A Progress Report for a Continuing Research and Extension Project Submitted to:
The New York Wine and Grape Foundation and The Lake Erie Regional Grape Program
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Project Title: Evaluation of fungicide efficacy, spray intervals and timing, and crop load, on powdery mildew leaf disease development on Concord grape.

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New Research ☒ Continued Research ☐

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SUMMARY IMPACT STATEMENT

Concord grape growers strive to maximize production while still achieving minimum crop quality (minimum brix at minimum cost) by harvest. One of the limitations to this strategy is canopy health, which must be maintained against powdery mildew to ensure that vines can ripen the crop, every year, regardless of crop size. To address this challenge, we designed experiments to examine and compare the effects of new and existing fungicides, applied at different spray intervals, and in different programs and timings on powdery mildew disease development on Concord grape. The first year of results have demonstrated the superior performance of the newer fungicide chemistries on Concord canopy health (versus older chemistries) in the context of various spray intervals, timings, and programs, and ultimately how these factors affect the relationship between crop maturity (brix) and yield. The new information generated will impact disease management recommendations for Concord growers that improve their odds of reaching minimum sugar standards while streamlining fungicide programs to save money and time.

OBJECTIVES in 2022

- Determine how spray interval may affect fruit and leaf disease development
- Determine how choice/quality of fungicide rotation may affect fruit and leaf disease development
- Determine how timing and span of fungicide programs may affect fruit and leaf disease development
- Determine how all these factors affects crop ripening and quality by harvest.

ACTIVITIES/METHODS

Two field trials were set up in Concord vineyard blocks at the Lake Erie Regional Grape Research and Extension Center in North East, PA in 2022. Treatment plots consisted of 6-9 vines each, replicated 4 times within a replicated complete block design. Fungicide treatments were applied with a covered boom plot sprayer adjusted to deliver 50 gallons/A of water pre-bloom and 100 gallons/A water post bloom.

Trial 1 addressed the effects of spray interval (10, 14, and 18 days) and fungicide quality (rotation of old (Quintec/Vivando/Tebuzol) versus new (Cevya/Gatten/Endura) on efficacy against powdery mildew on clusters and leaves. There were six spray treatments (Table 1 below) and an unsprayed check. Fungicides were applied at rates listed in the "costs" section below.

Table 1

Fungicide treatment rotation	10 day intervals	14 day intervals	18 day intervals
OLD: Quintec/Vivando/Torino	X	X	X
NEW: Cevya/Gatten/Endura	X	X	X

Fungicide sprays began at immediate prebloom and ran through two post bloom sprays (3 sprays total). All other diseases (black rot, downy mildew, and Phomopsis) were controlled by Manzate ProStick pre bloom and Ziram post bloom. Incidence (percent clusters infected) and severity (percent surface area infected) of powdery mildew were determined on August 15 from 40 randomly selected clusters per plot (Table 1), and on August 31 and September 14, from 30 randomly selected leaves per plot (Tables 2, 3). Data for tables 3-5 were subjected to analysis of variance (ANOVA) and mean separation, using the general linear model function and Fisher's LSD (P = 0.05), respectively, in Minitab 20.

Trial 2 addressed the effects of fungicide efficacy (old versus new fungicides), fungicide timing and duration of fungicide program (2, 3, 4, and 5 applications), on cluster and leaf mildew. Spray intervals were 10- 14 days (standard intervals) and 8 fungicides programs (and an unsprayed check) were applied at the following stages in Table 2. Fungicide rates are listed in the "costs" section below. Trial 2 also addressed the effects of 'new' versus 'old' fungicides on the relationship between yield and brix. Statistical analysis (ANOVA and regression) was performed using Minitab 20 at P=0.05.

Table 2

Treatment no./ old vs new	8-12" shoots	Immediate prebloom	1st post bloom	2nd post bloom	3rd post bloom	4th post bloom
1; old		Quintec	Vivando			
2; new		Cevya	Gatten			
3; old	Tebuzol	Quintec	Vivando			
4; new	Endura	Cevya	Gatten			
5; old		Quintec	Vivando	Torino	Tebuzol/HvstMore	
6; new		Cevya	Gatten	Endura	Cevya/HvstMore	
7; old		Quintec	Vivando	Torino	Tebuzol	HvstMore
8; new		Cevya	Gatten	Endura	Cevya	HvstMore

