Understanding crop nutrition

A guide for Australian mango growers

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 orchards characteristics (e.g. soil types within the orchard) and an understanding of crop growth stages.

Soils and impact 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 their 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 (eg loam) are able to attract and hold nutrient elements far better than coarser textured soils (eg 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 far less of a problem.

It is therefore necessary to modify fertiliser practices depending on the soil type involved. To maintain 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 applying fertilisers during the peak period of the wet season should usually be avoided.

Understanding the growth cycle of the tree will assist you with decisions on when to apply which fertiliser.

Soil tests

Decisions on fertiliser application rates should be based on accurate soil test records. Testing should be carried out regularly – at least twice per year. It is generally accepted that a soil test near 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. But care must be taken applying fertiliser at this time of the year as consideration of increased rainfall leading to significant fertiliser leaching needs to be taken account.

Soil acidity – pH

This should be about 6.5. In some production regions of Australia, soil pH tends to be lower than the critical level, resulting in the reduced availability of some soil nutrients. In such situations the soil has become more acidic, a problem that can be rectified by the addition of lime. Large amounts of lime may be required to correct low pH. To raise pH from 5.0 to 6.5 requires 3.6 t/ha of lime. In this situation, a sensible approach is to apply the amount in several split applications, say at 1-2 monthly intervals.

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. Also note that adding lime will also influence soil Ca levels. One form of lime, dolomite, contains Mg and care should be taken to avoid this if extra Mg is not required.

Some soils have high limestone content which is associated with pH in the range 7-8. For these soils lime applications should be avoided and, where possible, the sulphate form of fertilisers should be used. High pH will reduce the availability of zinc and iron making foliar applications of these elements more important.

Root systems

The mango root system is a combination of fine (about 5 mm diameter or less), highly-branched surface roots and large (diameter up to several centimetres), occasionally branched 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 be considering 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 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. So soft, well-fertilised, moist soil will have more root

growth than hard, dry soil that is not fertilised. 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 if the soil has been allowed to dry to encourage flowering. 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

Tree growth
Mango trees grow through a series of growth events. These events are influenced by variety, the environment, and your management - this in turn impacts on productivity
The sequence of growth stages are (from harvest)

1. Shoot flush
2. Root flush
3. Shoot dormancy
4. Flowering
5. Fruit set
6. Fruit development
7. Root flush
8. Harvest

Vegetative phases influence the other growth phases, **shoot flushes** provide young leaves for photosynthesis, which once mature provide resources for **root flushes**, which influence nutrient uptake.

Shoot dormancy also provides time for the tree to accumulate sufficient carbohydrate reserves for flowering.

Vegetative dormancy is required in mangoes before flowering and this dormancy can be induced by temperature or water stress, however high productivity is related to the successful completion of the other growth phases, not just stress

In the normal growth cycle of tree crops, **root flushing** generally follows **vegetative flush**, however in mangoes root flushing is poorly understood. Events including cincturing, waterlogging and cold weather can interfere with root development.

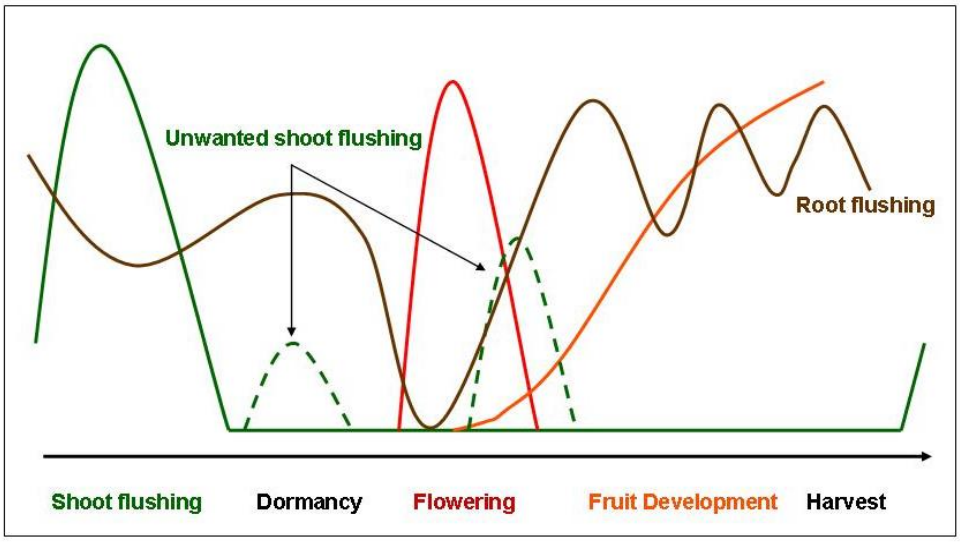

Figure 1. A simplified growth cycle for a mango tree

Productivity of mangoes is a reflection of the growth events of the cycle, management interventions and in some instances residual influence of previous management and environment factors.

