Final Report for the Virginia Wine Board (FY 2016)

The Role of Soil Mineralogy in Potassium Uptake by Wine Grapes

Year 2 of 2

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Objective: To help Virginia winegrowers better understand the role that soil minerals and Mehlich 3 extractable potassium play in the potassium status of vines and grapes.

Introduction

Potassium (K) in fruit plays a critical role in the pH of must and wine (Keller 2010). pH is known to be a major influence on a number of wine quality factors including color, acid balance and microbiological stability (Zoecklein et al 1990). Potassium availability in the soil can vary greatly and deficiencies can occur; however, in Virginia excess K absorption by wine grapes is much more common than K deficiency (Wolf 2007). As discussed in our year 1 Virginia Wine Board research report (Beasley, Morton, Ambers 2015), growers are commonly led to believe by laboratory analysis that potassium levels in their soils are low, when petiole analysis from the same location shows elevated K levels in the plant tissue.

In her many decades of working in Virginia vineyards, Lucie Morton has virtually never seen K deficiency in mature vineyards. In her opinion, this study will start a conversation about why that is the case. Clearly the current approach to soil testing, based on an assumption of six inch topsoil layer, makes no sense for grapevines that are known to for their deep rooting and ability to grow well in nutrient poor conditions. Interpretations of the availability of K to grapevines based on a five minute acid extraction do not reflect what is actually available to vines in soils. She works with several Virginia vineyards where the K status of the soils is the only difference between blocks where the K status in soils and vines is lower. It is her opinion that, in the absence of clear deficiency symptoms, any recommendation to add potash to any vineyard soil in Virginia is misguided. In the few cases where she has seen young vines in need of additional K, foliar applications corrected the deficiency.

Background

Our study examines the relationship between bedrock geology, vineyard soil mineralogy, soil and plant tissue chemistry, and the potassium levels (and pH) of the fruit. The first year of this work identified individual soil minerals in our vineyard soils and explored their influence on vine K uptake. In year 1 of this study, we encountered numerous confounding variables and observed that many environmental and viticultural factors unrelated to soil can obscure the direct effect of soil on vine and fruit chemistry. Year 2 of this work included both laboratory and field-based trials with the ultimate goal being to control for many of the variables encountered in year 1, simplifying the problem by attempting to study individual bite-sized components of the complex soil-vine system.

First, it is very important to recognize the distinction of the geological usage of "mineral" here with the common biological and nutritional usage of "mineral" that refers to a dissolved ionic species that is used by an organism as a nutrient. We do not use "mineral" in the biological sense anywhere in this study except in this clarification. Mineral as used here in the geological sense <u>only</u> means the solid, crystalline components (grains) of rocks that exist at nearly constant composition and crystallography regardless of the bulk composition and fabric of the rocks containing them.

As an example, quartz is the most common mineral found in the soils of Earth. It is always nearly pure SiO2 and crystallized with trigonal crystal symmetry. It is essentially the same material regardless of whether it is found in granite, sandstone, shale, schist, gneiss, flint or vein quartzite.

Other common minerals that are discussed in this study include the primary, high temperature, parent rock minerals: feldspar group (subdivided into the K--Na---bearing "alkali feldspars" and the Ca---Na---bearing "plagioclase" feldspars), micas (subdivided into low Mg---Fe and K---rich "muscovite", high Mg---Fe and K---rich "biotite", and Low Mg---Fe and Na---rich "paragonite"), chlorite, epidote, hornblende, pyroxene; and the secondary, low temperature minerals formed

Role of Soil Mineralogy in Potassium Uptake by Wine GrapesBeasley, Morton, Ambersby surface weathering of primary minerals: clay minerals (kaolinite, degraded mica, vermiculite, chlorite, smectite, and interlayerings thereof), Fe---Mn oxyhydroxides (goethite, pyrolusite), and non- to poorly-crystalline Al-
Si-Fe-Mn precipitates (allophanes). Figure 1 of our October 2015 Progress Report for this work shows a collection
of photomicrographs of the main parent material rocks as seen in thin section.

A few of the aforementioned minerals are of particular interest (feldspars and micas) in this study because of their high potassium content which makes them the main source of natural potassium in the soils derived from them. The feldspars as a group include the plagioclases, which do not contain more than 10% K-feldspar dissolved in them, and the alkali feldspars which do not contain more than 10% Ca-feldspar dissolved in them.

