Peach Bacterial Spot Management: Evaluation of Kasugamycin and a Bactericide Application Timing Program

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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.

Currently, only two types of bactericides are available for management of peach bacterial spot: copper and the antibiotic oxytetracycline. Recently, however, the antibiotic kasugamycin, sold as Kasumin 2L, has been registered for use on apple, but not yet on peach. This antibiotic acts directly on the pathogen by inhibiting protein synthesis. Most importantly, kasugamycin has a different mode of action than oxytetracycline. Thus, if found effective for peach bacterial spot management, kasugamycin could provide important resistance-management benefits in an integrated program with copper and oxytetracycline.

Given the possible availability of kasugamycin for stone fruit, the main objective of this study was to determine its ability to manage bacterial spot. Results from the Kasumin treatment were compared to the current copper and antibiotic standards, Kocide 3000 and oxytetracycline (FireLine, Mycoshield). Comparisons will be made using disease incidence and marketable fruit assessments.

When applied for disease control, antibiotics break down quickly and therefore have short residual capacity. Copper materials have better residual capabilities, but can only be applied to peach at very low rates due to phytotoxicity. Thus, for both types of bactericides, application immediately prior to an infection event should provide the greatest control since residuals will be at their highest at the time of infection. Therefore, a second objective of this study was to evaluate a set of rules or program for timing bactericide applications. These rules will forecast sprays based on rainfall probability and time of last bactericide application.

Materials & Methods

Orchard Site. The experiment was conducted during the spring and summer of the 2016 and 2017 growing seasons at the Rutgers Agricultural Research and Extension Center. The test block trees consisted of highly susceptible O'Henry cultivar grafted on Halford or Lovell rootstock. Trees were 10-13 years old and planted at 25 ft x 25 ft spacing.

Treatments. In each year, bactericide treatments were replicated four times in a randomized complete block design. Experimental plots consisted of single trees. 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 were applied as needed using a commercial airblast sprayer. No fungicides were applied during the course of the study. Bactericide treatment application dates and phenological timing are shown in Table 1.

Available water for spraying was acidic (pH=4.8). Thus, an alkaline buffer, potassium carbonate, was used to adjust water pH to 7.0 prior to addition of the copper material, Kocide 3000. This pH correction was not necessary for the two antibiotics.

Application Timing Program. The timing program was based on two variables, daily rainfall probability (DRP) and time since last spray (TLS). The program was purposely kept simple for ease of implementation and future modifications.

Application Timing Rules

- First application at ~ 5% shuck split
- Subsequent sprays at 10-day intervals while DRP < 50 % (default interval)
- If DRP is forecasted ≥ 50% then:
  1. If TLS < 5 days, no spray required (assume 4-day residual after spray)
  2. If 5 ≤ TLS < 7 days & DRP ≥ 70%, then apply next spray
  3. If TLS ≥ 7 days & DRP ≥ 50%, then apply next spray

Daily rainfall probabilities (DRP) were obtained from the 'Intellicast' web-based weather forecast system; other systems, such as Accuweather, could also be used. Forecasts are parsed two-days prior to an expected rain event to allow application on the day before the rain.

Assessment. Fruit disease incidence and marketable fruit evaluations were conducted at the end of the study in each year on 1 Aug16 and 26Jul17. A total of 25 fruit were examined per plot (tree) during each assessment. For the marketable fruit assessment, fruit were graded based on lesion size and area of fruit surface covered by lesions. Definitions for the grades, which are used commercially by NJ growers, are given in the data table footnotes.

During the 2017 epidemic from early May through the end of June, bacterial spot disease progress on fruit was monitored in the block on a set of five non-treated trees, which were separate from the four NTC trees used in the study. Twelve fruit were tagged on each tree and a total of eight assessments were performed at approximately 7-day intervals. During each assessment, the total number of lesions were counted on each fruit, allowing estimation of disease incidence and severity. Although disease progress was not monitored in 2016, an assessment was performed at the end of June, which allowed for comparison to the 2017

