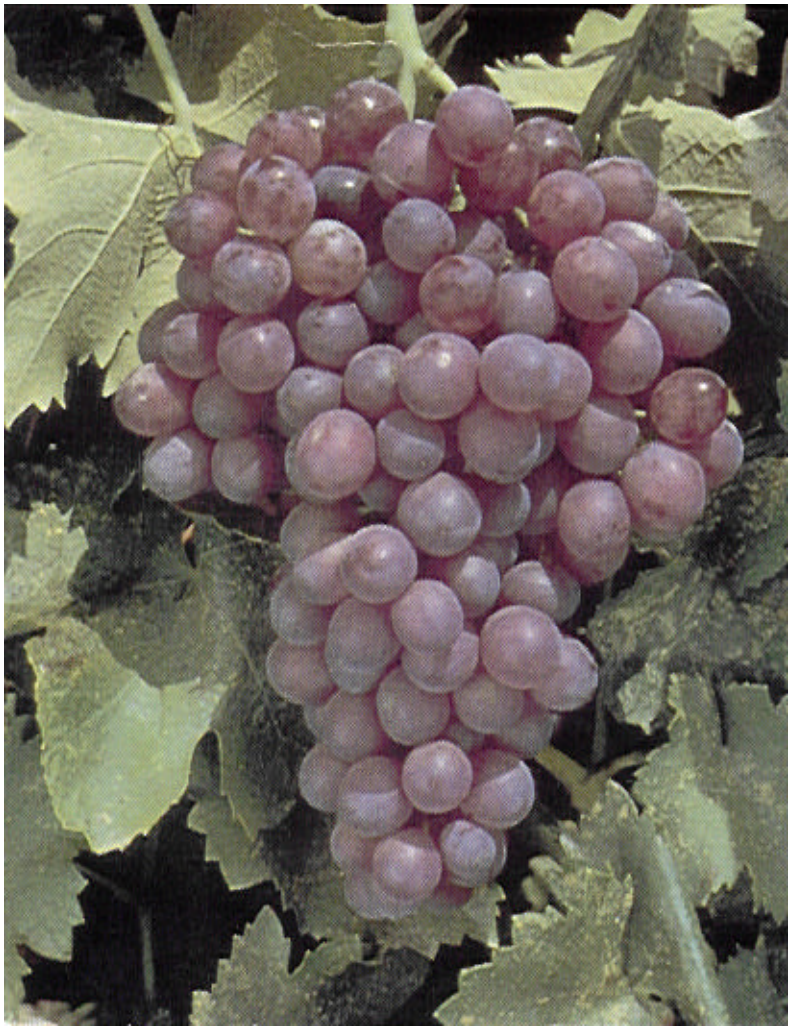
Spectrum Analytic Inc.

FERTILIZING GRAPES



Soil Analysis
Plant Analysis
Fertilizer Analysis
Manure Analysis

1087 Jamison Road
PO Box 639
Washington C.H., Ohio 43160

1-800-321-1562
(740) 335-1562
Fax: (740) 335-1104
www.spectrumanalytic.com

Table of Contents

INTRODUCTION

Grapes are deep-rooted perennial crops, and because of this may not respond to fertilizer as predicted by a soil sample taken only 7 inches deep. Grape producers should monitor their crops nutrient status with periodic soil testing and **annual tissue analysis.** We prefer leaf analysis rather than petiole analysis because it provides a better evaluation of all nutrients.

Reported values for the total nutrient uptake and removal of grapes vary somewhat. This is likely caused by differences in variety, rootstock, yield, and possibly in data collection methods. The values below are similar to other generally accepted and reported values for total uptake, but somewhat lower than some reports for crop removal of macronutrients.

TOTAL NUTRIENT UPTAKE

YIELD T/a	N	P_2O_5	K_2O	SO_4-S	Ca	Mg	B	Cu	Mn	Zn	Fe
	(Lb./acre)										
1.0	6.8	2.8	12	n/a	11.8	1.2	.003	.0052	.004	.009	.02
11.0	75	31	132	n/a	130	13	.033	.057	.044	.098	.216

IFA World Fertilizer Use Manual, 1992

According to the IFA World Fertilizer Use Manual, *"Stems and leaves, which are re-incorporated in the soil, account for about 70% of the N uptake and 60% of the P_2O_5 and K_2O, so the net removal in the harvest is clearly much smaller"*. While this may be true, remember that nutrients contained in plant residue may not be completely re-cycled in time to fully benefit the next crop.

