NYWGF RESEARCH - FINAL REPORT

Funding for fiscal year: $14,634

SECTION 1:

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** ☒
Amount Funded **$** 24,827 (total over 2 seasons)

SECTION 2: (This section should be in depth and akin to an academic report)

Project 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 results have demonstrated the superior performance of rotations of the newer fungicide chemistries on Concord canopy health (versus older chemistries) in the context of various spray intervals, timings, and programs, and how these factors might affect the relationship between crop maturity (brix) and yield. The new information generated has led to important adjustments in powdery mildew management recommendations for Concord growers, that will improve their odds of reaching minimum sugar standards by harvest, as they strive to maximize yields and profits.

Objectives:

- 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 may affect crop ripening and quality by harvest.

Materials & Methods: Over two seasons, 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 and 2023. Treatment plots consisted of 6-9 vines each, replicated 4 times within a randomized 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/Torino) versus new (Cevya/Gatten/Endura)) on efficacy against powdery mildew on clusters and leaves. This resulted in six spray treatments per season (Table 1A and B below) and an unsprayed check. Note that the order of the OLD fungicide rotation changed from 2022 to 2023. This was done to gauge the potential effects of Vivando versus Quintec for powdery mildew control on fruit. The result of this switch is discussed below. However, the order of the NEW fungicide rotation remained the same in both years. Fungicides were applied at the following rates: Cevya 4 fl oz/A, Endura 4.5 oz/A, Gatten 6.4 fl oz/A, Quintec 5 fl oz/A, Torino 3.4 fl oz/A, Vivando 15.4 fl oz/A. Fungicide sprays began at immediate prebloom and ran through 2 post bloom sprays (3 sprays total: 2022) OR 3 post bloom sprays (4 sprays total: 2023). All other diseases (black rot, downy mildew, and Phomopsis) were controlled by Manzate ProStick pre bloom and Ziram post bloom. Incidence (percent clusters or leaves infected) and severity (percent surface area infected) of powdery mildew were determined on clusters on August 15 (2022) and August 8 (2023) from 40 randomly selected clusters per plot, and on August 31 and September 14 (2022), and September 14 and October 4 (2023) from 30 randomly selected leaves per plot. Data were subjected to analysis of variance (ANOVA) and mean separation, using the general linear model function and Fisher's LSD (P = 0.05), in Minitab 20.

Table 1A: Fungicide treatment layout for trial 1 in 2022

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

Table 1B: Fungicide treatment layout for trial 1 in 2023

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

Trial 2 addressed the effects of duration of fungicide program (2, 3, 4, and 5 applications) and fungicide quality (rotation of old (Quintec/Vivando/Torino) versus new (Cevya/Gatten/Endura)) on efficacy against powdery mildew on clusters and leaves. Spray intervals were 10 to 14-days and 8 fungicide programs (and an unsprayed check) were applied at the following stages in Table 2A (2022) and 2B (2023). Note that the order of the OLD fungicide rotation changed from 2022 to 2023 (as in Trial 1). However, the order of the NEW fungicide rotation remained the same in both years. Fungicides were applied at the following rates: Cevya 4 fl oz/A, Endura 4.5 oz/A, Gatten 6.4 fl oz/A, Quintec 5 fl oz/A, Torino 3.4 fl oz/A, Vivando 15.4 fl oz/A, Tebustar 4 oz/A, HarvestMore 5 lbs/A. All other diseases (black rot, downy mildew, and Phomopsis) were controlled by Manzate ProStick pre bloom and Ziram post bloom. Incidence and severity of powdery mildew were determined on clusters on July 25-27 (2022) and August 2-3 (2023) from 40 randomly selected clusters per plot, and on leaves on August 9-10 and 19-22, and September 8-10 and 19-22 (2022), and September 12-13 and October 3 (2023) from 30 randomly selected leaves per plot. Trial 2 also addressed the effects of 'new' versus 'old' fungicides on the relationship between yield and brix. Brix was determined just before harvest from 20 clusters per vine, from 2 (2022)

and 1 (2023) data vines per plot. Yield was determined from all clusters from those same vines. Data were subjected to analysis as in Trial 1.

Table 2A: Fungicide schedules/programs for trial 2 in 2022.

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

Table 2B: Fungicide schedules/programs for trial 2 in 2023.