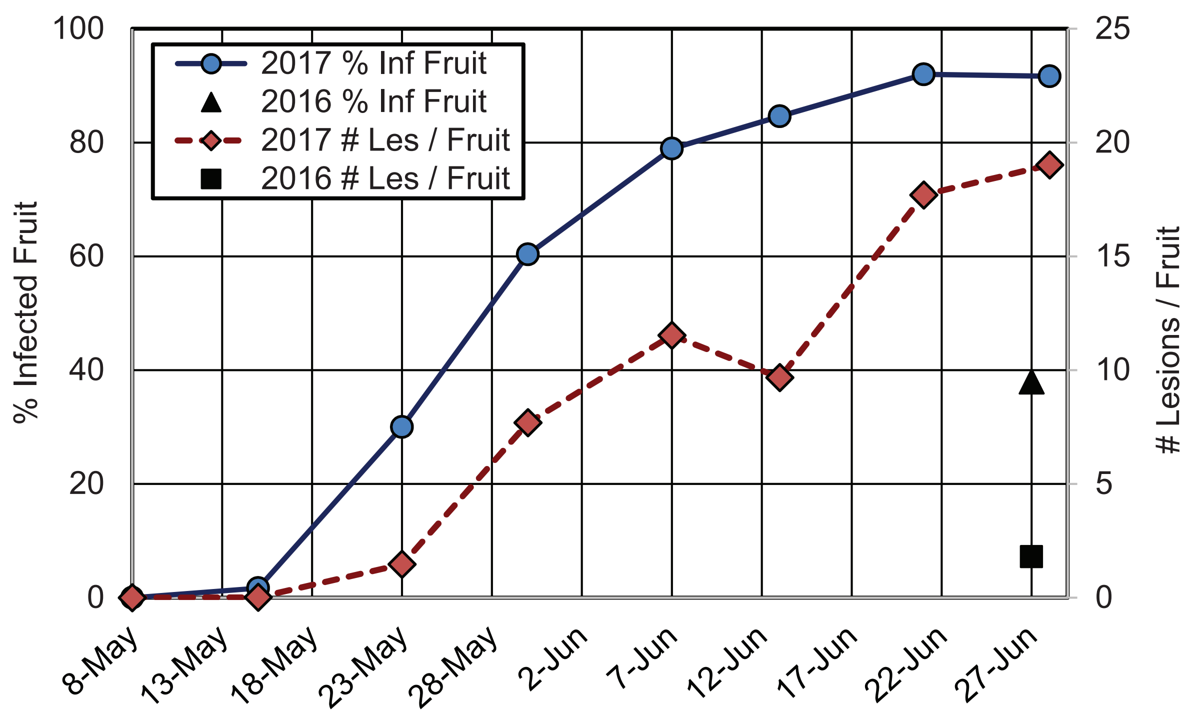


Figure 1. Progression of bacterial spot fruit disease incidence (% infected fruit) and severity (# lesions / fruit) on O'Henry peach during the 2017 epidemic. Data points are means of 7 to 12 tagged fruit on five non-treated trees (48 – 60 fruit total / assessment). The triangle and square data points represent disease incidence and severity levels, respectively, observed on NTC trees in the same block in 2016.

data.

Weather Data. Air temperature 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 aver-

TABLE 1. Average air temperature, rainfall frequency, and total rainfall during bactericide spray intervals resulting from application timing rules

Bactericide Application Interval			Ave. Temp.	# Rains	Rainfall
Spray Interval	Phenology	Length (d)	°F	≥ 0.10 in	Total (in)
2016					
27 Apr – 2 May	SS – 1C	5	48.8	1	0.52
2 May – 10 May	1C – 2C	8	53.8	4	1.92
10 May – 17 May	2C – 3C	7	57.7	4	0.93
17 May – 23 May	3C – 4C	6	57.8	4	1.56
23 May – 31 May	4C – 5C	8	71.8	4	2.06
31 May – 6 Jun	5C – 6C	6	71.7	2	0.91
6 Jun – 15 Jun	6C – 7C	9	70.3	1	0.19
15 Jun – 24 Jun	7C – 8C	9	71.8	2	1.55
24 Jun – 1 Jul	8C – 9C	7	72.3	2	2.33
1 Jul – 12 Jul	9C – 10C	11	75.4	4	1.35
12 Jul – 21 Jul	10C – 11C	10	78.3	4	0.72
Mean / Total	-----	7.8	66.3	32	14.04
2017					
21 Apr – 1 May	SS – 1C	10	61.0	3	1.02
1 May – 11 May	1C – 2C	10	61.3	1	1.54
11 May – 21 May	2C – 3C	10	63.5	1	1.84
21 May – 2 Jun	3C – 4C	12	62.8	4	4.92
2 Jun – 12 Jun	4C – 5C	10	66.8	4	2.06
12 Jun – 22 Jun	5C – 6C	10	77.2	2	1.06
22 Jun – 30 Jun *	6C – 7C	8	75.0	2	0.44
30 Jun – 6 Jul	7C – 8C	6	79.2	1	0.18
6 Jul – 14 Jul	8C – 9C	8	77.6	3	1.15
14 Jul – 21 Jul	9C – 10C	7	78.9	1	1.93
Mean / Total	-----	9.1	70.3	22	16.14