Based on the above estimate of nutrient recycling, the net removal of N, P_2O_5, and K_2O would be as follows…

MACRONUTRIENT REMOVAL

YIELD (T/a)	N	P_2O_5	K_2O
	(Lb./acre)		
1.0	2.0	1.1	4.8
11.0	23	12.4	52.8

Grape producers should realize that it is not normally profitable to apply only crop removal rates of nutrients to the crop, unless the soil contains a proven, exceptionally strong ability to supply the crop with those nutrients. This proof must include recorded yields, and tissue analysis results. Remember, we are applying nutrients to the soil…not the plant! There are chemical and biological interactions that will occur in the soil to both tie-up and release nutrients that are applied, before the plant is able to absorb the nutrients. Another complicating factor in fertilizing grapes is that the grower is after both volume and quality in his crop. The correct fertilizer program for maximum volume yield may lower quality. The reverse may also be true.

General Fertilizer Application Methods

It is generally agreed that soil applications in established vineyards should be in a 3 to 5 ft. wide band, parallel to the row. Take care to keep the band 18" to 24" away from the base of the vines. This is most important on young vines.

Soil pH

Grapes fall into two general categories related to pH preference. American grapes (Lambrusca) generally prefer a lower soil pH than do European varieties (Vinifera, French hybrids). University publications and other authorities differ somewhat on the ideal soil pH for the two types of grapes, especially the American varieties. These sources indicate that American grapes perform best when the soil pH is between 5.0 and 6.0, with several suggesting a soil pH of from 5.5 to 6.0. It is generally agreed that the European varieties do best with the soil pH near 6.5.

The following is a list of some varieties by type:

AMERICAN VARIETIES (Lambrusca)				
Alden	Concord	New York Muscat	Reliance	Steuben
Bath	Delaware	Niagara	Remaily	Suffolk Red
Buffalo	Himrod	Norton	Schuyler	Van Buren
Canadice	Mars	Price	Seneca	Vanessa

EUROPEAN VARIETIES (Vinifera, French hybrids)				
Aligote	Cabernet Sauvignon	Chardonnay	Landot	Seyval Blanc
Aurore	Carmine	Cardonnel	Merlot	Vidal Blanc
Baco Noir	Cayuga White	DeChaunac	Pinot Noir	
Bignoles (ravat 51)	Chambourcin	Foch	Rayon d'Or	
Cabernet Franc	Chancellor	Gewurztraminer	Riesling (also called White Riesling	

Nitrogen (N)

Grapes do not have a high N requirement, when compared to many other crops. In fact, a high plant N content late in the season is often detrimental to the quality of both types of grapes, whether for jams, juice, jelly, or wine. High plant N levels late in the season can also adversely affect the vines ability to withstand a severe winter. However, inadequate N will reduce yields and profits. It is important to understand and identify the needs of a specific crop, or section of the vineyard.

New Plantings

There is little in the literature to suggest a different N rate for new plantings. Some sources recommend about ½ the rate of N for new plantings. However, a logical case can be made for maintaining the same, or increasing the rate of N on new plantings, since the goal is to grow vines, not grapes. The use of a higher N rate should be tempered by the possibility of having a soft succulent plant going into winter or creating a significant amount of carry-over N in the first year of bearing fruit.

Established Vineyards

Depending on the inherent N supplying ability of the soil, the correct N rate for a vineyard will typically range from 30 to 100 lb. N/acre, with 75 lb. N/acre being a commonly needed N application rate. One significant difference from this is when the vines are planted in the "Geneva Double Curtain" system. This system often produces best with up to twice the N rate of a single trellis design. Where a sod cover crop is present, it may require an additional 40 lb. N/acre to maintain a healthy grass stand.

N Application Timing

There is significant disagreement here as well. Most authorities agree that the greatest demand for N is from bud-break through early berry development. In wine producing areas such as California and Europe the recommendations are typically for a single N application prior to bud-break. This is probably so that the proper concentrations of compounds desirable for wine production form in the berries by harvest. In areas where the production is primarily for table or other uses, a split application is sometimes recommended. They typically suggest applying ½ of the N prior to bud-break and ½ post-bloom.

While this is not necessarily a large difference, it could be very significant on soils with a high possibility of N leaching. Some recommendations suggest that mid-winter N applications are satisfactory. Producers that are interested in this option should consider the possibilities of N losses on their particular land and typical weather pattern.

