Evaluation of Kasugamycin: Control of Bacterial Spot on Peach

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Infection of peach fruit by the bacterial spot pathogen *Xanthomonas arboricola* pv. *pruni* results in the formation of blackened, pitted lesions on the fruit epidermis. Infections that occur early in growing season result in larger, deeper pitted lesions, while those that occur in mid-to-late summer tend to be more numerous, but shallow. Infection of foliage, results in the formation of angular, black lesions that eventually shot-hole. If a sufficient number of lesions occur, the leaves become chlorotic and abscise. In disease favorable years, significant crop loss and defoliation can occur on susceptible cultivars.

Current management of peach bacterial spot is dependent on (i) planting of less susceptible cultivars; (ii) application of the antibiotic oxytetracycline (Mycoshield, FireLine); and (iii) application of copper-based bactericides (e.g., Kocide, Cueva, etc…). Unfortunately, residual activity for the oxytetracycline products is only a few days at best, and copper bactericides used during the growing season need to be applied at low rates since copper also causes phytotoxicity. These bactericide limitations often make control difficult, especially when environmental conditions are favorable for disease development.

A new antibiotic, kasugamycin, is now available for agricultural use in the United States. The product Kasumin 2L, which contains kasugamycin as its active ingredient, is currently registered for control of fire blight on pome fruit. Kasugamycin is a hexopyranosyl antibiotic, which is a different chemistry than either streptomycin (glucopyranosyl) or oxytetracycline (tetracycline). Thus, cross-resistance is not likely and the different antibiotics could be used together in a program. Furthermore, FRAC guidelines list kasugamycin as a 'medium risk" for resistance development, while the other two antibiotics are rated as having a "high risk" of resistance development.

The purpose of this study was to examine the ability of kasugamycin to manage bacterial spot on peach. Since the number of kasugamycin applications will be limited per season, treatments consisted of programs that integrated Kasumin with the current registered antibiotic, oxytetracycline. Programs that incorporated copper bactericide (Kocide) were also examined. In addition to providing full season coverage, the integration of these different bactericides also acts as a resistance management strategy. Finally, a full season program of Kasumin, applied with the non-ionic spreader-activator Regulaid, was included for determining the antibiotic's lone efficacy. Except for the Kasumin-only program, treatments followed a USDA / IR-4 protocol.

Materials & Methods

Orchard Site. The experiment was conducted in a highly susceptible O'Henry peach orchard, located at the Rutgers Agricultural Research and Extension Center, Bridgeton, during the spring and summer of the 2015 growing season.

Treatments. Bactericide treatments were replicated four times in a randomized complete block design. Due to low fruit set, two trees were used per plot. Treatment trees were surrounded on all sides by non-sprayed buffer trees. A Rears Pak-Blast-Plot airblast sprayer calibrated to deliver 100 gal/A at 100 psi traveling at 2.5 mph was used for applications. Insecticides and miticides were applied as needed using a commercial airblast sprayer. Bactericide treatment application dates were 11May (shuck-split), 21May (1C), 31May (2C), 11Jun (3C), 22Jun (4C), 2Jul (5C), 13Jul (6C), and 23Jul (7C). Except for a leaf curl application on 3 April, consisting of Ziram 76DF at 4 lb/A, no additional fungicides were applied during the course of the study.

Available water for spraying was acidic (pH=4.8). Thus, an alkaline buffer, potassium carbonate, was used to adjust pH of the water to 7.0 prior to mixing in the bactericides. This pH correction was performed only for those applications

Table 1. Bacterial Spot on Fruit (August 7).							
					% Fruit in Category [1]		
Treatment	Rate / A	Timing	% Infected Fruit [2]	# Lesions / Fruit [2]	Market Grade 1 [2]	Market Grades 1+2 [2]	Cull [2]
Non-treated control	--------	------	93 a	96.8 a	37 c	58 b	42 a
Kasumin Full Season							
Kasumin 2L [3]	64 fl oz	SS, 1C-7C	87 ab	64.4 a	45 c	74 ab	26 ab
Kasumin / Mycoshield Block Programs							
Kasumin 2L Mycoshield	64 fl oz 12 oz	SS, 1C-3C 4C-7C	90 a	86.0 a	50 abc	72 ab	28 ab
Mycoshield Kasumin 2L	12 oz 64 fl oz	SS, 1C-3C 4C-7C	87 ab	101.4 a	46 bc	64 b	36 a
Antibiotic + Copper Mixture / Alternation Programs							
Kasumin 2L + Kocide 3000 [4] Mycoshield Kocide 3000 [4]	64 fl oz + 8 oz 12 oz 8 oz	SS, 1C-3C 4C, 6C 5C, 7C	72 bc	28.2 b	67 ab	85 a	15 b
Mycoshield + Kocide 3000 [4] Kasumin 2L Kocide 3000 [4]	12 oz + 8 oz 64 fl oz 8 oz	SS, 1C-3C 4C, 6C 5C, 7C	61 c	34.4 b	70 a	86 a	14 b

