Monitoring and Interpreting Vine Mineral Nutrition Status for Wine Grapes

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Monitoring vineyard mineral nutrition has become increasingly important and complex as we plant vineyards into more diverse sites and differing scion-rootstock combinations. While tissue analysis is the most common laboratory technique used for this purpose, the monitoring should also integrate information on soil chemical and physical characteristics, irrigation water analysis, known rootstock and variety requirements, fertilizer history, and observations of vine growth.

Use of Soil Analysis

Soil analysis is primarily used to determine soil chemical problems or nutrient imbalances. This includes problems related to pH, salts, permeability (excess sodium or very acid pH), toxic ions (chloride and boron), and imbalances of magnesium, calcium and potassium. Growers may also wish to have some nutrient analyses run to establish base-line levels or to anticipate potential mineral nutrition problems in new plantings. However, nutrient analysis of soil should not be used to guide routine fertilizer practices.

Basically, it has not been possible to establish critical soil mineral nutrient values for grapevines. This is due to the many soil and plant factors that influence vine uptake and utilization. Soil analysis does not take into consideration the influence of rootstock, cultivar, soil depth, root distribution, soil water status through the season, crop load, soil pests, and rate of nutrient availability. In this discussion, rootstock nutrition will be used to demonstrate the importance of one of the above factors.

Rootstock Influence on Mineral Nutrition

Rootstock trials throughout the State have demonstrated the profound effect that rootstocks have on scion mineral nutrition. It was also shown that rootstocks tend to rank similarly across planting sites. For example, Freedom usually ranks high for K uptake in all trial sites, while 110R is among the lowest. This has enabled us to generally rank rootstocks according to their potential influence on scion mineral nutrient status. Table 1 gives the general ranking of rootstocks for NO_3-N, P, K and Zn. The information was developed from Cooperative Extension Farm Advisor trials in 7 Counties -- from Sonoma to Santa Barbara in coastal districts and from San Joaquin to Kern in central valley districts. The data were based on comparative bloom time petiole concentrations in the scions over 3 or more years of study.

Tissue Analysis

Tissue analysis is a direct measure of the plants' status based on their ability to absorb, accumulate and utilize mineral nutrients. Therefore, its determination involves all of the above soil and plant factors and avoids the limitations of soil analysis. It is also easy to perform and is repeatable, making it easy to track changes during the season and from year to year.

Why Petioles?

Methods of tissue analysis have been studied since its inception. Pioneers in vine tissue analysis -- Albert Ulrich, Nelson Shaulis and James Cook -- found leaf petioles to be generally preferable over other tissues, including leaf blades. Petiole surfaces tend to have less surface contamination than blades. Other reasons include ease of sampling, handling, washing and drying petiole tissue. Petiole samples also represent more individual shoots and vines as compared to blades. This is because it takes 2 to 3 times more petioles to make up the same amount of dry tissue as compared to blades. Most importantly, we have more experience and data on which to base petiole critical values, and petioles show a greater range in values for nitrate-N (NO_3-N), phosphorus (P), potassium (K), magnesium (Mg), and zinc (Zn). Therefore, fertilizer response and deficient and excess values of these elements are more easily defined with petioles.

Limitations of Tissue Analysis

Critical bloom time petiole values (deficient, adequate and possible excess) have been established for all of the important nutritional elements with the exception of Fe and NO_3-N. The problem with Fe is that there is no relationship between Fe values and the presence of deficiency symptoms. Iron levels in deficient tissues are typically just as high as those in normal tissues. Most Fe deficiencies occur in calcareous soils, which affect Fe availability within the plant without affecting Fe concentration.

While critical NO_3-N values have been established for Thompson Seedless, they are lacking for other varieties. It is well known that petiole nitrate levels can vary widely among varieties and rootstocks. They are also strongly influenced by weather conditions and sampling location within canopies. Therefore, nitrate levels are very site specific, and critical values would have to be developed for every scion-rootstock combination in every district -- an insurmountable task.

Exploring Other Measurements of N Status

Other methods evaluated for N status include arginine in roots, canes and fruit, ammonium-N (NH_4-N) and total inorganic-N (NO_3 + NH_4) in petioles, and total-N in leaf petioles and blades. All of these methods have shown important limitations. The main problem with leaf petiole or blade total-N is that the range in content is much smaller than that of NO_3-N or NH_4-N among vines receiving low to high amounts of N. Thus, the defining critical ranges for deficiency and excess would be rather narrow. However, the

greater stability of total N values, as compared to NO_3-N and the adoption of total N for diagnosis in other countries prompted further study into its application for California conditions.

A Comparison of Leaf N Analysis Methods

Vineyard field trials were conducted over four years to compare leaf petiole and blade concentrations of NO_3-N and total-N in eight cultivars. The trial vineyards, consisting of Barbera, Cabernet Sauvignon/5C, Chardonnay/5C, Chenin blanc, French Colombard, Grenache, Ruby Cabernet and Thompson Seedless were located in the San Joaquin Valley and Central Coast. Comparative N fertilizer treatments ranged between 0 and 400 lbs N/acre for the San Joaquin Valley and 0 and 100 lbs N/acre for the Central Coast. Leaf petiole and blade samples were taken at three phenological stages -- bloom, veraison and harvest. Fruit composition and vine yield parameters were measured each year to compare vine response to fertilizer treatment and to correlate response to tissue N and NO_3-N concentrations at various growth stages.