Foliar N

Foliar N should not be considered a substitute for a sound soil applied program, and few authoritative sources make any recommendation for foliar N. However, where foliar N is needed the following program has been successful. Mix 5.0 lb. of low biuret urea per 100 gal. and apply at 200 gal./acre starting with the first cover spray and spacing the sprays about 10 days to 2 weeks apart. Up to 3 applications are recommended. Calcium nitrate can be applied at 5.0 – 7.0 lb. per 100 gal.

Some Universities recommend that growers allow weeds and grass to grow within the rows late in the season (from September on in the Mid-west). The reasoning is that the weeds will pull N and moisture from the crop. This will slow growth, promote fall hardening and help hold the soil in place for the winter.

Phosphorus (P)

It is generally agreed that grapes do not put a great demand on the soil for P. However, a crop grown on an acid soil will get less efficient use of the P in the soil, and should benefit from an adequate rate of P_2O_5. Also, most grapes are grown with a cover crop. This crop typically needs a sound P_2O_5 program to maintain a healthy, dense stand. Several sources suggest that corrective rates of P_2O_5 (up to as much as 300 lb./acre of P_2O_5) be applied when establishing a new vineyard. Our P recommendations try to reach a practical medium.

Soil Status	Pre-Plant Incorporated	Established Vineyard
	lb. P_2O_5/Acre	
Poor	200	60
Medium	150	40
Good	50	20
High	0	0

Application Methods

See **General Application Methods** discussed earlier.

Foliar

None suggested.

Potassium (K)

Potassium is one of the more important fertilizer elements for the grape producer. Grapes appear not to be particularly efficient at obtaining K from the soil, and they have a relatively high demand for K. Depending on the source of information, you can find recommendations in excess of 1,000 lb. K_2O/acre. In California, where the risk of high chlorides (Cl) is greater, growers are cautioned to avoid high rates of KCl unless they are able to leach the Cl from the soil. More common annual recommendations for Mid-west and Eastern established vineyards range up to 200 lb. K_2O/acre on poor soil tests.

New Plantings

Because of the responsiveness of grapes to K, many authorities recommend large corrective soil applications prior to planting. Corrective applications should be thoroughly tilled into the soil. Due to the differences between soils, there is no perfectly accurate way to make corrective K_2O recommendations. However, one way to make significant changes in the soil K test by selecting your "ideal" K level, subtracting the present soil test level, and applying about 3 lb. K_2O/ acre for every 1 lb. of soil K increase that you need. This approach of a single, very high application runs the risk of creating a temporary, and possibly long term imbalance with soil Mg, leading to an Mg deficiency in subsequent years. This is very likely to occur on low CEC soils. If you suspect that this imbalance may occur, apply appropriate amounts of Mg with the K_2O. The pre-plant recommendation below is a reasonable amount for many soils.

Established Vineyards

The numerical definitions of Poor, Medium, Good, and High soil tests listed below vary according to soil CEC. As the soil CEC increases, the numerical value of each range increases also. This set of values is too large to list here, but the recommendations at each soil status level are listed below. The recommendations assume that the grower's goal is to produce the maximum yield possible.

Soil Status	Pre-Plant Incorporated	Established Vineyard
	lb. K_2O/Acre	
Poor	600	200
Medium	450	120
Good	100	60
High	0	0

Foliar

Short term corrections of K deficiency can be corrected with foliar K applications. Foliar sprays of 6.0 to 10.0 lb. of either KNO_3 or KSO_4 per 100 gal. of water, applied at 200 gal. per acre is recommended as a corrective measure. Appropriate soil applications of any acceptable source of K should also be made because it will have a more lasting effect.

Calcium (Ca)

Supplemental Ca is not a common problem in vineyards. Proper liming will normally provide adequate Ca. Where Ca is needed, and the soil pH is correct, the procedures that follow should correct the problem.

Soil Application

Where soil applied Ca is necessary (confirmed by a leaf analysis) and no lime is needed, apply 500 to 1,000 lb./acre of gypsum ($CaSO_4$). Re-sample the soil and leaf tissue to monitor the success of the treatment.

Foliar

In the sources consulted for this paper, foliar Ca is rarely mentioned. Where it is, they suggest applying rates similar to apples and other tree fruits. The following recommendations have been adapted from foliar Ca recommendations proven effective for apples. You may need to make adjustments in the mixes due to different volumes of spray required in vineyards versus orchards.

