Management of Mineral Nutrition in Table Grape Vineyards

Jennifer M. Hashim-Buckey, Viticulture Farm Advisor, UC Cooperative Extension, Kern County
1031 S. Mount Vernon Avenue, Bakersfield, CA 93307
Phone: (661) 868-6200, jmhashim@ucdavis.edu

Introduction

An understanding of the seasonal uptake and partitioning of mineral nutrients of grapevines is essential in order to time fertilizer applications. Over the last three decades, several important studies were conducted to determine seasonal nutrition demands of field-grown grapevines and to quantify the partitioning of mineral nutrients (Christensen 1980, Conradie, 1981, Peacock, 1986, Peacock et al, 1989; 1991, Williams, 1987, Williams and Biscay, 1987). This paper aims to summarize what has been learned over the last few decades and highlight advances in grapevine mineral nutrition.

Nitrogen (N)

Nitrogen is the mineral element that grapevines require in the greatest amount. It serves as an important constituent of the protein makeup of all plant tissues and is a structural component of the chlorophyll molecule. When grapevines become deficient of N, vegetative growth slows and the foliage becomes chlorotic. In contrast, vines with an abundant supply of N have dark green foliage, growth is vigorous and canopies are dense, making canopy management difficult and may also contribute to other problems such as poor bud fruitfulness, poor coloration of red grapes, excessive shatter and increased levels of bunch rot and bunch stem necrosis (Christensen and Peacock, 2000).

The timing of N fertilizers, like other nutrients, should occur when demand is high and uptake is rapid. Nitrogen is needed most during the period of rapid vegetative growth, which occurs during the spring, from budbreak to early berry development. It is during this period that new growth may accumulate up to 50% of its annual N requirement (Conradie, 2005). Because active root growth and mineral uptake is generally minimal during the budbreak period, N demand is met primarily from reserves stored in the roots and other permanent woody structures (trunk, cordons, canes). The amount of N remobilized from permanent structures between budbreak and fruit set account for up to 40% of that needed by shoots, leaves and clusters (Conradie, 1980). Since the need for N is most critical in the spring and highly dependent on reserves, it can be inferred that the need for soil N is minimal very early in the season and that fertilizers should be applied when vines can best absorb and assimilate N as a part of the reserve while minimizing losses thorough leaching and denitrification (Conradie, 2005, Peacock et al, 1989).

Nitrogen absorption is most rapid between bloom and veraison, with the developing clusters being the largest sink for N during this time (Conradie, 2005, Peacock et al., 1989). Therefore, applications are best applied late in the spring, after the risk of frost, when uptake and demand is optimal (Christensen, 2008). A good timing for N fertilizer application is at fruit set (just after bloom), to correspond with rapid uptake and demand by developing clusters, and to a lesser extent by shoots and leaves. From bunch closure to veraison, when shoot growth slows, available N will also be allocated and incorporated into permanent vine structures for storage.

Another suggested timing for N fertilizer application is during the postharvest period. The postharvest period is an excellent time to provide N for uptake and storage to support new growth the following season. Studies using isotopically labeled N to measure seasonal uptake and partitioning of 'Thompson Seedless' grapevines, found that fertilizer applications made in July or late September (postharvest) resulted in the greatest concentration of labeled N in both storage tissues and in leaf tissue during the following spring and at bloom (Peacock et al., 1989). Furthermore, N absorbed during this period accounts for up to 60% of the total amount of N reserves available at the start of the next season (Conradie, 2005). When fertilizing during the postharvest period, the canopy should be healthy and functional to ensure adequate uptake—this application should be made before October in the San Joaquin Valley (Christensen et al., 1996). Furthermore, the postharvest window may be too short for late harvest varieties, like Crimson Seedless or Autumn King, for effective uptake to occur.

The N requirement of grapevines is considerably less compared to other agricultural crops (Mullins et al., 1992). A study conducted to determine the amount of N used by 'Thompson Seedless' grapevines grown for raisins in the San Joaquin Valley found that approximately 75 lb a^{-1} (84 kg ha^{-1}) was required to support annual growth of leaves, stems and clusters. Harvested fruit accounted for the greatest losses from the vine at approximately 31 lb a^{-1} (35 kg ha^{-1}), while other vine parts contributing to losses such as fallen leaves and prunings would be returned to the soil, recycled and remobilized within the vine (Williams, 1987). Based on this work and other studies, it has been estimated that a vineyard with an average yield of 10 ton a^{-1}, would require approximately 30 lb a^{-1}, or 3 lb per ton, of N in order to replenish the losses from the fruit at harvest (Christensen, 2008). Using this formula, a table grape vineyard with an average yield of 1000 (19-lb) boxes per acre, would require approximately 28.5 lb a^{-1} and the requirement would increase with larger yields. In general, vine yields and fruit quality can be sustained with 22.3 lb a^{-1} (25 kg ha^{-1}) to 44.6 lb a^{-1} (50 kg ha^{-1}) N applied annually (Peacock et al., 1996).

