Evaluation of alternative fungicides for organic apple production in Vermont

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Abstract

The objective of this trial was to compare the efficacy of potassium bicarbonate, neem oil, and *Bacillus subtilis* to a standard organic lime sulfur/sulfur fungicide program and a non-sprayed treatment for control of apple scab and other fungal diseases. Treatments were applied to 'Empire' trees arranged in a completely randomized design with five single-tree replications in 2007 at the University of Vermont Horticultural Research Center in South Burlington, VT. Fungicides were applied with a handgun to drip, using maximum label rates. Applications began on 26 April and continued on approximately a weekly schedule through the end of June and then every two weeks through 23 July. Data obtained, representing the first year of a two year study, were analyzed by analysis of variance and significance between means was determined by Fisher's Protected LSD Test ($P \leq 0.05$). The alternative fungicides showed some activity against foliar apple scab compared to the non-sprayed treatment and the potassium bicarbonate and neem oil treatments had significantly less fruit scab than the non-sprayed treatment. However, the lime sulfur/sulfur treatment provided the best overall control of scab. There were significantly more necrotic leaf spots in the neem oil and potassium bicarbonate treatments compared to all other treatments. On fruit, there was a significantly greater incidence of phytotoxic burn and russetting in the lime sulfur/sulfur treatment.

Materials & Methods

- 'Empire' trees planted in 1990 on M7 and Mark rootstocks
- Completely randomized design with five single-tree replications
- Fungicides applied with a 3-point hitch PTO sprayer with attached Green Guard handgun with L tip at 100 psi (Figure 1)
- Maximum labeled rates to drip
- Applications began on 26 Apr 2007 and continued on approximately a weekly schedule through the end of June and then every two weeks through 23 Jul
- Primary infection periods occurred on 27-30 Apr, 10-11, 15-17, 19-21, 27-28 May, 31 May – 2 Jun.
- 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 ($P \leq 0.05$). Incidence data were transformed using the arcsin square root transformation when necessary and severity data were log transformed when necessary, adding a positive constant (0.1) to the severity value prior to transforming the data. When the treatments showed very little, or no, disease or phytotoxicity symptoms, the transformation could not rescue the normality and significance was determined by Kruskal-Wallis Non-parametric Test ($P \leq 0.05$).

Results

Table 1. Apple scab on 'Empire', 2007

		Scab incidence %				Scab severity[y]		
	Application	Cluster leaves	Terminal leaves		Fruit	Cluster leaves	Terminal leaves	
Treatment and rate/ha	timing[z]	18-20 Jun	18-20 Jun	22-24 Aug	1-2 Oct	18-20 Jun	18-20 Jun	22-24 Aug
T1 potassium bicarbonate 4.2 kg	1-12	0.1[x]	0.4	12.3 b	11.2 bc	0.02	0.1	3.4 ab
T2 *Bacillus subtilis* 3.4 kg	1-12	0.3	1.5	17.0 b	22.4 ab	0.04	0.2	3.0 ab
T3 neem oil 18.7 L	1-12	0	1.2	9.9 b	11.6 bc	0	0.2	2.0 bc
T4 sulfur 16.8 kg	1, 5, 8, 10-12							
lime sulfur 18.7 L	2-4, 6-7, 9	0	0.7	1.1 c	0.4 c	0	0.1	0.3 c
T5 non-sprayed	1-12	0.3	2.4	29.2 a	25.2 a	0.04	0.4	4.9 a

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

		Cedar apple rust incidence %				Cedar apple rust severity[y]		
	Application	Cluster leaves	Terminal leaves		Fruit	Cluster leaves	Terminal leaves	
Treatment and rate/ha	timing[z]	18-20 Jun	18-20 Jun	22-24 Aug	1-2 Oct	18-20 Jun	18-20 Jun	22-24 Aug
T1 potassium bicarbonate 4.2 kg	1-12	0[x]	8.8 a	16.5	0	0	0.8 a	1.4
T2 *Bacillus subtilis* 3.4 kg	1-12	0	3.5 bc	13.8	0	0	0.6 ab	1.3
T3 neem oil 18.7 L	1-12	0	1.5 c	10.8	0	0	0.2 c	1.1
T4 sulfur 16.8 kg	1, 5, 8, 10-12							
lime sulfur 18.7 L	2-4, 6-7, 9	0.1	4.0 bc	12.6	0	0.02	0.4 bc	1.3
T5 non-sprayed	1-12	0	4.8 b	17.3	0	0	0.6 ab	1.3

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

		Necrotic leaf spot incidence %			Necrotic leaf spot severity[x]		
	Application	Cluster leaves[y]	Terminal leaves[x]		Cluster leaves	Terminal leaves	
Treatment and rate/A	timing[z]	18-20 Jun	18-20 Jun	22-24 Aug	18-20 Jun	18-20 Jun	22-24 Aug
T1 potassium bicarbonate 3.75lb	1-12	0.7 b[w]	8.4	35.3 a	0.1 b	1.1 a	5.8 a
T2 *Bacillus subtilis* 3 lb	1-12	0.5 b	9.3	22.4 b	0.1 b	1.0 a	1.3 c
T3 neem oil 2 gal	1-12	6.1 a	10.1	36.7 a	0.9 a	1.0 a	2.9 b
T4 sulfur 15 lb	1, 5, 8, 10-12						
lime sulfur 2 gal	2-4, 6-7, 9	0.9 b	5.6	19.5 b	0.1 b	0.5 b	2.7 bc
T5 non-sprayed	1-12	1.2 b	10.9	16.9 b	0.2 b	1.2 a	1.3 c

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

		Phytotoxic burn incidence %	Russet incidence %
	Application	Fruit	Fruit
Treatment and rate/ha	timing[z]	1-2 Oct	1-2 Oct
T1 potassium bicarbonate 4.2 kg	1-12	0[w]	0.4
T2 *Bacillus subtilis* 3.4 kg	1-12	0	0
T3 neem oil 18.7 L	1-12	0	0.4
T4 sulfur 16.8 kg	1, 5, 8, 10-12		
lime sulfur 18.7 L	2-4, 6-7, 9	8.8	5.2
T5 non-sprayed	1-12	0	0.4

Figure 1. Fungicides were applied with a handgun to drip, using maximum labeled rates.

[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]Mean number of lesions per infected leaf.

[x]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 Kruskal-Wallis, $P \leq 0.05$, when data normality could not be rescued with data transformation because of zeros in data).

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

Discussion

The three alternative fungicides showed some activity against foliar apple scab incidence by August compared to the non-sprayed treatment and the potassium bicarbonate and neem oil treatments had significantly less fruit scab incidence than the non-sprayed treatment at harvest (Table 1). The neem oil treatment resulted in significantly less cedar apple rust incidence than the non-sprayed treatment 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 (Table 2). There were significantly more necrotic leaf spots in the neem oil treatment in June compared to all other treatments and, in August, both the neem oil and the potassium bicarbonate treatments had significantly more necrotic leaf spots (Table 3). On fruit, there was a significantly greater incidence of phytotoxic burn and russetting in the lime sulfur/sulfur treatment (Table 4). 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.

Overall, the lime sulfur/sulfur treated trees had the lowest incidence of apple scab on the fruit, although it was not significantly different than the potassium bicarbonate and neem oil treatments. However, scab management with lime sulfur/sulfur came at the cost of phytotoxic burn and russetting on the fruit (Figure 2). These results represent the first year of a two year study, and therefore, the experiment will be replicated in 2008 under different environmental conditions to see if similar results are found.

Figure 2. Phytotoxic burn on fruit in the lime sulfur/sulfur treatment.