Two fertilizer products are the primary sources of foliar Ca. They are calcium nitrate ($Ca(NO_3)_2$) (15%N, 19.4%Ca), and calcium chloride ($CaCl_2$) (36% Ca). Apply calcium chloride (78% $CaCl_2$) at a rate of 1.0-2.0 lbs/100 gal., dilute equivalent basis, in 3 or 4 sprays at 14 day intervals beginning 7 - 10 days after flowering, followed by 2 sprays at 3.0 – 4.0 lbs/100 gal, 4 and 2 weeks before harvest. These rates provide 27.0 to 48.0 lb. of $CaCl_2$ (7.5 to 13.4 lbs. Ca) per acre for crops that require 300 gal of dilute spray per acre for thorough coverage. Calcium nitrate applied at 2.0 – 4.0 lbs/100 gal, dilute equivalent basis, may be used in place of calcium chloride. If calcium nitrate is used, remember that the crop is also receiving N. This N could have an effect on how the grapes harden-off in the fall. Chelated forms of Ca have not been effective due to the low Ca content. Alternative proprietary calcium compounds are available for use as foliar sprays. Effectiveness of these materials may be comparable to that of calcium chloride when used at rates providing equivalent rates of calcium. Likewise, the relative crop safety should be similar to that of calcium chloride when applied at equivalent rates.

In some areas, calcium chloride is added to each of the summer pesticide applications. These sprays may cause foliage and/or fruit injury if applied when low temperatures and wet weather delay drying of the spray, and under high temperature (over 80°F) and/or high humidity conditions. No sticker-spreaders are needed. Do not premix Solubor and calcium chloride if both are to be applied in the same spray. Some leaf burn may occur, especially at higher temperatures. Calcium Chloride is very corrosive and will rust spraying equipment unless removed following each application.

Magnesium (Mg)

Magnesium stress in grapes can be a problem. This should be expected because many varieties are grown on acid soils, low in Mg. Also, the high K_2O rates that are typically needed can reduce Mg uptake. It has been our experience that when the soil K to Mg ratio (K/Mg, in lb./acre or ppm) is higher (wider) than 1.5/1 you can expect Mg uptake to be reduced.

Soil Application

Spectrum recommendations are based on the soil Mg level, and the soil K:Mg ratio. Where lime is needed, we will recommend dolomitic lime (shown by a D after the recommendation), and reduce or eliminate the recommendation for fertilizer Mg. Recommendations are made for both row and broadcast rates. Use the broadcast rates for grapes, even though the application may be in a wide band as mentioned earlier. Fertilizer Mg recommendations will range from 22.0 to 66.0 lb. Mg/acre, as broadcast.

Foliar

There is a wide range in foliar Mg recommendations. They range from a low of no more than 4.0 lb. of magnesium sulfate (Epsom salts)/100 gal./acre to as much as 40.0 lb. of magnesium sulfate/acre as a concentrated spray (less than 100 gal./acre of mix). The most common recommendations are 15.0 to 20.0 lb. of magnesium sulfate/100 gal. sprayed as a dilute spray at 200 gal./acre. Do not exceed 40.0 lb. of this material per 100 gallons. Season-long correction may require 2 to 3 applications spaced 2 weeks apart. Epsom salts should not be combined with other materials. Do not mix with pesticide sprays as the effectiveness of the pesticide may be reduced and fruit injury could result. If a commercial, proprietary product is used, follow the manufactures recommendations.

Sulfur (S)

Supplemental S is rarely needed in vineyards. However, soil sulfur is predominately in the leachable sulfate (SO_4) form, and sandy may soils show a response to S. Any suspected shortage of S should be confirmed with a leaf analysis.

Soil Application

None of the publications used to compile this paper listed any recommendations for S. If soil applications of S are planned, the typical range of rates used to correct S shortages in other crops is from 10.0 to 50.0 lb. S/acre. From 15.0 to 20.0 lb. S/acre normally gives a yield response where a known shortage exists. Grapes, like all plants take up only the sulfate (SO_4) form of sulfur. This means that applications of elemental S will require a considerable amount of time for the soil bacteria to convert the S to SO_4, thus delaying any response.

Foliar

No recommendations are made. Soil applications of the sulfate form of S should be sufficient.

