Fertilization and Nutrition

The condition of your vineyard soil will affect the health of your vines, their productivity, and their ability to withstand drought, pests, and the rigors of the Minnesota winter. Visual inspection to determine nutritional health in the vineyard is at best a shot in the dark approach and by the time symptoms of deficiencies show, it is often too late. This section will discuss recommendations for fertilizing prior to planting and for a bearing vineyards.

Soil testing:

Pre-plant: Soil analysis before planting a vineyard is a very important practice that is extensively covered in the ***Considering Growing Grapes*** section of this publication. With information on the soil type, this analysis aids in determining if your site is suitable for grapevines. Tests should include: pH, phosphorus (P), potassium (K), magnesium (Mg), zinc (Zn) and organic matter (OM). Samples should be collected for each soil type and cropping history. Results from the tests will determine if the soil pH needs to be adjusted, if any major nutrient amendments are required, and provide some guidance on nitrogen fertilization practices (**Table 29**). Some nutrients are very immobile in the soil and for this reason any required P, K and Ca (lime) that are indicated by soil analysis, should be applied and tilled into the soil as deeply as possible before planting grapevines.

Table 29. The desirable soil test ranges for grapes.

Test	Desired Range	As pounds/acre[z]	Optimized as
Soil pH	6.0 to 6.5 *or* 7.0		
Organic matter	2 to 3 *or* 4 %	40 to 60 *or* 80	
Phosphorous (P)	>30 ppm	>60	140 lb/A as phosphate (P_2O_5)
Potassium	>150 ppm	>300	360 lb/A as potash (K_2O)
Magnesium (Mg)	100 to 125 ppm	200 to 250	
Boron (B)	0.75 to 1.0 ppm	1.5 to 2.0	
Zinc (Zn)	3 to 4 ppm	6 to 8	
Manganese (Mn)	>6 ppm	>12	

[z] Per plow slice or 8-inches of soil depth.

Bearing vineyards: Soil analysis is only good for some nutrients. Soil analysis does not give an accurate indication of the nutrient status of the vine. The value of soil analysis is in the determination if problems related to certain chemical imbalances or excesses such as pH problems exist. With the many types of vineyard soils, the grapevines' deep and far-ranging root system, and the inherent differences in nutrient uptake by different cultivars are largely to blame for the inability to correlate soil nutrient levels and vine nutrient status. Once the vineyard comes into production, tissue analysis will provide a more accurate measure of most essential nutrients in the vines and allow for fine-tuning of the fertilizer program. Tissue analysis in vineyard nutrition is much more effective and reliable than soil analysis. However, if the soil pH required adjustments before planting, a periodic soil analysis is advised.

Tissue Analysis:

Leaf or petiole (leaf stem) analysis can be used to diagnose or confirm nutrient problems after symptoms are present. More importantly, it is a powerful management tool in determining the nutritional needs of the crop. This is achieved by identifying nutritional shortages or excesses before symptoms develop. Often leaf or petiole analysis will reveal that certain fertilizers that are being applied are not needed, resulting in a more economical fertilizer program (Domoto, 2011, Rosen and Domoto 2013).

Leaf or petiole analysis should not be used until the vineyard comes into production unless visual symptoms are evident. Sampling time for petiole analysis is important because nutrient concentrations in the leaves and petioles change during the growing season. This is most evident for N and K that decline rapidly from bloom to harvest. The two recommended times for sampling leaves and petiole for tissue analysis are at bloom and the period from mid-July through mid-August *or* early veraison when berries begin to soften and change color. For the at bloom sampling time leaves or petioles are collect from nodes opposite of the first cluster, and for the mid-season sampling they are collected from the most recently fully-expanded leaf from fruit-bearing shoots - typically the 5th to 7th leaf from the tip (**Figure 33**).