[1] Market grade 1 = total lesion area no larger than 1/8” diameter; Market grade 2 = total lesion area no larger than 3/16” diameter and no single lesion larger than 1/8”; Cull = total lesion area larger than 3/16” and/or single lesion larger than 1/8”.

[2] Means in the same column with the same letter do not differ significantly according to the Waller-Duncan *K*-ratio t-test (α=0.05, *K*=100).

[3] Regulaid added to Kasumin full season treatment at rate of 1 pt / 100 gal.

[4] Spray water adjusted to pH=7.0 with potassium carbonate prior to addition of bactericides.

Table 2. Bacterial Spot on Foliage: Assessment #1 (June 25).						
Treatment	Rate / A	Timing	% Infected Leaves [1, 2]	% Infected & Shot-holed Leaves [1, 2]	% Abscised Leaves [2]	Overall Shoot Rating [2, 3]
Non-treated control	--------	------	39.9 a	39.9 a	11.1 bc	3.5 ab
Kasumin Full Season						
Kasumin 2L [4]	64 fl oz	SS, 1C-7C	45.2 a	48.0 a	9.0 c	4.2 ab
Kasumin / Mycoshield Block Programs						
Kasumin 2L Mycoshield	64 fl oz 12 oz	SS, 1C-3C 4C-7C	30.9 a	36.3 a	5.9 c	3.8 ab
Mycoshield Kasumin 2L	12 oz 64 fl oz	SS, 1C-3C 4C-7C	32.7 a	32.7 a	3.9 c	3.4 b
Antibiotic + Copper Mixture / Alternation Programs						
Kasumin 2L + Kocide 3000 [5] Mycoshield Kocide 3000 [5]	64 fl oz + 8 oz 12 oz 8 oz	SS, 1C-3C 4C, 6C 5C, 7C	34.9 a	48.7 a	23.8 a	4.5 a
Mycoshield + Kocide 3000 [5] Kasumin 2L Kocide 3000 [5]	12 oz + 8 oz 64 fl oz 8 oz	SS, 1C-3C 4C, 6C 5C, 7C	42.1 a	54.0 a	17.7 ab	4.5 a

[1] Infected leaves = leaves with at least one lesion (can have shot-holes); Infected & Shot-holed = infected leaves + leaves with only shot-holes.

[2] Means in the same column with the same letter do not differ significantly according to the Waller-Duncan *K*-ratio t-test (α=0.05, *K*=100).

[3] Overall shoot rating (OSR) = % leaf area infected or shot-holed (1=0%; 2=1-15%; 3=15-25%; 4=25-45%; 5>= 45%)

[4] Regulaid added to Kasumin full season treatment at rate of 1 pt / 100 gal.

[5] Spray water adjusted to pH=7.0 with potassium carbonate prior to addition of bactericides

Table 3. Bacterial Spot on Foliage: Assessment #2 (August 4).						
Treatment	Rate / A	Timing	% Infected Leaves [1, 2]	% Infected & Shot-holed Leaves [1, 2]	% Abscised Leaves [2]	Overall Shoot Rating [2, 3]
Non-treated control	--------	------	93.3 a	99.7 a	32.8 bc	3.8 b
Kasumin Full Season						
Kasumin 2L [4]	64 fl oz	SS, 1C-7C	91.3 a	100.0 a	49.6 a	3.6 b
Kasumin / Mycoshield Block Programs						
Kasumin 2L Mycoshield	64 fl oz 12 oz	SS, 1C-3C 4C-7C	89.2 a	97.1 a	22.9 c	3.8 b
Mycoshield Kasumin 2L	12 oz 64 fl oz	SS, 1C-3C 4C-7C	91.5 a	96.5 a	37.7 abc	3.4 b
Antibiotic + Copper Mixture / Alternation Programs						
Kasumin 2L + Kocide 3000 [5] Mycoshield Kocide 3000 [5]	64 fl oz + 8 oz 12 oz 8 oz	SS, 1C-3C 4C, 6C 5C, 7C	72.3 b	97.2 a	44.4 ab	4.6 a
Mycoshield + Kocide 3000 [5] Kasumin 2L Kocide 3000 [5]	12 oz + 8 oz 64 fl oz 8 oz	SS, 1C-3C 4C, 6C 5C, 7C	65.8 b	96.7 a	51.4 a	4.7 a

