VINEYARD NUTRIENT BUDGET AND SAMPLING PROTOCOLS

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Abstract:

Context and purpose of the study - Vineyard nutrient management is crucial for reaching production-specific quality standards, yet timely evaluation of nutrient status remains challenging. The existing sampling protocol of collecting vine tissue (leaves and/or petioles) at bloom or veraison is time-consuming. Additionally, this sampling practice is too late for in-season fertilizer applications (e.g. N is applied well before bloom). Therefore alternative early-season protocols are necessary to predict the vine nutrient demand for the upcoming season. The main goals of this project are to 1) optimize existing tissue sampling protocols; 2) determine the amount of nutrients removed at the end of the growing season.

Material and methods - Field trials were initiated in late summer 2020, and conducted through 2022 in commercial, drip-irrigated ownrooted vineyard blocks in arid eastern Washington. Three rates of K were applied in Chardonnay, and three and two rates of N were applied in Syrah and Concord, respectively. Dormant canes; whole shoots at the 5-6-leaf stage; leaves (blades and petioles) at bloom and veraison; and whole clusters at harvest were collected from each block for macro- and micronutrient analysis. Yield components and fruit composition were determined at harvest, and pruning weights were collected in winter. Vines were covered with bird nets after harvest, and leaves were collected after the first freeze for nutrient analysis.

Results - Blade and petiole nutrient concentrations were not well correlated with higher N concentrations and lower K concentrations in blades than petioles. The P and K concentrations in early-season shoots correlated with those in blades and petioles at bloom. There was no difference in yield components between the treatments in any vineyard block. Fruit harvest and leaf fall removed significant amounts of nutrients, depending on variety, crop yield, and vintage. On average across all varieties, 22 kg/ha of N, 5 kg/ha of P, 50 kg/ha of K and 3 kg/ha of Mg were removed at harvest and 6.4 kg/ha of N, 0.5 kg/ha of P, 2.9 kg/ha of K and 2.6 kg/ha of Mg were removed with leaves at leaf fall. Leaf fall constitutes an important loss of nutrients in addition to the loss in the harvested fruit. If the dead leaves remain in the vineyard, those nutrients may be available for vine uptake in subsequent growing seasons. However, if the nutrients are lost, they must be replaced through fertilizer addition to prevent the gradual buildup of nutrient deficiency and sustain vineyard productivity.

Keywords: Grapevine Nutrition, Vineyard Nutrient Management, Nutrient Sampling Protocol

1. Introduction

Management of vineyard nutrition is essential for achieving production-specific fruit quality goals, but the timely assessment of nutrient status is still difficult. Currently, the earliest time for plant tissue sampling is bloom. Accounting for the sample analysis time by commercial laboratories, this still makes it challenging to respond to a nutrient deficiency in a timely manner. Thus, fertilizers are often applied based on historical data. Moreover, current recommendations are based on studies conducted in California table grapes or northeastern U.S. juice grapes dating back to the 1940s and re-examined in the 1960s and 1980s (Ulrich 1942a, 1942b, Christensen 1969, 1984). Additionally, deficit irrigation, which is widely used in arid regions, can affect nutrient availability and uptake (Keller 2005). Consequently, relying on outdated recommendations may lead to ineffective nutrient management in dry regions. At the end of the growing season nutrients are being removed with the harvested fruit and recycled from the leaves to the permanent tissues of the vine. Therefore, nutrient

content of the emerging leaves after budbreak might be an indicator of the availability for the upcoming season. Also, nutrients that are removed from the vineyard with fruit during harvest and with leaves during leaf fall need to be accounted for while planning the fertilization program.