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

Results/Outcomes/Next Steps:

Observations on cluster disease in trial 1 (Table 3)

Powdery mildew was first recorded on unsprayed Concord clusters on June 22 (2022) and June 19 (2023), about a week after end of bloom (2022) and at full bloom (2023). So powdery mildew showed up earlier in 2023. We also observed that disease pressure was higher in 2023 than in 2022. Within each spray interval, newer fungicides were generally more effective at reducing powdery mildew severity on clusters, than older fungicides. These differences were significant for 14 and 18-day intervals in 2022, but only for 18-day intervals in 2023; 'old' versus 'new' tended to matter least at the shorter, 10-day intervals. This makes sense in that differences in efficacy between fungicide programs will be minimized as spray intervals become shorter, and maximized as spray intervals are stretched.

We also witnessed (as we suspected) that moving Vivando (paired with Quintec) out of a critical position for fruit protection (first post bloom spray in 2022), and replacing it with Quintec (paired with Torino at pre-bloom) in 2023, greatly improved efficacy of the 'old' rotation, in spite of higher disease pressure in 2023. This may relate, at least in part, to the development of resistance to Vivando at this location, where Vivando has been performing poorly for a number of years.

Within the old fungicides, 10-day intervals were consistently more effective at reducing severity than 18-day intervals. However, among rotations of new fungicides, interval made little difference on control of severity of mildew on clusters. Rotations of newer, more effective fungicides will provide more forgiveness for stretching intervals than rotations of less effective, older fungicides, where interval plays a more critical role. Overall, the best combination, averaged over 2 seasons, was 14-day intervals with new materials. The worst combination for fruit protection was 18-day intervals with old materials.

Table 3: Trial 1; Powdery mildew development on Concord clusters over 2 seasons. New or Old fungicide rotations were applied at 10, 14, or 18-day intervals.

Year	15 August 2022			8 August 2023		
	Incidence	Severity[z]	% Control[y]	Incidence	Severity[z]	% Control[y]
OLD: 10 days	45.0 abc[x]	1.08 b[x]	18	**90.0 b[x]**	**3.10 c[x]**	80
NEW: 10 days	25.6 cd	0.60 bc	55	**61.9 d**	**1.59 c**	90
OLD: 14 days	43.1 bc	1.23 b	7	**90.6 b**	**5.94 bc**	61
NEW: 14 days	**1.9 d**	**0.05 c**	**96**	**80.6 c**	**2.18 c**	86
OLD: 18 days	70.0 a	2.40 a	0	96.3 ab	**7.95 b**	48
NEW: 18 days	28.8 c	0.67 bc	49	**89.4 b**	**2.97 c**	80
Unsprayed check	43.1 bc	1.32 b		100.0 a	15.16 a	
P-value	**0.001**	**0.006**		**<0.001**	**<0.001**	

[z]Severity was rated using the Barratt-Horsfall scale (0-11) and was converted to % area infected (0-100 %) using Elanco conversion tables.
[y]Percent control = control of disease severity on clusters relative to the unsprayed check.
[x]Means followed by the same letter within columns are not significantly different according to Fisher's LSD ($P \leq 0.05$).

Observations on leaf disease in Trial 1 (Table 4): There were no statistically significant effects of the treatments in 2022. This was likely due to low, aggregated/non-uniform disease pressure across the trial area. The trial was repeated in 2023 in a different vineyard block, with better results. In general, trends were the same as with cluster effects, where rotations of new materials performed better than old materials. However, in 2022, differences between old and new become more apparent as you stretch intervals, whereas in 2023, differences become less apparent as you stretch intervals. In view of this lack of consistency, I think its important to remember that the 2023 results are likely to be more trustworthy and reliable as disease pressure was higher and more uniform across the test block in that year.

Table 4: Trial 1; Powdery mildew development on Concord leaves over 2 seasons. New or Old fungicide rotations were applied at 10, 14, or 18-day intervals.

