North Coast Citrus Nutrition Workshop Report

Sandra Hardy, NSW Coastal Cittgroup Coordinator and David Huett, Research Scientist, NSW DPI, Alstonville.

In May, North Coast citrus growers met to discuss the analysis results of recent leaf tissue samples. The workshop focussed on general principles of nutrition, interpretation of the leaf tissue results and strategies for matching plant nutrient requirements with fertiliser applications. The workshop was lead by Dr. David Huett, NSW DPI Research Scientist at Alstonville who has extensive experience in plant nutrition. This report is a summary of the presentation, results and discussion.

General Nutrition Principles

The nutrient requirements of plants fall into two categories. The nutrients required in large amounts are referred to as major (macro) elements and include nitrogen, potassium, phosphorous, calcium, sulfur and magnesium. Nutrients required in much smaller amounts are referred to as minor (micro) elements and include manganese, zinc, iron, boron, copper and molybdenum. The following information is a summary of some of the key issues associated with each element in citrus trees. Table 1 summarises the typical deficiency and toxicity effects in citrus as well as the relative mobility of each element in the plant and soil.

Major nutrients

Nitrogen (N) affects the photosynthetic rate of leaves, influencing production of carbohydrates and proteins which in turn control growth rates. Nitrogen is needed during periods of rapid growth, when trees are flowering and during the mid to late stages of fruit growth (late Stage 1 & Stage 2). Adequate nitrogen is required for consistent high yields. It also has a big impact on fruit quality. Table 2 summarises the effects of excessive nitrogen, phosphorous and potassium on citrus fruit quality parameters.

Nitrogen is mostly held in the soil organic matter and is readily leached. It is limiting in most soils, although soils with a high clay content tend to have higher amounts. Nitrogen is best applied in small amounts throughout the year, especially in areas of high rainfall or in sandy soils.

Potassium (K) plays an important role in plant metabolic processes including photosynthesis, protein synthesis, sugar production and fruit formation. Potassium is the main element in fruit and it has more effect on fruit quality than any other element (Table 2). It also affects fruit size and low levels usually mean smaller fruit. Potassium has

Table 2 : Effects of excessive NPK on fruit quality

Element	As levels of the element increase it increases:	As levels of the element increase it decreases:
Nitrogen Adverse effects of high N are more marked when P is low	rind thickness rind coarseness juice acidity % soluble solids (slight)	% juice content TSS/acid ratio TSS/tonne vitamin C content
Phosphorous Balance between N and P is important for good fruit quality (N:P = 15-20:1 for oranges)	% juice content TSS/acid ratio TSS/tonne	rind thickness rind coarseness juice acidity % soluble solids (slight) vitamin C content
Potassium (N:K = 2:1 for oranges)	rind thickness rind coarseness juice acidity vitamin C content	% juice content TSS/acid ratio

a key role in water efficiency and cell potassium levels regulate the opening and closing of the leaf pores known as stomata. It can therefore affect the plants ability to withstand the effects of drought. Trees require potassium in similar amounts to nitrogen.

Although most soils contain adequate potassium, only a small amount is available to plants. Sandy soils and those with a low cation exchange capacity have little ability to store potassium and high application rates can result in wastage due to leaching. In these soils potassium is best applied in small frequent applications.

Phosphorous (P) has a key role in plant processes that require energy, including photosynthesis, respiration, cell division and enlargement. Phosphorous also affects fruit quality and the right balance of nitrogen to phosphorous is important for good fruit quality. Excessive amounts of phosphorous can be detrimental to root growth especially in acid soils.

Many Australian soils are low in phosphorous however demand for phosphorous by citrus crops is also relatively low. Historically there has been a tendency to over-apply phosphorous in citrus orchards, so applications should be linked to leaf analysis results. Optimum soil moisture is also important for good phosphorous availability.

Calcium (Ca) is the major component of cell walls and is important in root growth and function. Demand for calcium is high during periods of rapid growth, especially the early stages of fruit growth when cells are dividing. Citrus trees contain more calcium than any other element and the demand for calcium is 2-3 times that of phosphorous. Successful calcium uptake requires a good water supply to the tree as it is taken up and moved around the plant in the water system (xylem). Calcium availability is affected by soil pH and is reduced in acid soils. Calcium is immobile in the plant and accumulates in old leaves.

