Soils, households and Governments – they all have budgets, deficits and surpluses.

by Stephen Tancred, Senior Horticultural Consultant

Orchard Walks

- Shepparton Vic. - 4th November 2013
- Batlow NSW - 5th November 2013
- Orange NSW - 6th November 2013
- Stanthorpe Qld - 8th November 2013

The soil is the reservoir of mineral nutrients, the bank or treasury if you like.

Deposits to the bank are mainly in the form of fertilisers applied by broadcasting or fertigation. Foliar applications are like interest payments earned – they are smaller, are strategic, but you can often survive without them.

Nutrients can become available from the base rock components of the soil – they are mineralised by weathering. These are usually very small amounts and not enough to run a productive agricultural system. Think of these as tax refunds – small and infrequent.

Withdrawals of mineral nutrients from the soil bank are from several sources;
Crop removal – what is driven out of the paddock in picking bins. These are the planned and desirable withdrawals.
Leaching to unavailable parts of the soil or leaching into ground or surface water. You can't get these back – they are like bank fees and charges. You try and minimise them but they are unavoidable.

Nutrients can become unavailable to plants within the soil – 'locked up' is a term sometimes used (often over used). Nutrients are also used to grow wood, roots and leaves and become unavailable for the long term (wood) or short term (leaves). Think of them as term deposits. They are not lost to the system but won't help the cash flow.

As plants go, apple and pear trees are big units and are themselves a storage system for nutrients (and carbohydrates). Think of this 'in-tree storage' of nutrients as like the ATM machine. It gives you some cash-flow when the bank is closed, but if it's not topped up regularly it runs out of cash. Depending on soil type trees can take one year to become deficient in a major mobile element like nitrogen or may take 10 years to become deficient in a trace element like copper.

The key parts of balancing the budget of plant nutrition are;

1. Match the deposits to the soil/plant reservoir to the withdrawals.
2. Only deposit less than is used if you have good reserves in the soil or the tree.
3. Make sure the deposits are timed properly to meet the demands of the withdrawals.

If either the size of timing of deposits are continually wrong then the tree will have to call on tree or soil reserves and eventually go into overdraft, which stresses the system, affects tree health and reduces yield or quality.

Let's look at some typical Australian nutrient withdrawals. I have actual fruit nutrient analysis data from;

- Stanthorpe Granny Smith and Red Delicious apples in 1997,
- Cobram Packham's Triumph pears in 2010,
- Orange Red Delicious and Pink Lady apples in 2013,
- Batlow Pink Lady apples in 2013 and
- Stanthorpe Pink Lady apples in 2013.

Stanthorpe 1997

		Nutrient removal with 40 t/ha yield			
	Unit	Red Del 1	Red Del 2	GS 1	GS 2
Potassium	Kg	64	58	47	52
Nitrogen	Kg	26	21	19	18
Phosphorus	Kg	6	4	3	5
Calcium	Kg	2.4	2.2	2.4	2.4
Magnesium	Kg	3.2	2.9	1.8	2.4
Sulfur	Kg	1.6	1.5	1.2	1.2
Boron	g	130	90	90	110
Copper	g	30	20	20	20
Zinc	g	20	30	20	20
Iron	g	360	180	340	130
Manganese	g	60	20	30	30
Sodium	g	790	720	590	600
Aluminium	g	10	60	70	30

Points to note;

- The removal rates don't vary drastically between orchards.
- Removal rates were higher in Delicious than in Granny Smiths, probably due to the GS being under fertilized as a vigour control mechanism.
- Potassium removal is similar to the 2013 Pink Lady Qld analysis.
- Nitrogen removal is higher than the 2013 Pink Lady Qld analysis.

Let's now look at some real time examples from modern productive orchards.