The micas (muscovite and biotite) are the second group of potassic minerals common in Virginia. Natural muscovites run about 11.2% K2O whereas biotites run about 8.5% K2O. Even though they contain less K2O than potassium feldspar, the micas are "sheet silicates" with their silica and alumina components arranged in 2:1, sandwich---like sheets, which gives these minerals structural weakness that contributes to their very rapid weathering. Between the 2:1 layers of silica and alumina sheets are housed potassium atoms. The mica minerals are famous for their "perfect cleavage" which allows them to be split into vanishingly thin sheets with a knife or razor blade. Impact or bending can also cause the crystals to cleave into seemingly infinite thinner sheets. Also, the edges of the layers do not have bridges of silica or alumina that would retard the entry of water along the potassium interlayers. This makes the potassium vulnerable to hydration and removal even without making water access very easy by cleaving the crystal.

The end result is micas release their potassium at a remarkably faster rate than K---feldpsar and, while they persist, are a large source of soil potassium. Another important aspect of mica weathering is that they may have most or all of their potassium removed and replaced with another cation (including K from fertilizers) along with its hydration water. When added potassium is reintroduced to the interlayer spaces in the mica structure, it remains there as "fixed K" that can become available over time to grape roots.

Accomplishments

We implemented the following five (5) sub experiments during our <u>second</u> year of research for this work:

1) Soil sampling to characterize native soil chemistry in relation to bedrock chemistry

In order to further investigate a traceable link between bedrock geology and soil chemistry, we collected soil samples from outside the vineyard where recent amendments are unlikely at four (4) of our research sites, each in a unique geologic setting. The soil chemical results were compared to previously published whole rock chemistries of each rock type and findings are discussed herein.

2) Saturated hydraulic conductivity testing to measure soil infiltration rates (Ksats)

We measured both topsoil and subsoil infiltration rates at our research sites to investigate the influence of soil drainage on potential fruit quality in the context of soil potassium status.

3) Fruit sampling and chemical analysis at our research sites

Composite fruit sampling was conducted at each previously mapped sample location for this work. Our previous work (year 1 of this study) included plant tissue chemistry, but it lacked any fruit chemical data beyond harvest pH and sugar.

4) Extended Mehlic 3 extraction on known mineral powders

We implemented an extended Mehlic 3 extraction on mineral powders of known composition to investigate the effects of long-term dissolution of common vineyard soil minerals in acidic conditions.

5) Greenhouse trials

We grew Cabernet Sauvignon vines on four different rootstocks in pre-mixed growing media of known quantities of different K-bearing minerals to investigate the influence of growing media on vine chemistry in a controlled environment.

Experiments

1) Soil chemistry and bedrock chemistry

Methods

The sample locations for this sub-experiment were selected based on farming history of each of four (4) of our research sites. The goal was to collect samples in areas that were least likely to have been farmed recently, so all locations were within wooded areas close to, but outside the vineyard. Soil samples were collected via hand auger from discrete depths at each location and GPS coordinates were logged. A topsoil and a subsoil sample from each location was submitted to Waypoint Analytical Laboratories for chemical analysis of the S3M list of nutrients via Mehlic 3 extraction and ICP analysis. The bedrock geology at each sample location was confirmed onsite by Ernest Beasley, a Virginia Certified Professional Geologist. We relied upon previously published whole rock geochemical data for this exercise, comparing our soil chemical data to the corresponding rock chemistries reported for each soil's parent material.

Results

	Alkali Syenite	Catoctin Metabasalt	Biotite-Plagioclase Augen Gneiss	ljamsville Phyllite
SiO2	72.14	46.55	55.8	53.13
TiO2	0.27	2.47	2.6	1.13
Al2O3	13.53	13.6	15	23.58
Fe2O3	3.28	5.23	11	5.21
FeO		8.3		4.68
Fe oxides	3.28	13.53	11	9.89
MnO	0.05	0.215	0.14	0.17
MgO	0.16	6.29	2.1	2.07
CaO	0.35	11	5.7	0.26
Na2O	4.99	2.005	3	1.88
K2O	4.84	0.165	2.5	3.41
H2O+		3.15		4.29
H2O-		0.075		0.1
P2O5	0.01	0.3	1.2	0.28
CO2		0.505		0
Sum:	102.9	99.855	99.04	100.19

Table 1: Whole-rock geochemical data for bedrock types of four research sites. Data previously published by others (Tollo and Lowe, 1993; Burton, W.C. *et al.* 1995; Weaver 1964; Hertz and Force 1987).

