A Progress Report for a Research and Extension Project Submitted to:
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Project Title: Side by side evaluation of clones and hybrids of *Vitis vinifera* 'Riesling' in the Lake Erie Region of Pennsylvania

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Co-PI Collaborators with contact info: Dr. Michela Centinari: Department of Plant Science, Associate Professor of Viticulture at Penn State, Phone: 814-867-0514; email: mzc22@psu.edu M. Centinari has an appointment split across research and extension. To this project, she adds pertinent expertise in wine grape production and physiology.

New Research ☐ Continued Research ☒

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SUMMARY IMPACT STATEMENT: *Vitis vinifera* 'Riesling' is an important variety for wine grape growers in Pennsylvania, New York, and other regions of the Northeast. There are many clones and hybrids of Riesling, but to our knowledge, direct, multi-year comparisons of these clones and hybrids do not exist for the Pennsylvania/New York grape growing regions, to aid growers in choosing which ones to grow. This project will yield valuable viticultural comparisons of several of the most popular clones and hybrids of Riesling, growing side-by-side in the same vineyard, that could aid producers in making clonal and varietal decisions when planning an expensive new vineyard. Data from 2021 and 2022 detail comparisons of 4 clones (90/12, 110/17, 198/9, 239) and 2 hybrids (Geisenheim and NY81) of Riesling regarding canopy density and fruiting zone microclimate, fruit rot susceptibility, yield parameters, cluster architecture, cold hardiness, fruit composition, and the response to efforts to alleviate bunch rot development with pre and post bloom mechanized leaf removal. Multiple years of data will be necessary to identify and confirm patterns that will lead to more reliable recommendations.

OBJECTIVES in 2022:

- Compare the viticultural characteristics (phenology, vegetative growth, yield, cluster/berry weight, cluster architecture), bunch/sour rot susceptibility, cold hardiness, and fruit composition, of 4 clones (90/12, 110/17, 198/9, 239) and 2 hybrids (Geisenheim and NY81) of Riesling.
- Compare the response to pre bloom and post bloom mechanical defoliation of these 4 clones and 2 hybrids of Riesling, and how it relates to canopy microclimate, disease development, and fruit yield and quality.
- Investigate the potential causes of any differences between these clones/hybrids and propose recommendations.

ACTIVITIES/METHODS

A one-half acre vineyard has been established in 2016 at the Lake Erie Regional Grape Research and Extension Center to directly compare Riesling clones 90/12, 110/17, 198/9, 239, and hybrids Geisenheim and NY81. Vines were planted on a 6 x 9 foot spacing, with 6 feet between vines within a row and 9 feet between rows. All vines were trained to a vertical shoot position (VSP) system and cane pruned to maintain roughly 4 shoots per foot of row. Each clone/variety is represented in 3 consecutive panel plots (12 vines per plot) within a row, with each plot replicated in 5 randomized complete blocks (60 vines per clone/variety). Within each plot, a different treatment was randomly imposed on each of the 3 panels: i) mechanized cluster-zone defoliation just before bloom (MD1), ii) mechanized cluster-zone defoliation at fruit set (MD2), and iii) no defoliation (control; C). Mechanized defoliation was accomplished with a BlueLine Deleafer (Blueline Manufacturing Company) that operates by blowing compressed air into the fruit-zone with enough pressure to shatter leaf tissue, while leaving inflorescences relatively undamaged (Hed and Centinari, 2018). The tractor mounted Blueline air sheer system has two pulse-air heads that are pressed against the fruit zone as it is driven down the row. The heads are mounted at slightly different heights from each other to fully accommodate the fruit zone on the VSP system, impacting leaves along the first 5-6 nodes on shoots. MD is applied to both sides of the canopy, 1 pass per side, at a tractor speed of about 0.8 mph.

Throughout the 2022 season, viticultural measurements were collected: key phenology stages (bud break, bloom, veraison, and harvest), bud survival, fruitfulness (shoots/bud, clusters/shoot), yield per vine and per shoot, leaf removal efficiency, canopy density (EPQA), cluster morphology (cluster weight and length, #berries/cluster, cluster compactness), fruit composition at harvest (Brix, pH, titratable acidity (TA)), fruit susceptibility to bunch rots (total rot at harvest), and susceptibility to crown gall. A conventional fungicide program was applied throughout the season for control of all diseases, including bunch rots. Weather data was collected with an onsite weather station.