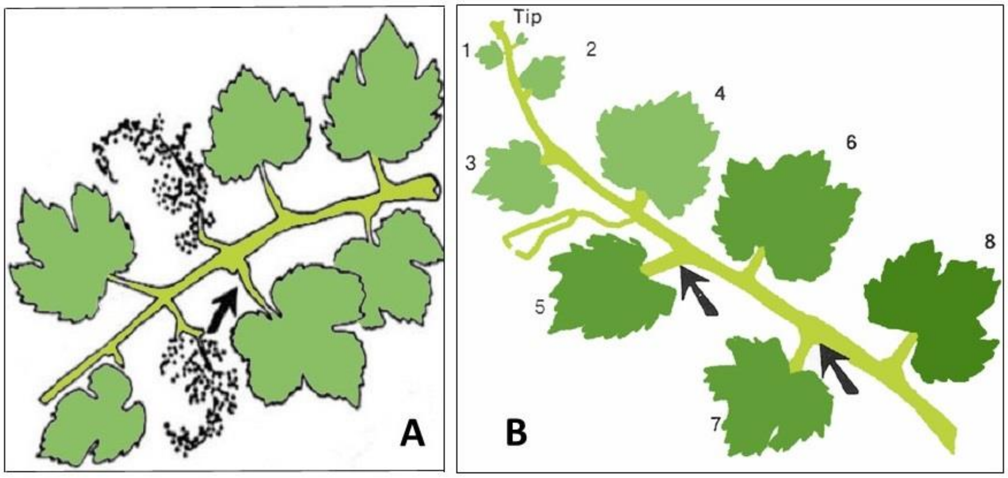


Figure 33. Position of leaves and petioles collected for tissue analysis at full bloom (A) and during the mid-July to mid-August (early veraison) (B) sampling periods. (Adapted from: *Grapevine Nutrition and Fertilization in the San Joaquin Valley*. 1978 Univ. of California publ. 4087)

Because the nutrient concentrations in the grapevines are changing during the season, sufficiency ranges are different for the two sampling periods (**Table 32**). Those changes are more rapid early in the growing season making the full bloom normal range much wider than the normal range at mid-summer, therefore the preferred time to sample for petiole analysis is during the mid-July to mid-August period with any adjustments of the fertilizer program aimed at the next growing season. However, analyzing for N and B at bloom would allow you to make any collections in your fertilizer program that season.

Table 30. Normal mineral nutrient ranges for grapes based on petiole analysis performed on tissues collected at full bloom and during the mid-July to mid-August (early veraison) sampling periods.

	Full Bloom[z, x]	**Mid-July to Mid-August (*early veraison*)[y, x]**				
Nutrient	**Normal range**	**Deficient**	**Below normal**	**Normal**	**Above normal**	**Excessive**
Nitrogen (N) %	1.60-2.80 (*2.50*)	0.30-0.70	0.70-0.90	0.90-1.30	1.40-2.00	>2.10
Phosphorous (P) %	(*0.16*) 0.20-0.60	0.12	0.13-0.15	0.16-0.29	0.30-0.50	>0.51
Potassium (K) %	1.50-5.00 (*4.00*)	0.50-1.00	1.10-1.40	1.50-2.50	2.60-4.50	>4.60
Calcium (Ca) %	0.40-2.50	0.50-0.80	0.80-1.10	1.20-1.80	1.90-3.00	>3.10
Magnesium (Mg) %	(0.20) 0.13-0.40	0.14	0.15-0.25	0.26-0.45	0.46-0.80	>0.80
Sulfur (S) %	No data (>*0.10*)	No data	No data	No data (>*0.10*)	No data	No data
Manganese (Mn) ppm	18-100	10-24	25-30	31-150	150-700	>700
Iron (Fe) ppm	40-180	10-20	21-30	31-50 (*100*)	(*101*) 51-200	>200 ?
Boron (B) ppm	25-50	14-19	20-25	25-50	51-100	>100
Copper (Cu) ppm	5-10	0-2	3-4	5-15	15-30	>31
Zinc (Zn) ppm	20-100	0-15	16-29	30-50	51-80	>80

[z] From Mills, H.A., B.J. Jones, Jr. 1996. *For American hybrids*. Plant Analysis Handbook II. MicroMacro Publ., Inc, Athens, GA
[y] From Dami, *et al*. 2005. Midwest Grape Production Guide. Ohio St. Univ. Ext. Bull. 919
[x] Values in italics developed for Minnesota and Iowa by Drs. C. Rosen and P. Domoto.

