Understanding mango crop nutrition

A guide for Australian mango growers

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A BEST PRACTICE RESOURCE

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Introduction

Having the right fertiliser program is critical for efficient tree growth, fruit yield and importantly, fruit quality. It is important you get both the quantity and timing right.

The objective of your fertiliser program is to maintain the soil with adequate nutrition to supply the needs of the trees as they grow throughout the season. To do this effectively requires an understanding of your orchard's soil characteristics and the nutrient requirements for each growth stage of the orchard throughout the year.

Soil impacts on crop nutrition

Soil type

The soil type on mango orchards varies considerably, from orchard to orchard and within different areas of the same orchard. To best understand the fertiliser requirements of the soils it is important that growers conduct soil surveys to determine soil type. Soil types generally fall into one of the four following categories:

- Loam
- Sand
- Loamy sand
- Clay types

Loams are characterised by having higher clay and silt content, while sands have a low content of these fine particles. Differences in soil type have many important influences on tree management but with regard to nutrition the main consideration relates to the ability to 'hold' nutrients in the soil profile.

Soils with a high proportion of fine, colloidal particles (e.g. loam) attract and hold nutrient elements far better than coarser textured soils (e.g. sand). This is related in part to the soil chemistry and in part to the physical characteristics. Water from rain or irrigation usually enters and percolates through sands at high rates which means that the nutrient elements, which are not strongly held by chemical bonds to the sand particles, are easily leached to a depth where the mango roots cannot access them. Leaching also occurs in loamy soils but is less of a problem.

It is therefore necessary to modify fertiliser practices depending on the soil type involved. To maintain a reasonably constant supply of nutrients, loams may require less frequent application of larger amounts of fertiliser, compared with sands where a strategy of applying small amounts (sand particles only hold small amounts of nutrient) at frequent intervals (to continually replace what is taken up or leached) may be more appropriate. Where soil type varies across a single property this means that different fertiliser strategies will be needed for each distinct area. For all soil types, extended periods of heavy rain following the application of fertiliser will result in significant losses, so where possible, avoid applying fertilisers during the peak period of the wet season.

Soil tests

Decisions on fertiliser application rates should be based on accurate soil test records. Testing should be carried out regularly, usually once per year. It is generally accepted that a soil test at the end of the harvest period will be important because large amounts of nutrients are removed from the orchard when fruit are picked, and it is important to replace these nutrients. Care must be taken when applying fertiliser at this time of the year, to consider the risks of high rainfall events which could lead to significant fertiliser leaching from the soil.

Soil acidity – pH

Soil pH should ideally be about 6.5, within an acceptable range of 5.5 – 7.0. In some production regions of Australia, soil pH tends to be lower than 5.5 resulting in the reduced availability of some soil nutrients including nitrogen, calcium and boron. In such situations the soil has become more acidic, a problem that can be rectified by the addition of lime or dolomite fertilisers. Soil pH can be increased by 0.11 units via the addition of 240kg lime/hectare or 400kg dolomite/hectare. When establishing a new orchard, large amounts of lime may be required to correct low pH. To raise pH from 5.0 to 6.5 would require a soil application of 3.6 t/ha of lime.

Lime should not be applied at the same time as nitrogen fertiliser because the high pH may cause loss of the nitrogen through volatilisation – allow two weeks between the application of lime and nitrogen fertilisers. Lime and dolomite contain high levels of calcium and are often applied annually to raise pH and soil calcium levels. Dolomite contains magnesium (Mg) and care should be taken to avoid this product if extra Mg is not required.

Some soils have high limestone content which is associated with pH in the range of 7-8. This high soil pH will reduce the availability of zinc and iron making foliar applications of these elements more important. Soil pH levels can be reduced by applying the sulphate form of fertilisers. Alkalising products such as lime and dolomite should not be used on these soil types.

Healthy root systems

The mango root system is a combination of fine (5 mm diameter or less), highly-branched surface roots and large (>5mm diameter), occasionally branched lateral and tap roots. The fine, surface roots play an important role in both nutrient and water uptake while the larger roots, which can grow many metres deep, mainly anchor the tree in the soil and take up water. In general, growers should mainly consider the surface roots when developing their fertiliser strategies. Beneficial soil microorganisms, such as mycorrhizal fungi, may also play a role in nutrient availability. These micro-organisms are likely to be present in greatest numbers near the soil surface.

The fine surface roots usually grow within the top 30 cm of the soil profile and, within that zone, most roots occur within the top 10 cm. Nutrient uptake requires live, healthy roots to transport the nutrients from the soil environment through the root surface into the tree. A good supply of soil and water, usually from irrigation or rain, is required to support the uptake processes and ensure that nutrients are in solution. In addition to the role of a good water supply in the uptake process, the proliferation and branching of the fine roots will be encouraged in moist soil. This further improves the capacity of the tree to intercept and take up nutrients from the soil.

