Nutrition: Calcium (Ca)

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Calcium function

Calcium (Ca) is the building block of plant cells, where it has three main roles. Calcium:

- strengthens cell walls
- is essential in all new growing points of mangoes including roots and root hairs, leaves, flowers, pollen tubes and developing fruit
- keeps the cell walls elastic and allows the cells to expand as they grow.

Calcium is of major importance for fruit firmness, shelf life, ripening and internal quality.

Calcium behaviour in the soil and plant

Calcium is a cation, or positively charged nutrient, that bonds to negatively charged sites on soil particles. Soils high in clay content and organic matter have more negatively charged sites, meaning they can hold more calcium as well as other positively charged nutrients, such as potassium and magnesium. Sandy, granitic or acidic soils have fewer negatively charged sites and less ability to hold these nutrients. The amount of positively charged nutrients a soil can hold is expressed as its cation-exchange-capacity or CEC.

Most of the plant-available calcium found in soils is in the form of exchangeable calcium. It forms weak bonds to soil particles, making it highly soluble and prone to leaching. Regions that receive high amounts of rainfall often have soils low in calcium and other positively charged nutrients. The levels of other cations in the soil such as potassium (K), magnesium (Mg) and sodium (Na) can compete with calcium for uptake through the roots. As a result, in some cases the soil calcium levels may appear adequate, however a low cation ratio (e.g. Ca/Mg ratio < 4:1) can impede adequate calcium uptake.

This project has been funded by Hort Innovation, using the mango research and development levy and contributions from the Australian Government. Hort Innovation is thegrower-owned, not-for-profit research and development corporation for Australian horticulture

A strategic levy investment, the project Building Best Management Practice Capacity MG17000 is part of the Hort Innovation Mango Fund.

Calcium, unlike nitrogen, does not move within the plant, it stays in old tissues. Uptake by young roots is passive and soil must be moist for uptake to occur. Calcium is difficult to get into fruit and uptake speed depends on particle size, with smaller particle sized Ca achieving better uptake. As calcium is important for all growth phases it needs to be available all year round. In colder weather, transpiration is reduced and the movement of calcium from the soil into the plant may be impacted. The best way to ensure adequate calcium availability and uptake, and to avoid impacts on fruit quality, is to apply calcium regularly throughout the year.

It is especially important for Ca to be readily available to the plant in the first 6-10 weeks of fruit development or until the seed starts to harden. During this period calcium is drawn into the flesh via water that is lost through the stomates, the pores in the skin of the fruit and leaves. The end of this time coincides with when the stomates on the fruit turn into lenticels and transpiration is reduced. Leaf flushing during early fruit development is not ideal as leaves have higher transpiration rates, and this may lead to insufficient calcium directed into the fruit.

Calcium deficiency

Calcium deficiency symptoms are not visually evident on the tree but will show up in the fruit. Calcium deficiencies are linked to internal fruit disorders like soft nose, jelly seed and reduced shelf life (Figure 1).

Figure 1. **Top image:** ***Internal defects of fruit are associated with calcium deficiency;*** **Bottom-left images:** ***Soft nose (left) and jelly seed (right);*** **Right image:** ***Stem-end cavity is another indicator of calcium deficiency.***

Calcium toxicity

Calcium (Ca) toxicity is not commonly seen in mangoes, except in some areas that have high limestone deposits, such as the Katherine area. In these highly alkaline soils, the calcium competes with the uptake of other nutrients such magnesium (Mg), zinc (Zn), boron (B), copper (Cu) and phosphorus (P) causing deficiency symptoms for these nutrients.

Optimum calcium levels

Calcium levels should be regularly monitored by annual leaf and soil analysis, in conjunction with soil pH monitoring. Optimum calcium levels are:

- soil: 3 – 5 meq/100 g, and generally a Ca:Mg ratio of 4:1 to 7:1
- leaf: 2.0 – 3.5% in acid soils and 3.0 – 5.0% in alkaline soils

Common calcium fertilisers

The most commonly used products to improve the calcium status of soils are lime, dolomite and gypsum (table 1). Care must be taken not to overuse these materials as excessive rates may significantly change the chemical and physical characteristics of the soil and subsequently affect plant growth.