RESULTS/PROGRESS/NEXT STEPS

Phenology 2022

Bud swell on all varieties in 2022 appeared to be well behind that of the previous year. On May 1, Geisenheim was at full bud swell (ahead of all other varieties/clones), followed by NY81 and all clones (at mid-swell). Cold weather in early May continued to delay bud development until about May 10, when warm weather finally swept in. Geisenheim was at 50% budbreak by May 11, followed closely by NY81 on May 12, and all clones by May 13.

Trace bloom was achieved by Geisenheim on June 13 (5 days behind 2021), by NY81 on June 15 (6 days behind 2021), and by all clones (90, 110, 198, 239) on June 16 (3 days behind 2021). Geisenheim reached veraison about August 6/7, followed by NY81 on August 8. Riesling clones reached veraison by August 17: hybrids and clones were about 9-10 days apart in development, remaining that way through harvest. NY81 was harvested first (September 15, only 2 days later than in 2021) followed by Geisenheim on September 20 (same day as in 2021) and the 4 clones on October 6-7 (same as 2021). So, after being 2-3 weeks behind 2021 in development at bud break, harvest of each variety occurred at about the same time as in 2021.

Percent bud survival 2022

Bud winter survival was determined in early June when bud, shoot, and cluster counts were made from long canes laid down on the training wire to serve as cordons. There was no effect of treatment ($P=0.258$), but there was an effect of variety ($P<0.001$), where Geisenheim was superior to all other varieties (93.7% bud survival). This was followed in the next statistical tier by clone 239 (78.9%), NY81 (77.6%), and clone 110 (75.7%). Last were clones 90 (73.2%) and 198 (73%), which were statistically lower than Geisenheim and clone 239 (of the clones, 239 had the hardiest buds).

Leaf removal efficiency 2022; Table 1

MD1 was applied on June 16, when Geisenheim was in mid bloom, NY81 was at early bloom, and clones were at trace bloom. MD2 was applied 2 weeks later, on June 30. Shoots were tucked into catch wires just before MD was applied. The leaf removal efficiency of each defoliation was determined by subtracting the weight of leaf tissue remaining after each defoliation, from the weight of leaves in the control, on the first 6 nodes of a sample of shoots in each panel. In 2022, MD efficiency was highest on Geisenheim

(MD1) and clone 198 (MD2), though in neither case were the differences significant. Also, MD2 efficiency was generally higher than MD1 efficiency. Over 3 seasons (from 2020-2022), average MD2 efficiency was higher than MD1 efficiency, and on varieties, average MD1 and MD2 efficiency is lowest on clone 110 and highest on Geisenheim. We did not determine the exact cause of these differences, but it may relate to shoot length at the time of application; MD efficiency increasing with increasing shoot length.

Enhanced point quadrat analysis 2022 (EPQA); Table 2.

Canopy density and light penetration into the fruit zone were measured just after veraison by Point Quadrat Analysis (PQA) and an LP80 ceptometer. These measurements were combined to provide an EPQA (enhanced PQA) of several canopy characteristics.

Fruit zone canopies of all varieties were less dense in 2022 than in 2021. And, as in 2021, the interaction between variety and treatment (MD) was not significant for any EPQA parameter in 2022, which means that MD produced similar results across varieties, for at least two consecutive years. Also consistent with 2021 data, the MD treatment in 2022 improved all fruit zone canopy density measurements regardless of timing (in comparison with the check (no MD)), with MD2 canopies having lower density than MD1 canopies, likely because the MD2 treatment was applied 2 weeks later, allowing less time for vegetative regrowth into the fruit zone. Overall, fruit zone canopies of clone 198/9 tended to be more dense than the hybrids, mainly Geisenheim.

