Grapevine Nutrition- An Australian Perspective

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Summary

The physiological and metabolic processes involved with grapevine growth and production are influenced by key macro or micro-nutrients. Elements, such as nitrogen, phosphorous, potassium, magnesium, boron, zinc, manganese, iron and copper, play important roles in vine functioning, growth, yield and/or quality. Nutritional effects on wine quality have also been identified, thus giving even greater importance to nutritional management. In many viticultural regions, particularly in Australia, nutritional deficiencies of the key elements in soils have led to research into fertilizer requirements of grapevines. The ancient soils of Australia present specific challenges with a range of nutritional deficiency present across the continent in different viticultural regions. As our understanding of the nutritional needs of grapevines has evolved, we, as grape growers, are better equipped to develop effective fertilizer management programs for healthy and productive vine growth. Fertilizer programs should aim to address individual elemental deficiencies experienced by vines to ensure balanced growth between foliage and crop, rapid ripening of fruit and wood and promote wine quality.
This paper will review vine nutrition by evaluating the roles of the essential nutrients in the growth and productivity of grapevines and the physical symptoms expressed when individual elements are deficient or exceed vine requirements. Nutritional and fertilizer management will also be addressed, in terms of assessing vine and soil nutrient status and answering the important fertilizer application questions, including selection of fertilizers, how much to fertilize and timing of fertilizer application for healthy grapevine production.

Grapevine Nutrition

Nutrients involved in development of grapevines, photosynthetic functioning and metabolic pathways are required in certain quantities to ensure healthy growth and performance. Essential elements are classified and macro- or micronutrients dependant on the quantity of that element required by the plant. Macronutrients include nitrogen, phosphorous, potassium, calcium, magnesium and sulfur occur at high levels in plant tissue, 0.2 to 3% of dry weight. Micronutrients occur at lower levels in plant tissue; iron and manganese at 50 to 150 ppm dry weight and molybdenum, copper, zinc and boron at 0.5 to 40 ppm dry weight. If an element is not available in adequate amounts then vine performance is limited by the supply of that one element. In the case of micronutrients it is availability, rather than element concentration that is often the limitation when deficiencies are recorded. Deficiencies or toxicity of individual essential elements can result in characteristic foliar symptoms and restricted growth habit.

What are the roles of nutrients in growth and productivity of grapevines and their sources?

Macronutrients

Nitrogen

Nitrogen (N) is involved in almost every metabolic process occurring in the growth of grapevines, including the development of berries and consists of about 1-2% of the total dry mass of a grapevine. Nitrogen is an essential component of functioning proteins and chlorophyll in leaves and thus, photosynthesis. Vines low in nitrogen generally display low vigour and poor production, as a result of reduced protein synthesis and photosynthesis. Vines deficient in nitrogen will also display a yellowing of all leaves and green tissue (Fig. 1). This symptom is indicative of a lack of chlorophyll content in the leaves, which is evidence of reduced photosynthetic capacity. Yellowed leaves may defoliate mid-season, which can lead to delayed ripening and in extreme cases defoliation and loss of bunches. Nitrogen deficient vines may produce smaller bunches with fewer and smaller berries. Vines with high or excessive nitrogen can also have an adverse effect on productivity of the vine, due to vigorous growth of vegetative parts leading to shading and subsequent reduction in fruit set and poor bud fertility.

Nitrogen concentration of Australian soils is generally low and can originate from the following processes: fixation of atmospheric nitrogen by microbes, decomposition of plant and microbial residues containing nitrogen, and nitrogenous fertilizer inputs. It is available to plants as mineral nitrogen (nitrate and ammonium), organic nitrogen (biomass) and gaseous nitrogen (atmospheric nitrogen, nitrous oxide and ammonium) in the soil. The availability of soil nitrogen depends on the level of organic matter in the soil and with continual harvesting of fruit and removal of prunings, then nitrogen fertilization may be necessary.