aged and summed, respectively, for each day.

Results

Epidemic Development. By the end of June in 2016, only 38% of non-treated fruit were infected with an average of two lesions per fruit (Fig. 1). However, disease development continued throughout July so that 86% of non-treated fruit were infected by the first of August, an increase of 48%.

In contrast to the 2016 epidemic, 92% of fruit were infected by late June 2017, with an average of 19 lesions per fruit (Fig. 1). By late July, disease incidence increased to 95% fruit infection, an increase of only 3%. Thus, the 2017 epidemic began and developed much more quickly than the 2016 epidemic. However, by late July / early August, both epidemics had achieved a similar amount of infected fruit.

Application Timing and Environment. When sprays were applied according to the program rules, a total of 11 bactericide applications were made in 2016 versus 10 applications in 2017 (Table 1). Spray intervals in 2016 ranged from 5 to 11 days with an average interval length of 7.8 days, while in 2017 application intervals ranged from 6 to 12 days with an average length of 9.1 days.

Application intervals in 2016 were relatively short during the early shuck-split through 5C period, ranging from 5 to 8 days in length (Table 1). In contrast, most of the spray intervals during this same early period in 2017 were 10 days in length. The shorter, more frequent intervals in 2016 were due to a greater number of rain events that triggered a spray advisory. A total of 17 rain events (≥ 0.10 in) were recorded between SS and 5C in 2016, while 13 rain events were observed during the same period in 2017.

Temperatures during the SS-5C period in 2016 were relatively cool, averaging 58.0°F; total rainfall accumu-

TABLE 2. Bacterial Spot on Fruit

Treatment	Rate/A	Timing	% Infected Fruit [2]	% Fruit in Category [1, 2]		
				Market Grade 1	Market Grade 2	Grades 1 + 2
1 August 2016						
Non-treated control	--------	------	86.0 a	35.0 c	19.0 ab	54.0 b
Kocide 3000 30DF	1.7 oz	SS, 1C-11C	46.5 c	70.1 a	14.6 b	84.7 a
FireLine 17WP	1.5 lb	SS, 1C-11C	42.0 c	72.0 a	16.0 b	88.0 a
Kasumin 2L + Regulaid	64 fl oz + 1 pt	SS, 1C-11C	63.0 b	55.0 b	22.0 a	77.0 a
26 July 2017						
Non-treated control	--------	------	95.0 a	10.0 b	7.0 b	17.0 b
Kocide 3000 30DF [4]	1.7 oz	SS, 1C-10C	83.0 b	31.0 a	13.0 ab	44.0 a
FireLine 17WP	1.5 lb	SS, 1C-10C	86.0 ab	24.0 ab	18.0 a	42.0 a
Kasumin 2L + Regulaid	64 fl oz + 1 pt	SS, 1C-10C	84.0 b	26.0 a	15.0 ab	41.0 a

[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] Within each year, 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).

lation during this period was 6.99 inches (Table 1). In comparison, average air temperature during this same SS-5C period in 2017 was 63.1°F with a total rainfall accumulation of 11.38 inches. Although there were 4 fewer rain events in 2017 during this early period, the 5°F higher temperatures and much greater amount of total rainfall most likely contributed to the early and more severe development of the epidemic in that year.