Year	31 August 2022		14 September 2022		14 September 2023		4 October 2023	
	Incidence	Severity[z]	Incidence	Severity[z]	Incidence	Severity[z]	Incidence	Severity[z]
OLD: 10 days	40.0	2.47	60.9	9.49	99.2 a[y]	**26.96 b[y]**	100.0 a[y]	38.67 a[y]
NEW: 10 days	40.8	2.22	55.0	10.30	90.0 ab	**8.54 c**	98.3 a	**20.07 c**
OLD: 14 days	36.7	1.27	58.3	8.31	100.0 a	**26.35 b**	100.0 a	**30.33 b**
NEW: 14 days	15.9	0.39	45.8	3.91	**79.2 b**	**5.32 cd**	96.7 a	**14.56 cd**
OLD: 18 days	58.4	3.74	77.5	20.67	**53.4 c**	**2.38 cd**	**75.9 b**	**5.93 e**
NEW: 18 days	30.8	2.73	49.2	6.82	**58.4 c**	**2.26 d**	95.0 a	**8.71 de**
Unsprayed ck	46.7	5.40	65.9	12.94	100.0 a	43.28 a	100.0 a	42.42 a
P-value	0.063	0.188	0.361	0.079	**<0.001**	**<0.001**	**0.007**	**<0.001**

[z]Severity was rated using the Barratt-Horsfall scale (0-11) and was converted to % area infected (0-100 %) using Elanco conversion tables.

[y]Means followed by the same letter within columns are not significantly different according to Fisher's LSD ($P \leq 0.05$).

The best combination, numerically, appears to be 18-day intervals with new materials. The worst combination appears to be 10-day intervals with old materials: stretching intervals later in the season (beyond 14 days) *may* provide a benefit and may result in less mildew at harvest, although the differences between rotations of new materials at 14 and 18-day intervals are small and not statistically significant.

In view of these results, recommendations should advocate the use of rotations of newer chemistries at 10 to 14-day intervals for the immediate prebloom and first and second post bloom sprays. Intervals can then be allowed to exceed 14 days for leaf disease control during mid and late summer.

<u>Observations on cluster disease (fruit and rachises) in trial 2 (Figure 1)</u>

First appearance of cluster infections occurred on about June 21 (2022) and June 19 (2023), similar to trial 1. Also, disease pressure was higher in 2023 than in 2022. There were few program effects on cluster disease incidence in either year (data not shown), but all programs controlled cluster disease severity when compared to the unsprayed check, with the exception of one pre and one post bloom spray of *older materials in 2022*.

Within each program, new materials provided statistically superior control of powdery mildew severity compared to older materials in 2022. However, in 2023, all programs provided statistically equivalent control of powdery mildew severity on clusters.

Within older or newer materials, 4 and 5 sprays performed superior to 2 and 3 sprays, in 2022, whereas in 2023, all programs provided equivalent control of powdery mildew severity on clusters. This was thought to be mostly a reflection of cluster rachis infection control, which was only rated in 2022 (because actual berry infections were extremely light) and was enhanced by extra post bloom sprays, beyond the first post bloom spray. Rachis infections may not necessarily affect crop yield or quality but may affect the development of leaf infections. However, in 2023, only berry infection was rated and therefore sprays made after the first post bloom spray provided little or no additional disease control on fruit. This is indeed a testament to the fact that most, if not all berry infection is controlled by just two sprays: the immediate pre bloom and first post bloom spray. Finally, adding a pre bloom spray at 8-12" shoots in 2022, provided no additional cluster disease control benefit to starting sprays at immediate pre bloom, regardless of the use of old or new materials.

<u>Observations on leaf disease</u> in trial 2 (Figure 2).

Powdery mildew was first recorded on unsprayed Concord leaves somewhere between July 21 (no leaf disease) and July 28 (37% incidence on leaves) in 2022 and on July 10 in 2023. This is about 4-5 weeks after first mildew on clusters in 2022, and just 3 weeks after first mildew on clusters in 2023 (a shorter period in 2023 likely due to higher disease pressure in 2023 than in 2022). Control of leaf disease severity improved as more applications (of older or newer materials) were made, and in general, as above, <u>*new materials provided better powdery mildew control than older materials.*</u>

In 2022, all treatments were controlling leaf disease severity on August 9/10, 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, where all programs still controlled leaf disease severity, <u>*but rotations of older materials*</u>

continued to slip farther behind rotations of newer materials with respect to mildew control. By September 8-10, control by rotations of older materials continued to deteriorate and only rotations of 4 (1pre+3post) and 5 (1pre+4post) newer fungicides 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.

