Virginia Wine Board Grant
Final Report

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Title: Improving Soil Testing to Better Predict Potassium Availability in Vineyard Soils
Proposal Number: PSz2WQNM
Project Type: ☒ Research ☐ Education ☐ Marketing
Is this a multi-year grant? ☐ Yes ☒ No

Original Funding Amount: 13,168
Current Balance: $0

Objectives and Results:
Objective 1: Compare soil sampling, handling, and extraction methods on vineyard soils **Objective 2*:*** Correlate soil analysis results with tissue and fruit samples
Objective 3*:* Make soil sampling, handling, and extraction method recommendations to improve fertilizer potassium (K) recommendations for grape growing

Site selection

We recruited 22 commercial and research vineyards throughout Virginia, Maryland, and New Jersey to participate in this research. The initial plan was to only sample in Virginia, but we expanded our recruitment north to ensure that we had ample data to draw conclusions after late spring 2020 frost damaged vines. Our final research sites included 48 vineyard blocks representing four physiographic provinces: Coastal Plain (5 blocks), Piedmont (21 blocks), Blue Ridge (5 blocks), and Ridge & Valley (17 blocks). The province from which we collected the most samples was the Piedmont due to the presence of soils having mineralogy that could provide plant-available K not extracted by routine soil test methods.

Wine grape varieties

We worked exclusively with red varieties, primarily *Vitis vinifera* varieties, a few French American hybrids, and one American variety. *Vitis vinifera* varieties included 12 Cabernet Franc, 11 Merlot, 8 Petit Verdot, 2 Cabernet Sauvignon, and 1 each of Malbec, Tannat, Teraldago, and Sangiovese. French-American hybrids included 4 Chambourcin, 1 Maréchal Foch, and 1 Landot Noir. Eight of the samples were from a University of Maryland replicated variety trial, from

which we sampled tissue from each variety.
Sample collection & processing

A minimum of 50 petiole and leaf blade (without petiole) samples were collected approximately 70-100 days following bloom from each vineyard block (variety). The first fully expanded leaf, approximately 5-7 leaves down from the shoot tip, was sampled from each block. We separated petioles and leaf blades, rinsed them with distilled water, and oven-dried at 25°C for at least 24 hours. For 18 of these blocks, we also collected bloom petiole samples from leaves directly opposite the primary cluster. Tissue samples were ground, digested with acid, and analyzed for K via ICP according to the methods of Huang & Schulte (1985).

Soil samples were mostly collected at the time of veraison tissue samples, but others were collected at bloom and later in the fall when the soil moisture was more ideal for sampling. We collected soil from 0-10 cm (0-4 in) and 0-38 cm (0-15 in) based on soil testing laboratory recommendations for no-till sampling and topsoil depths in Mid-Atlantic vineyards. At some sites, we were unable to sample to 38 cm due to the presence of bedrock, hardpans and other restrictive layers. We took the soil cores randomly or in a grid pattern throughout vineyard blocks, collecting them all into a clean bucket or large plastic bag. Composite soil samples were stored in plastic bags in a cooler at 5°C. We moist-sieved each soil sampled through a 2 mm sieve, then split each soil sample in half. Half of the soil was dried to a constant weight at 40°C and half stored at field water content. We then calculated the gravimetric water content of the field moist samples.

Soil extractions

We performed three soil extractions on both oven-dried and field moist samples: Mehlich 1, Mehlich 3, and Sodium Tetraphenylboron (NaBPh4). For the extractions of moist soil, we used the moisture content to standardize to the equivalent amount of dry soil. For example, we extracted 6.5 g of sample at 30% gravimetric water content in order to process the soil at a dry equivalent of 5 g.

For Mehlich 1, the standard extractant used by the Virginia Tech Soil Testing Lab, we used a ratio of 5.0 g dry soil to 20 mL extractant (0.0125 M H2SO4 + 0.025 M HCl; Maguire & Heckendorn, 2011; Mehlich, 1953; Mylavarapu et al., 2002). For Mehlich 3, the standard extractant for most other soil testing laboratories in the Mid-Atlantic region, we used 2.5 g dry soil to 25 mL extractant (0.2 M CH3COOH + 0.015 M NH4F + 0.013 M HNO3 + 0.001 M EDTA + 0.25 M H4NO3; Mehlich, 1984; Mylavarapu et al., 2002). Finally, for NaBPh4 extractions we used 1 g soil with 3 mL of extracting solution (0.167 M NaBPtu +1.7 M NaCl + 0.01 M EDTA), 25 mL of quenching solution (0.5 M NH4Cl + 0.14 M CuCl2), and 4-5 drops of 6 M HCl (Cox et al., 1999; Wang et al., 2013; A. Wolf & Beegle, 2009). Each extractant solution was analyzed via Inductively Coupled Plasma (ICP; Maguire & Heckendorn, 2011). Results from ICP analysis of extracted solution were converted to mg K/kg soil. JMP (SAS Institute, Cary, NC) software was

