9. CALCIUM Emerging Superstar

Calcium will be the most studied nutrient for the balance of this century, if it is not already, and over the next 100 years more calcium will be applied to agricultural crops than any other nutrient.

A good deal of the credit for the focus on calcium goes to USDA worker C.B. Shear who, in a 1975 paper, condensed much of the significant information on calcium into a little more than 3 pages followed by over a hundred references. Shear's short tract is truly a treasure trove of information and should open many eyes to the magnitude of potential calcium related disorders it can already be termed a classic. Shear also spearheaded an international symposium on calcium in 1977 that has provided an additional forward thrust to calcium related research.

It is understandable why calcium has not been given more consideration than it has. Most textbook discussions of calcium deficiency draw from nutrient culture studies in which plants are grown without calcium. Under these conditions cell wall structure deteriorates, providing classic pictures of drooping plants such pictures are permanently etched in the minds of plant nutrition students.

These textbook symptoms of calcium deficiency are simply not seen in the field. Couple this with the fact that calcium is the 5th most abundant element in the earth's crust and it is little wonder that calcium nutrition is the furthest thing from the minds of fieldmen when dealing with day to day problems in agriculture. When working on a crop disorder occurring on calcareous soils* it is little wonder that calcium nutrition is not even considered.

*calcareous soils are defined as those containing calcium carbonate (also referred to as lime); calcareous soils are extensive in arid areas.

The paramount role currently assigned to calcium is maintaining the structure of membranes. Calcium counteracts the potential harmful effects of other divalent cations and also of sodium and boron. One researcher put it this way: "The greater a demand is made on the selective machinery of the plasmalemma, through the presence in the medium of potentially damaging ions at high concentrations, the more crucial seems to be the role of calcium in maintaining the integrity of the membrane." Toxicities of other elements, including aluminum, are sometimes associated with calcium related disorders and such toxicities should be considered when attacking potential calcium related disorders.

In tackling calcium related problems, agriculturists should discard traditional thinking on nutrient deficiencies. One of the first steps towards understanding calcium nutrition is separating calcium "deficiency" from "calcium stress". A "deficiency" of calcium is a condition that is corrected only by the addition of calcium. "Calcium stress" is caused by a temporary localized inadequacy of calcium; the entire plant is usually not affected, with the stress often confined to the fruiting part or growing point. Addition of calcium to the soil does not always correct calcium stress since the temporary, localized shortage of calcium may be beyond the plant's adsorption and mobilization powers to correct. Environmental factors can have more influence on calcium stress disorders than actual amounts of soil available calcium.

Foliar sprays of calcium (usually calcium nitrate or calcium chloride) are often more effective than soil applications but even foliar sprays do not always correct calcium related disorders. Soft apples and bitter pit of apples, both calcium related disorders, are better corrected by post harvest treatment of apples than by soil and/or foliar applications of calcium.

A study of calcium related disorders shows that many are associated with moisture relations in crops. There are hundreds of research papers dealing with blossom end rot in tomatoes and peppers authors of some of these papers present convincing evidence that calcium nutrition is the causal factor and other authors present equally convincing data that moisture stress is the sole cause; probably both schools of thought are correct. Because of the precipitation of calcium compounds as the soil dries, moisture stress may automatically mean calcium stress. Calcium: sodium ratios of soil solution are also involved.

In an experiment on a highly calcareous clay soil with an ESP of 7.3, frequent (daily or twice daily) sprinkler irrigations gave a 4% incidence of blossom end rot vs. a 30% incidence on the control. The differences are likely related to Ca:Na ratios in the soil solution.

Epstein has stated that "although all growing points are sensitive to calcium deficiency, those of the roots are affected most severely." Calcium has been shown to improve the rooting of cuttings, primarily by improving (increasing) the calcium:sodium ratio. Research has shown that calcium **deficiencies** can occur on **calcareous** soils that have a high percentage of exchangeable sodium and other studies indicate that the ratio of calcium to other soluble salts is more important than the absolute value of calcium itself.

Improving the Ca:Na ratio (or reducing the SAR) in irrigation water and/or in soils has been shown to improve soil structure and water penetration and thus benefit plant growth. It is likely .that improvement of the Ca:Na ratio beyond that necessary for soil structure improvement will benefit some plant species. Since calcium compounds are the first to precipitate out of the soil solution as the soil dries, esp. in calcareous soils, the Ca:Na ratio of the soil solution is not constant (esp. in calcareous soils) but is significantly higher in wet soil than in drier soil. The constantly recurring association of calcium related problems to moisture stress can be explained in part by Ca:Na ratios in the soil solution.