It is important to recognise that root growth is not random. As a general rule of thumb, fine roots associated with nutrient uptake will proliferate in the regions of soil that provide the most favourable environment for root growth. Soils which are soft, well-fertilised and moist, particularly those with high organic matter levels and a surface mulch layer, will have more fine roots than hard, dry soils that are not fertilised and are more exposed to the extremes of high temperatures and drying. The practical extension of this is that the area of soil that is wet at irrigation is the best place to apply fertilisers. Similarly, it is of limited value to apply fertilisers directly to dry soils, unless rainfall or irrigation is imminent. If the soil is dry the roots will not be active, the fertilisers will not be in solution and tree water uptake is likely to be very low.

Fine, surface roots are known to grow in bursts of activity or ‘flushes’ comparable to the shoot flushes that produce new leaves. Fertiliser applications should therefore be timed to coincide with periods of active root growth where possible.

Tree growth cycles

Mango trees grow through a series of growth events also known as phenological stages (Figure 1). These events are influenced by variety, the environment, and your management—this in turn impacts on productivity. Productivity of mangoes reflects the growth events of the cycle, management interventions and in some instances residual influence of previous management and environmental factors. Each different growth phase has specific nutritional needs, so a key component of mango nutrition management is to match the fertiliser application program to these demands.

The sequence of canopy growth stages are (from harvest):

1. Shoot flushing
2. Shoot dormancy
3. Flowering
4. Fruit development
5. Harvest

Shoot vegetative flushing influences all other plant growth phases by providing the photosynthetic capacity to support future flower, fruit, root and shoot growth. The main period of shoot flushing in Australia's tropics, occurs after harvest in Spring/Summer, which also coincides with the warmest and wettest periods of the year. Often two or three flushes may occur during this period. Secondary shoot flushes can also occur during dormancy or late flowering; however, these are generally undesirable as they can redirect plant resources away from fruit set and development and potentially reduce that season's fruit yield and quality.

Shoot dormancy occurs after the main period of shoot flushing, generally in late Summer/Autumn in tropical Australia. Dormancy is usually induced by lowering temperatures and reduced soil moisture levels. This dormant period is important for fruit production as it allows the new leaves to mature and harden and provides time for the tree to accumulate sufficient carbohydrate reserves for flowering.

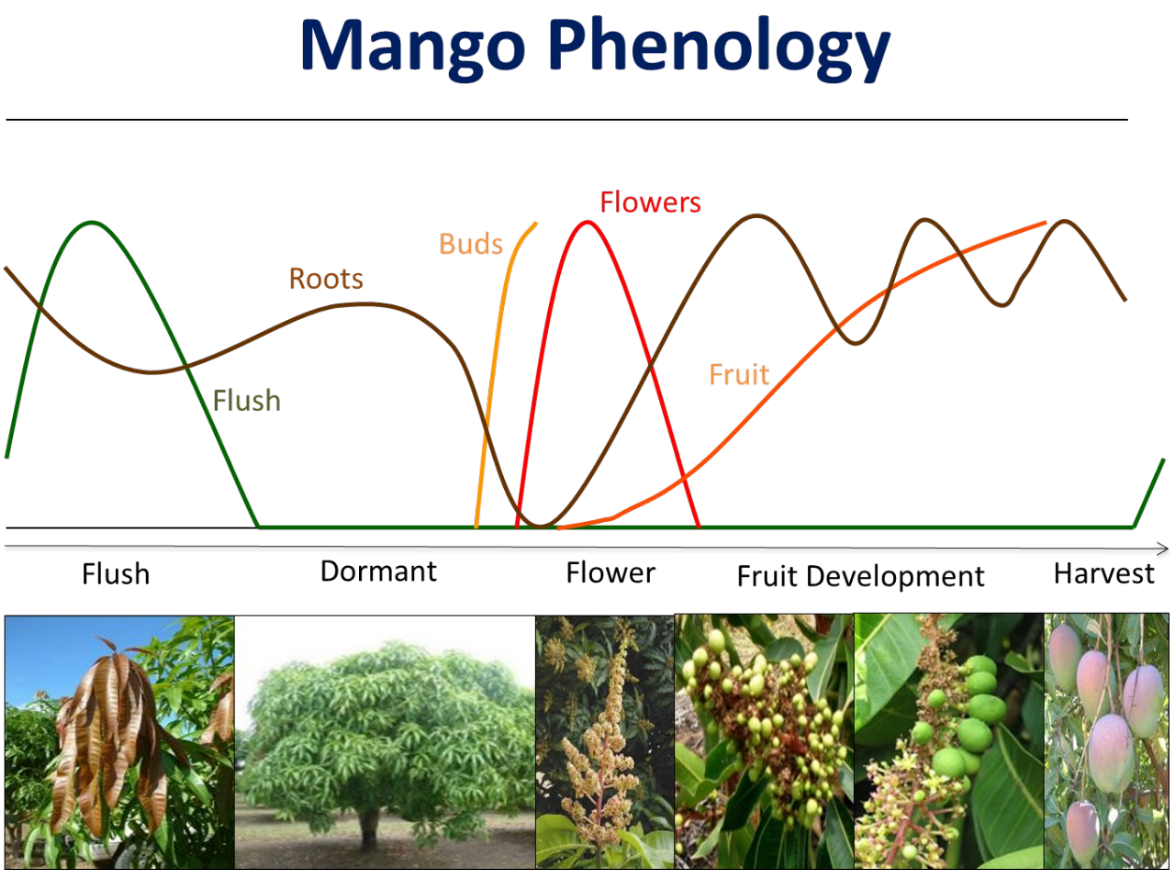
Flowering occurs after dormancy, when the mature shoot terminals are triggered by plant responses to seasonal and climatic factors (particularly lower temperatures) to initiate a flower flush rather than a vegetative flush. The emergence of full or partial vegetative flushes at this time can be due to climatic effects (e.g. unseasonably warm winters) and/or in response to excessive nutrient or moisture conditions in the late dormancy period.

