is a low-input method of raising hogs on a deep bed of carbonaceous material, such as corn stalks or hay. Vines were treated with elemental sulfur on April 19, 2002, before bud break, for prevention of anthracnose and powdery mildew. Vines were also treated with kaolin particle film in May, June, and July 2002.

Organic Grape Survey

Because of the increasing interest in organic grape production in Iowa, we conducted a survey in June-July, 2002, of organic grape growers. Each grower received a questionnaire (Table 1) that was completed at the time of the site visit or following the visit. Vines were inspected and data collected by a minimum two-scientist team, with the grower assisting when questions arose.

RESULTS AND DISCUSSION

Organic Apple Pest Management

Despite the adverse weather conditions, organic apple production was successful in 2000 (Friedrich et al., 2002). Precipitation was limited to 34 mm compared with a normal rainfall of 101 mm in May 2000 (Agricultural Meteorology, 2000), leading to an earlier apple harvest. Fruit from the Liberty cultivar was not analyzed due to a premature fruit drop during high winds. Apple diseases were not considered significant problems in the 2000 season, although fire blight (*Erwinia amylovora*), sooty blotch (*Gloeodes pomigena*) and flyspeck (*Zygophiala jamaicensis*) were observed within the orchard. Because apple maggot flies or larvae were not detected during the 2000 season, the kaolin particle film and kaolin particle film plus sticky red spheres data were pooled for analysis (Table 2). Kaolin clay was not effective in lowering disease ratings on leaves during the growing season, but kaolin particle film-treated Jonafree and Liberty apples had lower disease ratings than the controls. There was a significant treatment x cultivar interaction, however, with the lowest average disease ratings in the Redfree and Liberty cultivars.

Kaolin particle film was more effective in lowering insect attack during the growing season, as significantly less damage was observed on kaolin-treated Redfree and Jonafree apples compared to control apples. A significant treatment x cultivar interaction resulted in less insect damage overall on Liberty apples during the growing season (Table

2). Beneficial insects were not harmed by the kaolin clay treatments (Table 2).

Treatments, cultivars, and treatment x cultivar interactions significantly affected codling moth damage on apples at harvest in pooled data (Table 3). The three codling moth pheromone traps that were established in the orchard indicated a codling moth flight around 19 July, although most likely not the first flight, and another flight around 16 August 2000. Kaolin particle film and coloring bag treatments reduced codling moth damage in Jonafree and Redfree apples compared to the controls (Table 3). Codling moth damage was significantly less in Redfree control apples than in untreated Jonafree apples, but there was no significant difference between the coloring bag and kaolin particle film treatments in either cultivar. Redfree apples were harvested earlier than the Jonafree, potentially escaping the later flight of codling moths. Treatment and cultivar effects were also significant in the pooled data comparison for plum curculio damage in harvested apples. With lower plum curculio damage overall in Redfree, there was no difference in plum curculio damage in any treatment. Jonafree apples in the pooled kaolin treatments experienced significantly less plum curculio damage compared with coloring bags and control apples (Table 3).

The manipulation of apples while securing and removing coloring bags caused premature fruit drop in that treatment, but the number of apples per tree was equivalent among treatments (Table 3). Yields were not significantly affected by cultivar or pest management technique (Table 3). Percentage of marketable fruit at harvest was affected by cultivar and treatment x cultivar interactions (Table 3). In the pooled data comparisons, combined coloring bag treatments and combined kaolin clay treatments provided a greater percentage of marketable Jonafree fruits compared to the control trees. The highest percentage of marketable fruit was obtained in the Jonafree apples covered with coloring bags.

Coliform or *E. coli* colonies were not observed on Redfree and Jonafree apples from the control, coloring bag or kaolin particle film treatments in the postharvest microbial populations comparisons. One of four untreated control Liberty apples was found to contain 225.0 ± 95.0 CFU/apple. When kaolin particle film-treated apples were washed with water, yeast and mold populations were reduced from 362143 to 190929 CFU/apple. The range of yeast and mold on apples in Iowa has been 20000-12000000 CFU/apple and the range of coliform populations100-100,000 CFU/apple (Cummins, 2001). Peeling of apple skin will eliminate the protective particle film and decrease microbial loads if washing is not practiced.

Organic Grape Vineyard Demonstration and Vineyard Survey

The Organic Demonstration Vineyard experienced dry summer conditions and minimal disease pressure. The most prevalent insect pest was the grape leafhopper (*Erythroneura elegantula* Osborn) with only a 2% damage rating throughout the vineyard. Anthracnose (*Elsinoe ampelina* [de Bary] Shear) and powdery mildew (*Uncinula necator* [Schw.] Burr.) were observed but at a low infection rate of 5%. Grapes will not be harvested until the third year so effect on yields was not determined.

