FINAL REPORT TO:

Pennsylvania Wine Marketing and Research Board

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Project Title: Defining regional typicity of Grüner Veltliner wines (Year 1)

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Overall Goal and Objectives

The overarching goal of this multi-year study is to characterize the environmental, viticultural and sensory factors that drive typicity of Grüner Veltliner across the Commonwealth, and to develop marketing strategies that best appeal to current and potential Grüner V. wine consumers. Our goal is to increase Grüner V. recognition as one of the signature wine varieties that can be grown and produced throughout the Commonwealth.

Our **specific objectives** are to:

1. Conduct a multi-site study to identify the relationships among viticultural variables, grapevine physiology, environmental conditions, and volatile and non-volatile flavor compounds in Grüner V. wines.
2. Characterize wines made from PA-grown Grüner V. through basic wine chemistry, sensory and compositional analyses, including volatile and non-volatile flavor profiling.
3. Learn from grape growers and winemakers in the Commonwealth what barriers, perceived and actual, they feel prevent them from growing and producing Grüner V. This information will then direct researchers when developing future research and extension focuses.
4. Provide marketers, retailers, and intermediaries with profiles of consumers who are likely to purchase and consume Grüner V. (e.g., other wine preferences, generation, gender).
5. Develop recommendations to assist wine growers and producers in identifying specific flavor compounds that contribute to, or detract from, perceived Grüner V. wine quality

Experimental layout: The project was initiated in 2018 with the generous financial support of the PWRMB. Eight Grüner V. grower cooperators were identified in spring 2018 and nine experimental sites were set up (two experimental sites belong to the same grower cooperator). The selected sites represent multiple regions throughout the Commonwealth with considerable climatic variability (Figure 1). In May 2018, 30-40 vines were selected at each site for detailed environmental (e.g., weather, soil) and viticultural (e.g., vine nutrient and water status, vine vigor and yield components) measurements. To minimize confounding effects from viticultural management practices, the number of shoots per linear meter of row was standardized prior to bloom. A weather station was placed at each site to monitor real-time rainfall, air temperature and photosynthetically active radiation (PAR) throughout the duration of the project (Onset Computer Corporation). Growing degree days (GDD) and total amount of rainfall were calculated from bud burst to harvest and from veraison to harvest (Table 1).

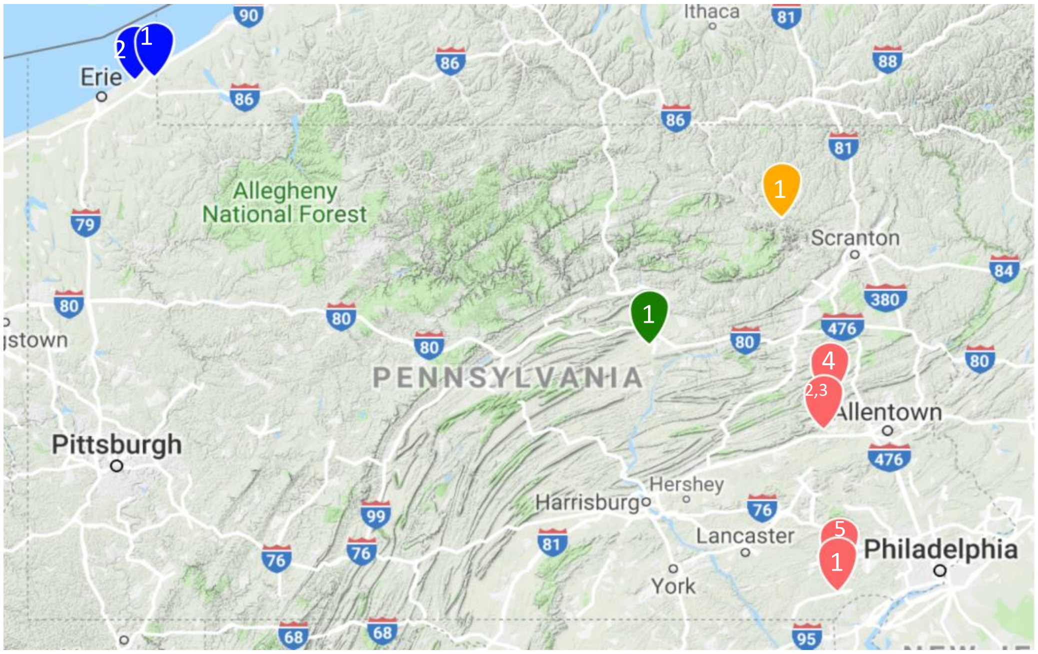

Figure 1. Map of vineyard sites chosen for the study. A symbol was imposed at the geographical coordinates of each study site. Different colors denote different regions. Abbreviations: SE = southeast, NC = north central, NE = northeast, NW = northwest.

Table 1. Weather data measured for nine Grüner V. vineyards during growing season (May 1 to October 31) and berry ripening period (veraison-to-harvest) in 2018.

Site	GDD	GDD_v[z]	Rainfall (mm)	$Rainfall_v$[y] (mm)
SE1	1668	409	626.0	76.0
SE2	1611	417	695.6	99.6
SE3	1611	417	695.6	99.6
SE4	1574	453	929.2	244.5
SE5	1733	480	396.2	9.6
NC1	1680	452	784.3	211.5
NE1	1482	436	782.4	139.2
NW1	1595	377	451.5	6.6
NW2	1492	381	366.0	94.7

[z]GDD_v = Veraison-to-harvest GDD. [y]$Rainfall_v$ = Veraison-to-harvest rainfall. Site abbreviations: NW= northwest; SE = Southeast; NE= Northeast; NC= north central.