Crop nutrient removal per hectare						
Actual Yield (t/ha)		**82**	**87**	**54**	**52**	**45**
Analysis	**Unit**	**Red Del Orange 2013**	**Pink Lady Orange 2013**	**Pink Lady Qld 2013**	**Pink Lady Batlow 2013**	**PT Pears Cobram 2010**
Potassium	Kg	107	144	69	105	51
Nitrogen	Kg	66	66	42	40	23
Phosphorus	Kg	7	8	7	7	6
Calcium	Kg	6.9	6.2	3.5	4.9	4.1
Magnesium	Kg	5.7	5.3	3.0	3.8	3.3
Sulphur	Kg	3.2	3.6	2.1	2.6	4.5
Boron	g	337	486	213	239	176
Copper	g	32	39	17	22	27
Zinc	g	57	59	40	27	45
Iron	g	470	504	191	181	
Manganese	g	38	59	86	30	23
Sodium	g	619	649	413	1353	
Aluminium	g	247	314	155	97	
Molybdenum	g	14	28	4	4	

Points to note;

- Potassium is the nutrient removed in greatest quantity.
- Very large differences in removal rates depending on yield, variety and district.
- Very small amounts of some trace elements removed (manganese, molybdenum)

Big thanks to the following agronomists for assisting with fruit collection and provision of soil test and yield data;

- Sam Beggs and Cam Forrest, agronomists at IK Calkwells in Shepparton and Cobram.
- Matthew McMahon from the Batlow Fruit Co-op.
- Antony Spruce, agronomist with EE Muirs at Orange

The apple and pear industry is lucky to be serviced by a good network of experienced and responsible agronomists, and these gents are part of that team.

Let's standardise the yield and see what the crop removal would be from the different orchards*.

Standardised Yield (t/ha)		**60**	**60**	**60**	**60**	**60**
Analysis	**Unit**	**Red Del Orange 2013**	**Pink Lady Orange 2013**	**Pink Lady Qld 2013**	**Pink Lady Batlow 2013**	**PT Pears Cobram 2010**
Potassium	Kg	74	105	76	121	68
Nitrogen	Kg	46	48	46	46	31
Phosphorus	Kg	5	6	7	8	8
Calcium	Kg	4.8	4.6	3.9	5.6	5.5
Magnesium	Kg	3.9	3.9	3.3	4.4	4.3
Sulphur	Kg	2.2	2.7	2.4	3.0	6.0
Boron	g	232	356	237	276	234
Copper	g	22	29	19	25	36
Zinc	g	39	44	44	31	60
Iron	g	324	369	212	209	
Manganese	g	26	43	95	35	30
Sodium	g	427	475	459	1561	
Aluminium	g	170	230	172	112	
Molybdenum	g	9	21	4	5	

* These are theoretical calculations, because if trees set heavier or lighter crops the nutrients directed to crop and shoots would not necessarily interact in a linear fashion.

Points to note;

- There are still large differences between varieties and districts.
- Queensland has the sandiest and poorest soil and the lowest levels of potassium and calcium in fruit.
- Nitrogen removal is very similar between all four apple orchards.
- The important trace elements are very similar.

Let's look at the characteristics of the main nutrients and how they fit into an orcharding system.

Nitrogen

Its main feature is that it is easily leached by rainfall and by irrigation. How much leaching depends on how much clay and organic matter is in the soil. Sandy soils leach easily.

There is potential to leach nutrients every time you irrigate. This is another reason shorter and more frequent irrigations are better than longer waterings. The policy with nitrogen should be to apply 'a little bit, often'. With the use of fertigation this is relatively easy to do.

Potential leaching is also a reason to be cautious about supplying a lot of nitrogen during the post-harvest period. Trees will take up nitrogen then and it makes the trees stronger for spring, but the risk is that broadcast nitrogen will be leached during the winter. Fertigation or foliar applications are more appropriate methods for post-harvest fertilising.

Every season is different and just as the removal by trees varies with crop load, so does the leaching each year based on the amount of rain and type of rain. It's good to anticipate in-season losses but soil testing in late winter is the best time to measure the residual soil fertiliser available for in-season tree use.