[1] Infected leaves = leaves with at least one lesion (can have shot-holes); Infected & Shot-holed = infected leaves + leaves with only shot-holes.

[2] Means in the same column with the same letter do not differ significantly according to the Waller-Duncan *K*-ratio t-test ($\alpha=0.05$, $K=100$).

[3] Overall shoot rating (OSR) = % leaf area infected or shot-holed (1=0%; 2=1-15%; 3=15-25%; 4=25-45%; 5>= 45%)

[4] Regulaid added to Kasumin full season treatment at rate of 1 pt / 100 gal.

[5] Spray water adjusted to pH=7.0 with potassium carbonate prior to addition of bactericides

that included the copper compound, Kocide 3000.

Assessment. Disease incidence, severity (lesion numbers), and "marketable fruit" assessments were performed on 7 August. A total of 25 fruit were examined per plot during each assessment. For the marketable fruit assessment, fruit were graded based on the size of lesions and the area of fruit surface they covered. Definitions for the grades, developed in cooperation with NJ growers, are given in the data table footnotes.

Infection of leaves by *X. arboricola* pv. *pruni* results in the formation of leaf spots, shot-holing, and defoliation. Foliar assessments for all three of these symptoms were performed on 25 June and 4 August. During each assessment, the number of missing leaves and leaves with lesions and shot-holes were counted on each of five vegetative shoots per plot. Results were presented as % leaves infected, % leaves infected and shot-holed, and % leave abscised. An overall shoot rating (OSR) was also performed based on the percentage of leaf area infected and shot-holed.

Weather Data. Air temperatures and rainfall data were recorded by a Campbell Scientific 23X data logger located at the research station. This weather station is part of the Mesonet Network operated by the Office of the NJ State Climatologist. Observations were taken every two minutes and summarized every hour. Hourly temperature and rainfall data were averaged and summed, respectively, for each day of the growing season. Monthly temperature averages and rainfall accumulations were compared to the 30-year means or sums, respectively, for Bridgeton, NJ.

Results

Environment. During the four-month experimental period, air temperatures were near normal in April, June, and July but 5°F above average for May (67 vs 62°F). Rainfall in April was slightly below normal relative to the 30-year average (3.25" vs 3.58"), while precipitation in May was 2.8" below normal (1.27" vs 4.07"). However, frequent rains in June resulted in a total monthly accumulation that was more than three times the 30-year normal. A total of 11.7" rainfall occurred in June versus the normal 3.37 inches. Precipitation greater than 0.09" was recorded on 16 days – more than half the days in the month. Rainfall in July was also considerably higher than average, 7.15 inches versus the 30-year normal of 4.30 inches. However, unlike June, this above-average performance was due to a few heavy rains.

Fruit Infection. Disease pressure was quite high on highly susceptible O'Henry fruit. At the end of the study, 93% of non-treated fruit were infected with an average 97 lesions per fruit (Table 1). As a result of this high disease severity, only 58% of control fruit were marketable, with 37% at grade 1.

Disease incidence and severity levels were generally lower for the full season Kasumin and two block programs relative to the control, but the reductions were not statistically significant (Table 1). Similarly, these three treatments had higher percent of fruit in grade 1 and grades 1+2 compared to the control. For example, the Kasumin / Mycoshield block program yielded 72% marketable fruit, which was 14% higher than the control. However, this and other increases in saleable fruit were not statistically significant.

The addition of the copper bactericide Kocide 3000 to the antibiotic programs resulted in significant reductions in disease incidence and severity and significant increases in both grade 1 fruit and total saleable fruit (Table 1). Fruit disease incidence was reduced by 21 to 32% and lesion density by 64 to 71%. Marketable fruit was 85 to 86% of the total harvested, of which 67 to 70% was grade 1. Of course, these improvements resulted in significant reductions in culled fruit for the two treatments.