Root flushing in mangoes is not well understood but seems to be most common at times when the other phenological cycles are less active. These times include towards the end of the main shoot flushing period, during canopy dormancy and at intervals during fruit development and maturity. Root flushing is rarely observed during the flowering period. Events including cincturing, severe canopy pruning, soil waterlogging and cold weather can interfere with root development.

Fruit development is a very important time to get the nutrient balance right in the mango tree. The developing fruit have a particularly high demand for Ca, B and K during this period. Excessive and unwanted vegetative flush during this period can also redirect these elements to the flush instead of into the fruit. This can lead to numerous fruit quality disorders and reduced productivity through increased fruit drop and reduced fruit size.

Harvested fruit results in a small amount of nutrient removal from the orchard. A crop of 10t/ha will remove approximately 8.5kg N, 12.9kg K, 11.5kg Ca and 2.0kg B from the orchard. This needs to be considered when developing next season's nutrition program. A short time after harvest, trees will then initiate a vigorous vegetative shoot flushing stage, restarting the annual growth cycle.

Figure 1. Tree growth cycles for a mango tree



Part 2: Key Nutrients

There are at least 14 elements or nutrients that are required for plant growth, however the four key nutrients for mango production are **nitrogen (N)**, **potassium (K)**, **calcium (Ca)** and **boron (B)**. Understanding the interactions of these four nutrients is the key to good productivity and fruit quality in mangoes.

Nitrogen (N)

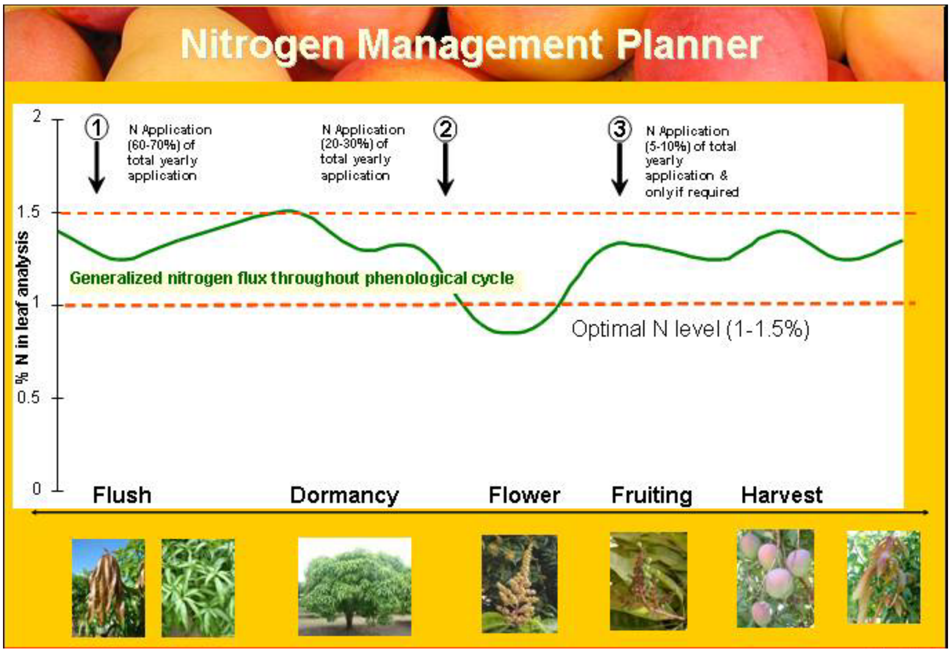
Nitrogen is the driver in plant processes. N:

- Is the most important element for growth, yield, and fruit quality
- Is essential for manufacture of chlorophyll, which in turn produces the sugars required for tree growth and development

N is readily translocated in the tree and this can be seen when flush 'yellows off' as it pushes out flower panicles. The use, timing, and application rates for N vary widely across industry. Monitoring plant N nutrient levels (particularly after harvest) is very important to maintain optimum plant growth and productivity.