Not surprisingly, seasonal weather conditions varied across the Commonwealth. The vineyards in Erie (NW1 and NW2) were the driest sites, while SE5 and NC1 were the warmest sites. Within- and between-seasons weather variation is preferred for the purpose of the study, as it will allow us to establish stronger correlations between weather parameters and wines aroma and flavor compounds. At the end of the study we will use three-year weather data to evaluate which and how weather parameters drive specific flavor and aroma in Grüner wines made from different grape growing regions of the Commonwealth.

Field data: Enhanced point quadrat analysis (EPQA) was used to quantify canopy density and light availability in the fruiting zone of the vine shortly after veraison. Vine nutrient status was assessed through plant tissue analysis at veraison, while vine water status was estimated via berry carbon isotope composition (δ13C) analysis at harvest. Overall nitrogen (N), phosphorus (P) exhibited small variations across sites, while potassium (K) varied from 0.59% to 5.81% (Table 2). δ13C values, a proxy for vine water status, were also similar across sites. More negative δ13C values indicate higher water status (i.e., no stress). In 2018, water status did not reach values that would indicate weak-to-moderate water stress at any site (-26 to -25‰).

Table 2. Leaf blade (N) and petiole macronutrient concentrations and water status (via δ13C) of Grüner Veltliner vines at the nine experimental sites for the 2018 season. Site abbreviations: NW= northwest; SE = Southeast; NE= Northeast; NC= north central.

	Leaf blade	**Leaf petiole**					**Fruit**
Site	**N (%)**	**N (%)**	**P (%)**	**K (%)**	**Mg (%)**	**Ca (%)**	**$\delta^{13}C$ (‰)**
SE1	2.89	1.09	0.21	5.81	0.69	1.82	-30.32
SE2	3.00	0.76	0.21	2.82	1.30	1.82	-30.31
SE3	3.00	0.95	0.34	4.43	0.57	1.80	-30.53
SE4	2.80	0.81	0.25	2.64	0.87	1.81	-29.99
SE5	3.12	1.01	0.18	2.59	1.06	1.73	-28.41
NC1	3.19	0.87	0.33	5.11	0.53	1.82	-29.26
NE1	3.31	0.96	0.32	0.59	1.92	2.03	-28.25
NW1	3.28	0.85	0.17	1.51	1.23	2.38	-30.31
NW2	3.25	1.05	0.12	1.82	0.83	2.26	-29.80

Experimental sites were harvested between September 14th and September 24th 2018 the day prior to or the day of commercial harvest. Cluster weight and the number of clusters per vine were measured. Ten clusters were randomly collected at harvest for berry δ13C analysis and berry size. Vine vegetative growth was assessed as winter pruning weight during the dormant season. Yield per vine varied greatly across sites (Table 3). This variation can be explained by different vine spacing (distance between vines); therefore, we also expressed the data per meter of row (or cordon) to help comparison across sites. Part of the yield variation among sites is also explained by crop losses due to high rot pressure at some of the sites and different management practices. Similarly, pruning weight and crop load considerably varied across sites. This variation is maintained when we normalized the data per unit of length (meter of row) and it is likely caused by different vigor potential of the sites and canopy management practices (e.g., pruning, shoot thinning). Vine crop load varied from 0.73 (SE1) to 14.7 (NW2). In general, crop load values for balanced vine should be between 4 and 10. Our data can help elucidate if higher than recommended crop load values influence wine chemistry and sensory perception. As for the weather data, production and physiological parameters measured at each site will be correlated with wine chemistry data to characterize what factors drive specific flavor and aroma in Grüner wines made from different grape growing regions of the Commonwealth.

Table 3. Production metrics of Grüner Veltliner vines at the nine experimental sites for the 2018 season. Site abbreviations: NW= northwest; SE = Southeast; NE= Northeast; NC= north central.

Site	Yield (kg/vine)	Yield (kg/m of row)	Cluster (no./ vine)	Cluster (#/m of row)	Cluster wt (g)	Prun. wt (kg/vine)	Prun. wt (kg/m of row)	Crop load (kg/kg)
SE1	0.43[z]	0.28[z]	11	7	40[y]	0.61	0.40	0.73
SE2	5.69	3.73	25	16	232	0.64	0.42	8.77
SE3	2.78	1.82	19	15	120	0.59	0.39	4.64
SE4	2.51	1.65	28	18	87[y]	1.02	0.67	2.44
SE5	1.29	1.41	8	16	89[y]	0.12	0.14	10.8
NC1	3.50	2.30	16	15	146	1.91	1.25	1.83
NE1	5.91	3.88	32	21	181	1.67	1.10	3.53
NW1	10.38	5.67	54	29	191	0.94	0.53	11.0
NW2	10.39	5.68	59	32	177	0.70	0.38	14.7

[z]Atypically low yield values were observed for sites with high incidence and severity of bunch rot; total yield was reduced due to significant fruit loss.

[y]Atypically low cluster weights (weight < 100 g) reflect sites that had high incidence and severity of bunch rot; clusters harvested from such sites had dropped significant portions of berries and total cluster weight due to rot.

Winemaking: The grapes were transported to Penn State Department of Food Science Wet Pilot Plant, stored overnight at 3°C, and processed the day after harvest. The winemaking was conducted by the graduate students under the supervision of the enology extension educator, Dr. Molly Kelly. A standard winemaking protocol was used to avoid that different winemaking practices would affect wine compositional profile. Protocol included chaptalization to 22 °Brix and addition of sulfur (SO_2) due to high rot levels. Wines were inoculated with EC1118 yeast (Lallemand) at a rate of 25g/hL, and 30g/hL Go Ferm nutrient was also added at inoculation.

