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Report to Sym-AGRO: Evaluation of several pre and postharvest applications of biopesticides for organic control of postharvest diseases in apple

Objective: Evaluate the efficacy of several biopesticides applied pre and postharvest to organically control major postharvest decays of apple.

Treatments. Seven treatments were evaluated in this trial (Table 1). In addition to the untreated control, Pristine and Serenade Opti were tested as conventional and organic standards, respectively. Aviv and Cinnerate @ 30 fl oz were tested preharvest whereas Cinnerate @ 60 fl oz and PAA were tested postharvest. Treatments were applied at the rates indicated in Table 1.

Table 1. Treatments evaluated in this study

Treat #	Treatment	Application time	Nature of treatment	Rate/100 gal of water
1	Untreated control	N/A	None	None
2	Standard	Preharvest	Pristine	16 fl oz
3	Serenade Opti	Preharvest	Bacillus subtilis S. QST713	16 fl oz
4	AVIV 1x	Preharvest	Bacillus subtilis S. IAB/BS03*	20 fl oz
5	Cinnerate	Preharvest	Cinnamon Oil	30 fl oz
6	Cinnerate	Postharvest	Cinnamon Oil	64 fl oz
7	S.B PAA 5.6	Postharvest	H_2O_2 + PAA	20 fl oz

Application type, timing, harvest and storage: Trials were conducted on Fuji apple block at Sunrise orchard near Rock Island, East Wenatchee. This block was not sprayed with any fungicides for years. Pristine, Serenade Opti, Aviv and Cinnerate were applied 7 days before harvest on October 5th, 2018 using a back sprayer until run-off. Four replicate-trees (in four different rows) were used for each treatment. On October 12th, 2018, thirty-five (35) fruit were harvested, at commercial maturity, from each replicate-tree for a total of 140 fruit per treatment. Each 140-fruit sample (same treatment) was kept in separate box with liner. In addition, 280 fruit were harvest from untreated trees for postharvest treatments (6 and 7). All harvest fruits were immediately transported to the Tree Fruit Research and Extension Centre in Wenatchee.

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For Treatments 6 and 7, fruit were immersed in the treatment solution of Cinnerate at 60 fl oz or PAA at 20 fl oz for 2 minutes and let to dry at room atmosphere for 1 hours. All fruit were immediately stored at 34°F (1°C) in a normal atmosphere.

Data collection. Fruit were checked monthly for decay development. Number of infected fruit and disease type were recorded for each fruit and replicate. After 180 days of CA storage, fruit were removed and stored at room temperature for 15 days to mimic a post-packing retail store period and diseases were recorded again. Number of infected fruits were transformed to disease incidence (%) relative to total number of fruit used/treatment. Incidence and disease type were subjected to ANOVA analyses and mean separation using Student' *t* test.

Results

1-Disease incidence

Overall disease incidence was relatively low with only 3.6% in the intreated fruit after 120 days, but it increased progressively as storage was extended to reach 18% after 180 days (Table 1). Among all the treatments tested, Aviv, Cinnerate preharvest, and PAA postharvest were the most effective for up to 180 days and beyond for Cinnerate which was the only treated that reduced disease significantly after 180 days + 15 days at room temperature (Table 1). On the other hand, Cinnerate applied postharvest at 60 fl oz did not reduce the disease incidence even at early stages of storage (120 days). It is interesting to note that Aviv outperformed Serenade Opti significantly at all evaluation timings. We can also note that the conventional fungicide Pristine did not reduce the postharvest diseases significantly. Possible reasons are provided in the discussion section below.

Table 1. Overall disease incidence recorded on Fuji apples treated with several bio-fungicides

		Application	Total Disease incidence (%) after			
Treatment #	Treatment	time	120 days **	150 days	180 days	180 days Cold + 15 D RT***
1	Control	None	3.6	7.1	17.9	49.3
2	Prisitne	7 Days preharvest	4.3	10.7	13.6	53.6
3	Serenade opti	7 Days preharvest	5.7	12.9	15.8	70.7
4	Aviv 1X	7 Days preharvest	0.7*	2.8*	4.7*	43.6
5	Cinnerate-PrH	7 Days preharvest	1.4*	3.5*	6.6*	38.5*
6	Cinnerate-PsH	At harvest	5.0	13.6	21.5	66.4
7	PPA 5.6	At harvest	0.0*	0.0*	2.4*	40.0

*: Numbers within the same column followed by an asterisk are significantly different.
**: Indicates number of days of cold storage at 34°F.
***: After 180 days in cold storage, fruit were stored at room temperature for 15 days.

