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James J. Stapleton, Charles G. Summers, Beth L. Teviotdale, Peter B. Goodell, Timothy S. Prather, Editors

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NORTH COAST APPLE SCAB TRIALS 1993/1994 ORGANIC AND CONVENTIONAL MATERIALS COMPARISON

Paul Vossen, U.C. Coop. Ext. Sonoma County, and Doug Gubler, Plant Pathology Department, U.C. Davis

Introduction

Apple scab, *Venturia inaequalis*, is a serious fungal disease on apples in the North Coast of California. It is particularly severe during early spring when leaves, flowers and fruit are developing. If not adequately controlled, especially in rainy years, scab can cause almost total destruction of an apple crop and defoliation of trees. Growers typically apply conventional fungicides at 7 to 10 day intervals, starting at the green tip stage, to prevent infection of susceptible tissue. There are many fungicides that provide temporary protection against apple scab and some provide a short term curative action (kickback) on leaves that have already become infected.

Some modern fungicides offer more than 10 days of protection, over 96 hours of kickback activity, and a minimum of phytotoxicity. They can be used after fruit formation without causing fruit russeting, a chemical burn of the fruit skin. Prior to their development, liquid lime sulfur was a commonly used fungicide. It provides approximately 5 days of protection, 36 to 72 hours of kickback activity, but is risky to use after fruit formation because it can burn foliage and fruit if applied during warm weather. Liquid lime sulfur and other alternative materials are currently staging a resurgence because of their status as products that can be used in an "organic" production system.

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Food safety and environmental protection are two very important issues to today's consumer. Therefore, the use of conventional pesticides has come under increased scrutiny and the use of alternatives under increased demand. Many North Coast apple growers are trying to produce apples organically to take advantage of higher market prices brought about by demand for environmentally-sensitive fruit production methods.

Apple scab has limited the ability of these growers to produce organically-grown apples economically due to yield losses when scab causes flower drop and lower prices for blemished, misshapen, and smaller fruit.

Materials which are legally classified as "organic" by the state health and safety code and organic food act of 1990 were tested in these experiments and include fixed coppers (Kocide & COCS), wettable micronized sulfur (Thiolux), lime sulfurs (Liquid Lime Sulfur & Orthorix), mineral oils (Hytech & Stylet), insecticidal soap (M-Pede) and nutritional supplements (Stoma Feast and Compost Tea). Many growers have used several of these materials to control apple scab, but without direct comparisons. Fixed coppers have never been used much because they can cause fruit russeting. The various sulfur materials have been used for years.

Oils and insecticidal soaps have been effective in controlling powdery mildew on some plants and in controlling some insect pests. Stoma Feast is a multi-mineral supplement in a gelatinous base and when combined with fixed copper and sulfur, it is claimed to enhance their effectiveness.

Compost Tea is made by bubbling air for 21 days through a mixture of water and finished compost made from dairy manure. Brewer's yeast is added to the liquid 24 hours prior to use. It looks like thinned down molasses with an agreeable organic odor. Compost tea presumably coats leaves with antagonistic fungi and bacteria and/or provides a nutritional stimulation to leaves, flowers, and fruit and thus prevents apple scab infection.

The conventional fungicides Captan, Ziram, Funginex, Benlate, and Topsin have been used for scab control for many years. These, plus two relatively new materials, Rally and Rubigan, control scab but cannot be used in an organic system. Fluazinam is a non-registered new product for control of apple scab. Benlate and Topsin have not been used for several years because resistance has developed by the fungus, and thus they were not included in this trial.

The experiments tested the efficacy of currently available organic chemicals in comparison to several conventional fungicides. Three different orchards were selected each with a history of severe apple scab infection in 1994. One orchard, Martinelli orchard, was also used in 1993.

Materials and Methods

Martinelli Orchard 1993

The orchard had standard-sized Golden Delicious trees spaced 14 X 20 ft. (155 trees/ac). Eighteen treatments and nine materials in various combinations and rates were screened. Conventional treatments used were Captan, Funginex, Rubigan, Rally and Ziram. Three Captan formulations were tested (50WP, 75WG, & 80WP) and Captan 50 WP and Captan 75WG were each tested with one application followed by two applications of Rubigan. Three Fluazinam applications were compared as follows: Fluazinam I, sprayed at 7 day intervals; Fluazinam II, sprays timed to weather forecasting and Fluazinam III, sprayed at 7 day intervals plus one additional spray 14 days later. Certified organic products tested were Thiolux, Orthorix and Kocide 101. We tested a tank mix of Thiolux and Orthorix, and an nontreated control was included.