Well-timed, optimum quantities of N have many positive effects including increasing tree vigour, stimulating flowering (in conjunction with potassium) and improving fruit set, retention, yield, size and brix or fruit sweetness (Figure 2).

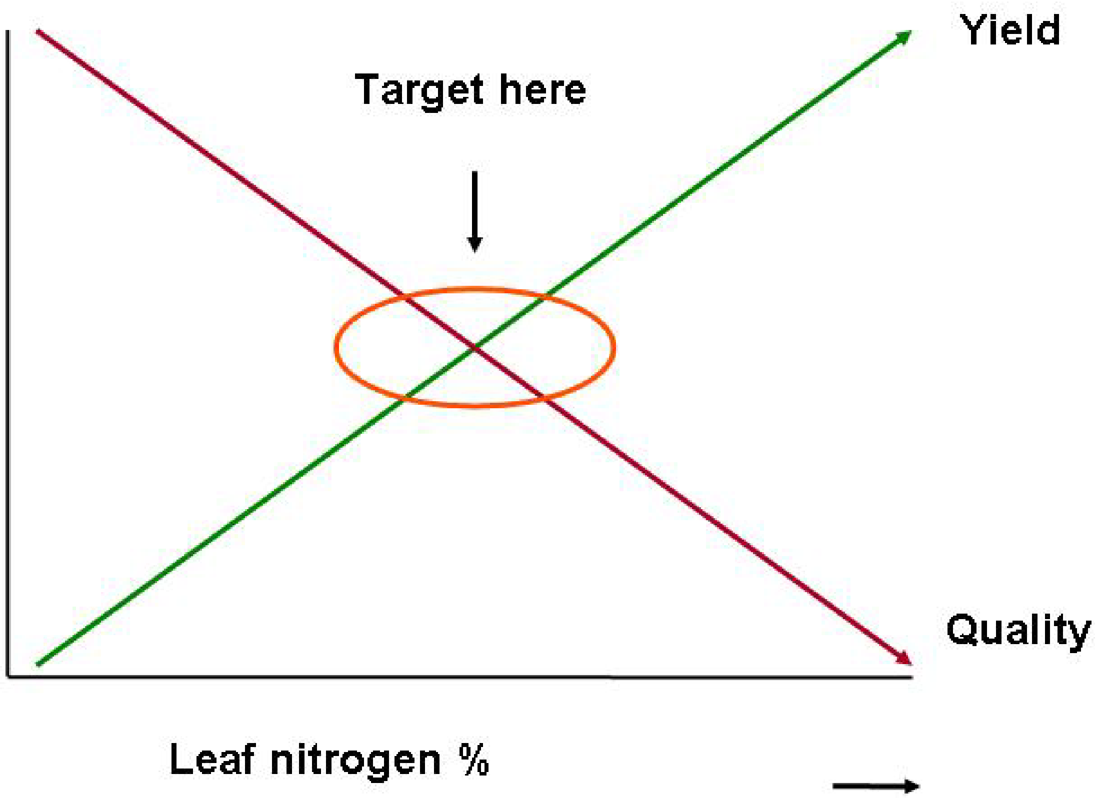
Figure 2. Nitrogen Management Planner



Poorly timed or excessive amounts of N however can have significant negative impacts on mango productivity by promoting excessive or unwanted vegetative flush after dormancy, instead of flowers. Excessive flush during fruit development can also have a major impact on fruit quality as calcium is directed to the leaves instead of fruit, causing problems including less blush, soft fruit, fruit not colouring when ripe and increased post-harvest diseases and disorders.

This careful nitrogen balancing act is called 'The nitrogen conundrum'. The figure below provides a representation of the positive and negative effects of N in mangoes and how they interact (Figure 3).

Figure 3. The nitrogen conundrum



Nitrogen deficiency symptoms include low vigour trees with pale yellow foliage, which often do not hold a good crop. As N is highly mobile in the plant, it can move from one part to another. Older leaves become yellow first as N moves to newer leaves, which remain green. A lack of N can affect the uptake of other nutrients. Trees which are too green are often blamed on excessive N application, however other nutrients including manganese (Mn), magnesium (Mg) and zinc (Zn) can also cause trees to become 'too green', as does Paclobutrazol. Use of a leaf test rather than a soil test is the best way to confirm N status.