Parent Material:	Alkali Syenite		Catoctin Metabasalt		Biotite-Plagiocla	ase Augen Gneiss	ljamsville Phyllite		
	Topsoil (ppm)	Subsoil (ppm)	Topsoil (ppm)	Subsoil (ppm)	Topsoil (ppm)	Subsoil (ppm)	Topsoil (ppm)	Subsoil (ppm)	
Fe	153	105	284	227	175	43	188	133	
Mn	171	32	36	19	26	11	102	144	
Mg	174	102	185	523	87	142	41	28	
Ca	1309	382	1102	2010	413	305	377	153	
Na	22	19	15	21	17	16	16	23	
K	138	263	96	41	100	311	96	55	
Р	38	7	56	106	19	3	19	6	
pН	5.5	5.1	5.4	5.3	4.6	5.1	5.0	4.8	
CEC (meq/100g)	11.3	5.6	10.3	21.2	6.8	5.8	4.3	2.3	

Table 2: Soil chemical data and corresponding parent material (bedrock type) for four research sites. Soil samples were collected in wooded areas close to, but outside vineyards in attempt to characterize soil that has not recently undergone cultivation.



- Bedrock Chemistry (as reported by others)



Plot 1: Bar graphs show relationships between select bedrock chemical constituents and the associated concentrations measured in our subsoil samples. Note the strong relationships on all four plots (A-D) for the Alkali Syenite and Catoctin Metabasalt sites – these are younger soils than the gneiss and phyllite soils which are ultisols. (Bedrock Fe Oxides were multiplied by 10 and all other bedrock constituents reported in Plots 1 B-D were multiplied by 100 to facilitate visual display)

Discussion

These data show an undeniable correlation. Two of the soils analyzed herein are relatively young soils (inceptisols), and 2 are much older soils which have undergone extensive leaching (ultisols). The chemistries of the two younger soils in this study (alkali syenite and metabasalt soils in Plots 1A-D) show a direct relationship to the relative reported amounts of the chemical constituents in the parent rocks. This observation aligns with our hypothesis in that we would expect the chemistry of a younger soil to be closer to that of the original parent material than that of a soil which has undergone extensive nutrient leaching.

While we did note relationships between the relative amounts of various chemical constituents in the parent material rocks and their associated soils in this study, because of the complex nature of soil genesis, nutrient cycling, and land use history, these correlations (especially any seen in the older soils, or ultisols) must be taken with a grain of salt. Factors such as cation-exchange capacity (CEC) directly affect the absolute amounts of chemical constituents in the soil; thus, the sample with the highest CEC (metabasalt soil) shows the highest absolute amounts of Ca and Mg as seen above. Although the metabasalt rock itself contains high levels of Ca and Mg, our current limited soil dataset is unable to distinguish between Ca and Mg that originated from the parent rock and Ca and Mg ions that were introduced by historical liming. In other words, these relationships might not be as direct as one would initially be led to believe and much more data would be required to arrive at a conclusion about specific drivers of the relationships seen above.

2) Saturated Hydraulic Conductivity Testing <u>Methods</u>

Saturated hydraulic conductivity (Ksat) tests were conducted at five (5) research sites using the Johnson Permeameter, a standard instrument for implementing constant head saturated hydraulic conductivity testing. The permeameter is inserted into a borehole at the desired test depth. A calibrated reservoir (graduated cylinder) on the ground surface is attached thereto with a suitable length of hose. Water is added to the calibrated reservoir and allowed to flow freely into the borehole until an equilibrium level is reached in the borehole and inside the soil permeameter. A filtered vent system, backflow check valve, and seals restrict entry of soil particles and debris. The soil permeability is determined by solving appropriate mathematical equations (the Glover Solution) which utilize the equilibrium height of water, rate of water flow, and dimensions of the borehole as input parameters. (US Patent: US 6938461 B1)

Ksat values are expressed in units of inches per hour (in/hr) and give an indication of how quickly water percolates through the soil at the depth measured. In most cases, higher Ksat values indicate soils that drain faster and lower Ksat values indicate soils that drain slower. We measured topsoil and subsoil infiltration rates at each sample location in order to characterize the inherently variable infiltration rates of each soil with respect to depth in the context of soil potassium status.