All sites were fermented in duplicate, with juice from seven of nine experimental sites fermented in 5-gallon glass carboys and two sites fermented in 1-gallon glass jars due to the small volume of juice. Temperature control was provided by carboy jackets for fermentation vessels set at 59°F. Fermentation progress was monitored daily using hydrometry until a negative reading was observed, after which Clinitests were used to measure residual sugar. When Clinitests read negative, fermentations were refrigerated and then racked off lees. After racking, KS enzyme (Scott Labs) and potassium metabisulfite were added to the finished wines. Juice samples (50 mL) were analyzed for total soluble sugars (TSS), pH, titratable acidity (TA), and yeast assimilable nitrogen (YAN) after pressing before chaptalizing the juice (Table 4).

Wine chemical analysis: Wines were analyzed for basic wine chemical analysis (residual sugar, alcohol, volatile acidity, free and total sulfur, titratable acidity, pH, lactic acid, and malate) before bottling to ensure stability in bottle. After cold stabilization, wines were bottled in December 2018 (Table 5).

Table 4. Juice chemistry and average berry weights of Grüner Veltliner vines at the nine experimental sites for the 2018 season. Site abbreviations: NW= northwest; SE = Southeast; NE= Northeast; NC= north central.

Code	Juice pH	Juice TSS (°Brix)	Juice TA (g/L)	Juice YAN (mg N/L)
SE1	3.56	14.2	6.45	98.9
SE2	3.36	16.4	6.15	177.3
SE3	3.52	15.6	6.43	241.1
SE4	3.28	16.4	6.26	216.0
SE5	3.48	16	5.54	261.2
NC1	3.22	14.2	7.41	248.2
NE1	3.25	16.4	7.77	221.2
NW1	3.06	18	7.33	57.6
NW2	3.37	19.6	5.68	128.2

Table 5. Basic wine chemistry results prior to bottling. Site abbreviations: NW= northwest; SE = Southeast; NE= Northeast; NC= north central.

Site	Rep	EtOH %	RS (g/L)	pH	TA (g/L)	Malate (g/L)	Lactic acid (g/L)	VA (g/L)	free SO2 (ppm)	total SO2 (ppm)
SE1	1	11.3	0.1	3.15	6.1	1.6	0	0.17	78	201
SE1	2	11.0	0.1	3.18	6	1.6	0	0.24	87	196
SE2	1	12.6	1.0	3.31	5.7	1.6	0	0.26	46	135
SE2	2	12.6	0.8	3.29	5.7	1.4	0	0.29	42	132
SE3	1	12.6	0.7	3.38	6.1	2.3	0	0.29	54	165
SE3	2	12.7	0.8	3.39	6.1	2.3	0	0.3	49	163
SE4	1	13.2	4.1	3.34	5.8	1.7	0	0.27	51	154
SE4	2	13.2	4.5	3.31	5.9	1.7	0	0.3	42	144
SE5	1	11.7	0.5	3.26	6.0	1.6	0	0.33	48	138
SE5	2	11.6	0.5	3.21	6.4	1.6	0.4	0.3	49	148
NC1	1	12.5	1.9	3.29	6.5	2.4	0	0.26	39	136
NC1	2	12.4	2.3	3.27	6.4	2.4	0	0.27	45	141
NE1	1	12.5	0.8	3.17	6.3	1.4	0.3	0.27	28	121
NE1	2	11.9	0.9	3.17	6.6	1.3	0.8	0.27	35	124
NW1	1	13.2	1	2.99	6.6	1.3	0.5	0.23	39	102
NW1	2	13.2	1	3.00	6.6	1.2	0.5	0.25	42	106
NW2	1	13.1	0.7	3.20	6.0	1.0	0.4	0.32	26	91
NW2	2	13.1	0.7	3.20	6.0	1.1	0.4	0.31	48	126

Total phenolic concentration in wines was measured with the Folin-Ciocalteau assay. Data were analyzed using one-way Analysis of Variance (ANOVA) and Tukey's test. There were significant differences in total phenolic concentration among Grüner wines, but no regional trend was observed (Table 6). NW2 had the highest phenolic concentration (275.17 mg/L), which was significantly higher than many other sites, except SE1 and SE5. Further chemical analysis for the wines includes high performance liquid chromatography (HPLC) to quantify specific phenolic compounds, which will provide further insight into how the phenolic content of the wines differ.

Table 6. Mean total phenolic concentration by Folin-Ciocalteau assay for samples. Means that do not share a letter are significantly different. Site abbreviations: NW= northwest; SE = Southeast; NE= Northeast; NC= north central.

Sample	Mean (mg/L)	Grouping
SE1	241.88	A B
SE2	225.21	B
SE3	235.55	B
SE4	234.74	B
SE5	237.60	A B
NC1	209.33	B
NE1	228.81	B
NW1	225.81	B
NW2	275.17	A

Aroma compounds were quantified via headspace - solid phase micro extraction - gas chromatography - mass spectrometry (HS-SPME-GC-MS). This method used d-napthalene and 2-octanol as internal standards and was optimized to capture fermentation- and grape-derived aroma compounds. Six analytical replicates were used to correspond to the samples that trained panelists evaluated in the descriptive analysis of the wines.Compounds were quantified relative to the internal standard, and one-way ANOVA and Tukey's test were used to analyze the data. Concentration of four volatile aroma compounds differed significantly among wine made from the 9 sites (Fig. 2). The compounds, in general, give fruity aromas such as apricot and pineapple to wine, and include ethyl hexanoate, hexyl acetate, ethyl octanoate, and 4-hexenyl acetate. Similarly to the phenolic data, no regional trend was observed with aroma differences.