Fruit Infection in 2016. By 1 August, 86% of non-treated fruit were observed to have bacterial spot infections (Table 2). All bactericides significantly reduced disease incidence, but the level of control varied. The Kocide 3000 and FireLine standards were the most effective, providing 46% and 51% control, respectively, and were not significantly different from each other. The Kasumin, however, provided an intermediate response, having significantly less disease than the non-treated control, but significantly more than the two standards. At this late stage in the epidemic, Kasumin yielded 27% control.

Results from the marketable fruit assessment mimicked results for disease incidence (Table 2). On non-treated trees, 54% of fruit were saleable (grades 1+2) with 35% grade 1 and 19% grade 2. Trees receiving the Kocide and FireLine standards had significantly greater amounts of grade 1 and saleable (grades 1+2) fruit than the control. Approximately 70 to 72% of fruit for these two standards were grade 1 and 85 to 88% were saleable.

As with the disease incidence results, Kasumin provided an intermediate level of control relative to the standard and control treatments (Table 2). Only 55% of fruit were grade 1 for the Kasumin treatment, which was significantly more than the control, but less than observed for the two standards. However, total saleable fruit (grades 1+2) for the Kasumin treatment was not significantly different from the levels observed for Kocide and FireLine. This outcome was due to the

Table 3. Bacterial spot on foliage.

Treatment	Rate / A	Timing	% Infected Leaves [1, 2]	% Abscised Leaves [1, 2]	% Infected & Abscised Leaves [1, 2]
25 July 2016					
Non-treated control	--------	------	57.6 a	28.0 a	67.5 a
Kocide 3000 30 DF [3]	1.7 oz	SS, 1C-11C	27.0 b	31.0 a	49.1 b
Fireline 17WP	1.5 lb	SS, 1C-11C	30.3 b	12.2 b	36.9 b
Kasumin 2L + Regulaid	64 fl oz + 1 pt	SS, 1C-11C	67.1 a	37.0 a	77.4 a
24-25 July 2017					
Non-treated control	--------	------	68.6 a	28.4 ab	76.3 a
Kocide 3000 30DF [3]	1.7 oz	SS, 1C-10C	72.6 a	31.0 a	80.5 a
FireLine 17WP	1.5 lb	SS, 1C-10C	69.6 a	20.3 b	75.3 a
Kasumin 2L + Regulaid	64 fl oz + 1 pt	SS, 1C-10C	65.9 a	30.4 a	75.7 a

[1] Infected leaves = leaves with at least one lesion and/or one shot-hole; abscised leaves are missing leaves.

[2] Within each year, 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).

significantly higher amount of fruit recorded in market grade 2 for the Kasumin. Essentially, the increase in grade 2 fruit compensated for the lower amount of grade 1 fruit.

Fruit Infection in 2017. Under the more disease favorable conditions of 2017, 95% of non-treated fruit were observed to have bacterial spot infections by 26July (Table 2). Fruit receiving the Kocide and Kasumin treatments had significantly lower incidence, but still relatively high disease levels (83-84%). Fruit treated with FireLine had an intermediate disease incidence level, being not significantly different from the control or other treatments.

Results from the marketable fruit assessment clearly revealed the intensity of the 2017 epidemic. Of non-treated fruit, only 17% were saleable with 10% grade 1 and 7% grade 2 (Table 2). The percent of grade 1, grade 2, and grade 1+2 (total saleable) fruit were not significantly different among all three bactericide treatments. And as observed in 2016, all three bactericides significantly increased the percent of total saleable fruit.

2016 vs 2017 Fruit Infection. Marketable fruit levels for the bactericide treatments in 2017 were nearly half the levels observed in 2016 (Table 2). This outcome was most likely due to the early season severity of the 2017 epidemic. Nevertheless, under both the moderate and severe epidemics of 2016 and 2017, the percent of total saleable fruit for the Kasumin treatment was equivalent to that provided by the two standards. Significantly fewer grade 1 fruit were observed for the Kasumin treatment in 2016, but this difference was not observed in 2017.

Foliar Infection in 2016. On non-treated control trees, more than half the leaves on shoots were infected and nearly one-third had abscised by late July (Table 3). The Kocide and FireLine standards significantly reduced the number of infected leaves and number of infected + abscised leaves. However, only FireLine significantly reduced defoliation. Although Kocide reduced infection, it also causes leaf drop from foliar phytotoxicity; hence the high level of defoliation.