Phosphorus

Phosphorus (P) is involved in the transfer of energy within plant cells that facilitate metabolism and is a constituent of the fatty portion of cell membranes and of compounds involved with assimilation and metabolism of carbohydrates. It constitutes approximately 0.1 to 0.3% of dry matter of the vine, equivalent to 1.3 lbs per ton of grapes (Robinson, 1988). Deficiency of phosphorus in vines can result in reduced vine vigor and yellowing of the interveinal area of basal leaves. In extreme cases, some red discoloration of the interveinal area of basal leaves may be observed (Fig. 2), followed by early defoliation of these leaves. These symptoms may be confused with leafroll virus but phosphorus symptoms occur earlier in the growing season (flowering). Poor bud initiation and fruit set may also be observed. Excessive phosphorus has not been shown to be a direct problem for grapevines; however it may limit the uptake of other essential elements, such as zinc.

Phosphorus is available from the breakdown of organic materials in the soil or as an applied fertilizer, which is common practice in Australia where the soils are inherently low in native concentrations of phosphorus.

Potassium

Potassium (K) constitutes up to 3% of the dry weight of a grapevine and is an important component of grape juice and thus wine. The role of potassium is to contribute to the regulation of water movement within the vine by providing an electrical balance for anions in the vacuole of plant cells and maintaining turgidity of cells. In red varieties, potassium is important for berry color development. Potassium deficiencies is expressed as marginal leaf yellowing in white varieties and marginal leaf reddening in red varieties, followed by marginal leaf burn, marginal leaf curling (Fig. 3) and defoliation of all varieties in severe cases. Potassium is readily mobilized in vines as symptoms move from basal leaves to younger leaves, as the vine grows. Other less common symptoms include reduced bunch weight, uneven berry ripening and blackening of leaves. Like phosphorus, high levels of potassium do not directly affect the vine or fruit but may limit calcium and magnesium uptake and increase grape juice pH levels.

Potassium is generally bound to negatively charged clay particles in the soil and many viticultural regions in Australia are based on clay mineral enriched soils, thus potassium availability is not a significant problem. However, potassium deficiency may occur in leached, acidic soils.

Other Macronutrients

Calcium (Ca), Magnesium (Mg) and Sulfur (S) are also found at high levels in grapevine tissue and contribute to the functioning and structure of the vine. Calcium plays a role in the structure of the vine and may be associated with bunch stem necrosis, but this has not been confirmed. Calcium can be applied to the soil in the form of lime or gypsum. Magnesium is a component of chlorophyll, thus contributes to carbohydrate production in leaves through photosynthesis. Magnesium symptoms appear in mid- to late season and include marginal leaf yellowing or reddening of basal leaves, which extends to the interveinal area, while the mid-vein region remains green. High magnesium levels may limit uptake of potassium by the vine. Sulfur (S) is present in proteins and chlorophyll and plays a role in energy metabolism. Sulfur deficiency symptoms are similar to nitrogen deficiency, yet are rare given the widely adopted use of sulfur-based sprays for fungicide management and sulfur containing fertilizers in Australia and around the world.

FIGURE 1: A nitrogen deficient leaf compared to a healthy leaf (sourced from Treeby *et. al*. 2004)

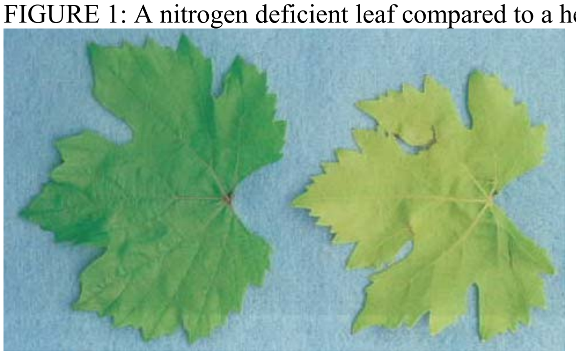
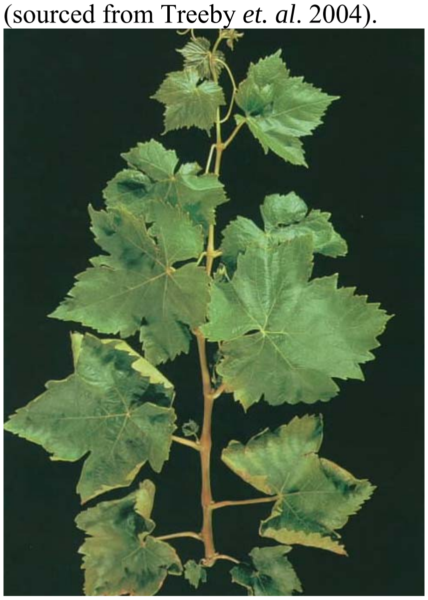