Color of wine samples was measured using the method described by the Compendium of International Methods of Wine and Must Analysis. Samples were centrifuged and transferred to a glass cuvette. A UV-Vis spectrophotometer was used to scan samples in transmittance mode from 380 nm to 780 nm in 5 nm increments and CIE-LAB parameters (L^*, a^*, b^*, C^*_{ab}, h_{ab}) were obtained through integration (Table 7). L^* is a measure of lightness, while a^* and b^* measure the red-green and yellow-blue aspects of a sample, respectively. Chroma (C^*_{ab}) is an indicator of intensity, while hue (h_{ab}) is derived from a^* and b^* values and is a measure of the appearance of sample color. Color data is currently being analyzed and will be included in the progress report of year 2 of the project.

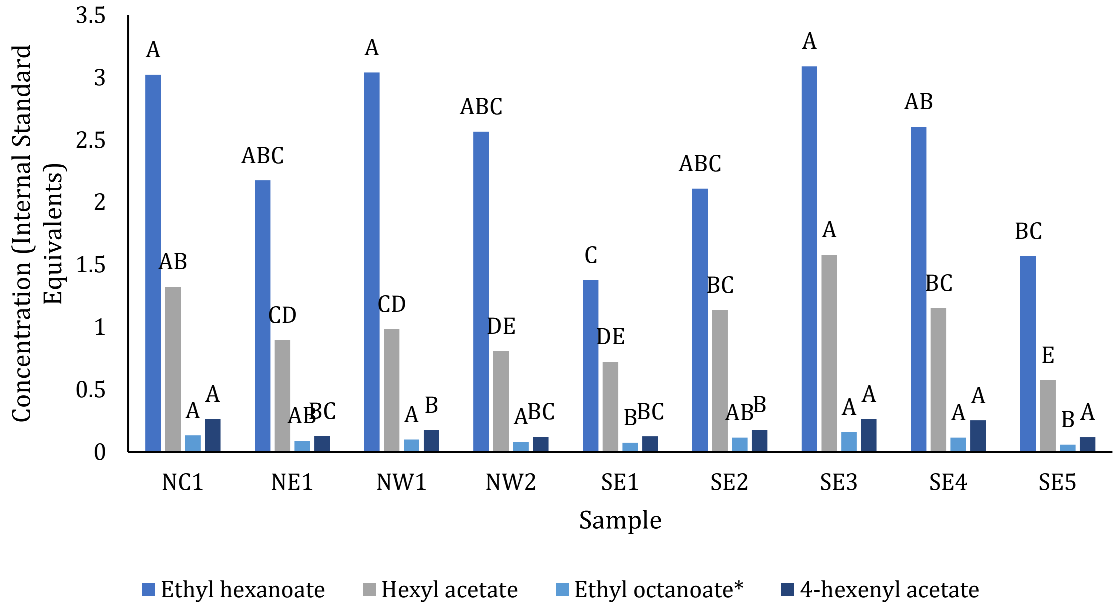

Figure 2. Aroma compounds that differed in samples quantified relative to the internal standard. Mean concentrations that do not share a letter are significantly different. An asterisk denotes microequivalents displayed in the figure. Site abbreviations: NW= northwest; SE = Southeast; NE= Northeast; NC= north central.

Table 7. CIE-LAB color parameters obtained for wine samples. Site abbreviations: NW= northwest; SE = Southeast; NE= Northeast; NC= north central.

Site	Rep.	L	a	b	C(ab)	H(ab)
SE1	1	98.45	-0.37	2.52	2.55	98.28
SE1	2	98.91	-0.38	2.42	2.45	99.04
SE2	1	99.19	-0.59	2.62	2.69	102.72
SE2	2	99.13	-0.6	2.34	2.42	104.46
SE3	1	99.09	-0.67	2.75	2.83	103.78
SE3	2	99.10	-0.62	2.83	2.9	102.39
SE4	1	98.78	-0.65	2.9	2.98	102.62
SE4	2	99.17	-0.64	2.83	2.9	102.74
SE5	1	98.89	-0.81	2.96	3.07	105.38
SE5	2	99.19	-0.74	2.53	2.64	106.36
NC1	1	99.22	-0.64	2.05	2.15	107.28
NC1	2	98.66	-0.65	2.5	2.58	104.6
NE1	1	98.97	-0.69	3.58	3.65	100.93
NE1	2	98.70	-0.75	3.73	3.81	101.46
NW1	1	99.19	-0.78	3.5	3.58	102.59
NW1	2	99.13	-0.82	3.38	3.47	103.58
NW2	1	98.74	-0.86	4.57	4.65	100.68
NW2	2	99.02	-0.88	3.81	3.91	103.03

Wine Sensory analysis: Sensory evaluation of the wines was completed in March and April 2019 using descriptive analysis. Eight panelists were trained on identifying appearance, aroma, taste, and flavor attributes present in the Grüner V. wines. Training sessions were conducted three times per week for four weeks for an approximate total of 14 training hours. Training began with language development by panelists generating terms to describe Grüner V. wine samples they tasted. Panelists trained with each Grüner V. wine sample before evaluation to ensure that attributes of importance would be identified for all samples. References were created for the generated terms to align each panelist's concept of that term. In some cases, multiple references were created for the same term, and the panel was prompted to choose the reference that best captured their idea of that term. For example, a total of five citrus references were created using lemon, lime, orange, or grapefruit pieces and juice, but only two citrus references were kept for evaluation of the wines.