RESULTS/PROGRESS/NEXT STEPS

Trial 1: Observations on cluster disease (fruit and rachises) in trial 1 from first year results (Table 3) Powdery mildew was first recorded on unsprayed Concord clusters on June 22, about a week after end of bloom. Final cluster disease was recorded on August 15, about 2 months after bloom. Within each interval, newer fungicides were generally more effective at reducing powdery mildew than older fungicides. However, the differences were significant only for 14 and 18-day intervals; 'old' versus 'new' mattered least at the shortest, 10-day intervals. Within old or new fungicides, 10 and 14-day intervals and 10 and 18-day intervals resulted in similar disease incidence, but 14-day intervals resulted in significantly

lower disease incidence than 18-day intervals. Within old fungicides, 10 and 14-day intervals resulted in similar disease severity but were both significantly lower in severity than 18 days. However, within new materials, disease severity was statistically equal regardless of interval. Overall, the best combination was 14-day intervals with new materials. The worst combination was 18-day intervals with old materials.

Trial 1: Observations on leaf disease in trial 1 from first year results (Tables 4 and 5): There were no statistically significant effects of the treatments at P=0.05, in comparison to the check. This may have been partly due to low, aggregated disease pressure across the trial area, and the trial should be repeated in 2023. Still, the best treatment controlled the disease by 93 and 70% by August 31 and September 14, respectively. Trends were the same as with cluster effects, where new materials generally performed better than old materials, with the exception of the shortest 10-day intervals; at short intervals, differences between the performance of old versus new materials are small, but as you stretch intervals, differences become more apparent. The best combination, numerically, was still 14-day intervals with new materials. The worst combination was 18-day intervals with old materials: stretching intervals later in the season (beyond 14 days) provides no benefit and may make leaf mildew control less effective. This is especially noticeable when using older materials.

How do these programs compare in cost? These prices are from late 2022 estimates; 2023 prices may be different. So, *the price of the old rotation is actually more than the new rotation.*

NEW MATERIALS
Cevya at 4 fl oz/A = $17.60/A
Endura at 4.5 oz/A = $15/A
Gatten at 6.4 fl oz/A = $27/A
Total: $59.60/A

OLD MATERIALS
Quintec at 5 fl oz/A = $17/A
Torino at 3.4 fl oz/A = $25/A
Vivando at 15.4 fl oz/A = $31/A
Total: $73/A

Trial 2: Observations on cluster disease (fruit and rachises) in trial 2 from first year results (Table 6)
First appearance of cluster infections occurred on about June 21, similar to trial 1. By July 5 (2 weeks later) incidence on clusters in the check shot up to 54%, and it was already apparent that new fungicides were more effective than old. At the final rating on July 25-27, 50 clusters were examined in each plot for incidence and severity of cluster powdery mildew. Data were analyzed as in trial 1, with the following conclusions. Only programs that included 3 post bloom sprays of new materials, significantly lowered cluster disease incidence. However, all programs controlled cluster disease severity (when compared to the check), with the exception of one pre and one post bloom spray of *older materials*. *Within each program, new materials performed statistically superior to older materials.* Within older or newer materials, 4 sprays performed superior to 2 or 3 sprays. This was mostly a reflection of cluster rachis infection control, which was enhanced by extra post bloom sprays. Rachis infections may not necessarily affect crop yield or quality but may affect the development of leaf infections (detailed below). Adding a pre bloom pm spray at 8-12" shoots provided no additional cluster disease control benefit to starting sprays at immediate pre bloom, regardless of the use of old or new materials.

Trial 2: Observations on leaf disease in trial 2 from first year results (Figure 1).
Leaf disease in trial 2 was first observed during a rating on July 28, one day after the last spray was applied. We determined powdery mildew incidence and severity from 30 leaves per plot on August 9-10 and 19-22 and September 8-10 and 21-23 (Figure 1). On August 9-10, all treatments were controlling leaf disease severity, but 4 and 5 spray programs were already statistically outperforming 2 and 3 spray programs within the categories of older and newer materials. Veraison occurred about a week later (August 16/17), followed by a second rating on August 19-22. All programs controlled leaf disease severity at that time, *but rotations of older materials continued to slip farther behind rotations of newer materials with respect to mildew control.* By September 8-10, rotations of older materials continued to deteriorate and only rotations of 4 (1+3) and 5 (1+4) fungicides that included newer materials, provided significant control of mildew on leaves, compared to the check. A last rating was made on September 21-23, about 5 weeks after veraison, when 4 and 5 rotations of new materials continued to provide significant control of leaf disease, compared to the check, while all other programs had failed weeks earlier. In general, as above, *new materials provided better powdery mildew control than older materials.*

How do these programs compare in cost? As in trial 1, the use of newer, more effective fungicides does not have to cost more!