It is common to apply up to twice the amount of nitrogen removed by the crop each year. In wet years or in inefficient system the ratio may be even higher.

Nitrogen is the main nutrient required by all plants for healthy growth. Trees will readily tell you if they are deficient with pale leaves and reduced growth. Orchards with excess nitrogen have dark green leaves, excess shoot growth and will produce lower quality softer fruit.

Nitrogen fertilising is the major reason that soil pH's drop over time. The other main reasons are increases in organic matter, cultivation, rainfall and irrigation. Different forms of nitrogen will have different effects on soil pH. Unfortunately the forms that lower pH the least are the most expensive. However the need for regular lime and dolomite is greatly reduced and the benefits on tree health will outweigh any savings from cheaper forms of nitrogen. Mixed fertilisers often have a component of Ammonium Sulphate and tend to lower soil pH.

Fertiliser	**Solubility***	**Effect on soil pH**
Ammonium Sulphate	73	lowers pH a lot
Urea	84	lowers pH
Nitram	158	lowers pH
Potassium Nitrate	21	lowers pH
DAP	63	lowers pH
C.A.N.		neutral or raises pH
Calcium Nitrate	84	neutral or raises pH
Muriate of Potash	31	neutral
Sulfate of Potash	9	neutral

* kg per 100 litres water at 30^0C

Potassium

This is the major mineral component of fruit and is the most important major element for growing quality fruit. Crop removal is always high. Leaf deficiency symptoms are interveinal yellowing and some leaf cupping inwards and marginal scorching when severe. Fruit deficiency symptoms include smaller, paler and poorer tasting fruit.

As potassium is less easily leached than nitrogen the amount applied can more closely match the potassium removed by the crop. However substantial potassium is used to grow wood so although the requirements are lower for young trees the element should always be well supplied.

Lower leaching means that the timing of potassium is not as important as the timing of nitrogen. However, fruit demands increase as the season progresses, so don't stop potassium fertilising too early. If you are fertigating with 'straights' (potassium sulphate, potassium chloride) this is possible. However if you are using mixed fertilisers (potassium nitrate, mixed soluble products) you will be also be applying nitrogen and late applied nitrogen can alter the fruit nitrogen/calcium ratio and adversely affect fruit storage.

It takes several years for the soil and tree potassium reserves to be depleted and leaf symptoms only show up at the end of the season when there is peak demand from the fruit and potassium is relocated from leaves to fruit by the tree. By then fruit quality and yield has been affected.

Once every 4 or 5 years I see an extreme situation where a sales focussed agronomist has recommended a very complex and expensive fertiliser program that involves lots of foliar and fertigated products that is grossly short of potassium. The grower thinks he is doing the right thing because of the cost and frequency of his fertilising but its only when I do a 'fertiliser budget' of the contents of the fertilisers that it becomes obvious why the fruit is small and pale and the leaves have tattered brown edges.

Some soils have naturally high levels of potassium and only small amounts are ever applied with manures or mixed fertilisers. This is appropriate; however the trees are removing the potassium from the soil just where the roots mainly are – which is just a subset of the whole soil. After several years the localised supply may be depleted and to be adequately supplied the release of available potassium from the soil (mineralisation) will have to match the removal by trees. In soils with high natural potassium it would be worth doing soil tests from different parts of the orchard floor and at different depths to see if local variations occur.

Phosphorus

Very little phosphorus is removed by fruit each year and growers often over supply this element. Phosphorus is not very readily leached from soils but is tied-up or made unavailable in some soil types. Most orchards are on older horticultural soils that have been repeatedly fertilised for many years and soil tests often show high to very high levels of available phosphorus.

On mature orchards and in soils that have high levels of phosphorus the timing and form of phosphorus is not critical.

Phosphorus is very important for root growth of young trees and because it does not always easily move down the soil profile it is important to apply it while preparing the soil of new blocks.