Panelists were tested on their ability to consistently evaluate samples by prompting them to evaluate blind duplicate samples. Panelists rated these wines in testing booths in the Sensory Evaluation Center and then discussed their results after evaluation. After successful evaluation of duplicate samples during training, the relevant attributes for all samples were agreed upon by the panel for evaluation. Table 8 includes the category of attributes used and the corresponding terms.

Table 8. Attributes used in Grüner V. descriptive analysis.

Appearance	Aroma and Flavor	Taste and Mouthfeel
Yellow Color	Green Apple	Sour
Haziness	Pear	Sweet
	Other Fruit (stone fruit, mixed fruit)	Salty
		Bitter
	Citrus (lemon, orange, grapefruit)	Umami
	Floral	Viscous/Thick
	Earthy	Astringent
	Thiol	Warm/Hot
	Canned Vegetable	
	Rotten Egg	
	Sulfur	
	Yeasty	
	Oxidized	
	Chemical/Solvent	
	Ethanol	

Table 9. Aroma reference standards used for descriptive analysis reference training. Reference wine used to make standards was Bota Box Pinot Grigio.

Name	Description
Canned Veggie	0.5tsp canned pea juice and 0.5tsp canned green bean juice in 20ml wine
Chemical/Solvent	1 drop ethyl acetate in 50ml wine
Earthy	1g potting soil in 20ml wine
Ethanol	10% EtOH in water
Floral	4 drops stock in 20ml wine (Stock: 1 drop lavender essential oil in 25ml wine)
Grape	3 halved green grapes in 20ml wine
Green Apple	10g fresh granny smith apple in 20ml wine
Lemon	3x2cm fresh lemon peel in 20ml wine
Mixed Fruit	10ml canned fruit cocktail juice in 20ml wine
Orange/Grapefruit	3x2cm fresh orange peel and 3x2cm fresh grapefruit peel in 40ml wine
Oxidized	5ml dry sherry in 20ml wine
Pear	25g Barlett pear in 25ml wine
Rotten Egg	0.4g hard-boiled egg yolk in 20ml base wine
Stone fruit	10g fresh nectarine and 10g fresh peach in 40ml wine
Sulfur	1 pinch KMBS in 25ml wine
Thiol	75µL 4MMP in 50ml dH2O
Yeasty	2 pinches baker's yeast in 5ml water

Panelists evaluated the wines in individual testing booths in the Sensory Evaluation Center. Two wines (SE1, SE5) were rated in duplicate due to low volume, while the other wines were rated in triplicate. Fermentation replicates were rated separately, so panelists rated four samples in duplicate and 14 in triplicate. A Williams-Latin-Square design was used to control for serving and carry-over effects. Panelists evaluated six to seven wines per session.Panelists completed the evaluation using Compusense software. First, they were prompted to look at the sample and rate the appearance, then smell the sample and evaluate the aroma of the sample. Panelists were then prompted to taste the wine and rate the taste, mouthfeel, and flavor attributes.

ANOVA with Wine, Judge, Fermentation Rep, and all interactions as factors was used to determine which attributes were significantly different among the wine samples. Significant attributes included one appearance (Yellow Color), two aromas (Thiol and Sulfur), two flavors (Thiol and Ethanol), one taste (Sour) and one mouthfeel attribute (Warm/Hot). Principal Component Analysis (PCA) was used to analyze the descriptive analysis results. Figure 3 shows the scores plot which maps each wine (averaging over fermentation rep) to explain the greatest amount of data variation. Plots were generated using the {SensoMineR} package in R.