NEW MATERIALS
Cevya + Gatten = $44.60/A
Endura + Cevya + Gatten = $59.5/A
Cevya + Gatten + Endura + Cevya/HarvestMore = $86/A
Cevya + Gatten + Endura + Cevya + HarvestMore = $86/A

OLD MATERIALS
Quintec + Vivando = $48/A
Tebustar + Quintec + Vivando = $51.50/A
Quintec + Vivando + Torino + Tebustar/HarvestMore = $85.50/A
Quintec + Vivando + Torino + Tebustar + HarvestMore = $85.50/A

Does severity of cluster infection affect progression of severity of leaf infection? (Figure 2)
Regression analysis of the trial 2 data showed that about half the variation in leaf disease could be explained by the variation in cluster disease (determined on July 27). Indeed, regression of powdery mildew severity on clusters x powdery mildew severity on leaves at August 10 and 22 and September 10, returned positive relationships (leaf mildew increases with increasing cluster mildew) between the two variables with adjusted R^2 values of 54.6, 55, and 48%, respectively. Combining this data with data from trial 1, increases the strength of the relationship; about 70% of the variation in leaf disease severity is explained by the variation in cluster disease severity. This suggests that control of powdery mildew on clusters in June/July, can influence powdery mildew development on leaves in August and September.

Treatment effects on yield and fruit maturity (brix at harvest)
Our last consideration was to evaluate the effects of program length and fungicide quality on the relationship between yield and brix at harvest. A regression of yield x brix (all treatments combined, N=72) showed a significant (and expected) negative relationship between brix and yield ($P<0.001$, adjusted $r^2 = 53\%$); brix at harvest decreased as yield increased. Next, we broke down treatments into 4

separate yield x brix regressions: programs of one post bloom spray/old fungicides *versus* one post bloom spray/new fungicides AND 3 to 4 post bloom sprays/old fungicides *versus* 3 to 4 post bloom sprays/new fungicides. The results showed that the effect of yield on brix was minimized among treatments that provided better mildew control on leaves (new fungicides), whereas the effect of yield on brix was maximized where leaf mildew control was minimal (old fungicides). In other words, with increasing yield, the relationship of decreasing brix is slowed on vines that received new fungicides compared to vines that received old fungicides. Therefore the use of newer fungicides will help a given yield reach minimum brix sooner than if one were to use the older fungicides.

Gadoury[b], D. M., Seem, R. C., Ficke, A., and Wilcox, W. F. The epidemiology of powdery mildew on Concord grapes. 2001. Phytopathology 2001 Vol.91 No.10 pp.948-955.

Gadoury[a], D. M., Seem, R. C., Pearson, R. C., Wilcox, W. F., and Dunst, R. M. 2001. Effects of powdery mildew on vine growth, yield, and quality of Concord grapes. Plant Disease Vol.85 No.2 pp.137-140.

TECHNOLOGY TRANSFER PLAN

These initial results have been presented to growers through the November 10 newsletter of the Lake Erie Regional Grape Program and the zoom meeting "2023 Pest Management Spray Schedule; What's Your Plan", on December 9, 2022. They will also be presented to/discussed with growers at the Lake Erie Regional Grape Program Conference on March 16, 2023 at the SUNY campus in Fredonia. Information from this project will also be extended to growers during coffee pot meetings, Crop Updates, and other extension based/grower meetings in Pennsylvania and New York during the 2023 growing season.

RELEVANT CHARTS, FIGURES, TABLES

Trial 1, Table 3: Powdery mildew development on Concord clusters (15 Aug).

Fungicide treatment rotation	10 day intervals		14 day intervals		18 day intervals	
	Incidence	Severity	Incidence	Severity	Incidence	Severity
OLD: Quintec/Vivando/Torino	45.0 abc	1.08 b	43.1 bc	1.23 b	70.0 a	2.40 a
NEW: Cevya/Gatten/Endura	25.6 cd	0.60 bc	**1.9 d**	**0.05 c**	28.8 c	0.67 bc
Unsprayed check	43.1 bc	1.32 b	43.1 bc	1.32 b	43.1 bc	1.32 b
P-value	0.001	0.006	0.001	0.006	0.001	0.006

Trial 1, Table 4: Powdery mildew development on Concord leaves (31 Aug).