The 1946 study that showed that calcium **deficiency** occurred on calcareous soils (that have a high sodium %) answers those that say "impossible" when it is suggested that physiological disorders on a calcareous soil may be due to calcium stress. It is of interest that the two calcareous soils on which calcium deficiencies were found in this study were from Oregon and Washington where calcium disorders on apples are widespread. If calcium deficiency can occur on calcareous soils with a high sodium % it is certainly probable that calcium stress disorders can occur on calcareous soils that have a moderate sodium content, especially in the lower ranges of soil moisture.

Although calcium analysis of affected plant parts can sometimes provide useful information, plant analysis for (total) calcium is generally of very limited value in diagnosing calcium related problems. Plants accumulate large amounts of calcium as

relatively insoluble, biologically inert compounds, particularity calcium oxlate*. The calcium in these compounds is not readily translocated and therefore not available to the areas of need of the plant. As leaves get older, the amounts of these biologically inert compounds increase (calcium levels in leaves are used as an index of leaf age in the interpretation of citrus leaf analysis). Plant analysis for calcium has been of little value in diagnosing calcium related disorders because calcium analysis values that include biologically inert compounds are not meaningful. It is possible that calcium is required in only micronutrient quantities during certain critical stages of plant growth.

*plants produce oxalic acid during periods of high activity. Accumulation of high amounts of oxalic acid can cause toxicity. Calcium is probably needed to neutralize oxalic acid by forming calcium oxalate.

With their favorite tool, plant analysis for the target element, taken from them, many fieldmen do not pursue potential calcium related problems. Such problems are classified as "physiological disorders" an imprecise but not incorrect term. "Physiological disorder" has become an accepted euphemism for "we don't know the answer."

Why are more and more calcium related disorders being reported? An historical look at the origin of the affected crops provides some clues. Crops on which calcium related disorders are most common originated on soils that were high in calcium, many of them calcareous. These plants could be termed calciphilic, or calcium loving species. Grow these crops under the same conditions as they originated and there should be no calcium related disorders. However, grow the same crops under intensive irrigation with a low calcium irrigation water (e.g., snowmelt from the Sierras) and you will gradually deplete calcium levels in the soil. Plant species that have evolved over the eons on low calcium soils or acid soils do not exhibit calcium related disorders because they have learned to survive with a minimal amount of soil calcium, i.e., they are not calcium stress susceptible.

Soils that are low in calcium are often low in boron because the same factors that caused low calcium cause low boron. Calcium stress disorders often occur along with and are interrelated with boron deficiency disorders; both must be corrected to effect a cure to a particular problem.

Today (1 980) there are a number of "mystery" disorders showing up on California crops that have not been seen before and that cannot be traced to any known pathogen. These disorders are more common on the east side of the great central valley and include:

Pox on nectarines

Die back on walnuts

Shedding (or shattering) of walnut flowers

Shattering (or shedding) of grape flowers

Fruit drop on a number of crops.

These disorders are currently labeled "physiological disorders" and are causing considerable head scratching among researchers. Perhaps calcium will be implicated in these disorders at a future date. (Boron may also be involved see Chapter 13).

Calcium nutrition still represents the largest unexplored area of plant nutrition this in spite of the fact that there is already a wealth of information on calcium. Much of this information, however, is fragmentary and contradictory and inevitably leads to frustration on the part of anyone trying to obtain a solid grip on calcium nutrition. This frustration was expressed in the following way by an extension specialist from Oregon: "The list of what we don't know about the factors influencing calcium distribution is really much longer than I have indicated. Our ignorance is so profound and the literature so full of poor research and unwarranted conclusions that I would be tempted to advise young pomologists and physiologists to discard all their reprints of research papers and start over from scratch."

Many calcium related problems rest in the "no man's land" between the disciplines of plant science and soil science and an interdisciplinary approach is needed to solve these problems.

Significant progress in calcium nutrition will only be made after more fieldmen ask the question, "is it possible that calcium nutrition is involved?"

General References

1. Shear, C.B., **Calcium-related disorders of fruits and vegetables.** HortScience 10:361-365. 1975.
2. Shear, C.B. (editor). **International symposium on calcium nutrition of economic crops.** Communications in Soil Science and Plant Analysis, 10(1 & 2): 1-502 (special issue devoted entirely to the calcium symposium and comprising 37 papers). 1979.