2. Material and methods

Plant materials – Field trials were initiated in late summer of 2020 and conducted through 2022 in Ste. Michelle Wine Estates (wine grapes) and Schilperoort Farm (juice grapes) drip-irrigated, own-rooted vineyard blocks in arid eastern Washington, USA. Three rates of K (0, 40, 80 kg/ha, as liquid potash) were soil-applied in Chardonnay, and three (20, 40, 80 kg/ha, as liquid urea ammonium nitrate) and two (40 and 80 kg/ha, as UAN32) rates of N were soil-applied in Syrah and Concord, respectively. All fertilizers were obtained from Bleyhl Co-op, Sunnyside, WA, USA. All trials had four replicated blocks.
Measurements - Dormant canes; whole shoots at the 5-6-leaf stage; leaves (blades and petioles) at bloom and veraison; and whole clusters at harvest were collected from each block for macro- and micronutrient analysis. Samples were sent to a commercial testing lab for analysis (Soiltest Farm Consultants, Moses Lake , WA, USA): Total N and C were analyzed by dry combustion (Dumas method, LECO CN628, St. Joseph, MI, USA); nitrate and ammonium were analyzed following KCl extraction (FIA Lab, SM4500NH3, colorimetric, Bellevue, WA, USA); P, K, S, Ca, Mg, Na, Zn, Mn, Cu, Fe were analyzed by ICP-OES (Perkin Elmer Optima DV7300, Waltham, MA, USA) following nitric/perchloric digestion. Cluster number and weight per vine were determine at harvest, and berries were collected and analyzed for total soluble solids (TSS) by refractometry (MT RE40D, Mettler-Toledo, Greifensee, Switzerland), titratable acidity (TA) by using an autotitrator (Titrino plus 848, Metrohm, Herisau, Switzerland) connected to a compact sample changer (869 CSC, Metrohm), and pH was measured using an MP225 Quattro pH-meter (Mettler-Toledo). Vines were enclosed with bird nets after harvest, and leaves were collected after the first frost for nutrient analysis to estimate the amount of nutrients remaining in the leaves at the end of the growing season. Pruning weights were collected in winter.
Statistical analysis - Data were processed using ANOVA procedures, and means were separated by Tukey's test using JMP 14 (SAS Institute, Cary, NC, USA).

3. Results and discussion

3.1. Effect of K and N application on tissue nutrient status.

In 2021 the P concentrations in early-season shoots correlated with those in blades at bloom in Chardonnay and Concord; K concentrations of shoots correlated with those in petioles at bloom in Chardonnay and Concord as well as with blades at bloom in Syrah and Concord. There was no correlation between N concentrations in early season shoots and those in blades or petioles at bloom. Additionally, no correlation was observed in 2022 between shoots and blades; petioles are currently being analyzed. Blade and petiole nutrient concentrations were not well correlated. Nutrient concentrations generally decreased from the 5-6 leaf stage (whole shoots) through bloom (leaf blades) and veraison (leaf blades), but the leaf Mg concentration increased from bloom to veraison. In Chardonnay, high (80 kg/ha) K slightly but significantly decreased N, and low (40 kg/ha) K increased P, K, and Mg in shoots collected at the 5-6 leaf stage. No consistent differences were found in leaf blades at bloom, but at veraison, the leaf-blade P was slightly lower, and K was much lower (45%), at the 0 kg/ha K rate, while Mg was lower at the 80 kg/ha rate. In Syrah and Concord, the N treatments did not affect N in shoots sampled at the 5-6 leaf stage or in leaf blades sampled at bloom and veraison. Cane tissues are currently being processed. The N and K treatments did not have any effect on yield in either wine grapes or juice grapes. On average across three years the yield was about 15 t/ha, 12 t/ha and 24 t/ha for Chardonnay, Syrah, and Concord, respectively. The average Brix was recorded as 23.1, 25 and 16.5 for Chardonnay, Syrah, and Concord, respectively; pH in Concord and Chardonnay was 3.5 while in Syrah it was 4, and TA in Concord was 10.5 g/L, while in Chardonnay and Syrah it was 6.3 and 5.1 g/L, respectively.

3.2. Nutrient loss at the end of the growing season.

On average across the three varieties and three years, fruit harvest removed about 1.3 kg of N, 0.3 kg of P, 2.9 kg of K and 0.2 kg of Mg with each ton of fruit (Table 1). While P removal was consistent across the years, more P was removed in the Syrah vineyard compared to Chardonnay and Concord. The fruit in wine grapes contained