A summary of the survey results from eleven Organic Vineyards is presented in Table 4. The organic grape industry is relatively young in Iowa, with the average age of vines at 2.2 yr. Growers are incorporating varietal diversity in their vineyards, averaging 3.5 grape cultivars per farm. The most predominant cultivar was Marechal Foch, with 64% of vineyards cultivating this grape. Productivity varied among vines surveyed, with the average vine length for 1 to 3 yr-old vines at 133-192 cm and 258 cm in vines 4 yr and older. The average number of grape clusters was 16 per vine, with an average of 33 grapes per cluster.

In organic vineyards in Iowa, 73% use on-farm or local sources of manure or composted manure for plant nutrition. On the majority of grain-based organic farms in the U.S, farm animals consume crops/crop residues and recycle nutrients into soil. According to USDA rules, raw manure can be applied 4 months prior to harvest but compost is recommended. Compost application rates vary from 1 Mg to 20 Mg ha^{-1} depending on soils/crop requirements. “Finished” compost is used to avoid N immobilization and excess applications are avoided to prevent groundwater contamination from nitrates and phosphates. Cover crops provide an additional source of nutrition and weed management, and up to 73% of organic viticulturalists surveyed reported using grass-based cover crops. Although legume-based cover crops can supply up to 75 kg ha^{-1} N, the additional management required for cultivation and irrigation has limited their use.

Insect and disease pests were not considered significant among organic grape growers surveyed. The most prominent concerns were herbicide drift and deer damage. Herbicide drift can disqualify organic vineyards form certification for at least one year (IDALS, 1999). Deer can be managed with fencing but most vineyards in Iowa were not fenced. The following insect pests were reported to occur in vineyards:

- Grape leafhopper in 50% of vineyards
- Japanese beetle (*Popillia japonica* Newman) in 20% of vineyards
- Lepidopteran larvae, such as climbing cutworm (Lepidoptera: Noctuidae), Western grape leaf skeletonizer (*Harrisina brillians* Barnes & McDunnough), sphinx moth larvae (*Eumorpha achemon* [Drury]), and eightspotted forester (*Alypia octomaculata* [Fabricius]) in 20% of the vineyards
- Grape flea beetle (*Altica chalybea* Illiger) in 10% of vineyards
- Grape phylloxera (*Daktulosphaira vitifoliae* [Finch]) in 10% of vineyards

Grape berry moth (*Lobesia botrana* [Denis and Schiffermuller]) and mites (*Tetranychus* spp.) have been reported in conventional vineyards, but due to the time of year, were not observed in any organic vineyards. Leafhoppers or leafhopper damage was the most prevalent damage observed from insect pests, although damage did not exceed 10% in most vineyards. Preventative pest management methods were observed on the majority of farms. These methods included the following:

- Disease-tolerant cultivars
- Crop diversity (host-masking)
- Flowering plants (insectary plants) to attract predators and parasitic wasps.

Low-toxicity, organically-approved insecticides were used on 18.1% of grapes surveyed, and included the following:

- Botanicals: neem, pyrethrum, sabadilla, and ryania for leafhoppers
- Soap products; diatomaceous earth (D.E.); kaolin clay for leafhoppers
- Biological Controls: *Bacillus thuringiensis* (*B.t.*) natural bacteria spray for all lepidopteran pests and *Bacillus popillae* (milky spore) for Japanese beetle.

Trichogramma spp. and *Anagrus* spp., parasitic wasps whose eggs are inserted into grape berry moth and leafhoppers, respectively, have been reported to be an effective augmentative biological controls in Western U.S., but are currently not released in Iowa. Increased suppression of leafhoppers, spider mites, and ants (which limit bio-control of aphids and mealybugs) has been reported in California vineyards with the planting of cover crops, such as vetch/rye and oat/vetch combinations (Zalom, 1993).

Diseases that have been reported on grapes in the Midwest include the following:

- Black rot (*Guignardia bidwelii* [Ellis] Viala & Ravaz)
- Downy mildew (*Plasmopara viticola* [Berk & Curt.] Berl. & de Toni)
- Powdery mildew (*Uncinula necator* [Schw.] Burr.)
- *Phomopsis* cane and leaf spot (*Phomopsis viticola* [Sacc.] Sacc.)
- Anthracnose (*Elsinoe ampelina* [de Bary] Shear).