Bunch rot 2022; Tables 3A and B

Nearly all of the 'bunch rot' in 2022 was a result of cluster desiccation and necrosis, initiated in July and proceeding all the way to harvest. The necrosis is thought to be a result of the combined effects of hot, dry weather in June and July and manual un-hilling of grafts during that period that may have damaged some roots, leading to partial abortion of the crop. Total bunch rot/necrosis was initially determined on July 21, using a scale of 0-3 (0=no damage; 1=light damage; 2=moderate damage; 3=severe damage). Treatment had no effect on the cluster necrosis (P=0.162), but there was a significant effect of variety (P<0.001), with hybrids being unaffected (NY81 0% necrosis) or little affected (Geisenheim 0.25), to clones being significantly more affected than hybrids (1.35-2.03). Among the clones, 239 was significantly less affected than 110 and 198.

Total rot/necrosis at harvest was rated using the Barratt-Horsfall scale (0-11) and converted to % area infected (0-100 %) using Elanco conversion tables. Incidence and severity of rot/necrosis was determined on September 14 on NY81 (the day before its harvest), on September 19 on Geisenheim (the day before its harvest) and on all the clones on October 4-5 (harvested on October 6-7). There was no effect of MD on total rot at harvest (Table 3A) but there was a strong effect of variety (Table 3B). Again, the effects were largely confined to the clones; the hybrids suffered only minor - and significantly less - damage. Among the clones, 239 was least affected and 110 was most severely affected.

Yield results 2022; Table 4.

The variety by treatment interaction was not significant for yield per vine, yield per shoot, or cluster weight (MD produced similar results with respect to these parameters, across all varieties). MD generally reduced yield parameters, but timing had an effect. For example, only MD2 reduced yield per shoot, but both MD1 and MD2 reduced cluster weight. The assessment of cluster metrics like berry weight and # berries/ cluster will help understand what causes these effects. There was a varietal effect where yield per shoot, yield per vine, and cluster weight of hybrids was superior to all clones. This difference was directly related to the cluster necrosis that took place among all clones but had little effect on hybrids.

Crown gall 2022

Crown gall was determined on October 12, just after harvest. There was no effect of treatment (no MD, MD1, or MD2) on the incidence of crown gall (P=0.656). However, there was an effect of variety (P<0.001): hybrids - Geisenheim and NY81 - had significantly less incidence of crown gall (6.7 and

1.7%, respectively) than Riesling clones (26.7 to 36.7% incidence). This is not surprising given the assumption that hybrids are more cold hardy and less apt to suffer winter cold damage to vascular tissues.

Remaining data for 2021:
Cluster morphology for 2021: Table 5. Hundreds of clusters had been collected and frozen from the 2021 harvest, that were dissected and evaluated during 2022 for *number of berries/cluster, berry weight, cluster length, accumulation of bloom trash, and cluster compactness, assessed as number of berries per cm of rachis length.* The treatment by variety interaction was not significant for any of these parameters; MD affected all the varieties similarly, according to these cluster metrics.
Treatment comparisons: Both MD1 and MD2 decreased the number of berries/cluster, cluster compactness, and number of pieces of bloom trash (debris), compared to the control (no MD) although MD1 reduced number of berries to a larger extent than MD2, and MD2 reduced debris to a larger extent than MD1. Only MD2 affected berry weight. MD2 vines may have reduced berry number due to machine damage of some of the clusters (actual physical removal of berries). MD2 increased the number of small shot berries at harvest.
Cultivar comparisons: Geisenheim vines had the highest number of berries/cluster while clone 239 had the lowest, differing from Geisenheim by two statistical tiers. This relates directly to Geisenheim having the heaviest clusters and clone 239 having the lightest clusters at harvest 2021 (previous progress report). Berry weight, which also can affect cluster weight, did not differ statistically between these two varieties, and had little or no effect on cluster weight in 2021. NY 81 had the highest number of shot berries per cluster and lowest average berry weight. Hybrid clusters had longer rachises, and their clusters were less compact than most clones (except clone 239, which was not different from Geisenheim). Geisenheim clusters contained the most accumulated bloom trash, while clone 239 contained the least.

Juice Chemistry for September 2021: Tables 6A and 6B. The interaction between variety and treatment (MD) was not significant for any juice chemistry parameter in 2021, which means that MD produced similar results across varieties. When all 6 varieties were analyzed, MD grapes had increased ripeness compared to the control (no MD) and Geisenheim vines had the ripest (most mature) fruit: highest TSS and pH, and lowest TA. NY81 had higher TSS than all the clones but tended to have pretty high TA overall; indeed, NY 81 TA mean value was similar or higher (110/17) than those of the clones. When just the clones were analyzed, MD increased ripeness (as above) and clones 239 and 110/17 had higher TSS than 198/9, while at the same time clone 239 had higher TA than 110/17. Interestingly, 239 was the clone with the highest TSS and TA.