Table 1. Common calcium fertilisers and their chemical composition

Fertiliser	Calcium (%)	Other nutrients (%)
Dolomite (calcium & magnesium carbonates)	12-15	8-12.5 Mg
Lime (calcium carbonate)	35-40	
Gypsum (calcium sulphate)	18-20	14-18 S
Ozcal granular lime	39.2	
Calcium ammonium nitrate (CAN) e.g. Cal Am®	8	27 N
Calcium nitrate	18-19	15 N
EASY Cal® (liquid)	18.1	12.6 N
Calcium chelate	7	
Yara calcinit (liquifert soluble solid)	19	15.5 N

Application methods, rates and frequency

Soil/plant calcium management varies widely between soil types and orchard management practices and remains an area that is still not well understood. The amount of calcium removed annually from a harvest of 20 tonnes of mango fruit/ha/year is low at only 23kg Ca/ha/year, however it is common within Australian mango orchards to apply calcium at rates of > 400kg Ca/Ha/year to maintain sufficient calcium levels for high fruit quality.

Calcium is often applied in multiple applications throughout the year as it is required during each plant growth phase, it is not mobile within the plant and is prone to leaching in the soil. A common calcium application program in Australia is one very large application of a dry calcium product to the soil in the second half of the wet season, followed by 5-10 small applications of liquid calcium via fertigation or foliar application during the critical flowering and early fruit development stages.

Key calcium application factors:

- When applying calcium products to the soil, the product used depends on soil pH. If the soil is acidic (pH < 6.5), apply as either lime or dolomite, if the soil pH is neutral, apply as gypsum.
- If pre-planting calcium and/or pH levels are inadequate, calcium fertilisers should be applied well before planting and incorporated with soil cultivation.
- Moisture is needed for Ca uptake, so apply either towards the end of the wet season, as this reduces leaching losses, or apply prior to, or with, irrigation.
- Fine-mesh, ultra-fine Ca forms (liquid and powder) are absorbed by roots and plant tissue more quickly than coarse particles.
- The majority of soil Ca is taken up by new roots, thus soil applications should coincide with root flushes.
- Adequate soil/plant boron levels help promote calcium absorption and transport within the plant
- Calcium application to the tree canopy by foliar sprays, is only effective when soft tissues are present (young leaves, flowers or young developing fruit).

Powder and granular products

Mango orchards usually receive one very large application (e.g. 0.5-2.0 tonnes/Ha) of a dry calcium product (lime, gypsum or dolomite) every one or two years using a fertiliser spreader/spinner. If the soil is acidic (pH < 6.5) lime or dolomite is applied. One tonne of lime/ha can increase soil pH by 0.4 units (e.g. pH 5.5 to 5.9). If the pH is neutral (>6.5) gypsum should be applied.

Regular calcium powders consist of a mixture of coarse and fine particles. The fine calcium particles bond weakly to soil particles and can be actively taken up by plant roots in moist conditions. The coarse calcium particles break down slowly over time and may take many

months before they are available to the plant. Calcium powders may have some advantages as a longer term, slow-release form of calcium, however there are greater risks of losses through leaching and water run-off. New “ultra-fine” granular lime products (e.g. Ozcal), are an alternative dry calcium fertiliser, and can enable more rapid and effective calcium uptake. These products are generally applied in smaller amounts at more regular intervals.

Liquid soil-applied products

Liquid soil-applied calcium products are primarily used at the critical times of flowering and fruit development, when there is a high plant calcium requirement to support fruit development. This period coincides with the dry season, and irrigation is required to ensure adequate soil moisture to enable calcium uptake by the roots. Liquid calcium fertiliser products (e.g. Gypflow, Calcium chelate) are usually applied to the soil via fertigation over this period, at regular intervals. Calibrated boom sprays may be used to apply these liquid products, where fertigation is not available. Care should be taken to ensure boom spray coverage is directed towards the sprinkler-irrigated areas only, to enable calcium uptake by the roots.

Liquid canopy-applied products

A recent development in the mango industry is the use of foliar calcium sprays during flowering and early fruit development, although the effectiveness of these foliar-applied calcium products remains debated. It is important to recognise that these products should only be applied to soft tissues (young leaves, flowers, young developing fruit), as they are not readily absorbed by mature leaves or advanced fruit. Foliar calcium products include calcium chelate. It has been suggested that chelated calcium products may have better foliar uptake than non-chelated forms.

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