Only a 2% disease damage rating was observed in the organic vineyards surveyed from anthracnose and powdery mildew. The biological control antagonistic competitors *Trichoderma harzianum* (T22 Planter Box™) against *Botrytis* and AQ-10 (*Ampelomyces quisqualis*) against powdery mildew have been reported throughout the U.S., but these methods were not reported in Iowa. Methods of disease management included the following:

- Site selection
- Planting design
- Weed control

- Resistant varieties
- Naturally-based fungicides
- Compost tea
- Pruning

The majority of growers relied on preventative measures for disease management, including site selection, planting design, resistant cultivars, weed control and pruning.

CONCLUSIONS

Organic fruit production will become a viable niche market in the Midwestern U.S. as producer and consumer demand for less pesticides in the environment increases. Organic pest management programs are based on multiple tactics including pheromone technology, kaolin sprays, traps, and early harvest. Our research has demonstrated increased disease and insect pressure in organic apples compared to organic grapes. Kaolin clay products, such as Surround™, offer great promise in the area of insect management in organic orchards. Kaolin particle film was effective in mitigating codling moth damage in Redfree and Jonafree apple cultivars, but plum curculio was more difficult to control. Kaolin particle film was most effective in the Jonafree cultivar. There were no significant differences in overall yields among the treatments for both cultivars. Overall fruit marketability was greatest in the Jonafree cultivar. In both organic apple and grape systems, weed management, which includes mulching, mowing, and cover crops, is a critical need. Further research will examine the interactions among weed, insect and disease management.

Organic grape/apple marketing cooperative or alliances are increasing in the U.S. in order to share the expense of equipment for wineries, juice factories and tourist outlets. Cooperative development of markets with a regional marketer/processor and/or consumer-owned retail cooperatives is necessary to overcome issues of supply in a limited area of production. Alliances with independent midsize grocers/restaurants and cooperation with local universities to develop cultivars, pest management techniques and markets will assist in meeting consumer demand for organic fruits in the Midwestern U.S.

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Tables

Table 1. Survey question posed to organic grape growers.

Survey Questions
1. What is the age of your vines?
2. What cultivars do you grow? What is the percent of each cultivar?
3. What is the average length of the longest 1st year shoot for each cultivar (please average based on 30 vines)?
4. What is the number of grape clusters per vine for each cultivar (please average based on 30 vines)?
5. What is the number of berries per cluster for each (please average based on 10 clusters)?
6. What insects have you observed on 30 samples and on which cultivar?
7. What insects do you perceive as a problem?
8. What methods do you use to control pests?
9. What diseases have you observed on 30 samples on each cultivar?
10. What disease do you perceive as a problem?
11. What methods do you use to control diseases?
12. What methods of fertilization do you use? How much?
13. What percentage of area for each cultivar, in a 2-ft radius around the vine, is occupied by weeds?
14. What weed management methods do you use?

Table 2. Pooled insect damage, beneficial insects and disease on Redfree, Jonafree and Liberty apple leaves during the growing season.

Treatment	Insect Damage on Leaves	Beneficial Insects on Leaves	Disease Rating on Leaves [1]	Insect Damage on Apples	Disease Rating on Apples [1]
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Redfree					
Control (no kaolin particle film)	1.44 ± 0.26	0.25 ± 0.08	1.45 ± 0.07	1.80 ± 0.21	1.00 ± 0.00
Kaolin (pooled with kaolin particle film plus sticky red spheres)	1.60 ± 0.16	0.39 ± 0.06	1.54 ± 0.04	1.16 ± 0.11	1.00 ± 0.00
Jonafree					
Control (no kaolin particle film)	1.10 ± 0.13	0.15 ± 0.04	1.44 ± 0.05	1.32 ± 0.13	1.31 ± 0.05
Kaolin (pooled with kaolin particle film plus sticky red spheres)	0.97 ± 0.08	0.14 ± 0.03	1.39 ± 0.04	0.73 ± 0.07	1.15 ± 0.03
Liberty					
Control (no kaolin particle film)	1.46 ± 0.13	0.23 ± 0.05	1.26 ± 0.04	0.98 ± 0.10	1.21 ± 0.04
Kaolin (pooled with kaolin particle film plus sticky red spheres)	1.47 ± 0.10	0.24 ± 0.04	1.36 ± 0.03	0.93 ± 0.08	1.04 ± 0.02
$LSD_{0.05}$ [2]	n.s.	n.s.	n.s.	0.18	0.04
$LSD_{0.05}$ [3]	0.24	0.08	0.08	0.20	0.05
Treatment x Cultivar	n.s.	n.s.	n.s.	*	*

[1] Mean disease incidence was rated visually: 1 = no symptoms of disease; 2 = 1 – 25% of apple or leaf showing disease symptoms; 3 = 26 – 50% showing disease symptoms. There were no apples or leaves with disease symptoms above 50%.
[2] Comparing treatments within a cultivars.
[3] Comparing treatments between cultivars.
[n.s. *] Nonsignificant or significant at $P < 0.05$.