Boron (B)

Boron deficiency prevents the normal development of pollen tubes and drastically reduces fruit set, causing a high number of small deformed berries, as well as much fewer berries. Leaf symptoms include interveinal chlorosis of the younger leaves, progressing to include leaf-edge die-back (burn), and finally death. Death of the primary shoot tip is also typical, resulting in increased branching.

Boron may also be toxic when applied in high amounts. Leaf symptoms include speckling and downward cupping of mature leaves. Visual toxicity symptoms are associated with leaf B levels of 200 to 300+ ppm.

Recommendations for B vary widely across the country. California and Washington State recommend applying 3.0 lb. B/acre where the soil test is very low. Most Extension services in the mid-west and east suggest foliar B application rates (some of them very strong), but say very little about soil applications. At Spectrum Analytic, we have chosen to recommend B application rates that are conservative, in order to avoid potential toxicity. Growers should monitor their crops with leaf or petiole analysis to determine the correct rate in their specific situation.

Soil Application

Where soil tests are low, or a leaf sample has confirmed a need for B, recommendations should be in the range of 1.0 to 2.0 lb. of actual B per acre on loam or finer textured soils, or soils with a pH above 6.5. Reduce the B rate to 0.5 to 1.0 lb. of actual B/acre on coarse textured or acid soils.

Foliar Application

When plant samples are deficient, apply foliar spray of Solubor at 1.25 lb. per acre per spray (0.25 lb. actual B) 10 to 14 days before bloom and again at the beginning of bloom. When plant samples are Low, apply Solubor at 1.0 lb. per acre (0.2 lb. actual B) with normal pre-bloom pesticide spray.

Copper (Cu)

None of the sources referenced here made any recommendation for Cu, by either soil or foliar applications. Copper is an element that can easily build up in the soil as a result of repeated applications. There is the potential to increase soil Cu to toxic levels. Therefore, the grower should begin an annual soil testing program while soil Cu is being applied to monitor any build-up. It is entirely possible that they can correct a shortage of soil Cu after a few seasons of applying Cu, and never need to apply Cu again. Also, if we were to rank the nutrients as to phytotoxicity from foliar applications, Cu would likely rank near the top for most crops. Growers should make the soil applications that are needed, but use the proper rates, and discontinue its use when soil and leaf analysis indicates that the crop no longer needs it.

Soil Application

The maximum range of Cu applications that we will recommend for any crop is from 0 to 10.0 lb. Cu/acre on a broadcast basis, or 50% of the recommendation as a concentrated “starter” band on responsive row crops. Copper is not mobile in the soil, so maximum effectiveness requires tillage to mix the Cu throughout the soil profile. Application in broad bands to the soil surface, as will be used in many vineyards, will concentrate the Cu in a layer near the soil surface and not be as efficient as it could be. The vines may show a better response in the second year after application than they do in the year of application. We recommend that the grower limit soil Cu applications to from 2.0 to 5.0 lb. Cu/acre.

Foliar Application

Copper sulfate ($CuSO_4$ 25% Cu) is a common source for foliar applications. Chelate forms are also available, and some Cu uptake occurs from disease control materials such as Bordeaux mixtures, and various commercial fungicides. Foliar Cu from copper sulfate requires as little as 0.1 to 0.25 lb. Cu/acre to be effective. It is easy to over-apply Cu and get foliage damage, be sure to apply the proper rates.

Iron (Fe)

Iron is not likely to be a problem for grape producers outside of California, or a few other places with dry or Mediterranean climates. Iron is most likely to become deficient where the soil pH is exceptionally high, such as pH 7.5 to 8.0. Most grapes produced in the U.S. east of the Rocky Mts. are grown on acid soils. If it is decided to apply Fe to grapes, foliar applications are the most viable option.

Manganese (Mn)

Manganese deficiency is often an indicator of a high soil pH. It is not likely to be deficient in American grape varieties because they are typically grown on acid soils. However, they could be more likely to occasionally suffer from manganese toxicity, caused by excessively acid soil. European type grapes are typically grown on higher pH soils and could be more susceptible to Mn shortages.

Soil Application

Manganese applied at practical rates is quickly "tied up" by the soil when broadcast applied. For that reason, we do not recommend soil applications of Mn to correct deficiencies.

Foliar Application

Mix $MnSO_4$ at the rate of 4.0 lb. plus 2.0 lb. of hydrated lime per 100 gallons. Spray either at the rate of 200 to 300 gallons per acre. Two applications usually will provide season-long control. Apply just after first bloom or when symptoms first appear and again 2 weeks. Later, if Mn chelate is used, follow the manufacturer's label recommendations.