Not all growth events are desirable as unwanted shoot flushing events can cause fruit drop, yield reduction or poor fruit quality and internal disorders.

Crop management.

Each different growth phase has specific nutritional needs, so a key component of mango nutrition management is to match fertiliser application to demand.

Other important considerations include pest and disease management, particularly with the post-harvest flush. This flush builds the reserves for flowering so it is important not just to feed the flush, but also to protect it.

Flushing post-harvest uses stored resources to develop. To allow trees to accumulate adequate reserves for flowering, it is important that late unwanted flush is stopped. In mangoes a 2-3 month shoot dormancy during autumn and winter is required for flushes to mature prior to flowering.

Stresses of any type will reduce productivity. It is important therefore that stresses, which include poor nutrition and irrigation practices and pests and diseases, are reduced during the key growth events of flushing, flowering and fruit set and development.

Key nutrients

Although there are at least 14 elements or nutrients that are required for plant growth, the 4 key nutrients for mango production are **nitrogen (N), potassium (K)**, **calcium (Ca)** and **boron (B)**. Understanding the interactions of these 4 nutrients is the key to good productivity and fruit quality in mangoes.

Nitrogen

Nitrogen is the driver in plant processes. Nitrogen:

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

Nitrogen 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 and plant status is generally only assessed once a year, post-harvest.

Important positive effects of well timed sufficient quantities of N include; increasing tree vigour, stimulating flowering in conjunction with K and improving fruit set, retention, yield, size and brix or fruit sweetness.

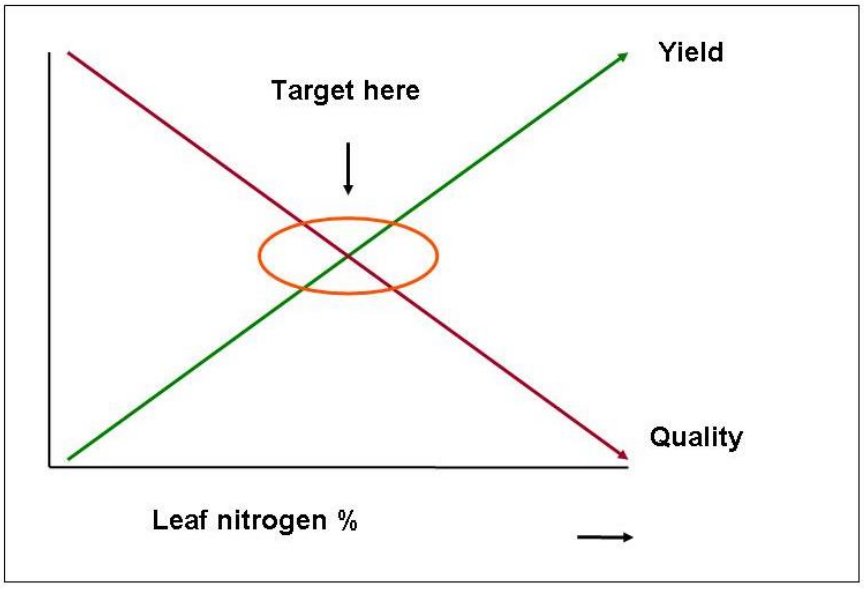

Figure 2. The nitrogen conundrum.

'The nitrogen conundrum' provides a representation of the positive and negative effects of N in mangoes and how they interact.

Poorly timed or excessive amounts of N however can have significant negative impacts on mango quality by promoting excessive or unwanted flush which can direct Ca from fruit and cause problems including less blush, soft fruit, fruit not colouring when ripe and increased post- harvest diseases and disorders. Excessive N can also impact on yield as it can negatively impact flowering.