Treatment program	10 day intervals		14 day intervals		18 day intervals	
	Incidence	Severity	Incidence	Severity	Incidence	Severity
OLD: Quintec/Vivando/Torino	40.0	2.47	36.7	1.27	58.4	3.74
NEW: Cevya/Gatten/Endura	40.8	2.22	**15.9**	**0.39**	30.8	2.73
Unsprayed check	46.7	5.40	46.7	5.40	46.7	5.40
P-value	0.063	0.188	0.063	0.188	0.063	0.188

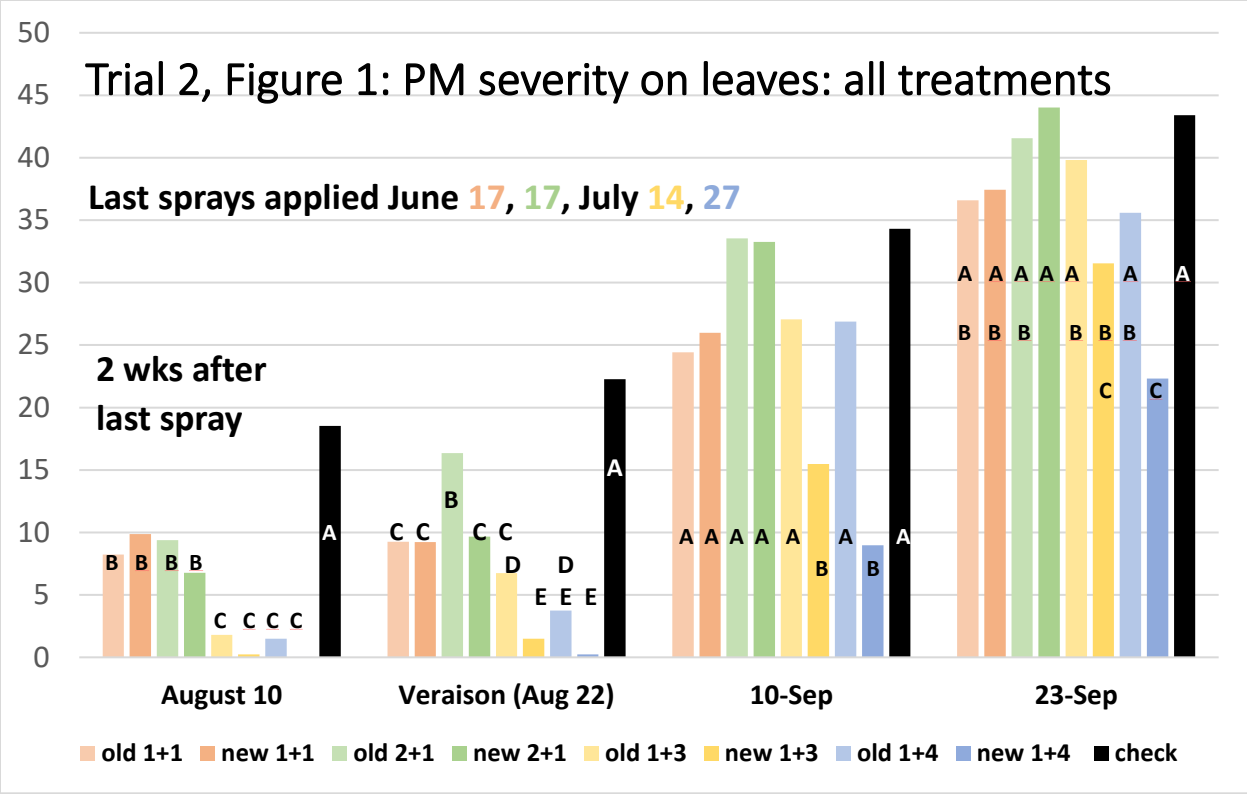
Trial 1, Table 5: Powdery mildew development on Concord leaves (14 Sep).