Figure 1: Field worker records volumetric measurements from above-ground graduated cylinder during Ksats test. Water flows out of the cylinder through the hose into the permeameter device at the bottom of the borehole. Volumetric measurements are collected at predetermined time intervals in the field – these data are utilized to calculate Ksat values using appropriate mathematical calculations.



Results

Site ID	NRCS Mapped Soil Series	Subsoil Texture	Topsoil Ksat (in/hr)	Subsoil Ksat (in/hr)	Topsoil K (ppm)	Subsoil K (ppm)	Topsoil pH	Subsoil pH	Petiole K (%)
K1	Glenelg	Gravelly Loam	0.12	0.35	42	35	6.5	6.8	2.22
O1	Lloyd	Clay	2.22	0.21	96	53	6.2	5.6	4.98
O2	Lloyd	Clay	0.1	0.01	71	37	6.2	6.9	3.32
R1	Pigeonroost	Gravelly Silty Clay Loam	ND	0.31	106	48	5.3	5.7	3.65
R2	Pigeonroost	Gravelly Clay Loam	ND	0.05	272	251	5	4.9	4.91
S1	Myersville	Silt Loam	0.04	0	62	24	5.9	6.2	4.23
P1	Dyke	Clay	0.48	0.02	160	75	7	7.1	3.79
P2	Dyke	Gravelly Clay Loam	1.98	1.63	151	33	6.4	5.3	3.23

Table 3: Ksats data for five research sites shown in box above. Each capital letter in Site ID corresponds to a different Vineyard – subsequent numbers indicate specific sample ID as 3 of the sites consisted of 2 sample locations. Also shown are soil series (as mapped in the SSURGO database), subsoil texture (as determined via hydrometer method), soil K and pH, and petiole K.

Discussion

Site K

The Ksats data from this site show faster infiltration rates in the subsoil vs. the topsoil, making the Site K test location an outlier with respect to both the rest of the dataset and to the majority of Ksat values seen by the authors in their collective work. The elevated subsoil pH seen here can be explained by the hydrologic implications suggested by the measured Ksat values: liming material added to the soil over many years of farming has been able to move downward through the soil profile over time.

This site shows the lowest petiole K levels in the above table, perhaps a function of the lower K status of the soils in combination with the high rock content, as opposed to being directly related to the Ksat.

Site O

This site was incorporated into our study because two different Merlot blocks with similar soils, geomorphology, and viticulture consistently produce fruit of different qualities, with that from O2 being preferred by the winemaker over that from O1. A previous hypothesis regarding this specific scenario was that wines from O2 are preferred in part because the soil must have higher infiltration rates at that location. The above data table suggests that in this particular case, soil chemistry is more important for wine quality than infiltration rate. O1 soils appear to be better-drained than those at O2, as implied by the Ksat values above. The petiole K status documented in Table 3 correlates to the winemaker's experience, with the preferred fruit coming from the vines with lower petiole K. As seen above, soil K shows a positive correlation to petiole K while soil pH shows a negative correlation. The hypothesis that an inverse relationship between Ksat and petiole K would be seen is not supported by the data, suggesting that soil pH and K status could have a greater influence on wine quality than soil infiltration rate in soils with relatively low subsoil permeability rates.

Sites R and P

Sites R and P include 2 sample locations each and both sites show lower soil and petiole K values at the location with a faster infiltration rate. Site R shows lower subsoil pH at the location with higher petiole K and site P shows higher subsoil pH at the location with higher petiole K.

Site S

This site is the only location in the above table within a Petit Verdot block (PV 400 clone on Riparia Gloire rootstock) as all other sample locations are from Merlot vines. Note that the Ksat for Site S is the lowest shown in the above table, soil K status is low, and petiole K is one of the higher values. This particular scenario illustrates in a poorly-drained soil that with what many agronomists would consider very low K and acceptable pH, the vines can uptake excessive amounts of potassium.

3) Fruit Sampling

<u>Methods</u>

We used petioles as opposed to leaves for plant tissue samples in this work as petioles have been shown to be more representative of vine K status than leaves (Robinson 1992). Petioles were collected at both bloom and veraison. Composite fruit sampling was conducted at each previously mapped sample location for this work. For each sample, we randomly collected 150-berry samples by hand prior to harvest, in a 3 panel x 3 panel configuration surrounding the soil borehole location. Each 150-berry sample was blended into a slurry, which was then dried in a food-grade dehydrator and submitted to Waypoint Analytical Laboratories for bulk chemical analysis.