Zinc (Zn)

Zinc deficiency symptoms differ somewhat by variety, but generally include undersized leaves which may have interveinal chlorosis. They may also show a widened petiolar sinus (the leaf indentation where the petiole is attached). The vines will normally have smaller "straggly" clusters, of undersized berries, containing only one or two seeds per berry.

Soil Application

Surface applied Zn is not likely to be very effective because Zn is not mobile, and any grass cover crop will intercept a significant portion of the application. Mid-western and Eastern universities do not address the subject in any significant way. Where surface applications to established vineyards are intended, and the method will be an application of a band beside the trellis several feet wide, it will probably require a Zn rate in excess of 20.0 lb. per acre to have any significant effect. Data from several states indicate that the required Zn rate could exceed 100 lb. of Zn per acre. Unless further data indicates otherwise, it may be best to apply Zn foliar when needed. Where grapes are growing on very sandy soils, surface applications may be more effective.

Foliar Application

Specific information on foliar application of Zn to grapes is not abundant. Grapes are often included with tree fruit recommendations. Using fruit tree recommendations often results in relatively high recommendations compared to most agronomic or vegetable crops. We have chosen not to recommend the higher rates of foliar Zn that can be found in the literature for two reasons:

1. We do no think that the higher rates per application are needed
2. Higher rates run the risk of foliar damage.

Most crops will respond to foliar Zn rates, from zinc sulfate, of from 0.3 to 1.0 lb. Zn/acre, beginning 2 to 3 weeks before bloom. The grower may need a second application about 10 to 14 days later for full effect. Where chelate sources are used, follow the manufacturer's label recommendations. Zinc containing fungicides provide some nutrient uptake to the crop, but are not likely to correct a severe shortage. The Book "General Viticulture", Univ. of California Press, 1974, suggests the following Zn program for grapes (grown in California). We quote it here only to show the range of suggestion that can be found for supplying Zn to grapes. Spectrum Analytic makes no recommendation that the rates or methods of application suggested in the quote are safe or effective. The quote is … *"Supplying zinc to vines*. - Zinc is a micro, or trace, element, and vines need only a very small amount of it—a half pound per acre at most. Yet, according to Cook (1958), it is difficult to get even this small amount of zinc into the vine. Most soils will "fix" such large quantities of zinc sulfate that soil applications are impractical. On very sandy soil, however, 1.0 to 2.0 pounds of zinc sulfate per vine will give fair success when applied in the manner described above for potash (make a deep plow furrow as close to the root zone as possible, consistent with minimum root damage, and place a band of potash at the bottom of this furrow (This is not recommended by Spectrum Analytic Inc.). For spur pruned varieties the most common, and by far the most successful, treatment is to daub the pruning cuts with a zinc sulfate solution. Pruning must be so timed that little or no bleeding occurs. Results are best when pruning cuts are daubed immediately, but may be profitable even after delays of as much as 24 hr. (Snyder and Harmon, 1954). The usual solution is 1.0 to 1.5 lb. of zinc sulfate (23% metallic Zn) per gallon of water. Higher concentrations severely injure the dormant buds on the spurs.

Daubing the pruning cuts of cane-pruned varieties is not effective. This is particularly true of Thompson Seedless. The zinc moves inward only a few inches at most. Foliage sprays are more promising, though at best only moderately successful. Foliage sprays containing zinc should be applied 2 to 3 weeks before bloom, with as much wetting of the undersurface of the leaves as is possible. When obtaining berry set is the problem, one spray may suffice; when vine growth is stunted, a second spray is needed several weeks after bloom. Spray concentrations can vary from 4.0 to 10.0 pounds of zinc sulfate per 100 gallons of water. To prevent foliage burn, however, all concentrations in this range *require* an addition of half as much spray lime as zinc sulfate. A normal proportion would be 6.0 pounds of zinc sulfate to 3.0 pounds of spray lime in 100 gallons of water. A good wetting agent should be included (Cook, 1962)."

Plant Sampling Instructions for Grapes

Grape fertility, like other perennials, is best managed through the use of **annual tissue analysis**. Interpretation data is available for both leaf blades and leaf petioles, so we can interpret both types of tissue. It is important to sample the correct plant part for a given stage of growth, and to list this information on the sample information forms, to insure that we make a correct interpretation of the data. A current soil sample plus information on the recent fertilizer applications, weather conditions, and other cultural practices greatly improves Spectrum's ability to interpret the analytical results. This provides you with better information from plant analysis.

