APPLE (*Malus* x *domestica* 'Empire')
Apple scab; *Venturia inaequalis*
Cedar apple rust; *Gymnosporangium juniperi-virginianae*
Flyspeck; *Zygophiala jamaicensis*
Sooty blotch; disease complex
Necrotic leaf spot; (unidentified)

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**Evaluation of alternative fungicides for organic apple production in Vermont, 2007.**

Fungicides approved for use in organic apple production in Vermont were tested for control of apple scab and other fungal diseases. A standard program of lime sulfur and sulfur applications was compared to more recently approved fungicides, potassium bicarbonate, *Bacillus subtilis,* and neem oil, and to a non-sprayed control. The study was conducted at the University of Vermont Horticultural Research Center in South Burlington, VT on Empire trees planted in 1990 on M7 and Mark rootstocks. Treatments were arranged in a completely randomized design with five single-tree replications. Fungicides were applied with a Green Guard handgun sprayer using an L tip at 100 psi. Maximum labeled rates were applied dilute to drip. Fungicide applications began on 26 Apr and continued on approximately a weekly schedule through the end of June and then every two weeks to the last fungicide application on 23 Jul. Weather was monitored with a Davis Vantage Pro Wireless Weather Station (Davis Instruments Corp.) and primary scab infection periods were determined using "revised" Mills criteria, with the exception that all wetting periods including those starting at night were used in infection period determinations. Primary infection periods occurred on 27-30 Apr, 10-11, 15-17, 19-21, 27-28 May, and 31 May – 2 Jun. Scab in the test block had been well controlled during the previous year using conventional fungicides. Disease incidence and severity on cluster leaves, terminal leaves, and fruit were assessed on 10 clusters and 10 terminals per tree on 20-21 Jun, 10 terminals per tree on 22-24 Aug, and 50 fruit per tree at harvest (1-2 Oct). Data obtained were analyzed by analysis of variance and significance between means was determined by Fisher's Protected LSD Test ($P \leq 0.05$). When necessary, incidence data were transformed using the arcsine square root, and severity data were transformed by taking the log (severity + 0.1). In treatments with little or no disease or phytotoxicity data could not be normalized and significance was determined by the non-parametric Kruskal-Wallis Test ($P \leq 0.05$).

All of the newer fungicides reduced foliar apple scab relative to non-sprayed controls in August evaluations, and potassium bicarbonate and neem oil treatments had significantly less fruit scab incidence than controls at harvest. However, lime sulfur/sulfur provided the lowest scab incidence on terminal leaves. Similarly, fruit incidence of scab and severity of scab on terminal leaves was much lower in the lime sulfur/sulfur treatment, though differences between lime sulfur/sulfur and other fungicide treatments were not always significant. The lack of statistical significance is probably caused by relatively low disease pressure in the test block in general, as indicated by the low disease incidence and severity on non-sprayed trees. Neem oil resulted in significantly less cedar apple rust incidence than the control in the June foliar assessment, although there were no significant differences among the treatments in foliar incidence in August. No cedar apple rust was observed on the fruit in any of the treatments. There were significantly more necrotic leaf spots in the neem oil treatment in June compared to all other treatments and, in August, both neem oil and potassium bicarbonate treatments had significantly more necrotic leaf spots. On fruit, there was a significantly greater incidence of phytotoxic burn and russetting in the lime sulfur/sulfur treatment. There was very little incidence of flyspeck observed (0-2%) in any treatment and no sooty blotch symptoms were observed on any fruit at harvest (data not shown).