Separate petiole samples should be collected from each cultivar, from the same cultivar on different soil types or areas with a different history of fertilization practices. A sample of 100-150 petioles (150-200 from cultivars with short petioles) for analysis should be collected from random vines representative of the cultivar in the vineyard. If the tissue analysis is being use to diagnose a problem, samples can be collected at any time, and separate samples should be submitted from affected and healthy vines (Domoto 2011, Rosen and Domoto 2013).

Petiole samples should be submitted to a laboratory that performs soil and tissue analysis (*See* listing of laboratories in the **Resources** section). It is best to check with the laboratory before collecting the sample(s) to find out if they have any special instructions on sampling procedures, sample preparation, information on current and past cultural practices, pricing and to obtain sampling containers. If the lab does not provide sample containers, the petioles should be placed in common brown paper bag. For more information on petiole sampling procedure *See* **Collecting Grape Petioles for Tissue Analysis** (Domoto, 2011). Tests that should be performed include: total N, P, K, Mg, Ca, S, Mn, Fe, B, Cu and Zn.

When you get the test results back, it will include an interpretation on the sufficiency range of each mineral nutrient. However, this interpretation is computer-generated and the standard ranges being used are often for samples collected at bloom for *vinifera* cultivars. Therefore, check your results with the values listed in **Table 30**. For further assistance in interpreting the results, contact your state's Extension viticulture specialist listed in the **Resources** section.

To fully implement a sound vineyard fertilizer management program, record keeping is essential. Records should be maintained on each cultivar and petiole sampling area for:

- Annual soil and foliar fertilizer applications.
- Petiole analysis results.
- Average annual pruning weights from sentinel vines.
- Annual yield from sentinel vines and total yield for the plot.
- Average cluster weight from sentinel vines.

This information will allow you to fine tune your pruning and fertilizer practices by making adjustment based upon the previous season's results and longer term trends.

Minnesota concerns: [z]

Nitrogen (N) ....too high on organic soils

Phosphorous (P)...........................low mostly in western Minnesota

Potassium (K) ....low on sandy soils and high Mg soils

Magnesium (Mg) ....high on glacial soils with marine origins - low on sandy soils

Zinc (Zn).......................................often low or deficient in petiole samples

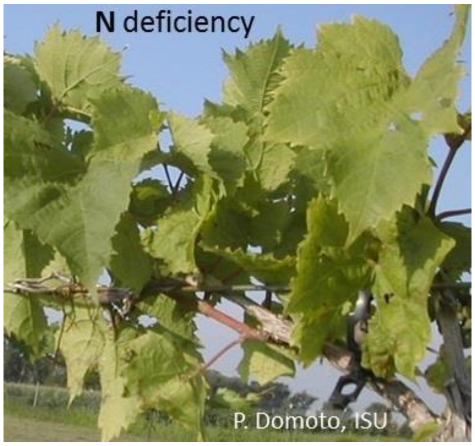
Manganese (Mn)..........................low on high pH soils

Boron (B) ....low on many soils, particularly on sandy soils

Iron (Fe) ....low on high pH soils

[z] *From:* "Vineyard Fertilization Working to Get it Right" a presentation given by P. Domoto at the MGGA Cold Climate Conference in 2006.

Nitrogen



Nitrogen deficiency commonly occurs in grapevines. Low N symptoms include the oldest leaves exhibiting a light-green to yellowish-green color, poor vegetative growth and reduced fruit set.

Nitrogen should be applied when vine uptake is rapid, and N rates should not exceed vine requirements. Nitrogen inputs from mineralization of soil organic matter (**Figure 34**) must be considered when determining N fertilizer requirements. The principal objective of N fertilization is to maximize crop development rather than vegetative growth. Grapevines have a small N demand relative to many other fruit crops. Nitrogen is most critically needed by grapevines during the period of rapid shoot growth in the spring through bloom and early berry development. The need for N declines from midsummer to senescence (Peacock, B., P. Christensen, and D. Hirschfelt. 1998).