Starting at the green tip stage of development, three to four applications were made 7-10 days before rainfall or within 24 hours after rainfall. A weather monitoring system (Metos brand) within the orchard helped schedule applications based on Mills Tables as a prediction of the severity of the scab infection periods. Treatments were applied with a hand-gun sprayer using 2 gallons per tree (310 gallons per acre) at 200 psi.

There were four replications of each treatment, arranged in a randomized complete block design. In early June, 100 fruit were randomly selected from each single tree replication. The percent fruit infected with scab was determined. Leaf scab was rated based on a visual estimation of percent leaf area infected. Two readings were taken from each tree and averaged. We used a scale of 0 to 5: 0 = no scab, 1 = 0 to 10 % leaf area infected, 2 = 10 to 25% leaf area infected, 3 = 25 to 50 % leaf area infected, 4 = 50 to 75% leaf area infected, and 5 = 75 to 100 % leaf area infected with scab lesions.

Martinelli Orchard 1994

Fourteen treatments were applied: Kocide (fixed copper) at 0.5, 1, 2, & 4 lbs. per acre, COCS (fixed copper), Compost Tea, Thiolux, Hytech oil and Stylet oil each alone, Stylet oil in combination with a lower rate of COCS to reduce the potential for fruit russeting, four applications each of Rally and Thiram, and one application of Rally (at green tip) and a nontreated control. Rates of COCS and Thiolux began high, rates prior to fruit formation, and later were reduced to avoid fruit russeting.

Treatment application procedures, experimental design and evaluation procedures were the same as in 1993. In 1994, fruit russeting was rated on a scale of 0 to 5: 0 = no fruit russeting; 1 = slight, a normal level mostly at the stem end; 2 = mild, a marketable fresh market fruit with most of the fruit russeting at the stem end; 3 = moderate, some abnormal fruit russeting on the side of the fruit; 4 = heavy, severe fruit russeting on the side and stem end of the fruit; 5 = very heavy, very severely fruit russeted, covering over 50% of the fruit on the sides and stem end. The rating of 0 - 2 is packable fruit based on market standards.

Foreman Orchard 1994

The orchard was planted with standard-sized Golden Delicious trees spaced 14 X 20 ft (155 trees/ac). Treatments included Compost Tea, Stylet oil, M-pede, Thiolux, Kocide, COCS, Thiolux with COCS, and Thiolux with Kocide in various combinations . A tank mix of Stylet oil with a low rate of Kocide was applied to reduce the fruit russeting caused by the fixed copper.

The "Organic Grower's Best Scenario" anticipated by several local organic growers to give the best control without russeting the fruit was tested at this orchard. Either lime sulfur or Orthorix sprayed at the green tip stage (one application) was followed by COCS during bloom (one application) then Thiolux (three applications).

There were five replications of each treatment arranged in a randomized complete block. Treatment applications and evaluation of percent fruit infected, leaf rating and fruit russet rating were the same in all of the 1994 orchards.

Rio Linda Orchard 1994

The Rio Linda orchard was a semi-dwarf orchard planted with the Golden Delicious variety and trees were spaced 12 X 18 ft (201 trees/ac). Compost Tea, Stylet oil, Orthorix and Thiolux were applied four times, beginning at green tip. Lime sulfur and Kocide were applied four times but at reduced rates in the later three applications to reduce fruit russeting. Each treatment was applied to one 2-acre block using an airblast speed sprayer.

Analysis of variance was performed on data and means separated by Duncan's multiple range test. In the tables, numerical values followed by the same letter do not differ significantly (P = 0.05) for the Martinelli 1993 orchard and (P = 0.01) for the Martinelli 1994 and Foreman 1994 orchards.

Results and Discussion

Martinelli 1993 Orchard

All materials gave significant control of fruit and leaf infection compared to nonsprayed control trees (Table I). Rally gave significantly better control of fruit infection than most of the Captan formulations, Captan followed by Rubigan, Orthorix and Fluazinam with Rubigan. Rally gave significantly better control of leaf infection than the other materials, except for Kocide, Captan 75WG and Funginex. Of the organic materials, Kocide and Thiolux controlled scab significantly better than Orthorix and had a fruit infection percentage and leaf rating similar to Funginex, Ziram and Rubigan. There were no differences among the three Fluazinam treatments.