Deficiency symptoms include pale yellow foliage with low vigour trees, which often will not hold a good crop. As N is 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 is the best way to confirm N status.

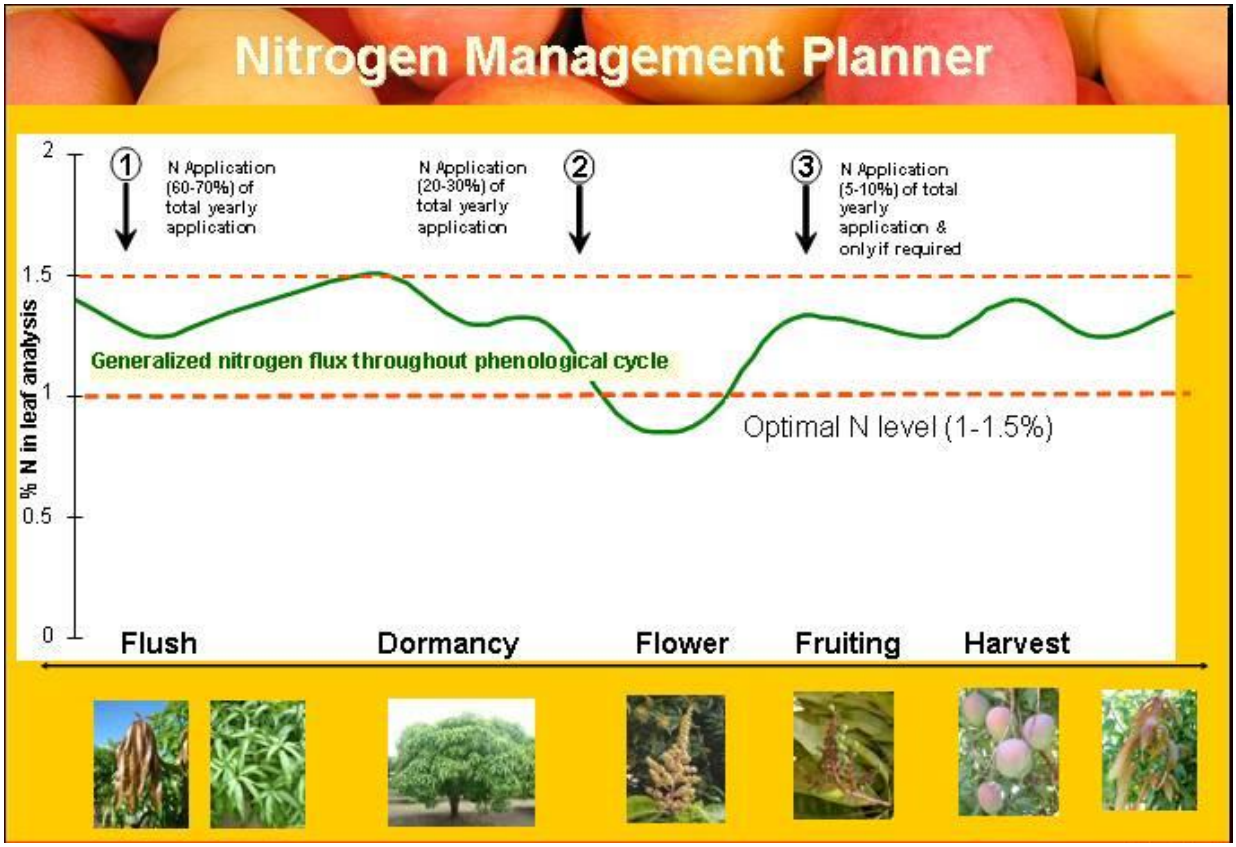

Figure 3. Nitrogen Management Planner

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

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

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

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.

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

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

Calcium

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

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

Calcium, unlike N, 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. Potassium, Mg and sodium (Na) compete with Ca for uptake through the roots. Calcium is difficult to get into fruit and uptake speed depends on particle size, with smaller the particle size Ca ensuring better uptake. As calcium 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 6-10 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 time coincides with when the stomates on the fruit turn into lenticels and transpiration is reduced.

Calcium is important for fruit firmness, shelf life and internal quality. Fruit 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 (Image 1).