Experience and research have shown different mango cultivars have different requirements for N. Suggested leaf N levels for each of the commonly grown mango cultivars in Australia are shown in Table 1 below:

Table 1. Optimum leaf nitrogen levels for the different mango cultivars.

Cultivar	Optimum leaf nitrogen level (%)
Asian cultivars	1.2 – 1.4%
Calypso	1.0 – 1.5%
Honey Gold	1.3 – 1.4%
Keitt	1.0 – 1.2%
Kensington Pride	1.1 – 1.3%
R2E2	1.3 – 1.4%

A good way to calculate N application rate is by the amount required per m^2 of canopy, that is, the area shaded by the tree. Based on research conducted on Honey Gold between 2007 and 2010, rule of thumb application rates for N are shown in Table 2 below:

Table 2. Rule of thumb application amount of N per m^2 of canopy, based on measured leaf levels.

Leaf nitrogen (%)	Applied nitrogen per m^2 of canopy
<1.0%	8g
1 - 1.2%	4g
1.3 - 1.5%	None required
>1.5%	Levels too high

Calcium (Ca)

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

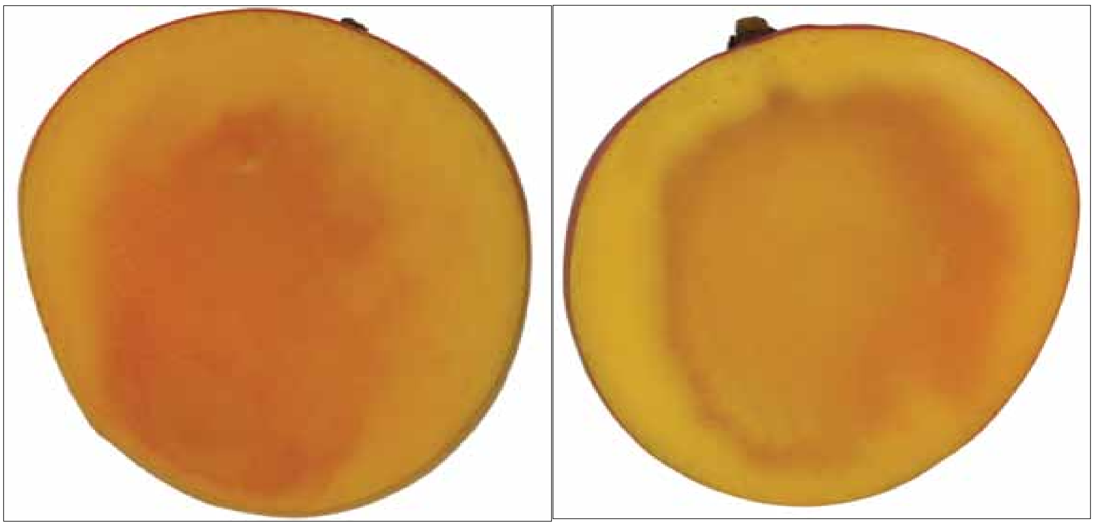
- Strengthens cell walls
- Is essential in all new growing points of mangoes including roots and root hairs, leaves, flowers and pollen tubes
- Keeps the cell walls elastic and allows the cells to expand as they grow.

Calcium, unlike nitrogen, does not move within the plant, so it stays in old tissues. Uptake by young roots is passive and soil must be moist for uptake to occur. K, Mg and sodium (Na) compete with Ca for uptake through the roots. Ca is difficult to get into roots and uptake speed depends on particle size, with smaller particle size Ca ensuring better uptake. As Ca is important for all growth events it needs to be available all year round.

It is especially important for Ca to be readily available to the plant in the first six to ten weeks of fruit development or until the seed starts to harden. During this period Ca 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 uptake into the fruit coincides when the stomates on the fruit turn into lenticels and transpiration is reduced.

Ca is important for fruit firmness, shelf life and internal quality. Deficiency symptoms are not visually evident on the tree but will show up with the fruit where Ca deficiencies are linked to internal disorders like soft nose, jelly seed and reduced shelf life (shown in image 1 below).

Image 1. Soft nose (left) and jelly seed (right). These disorders are linked to calcium deficiency in the fruit.



Calcium is needed in large amounts and most Ca is taken up from the soil.

- The form of Ca to apply depends on soil pH. If the soil is acidic (pH < 6.5), apply as either lime or dolomite, if the soil pH is acceptable, apply as gypsum.
- 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.
- As the majority of Ca is taken up by new roots, time your applications to that of root flushes

- Fine mesh liquid or powder forms of Ca are absorbed quicker so apply these during flowering and early fruit development.
- Foliar applied Ca products are becoming more popular, but these must only be applied during flowering or during early fruit development when plant tissue uptake is more likely.