Almost every leaf on the control trees had scab lesions (rating of 4.5) and the trees were almost defoliated in early June. The control trees also dropped many blossoms and fruit from scab lesions on the petioles. Twenty-nine percent of the remaining fruit was infected with scab lesions.

Martinelli Orchard 1994

Rally (applied four times), Kocide (all rates), COCS, Stylet oil, Stylet oil with COCS, Thiram and Hytech oil controlled scab significantly better than the nontreated control, Compost Tea, and a single early application of Rally (Table II). Thiolux, Thiram, COCS, Stylet oil with COCS, Rally (four applications) and Kocide (at 4 lbs/ac) completely controlled scab. They all had 0% fruit infected and almost no visible leaf infection. Trees sprayed with Compost Tea had more scab on leaves and fruit - though not significant - than the nonsprayed trees.

The lower rates of Kocide (0.5, 1, & 2 lbs. per acre) not only controlled scab but produced fruit russet rating levels that were not significantly different from the nonsprayed control fruit. However, the higher rate of fixed coppers, Kocide (4 lbs/ac) and COCS (4 lbs/ac), severely fruit russeted the fruit. The lower rate of COCS (1 lb.) with Stylet oil did not significantly reduce fruit russeting. Thiolux and Thiram were the only two which had a fruit russet rating at or below control levels. The best overall material for scab control and low fruit russeting was Thiram.

Foreman Orchard 1994

All materials were significantly better in controlling fruit infection than the nonsprayed and Compost Tea treatments (Table III). They were significantly better in leaf rating than the nonsprayed control, Compost Tea and Stylet oil treatments. Kocide with Thiolux, COCS with Thiolux, Kocide alone and Thiolux alone were not significantly different in percent fruit infection or leaf rating. The leaf rating of Compost Tea was numerically, but not significantly, worse than the control. The high and low rates of Fluazinam and Fluazinam with a surfactant performed equally.

Low fruit russeting levels, not significantly different than the control, were associated with Compost Tea, Stylet oil, Stylet oil with Kocide, Thiolux, Fluazinam and the two "Organic Grower's Best Scenario" sprays. The latter two spray programs used only Thiolux at a stage when fruit is susceptible to fruit russeting.

Rio Linda Orchard 1994

Thiolux and Kocide out-performed the other materials in scab control for percent fruit infected and leaf rating (data not shown). Kocide, Thiolux, Lime Sulfur, Orthorix and Stylet oil controlled scab infection on the fruit and leaves better than the nonsprayed control and Compost Tea treatments. Thiolux was the only material comparable in fruit russet level to the nonsprayed control fruit.

Results from this trial using a grower's spray equipment is very comparable to the results using single tree replications and a hand-gun sprayer.

Overall Comparisons

After two years of experiments and several years of observations, we have come to the following conclusions about organic scab control materials:

Lime sulfur is difficult to work with, especially out of large drums. It controls scab moderately well in the early part of the season but not as well as Thiolux or the fixed coppers. When used after fruit formation it causes russeting on fruit, even at a lower rate (1 gal/100 gal). It can be used to eradicate or give kickback control of infections within 36 to 72 hours of the infection period.

Orthorix is very similar to lime sulfur but somewhat easier to work with. It is used at a much lower rate since it is formulated with a surfactant. It has the same tendency to russet fruit.

Thiolux, one of the micronized sulfurs, is easy to work with but requires large quantities per acre (12 to 25 lbs). It performed well in all trials with 3 to 5 well-timed applications. Starting at the high rate and finishing at the lower rate when fruit is formed, it did not cause fruit russeting.

Kocide performed well in controlling scab infection on fruit and leaves and is very easy to work with. At higher rates, 4 lbs. per acre and above, it caused severe fruit russeting. At 0.5 lbs. per acre, it controlled scab without severe fruit russeting. It also could be combined with Stylet oil or Thiolux and used at a lower rate without fruit russeting and perhaps enhancing control. Registration is pending in California. COCS performed similar to Kocide in all experiments.

Stylet Oil and ***Hytech Oil*** showed some efficacy in controlling apple scab. Stylet oil was more effective in combination with one of the fixed coppers. Both were somewhat difficult to work with since they are heavy liquids used at fairly high rates.

