5 CALCIUM

5.1 Role in citrus production

Calcium and strong cells and hence shelf life are synonymous. The role of calcium (Ca) can be compared with that of cement in a brick wall. In the absence of Ca the cells loose their cohesion and sturdiness and the structure collapses. Calcium is required in processes involving cell division and cell growth and plays an important roll in the activities of biological membranes. When Ca is substituted by H^+ in the nutrient solution, these membranes loose their permeability, organic compounds leak from the cells and the cells die.

The concentration of Ca in the soil solution is 10 times as high as that of potassium, but less Ca is absorbed than K. Calcium is absorbed by a passive process where it enters the plant and is translocated to the fruit and leaves via the flow of the stream of water. The transpiration of young leaves is much higher than that of young fruit and more water and thus more Ca will end-up in the leaves.

Climatic conditions have therefore an over riding effect on the supply of Ca to cells of trees in commercial orchards. Any element of climate that reduces the flow of water from the roots to the fruit, leaves and shoots can induce a Ca deficiency. Therefore too high temperatures will result in closing of the stomata resulting in stopping the flow of water. With no water flowing through the plant no Ca is delivered to the fruit.

Calcium only moves upwards in the trees. Therefore Ca applied to leaves will not be relocated to other parts of the plant. Only the leaves sprayed with Ca will benefit and only at the time of contact. Ca that is not utilised will be precipitated as calcium oxalate. Calcium oxalate is not soluble in water and is, for all practical purposes lost to the tree and fruit.

Plants require fairly small amounts of Ca for normal functioning, but under field conditions, the absorption of Ca is inhibited by other divalent cations of metals. Calcium is also involved in the detoxification of heavy metals and higher concentrations of Ca can be required under field conditions to satisfy the demand.

Calcium absorption is best in combination with nitrate and absorption is most active in the area just behind the root tip.

No relocation of Ca is possible and no Ca will be transported from old to young leaves or fruit. However, during the night when the humidity is high and temperature is not too low, the roots will keep on absorbing water. Pressure is building within the plant and some Ca can be forced backwards in the phloem tissue to the fruit.

Calcium is also very important for the development of roots. In the absence of Ca, the roots tips will die within days.

When high levels of nitrogen increases vegetative growth, fruit will receive less Ca. Fruit cannot compete with young leaves for water and hence Ca.

Calcium fulfils an even important role in the soil. There it is also responsible for building and maintaining the structure. A proper structure of the soil will enhance root efficiency through better aeration and water penetration. Calcium is also involved in detoxification of high concentrations of B, Cl and the acid soil complex. By applying only Ca without increasing the pH of the soil at pH 4,0, an improvement in production of Valencias of 500%, was achieved. When the soil pH was 6,00 the improvement in yield with additional Ca was 56% (Anderson, 1972).

Calcium deficiency

A lack of calcium needs only to last for a few hours to have an impact on quality. If the transpiration rate is reduced for a few hours by clouds, all cells formed during that period are potentially at risk to show calcium deficiency. Plants rely on a low but constant supply of Ca every hour of the day. Freshly absorbed Ca cannot correct previous short supplies nor can it be stored for future use.

Because Ca can not be relocated, a Ca

deficiency will first of all affects the growing cells like root and shoot tips, meristem and storage organs. It is also involved in leaf drop but has apparently no function in enzyme reactions.

Sporadic deficient supplies of calcium are more prevalent in commercial orchard than can be appreciated. The cause of creasing is most probably an interruption in the supply of Ca to the fruit. Factors that induce or aggravate the incidence of creasing are also those that limit the flow of water through the plant.

Calcium absorbed during the first 5 to 6 weeks after blossom is primarily channelled to the young leaves and little enters the fruit. This is also the period when the incidence of creasing is determined. Fortunately Ca is absorbed more strongly during the 5 weeks following flowering.

The relationship between the climatic conditions that aggravate the incidence of creasing and that restrict the flow of water are summarised in Table 19.

Table 19. The relationship between factors that increase creasing and climatic conditions that restrict flow of water.

Factors that > the incidence of creasing	**Factors that reduce the supply of Ca.**
Large number of fruit	Fruit set was improved by mild climatic conditions like overcast and cool weather.
Inside fruit	Transpiration is less on the inside of the canopy than on the outside
Inner half of the fruit shows more creasing	Transpiration is less on the side shaded by the tree than on the exposed side of the fruit.
Low temperature	Cell division is less affected by lower temperatures than transpiration.
Very high temperature	Stomata close and respiration is reduced.

Calcium is supplied to the soil based on parameters that have no bearing on the physiological processes in the plant. When the soil analyses indicate a low pH or low calcium saturation, lime and/or gypsum are applied. Calcium is also present in single super phosphates and LAN and is applied indirectly. However, even when enough Ca is present in the soil, sporadic short supplies to the fruit is still possible.