Boron (B)

Boron as a plant nutrient has several roles. B:

- Is necessary for all new cell growth where it affects the movement of plant hormones and sugars
- Is essential for fruit set as it helps with pollen viability and pollen tube growth
- Is a key component of cell walls and helps Ca move to the cell walls

B is highly soluble and is very easily leached from soils. Boron is similar to Ca as it is not translocated within the plant. Small amounts are required during all growth phases, but the majority is required during pollination and early fruit development. As it is needed in small quantities, it is easy to go from deficiency to toxicity.

Symptoms of B deficiency include 'shot hole'—small holes in the leaf or lopsided growth of leaves as shown in image 2 below. Flower panicles bent at a right angle are another sign of insufficient B. R2E2 is particularly susceptible to low B levels and lumpy/bumpy fruit is often associated with B deficiency.

Toxicity symptoms of B are a wavy burn pattern along the leaf margins of older leaves, starting at the leaf tip or a dark brown to black discolouration between the leaf veins.

Image 2. Shot holes, indicated by the yellow arrows, are a key indicator of boron deficiency.

B is needed each time there is a new growth event.

- Apply small amounts frequently, particularly on lighter soil types to avoid losses from leaching.
- Foliar applications can only be absorbed by soft tissue, new flush or flower panicles. Using a small amount of N will help with absorption or uptake.
- Applications at flowering will help pollination as B helps in the development of pollen tubes.

However, B can be toxic to mangoes at high levels and care should be taken when applying this fertiliser, so adhere to the recommended rate.

Potassium (K)

Potassium has several key roles in a mango plant. K:

- Is required for cell division and expansion during all growth phases, but particularly fruit development
- Controls plant water uptake, and therefore the uptake of other nutrients, by regulating the opening and closing of the stomates
- Helps move sugars around the plant.

Key benefits of K on mango are increased fruit size and better flavour and skin and flesh colour. K is very mobile in both the soil and plant. K competes with Ca, Na, and Mg for uptake, so ensure excessive amounts of K are not applied early in fruit development to outcompete the uptake of Ca.
Symptoms of K deficiency include general yellowing of leaf margins which can progress to a marginal leaf burn starting at the tip. K is required during cell division so apply it post-harvest, during flowering and especially fruit filling.

- It is easily leached so apply small amounts often, particularly in lighter soil types.
- Apply >60% of the required amount during the fruit filling period.
- Adjust the amount with your crop load, so apply more with a heavier crop.

Good results have been achieved when K fertiliser is split into small applications at several (up to five) two to three weekly intervals during fruit development compared to a single, large application early in this period. This can be most efficiently achieved via fertigation or using foliar canopy sprays.

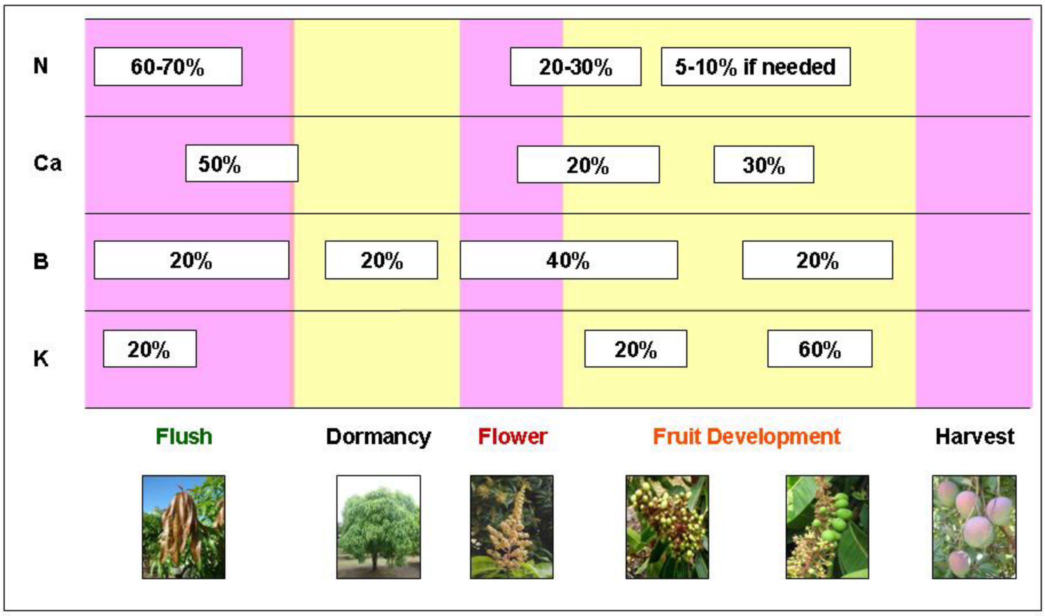
Part 3: Designing your fertiliser program

There are several factors to take into consideration when designing your fertiliser program:

- All recommendations should be based on leaf and soil tests
- Recognising that each tree growth stage has different nutritional requirements. What is the tree doing when and what is the nutrient demand at each growth stage?
- The amount of nutrients lost by either leaching, fixation or volatilisation and how this needs to be included in your nutrient replacement strategy.
- Crop nutrient removal. How much did the crop from the season remove in nutrients when it was harvested?