Determining the amount of nitrogen to apply to the vineyard depends on several factors. Nitrogen sources from irrigation water, crop residues/cover crops, and mineralization of soil organic matter and other factors such as the variety, rootstock, irrigation practices and canopy management practices should be taken into consideration when determining the nitrogen fertilizer requirements. In table grape vineyards, the goal of nitrogen fertilization is to meet the vine requirements in order to maximize yields and quality. Fertilization practices should be assessed and adjusted annually according to tissue analysis and observations of vine vigor and fruit quality.

Potassium (K)

Potassium is essential for grapevine growth and yield and serves an important purpose in several different plant functions. Potassium is readily translocated throughout the grapevine and may be involved in carbohydrate transport and metabolism. Potassium, a cation, is used as an osmotic agent in the opening and closing of stomata, an important mechanism of vine water relations. Potassium also neutralizes organic acids and plays a role in controlling acidity and pH of the fruit's juice (Mullins et al., 1992). Very little is known about the exact functions of K in grape berries, however it is known that K is vital for berry growth (Mpelasoka et al, 2003)

Potassium deficiency is generally not widespread in the vineyard and is often observed in areas with sandy soils with low native K fertility or where topsoil was removed for leveling. Compacted soils, poorly drained soils, water stress and vines with weak root systems due to damage by soils pests (phylloxera and nematodes) may also contribute to K deficiency due to poor K uptake (Christensen and Peacock, 2000). Vines deficient of K will exhibit chlorosis of the leaf margin and between the main veins by mid-summer and marginal burning and curling as symptoms progress. When K deficiency is severe, shoot growth is significantly reduced and vines may defoliate prematurely, especially if the crop is large. Vines may also have fewer, smaller clusters with poorly colored, small berries (Christensen and Peacock, 2000).

Like nitrogen, the demand of new growth for K in the spring exceeds root uptake during the period from budbreak to bloom. The need for K is most critical during berry development and ripening, and it is during this time that the fruit becomes the strongest sink for available K (Mpelasoka et al, 2003). This period also corresponds with the time at which root uptake for K is most rapid. Root uptake of soil K accounts for only about 50% or less of K accumulated in developing clusters and the remainder of the demand to support fruit growth is met from K reserves in the permanent vine structures (Conradie, 1981, Williams and Biscay, 1991).

Given that the developing fruit is such a strong sink for K, timing of K fertilizers should be applied during the early spring (a few weeks after budbreak) up to veraison. Potassium fertilizer efficiency is best when applied under drip irrigation, as much lower rates are required to correct deficiencies compared to banded applications in furrow irrigated vineyards. This is due to the fact that many soils in the San Joaquin Valley have a great capacity to fix (tie up) K. Efficiency under drip delivery is improved because high concentrations of K saturate the soil reaction sites in the area of greatest root density (Peacock, 1999). Previous work has demonstrated that a single application of K with drip is just as effective as multiple applications, given that the same amount is applied (Christensen and Peacock, 1986). However, it is often more practical to apply K in incremental units through the drip system on a weekly basis rather than all at once. Recommended K fertilization strategy for effective for K maintenance is 10 to 15 lb a^{-1} applied weekly over the course of 10 to 15 weeks (ending at veraison).

Magnesium (Mg)

Magnesium in grapevines plays two main roles. First, magnesium is an essential component of the chlorophyll molecule and is vital for photosynthesis. Magnesium also activates enzymes required for plant growth (Mullins et al., 1992). Because Mg is a constituent of chlorophyll, deficiency symptoms are observed as creamy-white chlorosis of the leaf. The chlorotic pattern is quite distinct with Mg deficiency, where fading begins near the leaf margin and progresses inward toward the primary and secondary veins. The pattern is generally described as a "Christmas tree" where areas surrounding the veins remain green. Magnesium is a mobile element and is readily translocated from older tissues to younger tissues. Because of this, older basal leaves show deficiency symptoms first, usually in mid- to late-summer (Christensen and Peacock, 2000).