Photo 1: Magnesium deficiency

Magnesium (Mg) is essential for the production of chlorophyll in plant leaves and is therefore important for photosynthesis. Demand for magnesium is similar to that of phosphorous. Magnesium availability is reduced by a low soil pH (acid soils). Magnesium deficiency is commonly seen in citrus orchards and can be treated with foliar sprays (Table 3).

Sulfur (S) is a component of amino acids, vitamins and enzymes. Most sulphur is held in the soil organic matter and deficiencies are not common. Sulfur availability is reduced by high soil pH.

Minor nutrients

These elements are required by the plant in much smaller amounts and in NSW it is common to find deficiencies of zinc, manganese and iron in citrus orchards. Deficiencies can be recognised by leaf symptoms which appear first in the young leaves. (Photos 1-3). These minor nutrients are immobile in the plant and cannot be easily transported from the old leaves to the new growth. Deficiencies of these elements are normally rectified by the use of foliar sprays which if required can be applied to the newly expanded growth flushes in spring and summer. For information on foliar sprays see Table 3.

Photo 2: Zinc deficiency

Zinc (Zn) is involved in metabolic processes. In NSW zinc deficiency is a common occurrence

Table 1: General guide to plant nutrients in citrus

Element	Deficiency Symptoms	Excess Symptoms	Movement in the Plant	Movement in the Soil	Other Information
Nitrogen (N)	Found first in **old leaves.** Pale green-yellow leaves. Stunted growth, thin foliage cover & dieback of twigs. Poor fruit set & fruit size.	Promotes luxurious vegetative growth. Poor fruit quality & shorter storage life. Fruit thick-skinned large, puffy, delays colour break and increases regreening.	Mobile	Mobile	Most N is contained in the soil organic matter. Effects of too much N worse when P is low. There is an antagonistic effect between N & P.
Phosphorus (P)	Found first in **old leaves**. Dull bronzed green leaves which shed readily. Reduced flower formation. Misshapen fruit, open centres, thick coarse rinds.	Decrease in fruit size.	Mobile	Immobile	Soils high in clay fix more P. Optimum soil moisture conditions promote more available P. Most available in range 6-7. Too much P can result in deficiencies of Fe, Zn and Cu. In alkaline soils P forms insoluble compounds with Ca and Mg and in acid soils with compounds of Fe, Mn and Al.
Potassium (K)	Found first in **old leaves**. Slower tree growth, small leaves, and heavy leaf fall. Fruit small, thin skinned, colours early, splits easily, more creasing. Severe deficiency causes heavy fruit/ flower drop.	In oranges delays colour break, increases rind thickness, and regreening.	Mobile	Mobile in sandy and organic soils	High pH induces a deficiency. K can outcompetes and reduce uptake of Mg and Ca. Low soil temperature reduces availability and uptake of K. Optimum soil moisture needed for K uptake. Waterlogged of dry soils reduce K uptake. K is held tightly in clay soils.
Sulfur (S)	Found first in **young leaves**. Small pale green-yellow leaves with lighter veins.		Immobile	Mobile	High pH induces a deficiency. Most S held in the soil organic matter.
Calcium (Ca)	Found first in **young leaves**. Stunted roots, fruit quality problems.	Reduction in availability of trace elements. Iron chlorosis.	Immobile	Immobile	Deficient in low pH (acid) soils often associated with high Al and Mn levels. Heavy applications of K induce deficiencies, especially in acid soils. Ca is taken up and moved around in the plant in the water system. Too high or low humidity can reduce Ca uptake.
Magnesium (Mg)	Found first in **old leaves**. Yellowing towards apex of leaves with a triangular area remaining green at base. Defoliation, twig dieback and poor root growth.		Mobile	Attaches to organic matter and clay particles.	Frequently deficient in coastal sandy soils and deficiency more acute when N levels low. Uptake is also reduced by high potassium levels. Mg has a synergistic effect on Zn & Mn and a Mg deficiency accentuates deficiencies of these two elements.