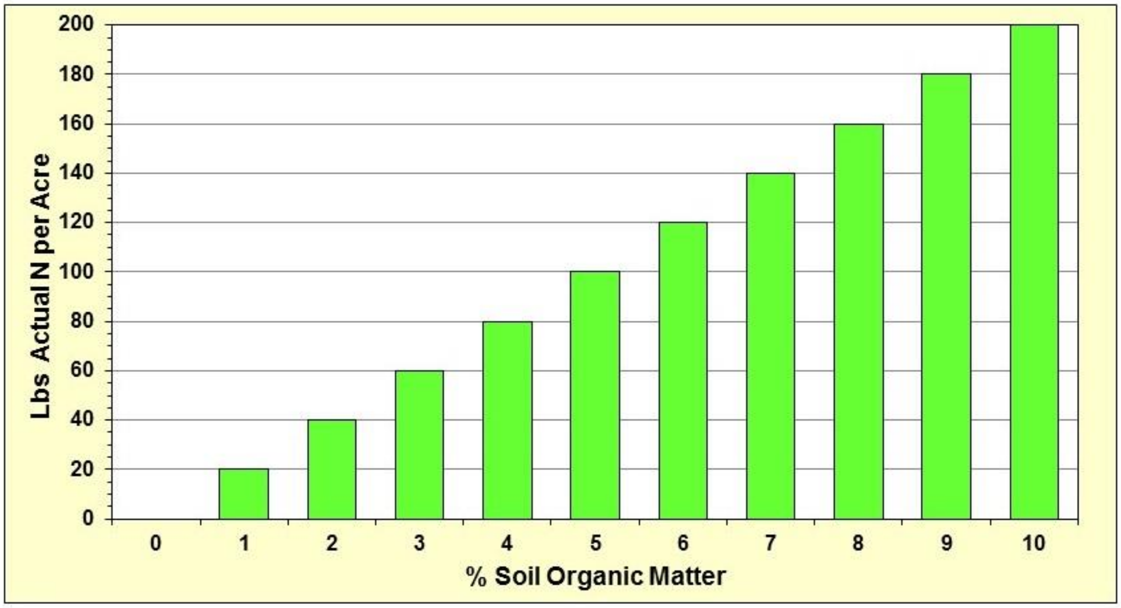


Figure 34. Annual nitrogen released from soil organic matter through mineralization.

Grapes require 40 to 50 pounds of annual nitrogen per acre. Soil with organic matter less than 3% may need added nitrogen the first and second year and supplemental nitrogen based on petiole analysis and the weight of vine trimmings removed in future years. About 0.4 to 0.6 oz. of actual N should be applied around each vine and the remainder broadcast applied. Ammonium sulfate (21-0-0) should be used whenever the soil had to be acidified before planting and urea (46-0-0) can be used whenever the soil pH is in the desired range for grapes (Rosen and Domoto, 2013).

Nitrogen utilized for the initial growth of grapevines up to about bloom is from reserves stored in the roots, and studies have shown that supplemental N applications are most effective when the N becomes available around bloom. The form of N applied also affects its availability. Nitrate (NO_3) forms of N (NO_3-N) are readily available to grapevines and can be applied close to bloom. Ammonium form of N (NH_4-N) must convert to NO_3-N before being take up and needs to be applied much earlier. Some urea can be taken up by grapevines and the remainder needs to convert to NH_4-N and then to NO_3-N before being taken up. Therefore, urea can be applied intermediate between NO_3-N and NH_4-N applications. On sandy soils, it is best to apply the N in split applications, half around bud break and the other half about 4-6 weeks later.