Unlike results observed for fruit disease control, Kasumin did not appear to provide any control of foliar infection (Table 3). No significant differences were observed between the Kasumin foliar disease levels and those of the non-treated control treatment.

Foliar Infection in 2017. Under the more severe epidemic conditions of 2017, none of the bactericide treatments significantly reduced the amount of leaf infection or defoliation (Table 3). Significant leaf infection, shot-holing, and loss is often observed in disease-favorable growing seasons, regardless of treatment.

FireLine treated trees had significantly less defoliation than observed on Kocide or Kasumin treated trees (Table 3). However, the amount of leaf abscission on FireLine treated trees was still not lower than observed on non-treated control trees.

Discussion

Kasugamycin. Overall, Kasumin 2L was nearly as effective as FireLine and Kocide 3000. Kasumin did provide an equivalent amount of total saleable fruit as these standards in both years of the study. However, in one of the study years (2016), the proportion of grade 1 and grade 2 fruit were significantly lower and higher, respectively, than observed for the standards. Thus, crop values in this year would have been diminished, even though total saleable fruit was the same.

Kasumin 2L is not currently registered on peach. Given the intermediate level of fruit disease control and apparent lack of foliar disease control, Kasumin would probably be best deployed in combination with copper bactericides if it were to become available. This combination may provide enhanced control (to be determined). Also, alternation of this mixture with FireLine or Mycoshield would produce a robust program for pathogen resistance management.

Application Timing Program. The same spray timing rules were followed in both years of the study, yet only about 50% as much saleable fruit were obtained in 2017 versus 2016. Several possible causes for this discrepancy are discussed below.

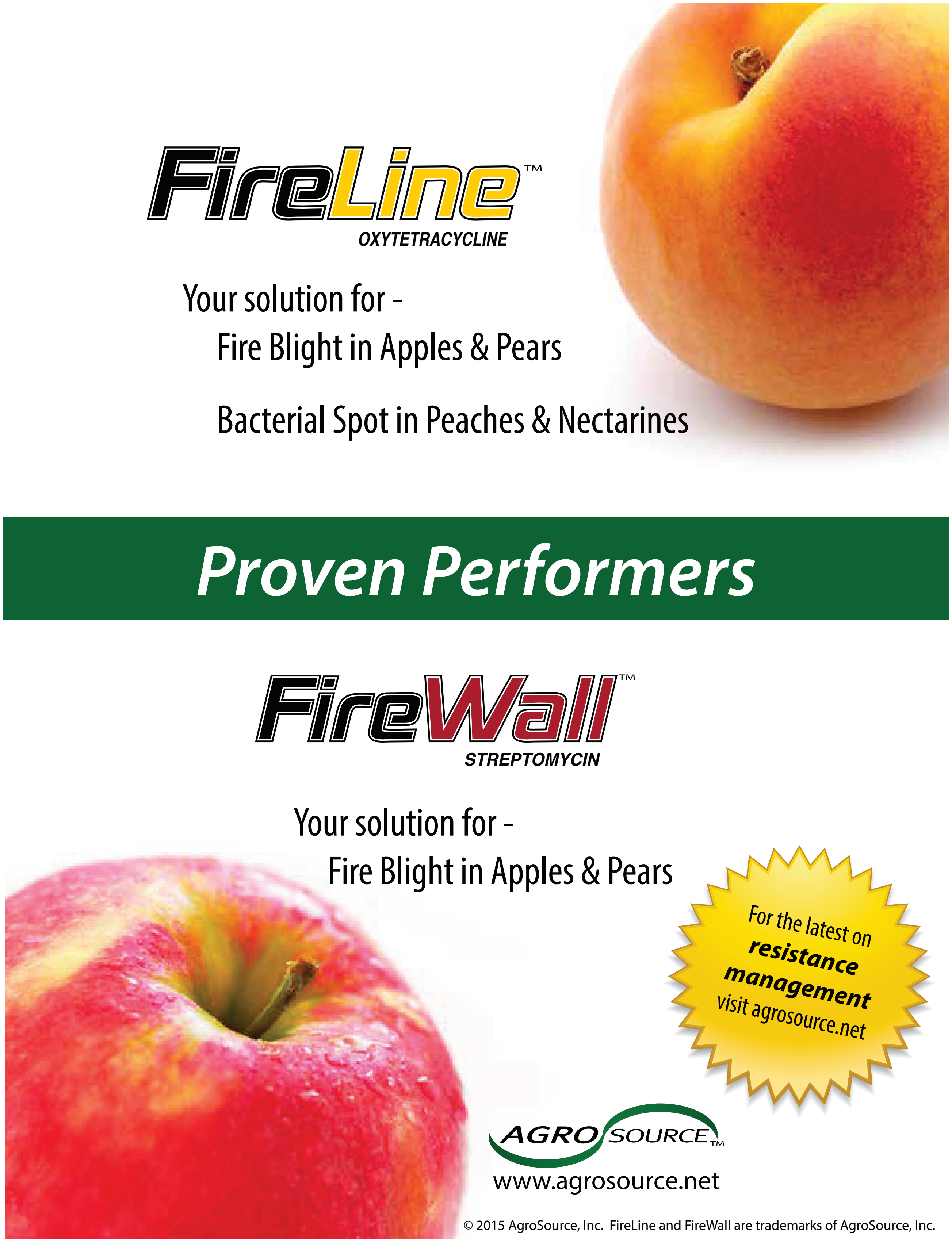
1. **Control Failure.** Disease progress data indicated a much more severe epidemic in 2017 than in 2016, particularly during the critical early part of the growing season. Under this heavy disease pressure, none of the tested bactericides may have been capable of providing effective control. Saleable fruit declined simply because of control failure.
2. **Temperature and Rainfall.** Fewer rain events in 2017 triggered less frequent applications, hence the longer spray intervals. However, temperatures were more disease-favorable and rainfall amounts were much higher early in the season, resulting in a rapid early development of the epidemic. Higher temperatures favor bacterial multiplication in the