Results and Discussion



Plot 2A: Positive correlation between veraison and bloom petiole K, suggesting consistency in vine nutrient status and sampling methodology. **Plot 2B:** No relationship between petiole K and fruit K, suggesting the influence of confounding variables such as crop load, sampling time, environmental conditions, etc.

The veraison vs. bloom petiole K plot (Plot 2A) shows a strong positive correlation, suggesting that the petioles we collected consistently (and perhaps accurately) reflected vine nutrient status; thus apparently validating the significance of the correlations noted between the petiole and soil data previously discussed in our work.

In Plot 2B, no correlation between petiole K and fruit K is noted, illustrating a fundamental obstacle to *terroir* research on the regional scale: the many viticultural factors that can contribute to fruit pH variations from site-to-site (i.e. crop load, sample timing, vine spacing and size, canopy management (shading), leafing strategy, weather at key phenological moments in the season, rootstock, etc.) can overprint the relationship between petiole and fruit nutrient status, obscuring the relationship between soil and fruit quality that we are trying to isolate and study in detail.

In a regional study, many of these confounding variables cannot possibly be controlled; thus, we have found the most meaningful assessments to take place on single sites with multiple sample locations in the same vineyard as many of the confounding variables can be controlled relatively easily.

Our research sites were chosen for differences in soil conditions. Along with that came differences in vineyard management practices, which obscured the already unclear picture of the soil-vine dynamic we are studying. Future work will include trials on single sites with numerous sample locations in attempt to control for these confounding variables so that the relationships we are interested in can be isolated and fully understood.

4) Extended Mehlic 3 Extractions Methods

We implemented extended Mehlic 3 extractions on washed mineral powders of known chemistries (the same powders used in the greenhouse trials discussed herein). The specific mineral powders were selected because each represents common soil-forming minerals found in Virginia vineyards. Five-minute (soak time) samples were analyzed via ICP at Waypoint Analytical just as is typically done with normal soil samples (2g powder/20ml Mehlic 3 solution). Eight subsequent samples were collected from 2g dry, phosphoric acid- washed mineral powder per 100ml Mehlic 3 solution in continuous contact with the pH 2.5 solution with each sample removed from the homogenized (stirred) mixture to maintain a constant solid:solution ratio. Results were back-calculated post lab analysis to account for dilution factor. Samples were collected at T=5min, T= 1, 12, 36, 72, 144, 313, 670, and 1383 hours. All extracted solutions were filtered in the lab, stored in glass jars and analyzed via ICP by Waypoint Analytical Laboratories.



Plot 3A-I: Time vs. concentration for extended Mehlic 3 extractions on prewashed mineral powders. Curve color corresponds to mineral (K = K-feldspar, MS = minspar, an intermediate feldspar, MU = muscovite, PH = phlogopite, Q = quartz). Clear relationships are noted.

	B (ppm)	Ca (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Mg (ppm)	Mn (ppm)	Na (ppm)	P (ppm)	S (ppm)	Zn (ppm)
Kspar	0.04	40.80	0.12	5.20	31.60	4.60	2.00	4.60	2.00	0.60	0.18
Minspar	0.04	21.40	0.12	2.20	18.00	2.40	0.40	15.80	0.80	0.40	0.08
Muscovite	0.08	37.80	0.24	40.80	113.60	12.00	3.00	6.60	4.20	0.20	0.30
Phlogopite	0.04	295.80	0.40	32.40	18.60	64.80	11.20	4.40	3.40	0.20	0.60
Quartz sand	0.02	13.00	0.10	3.20	3.80	2.20	0.20	2.60	1.20	0.60	0.14

Table 4: Chemical data from standard 5-minute Mehlic III extractions of mineral powders. Samples were run as if they were soil samples submitted to Waypoint Analytical by a grower. Kspar is a nearly pure orthoclase feldspar (potassium feldspar) powder; Minspar is the proprietary name of an intermediate K-Na feldspar; Muscovite is a K-bearing mica; our Phlogopite sample, a high Mg biotite mica (which also contains a significant amount of interlayer K), shows anomalous values throughout these experiments due to the presence of an unidentified coating on the powder for use in pottery and materials science.