Table 1 : General guide to plant nutrients in citrus

Copper (Cu)	Found first in **young leaves**. Dieback of twigs. Dark brown gum pockets on young shoots. Rind can be brown, with gum stained areas, split fruit.	Stunted growth. Toxic to plant roots, especially small feeder roots.	Slightly mobile	Mobile in acid soils.	Dependent on pH, organic matter content, presence of Al, Mo & Fe. Becomes unavailable as pH rises above 7.0 Excess induces Fe deficiency. Deficiencies common in sandy soils. Copper can depress leaf Zn and Mn levels.
Zinc (Zn)	Found first in **young leaves**. Creamy white to yellow blotches in leaves. Small, narrow leaves. Retarded terminal growth, reduced leaf size. Small twigs die.		Immobile	Mobile in acid soils.	Becomes less available as pH rises or in soils with high P. There is an interaction between Zn and P, and high levels of one element reduce the uptake of the other. Deficiencies can occur when soils are cold & wet due to poor root growth. Can depress Mn leaf levels.
Manganese (Mn)	Found first in **young leaves**. Mottled pale green leaves, reduced cropping and growth. Intervienal yellowing.	Bright yellowing on leaf edges (old), dark brown tar spots on leaves.	Immobile	Mobile in acid and water-logged soils	Soil moisture affects availability. Toxicity common in high rainfall areas, organic, acid or waterlogged soils. Becomes unavailable as pH rises above 5.5 and deficiencies may occur with imbalances of Ca, Mg and Fe. Increases the availability of P and Ca.
Iron (Fe)	Found first in **young leaves**. Chlorosis of leaves, stunted abnormal growth. Tips/margins and veins stay green longest.		Immobile	Mobile in waterlogged soils.	Deficiency trigged by high pH, excessive P, lime or bicarbonate levels and wet cold soils. High Fe levels can induce a Mn deficiency. Soil organic matter an important source. P.*trifoliata* rootstock is more sensitive to iron deficiency than sweet orange, rough lemon or Troyer citrange.
Boron (B)	Found first in **young leaves**. Lopsided fruit heavy fruit shedding & yellow leaf veins. Fruit grey to brown with gum pockets throughout rind & flesh.	Yellow, dead leaf tips, leaf fall and dieback.	Immobile	Mobile	Optimum in pH 5-7. Soil organic matter an important source. Dry periods and over liming can induce a deficiency. Easily leached.
Aluminium (Al)	Stunted root growth. Lack of root hairs			Immobile	As pH rises above 5.5 Al solubility increases. Fixes P. Al toxicity common in acid soils.
Sodium (Na)	Found first in **old leaves**.	Leaf burn, leaf fall & dieback		Mobile	A problem in alkaline soils. Na ions displaced by Ca.

in citrus orchards, especially in alkaline and acid coastal soils. Excessive phosphorous levels can also accentuate a zinc deficiency.

Manganese (Mn) is another element commonly deficient in citrus orchards. Deficiencies most often occur on soils with a high organic matter content and when soil pH rises above 7.0. Also an excess (toxicity) of manganese can be a problem in very acid soils (<5.0) especially when they are damp or poorly drained.

Photo 3: Manganese deficiency

Boron (B) is important in protein formation, the growth of pollen tubes, seeds and cell walls. Boron deficiency is not common in NSW and application should be linked to leaf analysis results as citrus is sensitive to an excess of this element.

Iron (Fe) is used to produce chlorophyll and deficiencies are common in calcareous soils with a high pH. Iron deficiency can also be induced by high phosphorous levels in the soil.

Table 3: Foliar sprays for treating micronutrient deficiencies in citrus

Nutrient	Treatment	Application Rate	Comments
Magnesium	Magnesium nitrate	1kg/100L	
	or Magnesium sulphate plus Calcium nitrate	1kg/100L 1kg/100L	Mix magnesium in half full vat then add calcium while agitating, then top up tank
Zinc	Zinc sulphate heptahydrate (23% Zn)	150g/100L	
Manganese	Manganese sulphate	100g/100L	500g of urea can be added to improve uptake
Zinc & Manganese	Zinc sulphate plus Manganese sulphate	150g/100L 100g/100L	

Source: Citrus Nutrition. R. G. Weir & R. Sarooshi. 1991 NSW DPI. Agfact H2.3.11

Table 4: Percent of Leaf Samples in each nutrient concentration range

Element	Deficient	Marginal	Adequate	High	Toxic
Nitrogen	72	-	28	-	-
Phosphorous	-	-	14	86	-
Potassium	-	-	72	28	-
Sulfur	28	-	72	-	-
Calcium	-	43	43	14	-
Magnesium	-	-	100	-	-
Sodium	-	-	100	-	-
Copper	-	-	14	-	86
Zinc	86	14	-	-	-
Manganese	28	44	28	-	-
Iron	-	44	28	28	-
Boron	14	-	72	14	-

North Coast Leaf Analysis Results

Figures 1 & 2 and Table 4 show the results of the seven leaf samples taken from North Coast citrus orchards. Of the seven samples, six were Tahitian limes and one was a navel orange. Soils in the region are predominately red Ferrosols, which are typically deep well structured soils with a good water and nutrient holding capacity.