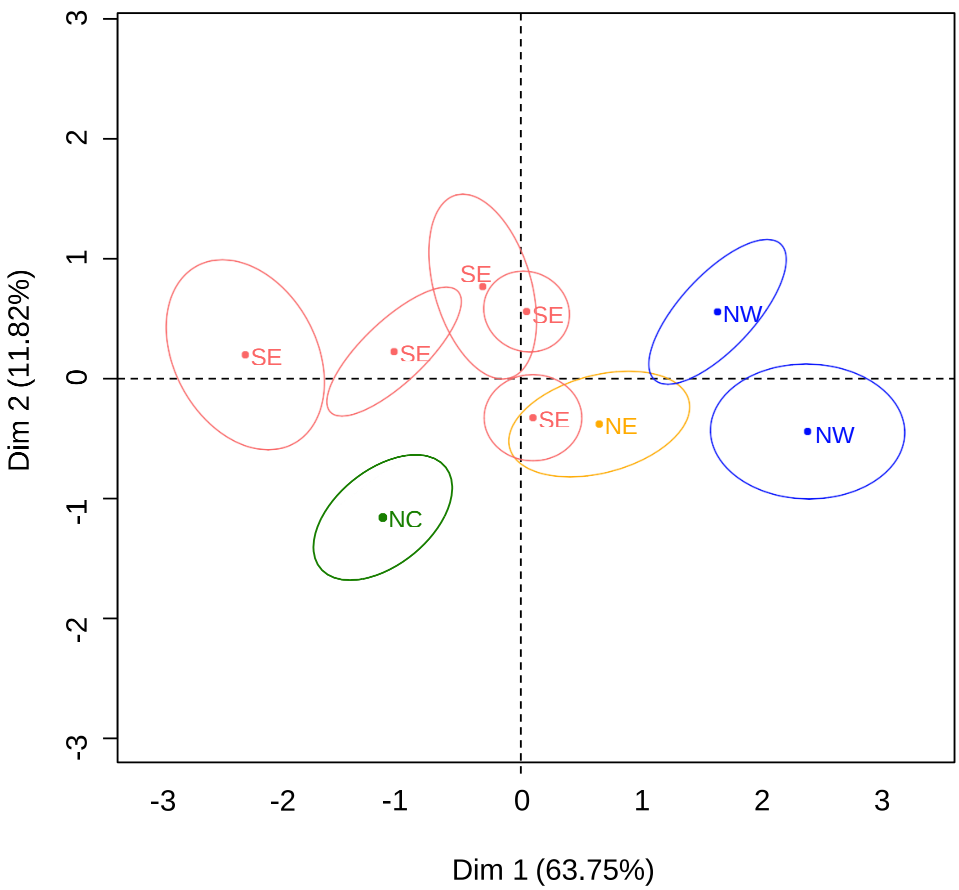

Figure 3. Scores plot with 95% confidence ellipses for each sample. Dimension 1 captures 63.75% of variation in the data, while Dimension 2 captures 11.82%. Abbreviations: SE = southeast, NC = north central, NE = northeast, NW = northwest.

The distance between the samples indicate how similar or different they were rated. For example, NW1 and NC1 are mapped on opposite sides of the plot, and so were perceived very differently among the panelists. NE1 is more similar to NW1 since they are mapped closer. The majority of samples did group by region. Samples from the southeast, shown in pink, grouped well together and had three samples that were not perceived differently, shown by the overlapping confidence ellipses. Samples from the northwest (blue) also grouped together on the right side of the plot. Figure 4 shows the loadings, or variables, plot for the samples. Significantly significant attributes were mapped with the two dimensions. Attributes with opposing arrows are negatively correlated, while attributes with arrows pointing in the same direction are positively correlated.

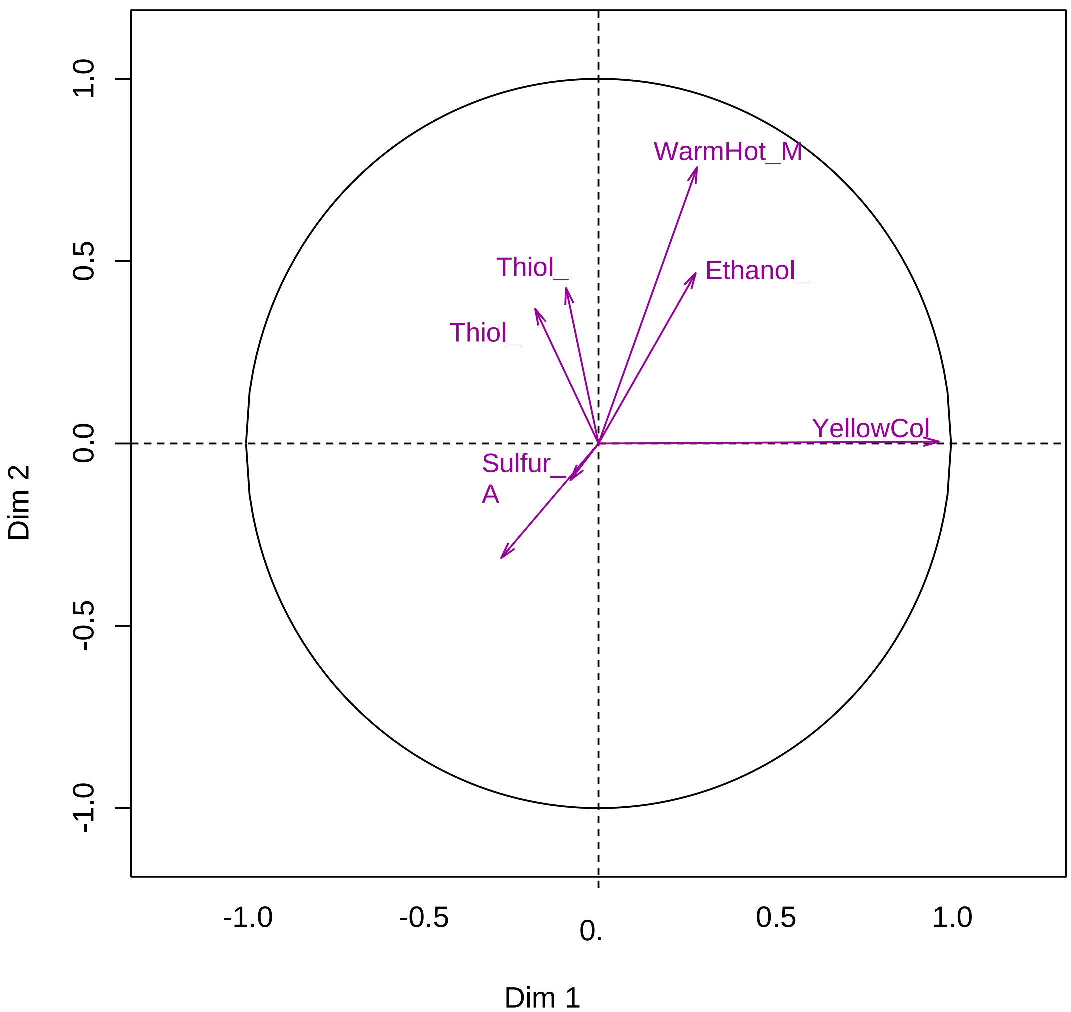

Figure 4. Loadings plot for significant attributes. "T," "A," "F," and "MF" indicate if the attribute was a taste, aroma, flavor, or mouthfeel attribute respectively. Site abbreviations: NW= northwest; SE = Southeast; NE= Northeast; NC= north central.