The ratio between the cations, Ca+Mg and Na (sodium absorption ratio) will also influence the infiltration rate (IR) of water into the soil. A sodium adsorption ratio (SAR) of <2,00 will reduce the IR. Other factors like precipitation rate of irrigation water or rain, mulches and organic material are also involved. Soils containing more than 10-15% clay should have a calcium saturation of 70 to 75% in order to maintain the structure.

In soils planted to avocado, less problems with *Phytophthora* infection is experienced when the Ca content in the soil is high. The higher the Ca contents the less root rot.
Absorption of Ca is also determined by factors like light intensity, humidity, temperature of the air and salinity.

Gypsum is a cheap and abundant source of Ca. Although it is only slightly soluble in water, it can also be applied where drip irrigation is used. When gypsum is applied it is important to watch the concentration and saturation of potassium. Ca will displace the K on the clay complex and the displaced K is subjected to leaching. When K is applied again at a later stage, the reveres reaction will adsorb more K leaving less K available for absorption by the plants.

Excess calcium

Excessive Ca is not commonly found in plant tissue. The high concentration sometimes reported on leaf analyses is more often than not due to the leaves being older than the diagnostic leaf, than an over supply.

The absorption of elements like K and manganese (Mn) is reduced by very high concentrations of soluble calcium. In alkaline and saline soils the poor performance of trees is more likely due to the other complicating factors like high concentrations of sodium and chloride and poor aeration than to the high concentrations of Ca.

In general excess Ca is less detrimental than a deficient supply. Plants grown in soils containing high concentrations of Ca but moderate to low concentrations of the other cations, experience less problems than when grown in soils where one or more of K, Mg and Na are in excess. "Peteca spot" in lemons is apparently due to damage caused by calcium oxalate crystals in the cells. Calcium oxalate is precipitated in the cells when the supply of Ca exceeds the demand.

5.2 Sources of calcium

Calcium is generally supplied to the soil to improve or maintain the structure of the soil (lime and/or gypsum) or to correct the pH (only lime). Acid soils usually have low calcium saturation and this can be corrected by applying dolomitic, calcitic, hydrated or slaked lime. Also refer to Chapter 20.

On alkaline soils, gypsum is the best source to correct low calcium saturation. For all practical purposes, gypsum has no effect on the pH of the soil. When the pH(water) of the soil >8,30, dolomitic or calcitic lime can also be applied to supplement the low calcium saturation. The pH of these two limes is 8,30 and by applying them, the pH of the soil will not be increased. Dolomitic and calcitic limes are much less soluble than gypsum and the residual effect creates the impression that is better than gypsum. Super phosphates also contain Ca.

5.3 Fertilisation with calcium

Soil applications.
The lime applied to increase or maintain the pH of the soil, is also the main source of Ca. In alkaline soils gypsum is the number one choice due to price and availability. As mentioned above dolomitic or calcitic lime can also be used on alkaline soils provided the pH (water) exceeds 8,3. Where the calcium saturation exceeds 80%, little of the applied K will be available (See above).

Fertigation with microjets
Calcium nitrate is about the only soluble source of Ca and can be used with microjets. However the application of gypsum or lime is more effective methods to add Ca to the soil and the nutritional program. Calcium nitrate is too expensive to use with microjets.

Fertigation with drippers.
The most important feature of fertigating Ca with drippers is that it must be supplied for every day light hour during the 6 weeks during and after flowering. Calcium nitrate can be used and will also supply all or part of the nitrogen required. Calcium chloride is very seldom used. Gypsum can also be used but must be placed in a small basin below each dripper. Limes cannot be used in this manner. Lime will precipitate elements like P, Cu, Zn, Mn and Fe. When the irrigation water is acidified to pH 6,00 to 6,50, all the calcium in the water will be available. If the concentration exceeds 50mg Ca per litre it should be enough to meet the demand. However, extra Ca during the critical period during and after flowering will do no harm.

5.4 Foliar sprays

Due to the physiology of calcium, Ca cannot be stored for later use nor can an existing deficiency be corrected, and foliar sprays will have limited value. Only during the actual application period will a foliar spray be of any use. This renders foliar applications of Ca an impossible logistic task.

Apparently apples have a different mechanism. During the first part of the season (up to December), apples can utilise the Ca effectively to satisfy all growth and quality requirements. However, during the second part the absorption is too little and foliar sprays can supplement the shortfall to improve quality (Wojcik, 1999). With citrus it is quite the opposite. Creasing develops during the early stages of development when the supply of Ca to the fruit is too low. Calcium citrate and calcium acetate can also be used with drip systems but no work has been done with these two sources.