used to perform regression analysis.
<u>Results:</u>

1. Which tissue %K best correlates best with fruit pH?

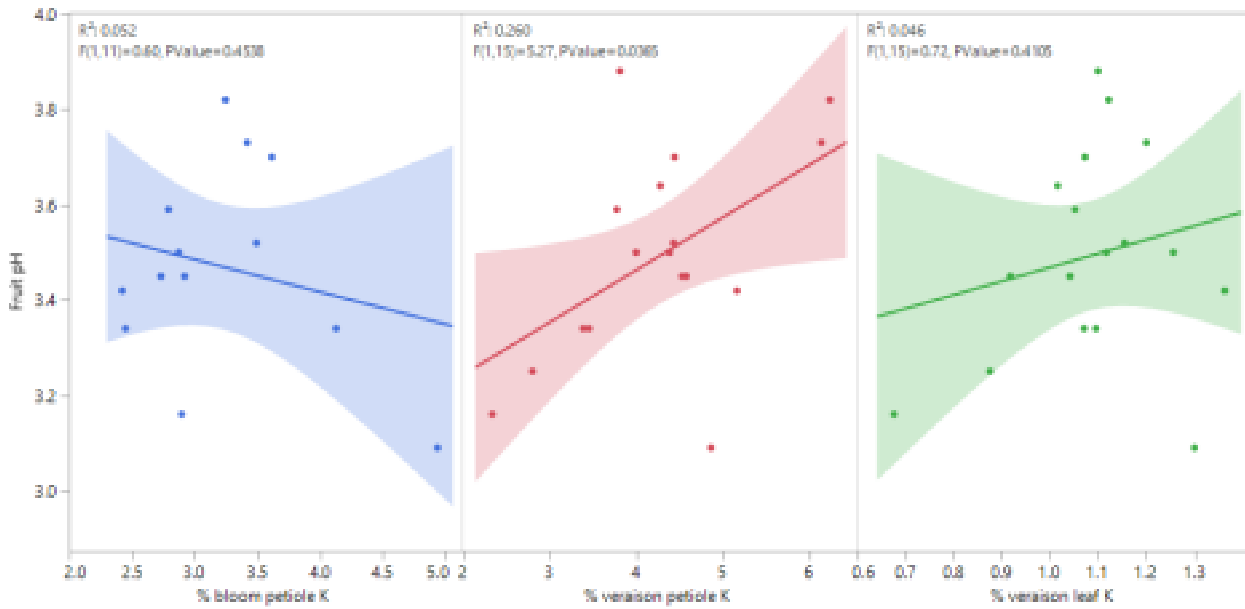

Figure 1. Fruit pH (on y-axis) versus 3 different vine tissues/timings (x-axis). Better relationships have higher R^2 values, higher F-statistics, and lower p-values. The shaded area around the line is the 95% confidence interval, so a smaller/tighter shaded area indicates a better relationship. For reference, the recommended upper limit (excessive) %K is considered 1.5% in bloom petioles and 1.0% in veraison petioles (Wolf, 2008).

Table 1. R^2 values for regression between fruit pH and different vine tissues

	Bloom petiole %K	Veraison petiole %K	Veraison leaf blade %K
Fruit pH at harvest	0.052	0.260*	0.046

*denotes significance at p-value of <0.05

The data (Fig. 1, Table 1) suggest that veraison petiole %K has the best relationship with fruit pH, so we used veraison petiole %K as the plant parameter by which to assess the best soil parameters for K availability.

Until now, tissue types have neither been extensively compared nor have resulted in useful correlations with soil analyses in Virginia. Petiole data in Virginia have generally shown a better correlation with K fertilizer applications than leaf blades. Hepner & Bravdo (1985) found that veraison petioles were better predictors of vine K status than leaf blade or veraison analyses in Cabernet Sauvignon and Carignane vines in the coastal plain of Israel. They also found that higher K was correlated with lower crop load and more frequent irrigation (Hepner & Bravdo, 1985). Other researchers (e.g., Dominguez et al., 2015) have shown that leaf blades are better at predicting K at both veraison and bloom, including a study of Tempranillo vines in Rioja, Spain (Romero et al., 2014). Our results were contrary to those of Schreiner & Scagel (2017) who found no significant differences between leaf blade and petioles in Pinot Noir in Oregon for predicting growth, yield, and must K. Schreiner & Scagel (2017) also found no differences between the predictive strength of bloom versus veraison samples.