One of the challenges with limes growing in a subtropical region, is the potential for continuous growth flushes, multiple flowerings and several crop stages on the tree at the one time. Trees are therefore actually undergoing different growth phases simultaneously, which makes working out a fertiliser strategy a bit more tricky.

The Standards used to interpret leaf analysis results (Table 5) have largely been developed using information from citrus varieties (such as oranges) bearing one main crop a year. For limes these Standards should be used as a guide in association with other information such as trends in yield, fruit quality and size and the visual health of trees.

For the major elements, the results showed that most samples (72%) were deficient in nitrogen. However, the orange nitrogen standards are probably a little too high for limes. If the grapefruit standards are used, only 14% of the samples would indicate a nitrogen deficiency. Leaf nitrogen levels can vary from year to year and are influenced by seasonal conditions and crop load. At the time samples were taken the main crop was being harvested (harvest is from February to May). Supplies of nitrogen are stored in the soil organic matter and most soils only contain small amounts, so nitrogen needs to be applied regularly. In sandy soils and high rainfall areas such as those on the coast nitrogen is best applied in small amounts frequently to avoid losses from leaching. When nitrogen is applied to the soil as urea, high amounts can also be lost to the atmosphere through volatisation if it is not washed into the soil within 2-3 days. Although leaf levels were low there were no obvious deficiency symptoms visible in the trees.

Most samples had adequate levels of phosphorous (86%). This is quite a common occurrence in coastal citrus orchards where regular annual applications of superphosphate or blended fertilisers with a high P content are normal practice. It was suggested that applications of phosphorous could be reduced and levels monitored with annual leaf analysis.

Potassium and magnesium levels were adequate in nearly all samples.

Levels for calcium were variable with 43% marginal, 43% adequate and 14 % in the high range. Low levels of calcium could be a result of low soil pH, low soil calcium levels or an imbalance with magnesium. The sample with a high level of calcium was a result of incorrect leaf sampling. Calcium is not easily moved within the plant and tends to accumulate in leaves as they age. Therefore old leaves tend to have high levels of calcium.

For the minor elements all samples had low levels of zinc. A high proportion of samples had marginal to deficient levels of manganese and marginal iron levels. All these nutrients can be affected by soil pH. It was recommended that 1-2 foliar sprays of zinc and manganese be applied annually and monitored using leaf analysis. Foliar sprays of micronutrients have not been normal practice in these orchards. On most soils, zinc deficiency cannot be corrected by a soil application whereas a foliar application gives a rapid response.

Tools for Developing a Fertiliser Program and Matching Applications to Tree Growth Stages

The amount of nutrients required by he tree is dependent on a range of factors including: tree age and size, crop load, variety and rootstock, soil type and climatic conditions. To develop a fertiliser program you can use a range of tools, including: leaf and soil analysi

Soil and Leaf Analysis

Soil and leaf analysese are useful tools for assessing nutrient levels. Samples for analysis must be collected correctly and be representative of the block. Soil analysis gives you information about what nutrients are present in the soil at the time of sampling, but it does not tell you what is available to the plant. Testing your soil is especially important prior to planting out a new block and -should be repeated every 3-5 years to monitor soil pH, organic matter levels, cation exchange capacity (CEC), the calcium/magnesium ratio and level of other nutrients. Maintaining a soil pH of between 5.5 and 6.5 will usually mean fewer problems with the availability of micronutrients.

Leaf analysis provides a snapshot of the nutrient levels in the leaves at the time of sampling, reflecting what the plant was able to extract and store. Regular plant analysis every 1-2 years allows you to more accurately monitor the nutrient status of your trees and assess and fine tune a fertiliser program. Major changes to your fertiliser program should not be based on the results of just one leaf analysis.