Mild Mg deficiency, where a few basal leaves express symptoms, are commonly observed in table grape vineyards by late summer and are usually ignored. This generally does not contribute to negative effects on vine growth or yield because these basal leaves are well shaded during the summer and their contribution to the photosynthetic capacity of the vine is negligible. However, if 10-20% or more of the canopy is affected, correction is warranted, as 20% reduction in functional leaf area and thus photosynthetic capacity could present problems with respect to carbohydrate production, fruit ripening and overall vine growth (Peacock, 1999).

Magnesium is leachable in the soil and is often found in subsoils rather than in the upper portion of the profile where most of the root activity and uptake occurs. Because of this, young vines with shallow root systems and vines planted on older, highly weathered soils are more susceptible to Mg deficiency (Christensen and Peacock, 2000). It is important to note that severe and/or chronic Mg deficiency maybe caused by a preexisting soil condition or an interaction with other nutrients on the soil's (cation) exchange sites. Magnesium deficiency is more prevalent where soils have become acidic (pH $\leq$ 5.5) after years of repeated use of urea and/or ammonical fertilizers. This can be corrected with the application and incorporation of lime, thus neutralizing the acid and adding calcium and Mg to the base exchange site (Peacock, 1996). Furthermore, calcium, potassium and Mg interact on the soil's exchange site and compete for entry into plants. It has been observed in vineyards under drip irrigation, that the application of calcium to improve water infiltration, or the application of potassium through the drip, has reduced Mg levels in vines (Peacock, 1996).

Seasonal uptake and partitioning of Mg within the grapevine begins at budbreak and from the period of budbreak to bloom, reserve Mg (mainly from roots) contributes 18% toward the requirement of new vine growth (Conradie, 2005). Leaves and shoots account for the greatest portion of total vine Mg throughout the season. The greatest amount of absorbed Mg partitioned to the permanent vine structures occurs about 4 weeks after harvest. Overall, the absorption pattern for Mg shows a steady accumulation for all measured vine organs (trunk, roots, shoots, leaves, bunches) from budbreak on and accumulation ceases just before the onset of leaf abscission in the fall (Conradie, 1981). Given that uptake and accumulation increase steadily from budbreak on, and if Mg fertilization is warranted, Mg applications can be delivered either through drip irrigation or foliar sprays anytime during the spring.

Zinc (Zn)

Zinc is the most common deficient micronutrient in vineyards (Christensen, 2005). Zinc is involved in the synthesis of plant hormone, indoleacetic acid (IAA) and in the formation of chloroplasts and the process of pollination (Mullins et al., 1992). Zinc deficiency in grapevines is observed on sandy soils of low Zn content and calcareous (high lime) soils where the high pH reduces Zn availability. Vines grafted to rootstocks of *Vitis champinii* parentage such as, 'Freedom' and 'Harmony' are also prone to Zn deficiency. Zinc deficiency in grapevines, depending on the severity, may affect both fruit and foliage. Fruit symptoms include reduced fruit set and the formation of shot berries. Severe deficiencies are expressed in the foliage, where shoot growth is stunted, with shortened internodes and many short lateral shoots, with abnormally small leaves. Leaves on main shoots also appear stunted with wide petiolar sinuses and interveinal chlorosis (Christensen and Peacock, 2000).

Most Zn deficiencies are corrected with foliar spray applications applied before bloom in order to improve fruit set and berry development. Studies to determine optimum timing of Zn and its effects on fruit set, berry size, cluster weight and petiole Zn levels demonstrated that the best timing is from two weeks prior to bloom to full bloom (Christensen, 1980). In addition, fall sprays were not effective in reducing Zn deficiency symptoms the following spring (Christensen, 1980).

Cultivar and Rootstock Effects on Mineral Nutrition

Cultivar and rootstock selection can have a strong influence on grapevine mineral nutrition. For example, when comparing the results of tissue analysis for N (NO_3-N) levels of different own-root table grape cultivars, it is consistently observed that healthy 'Flame Seedless' will tend to have relatively low (100-200 ppm) NO_3-N levels, while 'Thompson Seedless' grown on the same soils in the same location will have substantially higher levels (1,000-1,200 ppm NO_3-N). In addition, it is known that vines grafted to vigorous, nematode-resistant rootstocks 'Freedom' and 'Harmony' have larger, more explorative root systems compared to own-root vines, and as a result have higher N and K status and lower fertilizer requirements.

In conclusion, determining the nutrition requirement for table grape vineyards must take into account the following factors: soil type and chemistry, characteristics of the cultivar and rootstock, vine vigor and canopy management strategies, soil pests, fertilizer history, knowledge of nutrient inputs (other than synthetic fertilizers) and results of tissue analysis. Timing of fertilizer applications should be made when demand is high and uptake is rapid, while minimizing losses from the soil through leaching.