2. Moist were better than dry soil samples for extractable K relationships with veraison petiole K.

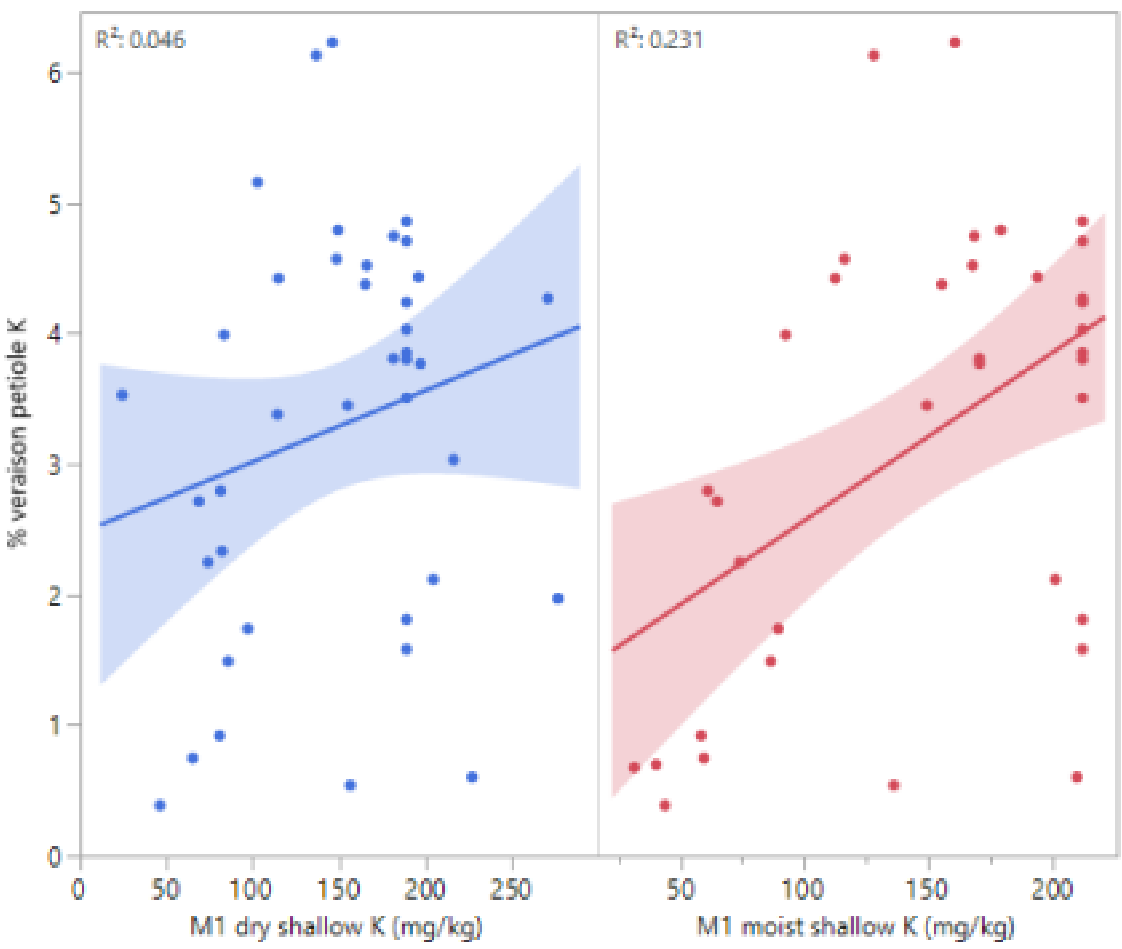

Figure 2. A comparison of Mehlich 1 extractions of dry versus moist samples. For reference, the Wine Grape Production Guide for Eastern North America lists the upper limit (above which is considered excessive) for soil K as 28 mg/kg by Mehlich 1 but does not specify moisture content or sampling depth (T. K. Wolf, 2008).

For the Mehlich 1 extractions, moist samples were better correlated with tissue %K. There was no consistent relationship with Mehlich 3. We suspected that extractable K from moist samples would have a better relationship with tissue %K because some soil minerals, such as illite and vermiculite, can ”fix” (trap) K when they are dried that is not accessible by the extractant but can be available to the plant. Thus, air-dried soil subject to Mehlich I extraction may underestimate the amount of plant-available K.