These two plots can be combined to gain a full understanding of why samples were mapped in this orientation. Figure 4 shows both plots combined. Since Yellow Color is well aligned with the x-axis (Dim 1), it can be determined that Yellow Color is driving the separation of samples on the x-axis. This means that samples from the northwest were perceived to have higher yellow color than the other samples, while southeast Grüner V. wines and the sample from the north central region had lower yellow color ratings. Thiol_A and Thiol_F are driving sample separation along the second dimension (y-axis), and samples from the southeast had more thiol aroma and flavor. Figure 5 also shows samples from the north central region were perceived as more sour than other samples.

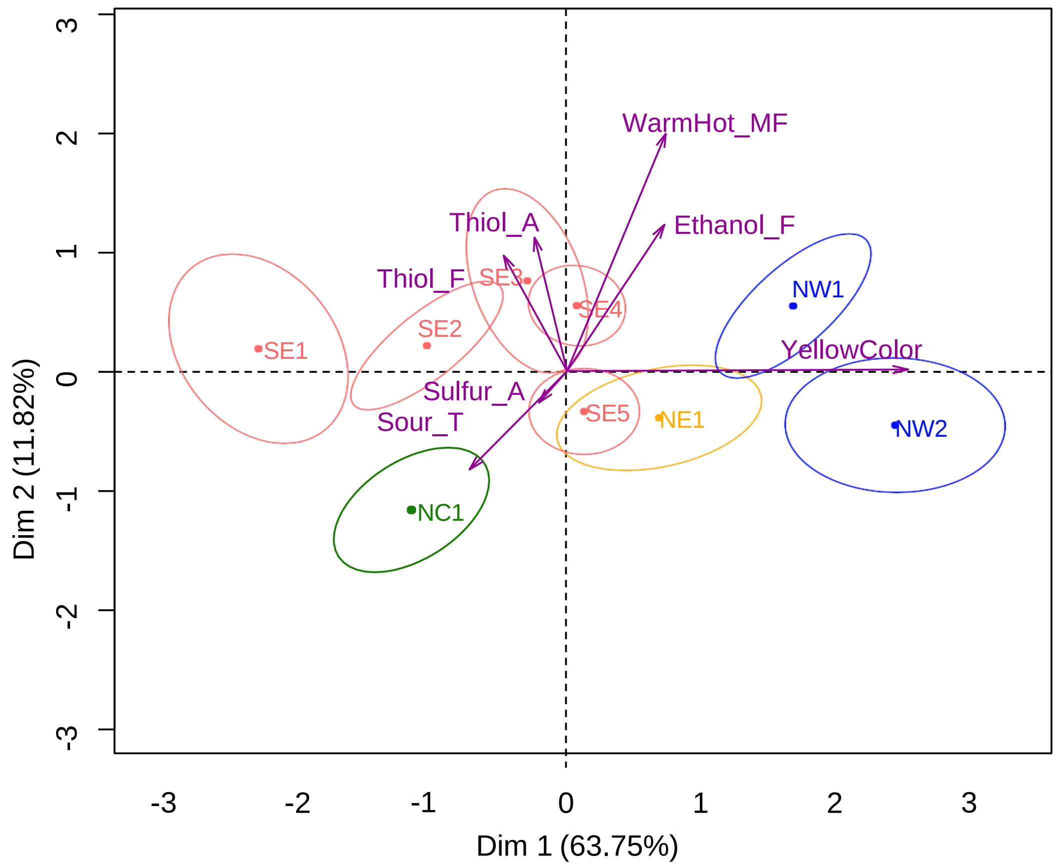

Figure 5. Scores and loadings plot for significant attributes. Site abbreviations: NW= northwest; SE = Southeast; NE= Northeast; NC= north central.

Consumer focus group session: This component of the proposed research investigates mid-Atlantic wine consumer awareness and interest in Grüner V. Researchers invited white-wine consumers to participate in a focus group session to understand their level of familiarity with Grüner V. and issues that these consumers might have with tasting and buying a wine they may not have consumed before. The focus group session also allows researchers to pre-test potential questions and areas of investigation.

<u>Consumer focus group session results:</u> Two separate focus group sessions were conducted on March 25 and April 26, 2019, with six and five participants, respectively. Participants were regular white-wine drinkers, age 21 and older, participants were selected for being more "adventurous" with food and met other key criteria. The one-hour sessions provided a great deal of insight that helped the researchers develop the draft for the consumer Internet survey.

Key outcomes include:

- Participants were asked to describe what they thought Grüner V. would look like/taste like/what the bottle would look like. Few accurately described the wine as being a white wine. There was a consensus that "Gruner Veltliner" would be difficult to pronounce and/or remember. One participant mentioned, based on hearing the phrase, that it sounded very "harsh" and they would not have expected it to be as "light" as it was.
- A few participants had tasted Gruner Veltliner, with one having a positive experience. The other found the bottle that they purchased to be too sweet. In one of the sessions, all of the participants enjoyed sampling the Gruner Veltliner provided and expressed strong interest in purchasing the wine in the future.
- Many participants found the bottle shape very appealing (the shape and the green color of the bottle).
- There was a bit of discussion about creating a nickname (gru ve, for example) that would make the wine more approachable.
- The bottle of wine that was sampled was $19.00 for a 750ml Pennsylvania Gruner Veltliner. All participants in the first focus group session indicated that they would purchase the bottle for that price.