TECHNOLOGY TRANSFER PLAN

The progress of this project was briefly discussed at a meeting with wine and juice grape processors and Cornell/Penn State extension staff on 12/1/22. In 2023, after all data have been analyzed, the results will be discussed with extension/research colleagues and growers at extension based/grower meetings in Pennsylvania and New York, and possibly other parts of the Northeast. At completion of the project, the results will be submitted for publication in a peer-reviewed journal.

RELEVANT CHARTS, FIGURES, TABLES

Table 1. Leaf removal efficiency of MD1 (June 16) and MD2 (June 30) in 2022

Variety/clone	Percent leaf area removed by MD1	Percent leaf area removed by MD2
90	35.7	46.7
110	23.8	38.6
198	34.9	57.1
239	25.2	47.1
Geisenheim	37.2	53.1
NY81	26.0	49.2

P-value	0.088	0.196

Means followed by the same letter within columns are not significantly different (Tukey test at $P \leq 0.05$).

Table 2. Enhanced point quadrat analysis characteristics of Riesling varieties with and without MD. Measurements were taken close to the onset of fruit ripening in 2022.

	Leaf layer number (n)	**Interior leaves (%)**	**Leaf exposure availability (%)**	**Cluster exposure availability (%)**
Treatment (T)				
Control	1.97 a	29.13 a	51.8 c	48.2 c
MD1	1.36 b	19.76 b	65.6 b	64.6 b
MD2	1.01 c	14.66 b	72.9 a	70.4 a
p value (T)	<0.001	<0.001	<0.001	<0.001
Variety (V)				
239	1.45 ab	17.35	64.3	58.5 ab
198/9	1.61 a	24.30	60.2	56.3 b
90/12	1.58 a	23.92	61.7	60.5 ab
110/17	1.49 ab	19.18	63.2	60.5 ab
Geisenheim	1.26 b	20.10	66.0	66.2 a
NY81	1.28 b	22.25	65.4	64.4 ab
p value (V)	0.012	0.085	0.089	0.024
p value (TxV)	0.262	0.261	0.524	0.186

Means followed by the same letter within columns are not significantly different (Tukey test at $P \leq 0.05$).

Table 3A: Effects of machine defoliation (MD) on total rot/necrosis at harvest of 2022.

Treatment	**Percent cluster with rot/necrosis (%)**	**Percent area cluster with rot/necrosis (%)**
MD1	73	18.54
MD2	75.5	23.29
Check	80.3	19.6
P-Value	0.638	0.599

Means followed by the same letter within columns are not significantly different (Tukey test at $P \leq 0.05$).

Table 3B: Effects of variety on total rot/necrosis at harvest of 2022

Treatment	**Percent cluster with rot/necrosis (%)**	**Percent area cluster with rot/necrosis (%)**
90	98.0 a	29.99 ab
110	94.7 a	38.95 a
198	96.3 a	31.15 ab
239	89.0 a	19.18 b
Geisenheim	51.7 b	2.88 c
NY 81	28.0 c	0.71 c
P-Value	P<0.001	P<0.001

Means followed by the same letter within columns are not significantly different (Tukey test at $P \leq 0.05$).

Table 4. Yield parameters measured at harvest 2022.

	Yield/shoot (g)	Cluster weight (g)	Yield/vine (kg)
Treatment (T)[a]			
Control	134.2 a	61.6 a	2.97
MD1	114.7 ab	54.3 b	2.71
MD2	109.0 b	52.7 c	2.53
p value (T)	0.025	0.028	0.111
Variety (V)			
239	86.1 b	37.6 b	1.97 b
198/9	56.8 b	34.1 b	1.34 b
90/12	73.2 b	42.2 b	1.61 b
110/17	54.3 b	33.7 b	1.27 b
Geisenheim	235.5 a	91.9 a	5.23 a
NY81	210.0 a	97.8 a	5.01 a
p value (V)	<0.001	<0.001	<0.001
p value (TxV)	0.794	0.804	0.891

Means followed by the same letter within columns are not significantly different (Tukey test at $P \leq 0.05$).