3. Better petiole K-soil K relationships occurred with deep rather than shallow samples.

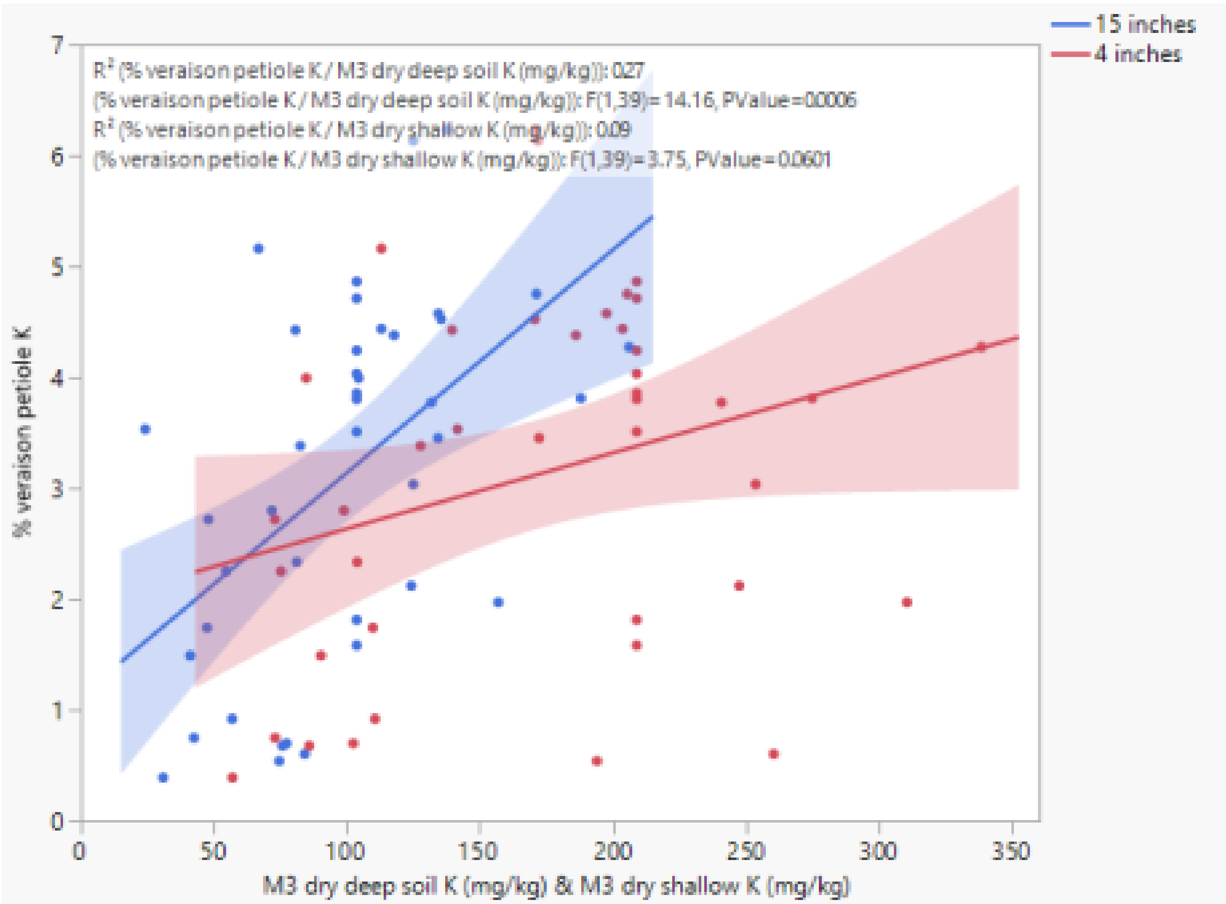

Figure 3. Relationships between veraison petiole K and deep and shallow dried soils extracted by Mehlich 3 dry extractions (for full results see Table 2).

Our data (Fig. 3, Table 2) consistently demonstrate that deeper samples (15”) were better correlated with tissue %K than shallow samples (4”). Every deep sample had at least a slightly higher R^2 than its associated shallow sample. Potassium can be released from soil minerals so the source of K to the plant includes mineral weathering and cation exchange. This is different from other nutrients like nitrogen and phosphorus which are primarily derived from microbial decomposition of organic material and therefore mostly present in organic matter matter-rich (shallow) topsoil.