How the Leaf Analysis Methods Compared

As expected, petiole NO_3-N levels were the most responsive to N fertilizer treatment. However, they also showed the greatest variation among the years of study and cultivars. Overall, the poorest relationship of vine N response and tissue analysis was with total N in leaf blades, especially at bloom. Surprisingly, blade total N sometimes showed little difference, whether the vines received 0 or 400 lbs N/acre, even over a 4-year period. In contrast, total-N and NO_3-N of petioles most often showed significant relationships to N treatment and responses. However, the tissue levels at which one could expect N deficiency or excess varied among the cultivars/sites. Therefore, it is necessary to report a range of tissue concentrations at which deficiency or excess may occur. These are given in Table 2.

The values in Table 2 show the ranges where N deficiency and excesses may occur for petiole NO -N, petiole total-N and blade total-N. For example, N deficiency may occur between 50-350 ppm NO_3-N and 0.65-0.9 % total-N in bloom petioles and 2.6-3.4 % total-N in bloom blades, depending on cultivar/site. However, the threshold for excess N effects is just above this range for petioles (>350 ppm NO_3-N and >0.9 % total-N). This means that vines with petiole levels below 350 ppm NO -N and 0.9 % total-N should be checked with deficiency in mind whereas excess effects should be checked with levels above this threshold. The lack of spread between the deficient and excess ranges resulted from the wide ranges experienced among the cultivars and years of study.

Note the overlapping between the deficient and excess ranges for blade total-N. This resulted from the poor relationship between blade total N-and N fertilizer effects. This demonstrates the futility in trying to use bloom blade N values as a diagnostic tool.

The critical ranges for the N determinations mostly decline through the season from bloom to harvest. There is less overlapping of deficiency and excess ranges for blade

total-N at veraison and harvest as compared with bloom. Thus, blade total-N becomes more useful at veraison and harvest. However, blade values were more often poorer than petiole values in their relationship to N effects.

The results are encouraging because we now have some critical ranges for analysis other than bloom NO_3-N. However, they are disappointing in that we still do not have a definitive critical value for all cultivars and situations. This is not surprising, considering the environmental and physiological dynamics of N and the inherent differences among cultivars and rootstocks. Therefore, we will have to deal with a range of critical values and depend mostly on observation and judgement in guiding fertilizer practice.

Assessment of N Need

Tissue analysis for N assessment still has its limitations. Therefore, N fertilizer decisions must necessarily depend heavily on subjective criteria rather than laboratory numbers. The following factors should be taken into consideration:

- Vine vigor
- Canopy density
- Cultural requirements of the cultivar and site
- Knowledge of N inputs -- fertilizer, irrigation water, cover crop, etc.
- Soil and root conditions
- Laboratory tissue analysis
- Baseline soil chemical analysis

The trial results described above have established some threshold levels for N tissue analysis. However, the values consist of ranges in which deficiency or excess may occur. Thus, a vineyard will either be in a possible deficient or possible excess range due to the meeting or overlapping of ranges. Unfortunately, the "normal" or "adequate" range for each vineyard situation is somewhere within these ranges. Therefore, tissue analysis should only be used as a general guide toward establishing norms for individual vineyard blocks. The decision of whether or how much fertilizer to apply rests on grower judgement. Building a tissue analysis data base, along with visual assessment, should help to establish how individual blocks fit within these guidelines.

Table 1

General Ranking of *Vitis* Rootstocks for Nitrate-Nitrogen, Phosphorus, Potassium and Zinc from Mean Bloom Petiole Values in Comparative Vineyard Trials

	HIGH	**MEDIUM**	**LOW**
NITRATE-NITROGEN	039-16 Freedom St. George Ramsey	101-14Mgt 5BB 1103P 3309C Schwarzmann 44-53M 110R	Harmony 5C 1616C 420A
PHOSPHORUS	110R 1103P Ramsey Freedom	Harmony 5C 5BB 039-16 Schwarzmann	St. George 420A 101-14Mgt 3309C
POTASSIUM	Freedom St. George Schwarzmann 44-53M 1616C Harmony 039-16 101-14Mgt	5C 5BB Ramsey 3309C	1103P 140Ru 110R 420A 5A
ZINC	*Vitis vinifera* (own roots)	110R 3309C 101-14Mgt 5BB 5C 1103P 420A	039-16 Freedom Ramsey Harmony

Table 2

Critical Value Ranges for Nitrate-N and Total-N in Petioles and Blades at Three Phenological Stages. Onset of Deficient and Excess N Effects May Occur Within Each Range. Trial Data of Eight Cultivars.

	BLOOM		VERAISON		HARVEST	
	Deficiency	Excess	Deficiency	Excess	Deficiency	Excess
PETIOLES						
NO_3-N ppm	50-350	350-1000+	50-200	200-750+	50-200	200-750+
Total-N %	0.65-0.9	0.9-1.2+	0.65-0.85	0.85-1.2+	0.6-0.8	0.8-1.1+
BLADES						
Total-N %	2.6-3.4	2.8-3.5+	2.5-3.1	3.1-3.5+	1.8-3.0	2.8-3.4+