Treatment program	10 day intervals		14 day intervals		18 day intervals	
	Incidence	Severity	Incidence	Severity	Incidence	Severity
OLD: Quintec/Vivando/Torino	60.9	9.49	58.3	8.31	77.5	20.67
NEW: Cevya/Gatten/Endura	55.0	10.30	**45.8**	**3.91**	49.2	6.82
Unsprayed check	65.9	12.94	65.9	12.94	65.9	12.94
P-value	0.361	0.079	0.361	0.079	0.361	0.079

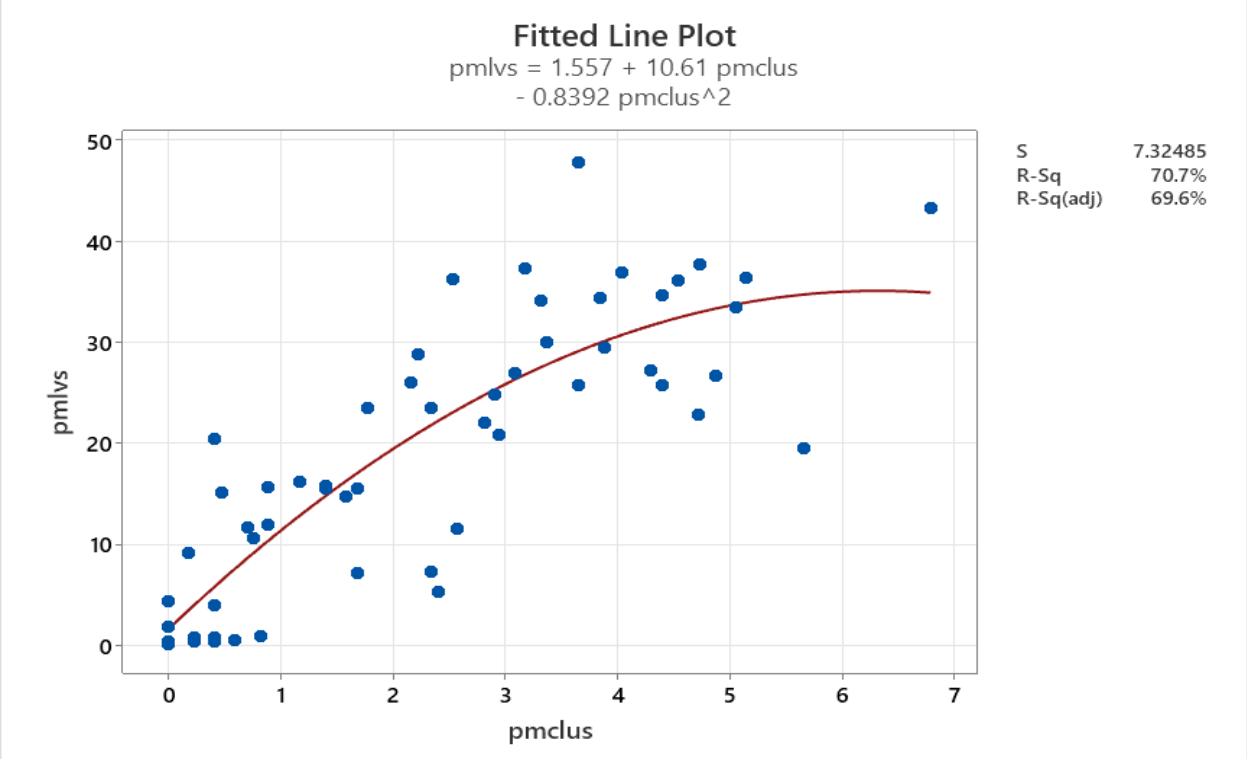
Trial 2, Table 6: Powdery mildew development on Concord clusters (July 25-27)