Table 3. Pooled harvest data of Redfree and Jonafree apple cultivars. All fruits from 5 trees per treatment per cultivar (n = 60 trees) were measured. Liberty apple harvest data were not collected.

Treatment	Yield (kg/tree)	Apples/tree	% Marketable fruit	% Plum curculio damage	% Codling moth damage
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Redfree					
Control (pooled with Sticky red spheres)	5.92 ± 2.88	42.30 ± 7.00	80.22 ± 3.80	6.29 ± 1.97	10.93 ± 4.40
Kaolin (pooled with kaolin particle film plus sticky red spheres)	5.85 ± 0.56	36.40 ± 4.48	81.71 ± 5.33	3.03 ± 1.62	1.36 ± 0.59
Coloring bags (pooled with coloring bags plus sticky red spheres)	3.90 ± 0.36	25.10 ± 2.41	86.51 ± 3.63	2.56 ± 1.52	1.76 ± 0.98
Jonafree					
Control (pooled with Sticky red spheres)	7.59 ± 0.38	55.80 ± 3.61	58.57 ± 3.80	24.33 ± 5.13	26.77 ± 3.32
Kaolin (pooled with kaolin particle film plus sticky red spheres)	6.38 ± 0.78	44.90 ± 7.37	84.76 ± 2.08	4.66 ± 1.60	2.04 ± 0.57
Coloring bags (pooled with coloring bags plus sticky red spheres)	6.65 ± 2.41	26.70 ± 4.84	90.94 ± 3.03	15.00 ± 7.48	1.67 ± 1.14
$LSD_{0.05}$ [1]	n.s.	n.s.	7.45	7.92	4.72
$LSD_{0.05}$ [2]	n.s.	n.s.	n.s.	6.47	3.86
Treatment x Cultivar	n.s.	n.s.	*	n.s.	*

[1] Comparing treatments within a cultivar.
[2] Comparing treatments between cultivars.
n.s. * Nonsignificant or significant at $P < 0.05$.

Table 4. Survey results from organic grape survey (n=11).

Survey Questions	**Answers**
• Average age of vineyard	2.2 ± 0.4 years
• Average number of cultivars Most popular cultivar	3.5 ± 0.7 Foch, 64%
• Average length of the longest 1st year shoot.	109.2 ± 4.3 cm
• Average number of grape clusters per vine for each cultivar	15.5 ± 6.0
• Average number of berries per cluster for each	33.3 ± 1.1
• Insects observed in vineyard Grape leafhopper Wasps or yellow jacket Japanese beetle Grape flea beetle Lacewing Lady beetle Grape cane girdler Grape berry moth	 45.5% 27.3% 18.2% 9.0% 27.3% 72.3% 0.0% 0.0%
• Insects perceived as a problem	None reported
• Methods used to control pests Naturally based pest management Traps Cultural management Resistant varieties Sanitation	 18.1% 18.1% 63.6% 81.8% 72.7%
• Diseases observed. Powdery mildew Downy mildew Black rot Phompsis canker and leaf spot Botrytis bunch rot Anthracnose other	 27.3% 0.0% 0.0% 36.4% 0.0% 81.8% 9.0%
• Disease perceived as a problem.	None reported
• Methods used to control diseases. Site selection Planting design Weed control Resistant varieties Naturally-based fungicides Compost tea Pruning	 63.6% 72.7% 81.8% 81.8% 36.4% 9.1% 81.8%
• Methods of fertilization used. Compost Manure Fish emulsion Other	 54.5% 18.2% 9.0% 36.4%
• Percentage of area occupied by weeds, in a 2-ft radius around the vine. 0 - 25% weeds 26 - 50% weeds 51 - 75% weeds 76 - 100% weeds	 70.0% 10.0% 0.0% 20.0%

• What weed management methods do you use? Cover crops Weed badger Hand hoeing Mulching Flaming Vinegar Mowing	 72.7% 0.0% 54.5% 45.5% 0.0% 0.0% 63.6%