2. Maintenance of P. K. S and Micronutrients

Phosphorus

Phosphorus (P) is an essential constituent of every living cell. It is concerned with structural compounds, energy transformation, cell division, and generally proper metabolism. Seeds, grains and tubers, especially of high protein, require higher amounts of P for growth. In tree fruits and vines, the highest P concentration is in the seeds; since this is a small part of the crop, only 5-40 #/ac are removed with the crop or tied up in woody parts.

25-80% of phosphorus is in the organic matter in the soil (Bear, 1964), with the remainder in various inorganic compounds. These inorganic forms are generally not available to plants at high or low pH levels.The form considered most important for uptake is the P_2O_5 ion, although Ratever & Ratever (1993) made a very good case for the importance of mycorrhizae (fungi that grow on roots) delivering P to plants. Since these life forms are often missing from crop soils, crops must often get by with mineral P. Either way, the availability of P depends on optimum temperature, moisture, pH, active organic matter, and aeration.

Because of the low removal and utilization by tree fruits & vines, P deficiency has been reported rarely in California, and fertilization was generally not recommended. Because wine grapes are often grown on marginal hillside soils, around 1979 agronomists such as myself recommended both limestone and phosphate additions to acid soils with low P levels. In 1983, Cook, Ward and Wicks documented P deficiency on Napa hillside vineyards. Applications of calcium phosphate to vineyards every 3-5 years is now a common practice in northern California. Establishment of young trees and vines are aided by low amounts of P fertilizer. Often the application of limestone insures adequate uptake of P from soil reserves.

Although actual deficiencies are rare, adequate P levels are encouraged to insure optimum fruit set & quality, and fruitfulness of buds in trees and canes of vines. Neilsen, Parchomchuk and Neilsen (1994) reported that young apple trees fertilized with P had more fruit in the second year. The SLAN method is valuable for setting critical levels; BCSR helps insure optimum pH, aeration, and subsequent availability.

Potassium

Potassium is used in the plant in the simple ionic form; it moves about and is not incorporated into any organic compounds in significant amounts. Its functions are: ionic balance in plant fluids, osmotic regulation, and formation of proteins, carbohydrates and sugars. It helps regulate water relations, balances out effects of nitrogen, and aids in over 60 enzyme reactions. Thicker cell walls with adequate K help plants resist pests & diseases (Bennett, 1993). Potassium is often described as a quality element because of its effect on color, skin quality, and storage life of fruits and vegetables. In many crops more pounds of potassium are removed than any other nutrient.

In soils, K^+ adsorbs on the clay with the other cations, and is sometimes tightly held ("fixed"), so its availability can be highly variable. Both solution and exchangeable K are available to plants, however some soils have a high K-fixing ability. Optimum K availability is hampered by cold, wet, poorly aerated soils, and poor cation ratios. Because potassium resists leaching, as do iron and aluminum, they all three tend to dominate the clay in very high rainfall soils.

In tree fruits, K assists in flower bud formation, fruit set, and the color and size of fruit at harvest. Sugar and acidity of fruits are all affected by K nutrition and its balance with calcium and magnesium is important in several fruit quality disorders (Peterson & Stevens, 1994). Lowered resistance to frost, winter kill, and many disorders, pests, and diseases occurs with K deficiency . In vineyards, leaf scorch occurs with low K, along with hampered ability to ripen grapes, and resist mildew, bunch rot and other diseases. A symptom called black leaf shows up on sun exposed leaves, especially on white grape varieties. Excess K in juice can cause pH problems in the wine. Numerous examples of nutrient-disorder relationships are given in Appendix D.

The SLAN method is usually used to manage potassium fertilization, however this model results in recommendations that "the high fixation capacity be saturated before planting with a single massive rate of K..." to avoid K deficiency (Bennett, 1993, p. 179). This makes sense from their perspective, but the BCSR method works much better in practice.

Sulfur

The role of sulfur (S) in plants is similar to nitrogen; it is part of amino acids and proteins. About 1 pound of S is needed for every 10-15 pounds of N. The higher S amounts are needed in protein crops. Sulfur helps control nitrate buildup in plants. Deficiency symptoms of S can be difficult to diagnose because they are similar to those of low N. In tree fruits, S deficiency symptoms appear first on young leaves; N deficiencies show up on oldest leaves. In wine grapes sulfur and nitrogen metabolism has been related to the evolution of SO_2 and H_2S in wine, which leave undesirable flavors. About 15-35 pounds of S per acre per year are needed by tree fruits and vines.

Sulfur occurs largely in the organic matter of the soil. As with nitrogen it occurs in a cycle, and transformations are largely biological. Uptake is through assimilation of SO_4, small amounts of organic S, and even atmospheric sulfur dioxide (Bear, 1964). Under anaerobic conditions such as in wet manure piles, tidal flats and sewage ponds, decomposition of organic matter releases noxious sulfites, hydrogen sulfide, or organic compounds. Optimum soil aeration is most important to protect against toxic forms of S and provide plant-available forms. This also minimizes loss through volatilization.

In tree fruits and vines, the use of elemental S as a fungicide can apply from 25-50 pounds per acre per year to a field. Commonly soil analyses show low S despite these annual applications. Apparently this sulfur is tied up in organic form or easily leached as SO_4. Attention to sulfur is important for wine quality and efficient nitrogen management in orchards.

The SLAN method helps with determining critical S levels in soil; however BCSR interpretation is the key to optimum sulfur nutrition.