Treatment and rate/A	Days after first application[z]	Incidence (%)	Severity[y] (%)	% Control[x]
Quintec 5 fl oz	14			
Vivando 15.4 fl oz	25	100.0 a[w]	4.58 ab[w]	14
Cevya 4 oz	14			
Gatten 6.4 fl oz	25	91.5 a	2.95 c	45
Tebustar 4 oz	0, 14, 25			
Quintec 5 fl oz	14			
Vivando 15.4 fl oz	25	100.0 a	4.46 b	16
Endura 4.5 oz	0			
Cevya 4 oz	14			
Gatten 6.4 fl oz	25	97.0 a	2.98 c	44
Quintec 5 fl oz	14			
Vivando 15.4 fl oz	25			
Torino 3.4 fl oz	38			
Tebustar 4 oz + HarvestMore 5 lbs	52	97.5 a	3.52 c	34
Cevya 4 oz	14			
Gatten 6.4 fl oz	25			
Endura 4.5 oz	38			
Cevya 4 oz + HarvestMore 5 lbs	52	58.5 b	1.44 d	73
Quintec 5 fl oz	14			
Vivando 15.4 fl oz	25			
Torino 3.4 fl oz	38			
Tebustar 4 oz	52			
HarvestMore 5 lbs	65	94.5 a	3.42 c	36
Cevya 4 oz	14			
Gatten 6.4 fl oz	25			
Endura 4.5 oz	38			
Cevya 4 oz	52			
HarvestMore 5 lbs	65	58.0 b	1.40 d	74
Untreated Control		99.0 a	5.32 a	

[z]Timing: The first fungicide application (day 0) was made on May 23 (day 0). 0 = 8-12" shoots; 14 = immediate prebloom; 25 = 1st post bloom; 38 = 2nd post bloom; 52 = 3rd post bloom; 65 = 4th post bloom.
[y]Severity was rated using the Barratt-Horsfall scale (0-11) and was converted to % area infected (0-100 %) using Elanco conversion tables.
[x]Percent control = control of disease severity on clusters relative to the untreated control.
[w]Means followed by the same letter within columns are not significantly different according to Fisher's LSD ($P \leq 0.05$).



Trials 1+2, Figure 2: Relationship between the severity of cluster powdery mildew and severity of leaf powdery mildew (N = 56). Pmclus = severity of cluster mildew on August 15 (trial 1) and July 27 (trial 2). Pmlvs = severity of leaf mildew on September 14 (trial 1) and 10 (trial 2).



SECTION 3

PROJECT SUMMARY AND OBJECTIVES

Over 20 years ago, research at Cornell University established a relationship between the management of leaf powdery mildew, crop size, and the achievement of minimum standards of ripeness by harvest. Many new fungicide products have become available to Concord growers in New York and Pennsylvania since then, that need to be evaluated in this context. Our goal is to examine and compare programs of new and existing fungicides, applied at different spray intervals, and in different programs and timings, for their effects on powdery mildew disease development and the relationship between yield and brix, on Concord grape. The new information generated will be used to update disease management recommendations for Concord growers that improve their odds of reaching minimum sugar standards while streamlining fungicide programs to save money and time.

IMPORTANCE OF RESEARCH TO THE NEW YORK WINE INDUSTRY

Though the immediate focus of this project is on Concord grape and the juice industry, good powdery mildew control is obviously essential to the wine grape industry too. Our first-year results have updated the importance of canopy health to crop ripening and maturity and demonstrated the importance of fungicide choice and the impacts that has on spray interval, spray timing, program length, and program costs; important factors that must be considered to maximize the biological and economic sustainability of disease management programs in wine grape vineyards. The results will help extension staff to better advise Concord AND wine grape growers regarding powdery mildew control in the Lake Erie region and beyond. Area wide improvements in mildew control, through the concerted application of 'best' programs and chemistries can lead to widespread reductions of powdery mildew pressure and healthier vines for an entire industry.

PROJECT RESULTS/NEXT STEPS

This project provided results on which to draw several conclusions of benefit to juice and wine grape growers:

1) The amount of mildew that is allowed to develop on clusters in June and July, can have important implications on the amount of mildew that develops later on leaves in August and September. Therefore, mildew on clusters may be an important source of inoculum for later leaf infections,
2) Spray interval is more critical when using older, less effective fungicides than when using newer, more effective fungicides.
3) The number of post bloom sprays has a direct effect on leaf mildew in August and September, but the effect was significantly modified by choice of fungicide (older versus newer) with newer chemistries providing higher levels of control for longer into the ripening period. This can also have important implications on the amount of over-wintering inoculum available for epidemic development the following season.
4) Choice of fungicide can have profound implications for crop health and maturity at harvest, regardless of crop size.
5) Despite a very significant difference in fungicide efficacy, there was little difference in the cost of rotations of newer fungicides versus older fungicides: optimum control of powdery mildew on fruit and leaves does not have to cost more!!!

Our next step is to apply for a second year of funding for these trials to confirm these results and provide a more solid research-based foundation for improving disease management recommendations. We can also tweak the programs in our year-one trials to obtain a more robust outcome from which to develop those recommendations.