Examining the results of 2023, we see that newer materials performed better than older materials within each program (2, 3, 4, or 5 applications). By September 12, significant control with older fungicides was only achieved by 5 applications, whereas 3, 4, and 5 applications of the newer materials continued providing significant control of severity, when compared to the check. By October 3rd, 3 and 5 applications of older materials, and all programs of newer materials, provided a significant reduction in leaf mildew severity, compared to the check. Note that in all these cases, the rotations of newer materials performed better than the rotations of older materials, to the point where 2 applications of the newer materials provided control of leaf disease severity that was equivalent to 5 applications of the older materials. Also, just 3 applications of newer materials was superior to 5 applications of older materials.

Does severity of cluster infection affect progression of severity of leaf infection?

Regression analysis of the data showed that in 2022, about 70% of the variation in leaf disease severity is explained by the variation in cluster disease severity, suggesting that powdery mildew on clusters in June/July, can influence powdery mildew development on leaves in August and September. However, in 2023, when disease pressure was higher, a similar analysis showed only a very weak relationship between powdery mildew on clusters in June/July, and powdery mildew development on leaves. A possible explanation may relate to the higher disease pressure in 2023, where high levels of mildew saturate the vineyard by harvest, regardless of the amount of disease on clusters in early summer.

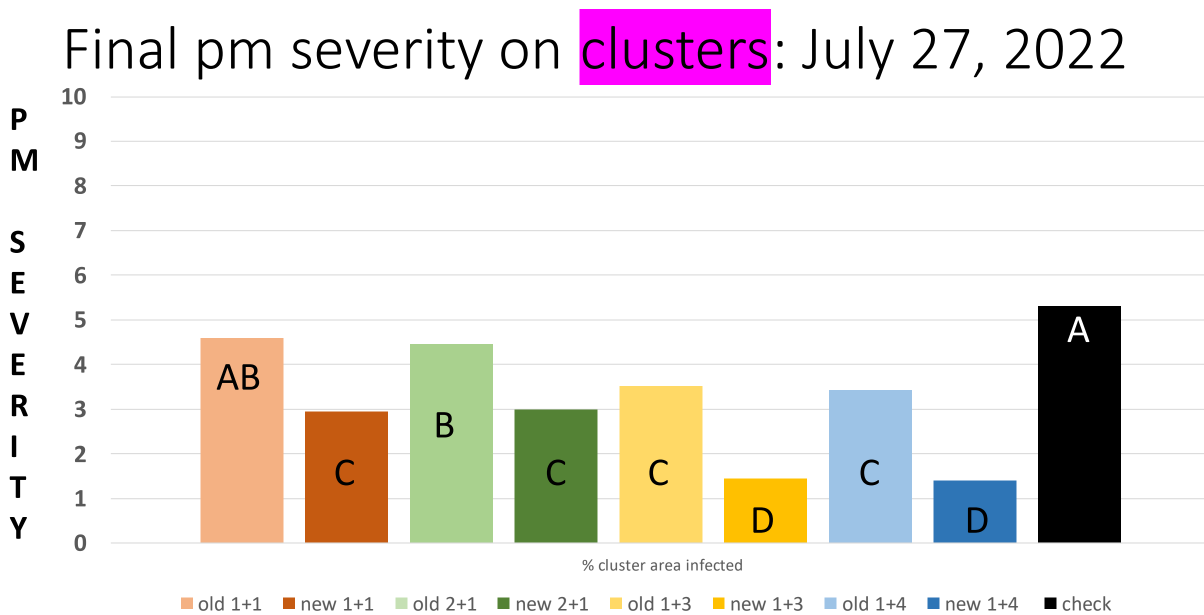
Treatment effects on yield and fruit maturity (brix at harvest: Figure 3A and B)

Our last consideration was to evaluate the effects of fungicide quality (old rotations versus new rotations) on the relationship between yield and brix at harvest. Each year, we collected yield and brix data from single vines in each treatment plot, from i) the four older fungicide treatments and ii) the four newer fungicide treatments. The two years of data were combined (n=52 data points in each set) and regressed as yield x brix (Figures 3A and B). As expected, there was a negative relationship between brix and yield for both new and old fungicide treatments: brix at harvest decreased as yield increased, regardless of fungicides used. Also, each regression was highly significant at $P < 0.001$, and each regression explained about two thirds of the variation in the data (Figures 3A and B). However, the effect of yield on brix was less pronounced (flatter slope of the linear regression) among treatments of the new fungicides, compared to the older fungicides. This means that with each increase in yield, brix decreased less on vines that received new fungicides compared to vines that received old fungicides. Converting kg/vine to tons/A, the figures show that by the time of harvest, vines in the new rotations brought 10.44 tons/A to 16 brix, while the old rotations brought 9.14 tons/A to 16 brix. Viewed another way, these data suggest that a given yield will ripen to 16 brix earlier if you use rotations of newer fungicides, as opposed to using rotations of older fungicides.