M-Pede, an insecticidal soap, showed some ability to prevent scab infection, and was similar to the mineral oils.

Stoma Feast tended to congeal in the mixing process and plug the sprayer filter, thereby altering spray nozzle emissions. Its effectiveness in enhancing control is not known at this time.

Compost Tea was not effective in preventing scab infection and in some cases appeared to enhance apple scab.

Timing of spring spray applications is an important factor in apple scab control since the fungicides used offer only temporary protection or limited kickback activity. New tissue that is generated by the tree during

this rapid growth phase must be covered with a fungicide to prevent crop loss.

Most of the conventional fungicides used in these trials did an excellent job in preventing apple scab infection. Several of the organic materials have now been documented as potential alternatives by also providing excellent control of scab. These materials can be used for the purpose of lowering the environmental impact of more toxic fungicides, to reduce the threat of resistance when alternated with conventional fungicides, and to conform to organic certification laws.

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Table I. Comparison of Several Fungicide Programs to Control Apple Scab, Martinelli Orchard, Sonoma County, CA, 1993.

Material	Rate	Timing: Spray Dates	Percent Fruit Infected		Leaf Rating	
Control	0	Not sprayed	29.0	a	4.5	a
Orthorix	2 qt/100 gal	3-29, 4-8, 4-18	18.0	b	2.4	b
Fluazinam & Rubigan	12.8 oz & 4.0 oz/ac	3-29, 4-8, 4-18	12.0	bc	2.2	b
Captan 50 WP	6 lb/ac	3-29, 4-8, 4-18	12.0	bc	1.8	b
Captan 75WG then Rubigan 1 EC 2 appl.	4 lb/ac; 8 oz/ac	3-29 4-8, 4-18	11.0	bcd	2.4	b
Captan 50 WP then Rubigan 1 EC 2 appl.	6 lb/ac; 8 oz/ac	3-19 4-8, 4-18	10.0	bcd	2.3	b
Captan 80 WP	3.75 lb/ac	3-29, 4-8, 4-18	9.0	cde	2.1	b
Fluazinam I	0.8 pt/ac	3-29, 4-5, 4-12, 4-18	8.0	cdef	1.9	b
Fluazinam III	0.8 pt/ac	3-29, 4-5, 4-12, 4-18, 5-2	6.0	cdef	1.9	b
Orthorix & Thiolux	1 qt/100 gal & 15 lb/100 gal	3-29, 4-8, 4-18	5.0	cdef	2.4	b
Fluazinam II	0.8 pt/ac	3-29, 4-8, 4-18	5.0	cdef	1.9	b
Captan 75 WG	4 lb/ac	3-29, 4-8, 4-18	5.0	cdef	1.3	bc
Funginex	10 oz/100 gal	3-29, 4-8, 4-18	4.0	def	1.4	bc
Thiolux 80 DF	15 lb/100 gal	3-29, 4-8, 4-18	4.0	def	1.8	b
Ziram	8 lb/ac	3-29, 4-8, 4-18	4.0	def	1.8	b
Rubigan 1 EC	8 oz/ac	3-29, 4-8, 4-18	3.0	ef	1.8	b
Kocide 101	2 lb/100 gal	3-29, 4-8, 4-18	2.0	ef	1.3	bc
Rally 40W	8 oz/ac	3-29, 4-8, 4-18	0.2	f	0.1	c

Table II. Comparison of Several Fungicide Programs for Control of Apple Scab, Martinelli Orchard, Sonoma County, CA, 1994