4. Mehlich 1 extractions were better indicators of plant-available K than Mehlich 3.

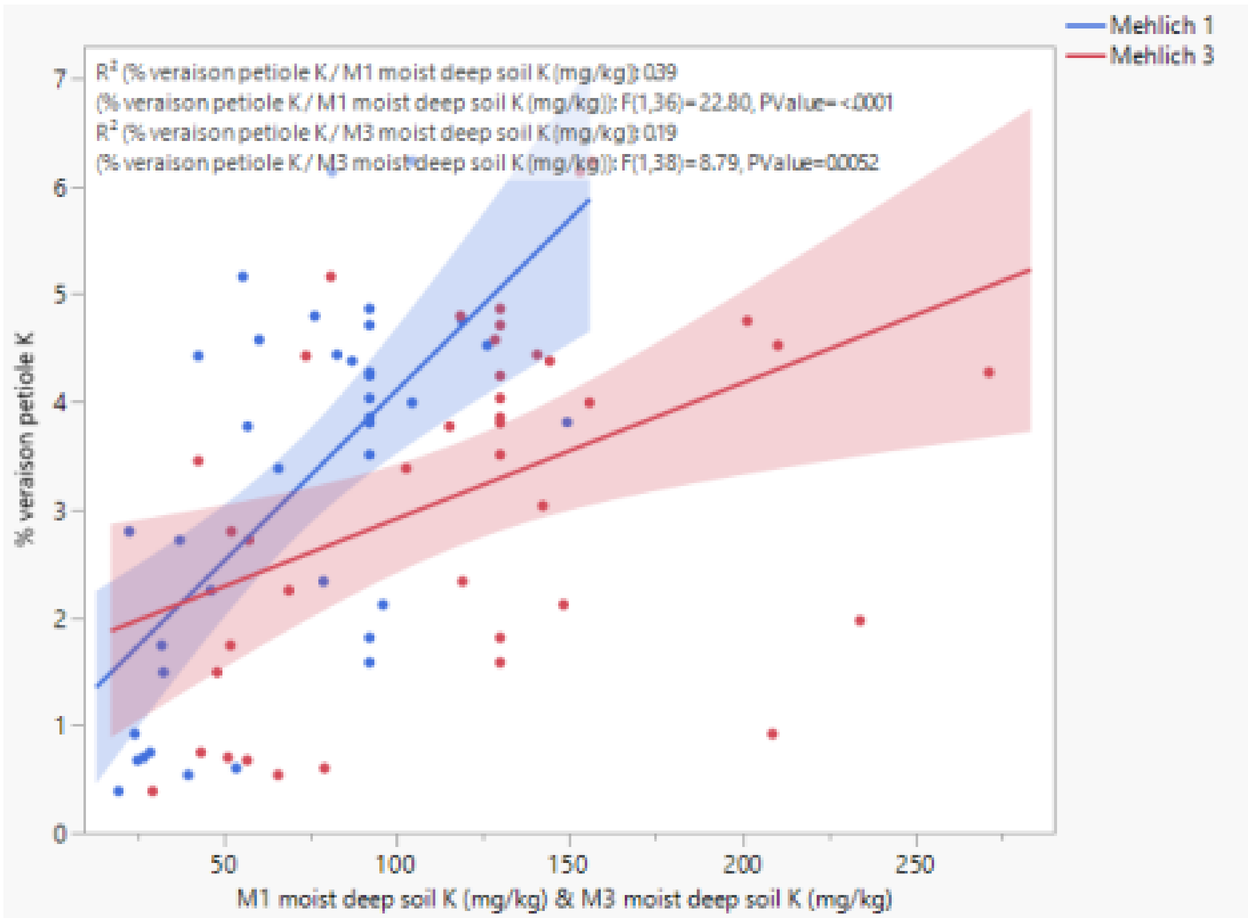

Figure 4. Comparison of Mehlich 1 versus Mehlich 3 extraction on the same soil (deep sampled, field moist soils).

Although more K is extracted by Mehlich 3 than Mehlich 1, Mehlich 3-K did not give as high a correlation with tissue %K as Mehlich 1-K; thus, we recommend the Mehlich 1 extraction for grapevine K availability.

Overall, the best relationship and predicter of veraison petiole tissue %K was Mehlich 1 moist-extraction on soils collected from 0-15 inches.