Technology Transfer Plan:

The results have been presented to growers through the November 10 newsletter of the Lake Erie Regional Grape Program and the zoom meetings “2023 Pest Management Spray Schedule; What’s Your Plan”, on December 9, 2022 and December 5, 2023. The results were also presented/discussed with growers at the Lake Erie Regional Grape Program Conference on March 16, 2023 and March 14, 2024 at the SUNY campus in Fredonia. Information from this project were also/will be, extended to growers during coffee pot meetings, Crop Updates, and other extension based/grower meetings in Pennsylvania and New York during the 2023 and 2024 growing season.

Figure 1: Trial 2; powdery mildew severity on clusters over 2 seasons. Older or New fungicides were applied in programs of 2, 3, 4, or 5 applications, at 10-14 day intervals.



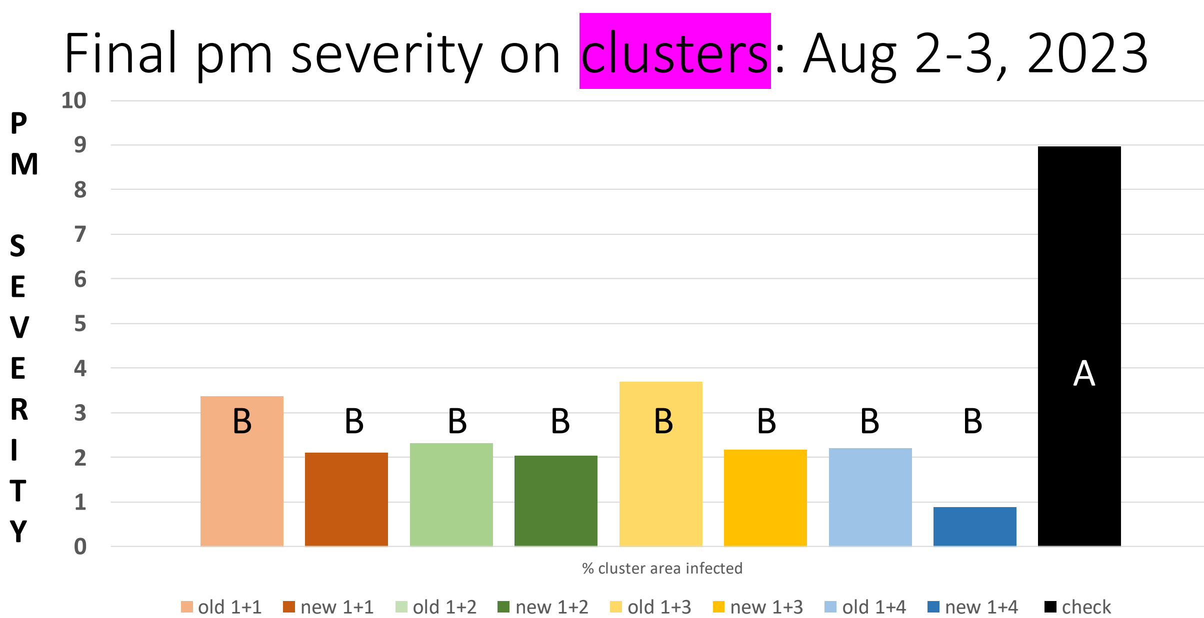
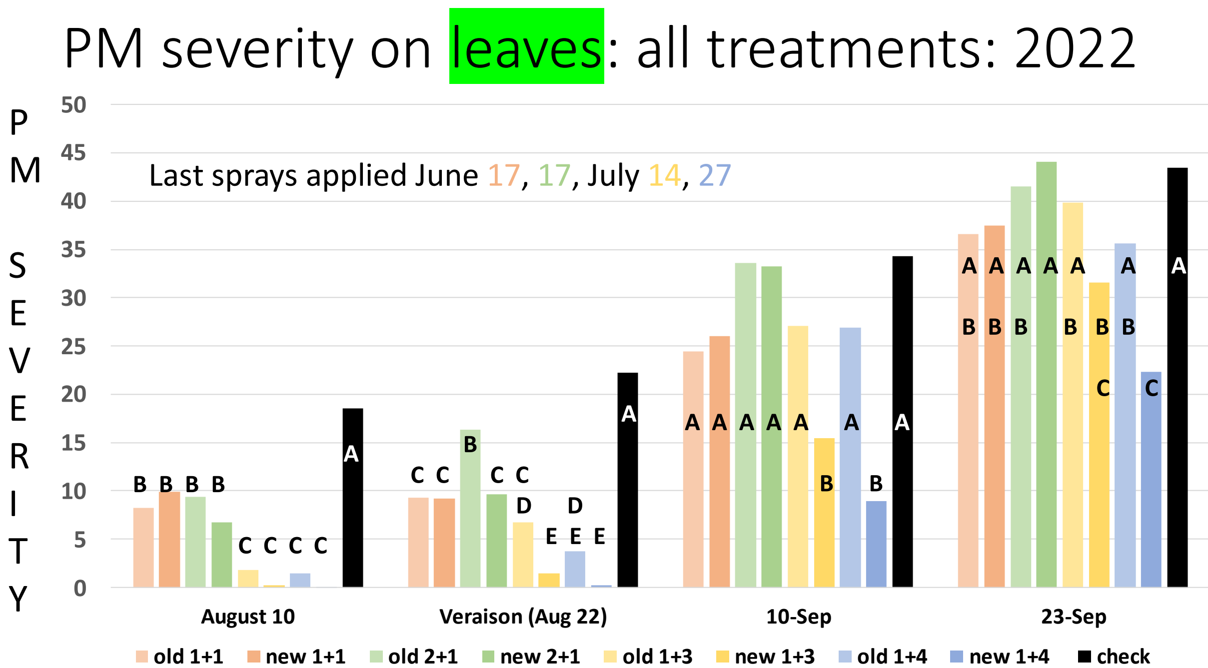