For leaf analysis it is very important to select the right leaves for analysis as the mineral composition of leaves is significantly affected by leaf age and

Figure 1: Leaf analysis results for the major elements

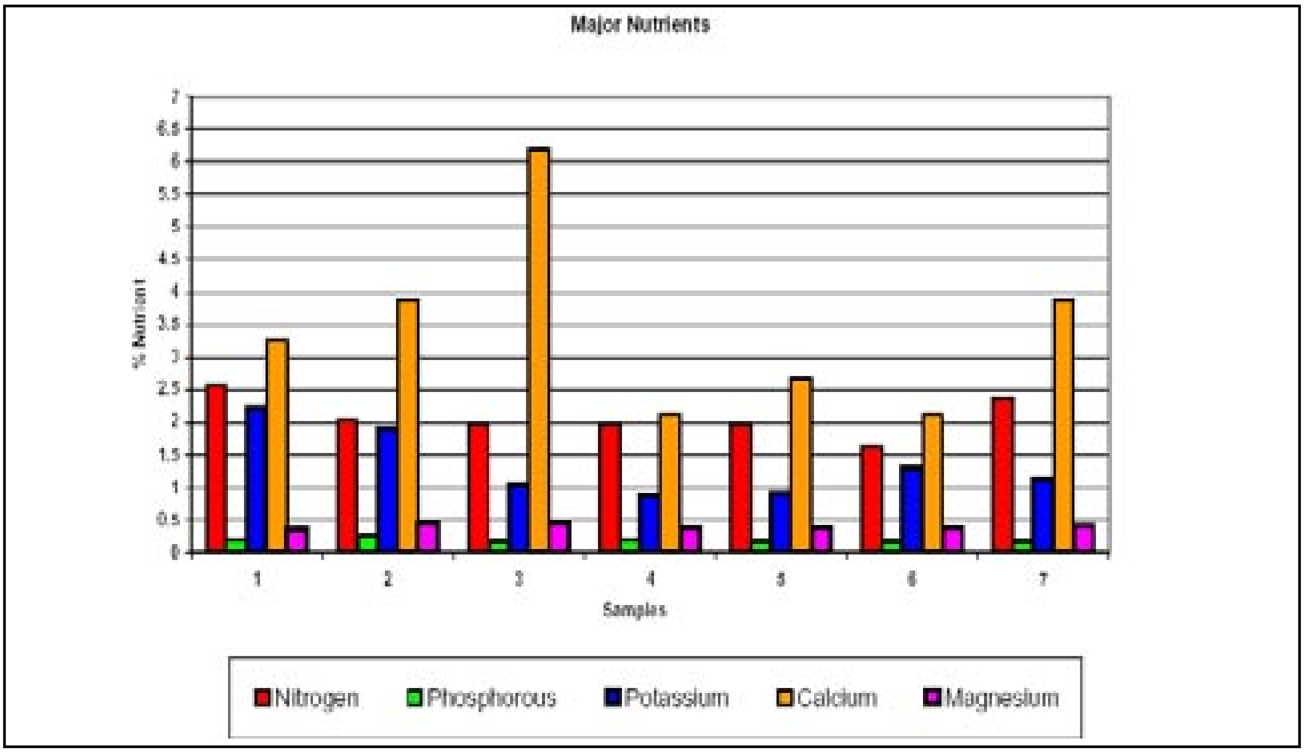
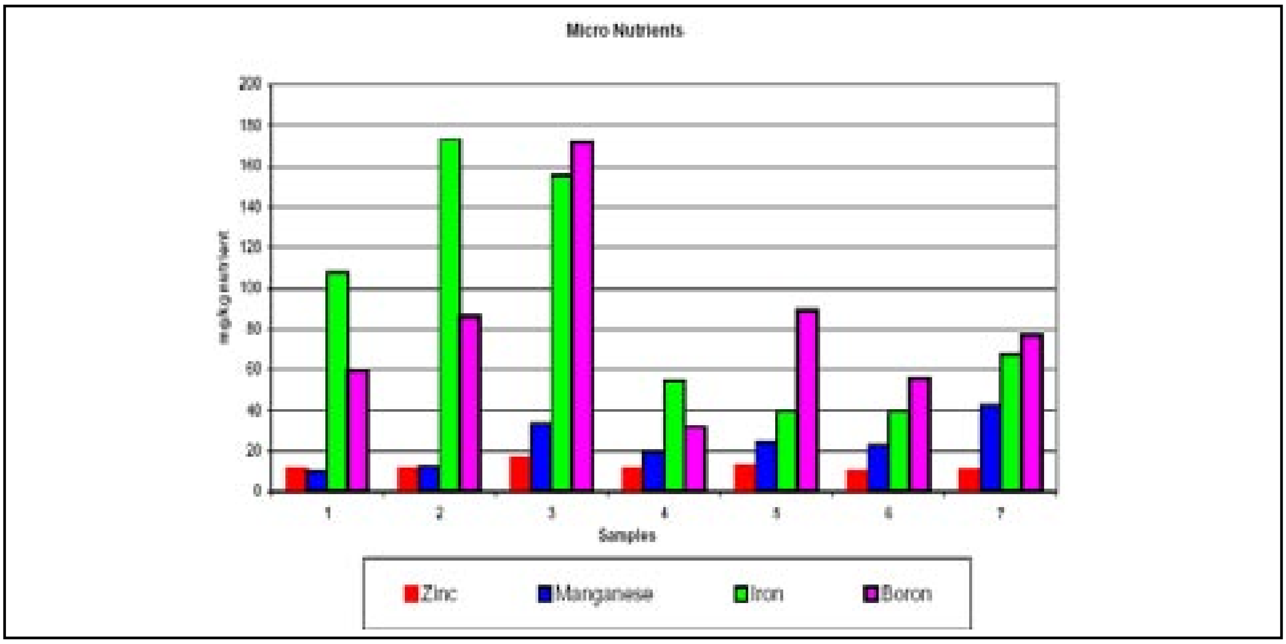