overwintering cankers and heavy rains rapidly deplete bactericide residues. Neither of these factors are evaluated in the timing program; their addition as “triggers” for spray advisories may be needed.

3. **Overwintering Inoculum.** The number of overwintering cankers in 2017 may have been very high relative to the number of cankers present in 2016. A higher amount of cankers would have provided more initial inoculum for the epidemic. And this greater amount of inoculum resulted in the early rapid increase in disease in 2017.
4. **Dormant Season Temperatures.** From January through April, air temperatures were 2°F warmer in 2017 than in 2016. Perhaps most importantly, for the critical month of April (one month before epidemic initiation in May), the average daily and maximum temperatures were 6°F warmer in 2017 than 2016. These warmer temperatures favor greater bacterial multiplication in cankers and therefore greater inoculum for the ensuing epidemic.

Editor's Notes: I asked Dr. Lalancette some questions regarding Kasumin:

1) *Where is* **Kasumin 2L** *with relation to labeling on Peaches in NJ?* ***Response:*** In fall 2016 the EPA was holding up antibiotic registrations pending additional review. However, that is now over and IR-4 has just recently received the PR 09888 kasugamycin / peach residue analytical report from EPA. IR-4 will now be writing the final report and should be making a submission this year for registration on stone fruit. Arysta is in support of this registration. **So, Kasumin 2L might be available late this year or in 2019 on Peaches in NJ.**
2) *Technical question, did you look at how fast Kasugamycin breaks down in sunlight after application? My memory says that is a limitation of* oxytetracycline*, that it breaks down quickly. That is why your weekly low rate copper program for peaches has been so useful.* ***Response:*** Yes, oxytetracycline breaks down quickly from light decomposition – even on cloudy days. Hence, the suggestion that sprays be applied late in the day or evening so as to maximize contact with the pathogen (overnight) before the next day. However, we usually spray in the early morning and have still managed to get very good control, perhaps because we're spraying right before a rain [infection] period. To my knowledge, no one has examined kasugamycin for photo or other degradation on plant surfaces. However, since we coddle ALL of our various antibiotics in the laboratory by keeping them in the refrigerator, it's probably safe to assume that all antibiotics, including kasugamycin, have very short residuals in the field. We keep our streptomycin (Agri-Mycin, FireWall) in the refrigerator even though the companies don't recommend doing so on the label. Our spray shed doesn't get very hot, but is certainly not a “cool” environment in the middle of the summer.
3) Please note that Kasumin 2L - Arysta Lifesciences is labeled on apple and pear for the control of fire blight.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