5. Trends are consistent across geologic provinces.

We quantified plant (veraison petiole) and soil K concentrations for Coastal Plain, Piedmont, Ridge & Valley, and Blue Ridge soils (Fig. 5, 6, 7) to determine whether we could provide soil region-specific guidance. Based on a small data set (only 4 points in the Blue Ridge), we found
that veraison petiole K increased in the order Coastal Plain < Piedmont < Ridge & Valley < Blue Ridge. These differences are likely due to parent material, mineralogy, and cation exchange capacities of the soils in each region.

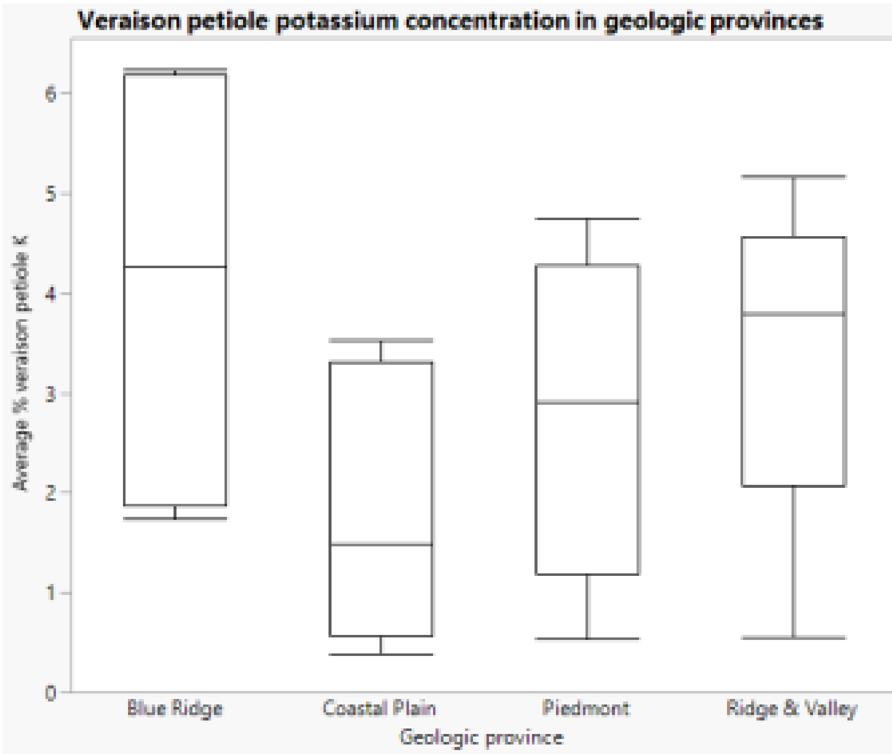

Figure 5. Distributions of K in veraison petioles across geologic provinces. The horizontal lines in the boxes represents the median of each data set (for instance, the coastal plain has the lowest median value). The top and bottom of the boxes are the lower and upper quartiles, while the box covers the interquartile interval where 50% of the data is found. Whiskers are 1.5 times the interquartile range.