Figure 2: Leaf analysis results for the minor elements



the presence of any fruit on the shoot. Select a representative sample of leaves which are healthy, mature (5-7 months old) from the middle of non-fruiting extension growth. Leaf samples for citrus are normally taken in late February–March.

Crop Nutrient Removal Rates

Crop nutrient removal rates are an estimate of the amount of nutrients removed from the tree in the fruit. They can also include estimates of the amount of nutrients lost by leaching and through leaf fall and pruning. They are a starting point for estimating how much of each nutrient needs to be replaced annually. If the nutrients aren't replaced, the mining of the soil will reduce nutrient availability over time and this can be difficult to correct. Tables 6 and 7 contain information on crop removal rates for citrus.

Table 5: Citrus Leaf Analysis Interpretation Guide

	Concentration Range				
Element	Deficient	Marginal	**Adequate**	High	Toxic
Nitrogen % Range [A] Range [B]	<2.2	2.2-2.3	**2.4-2.6** **2.4-2.8**		
Phosphorous % Range [A] Range [B]	<0.09	0.09-0.11	**0.12-0.16** **0.14-0.18**	0.17-0.25	>0.25
Potassium % Range [A] Range [B]	<0.4	0.4-0.69	**0.7-1.5** **1.0-1.5**	1.6-2.3	>2.3
Sulfur % Range [A]	<0.14	0.14-0.20	**0.21-0.4**	0.41-0.5	>0.5
Calcium % Range [A]	<1.6	1.6-2.9	**3-6**		>7.0
Magnesium % Range [A] Range [B]	<0.16	0.16-0.25	**0.26-0.6** **0.3-0.7**	0.7-1.2	>1.2
Sodium % Range [A]			**<0.16**	0.17-0.25	>0.25
Copper mg/kg Range [A] Range [B]	<3	3-5	**6-10** **6-15**	11-15	>15
Zinc mg/kg Range [A] Range [B]	<16	16-24	**25-80** **30-100**	81-300	>300
Manganese mg/kg Range [A] Range [B]	<16	16-24	**25-80** **25-100**	81-300	>300
Iron mg/kg **Range [A]** **Range [B]**	<36	36-60	**61-120** **60-120**	121-200	>200
Boron mg/kg Range [A] Range [B]	<21	21-30	**31-100** **50-150**	101-260	>260

A - Source: Plant Analysis: An Interpretation Manual. D J Reuter & J B Robinson. 2nd edition 1997. CSIRO
B - Source: Fruit Size Management Guide: Part 1. Australian Citrus Growers 2003

General Crop Fertiliser Recommendations

Information generated from fertiliser trials can provide base data on the amount of nutrients required by trees. These general recommendations are normally provided on a district or regional basis to take into account local soil and climatic conditions. They are another tool to assist in developing a fertiliser program.