Several authorities have concluded that petioles are weak indicators of N and micronutrient status and leaf samples are recommended. However, petioles can be used to compare between samples. Since boron (B) affects fruit set, a late spring leaf sample to identify suspected B problems is normally recommended. For other situations, a sample of either tissue taken closer to fruit maturation is considered preferable as the best indicator of the crops nutrient status. Earlier samples can be taken if it is suspected that the crop will need in-season nutrient applications. Follow these steps in sampling grapes.

1. Sample Size

- Leaf blades- A "rounded double handful" of strongly wilted leaves (about 15 to 20 leaves).
- Petioles- About 40 to 60 petioles per sample, with a minimum of 2 petioles from each plant.

2. Stage of Growth vs. Plant Part

- Pre-Bloom: Youngest fully matured leaf or petiole from the same leaf (see figure 1).
- Bloom or Fruiting: Leaf or petiole adjacent to fruit cluster position (see figure 2).

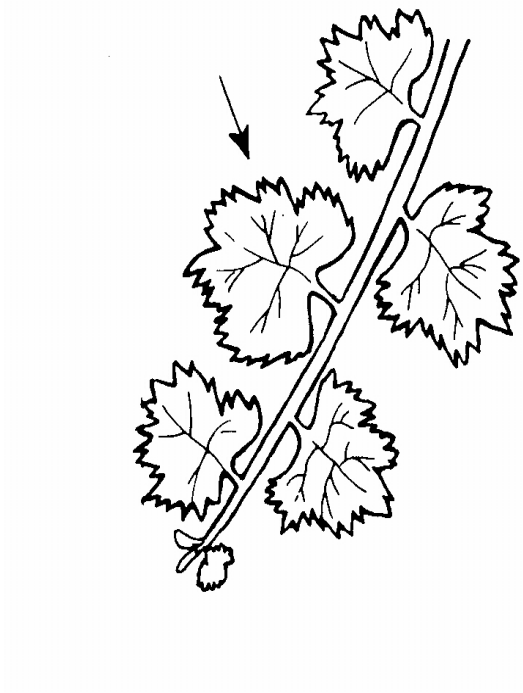


Figure 1 Pre-Bloom: upper mature leaf/petiole

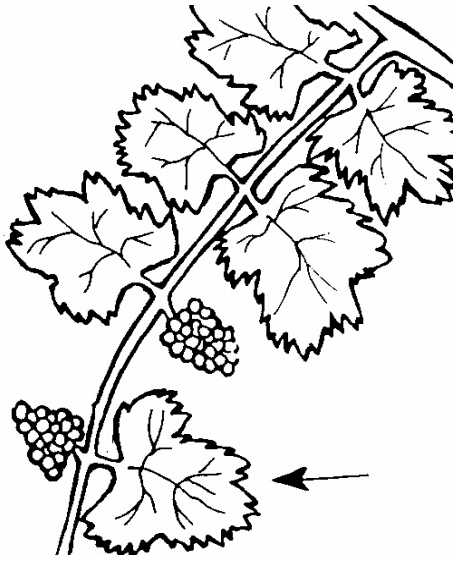


Figure 2 Bloom/Fruiting: leaf/petiole opposite cluster

References

IFA WORLD FERTILIZER USE MANUAL, International Fertilizer Industry Association, 1992

GENERAL VITICULTURE, Winkler, et al, University of California Press, 1974

GRAPEVINE NUTRITION AND FERTILIZATION IN THE SAN JOAQINE VALLEY, University of California, Division of Agriculture and Natural Resources, Publication 4087, 1978

FERTILIZING FRUIT CROPS, Michigan State University, Extension Bulletin E-852, June, 1996
GRAPES Production, Management and Marketing, The Ohio State University, Bulletin 815, 1991

FERTILIZING FRUIT CROPS, Ohio Cooperative Extension Service, The Ohio State University, Bulletin 458, 1985

MODERN FRUIT SCIENCE, Norman F. Childers, et al, Horticultural Publications, 1995

THE MID-ATLANTIC WINEGRAPE GROWERS GUIDE, http://www.ces.ncsu.edu/resources/winegrape/

Dr. Ann Wolf, Penn State University, personal communication