FIGURE 2: Severe leaf symptoms of phosphorus deficiency in a basal leaf of a red variety of grapevine (sourced from Treeby *et. al*. 2004)

FIGURE 3: Potassium deficiency expressed as leaf curling of the older leaves and subsequent leaf margin necrosis (sourced from Treeby *et. al*. 2004).



Micronutrients

Iron

Iron (Fe) is a micronutrient present in proteins for energy transfer in assimilation and respiration and is involved in chlorophyll formation. Deficiency of iron is observed as stunted growth and diffuse yellowing of young leaves and shoot tips (Fig. 4). In severe cases the whole leaf becomes chlorotic (bleached appearance), whereas leaf veins remain green with mild deficiency. Iron can be found in complexes with soil organic matter or in insoluble minerals and its availability is restricted by bicarbonate inhibition in compacted or waterlogged alkaline soils. To date iron toxicity is not known to occur in vineyards.

Manganese

Manganese (Mn) plays an important role in the synthesis of chlorophyll and nitrogen metabolism and is present in soil as exchangeable manganese or manganese oxide. Manganese deficiency is expressed as yellowing of the interveinal area of older leaves (Fig. 5) and may be mistaken for zinc or iron deficiency. These symptoms may be found in vines on sandy, calcareous soils or in areas of high rainfall. Toxicity of manganese is rare but can be seen as black spots on the leaves, shoots and bunch stems.

Molybdenum

Molybdenum (Mo) is involved in nitrogen metabolism and deficiency symptoms include stunted growth. Poor fruit set in Merlot has been linked to molybdenum deficiency and foliar Mo sprays have been use in southern Australia to successfully improve Merlot productivity and growth. Molybdenum is found in soil as molybdate and availability is greater in alkaline soils.

Copper

Copper (Cu) is a component of enzymes involved in oxidation and also chlorophyll synthesis. Deficiency symptoms are not common, probably due to the use of copper based fungicidal sprays but may be expressed as low vine vigor, poor production, shoots do not mature and bark appears rough. In areas of persistent copper fungicide use, toxicity has been reported and results in decreased levels of other essential elements (P, Fe and Zn) in plant tissue.

Zinc

Zinc (Zn) deficiency is common in Australian viticultural regions and is involved in protein synthesis, some plant hormone production and fruit set. Deficiency of zinc can result in stunted growth and development of small, undersized leaves with mottling between veins, clawed margins and widened petiolar sinus. Poor fruit set and “hen and chicken” bunches of variable sized berries may occur even when leaf symptoms are not observed. As a result, pre-flowering zinc foliar sprays are common practice in vineyards.

Boron

Boron (B) exists in the soil as the anion, borate and plays a role in the synthesis of growth regulating plant hormones and fruit set. Boron deficiency is observed as stunted growth with shorten internodes displaying a “zig-zag” pattern, death of shoot tips and interveinal chlorosis of older leaves. In cases of severe deficiency bunch and tendril abortion can occur and pollen tube growth is affected, resulting in poor fruit set. Boron toxicity symptoms include cupped leaves on young shoots, followed by brown necrotic spots on the leaf margin and yellow streaks between veins.

FIGURE 4: Shoot and leaf symptoms of iron deficiency (sourced from Treeby *et. al*. 2004).

FIGURE 5: Manganese deficiency expressed as interveinal chlorosis of basal and mid-shoot leaves (sourced from Treeby *et. al*. 2004).