Matching Applications to Growth Stages

The nutrients required for growth, flowering and fruit production, actually have to be present in the tree when they are needed. Soil applied fertilisers (depending on the form of nutrient present) usually have to be applied 4-6 weeks prior to when they are required in the plant. For foliar application or fertigation systems the nutrients can be applied much closer to the time they are required in the tree.

Citrus trees go through a cycle of growth phases annually. These growth stages include several leaf flushes (mainly in spring, early-summer and autumn), several root flushes (mainly in spring and autumn), and the fruit development stages from floral induction through flowering, fruit set, fruit growth and maturation. These different stages require an adequate supply of certain nutrients. Table 8 outlines application times for N, P and K with reference to the key growth stages.

Fertiliser Programs

The aim of a fertiliser program is to provide adequate supplies of the right nutrients to the trees when, and if, they are needed. Fertiliser programs are not set in concrete and need to be regularly monitored and adjusted. The amount of fertiliser required is dependent on a range of factors including: tree age and size, crop load, variety and rootstock, soil type and seasonal climatic conditions.

Managing tree nutrition is a dynamic process and your fertiliser program needs to be assessed annually. Keeping records of application rates and times, fruit quality and yield, seasonal conditions and previous soil and leaf analysis results are essential in managing a fertiliser program and achieving good tree nutrition.

Table 6: Removal Rates per hectare for Oranges producing 20t/ha
(Based on the Orange Crop removal Charts produced on the ACG website from information provided by M.Treeby and R. Storey, CSIRO.

Nutrient	N	P	K	Ca	Mg
Leaf & fruit (kg/ha)	64	8	45	70	9
Fruit (kg/ha)	36	3	33	12	3
Total (including losses from leaching & fixation)	78	11	54	82	12

Table 7: Removal Rates per tonne for citrus producing 56t/ha
(From the Australian Soil Fertility Manual. J.S. Glendinning, CSIRO. 1999)

Nutrient	N	P	K	Ca	Mg	Cu	Fe	Mn	Zn	B
Yield of 56t/ha	**kg/t**					**g/t**				
Orange[(1)(2)]	***1.8***	***0.2***	***1.9***	0.72	0.22	0.6	0.3	0.8	1.4	2.8
Mandarin[(1)]	1.83	0.16	2.05	0.5	0.11	0.6	2.6	0.4	0.8	1.3
Lemon/Lime[(1)]	1.64	0.16	1.73	0.47	0.13	0.3	2.1	0.4	0.7	0.5

[1] Halliday D.J., Trenkel M.E and Wichmann W. 1972 IFA World Fertiliser Manual International Fertiliser Industry Association Paris.
[2] Moody P. 1993 Qld.DPI Nutrition in Horticulture Workshop, Unpublished data.

A fertiliser program should never be based on just one years worth of data, but based on information over a number of seasons. Keeping good records enables you to see trends over time and compare application rates and timing to tree growth, fruit quality and production levels. Adjustments to your fertiliser program should be made gradually. If changes need to be made, try not to vary application rates of the major nutrients by more than 30% annually.

References.

- Smith, P.F. *Citrus Nutrition in Nutrition of Fruit Crops* by N. F. Childers.
- Weir. R.G. and Sarooshi, R. 1991. *Citrus Nutrition* Agfact H2.3.11. NSW DPI.
- Glendinning, J.S. 1999. *Australian Soil Fertility Manual*. CSIRO.
- Slack, J.M, Huett, D.O. and George. A. 1996. *Fertlising Low-Chill Stone Fruit.* NSW DPI.

Table 8: Application times for N, P and K for navel oranges

Growth Stage	Nutrients Required (% of annual requirements)
Budswell	Nitrogen (40-50%)
Pre-bloom	Phosphorous (100% if banding, 50% if fertigating) Potassium (30%)
Spring and Summer flush	Foliar magnesium, zinc and manganese if required
Stage 1 Fruit Growth (Nov/Dec)	Nitrogen (25%) Potassium (30-50%) Phosphorous (fertigation- 50% at monthly intervals)
Stage 2 Fruit Growth (after final fruit drop)	Nitrogen (25%) Potassium (30%)

Extracted from the Fruit Size Management Guide Part 1, ACG 2003.