Foliar Infection. At the first assessment on 25June, about 40% of leaves on non-treated trees were infected and shot-holed with 11% defoliation (Table 2). By early August, almost 100% of the highly susceptible O'Henry leaves on control trees were infected and shot-holed with 33% defoliation (Table 3).

At both assessments, most of the treatment means were not significantly different from the non-treated control means (Tables 2 & 3). That is, the bactericide programs appeared to have little efficacy at controlling foliar infection on highly susceptible O'Henry. However, both programs with copper had significantly less infected leaves than the control, indicating that these programs were having some impact at reducing disease development on foliage. Unfortunately, the shot-holing and leaf drop caused by the copper tended to negate any reductions in disease levels.

Conclusions

Antibiotics. The antibiotic treatment programs examined in this study consisted of the two Kasumin / Mycoshield block programs and Kasumin full season program. On highly susceptible O'Henry peach, none of these programs provided any significant control of disease incidence and severity on fruit or leaf infection and defoliation on shoots. Although these three programs yielded higher levels of marketable fruit in grades 1 and grades 1+2 than the control, none of these increases were significant. For example, the Kasumin full season program yielded 74% marketable fruit versus 58% for the non-treated control. This amount of saleable fruit is "respectable" given the high susceptibility of the cultivar! Nevertheless, under the conditions of the study, this difference was not statistically significant.

Two factors are proposed as possible causes for the lack of efficacy by the antibiotics, particularly for the known standard Mycoshield. The treatment protocol for the study stipulated a 7 to 10 day spray interval with a maximum of eight applications per season. Thus, in order to equally cover the infectious period from shuck-split in early May through the end of July, sprays were applied at 10-day intervals. This agrees with the typical summer cover spray interval range of 10 to 14 days. However, this timing is primarily for fungicide applications, which provide reasonably long residual activity. The antibiotic programs would probably have benefited from shorter spray intervals given their shorter residual activity (2-3 days for Mycoshield; Kasumin unknown). But, of course, use of shorter intervals would have required additional applications beyond the protocol's specification. For example, a 7-day interval would have required 12 applications for the same time period.

A second factor that could explain the antibiotic programs' lack of efficacy was the unusually high amounts of rainfall that occurred, particularly throughout June and the first half of July. No doubt that the frequent and heavy rainfalls that occurred would have made the short residual activity of Mycoshield, and perhaps Kasumin (?) practically non-existent. And to make matters worse, temperatures during the rainy last three weeks of June and first two weeks of July were quite favorable for bacterial growth (optimum at 75-84°F). Thus, infection periods would have been occurring at a time when antibiotic activity was compromised. The applications probably lowered epiphytic bacterial populations temporarily, but the continuous, favorable conditions allowed rapid population rebounds.

No doubt frequent, unusually high rainfalls and long spray intervals were a deadly combination in the 2015 growing season, especially on highly susceptible O'Henry. Further testing is needed to better discern kasugmycin's efficacy, particularly under more typical rainfall conditions.

Copper. Given the inability of the three antibiotic-based programs to control bacterial spot under the conditions of the study, one can conclude that the efficacy of the antibiotic + copper programs was primarily due to the activity of the copper component. The fact that both these integrated programs resulted in very similar levels of fruit infection and proportions of marketable fruit was also evidence that the copper bactericide, in this case Kocide 3000, was the efficacious element of the programs.

The relatively high rate of Kocide 3000 used in the study may be responsible for the effective fruit disease control, especially with the longer spray interval and considerable amounts of rainfall. The recommended rate for Kocide 3000 30DF, when used for consecutive summer cover sprays on peach, is 1.65 oz per acre. This amount provides 0.5 oz metallic copper per acre (equivalent to the former standard Tenn-Cop 5E at 8 fl oz/A). The rate used in the study, 8 oz/A, is therefore 4.8 times more concentrated.

Given the high rate of copper used, the test trees no doubt suffered high levels of defoliation (nearly 50%), but the trade-off was a higher percentage of grade 1 and total saleable fruit. Perhaps this is acceptable since we don't eat the leaves! However, had 7-day spray intervals been used and/or more normal levels of rainfall encountered, much greater levels of defoliation would probably have occurred. In past studies examining a variety of copper bactericides (Kocide 3000, Badge X2, Nordox, Cueva), high rates at 7 to11 day intervals resulted in 74 to 80% defoliation by harvest time.