Table 5. Impact of defoliation treatments (MD1 and MD2) and 'Riesling' clone/variety effects on number of berries per cluster (total and small berries) number of debris, length of cluster's rachis, and cluster compactness assessed at harvest 2021

	Tot no. berries / cluster	No. shot berries/ cluster	Berry weight (g)	Rachis length (cm)	Cluster compactness (berries/cm)	Debris (no./cluster)
Treatment (T)[a]						
Control	117.3 a	12.90 b	1.51 a	7.91 a	11.18 a	38.9 a
MD1	92.6 c	11.47 b	1.50 a	7.41 b	9.47 b	26.4 b
MD2	104.5 b	16.86 a	1.39 b	7.71 ab	9.83 b	18.2 c
p value (T)	<0.001	0.008	<0.001	0.020	<0.001	<0.001
Variety (V)						
239	83.4 c	10.9 b	1.50 a	6.17 b	9.53 bc	17.2 c
198/9	107.4 b	12.8 b	1.52 a	6.89 b	11.60 a	33.5 ab
90/12	106.9 b	13.6 b	1.52 a	6.65 b	11.64 a	24.5 bc
110/17	96.7 bc	12.8 b	1.46 ab	6.34 b	11.20 ab	21.0 bc
Geisenheim	127.3 a	12.3 b	1.42 ab	10.13 a	9.31 c	40.7 a
NY81	107.2 b	20.0 a	1.39 b	9.86 a	7.68 d	30.0 abc
p value (V)	<0.001	0.008	<0.001	<0.001	<0.001	<0.001
p value (TxV)	0.303	0.724	0.142	0.402	0.212	0.575

Means followed by the same letter within columns are not significantly different (Tukey test at $P \leq 0.05$).

Table 6A. Juice chemistry -September 2021 (clones and hybrids)

	TSS (Brix)	TA (g/L)	pH
Treatment (T)[a]			
Control	17.7 b	10.11 a	3.55 b
MD1	18.6 a	9.71 b	3.58 a
MD2	18.8 a	9.55 b	3.57 ab
p value (T)	<0.001	0.008	0.045
Variety (V)			
239	18.0 c	10.40 a	3.55 b
198/9	16.9 d	9.90 ab	3.55 b
90/12	17.3 cd	9.97 ab	3.56 b
110/17	17.7 cd	9.57 b	3.55 b
Geisenheim	20.7 a*	8.32 c	3.68 a
NY81	19.6 b	10.58 a	3.53 b
p value (V)	<0.001	<0.001	0.871
p value (TxV)	0.194	0.823	0.371

Means followed by the same letter within columns are not significantly different (Tukey test at $P \leq 0.05$).
Brix P value between 5 and 6 is 0.07

Table 6B. Juice chemistry data. September 2021 Only clones

	TSS (Brix)	TA (g/L)	pH
Treatment (T)[a]			
Control	16.8 b	10.33 a	3.53 b
MD1	17.5 a	9.92 b	3.57 a
MD2	18.0 a	9.66 b	3.55 ab
p value (T)	<0.001	0.008	0.045
Clone (C)			
239	18.0 a	10.44 a	3.55
198/9	16.9 b	9.90 ab	3.55
90/12	17.3 ab	9.97 ab	3.56
110/17	17.7 a*	9.57 b	3.55
p value (C)	0.015	0.011	0.871
p value (TxC)	0.293	0.674	0.371

Means followed by the same letter within columns are not significantly different (Tukey test at $P \leq 0.05$).

SECTION 3

PROJECT SUMMARY AND OBJECTIVES

This project is designed to compare the viticultural characteristics (phenology, vegetative growth, cluster/berry weight, yield, cluster architecture), bunch/sour rot susceptibility, cold hardiness, susceptibility to crown gall, and fruit composition, of 4 clones (90, 110, 198, 239) and 2 hybrids (Geisenheim and NY81) of Riesling, planted side-by-side in a half-acre research vineyard in the Lake Erie region of Pennsylvania. It also compares the response to pre bloom and post bloom mechanical defoliation of these 4 clones and 2 hybrids of Riesling, and how it relates to canopy microclimate, disease development, and fruit yield and quality. Finally, this project will investigate the potential causes of any differences between these clones/hybrids and proposes recommendations that will aid growers in deciding which varieties to grow.