Figure 2: Trial 2; powdery mildew severity on leaves over 2 seasons. Older or New fungicides were applied in programs of 2, 3, 4, or 5 applications, at 10-14 day intervals.



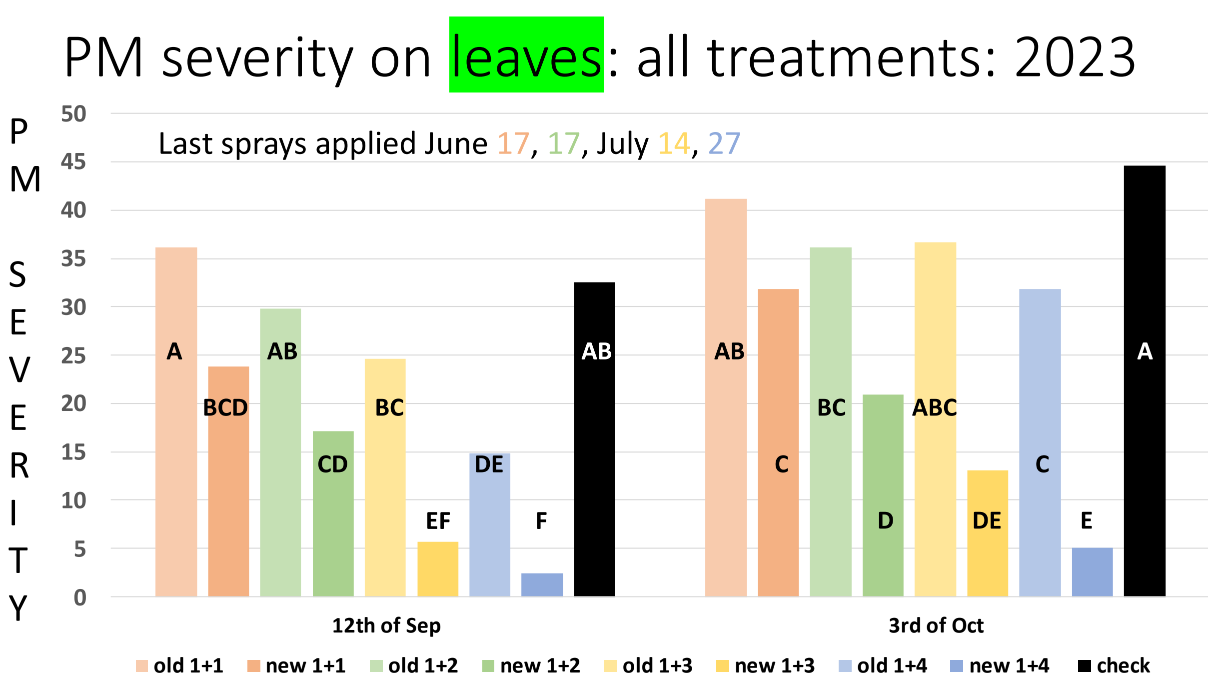


Figure 3A: Brix x yield (kg/vine) data from two years and 52 vines, at harvest of Concord vines treated with rotations of *older* fungicides (Quintec, Torino, Vivando) in programs of 2, 3, 4, and 5 applications.

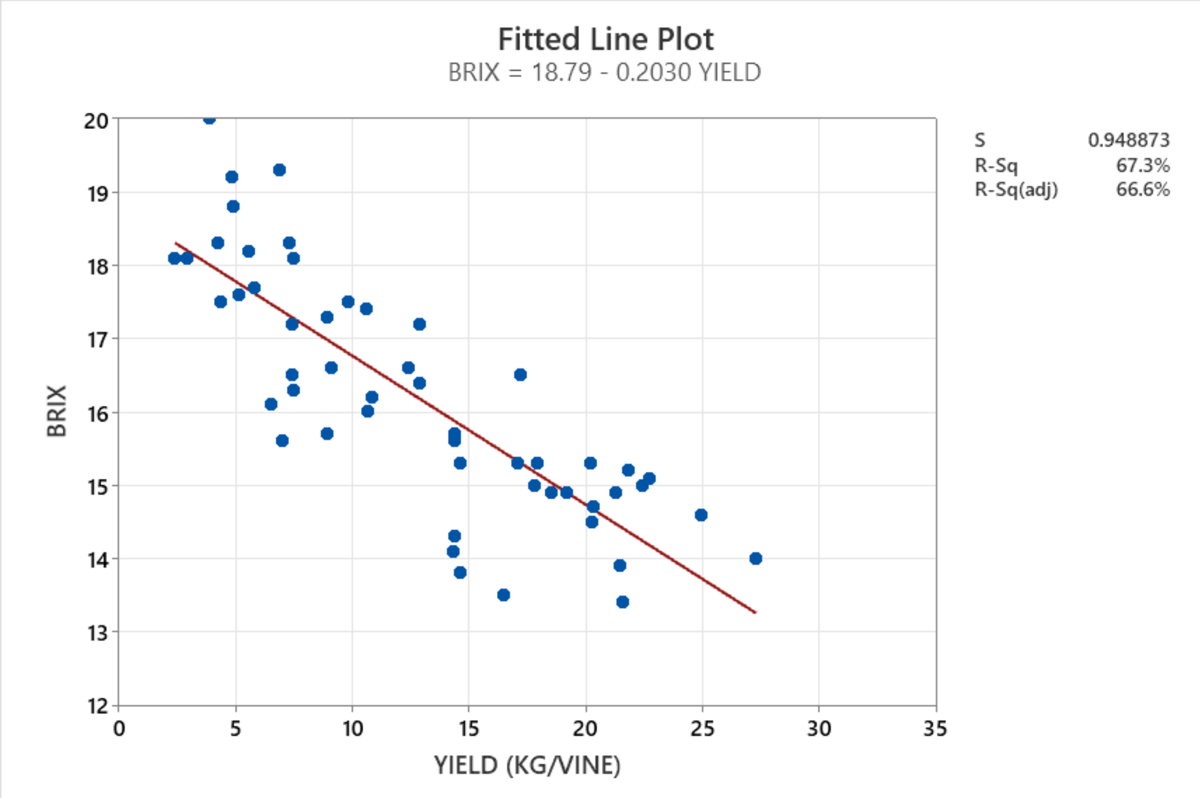
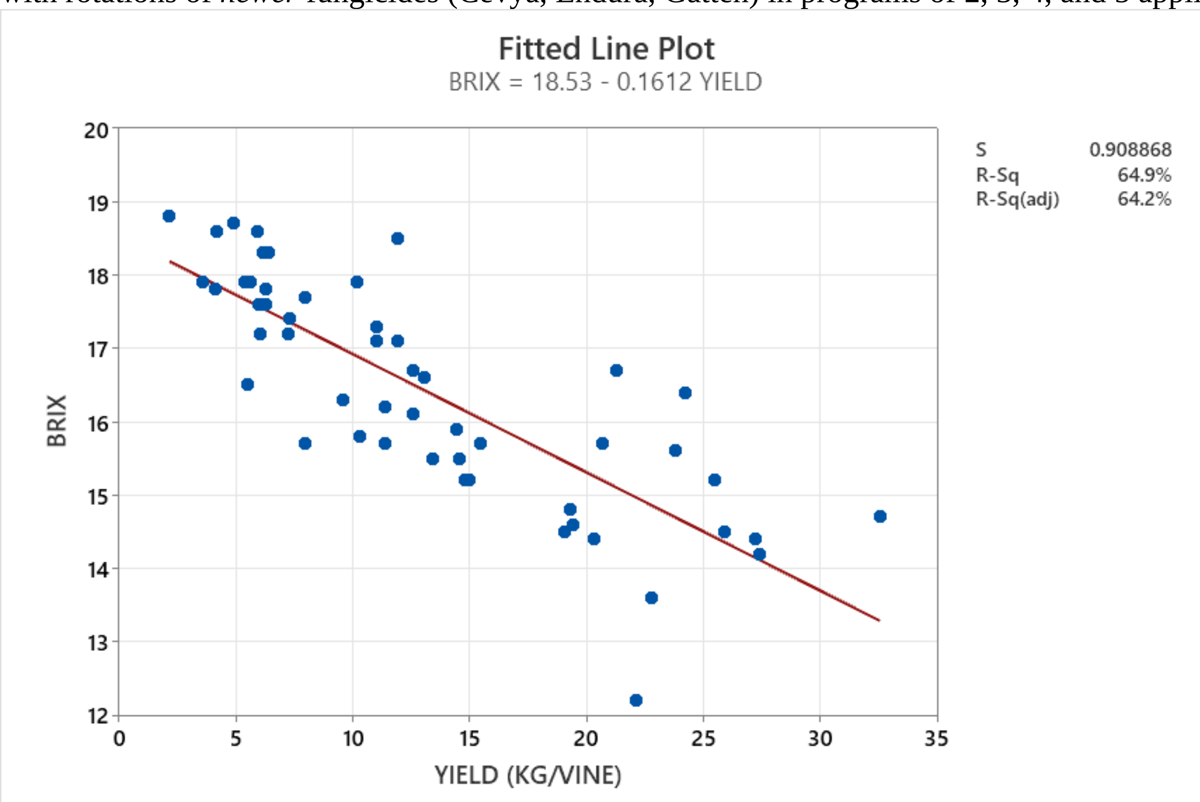


Figure 3B: Brix x yield (kg/vine) data from two years and 52 vines, at harvest of Concord vines treated with rotations of *newer* fungicides (Cevya, Endura, Gatten) in programs of 2, 3, 4, and 5 applications.



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 on Concord grapes. With the emergence of several new powdery mildew fungicides since that time, our goal was to compare programs of the newest fungicides with similar programs of older/existing fungicides for their effects on powdery mildew disease development, and the relationship between brix accumulation and yield. Our results showed that rotations of the newest materials provided control of powdery mildew on clusters and leaves, that was superior to that of the older/existing materials, when compared at various spray intervals (10, 14, and 18-day intervals) and programs (2, 3, 4, and 5 applications per season). The results also suggest that the use of rotations of the newer fungicides, instead of the older fungicides, may improve the odds of ripening a given crop. This new information is being used to update disease management recommendations for Concord growers, at grower meetings, and in newsletters and crop updates, that will improve their odds of reaching minimum sugar standards while streamlining fungicide programs to save money and time.

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.

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 results demonstrated the impact of fungicide choice 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 juice and 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, may 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) These results will be used to update fungicide recommendations for the control of powdery mildew on juice and wine grapes in Pennsylvania and New York.