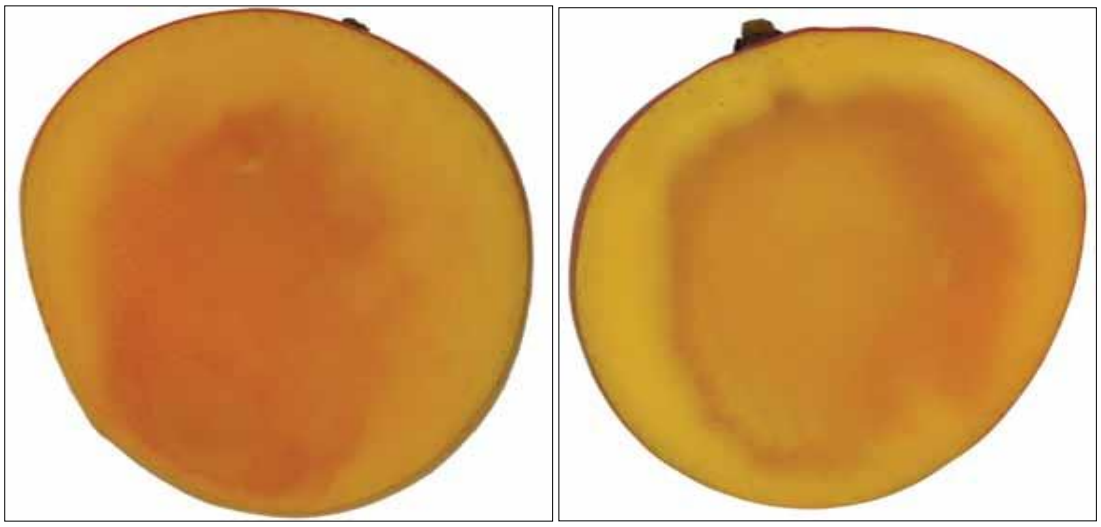

Image 1. Soft nose (left) and jelly seed (right). These disorders are linked to calcium deficiency in the fruit.

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

1. The form of Ca to apply depends on soil pH. If the soil is too acidic, apply as either lime or dolomite, if the soil pH is acceptable, apply as gypsum.
2. Moisture is needed for Ca uptake, so apply either towards the end of the wet season as this reduces leaching loses, or apply prior to or with irrigation.
3. Fine mesh liquid or powder forms of Ca are absorbed quicker so apply these during flowering and early fruit development.
4. As the majority of Ca is taken up by new roots, time your applications to that of root flushes.

Boron

Boron as a plant nutrient has several roles. Boron:

1. is necessary for all new cell growth where it affects the movement of plant hormones and sugars
2. is essential for fruit set as it helps with pollen viability and pollen tube growth
3. is a key component of cell walls and helps calcium move to the cell walls.

Boron is highly soluble and is leached from soils very easily, but 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. 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.