Material	Rate	Timing: Spray Dates	Percent Fruit Infected		Leaf Rating		Fruit Russet Rating	
Compost Tea	16 oz/100 gal	3-23, 4-7, 4-22, 5-6	37.50	a	3.00	a	2.75	ab
Control	0	not sprayed	26.00	ab	2.68	a	2.13	b
Rally 1 appl.	8 oz/ac	3-23 only	11.30	bc	0.44	bc	2.50	ab
Kocide 0.5	0.5 lb/ac	3-23, 4-7, 4-22, 5-6	6.50	c	0.44	bc	2.75	ab
Hytech Oil	2 gal/100 gal	3-23, 4-7, 4-22, 5-6	4.50	c	0.63	bc	2.75	ab
Stylet oil	2 gal/100 gal	3-23, 4-7, 4-22, 5-6	4.00	c	0.13	bc	3.00	ab
Kocide 1	1.0 lb/ac	3-23, 4-7, 4-22, 5-6	1.50	c	0.20	bc	3.38	ab
Kocide 2	2.0 lb/ac	3-23, 4-7, 4-22, 5-6	1.00	c	0.06	bc	3.85	ab
Thiolux	25 lb/ac, 2 appl.; 15 lb/ac, 2 appl.	3-23, 4-7 4-22, 5-6	0.50	c	0.01	c	2.00	b
Thiram	2 lb/100 gal	3-23, 4-7, 4-22, 5-6	0.00	c	0.00	c	1.88	b
Stylet Oil & COCS	1% oil & 1 lb/ac	3-23, 4-7, 4-22, 5-6	0.00	c	0.01	c	3.13	ab
COCS	8 lb green tip/4 lb, 3 appl.	3-23 4-7, 4-22 5-6	0.00	c	0.00	c	4.50	a
Kocide 4	4 lb/ac	3-23, 4-7, 4-22, 5-6	0.00	c	0.00	c	4.50	a
Rally	8 oz/ac, 1 appl.; 5 oz/ac, 3 appl.	3-23 4-7, 4-22, 5-6	0.00	c	0.00	c	3.13	ab

Table III. Comparison of Several Fungicide Programs for Control of Apple Scab , Foreman Orchard, Sonoma County, CA, 1994.

Material	Rate	Timing: Spray Dates	Percent Fruit Infected		Leaf Rating		Fruit Russet Rating	
Control	0	not sprayed	18.8	a	3.0	ab	0.1	e
Compost Tea	1 qt/100 gal	3-24, 4-1, 4-8, 4-28, 5-8	18.0	a	3.6	a	1.0	de
Stylet Oil	2 gal/100 gal	3-24, 4-1, 4-8, 4-28, 5-8	12.7	b	2.2	bc	0.9	de
M-Pede	2 gal/100 gal	3-24, 4-1, 4-8, 4-28, 5-8	4.2	c	2.1	c	3.5	ab
Stoma Feast + Cu + S	50 oz/100 gal + 1 lb. + 5 lb/ac	3-24, 4-1, 4-8, 4-28, 5-8	3.2	c	0.2	d	3.6	ab
Lime S then COCS then Thiolux	2.5 gal/100 gal, 1 appl.; 4 lb/ac, 1 appl.; 15 lb/ac, 3 appl..	3-24, 4-1, 4-8, 4-28, 5-8	2.8	cde	0.5	d	1.5	cde
Orthorix then COCS then Thiolux	2 qt/100 gal, 1 appl. 4 lb/ac, 1 appl. 15 lb/ac, 3 appl.	3-24, 4-1, 4-8, 4-28, 5-8	2.5	cde	0.5	d	1.6	cde
Stylet Oil & Kocide	1 gal/100 gal & 1 lb/ac	3-24, 4-1, 4-8, 4-28, 5-8	2.4	cde	0.5	d	1.5	cde
Kocide & Thiolux	4 lb & 15 lb/ac	3-24, 4-1, 4-8, 4-28, 5-8	1.7	cde	0.3	d	2.2	bcd
Thiolux	25 lb, 1 appl. 15 lb, 4 appl.	3-24, 4-1, 4-8,4-28, 5-8	1.1	de	0.2	d	0.6	de
Kocide	4 lb/ac	3-24, 4-1, 4-8, 4-28, 5-8	0.8	de	0.1	d	4.0	a
Fluazinam high rate	12.8 oz/100 gal	3-24, 4-1, 4-8, 4-28, 5-8	0.7	de	0.0	d	0.0	e
Fluazinam low rate	9.6 oz/100 gal	3-24, 4-1, 4-8, 4-28, 5-8	0.7	de	0.0	d	1.0	de
COCS & Thiolux	4 lb & 15 lb/ac	3-24, 4-1, 4-8, 4-28, 5-8	0.5	de	0.0	d	2.8	abc
Fluazinam & Surfactant	9.6 oz/100 gal & 1 pt/100 gal	3-24, 4-1, 4-8, 4-28, 5-8	0.2	c	0.0	d	1.6	cde
COCS	4 lb/ac	3-24, 4-1, 4-8,	0.0	c	0.0	d	3.5	ab