Magnesium

Magnesium (Mg) is at the center of the chlorophyll molecule. It is present in plants at 1/4 to 3/4 that of Ca, and aids in the uptake of other nutrients, notably phosphorous. It activates enzyme systems, and aids in the formation of sugars, oils, and fats. Deficiencies show up on older leaves, as Mg is moved to actively growing plant parts. This results in chlorosis of older basal leaves.

In the soil Mg disperses the clay aggregates, which glues the soil into a massive condition. This condition is responsible for most of the drainage problems in soils of northern California. This affects nutrient availability and disease problems in crops, drainage in septic and leach fields, erosion, and soil engineering.

Because of sodium's well known role of clay dispersion, Mg is commonly believed to "resemble calcium chemically and in its action in the soil" (Plaster, 1992, p. 264). This is not accurate. Calcium to magnesium ratios of about 6:1 are preferred by agronomists who pay particular attention to soil structure, aeration, and drainage. Although excess Mg in local soils is more common, excessive K, NH_3 or Ca applications can put the basic cation ratio out of the optimum range and induce Mg deficiencies.

In fruit trees, early fruit drop, defoliation of older leaves, and poor fruit quality accompany severe shortages of Mg. In grapevines, leaf chlorosis may limit production and vine health, although not as critically as potassium. Thus BCSR insures that Mg is not so concentrated that it causes clay dispersion and soil structural problems, while avoiding deficient levels.

Calcium

Calcium (Ca) in the plant is a constituent of the cell walls, forming a "protective 'sieve' for nutrients to seep through in passing into cells," and "acts as a cement between the walls of cells to hold them together" (Sprague, 1964, p. 9). Trees and vines in particular need good calcium supplies; just the above ground woody portions of a 36 year old apple tree contain 5.7 pounds of Ca and only 5 pounds of all other nutrients combined (Shear, 1975). Fregoni and, Scienza (1985) calculated the annual removal of calcium by the grape crop and vines to be 35-85 pounds per acre. Of the 150 pounds per acre of Ca utilized annually by a mature apple orchard (50 trees/ac), 105 pounds is returned via leaves and prunings while 45 pounds is permanently removed by wood and roots (Batjer, Rogers & Thompson 1952). Increased planting densities in orchards and vineyards may require even more attention to Ca nutrition.

It has been known for a long time that Ca is needed for growing roots and apical meristems. The supply must be "taken up from the soil surrounding the root tips and translocated to the growing points in the roots without interruption" (Jakobsen, 1993). When a soil contains less than optimum amounts or ratio of Ca to other cations, the plant must expend energy searching for the needed calcium. This will be aggravated in heavy clay soils, where root growth is more difficult. Temporary or chronic deficiencies of calcium result in physiological maladies rather than leaf symptoms as with other nutrient deficiencies (Traynor, 1980)

Shear (1975), one of the early pioneers in calcium studies, documented 35 disorders associated with Ca deficiency, including bitter pit of apples, cork spot of pears, cracking of cherries & prunes. Traynor proposed shatter of grape and walnut blossoms (1980), orchard decline, and aggravated nematode problems (1986) be added to the list . Since rapidly growing shoots demand Ca, N-stimulated shoot growth can compete with fruit for available Ca (Shear, 1975). Thus overuse of nitrogen can impair Ca uptake, and aggravate physiological disorders. A more complete list of Ca related disorders is found in Appendix D.

Calcium in the plant neutralizes toxins (Sprague, 1964), and one of its most important functions is protection against imbalances and excesses of trace metals (Wallace, 1979). This is especially important in our area, where acid soils and excess micronutrients result in unpredictable uptake.

In soils, when it predominates on the exchange complex, calcium increases nodulation on legumes, promotes organic matter breakdown, increases availability of other cations, and buffers the uptake of excess micronutrients. Ca should exist in balance with the other major cations, and excesses of Mg, K, Na or NH_3 can depress Ca uptake (Shear, 1979). Agronomists who pay particular attention to soil aeration, drainage and tilth suggest a 6:1 ratio of Ca : Mg, as BCSR theory suggests.

The Western Fertilizer Handbook (1980), lists the following agronomic benefits of the application of limestone to acid soils:

Correction of chemical, physical and biological conditions.
Toxicities of elements minimized.
Availabilities of micronutrients optimized.
Best biological activity, nitrogen fixation, organic matter breakdown.
Soil aggregation and good structure favored. (p. 118)

Micronutrients

Elements used in relatively small amounts were formerly called "minor elements." This term has been replaced by "trace elements" or "micronutrients" after agronomists learned that these elements were as important as "major" nutrients, simply used in lesser, or trace amounts. The micronutrients commonly recognized to be essential for plants are zinc (Zn), manganese (Mn), iron (Fe), copper (Cu), boron (B), chlorine (Cl), sodium (Na), molybdenum (Mo), and cobalt (Co) (CDFA, 1996). Despite claims from some plant food manufacturers that plants utilize every element from antimony to zirconium, the CDFA (1996) recognizes only these nine. According to Stevenson (1986), nickel (Ni) should be added to the list. Silicon (Si) is important for other crops. Efficacy studies to document plant response to fertilizers sold in California are required for state registration. This makes sense from a consumer standpoint. However subtle effects of micronutrients on plant disease resistance or quality may never receive the research needed for "proof" of efficacy.

Silicon is important for rice, and deficiency symptoms are described for sugar cane (Bennett, 1993). Biodynamic farmers have stressed the importance of Si sprays for plant disease resistance. More research on micronutrients is needed, especially on relations with pest & diseases.