Table 1. Apple scab on 'Empire' trees, 2007

| Treatment and rate/A | Application timing[z] | Scab incidence %: Cluster leaves[y] 18-20 Jun | Terminal leaves[x] 18-20 Jun | Terminal leaves[x] 22-24 Aug | Fruit[w] 1-2 Oct | Scab severity[u]: Cluster leaves 18-20 Jun | Terminal leaves 18-20 Jun | Terminal leaves 22-24 Aug |
|---|---|---|---|---|---|---|---|---|
| Potassium bicarbonate 3.75lb | 1-12 | 0.1 | 0.4 | 12.3 b[v] | 11.2 bc | 0.02 | 0.1 | 3.4 ab |
| *Bacillus subtilis* 3 lb | 1-12 | 0.3 | 1.5 | 17.0 b | 22.4 ab | 0.04 | 0.2 | 3.0 ab |
| Neem oil 2 gal | 1-12 | 0.0 | 1.2 | 9.9 b | 11.6 bc | 0.00 | 0.2 | 2.0 bc |
| Sulfur 15 lb + lime sulfur 2 gal | 1, 5, 8, 10-12 2-4, 6-7, 9 | 0.0 | 0.7 | 1.1 c | 0.4 c | 0.00 | 0.1 | 0.3 c |
| Non-sprayed | 1-12 | 0.3 | 2.4 | 29.2 a | 25.2 a | 0.04 | 0.4 | 4.9 a |

[z]Application timings: 1 = (Green-tip) 26 Apr; 2 = (TC) 7 May; 3 = (Pink) 11 May; 4 = (Pink) 17 May; 5 = (Pink-Bloom) 24 May; 6 = (Petal fall) 29 May; 7 = 7 Jun; 8 = 14 Jun; 9 = 22 Jun; 10 = 29 Jun; 11 = 12 Jul; 12 = 23 Jul.

[y]Assessment of 10 clusters per tree on 5 single-tree replicates per treatment

[x]Assessment of 10 terminals per tree on 5 single-tree replicates per treatment

[w]Assessment of 50 fruit per tree on 5 single-tree replicates per treatment

[v]Numbers within columns followed by the same letter do not differ significantly, Fisher's Protected LSD, $P \leq 0.05$; columns with no letters following the numbers do not have a significant F-value, Analysis of Variance, $P \leq 0.05$ or Kruskall-Wallis, $P \leq 0.05$, when data normality could not be rescued with arcsin square root transformation because of zeros in data.

[u]Mean number of lesions per infected leaf

Table 2. Cedar apple rust on 'Empire' trees, 2007

| Treatment and rate/A | Application timing[z] | Cedar apple rust incidence %: Cluster leaves[y] 18-20 Jun | Terminal leaves[x] 18-20 Jun | Terminal leaves[x] 22-24 Aug | Fruit[w] 1-2 Oct | Cedar apple rust severity[u]: Cluster leaves 18-20 Jun | Terminal leaves 18-20 Jun | Terminal leaves 22-24 Aug |
|---|---|---|---|---|---|---|---|---|
| Potassium bicarbonate 3.75lb | 1-12 | 0.0 | 8.8 a[v] | 16.5 | 0.0 | 0.00 | 0.8 a | 1.4 |
| *Bacillus subtilis* 3 lb | 1-12 | 0.0 | 3.5 bc | 13.8 | 0.0 | 0.00 | 0.6 ab | 1.3 |
| Neem oil 2 gal | 1-12 | 0.0 | 1.5 c | 10.8 | 0.0 | 0.00 | 0.2 c | 1.1 |
| Sulfur 15 lb + lime sulfur 2 gal | 1, 5, 8, 10-12 2-4, 6-7, 9 | 0.1 | 4.0 bc | 12.6 | 0.0 | 0.02 | 0.4 bc | 1.3 |
| Non-sprayed | 1-12 | 0.0 | 4.8 b | 17.3 | 0.0 | 0.00 | 0.6 ab | 1.3 |

[z]Application timings: 1 = (Green-tip) 26 Apr; 2 = (TC) 7 May; 3 = (Pink) 11 May; 4 = (Pink) 17 May; 5 = (Pink-Bloom) 24 May; 6 = (Petal fall) 29 May; 7 = 7 Jun; 8 = 14 Jun; 9 = 22 Jun; 10 = 29 Jun; 11 = 12 Jul; 12 = 23 Jul.