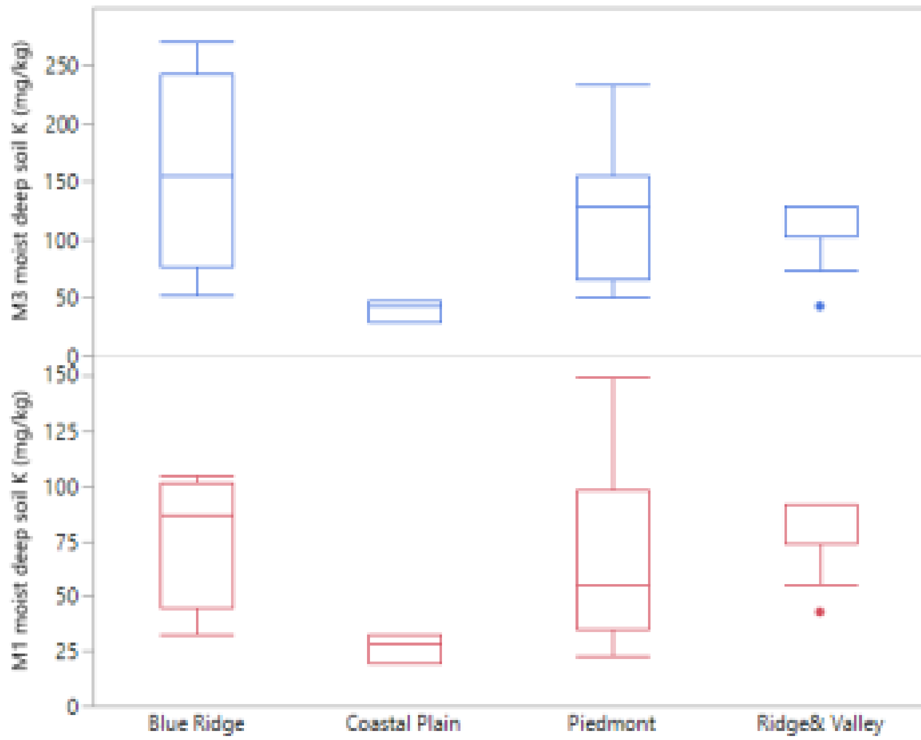

Figure 6. Distributions of Mehlich 1 and 3 extractable K in deep-sampled, moist soils. The horizontal lines in the boxes represents the median of each data set. The top and bottom of the boxes are the lower and upper quartiles, while the box covers the interquartile interval where 50% of the data is found. Whiskers are 1.5 times the interquartile range. Points outside the whiskers are potential outliers.

Although they extracted different absolute amounts of K, Mehlich 1 and Mehlich 3 showed similar K patterns across the different geologic provinces. Thus, it is likely that a critical soil K concentration could be developed for mid-Atlantic states that use the Mehlich 3 extractant.

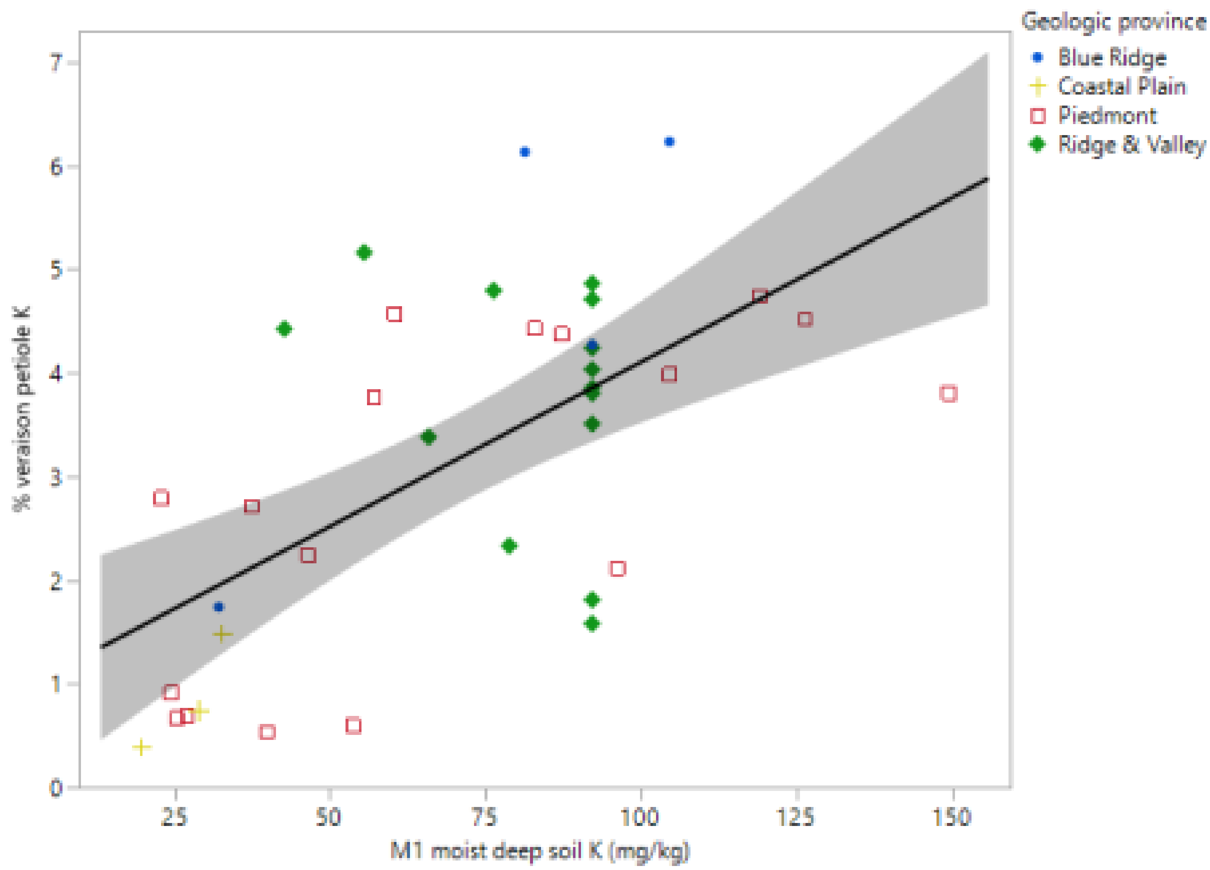

Figure 7. Relationship between veraison petiole %K and Mehlich 1 moist deep soil extractions across geologic provinces.