the lowest amount of N in 2022 and the highest in 2021, while the least N in juice grapes was recorded in 2020. The juice grapes also contained more N and K than the wine grapes in 2022, while in 2020 N and K were lower in juice grapes compared to wine grapes. Syrah grapes consistently contained more P than those of Chardonnay and Concord. The fruit Mg concentration was the same for all three varieties during 2020 and did not change for Chardonnay throughout the years; however, Mg was slightly lower in Concord grapes in 2021 and 2022 and in Syrah during 2022. In addition to fruit harvest, leaf fall contributes to nutrient removal from the vines. If senescent leaves stay in the vineyard, then nutrients can be gradually incorporated by soil microorganisms back into the vineyard soil. However, if winds blow those leaves away, significant amounts of nutrients can be lost (Table 2). There were large differences in end-of-season leaf nutrients among growing seasons and varieties. In 2022 the N, P and K amounts in juice grape leaves were much higher than those in wine grapes, while Mg in Concord was similar to that in Chardonnay and double that in Syrah. With the exception of P, nutrient losses via leaves in wine grapes seem to be higher in late seasons when leaves remain green until they are killed by the first frost (2022). When a frost kills leaves before their nutrients have been recycled back to the vines, then those vines have lower stored nutrients available to support budbreak in the following spring. At least in young vines, spring growth and fruiting may be more dependent on mineral nutrient reserves than on carbohydrate reserves (Cheng et al., 2004). Such seasonal differences should be taken into account when developing vineyard nutrient budgets for fertilizer recommendations.

4. Conclusions

Shoots at the 5-6 leaf stage might be an option for early season sampling, but more work needs to be done to provide any solid recommendations for nutrient sampling protocol adjustments. Nutrients are being removed with fruit during harvest which needs to be addressed when preparing fertilization plans for the following growing season. Moreover, nutrient loss with leaf fall is not negligible and may vary based on vintage, variety, and/or timing of first frost. If the dead leaves remain in the vineyard, those nutrients may be available for vine uptake in subsequent growing seasons. However, if winds blow the leaves out of the vineyard, the nutrients are lost and must be replaced through fertilizer addition to prevent the gradual buildup of nutrient deficiency and sustain vineyard productivity.

5. Acknowledgments

This study was funded by USDA-NIFA Specialty Crop Research Initiative, Washington State Grape and Wine Research Program, USDA/WSDA Specialty Crop Block Grant Program, and Washington State Concord Grape Research Council. Ste. Michelle Wine Estates provided wine grape vineyards, Schilperoort Farms provided juice grape vineyard, Soiltest Farm Consultants provided services for tissue analysis. We thank the Keller lab members for helping with data collection. Additional thanks to the Rippner lab members and Maria Mireles (Moyer lab) for field and lab work assistance.

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Table 1. Amounts of N, P, K and Mg (kg/ton) removed with harvested fruit in Chardonnay, Syrah and Concord grapevines over three years.

	N			P			K			Mg		
Variety	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
Chardonnay	1.2 b AB	1.3 b A	1.1 c B	0.3 b	0.3 b	0.3 b	3.4 a A	2.8 b B	2.6 b C	0.2	0.2 a	0.2 a
Syrah	1.3 a B	1.6 a A	1.2 b B	0.4 a	0.4 a	0.4 a	3.2 a A	3.2 a A	2.7 b B	0.2 A	0.2 a A	0.1 b B
Concord	1.0 b C	1.6 a A	1.4 a B	0.3 b	0.3 b	0.3 b	2.8 b C	3.2 a B	3.3 a A	0.2 A	0.1 b B	0.1 b B

Lowercase letters indicate significant differences within columns, capitalized letters indicate significant differences within rows at P=0.05 using the Tukey HSD test.

Table 2: Amounts of N, P, K (kg/ha) lost during leaf fall in Chardonnay, Syrah and Concord grapevines over three years.

	N			P			K			Mg		
Variety	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
Chardonnay	5.8 B	4.7 b B	7.4 b A	0.5	0.4 b	0.5 b	4.4 B	2.2 C	7.7 b A	2.8 B	2.5 B	4.2 a A
Syrah	7.2	8.0 a	8.7 b	0.6	0.6 a	0.5 b	2.9 B	2.3 B	4.6 c A	2.0 B	3.1 A	2.8 b AB
Concord	nd	nd	31.8 a	nd	nd	3.6 a	nd	nd	17.3 a	nd	nd	4.9 a

Lowercase letters indicate significant differences within columns, capitalized letters indicate significant differences within rows at P=0.05 using the Tukey HSD test.