Based on focus group discussions the PIs develop an online survey which was implemented in 2019. Results will be included in progress report of year 2 of the project.

Grower survey: A 15-minute survey targeting PA wine grape growers was developed and administrated online between April 8 - 30, 2019 to quantify who in the Commonwealth currently grows Grüner V. and learn who might be interested in growing this variety. In addition, the survey documented who has grown it in the past but no longer does, and why they no longer grow Grüner V. Survey outcomes do not only provide insights on the potential to expand Grüner V. acreage, but also identify perceived and actual barriers that impact growers' willingness to grow and/or expand their Grüner V. acreage.

Grower survey results: Forty-nine PA grape growers participated into the survey. More than half (55%) had a vineyard, winery, and winery tasting room, 33% only a vineyard, and 8% a vineyard and a winery. Two participants selected "other" with responses: 1) vineyard, blueberries, and fruit packing and 2) vineyard and tasting room. When asked which resources they consult when deciding to plant wine grape cultivar that they have never grown before, which participants were asked to select all that apply, responses were:

- Suggestions from other wine grape growers in my state and/or region = 31
- Grape production trade journal articles (e.g., Wines & Vines) and/or information learned at industry and association conferences (e.g., Eastern Winery Exposition) = 26
- University/state Extension (e.g., Penn State, Virginia Tech, Cornell) newsletters, presentations, and related resources = 32
- Paid industry consultants = 6

Of the 41 participants who had been involved in commercial grape production for more than five years, 69% responded the within the past five years they planted wine grape cultivars in their commercial vineyard that they had never grown before. Of all 49 participants, 47% plan to plant at least one wine grape cultivar for commercial purposes that they do not currently grow. While a few participants indicated that they were unsure which cultivars they would plant/were doing research with test plots, one participant specifically mentioned Grüner V. As to what motivates these participants to plant a wine grape cultivar that they had never grown before, the top four responses were:

- The grape seems to be suitable in my area (e.g., establishes well, provides consistent yield and fruit quality, appropriate level of cold hardiness) (n= 37)
- Results from field trials conducted by university researchers and/or state Extension services (n = 17)
- May provide a potential advantage if few other growers in my state or region are growing the cultivar (n = 15)
- Requests from winemakers or other commercial customers (n = 14)

Participants were asked to indicate their current involvement with Grüner V. Of the 46 participants who responded to the question, 46% have never grown the cultivar before and were not interested in doing so at this time, 26% currently grow the cultivar, 17% are unfamiliar with the cultivar, and 4% had grown the cultivar in the past but no longer do.

For the two growers who no longer grow the cultivar, one indicated that he/she changed jobs and no longer grows Grüner V. as a result, and the other responded that “Vines did not perform well. This was decades ago and probably due to poor clone/site selection.”

Participants that currently grown Gruner Veltliner (n=12) were directed to a question that asked if they experienced any issues related to growing Gruner Veltliner at their vineyard. Responses, which participants were asked to select all that applied, included:

- Finding a market or buyer for Gruner Veltliner grapes I grow (n= 2)
- Finding a market or buyer for Gruner Veltliner wine I make (n = 5)
- Managing diseases impacting Gruner Veltliner vines (n = 7)
- Winter damage/cold damage in the winter impacting Gruner Veltliner vine health and productivity (n = 7)
- More time was spent managing the canopy (e.g., hedging, shoot thinning, crop/cluster thinning, leaf removal) compared to other vinifera cultivars (n = 2)

One participant responded that he/she had just planted the cultivar the previous year, so he/she was unable to comment.

Participants who had not yet planted Gruner Veltliner (n=25) were directed to a question that asked what concerns they have related to growing the cultivar at their vineyard. Responses were:

- Winter damage/cold damage in the winter impacting Gruner Veltliner vine health and productivity (n = 7)
- Finding a market or buyer for Grüner V. wine I make (n = 5)
- Managing diseases impacting Grüner V. vines (n = 5)
- Finding a market or buyer for Grüner V. grapes I grow (n = 4)
- More time was spent managing the canopy (e.g., hedging, shoot thinning, crop/cluster thinning, leaf removal) compared to other vinifera cultivars (n = 1)
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While few participants selected responses presented, comments included:

- “Don't know enough about the variety.”
- “Have no desire to grow Grüner V. We have been researching Pinot Noir and Cab Franc for decades and are concentrating our efforts there.”
- “Have no interest in Gruner. There are a few marginal examples in the state but I do not think it will be a break out grape as far as marketing and the name still is not a household name. You will have a few wineries make a name for themselves with it but the rest will be marginal at best. Have only been impressed with 1 in the state so far.’
- “Have no interest in it. Higher demand for other varieties.”
- “I have no issues with Grüner V. and would be open to growing it if the opportunity presents itself. I am currently managing an established vineyard.”
- “I just prefer buying the grapes.”
- “I like Grüner V. but I have no plans to expand my vineyard.”
- “Not interested in growing any more acreage.”
- “Not interested in growing this grape at this time.”

Outreach Activities

Results of the project were presented at PWRMB symposium (University Park, PA, March 5, 2019), the American Society of Enology and Viticulture (ASEV)- Eastern section annual conference (Geneva, NY, July 17, 2019) and at the American Chemical Society National Meeting (San Diego, CA, August 29, 2019). The graduate students working on the project, Andrew Harner and Stephanie Keller, were both awarded an ASEV national and ASEV-ES scholarships. Andrew Harner also received and American Wine Society Educational Foundation scholarship. The project also offered training opportunities to 3 undergraduate students who assisted with the grower survey, winemaking, and laboratory analysis.