Discussion

This experiment clearly illustrates that many of the common soil minerals in our vineyards contain much more potassium than is detected by standard lab tests involving a 5-minute extraction. The majority of the Plot 3 curves show and increase in constituent concentration over time.

The relative amounts of dissolved K shown in Plot 3A correspond to the relative amounts in the original minerals and/or the expected kinetics of K-dissolution in the context of mineral structure (i.e. muscovite has lower total K than K-feldspar, but in muscovite the K occupies interlayer sites along structurally weak planes, making it more easily accessible to the extraction solution than the K ions locked up in the framework structure of K-feldspar).

Curves that show decreases in concentration with respect to time are interpreted to show particular elements precipitating out of solution in one form or another. For example, the boron shown on the curves in Plot 3C likely originated from the glass jars in which the extractions took place, with more and more precipitating out over time. The minerals with greater surface area per unit volume provide more nucleation sites for the boron precipitate, thus speeding along the kinetics of the precipitation reaction, as supported by the fact that the micas (muscovite and phlogopite) show very quick drops in B concentration, while the feldspars show slower drops in B concentration, and the quartz (with the largest grain size and least angular grain shape) shows the slowest decrease in B concentration over time.

The anomalously high calcium levels shown in the phlogopite sample (Plot 3B) are attributed to a proprietary coating applied to the powder by the manufacturer. When contacted regarding the composition of this coating, the manufacturer would not comment on its chemistry, but did confirm that the phlogopite does contain some sort of coating for use in pottery and materials science.

Two magnesium plots (Plots 3G and 3H) are shown for visual purposes as the phlogopite magnesium levels are an order of magnitude higher than those of the other samples.

The increasing aluminum concentrations with respect to time in Plot 3D are interpreted to reflect the breaking down of the framework structure of the minerals (which is where the aluminum ions exist) by the acidic solution, as opposed to only dissolving exchangeable ions and surface cations. This process releases previously "locked up" and virtually inaccessible nutrient ions into solution and, as indicated by Plot 3D, takes quite a bit of time relative to the 5-minute soak typically completed during standard soil lab testing.

5) Greenhouse Trials

Methods

This trial consisted of 48 potted Cabernet Sauvignon vines grafted on 4 different rootstocks: Riparia Gloire, 101-14, 3309, 420A. Note that the vines had some variation in size. Furthermore, we do not know the nutrient management program used by the nursery which would affect nutrients stored in the dormant plant tissue. including reserve K.

The vines were divided between 8 different predetermined K mineral root zone treatments. Before planting, all mineral powders were washed in a slightly acidic (pH 5.0) solution of phosphoric acid + reverse osmosis (RO) water to remove excess surface cations. Equal amounts of inert quartz sand + washed mineral powder were added to each of the 48 pots. Dolomite treatments were introduced into this study to investigate the effects of soil pH on nutrient uptake behavior.

A hydroponic system was used for uniform watering and nutrient supply. All water was treated with RO to ensure that no unwanted chemical additions were introduced to the system. We maintained a constant 5.5 pH in the reservoir water with phosphoric acid. To prevent deficiencies, we added N-Cal-Mag and a micronutrient solution (Nutrafin plant gro, containing B, Cu, Fe, Mn, Mo, Zn).

The only K we supplied to the vines came in the form of the various geologic mineral treatments, 2 feldspars and 2 micas, purchased from pottery suppliers. These specific mineral powders were chosen based on chemical analyses provided by the suppliers.

At the end of the 2015 growing season, we uprooted the plants. We photographed the shoots, leaves, and roots of each vine. Vine measurements included shoots lengths, trunk diameters, wet and dry shoot weights, % water, overall leaf color, leaf area, and root volume. We then dried the plants in a dehydrator, and shipped whole vine samples of green tissue (leaves + petioles + stems) to Waypoint Analytical Laboratory in Richmond, Virginia for chemical analysis.



Figure 2A: Research greenhouse at Vitipoint Research Center with 48 Cabernet Sauvignon vines. Each different mineral trial included each of the 4 different rootstocks.



Figure 2B: Leaf area, leaf color, shoot weights, lengths, and root volume were recorded for each vine at the end of the 2015 growing season.

Results

Plot 4: Shoot length vs. trunk diameter as measured upon harvesting vines at the end of the 2015 growing season. Each of four different rootstocks is represented by a unique color. Trunk diameters varied considerably within each treatment.