A nutrition planner, detailing the recommended percentages to apply of the four key nutrients discussed in this article is shown in Figure 4 (below). It is up to each grower to determine the actual amounts to be applied to the crop, based on leaf and soil analyses or in conjunction with your nutrition consultant. The position of the box indicating the percentage of the nutrient to apply, sits approximately where in the growth stage it is recommended to apply the amount of that nutrient. Smaller frequent nutrition applications are recommended.

Figure 4. A nutrition planner for N, Ca, B and K application for mangoes.



The key to a successful nutrition program is to apply the right nutrient in the right form, at the right rate, at the right time and in the right place. Table 3 (below) shows the amounts of the four nutrients removed by ten tons of fruit/hectare and potential losses to soil fixation, leaching and volatilisation. The amount of nutrients removed per tonne of fruit will help to calculate fertiliser application amounts to consider during ‘on’ and ‘off’ production years. Greater losses generally occur when larger amounts of the nutrients are applied.

Table 3. Amounts of nutrients removed by 10 tonnes of fruit, estimated fertiliser efficiency after leaching, fixation and volatilisation, and fertiliser equivalents to replace these amounts.

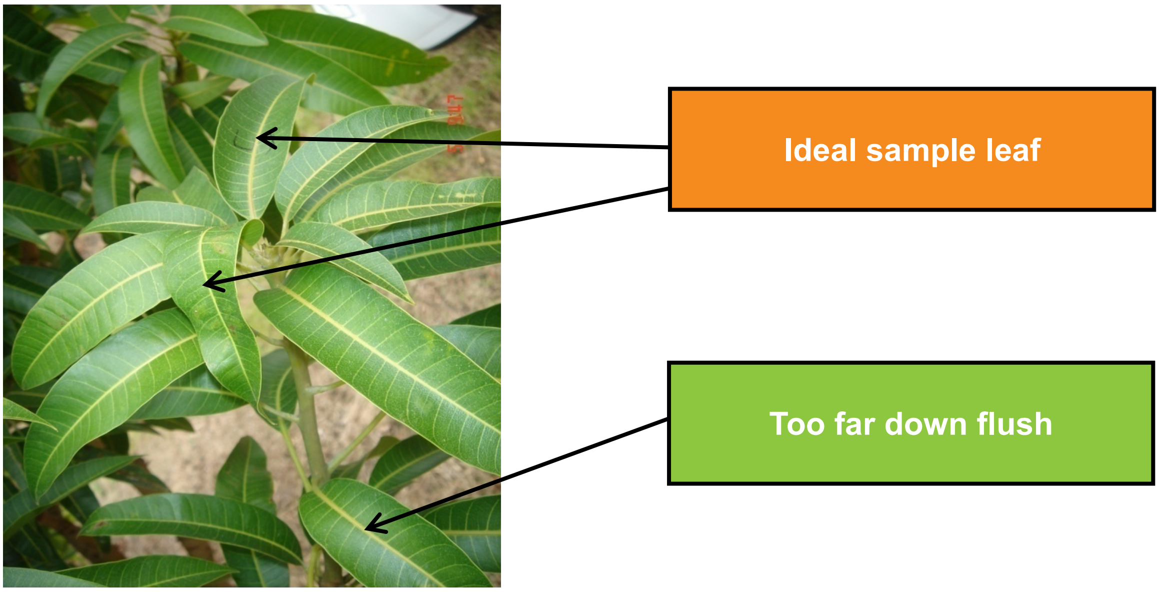
Nutrient	Amount removed (kg)	Fertiliser efficiency	Fertiliser equivalent
N	8.5	40%	21.3 kg N
K	12.9	60%	21.5 kg K
Ca	11.5	80%	14.4 kg Ca
B	2.0	40%	5 kg B

Soil tests and leaf tests

The importance of having regular soil and leaf tests should not be underestimated. **Make sure you speak with your local agronomist/crop consultant when interpreting soil and leaf test results and developing a fertiliser program.**

To help optimise nutrition planning in mangoes, it is recommended to take a soil sample at harvest time and leaf samples twice per year (harvest and pre-flowering). Soil sampling should be taken as a bulk sample from 20 representative trees, with two samples per tree (one each side) to a depth of 0-15cm, collected from inside the drip line. Leaf samples should be taken as a bulk sample from 20 representative trees, collecting mature leaves only (usually 3rd or 4th leaf from the growing tip) from all four sides of the tree. Ideal sample leaves are shown below in Image 3.