Calcium and magnesium

Calcium, magnesium, potassium and sodium are known as the 'cations' in soil chemistry. They are of a similar molecular size and all have positive charges. The uptake of one for the other can be substituted as the plant roots can't discern between them. So it's important to have the ratios right in the soil; potassium highest, sodium lowest. It is also good to have more calcium than magnesium by a factor of about 3 - 8.

Calcium takes on particular importance in apple production as it's important to prevent bitter-pit and to grow firm fruit that stores well. Remember, we want the fruit to have a lot higher calcium content than it thinks is 'normal'. The apple only needs to grow the fruit to maturity to complete its reproductive cycle. Keeping firm flesh and skin with no bitter-pit for 6 to 9 months is not part of its evolutionary fitness.

Some people are too cautious about having high soil potassium levels as they think it will interfere with calcium uptake. This will be the case if calcium is undersupplied. There are many good forms of soil applied calcium (calcium nitrate, lime, dolomite, gypsum) and foliar calcium products, and both soil and foliar applications should be made each year.

Much is made about the forms of foliar calcium product to use, especially by the companies that make specialised foliar products.

8 reasons why calcium nutrition is very important.

1. Fruit calcium content is strongly related to fruit quality.
2. Calcium only moves up from the soil in any quantity in the spring.
3. Calcium doesn't move from leaves to fruit.
4. Maximum effect from foliar sprays is if calcium is supplied to the apples as they grow.
5. Dry or excessively wet weather, vigorous growth and large apples all contribute to poor calcium uptake.
6. Some varieties are more prone to calcium deficiency (Delicious, Braeburn, perhaps Jazz).
7. Shallow and sandy soils experience uneven watering which interrupts calcium supply.
8. SmartFresh applied after harvest will make bitter pit calcium deficiency more noticeable.

Calcium Sprays - some other considerations.

- Costs and ease of use.
- Best products are calcium chloride or calcium nitrate based.
- Potential leaf burn from calcium chloride. Interacts with summer rainfall and concentrate spraying.
- Potential fruit burn from any product –use reputable company's products.
- Extra nitrogen from calcium nitrate based products can help or hinder nutrient budget.

A common source of magnesium is Epsom salts (9.6% Mg). It is often applied as a foliar spray (6-800 g/100 L) to trees during the growing season. One dilute spray (1,800 L/ha) provides 1.4 kg/ha of magnesium whilst up to 6 kg/ha is removed with a crop, so if soil reserves are low this can only be regarded as a maintenance supply. A good source of magnesium is dolomite as 2t/ha provides 160 kg/ha and supply several years' worth of magnesium.

Nutrient	Symbol	Ability to leach in soil	Mobility within plants
Nitrogen	N	High - especially in sandy soils	Mobile
Phosphorus	P	Low	Mobile
Potassium	K	Medium	Mobile. When crop demands are high late season leaves can show deficieny symptoms very quickly as K moves to fruit
Sulfur	S	Can be high in sandy soils	Some mobility
Calcium	Ca	Low	Not mobile, so won't move from leaves to fruit
Magnesium	Mg	Medium	Mobile

Trace Elements

Boron, zinc, iron, copper, manganese, sodium and aluminium are the main trace elements of interest. As their name suggests, and the crop removal figures show, they are only needed in small amounts - so they are called trace elements. Because of this they are often supplied as foliar sprays or as a component of a mixed fertiliser. However, the amounts supplied in mixed fertiliser usually do not supply enough to replace what the crop removes. For example 300 kg/ha of Rustica Plus fertiliser supplies 60 g of boron which is just a fifth of the boron removed by the crop.

Boron

Most Australian horticultural soils are naturally deficient in boron and it is a very important trace element for tree health and fruit quality. It is the most easily leached trace element so large applications to supply trees for several years should not be made as it may be lost before trees can take it up. Large applications are also toxic (boron was used as an early herbicide), so the application has to be "a little bit, applied often".