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2-Relation between the treatments and decay types

Blue mold was predominant in fruit treated with Serenade Opti and Cinnerate postharvest at 60 fl oz (Table 2). Gray mold was higher in the control and in fruit treated with Cinnerate preharvest and Pristine and was reduced the best by Aviv and Cinnerate postharvest. Bull's eye rot was higher (25%) in Pristine-treated fruit and lowest incidence was observed on fruit treated with Aviv and Cinnerate preharvest. Other diseases include minor decays such as Alternaria rot, Speck rot, and Mucor rot. Examples of symptoms observed on the different treatments are shown in Figure 1 below.

Table 2. Evolution of incidence of major diseases in storage on Fuji apples

	Incidence (%) of major diseases after											
	Blue mold			Gray mold			Bulls' eye rot			Other decays		
Treatment	120 Days	150 Days	180 Days	120 Days	150 Days	180 Days	120 Days	150 Days	180 Days	120 Days	150 Days	180 Days
Control	2.1	4.7	7.1	0.7	0.7	31.4	0.0	2.1	12.1	1.4	4.3	0.0
Prisitne	0.7	1.6	10.0	0.7	7.9	25.0	0.0	0.0	25.0	2.9	2.9	0.0
Serenade opti	0.7	0.7	46.4	0.7	4.3	20.0	0.0	1.4	12.1	4.3	7.1	0.0
Aviv 1X	0.0	0.0	27.1	0.0	1.4	7.9	0.0	0.0	2.9	0.7	1.4	0.0
Cinnerate-PrH	0.7	0.0	15.7	0.0	0.0	27.1	0.0	0.0	2.9	0.7	3.6	0.0
Cinnerate-PsH	2.1	5.7	55.0	0.7	2.9	1.4	0.0	0.0	2.1	2.9	5.0	0.0
PPA 5.6	0.0	0.0	25.7	0.0	0.0	20.0	0.0	0.0	5.7	0.0	0.0	0.0

Control

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Pristine

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Serenade Opti

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Aviv 1 x

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Cinnerate Preharvest

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Cinnerate Postharvest

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PAA 5.6

Figure 1. Representative symptoms of decays observed on Fuji apples treated with several fungicides applied pre and postharvest after 210 days of storage at 34°.

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Discussion and conclusions

Overall disease incidence results indicate that after 6 months of storage at 34°F, Aviv, Cinnerate applied preharvest and PAA applied postharvest harvest have great potential to control postharvest diseases efficiently as all the three treatments reduced overall disease incidence significantly compared to the untreated control. Interestingly, they outperformed Serenade Opti which failed to provide any control efficacy. While cinnerate showed a good efficacy when it was applied 7 days preharvest at 30 fl oz, this product failed when it was applied postharvest at 60 fl oz. Although, visible sign of phytotoxicity were not observed on fruit at application time or later, it is possible that the 60 fl oz may have caused some invisible phytotoxicity that damaged the cuticle and served as a way for penetration of *Penicillium* as it can be explained by the highest blue mold incidence observed in this treatment. Other plant essential oils have been reported previously to be able to cause some phytotoxicity on fruit. It may appropriate to test lower doses of cinnerate postharvest to investigate if a lower dose may be more appropriate.

When looking at the type of decay and their progression in storage based on the treatment applied, Cinnerate-preharvest and PAA postharvest were the most effective for blue mold. Aviv and Cinnerate postharvest reduced gray mold the best, whereas Aviv and Cinnerate reduced bull's eye rot the best. This observed efficacy, although may need confirmation, may have some implication for timing of application. One Aviv 7 days before harvest showed good efficacy for gray mold and bull's eye rot for which infections are initiated in the orchard. Disease pressure at the Sunrise orchard may not be as high as it may be in commercial orchard, therefore, applying Aviv and Cinnerate more than ones preharvest should improve efficacy even better.

PAA showed a great efficacy up to 5 months in storage against all the three major postharvest diseases. Five months is a relatively good length of storage for organic fruit after which disease incidence is expected to increase steadily. A combination with other treatments, may extend it efficacy beyond 5 months. Finally, it is interesting to note that the conventional fungicide Pristine did not provide a good efficacy. It is possible that resistance to Pristine has developed in the orchard, as our recent research has shown, which may have reduced it efficacy. The other possible reason is that a large portion of the diseases observed in this trial is caused by blue mold and bull's eye rot against which Pristine is not known to have the best efficacy.