Potassium

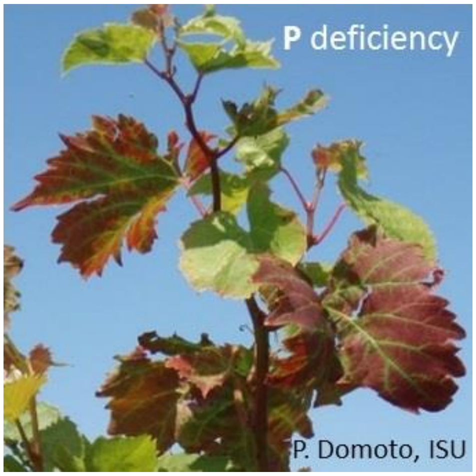
Grapevines require high amounts of potassium (K), and deficiencies are common, particularly when vines are carrying a heavy crop. Potassium deficiency symptoms begin to appear in early summer as yellowed (chlorotic) leaf margins of leaves on the middle portion of the shoot. As the season progresses, leaf margins may take on a burned appearance, the leaf may curl upward or downward, and dead areas may appear between the veins. On some cultivars purple or blackened leaf blotches may appear later in the growing season.

The potassium concentration in grapevines can range from 1% to 4% on a dry weight basis, depending on what vine part is sampled and when. That represents a considerable amount of K incorporated into the roots, trunk, shoots, and fruit of a vineyard. Deficiency is likely to occur in cut areas, where the K rich surface soil was removed during land leveling, or on very sandy soils that have low native K fertility. Deep placement of K fertilizer in a concentrated band close to the vine is the recommended application approach. Treatment can correct deficiency for 5 to 10 years, depending on deficiency severity and rate of application (Peacock, 1999).

Potassium is relatively immobile in the soil and if applied to the surface may take several years to move down to the roots. For this reason apply K before planting and incorporating it as deep as possible is recommended. The amount of potassium to apply should be based on the soil analysis and adjusted to a minimum of 150 ppm. After year two, petiole analysis will confirm if the vines are receiving adequate K. Excessive levels of magnesium (Mg) in the soil can inhibit the uptake of K and requires additional applications of K to correct the problem. A petiole analysis with determine if this is a problem.

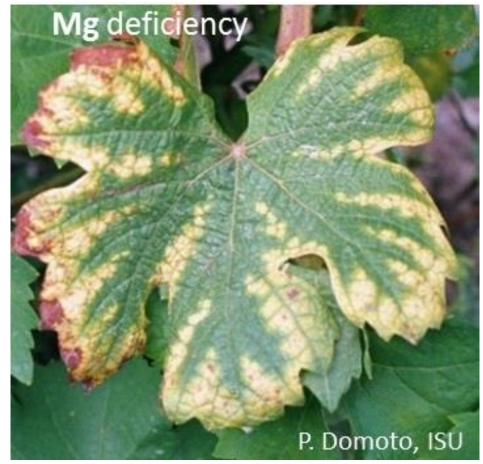
When low K or a deficiency is detected in an established vineyard, it is corrected with high applications of potash (K_2O) fertilizer ranging from 200-400 pound per acre applied in band under the vines. Because it takes time for the soil-applied K to move down to the roots, foliar applications of K are often needed initially to supplement the soil treatment. Foliar applications of K are absorbed by the leaves and can be included in your insect and disease spray program.

Phosphorus



Phosphorus is important for root development in young vines, as well as having a host of effects on mature vines, including wood maturation and fruitfulness. Phosphorus deficiency often shows up as reddened foliage, similar to symptoms that show up on vines suffering from winter trunk injury or crown gall that have restricted the flow of nutrients and carbohydrates to and from the roots. Phosphorous deficiency is extremely rare in Minnesota, and it is unlikely that a grower would have to amend his vineyard soil with additional phosphorus. Because P is so immobile in the soil, pre-plant soil testing and optimizing P before planting is the best solution to avoiding P deficiency issues. Phosphorous deficiency can occur on very sandy soils, but a fairly easy to correct because these soils have a low cation exchange capacity and do not tie-up the P.