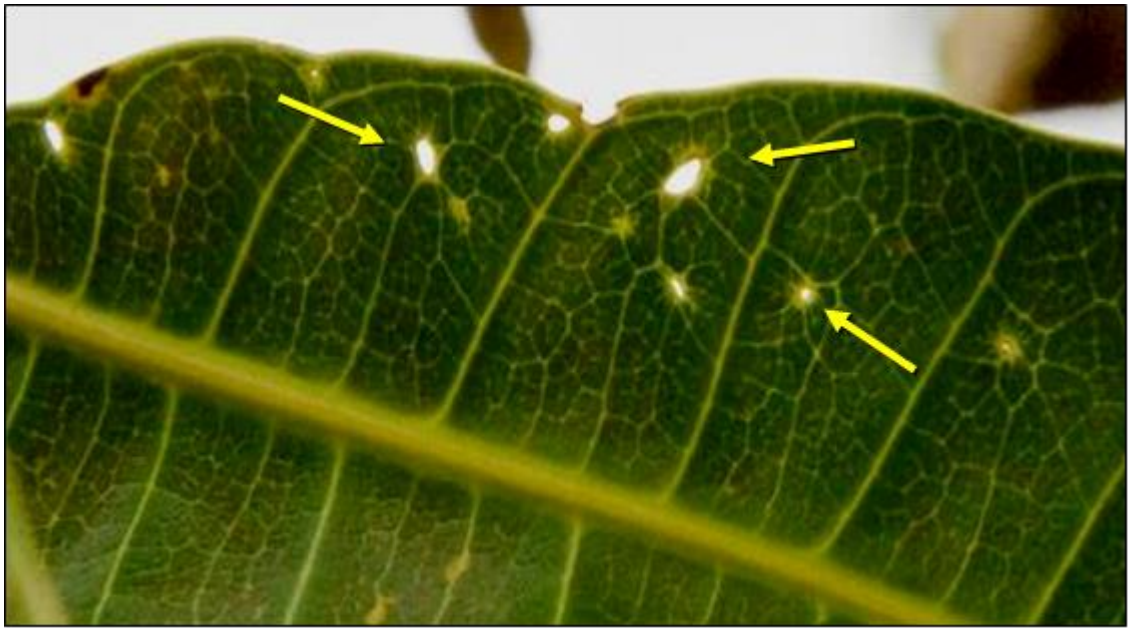

Image 2. Shot holes, indicated by the yellow arrows are a key indicator of boron deficiency.

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

1. Apply small amounts frequently, particularly on lighter soil types to avoid losses due to leaching.
2. 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.
3. Applications at flowering will help pollination as the B helps in the development of the pollen tube.

<u>However, boron can be toxic to mangoes at high levels and care should be taken when applying this fertiliser to adhere to the recommended rate.</u>

Potassium.

Potassium has several key roles in a mango plant. Potassium;

1. is required for cell division and expansion during all growth phases, but particularly fruit development,
2. controls plant water uptake, and therefore the uptake of other nutrients, by regulating the opening and closing of the stomates
3. helps move sugars around the plant.

Key effects of K on mango are increased fruit size and better flavour and skin and flesh colour. Potassium is very mobile in both the soil and plant. Potassium 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.

Potassium is required during cell division so apply it post-harvest, during flowering and especially fruit filling.

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

Good results have been achieved when potassium fertiliser is split into small applications at several (up to five) two-three weekly intervals during fruit development compared to a single, large application early in the period. A fertigation system, where the fertiliser is dissolved and applied with the irrigation water, is used

Designing your fertiliser program

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

1. all recommendations should be based on leaf and soil tests
2. tree growth. What is the tree doing when and what is the nutrient demand at each growth stage?
3. crop nutrient removal. How much did the crop from the season remove in nutrients when it was harvested and sold?
4. the amount of nutrient lost by either leaching, fixation or volatilisation.