Image 3. Ideal sample leaves for leaf nutrition tests.



Generally, the issue for growers is to overcome deficiencies but in some cases the nutrient levels can be quite high. This is usually not a problem and may reflect the recent application of a fungicide spray containing, for example, copper or manganese. Use high quality fertilisers, which have detailed analyses of their content to ensure that accurate amounts of nutrient are applied.

The guide below (Table 4) shows optimum soil test results for most important soil nutrients. These suggested levels are expressed in mg/kg dry soil, which is equivalent to ppm (parts per million). Optimum leaf nutrient levels for the four key elements (N, K, Ca, B) are presented below in Table 5.

Table 4. Optimum soil nutrient levels for the key nutrients.

Element	Comments - please seek independent advice for your particular orchard
Nitrogen – N	There are no clear guidelines for soil nitrogen levels. There are many forms of nitrogen in soil and a measure at any one time may not accurately reflect the amount of available N for the tree. Leaf tests are the preferred method for managing N nutrition.
Phosphorus – P	This should be about 70 mg/kg and once achieved the level should be quite stable.
Potassium – K	This should be about 100-150 mg/kg. The K level can fluctuate as a result of uptake by trees and leaching. Pay particular attention to K fertiliser during the period of fruit development. If flowering is particularly intense then adding extra K could be warranted.
Calcium – Ca	This should be at least 1,000 mg/kg, with some evidence that levels as high as 2,000 mg/kg or more can be beneficial. The advantages of maintaining soil Ca at levels above 1,000 mg/kg remain to be proven.
Magnesium – Mg	This should be about 90-120 mg/kg to maintain healthy plant growth. At higher levels it is associated with green skin colour and poor blush of the fruit at maturity. Also, an imbalance in the Ca:Mg ratio can interfere with Ca uptake. Aim to keep the Ca:Mg ratio about 8:1. If irrigation water is drawn from a dolomitic soil, Mg levels may be high, particularly during the irrigation season. In this situation, very high levels of Ca may be required to maintain the Ca:Mg ratio around 8:1.
Sulphur – S	This should be about 12-20 mg/kg. S will be applied as part of other fertilisers that contain sulphates and will generally not need special application.

Element	Comments - please seek independent advice for your particular orchard
Boron – B	For the most common method of analysis, this should be 1-2 mg/kg.
Copper – Cu	This should be about 2 mg/kg. Copper sprays are often applied as part of a fungicide program that provides adequate Cu for the trees. In such situations the copper reading may be much higher than 2 mg/kg but is not likely to be a concern.
Iron – Fe	This should be at least 5 mg/kg although rates as high as 60 mg/kg or more will do no harm. Lateritic soil can have high Fe levels.
Manganese – Mn	This should be at least 4 mg/kg although rates as high as 50 mg/kg will do no harm.
Molybdenum – Mo	This is not usually part of a soil analysis. It is required in minute amounts and is commonly included in trace element pre-mixes. If not, then a foliar spray of sodium molybdate at 0.5-1.0 g/L once or twice per year will be sufficient.
Zinc – Zn	This should be about 2-5 mg/kg.

Table 5. Desired leaf ranges for the four key nutrients.

Nutrient	Desired range
N	1.0 – 1.5%
Ca	2.0 – 3.5%
B	50 – 70 ppm
K	0.7 – 1.2 %

Acknowledgements

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MG1700 (2018-2022)

The current revision of this guide (2020) was undertaken within project MG17000 'Building Best Management Practice Capacity for the Australian Mango Industry'. Delivery partners include the Australian Mango Industry Association, Queensland Department of Agriculture and Fisheries (QDAF), Northern Territory Department of Primary Industries and Resources (NTDPIR), Western Australia Department of Primary Industries and Regional Development (WADPIRD) and Central Queensland University (CQU).

MG13017 (2014-2018)

The first version of this guide (2017) was prepared under project MG13017 "Capacity building, information, technology and extension for the Australian mango industry" by the Australian Mango Industry Association. Much of the information used to develop this guide was updated from a series of nutrition workshops and reviews conducted in previous projects; MG10013 and MG06007.

MG10013 (2011-2014) and MG0607 (2008-2011)

The projects 'MG06007 Delivering Mango Technology" and 'MG10013 Delivering Information and Technology to the Australian Mango Industry' (2008-2014) were pivotal in identifying and assembling the latest mango nutrition information and practices into a series of grower information resources. This information was presented to growers in each of the major mango growing regions of Australia through a series of conference and workshop presentations titled; 'Food for Fruit – Nutrition management in mangoes'. These projects were funded by Horticulture Australia Limited, mango grower levies and partners including QDAF, NTDPI, Tropical Horticulture Consulting, NT Farmers, AMIA and Pinata.

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