Most of our data were from the Piedmont region, and Figure 7 suggests that there is a good relationship between Piedmont (red squares) Mehlich 1 extractions of deep, moist soil samples with veraison petiole %K (when analyzed separately R^2 = 0.471, p=0.0024). There are too few samples from other geologic provinces to draw conclusions about those. Only 7 samples (5 from the Piedmont and 2 from the Coastal Plain) were under the critical value of 1.0% veraison petiole K.

6. Full data set

Table 2. Results of regressions with R^2 values for all relationships

	Bloom petiole	**Veraison petiole**	**Veraison leaf blade**	**Fruit pH**
M1 dry deep	0.387*	0.272**	0.121*	0.268*
M1 dry shallow	0.065	0.046	0.009	0.153
M1 moist deep	0.315*	0.388**	0.238*	0.194

M1 moist shallow	0.089	0.231*	0.146*	0.032
M3 dry deep	0.350*	0.266**	0.095*	0.371*
M3 dry shallow	0.016	0.088*	0.028	0.229
M3 moist deep	0.128	0.188*	0.051	0.185
M3 moist shallow	0.118	0.162*	0.096	0.202

*denotes significance at p-value of <0.05
** denotes significance at p-value of <0.001

Conclusions

Our data confirm that veraison petiole is the tissue best correlated with fruit pH. The best relationship and predicter of veraison petiole tissue %K was Mehlich 1 moist-extraction on soils collected from 0-15 inches. Thus, deeper than typically recommended soil samples of 0-15" (vs 4 to 6" routine sampling) may better be suited to assess the potential for excessive soil K for high quality grape juice. Extraction of field-moist samples also appear to be better suited to troubleshoot soils whose plant-available K may be excessive for wine production. While further data are required to reliably validate these recommendations, such information will be shared with the Virginia Tech Soil Testing Laboratory and the wine grape industry in Virginia for potential modification of wine grape soil K assessment and fertilizer recommendations.

We are also in the process of completing NaBPh4 extractions on the soil samples but were delayed in completing our analyses by laboratory supply chain shortages due to the Covid-19 pandemic. The NaBPh4 extraction data may prove to be better correlated with veraison petiole %K because this extractant releases forms of K that may be plant-available but not extracted by Mehlich 1 and 3 extractants. We hope to be able to identify critical K values for each extractant that will be used to evaluate potentially excessive soil K values. Those data will be included in our peer-reviewed research article, for which the financial support of the Virginia Wine Board will be acknowledged.

Overall Benefit for Virginia Wine Industry:

The main benefit of this project is improving the soil tests we use to predict K availability in vineyard soils. Results will allow soil testing labs to better serve grape growers with more accurate testing methods. Better testing methods will mean better results which will inform better fertilizer rate recommendations for optimizing wine quality in Virginia. The results will allow better site evaluation and soil preparation of new vineyards and allow existing vineyards to better control their fruit pH. This project is foundational for understanding the best ways to measure and predict K, which will allow future projects to try to reduce K in grapevines and improve wine grape quality.

Publications and Activities Associated with Project:
A peer-reviewed manuscript for publication in a scientific journal is being developed, as well as a presentation for the Soil Science Society of America conference in November. We will present the results at the Virginia Vineyards Association winter technical meeting, as well as next summer's American Society for Enology and Viticulture Eastern Section annual conference.

Future Work:
The results of this project are foundational for investigations of K in vineyards. We expect that more specific soil sampling and processing methodologies will come from this and future related research, such as removing or limiting K in vineyard soils, that will increase the quality of Virginia wine grapes.

Final Budget and Justification:

Item Type	Original Awarded Amount	Final Amount Spent
Personnel	[$3730.00]	[$3871.71]
Fringe	[$906.00]	[$1071.58]
Travel	[$4094.00]	[$5069.54]
Supplies & Materials	[$2600.00]	[$417.67]
Contractual	[$1838.00]	[$2737.50]
Total	$13,168.00	$13,168.00

Travel costs were higher than anticipated because we included additional sites to compensate for frost damage to some of the original research locations. Contractual costs included higher University truck service center costs (largely, operations & maintenance) than expected. Other supporting funds (i.e. supplies) for this research were covered by general research funds of the P.I. (Evanylo).

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