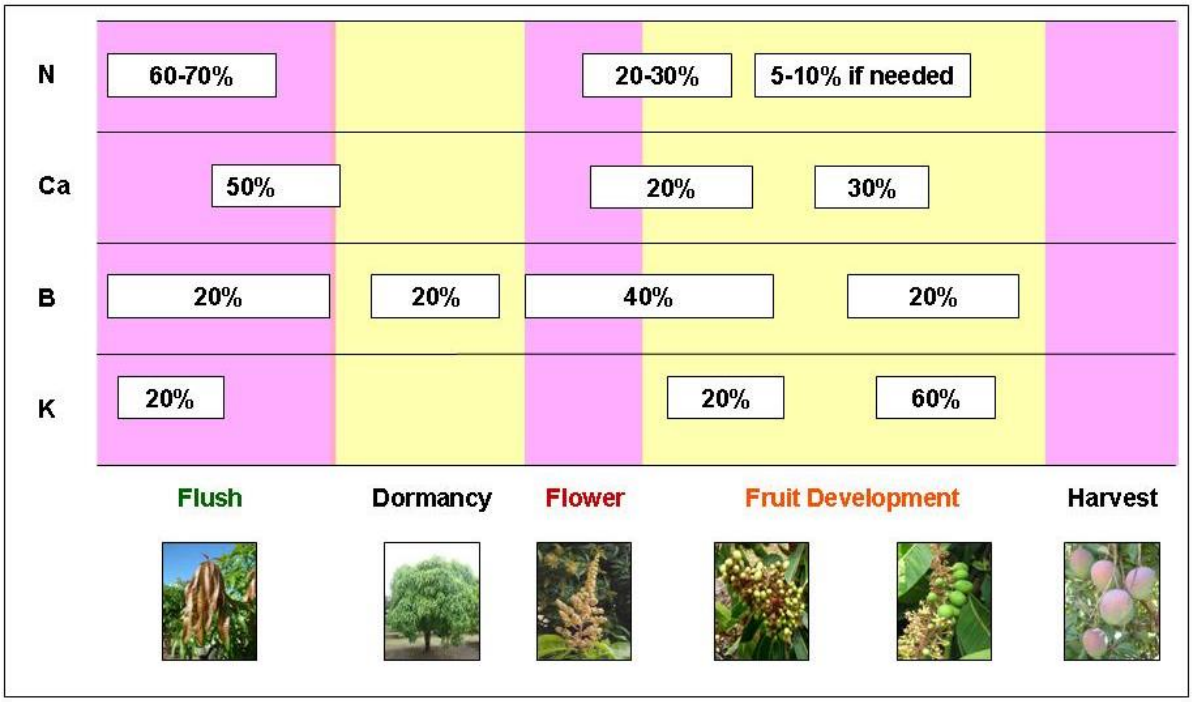

Figure 4. A nutrition planner for N, Ca, B and K application for mangoes.

A nutrition planner, detailing the recommended percentages to apply of the four key nutrients discussed in this article is shown in figure 4. It is up to each grower to determine the actual amounts to be applied for 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

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 shows the amounts of 4 nutrients removed by one tonne of fruit 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 take into account ‘on’ and ‘off’ production years. Greater losses generally occur when larger amounts of the nutrients are applied.

Nutrient	Amount removed (kg)	Fertiliser equivalent (kg)	Potential amount lost
Nitrogen	0.85	1.85 kg urea	30-50%
Potassium	1.3	9.6 kg potassium sulphate	20%
Calcium	1.2	6.2 kg gypsum	up to 20%
Boron	0.002	0.01 kg Solubor	20-30%

Table 3. Amounts of nutrients removed by 1 tonne of fruit, fertiliser equivalents of these amounts and potential nutrient losses from leaching, fixation and volatilisation.

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.

Table 4 shows the desired leaf levels for the four nutrients for mangoes discussed in this article.

Nutrient	Desired range
Nitrogen	1.0 - 1.5%
Calcium	2.0 - 3.5%
Boron	50 – 70ppm
Potassium	0.7 – 1.2 %

Table 4. Desired leaf ranges for the 4 key nutrients.

Soil tests and leaf tests

The importance of having regular soil and leaf tests should not be under estimated. Make sure you have an experienced interpret the results of your tests.

The following is a guide to soil test results. **Make sure you speak with your local agronomist/crop consultant when interpreting soil test results and developing a fertiliser program.** These suggested levels are expressed in mg/kg dry soil, which is equivalent to ppm (parts per million).

Element	Comments – please see independent advise for you particular orchard
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. 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.
Zinc – Zn	This should be about 2-5 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.
Manganese – Mn	This should be at least 4 mg/kg although rates as high as 50 mg/kg will do no harm.
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.
Boron – B	For the most common method of analysis, this should be 1-2 mg/kg. However, an alternative method used by at least one laboratory gives lower levels with an optimum range of 0.05-0.75 mg/kg. To interpret the B result it will be important to determine which method is used by the laboratory conducting the analysis.

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.
Nitrogen – N	There are no clear guidelines for nitrogen fertilisation. This is because there are many forms of nitrogen in soil and a measure at any one time may not accurately reflect the amount of N that is available for uptake by the tree. Also, N application is associated with stimulating new vegetative growth, the development of dark, dense canopies and green fruit with thin, easily damaged skins and little or no blush at harvest.

To help optimise nutrition planning in mangoes, it is strongly suggested to take soil samples at harvest time and leaf samples twice per year (harvest and pre flowering).

This guide has been developed using information from the following sources:

Food for Fruit - nutrition management in mangoes – article and presentation developed by Matt Weinert, horticulturalist, Queensland Dept of Agriculture and Fisheries, and Ted Winston, Independent crop consultant .

Operation KP: A production guide for mango grower in northern Australia – edited by the late Sam Blaikie, Northern Territory Department of Primary Industries and Peter Cavanagh Ex Chairman of the Northern Territory Mango Industry Association.

Mango information Kit – A Queensland Government publication

Agnote: Fruit Tree Fertiliser Rates in the Top End - M.Poffley and G. Owens, Northern Territory Department of Primary Industries.

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