Very small quantities are removed with fruit (~250 grams/ha with a 60 t/ha crop) and there are several good methods of application. Foliar applications are common and many growers also apply boron mixed with their first herbicide application of the year.

Apple trees are very good scavengers of boron so even though soil levels may be low, leaf tests often show levels to be adequate. However if applications are not made for several years trees will run down their reserves and tree health and fruit quality will suffer, this can happen rapidly in sandy soils or wet years.

Boron interacts positively with calcium nutrition, so indirectly assists fruit firmness and preventing bitter pit. Boron deficiency plays a role in the development of the bark measles disorder. It is also important for good pollination, but this tends to be over-emphasised by companies selling foliar boron sprays, who promote pre-bloom applications. I would rather see foliar boron sprays applied mid-season when there are ample leaves to absorb it than pre-bloom when most of the boron ends up on the tree's bark. In well fertilised orchards poor fruit set is much more likely to be because of cold/wet weather and low bee activity during bloom than from lack of boron.

Boron is most commonly applied mixed with a herbicide application and/or in spring as a foliar spray in November. November is when the trees are well leafed up and can absorb trace elements and the fruit is not small and tender and susceptible to any damage.

Iron is not a common deficiency as most soils have adequate iron, hence it is not often required as a fertiliser. It is hard to supply to tree crops successfully. Chelated foliar sprays have some success but the long term answer to a deficiency involved increasing the soil organic matter. Early season deficiencies often correct themselves as the soil warms up and the roots explore more soil.

Iron deficiency symptoms are extreme yellowing of young leaves. Severe deficiency can occur if a soil is over limed. This is an induced deficiency because the iron is present in the soil, but becomes unavailable at high pHs. I have only seen it a few times and it was associated with heavy liming of very acid soils and uneven incorporation of the applied lime.

Copper is rarely deficient because of the use of copper as a fungicide and bactericide. However many orchardists do not now use green tip copper sprays. In some young orchards on new soil the copper levels are low and copper should be used as a dormant spray for nutritional reasons rather than a bud movement spray for disease control. It can be mixed with dormant zinc spray or post-harvest sprays.

Copper deficiency symptoms are 'wither-tip' in apples, pears and stonefruit. The leaves at the end of branches are smaller, brown off and fall. It is not common but should be avoided, especially now that long pruning is in practice.

Copper can be supplied as copper oxychloride, copper sulphate or copper oxide as a fungicide - bactericide spray at bud movement or during dormancy. Summer copper sprays are very likely to burn leaves and fruit. Chelated forms are available but are best applied post-harvest. Copper sulphate can be applied during the season on the ground as a powder or in solution (with irrigation water or herbicide boom). Green tip copper sprays are less common now as they can contribute to fruit russet – especially in hail netted orchards as copper deposited on net can be washed down onto flowers.

In very old stonefruit and grape blocks copper levels can build up to toxic levels in the surface soil. However excess copper can be bound up by organic matter and clay so this can be managed by adding manures. Trees have a lot of roots at depth so the overall tree health may not be affected but vegetables or young trees may be.

Zinc is not well taken up by apple, pear stonefruit roots from the soil so it is best applied as a foliar spray to bark and buds during dormancy or as a summer zinc spray (eg Zinctrac). The quantities of zinc supplied during winter are quite large and a dormant spray is only needed every second year. Care should be shown as winter zinc can burn if the tree is not fully dormant or there are fresh pruning cuts. Likewise summer zincs need to be used carefully. Some fungicides (mancozeb, ziram) contain some zinc and this may partially supply the tree's needs. However it is not a replacement for zinc fertilisers.

Sodium, Aluminium and Manganese are only required in small amounts and are more likely to be a problem because of excesses or toxicities.

How much fertiliser should be applied ?