Magnesium



Magnesium (Mg) may be deficient on sandy soils or can excessively high on glacial soils with marine origins that are common to the upper Midwest. Symptoms of Mg deficiency show up as interveinal chlorosis on the older leaves and can progress to marginal scorching. Magnesium is considered somewhat mobile in the soil and if applied to the surface it will be available to the roots. Correcting Mg is dependent on the soil pH. If the pH is below 6.0, dolomitic lime can be applied to raise the pH to 6.5. If the soil pH is in the desired range, low or deficient Mg can be corrected with soil applications of 50-100 lb/A of magnesium oxide (MgO) or 300-600 lb/A Epson salt ($MgSO_4$). Low Mg can corrected with foliar applications of Epson salt applied at a rate of 10 lb per 100 gallons of water in two post-bloom applications.

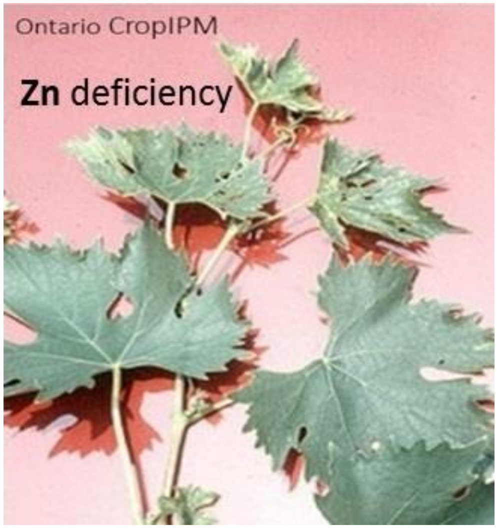
Trace Minerals

Boron (B) is involved in fruit set, so a common deficiency symptom is clusters with few berries. Its availability can be low on many Midwest soils and deficiencies are showing up in some northern vineyards on sandy soils. Care must be taken to add only the amount indicated by analysis as the range between boron deficiency and toxicity is narrow. Boron is considered mobile in the soil and can be applied to the soil surface. For pre-plant applications, the amount of boron to apply should be based on soil analysis and adjusted to .75 to 1.0 ppm. After the vineyard comes into production, petiole analysis will confirm if the vines are receiving adequate boron. If there is a shortage of B, it can be corrected with a soil application of 2-4 pound of B per acre. However, annual foliar applications often work better. Pre- and post-blooms of Solubor (20% B) applied at a rate of 2-4 lbs per acre beginning then the shoots are about 3-inches long is the recommended practice. You will need to consider if the post-bloom application is needed based experience and whether the cultivar forms loose or tight clusters.

Iron (Fe) can be deficient on high pH soils and some sandy soils. Symptoms of Fe deficiency are commonly referred to as “iron chlorosis” where the area between the leaf veins is light yellow to white in color and the area close to the veins remains green. The youngest leaves will appear to be almost “bleached out”. These symptoms can be temporary in vineyards that have been recently limed and on soils that become waterlogged.

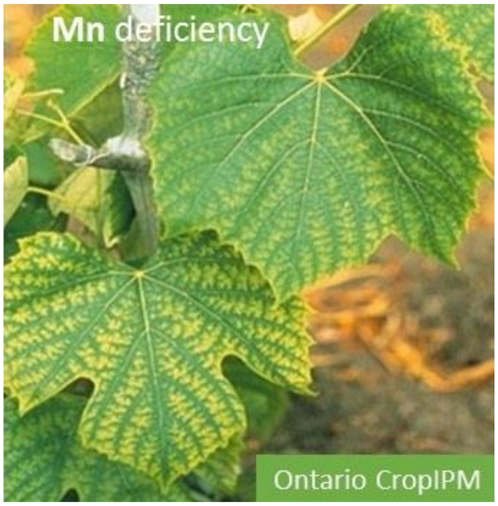
Practices to correct low or deficient Fe include taking measures to lower the soil pH, improving the internal drainage, and not applying more than 2 tons of lime per acre at a time in established vineyards. Soil applications of iron (ferrous) sulfate are not effective in correcting Fe deficiency. Some forms of chelated Fe can be used for soil treatments, but they are expensive and last for about a year. The three common chelating agents for Fe are EDTA, DTPA and EDDHA, and the soil pH is an important factor it their ability to keep the Fe soluble (EDTA up to 6.3, DTPA up to 7.5; EDDHA from 4.0 to 9.0). Foliar applications of ferrous sulfate or iron chelate are often the best approach for correcting low or deficient Fe when applied at 10 to 14 day intervals starting early in the season. They use less material than soil treatments and provide a quick response.