Grapevine Nutrition Management

Managing the nutritional requirements of a vineyard requires visual assessment of vines and their growth habit for abnormalities and assessment of the nutrient status of plant tissue and/or the soil to develop an appropriate fertilizer program. Analysis of the nutrient content of petioles gives a good indication of the available nutrients to the plant, whereas soil tests reflect the nutrient content present in the soil and not necessarily available to the plant.

Grapevines generally require some supplementary fertilizer to ensure maximum production. Macronutrients are usually applied to the soil surface in dry form, ripped into the soil or applied via fertigation, whereas micronutrients are generally applied directly to the vegetative part of the vine via foliar sprays. Successful fertilizer management is dependent on selection of the correct fertilizer to address the specific deficit experienced in the vineyard, correct calculation of nutrient requirements, timing of the application of the fertilizer and cost-benefit comparison of available fertilizers.

Assessing vine nutrient status

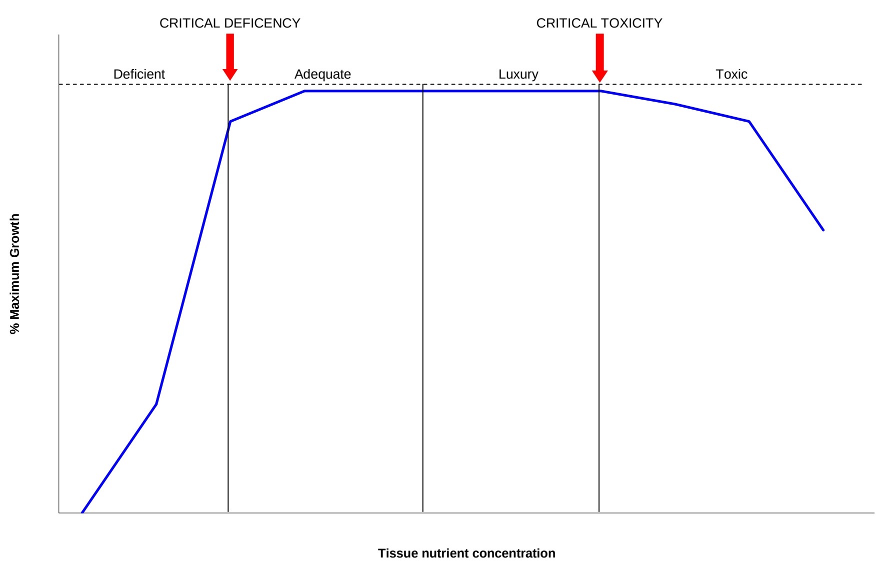
Soil Testing

Soil samples can be analyzed for nutritional composition; however this may not reflect what levels of nutrients are available for uptake by the grapevine. Soil physical properties, such as texture and structure may also be assessed, as they influence the availability of nutrients, especially nitrogen. Soils high in organic content generally have high levels of readily available nutrients. Whereas, sandy soils are likely to be leached of nutrients and high clay content soils will rapidly fix applied potassium fertilizers.

Petiole Testing

Petiole testing involves collection of a sample of approximately 100 leaf petioles taken from leaves opposite the basal bunch at 50% cap-fall (Treeby *et. al*., 2004). Samples should be collected from separate blocks, different varieties and rootstocks and from areas of apparent nutritional symptoms. Samples should be collected in the morning while wearing gloves, stored in a new paper bag and dispatched to the analytical laboratory immediately. Analytical results are expressed on a dry weight basis. Analyzed nutrient levels are compared to a range of nutrient concentrations standards representing deficient, adequate or high levels of specific elements based on plant performance. Deficient nutrient concentration limits vine performance and could be improved by nutritional supplement, adequate concentrations will not limit vine performance and high or excessive concentrations can be toxic and have an adverse effect on vine performance (Fig 6).

FIGURE 6: Schematic representation of the relationship between plant tissue nutrient concentration and vine performance.