Literature Cited

Christensen, L.P. 1980. Timing of zinc foliar sprays. I. Effects of application intervals preceding and during the bloom and fruit-set stages. II. Effects of day vs. night applications. Am. J. Enol. Vitic. 31(1): 53-59.

Christensen, L.P. 2005. Foliar fertilization in vine mineral nutrient management programs. *In* Proceedings of the Soil Environment and Vine Mineral Nutrition Symposium, San Diego, California, 29-30 June, 2004. L.P. Christensen and D.R. Smart (Eds.), pp. 83-90. American Society of Enology and Viticulture, Davis, California.

Christensen, L.P. 2008. Effective and efficient management of table grape vineyard mineral nutrition. *In* Proceedings of the San Joaquin Valley Table Grape Seminar, Visalia, California, 27 February, 2008.

Christensen, L.P. and W.L. Peacock. 1996. Potassium and boron fertilization in vineyards. Grape Notes, Newsletter from the University of California, Tulare County. Also available online at http://cetulare.ucdavis.edu/pubgrape/pubgrape.htm#Nutrition

Christensen, L.P. and W.L. Peacock. 1996. Magnesium deficiency becoming more common. Grape Notes, Newsletter from the University of California, Tulare County. Also available online at http://cetulare.ucdavis.edu/pubgrape/pubgrape.htm#Nutrition

Christensen, L.P. and W.L. Peacock. 2000. Mineral nutrition and fertilization. *In* Raisin Production Manual. L.P. Christensen (Ed.), pp. 102-114. University of California Agriculture and Natural Resources, Oakland.

Conradie, W.J. 1980. Seasonal uptake of nutrients by Chenin blanc in sand culture: I. Nitrogen. S. Afr. J. Enol. Vitic. 1(1):59-65.

Conradie, W.J. 1981. Seasonal uptake of nutrients by Chenin blanc in sand culture: II. Phosphorus, potassium, calcium and magnesium. S. Afr. J. Enol. Vitic. 2(1):7-13.

Conradie, W.J. 2005. Partitioning of mineral nutrients and timing of fertilizer applications for optimum efficiency. *In* Proceedings of the Soil Environment and Vine Mineral Nutrition Symposium, San Diego, California, 29-30 June, 2004. L.P. Christensen and D.R. Smart (Eds.), pp. 69-81. American Society of Enology and Viticulture, Davis, California.

Mpelasoka, B.S., Schachtman, D.P., Treeby, M.T. and M. Thomas. 2003. A review of potassium nutrition in grapevines with special emphasis on berry accumulation. Aust. J. Grape and Wine Res. 9:154-168.

Mullins, M.G., Bouquet, A. and L.E. Williams. 1992. Biology of the Grapevine. Cambridge University Press, New York.

Peacock, W.L. 1986. Fertilizing with nitrogen and potassium through drip irrigation. *In* Proceeding of the Dinuba Table Grape Seminar, Dinuba, California, 26 February, 1986.

Peacock, W.L., Christensen, L.P. and F.E. Broadbent. 1989. Uptake, storage and utilization of soil applied nitrogen by Thompson Seedless as affected by time of application. Am. J. Enol. Vitic. 40(1): 16-19.

Peacock, W.L., Christensen, L.P. and D. Hirschfelt. 1991. Influence of timing of nitrogen fertilizer application on grapevines in the San Joaquin Valley. Am. J. Enol. Vitic. 42(4): 322-326.

Peacock, W.L., Christensen, L.P. and D. Hirschfelt. 1996. Best management practices for nitrogen fertilization of grapevines. Grape Notes, Newsletter from the University of California, Tulare County. Also available online at http://cetulare.ucdavis.edu/pubgrape/pubgrape.htm#Nutrition

Peacock, W.L. 1999. Potassium in soil and grapevine nutrition. Grape Notes, Newsletter from the University of California, Tulare County. Also available online at http://cetulare.ucdavis.edu/pubgrape/pubgrape.htm#Nutrition

Williams, L.E. 1987. Growth of ‘Thompson Seedless’ grapevines: II: Nitrogen distribution. J. Amer. Soc. Hort. Sci. 112(2):330-333.

Williams, L.E. and P.J. Biscay. 1987. Partitioning of dry weight, nitrogen, and potassium in Cabernet Sauvignon grapevines from anthesis until harvest. Am. J. Enol. Vitic. 42(2): 113-117.