IMPORTANCE OF RESEARCH TO THE NEW YORK WINE INDUSTRY

Vitis vinifera 'Riesling' and its hybrids are popular varieties to grow among wine grape growers in Pennsylvania, and especially the Finger Lakes region of New York. With so many varieties available for commercial production, side by side comparisons of the most widely planted and successful clones and hybrids would provide valuable research-based information for growers deciding which ones to plant. This proposal directly compares several of the most popular and promising clones (90/12, 110/17, 198/9, 239) and hybrids (Geisenheim and NY81) of Riesling. Comparisons in 2021 and 2022 have provided detail on canopy density and fruiting zone microclimate, fruit rot susceptibility, yield parameters, cluster architecture, cold hardiness, fruit composition, and the response to efforts to alleviate bunch rot development with pre and post bloom mechanized defoliation (MD) of the fruit zone. An additional year of data (2023) will be necessary to confirm patterns that will lead to more reliable recommendations.

PROJECT RESULTS/NEXT STEPS

An examination of varieties after two seasons, shows that the hybrids (Geisenheim and NY 81) generally break bud, bloom, and are harvested earlier than the Riesling clones. They also tend to be less affected by physical stresses in the environment and suffer less from cold damage to buds and trunks and to crown gall. Machine defoliation (MD) by an 'air pulse' system, also tends to remove more cluster zone leaf tissue from the hybrids than from the clones, regardless of timing. However, this has not necessarily resulted in more open canopies among the hybrids, compared to the clones: MD generally produced similar results across varieties. The hybrids also tend to be less affected by cluster rots and deterioration, although it has been shown that Geisenheim can be severely affected by late season rots IF powdery mildew is not well controlled on clusters. Also, the hybrids ripen and can be harvested 2-3 weeks earlier than the clones, which can have major implications for fruit rot development. Geisenheim has generally produced the largest pruning weights whereas NY 81 has produced the smallest pruning weights. Geisenheim has also produced the largest clusters and yields, whereas NY 81 and the clones have produced smaller clusters and yields, especially clone 239. NY 81 has produced very consistent yields from year to year (averaging about 4.5 tons/acre), whereas yields from Geisenheim and the clones have been much more variable. The hybrids are certainly tougher, more reliable producers than the clones under our local environmental conditions, and while they do tend to break bud earlier in spring, with more potential for late frost damage, this is generally only by a few days, whereas ripeness and harvest can occur up to 2-3 weeks earlier than the clones. All respond about the same to MD.

Among the clones, 239 tends to produce the smallest clusters with the fewest berries per cluster. However, this does not always result in the lowest yields because 239 also tends to produce more clusters per vine and suffer less from late season fruit rots and deterioration than the other clones. Clones 90 and 110 tend to suffer most from fruit rots. Clone 239 tends to have higher titratable acidity than the other clones. However, this does not necessarily relate to lower fruit maturity, as 239 had the highest Brix among the clones in 2021.

Among MD treatments, the MD2 (later timing) tends to result in a greater removal of leaf tissue and a greater opening of the fruit zone than MD1, but this has resulted in little difference in terms of rot control, and both treatments have reduced rot on every variety and in every year, compared to no MD. MD does not appear to affect cluster number per vine, but sometimes results in lower yields and cluster weights. MD also tends to promote earlier fruit maturity, probably a result of reduced yields and improved sunlight exposure and air temperature. Therefore MD, whether applied before or after bloom can promote greater fruit health and maturity but *may* impose a cost on yields.

Next steps: Through early 2023, we will be assessing cluster morphology (cluster length, berries/cluster, cluster compactness) for the 2022 cluster samples. We will also assess bud winter survival and return fruitfulness (shoots/bud, clusters/shoot), through spring of 2023. Also, it will be essential that this research is repeated for one more season (in 2023) to examine for patterns and consistencies across years, among the various varieties and clones being examined. This will enable researchers to formulate more accurate, reliable recommendations for wine growers.