Fertilizer Management

Developing an appropriate fertilizer program for a vineyard should involve answering 3 key questions: what fertilizer is the most appropriate for the job, how much nutrient is required based on petiole analysis and seasonal vine usage and when should the fertilizer be applied to maximise its benefit? Significant levels of nutrients are removed from the vineyard as grapes and pruning material each year. Further losses of nutrients can be attributed to volatilization, leaching and adsorption in the soil.

Fertilizer selection requires an understanding of the elements present in the fertilizer, the concentration of those elements and their availability to plants. This information is critical for evaluating the fertilizers effectiveness as a nutrient supplement and its value for money. Other considerations in fertilizer selection include other nutritional supplements the product supplies, ease of application, occupational health and safety requirement around handling and storage, certification for organic status and additional side effects (soil improvement, odor, spray drift etc).

Fertilizers

Nitrogen can be applied as a fertilizer in 3 forms: nitrate, ammonium and urea. Vine roots take up nitrogen in the nitrate form more readily than the ammonium form. Yet the choice of nitrogen fertilizer can be determined on cost (urea is cheapest per lbs of N) or physical property of the fertilizer (sulfate of ammonium is easy to handle but is most acidifying). Fertigation with calcium nitrate is popular in Australia, as calcium is also supplied in soluble form which can neutralize acidic soils.

Phosphorus fertilizers are classified as water soluble, citrate soluble and citrate insoluble. Water soluble forms are readily leached into the soil, thus fertilizers with high levels of this form are preferable. Superphosphate is produced by the reaction of rock phosphate with sulfuric acid. The majority of the phosphorus is in the water soluble form and this fertilizer also contains calcium, as gypsum, which helps maintain soil structure. Mono-ammonium and di-ammonium phosphates are also popular fertilizer choices in vineyards, as they have the advantage of being readily soluble and provide a source of both nitrogen and phosphorus. However, these fertilizers are not suitable for use on acidic soils.

Mixed fertilizers are generally a combination of nitrogen, phosphorus and potassium in various ratios. These fertilizers have the advantage of lowered application costs but a suitable ratio should be selected based on the vineyards specific nutrient requirements.

Organic fertilizers are gaining popularity, as they are often viewed as a soil amendment to improve soil structure and microbial activity in addition to providing nutritional benefits. The increased cost of synthetic fertilizers in recent time and industry shift to sustainable practices in the vineyard has also aided the shift to organic fertilizers.

Micronutrients are applied as foliar sprays, as they are more readily available to the grapevine via the vegetative portion of the plant. Also, micronutrients become immobilized if they come in contact with the soil due to the soil exchange capacity, thus have minimal chance of being leached into the rootzone.

Timing of fertilizer application

The timing of fertilizer application depends on vine age, phenology, availability of soil moisture, nutrient mobility and cation exchange capacity. Young vines require increased nitrogen inputs to ensure rapid root and vegetative growth compared to older, established vines. The phenological development of a grapevine dictates which nutrients are required based on the growth of vegetative or reproductive components of the vines. Nitrogen, molybdenum, potassium and phosphorus are important after budburst, when the vine is undergoing rapid vegetative growth. Whereas, magnesium, zinc, manganese, boron and iron are critical prior to flowering when compounds are required for good bud initiation for the following season and fruit set in the current season. After harvest, a flush of root growth and carbohydrate storage in the trunk requires addition nitrogen, phosphorus and calcium inputs. The movement of applied fertilizers through the soil into the rootzone is dependent on the soil moisture content, as provided by irrigation and /or rainfall and also, the concentration of the negative charge of the soil in the case of the cationic micronutrients.

References

Robinson, J.B. (1988) Grapevine Nutrition. *In* 'Viticulture. Volume 2, Practices'. Eds. B. Coombe and P. Dry, Winetitles, Adelaide, South Australia. pp. 178-208

Treeby, M.T., Goldspink, B.H. and Nicholas, P.R. (2004) Vine nutrition. *In* 'Grape Production Series No. 2. Soil, irrigation and nutrition'. Ed. BP. Nicholas, South Australian Research and Development Institute, Adelaide, South Australia. pp. 173-197