[y]Assessment of 10 clusters per tree on 5 single-tree replicates per treatment

[x]Assessment of 10 terminals per tree on 5 single-tree replicates per treatment

[w]Assessment of 50 fruit per tree on 5 single-tree replicates per treatment

[v]Numbers within columns followed by the same letter do not differ significantly, Fisher's Protected LSD, $P \leq 0.05$; columns with no letters following the numbers do not have a significant F-value, Analysis of Variance, $P \leq 0.05$ or Kruskall-Wallis, $P \leq 0.05$, when data normality could not be rescued with arcsin square root transformation because of zeros in data.

[u]Mean number of lesions per infected leaf

Table 3. Necrotic leaf spots on 'Empire' trees, 2007

| | | Necrotic leaf spot incidence % | | | Necrotic leaf spot severity[v] | | |
|---|---|---|---|---|---|---|---|
| | | Cluster leaves[y] | Terminal leaves[x] | | Cluster leaves | Terminal leaves | |
| Treatment and rate/A | Application timing[z] | 18-20 Jun | 18-20 Jun | 22-24 Aug | 18-20 Jun | 18-20 Jun | 22-24 Aug |
| Potassium bicarbonate 3.75lb | 1-12 | 0.7 b[w] | 8.4 | 35.3 a | 0.1 b | 1.1 a | 5.8 a |
| *Bacillus subtilis* 3 lb | 1-12 | 0.5 b | 9.3 | 22.4 b | 0.1 b | 1.0 a | 1.3 c |
| Neem oil 2 gal | 1-12 | 6.1 a | 10.1 | 36.7 a | 0.9 a | 1.0 a | 2.9 b |
| Sulfur 15 lb + lime sulfur 2 gal | 1, 5, 8, 10-12 2-4, 6-7, 9 | 0.9 b | 5.6 | 19.5 b | 0.1 b | 0.5 b | 2.7 b |
| Non-sprayed | 1-12 | 1.2 b | 10.9 | 16.9 b | 0.2 b | 1.2 a | 1.3 c |

[z]Application timings: 1 = (Green-tip) 26 Apr; 2 = (TC) 7 May; 3 = (Pink) 11 May; 4 = (Pink) 17 May; 5 = (Pink-Bloom) 24 May; 6 = (Petal fall) 29 May; 7 = 7 Jun; 8 = 14 Jun; 9 = 22 Jun; 10 = 29 Jun; 11 = 12 Jul; 12 = 23 Jul.

[y]Assessment of 10 clusters per tree on 5 single-tree replicates per treatment

[x]Assessment of 10 terminals per tree on 5 single-tree replicates per treatment

[w]Numbers within columns followed by the same letter do not differ significantly, Fisher's Protected LSD, $P \leq 0.05$; columns with no letters following the numbers do not have a significant F-value, Analysis of Variance, $P \leq 0.05$.

[v]Mean number of lesions per infected leaf

Table 4. Phytotoxic affects of treatments on 'Empire' fruit, 2007

| | | Fruit[y] | |
|---|---|---|---|
| Treatment and rate/A | Application timing[z] | Phytotoxic burn incidence % | Russet incidence % |
| Potassium bicarbonate 3.75 lb | 1-12 | 0.0[x] | 0.4 |
| *Bacillus subtilis* 3 lb | 1-12 | 0.0 | 0.0 |
| Neem oil 2 gal | 1-12 | 0.0 | 0.4 |
| Sulfur 15 lb + lime sulfur 2 gal | 1, 5, 8, 10-12 2-4, 6-7, 9 | 8.8 | 5.2 |
| Non-sprayed | 1-12 | 0.0 | 0.4 |

[z]Application timings: 1 = (Green-tip) 26 Apr; 2 = (TC) 7 May; 3 = (Pink) 11 May; 4 = (Pink) 17 May; 5 = (Pink-Bloom) 24 May; 6 = (Petal fall) 29 May; 7 = 7 Jun; 8 = 14 Jun; 9 = 22 Jun; 10 = 29 Jun; 11 = 12 Jul; 12 = 23 Jul.

[y]Assessment of 50 fruit per tree on 5 single-tree replicates per treatment on 1 and 2 Oct

[x]Numbers within columns are significantly different, Kruskal-Wallis, $P \leq 0.05$.