Leaf area vs. Trunk Diameter 14 12 : 10 $R^{z} = 0.2025$ **Max. Trunk Diameter** \$: \$ 8 ŧ : (mm) 6 4 2 0 0 0.5 1 1.5 2 2.5 3 3.5 4 **Relative Leaf Area**





Plot 6A: Relative leaf color, leaf area, and root volume between rootstocks. Each bar represents the sum of ranked values for all vines with the same rootstock (12 vines of each).



Plot 6B: Relative leaf color, leaf area, and root volume grouped by rootstock. Each bar represents the sum of ranked values for all vines with the same rootstock (12 vines of each). Same data as Plot 6A presented differently.

Plot 7: Average percent Ca, K, and Mg shown for each mineral treatment. Note that these data include all 4 rootstocks combined. The general trend seen with dolomite additions was lower K and higher Ca+ Mg.



K:Ca+Mg

Plot 8: Ratio of average K to average Ca + Mg for each mineral treatment. Note again the general trend toward a lower K:Ca+Mg ratio seen with dolomite additions.

Discussion

4SPAR

1.2

1

0.8

0.6

0.4

0.2

0

It must first be noted that this greenhouse experiment took place over the course of a single growing season with vines that had been grafted the previous year. Existing nutrient reserve in the plant tissue, which is important for new growth, cannot be ignored in this scenario. Plots 4, 5, and 6A-B demonstrate the effects of rootstock and individual vine history on health and growth. Plots 7 and 8 suggest a direct link between the relative potassium and pH levels of the root zone growing medium and plant tissue K, Ca, and Mg.

Note that dolomite additions to root zone substrates appear to have lowered plant tissue K, while increasing plant tissue Ca and Mg. This is consistent with (Bates et al 2002).

The amount of dolomitic lime used in these experiments is equivalent to approximately 4.5 tons/acre added to the top 6 inches of soil – or 27 tons/acre uniformly mixed in to a depth of 36 inches. These findings suggest that strategic dolomite additions to vineyard soils could help reduce the uptake of K relative to Ca and Mg. The extent to which dolomite additions might help winegrowers reduce K uptake and fruit pH will depend on site specific factors such as soil chemistry, texture, soil depth, drainage, plant available water, grape varieties, rootstocks, vineyard design and management.

Summary

- Year two of our study documents a direct link between bedrock chemistry and subsoil chemistry in younger soils; this relationship has major implications for site selection.
- Favorable soil chemistry (specifically lower potassium levels) can outweigh internal drainage rate in importance for wine quality as seen at Site O.
- Our laboratory trials implementing extended Mehlic extractions (carried out for 2 months) show that more K exists in the mineral form than appears during a standard 5 minute lab extraction.
- Our greenhouse trials show that growing medium chemistry does affect plant tissue chemistry.
- The broad use of terms such as "clay" or "sand" are often misunderstood as actual soil textural classifications are based on relative amounts of sand, silt, and clay. Additionally, clay mineralogy is often not considered when such terms are loosely used.
- Our greenhouse trials suggest that high rates of dolomite additions could help reduce vine K:Ca+Mg ratio. The extent of this effect and its implications for wine quality require site-scale studies in existing vineyards.

Future Work

- Implement similar sampling methodology at multiple locations within single vineyard blocks to eliminate confounding variables.
- Further examine how soil pH affects vine K status and fruit pH.

Significant Outreach Activities:

- July 2016: EM Mapping and Potassium Uptake: Deciphering Relationships Between Soil and Wine Quality. Oral Presentation at the *11th International Terroir Congress* (Ernest Beasley; McMinnville, OR). Paper published in conference proceedings.
- July 2016: Potassium Fertilizer Revisions (Tony Wolf) Virginia Cooperative Extension Viticulture Notes Vol. 31 No. 5, p. 4.
- Waypoint Analytical Laboratories (formerly A&L) has lowered their recommended optimal vinifera K ranges for both soil and petioles as a result of this work.
- March 2016: Soil and Wine Quality Workshop *Eastern Wineries Exposition* (Morton, Beasley; Lancaster, PA)
- January 2016: Is it Time to Reconsider Potassium Recommendations? VVA Winter Technical (Tony Wolf, Lucie Morton and Ernest Beasley; Charlottesville, VA)

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