Zinc (Zn) can be low on sandy, high pH, eroded, and terraced or leveled soils. Zinc deficiencies have been observed in some Minnesota vineyards on gravelly soils. Symptoms include small misshapen leaves on shoots with short internodes with a zig-zag growth pattern. On clusters, reduced fruit set and the presents of many “shot” (small green) berries can be a sign of Zn deficiency. The term “little leaf” is often used to describe well the stunted appearance of new growth. Zinc is considered very mobile in the soil and can be applied to the soil surface. Optimizing the soil pH and Zn before planting will reduced the potential for Zn deficiency. The amount of zinc to applied before planting grapes should be based on the soil analysis and adjusted to 3 to 4 ppm (6 to 8 lb/A). When the vineyard comes into production, petiole analysis will confirm if the vines are receiving adequate zinc. Low or deficient Zn can be corrected through the use of early season Zn-containing fungicides [mancozeb (2% Zn, 66 day PHI), Ziram (16% Zn, 10 day PHI)] or foliar applications of Zn-chelates.



Manganese (Mn) can be low on grapes growing on sandy or high pH soils. Symptoms show up beginning as yellow spots between the veins on young normal sized leaves that progress to interveinal chlorosis on older leaves. Optimizing the soil pH before planting will reduce the potential for Mn deficiency. Once the vineyard comes into production, petiole analysis should be used to determine the status of Mn. Low Mn can be corrected through the use of earl season Mn-containing fungicides [mancozeb (16% Mn, 66 day PHI)] or foliar applications of Mn-chelates.

On acid soils, Mn toxicity can be a problem. To reduce the risk of toxicity, soils should be limed before planting to raise the pH into the 6.0 to 6.5 range.



Vineyard Best Management Practices – Care of Established Vineyards

Rate your vineyard establishment practices:

Management Area: **Fertilization and nutrition**	**Best Practices**	**Minor Adjustments Needed**	**Concern Exists: Examine Practice**	**Needs Improvements: Prioritize Changes Here**
Pre-plant soil testing	Conducted soil tests of the vineyard site for each soil type, and optimize the soil pH, status of important nutrients before planting.	Conducted a soil test of the vineyard site, and optimize the soil pH, status of important nutrients before planting.	Conducted a soil test(s) of the vineyard site after planting, and attempted to optimize the soil pH, status of important nutrients before planting.	Did not conducted a soil test(s) before or after planting the vineyard.
Non-bearing years (Years 1 & 2) **fertilization**	Applied N fertilizer annually, adjusting the rate based on the soil OM content.	Applied some N fertilizer annually without adjusting for the soil OM content.	Vines growth was vigorous, did not apply any N fertilizer.	Vine growth was poor, did not apply any N fertilizer.
Production years: Petiole analysis	Conducted annual petiole analysis for each cultivar & different soil types, and applied fertilizer based upon the results.	Conducted petiole analysis every 2-3 years for each cultivar & different soil types, and applied fertilizer based upon the results. Maintained records of test results and vine performance.	Conducted a petiole analysis when vines exhibited abnormal symptoms, and applied fertilizer based upon the results.	Conducted a soil test when vines exhibited abnormal symptoms, and applied fertilizer based upon the results.
Production years: Record keeping	Maintained organized annual records on petiole analysis test results, fertilizer practices, pruning weights, fruit yield and average cluster weights.	Maintained some records petiole analysis test results, fertilizer practices, and pruning weights.	Did not maintained some records on pruning weights and fertilizer practices	Did not maintained any records petiole analysis results, fertilizer practices or vine performance.