The amount being removed by the crop each season is the minimum. But because of leaching, nutrients going to parts of the soil that are unavailable, or being used by trees to grow wood and leaves there is a need to apply more than what is removed by the crop. Nitrogen should have the greatest multiplier, then potassium. This is because nitrogen uptake is so inefficient, and because potassium is so important.

But not all the elements removed by fruit have to come from applied fertiliser because there are reserves in the soil. Sometimes the soil is naturally well supplied with an element eg potassium in the Batlow and Orange soils. Sometimes because many years of excess application have built up a large soil reserve eg phosphorus in all four districts.

Let's look at the budgets and bank balance for six of the major nutrients and one trace element.

Potassium

- Less was applied than removed at three of the six orchards. Of greatest concern is the Pink Lady block at Orange where the deficient was 103 kg/ha.
- The lowest removal in apples was 69 kg/ha at Stanthorpe, possibly because the soil reserves are so low.
- The pears had the highest application rate, despite soil reserves being high. Local advice is that the pears do respond to applied potassium, even when soil levels are high.

Potassium	Red Del Orange	PL Orange	PL Stanthorpe	PL Batlow	PT Pears Cobram
Kg/Ha Applied	79	41	77	82	123
Kg/Ha Removed	107	144	69	105	51
"Excess" supplied	-28	-103	8	-23	72
Soil status pre-season	Medium	Low-medium	Very Low	Medium	High

Nitrogen

- Less was applied than removed at only one of the six orchards. But because nitrogen application and uptake is inefficient it is normal that this is the case.
- The highest excess in apples was 105 kg/ha in Batlow Pink Ladys and excess tree vigour was reported in that orchard.
- The pears had the highest application rate and the highest excess, and the highest soil level pre-season. There is definite scope to reduce nitrogen fertiliser rates there.

Nitrogen	Red Del Orange	PL Orange	PL Stanthorpe	PL Batlow	PT Pears Cobram
Kg/Ha Applied	116	30	68	145	160
Kg/Ha Removed	66	66	42	40	23
"Excess" supplied	50	-36	26	105	137
Soil status pre-season	Low	Very Low	Very Low	Very Low	Medium

Phosphorus

- More was applied than removed at all of the orchards. This is common and is why soil levels increase over time.
- The highest excess was 40 kg/ha in Batlow Pink Ladys, which was nearly six times what was removed.
- Most orchards could skip fertilising with phosphorus for several years with no effect on tree growth or fruit quality. The P applied with mixed fertilisers is unnecessary when soil reserves are so good.

Phosphorus	Red Del Orange	PL Orange	PL Stanthorpe	PL Batlow	PT Pears Cobram
Kg/Ha Applied	16	17	30	47	15
Kg/Ha Removed	7	8	7	7	6
"Excess" supplied	9	9	23	40	9
Soil status pre-season	High	Medium	Medium-High	Medium	High

Calcium

- Much more was applied than removed at all of the orchards. This is common and is why soil levels increase over time.
- The highest excess was 115 kg/ha in the Batlow Pink Lady block.
- The calcium story is about timing (spring for soil) and placement (foliar onto fruit) as much as it is about deficits or surpluses.

Calcium	Red Del Orange	PL Orange	PL Stanthorpe	PL Batlow	PT Pears Cobram
Kg/Ha Applied	122	32	53	132	52
Kg/Ha Removed	6.9	6.2	3.5	4.9	4.1
"Excess" supplied	115	26	50	127	48
Soil status pre-season	High	High	Medium	High	High

Magnesium

- Not a concern that a deficit occurred in the two Orange orchards as the soil status was medium and high.
- Magnesium easily supplied by foliar (mag sulphate), fertigation (mag sulphate) or broadcast (gypsum, also in many mixed fertilisers).

Magnesium	Red Del Orange	PL Orange	PL Stanthorpe	PL Batlow	PT Pears Cobram
Kg/Ha Applied	3.6	3.0	3.8	12.0	4.3
Kg/Ha Removed	5.7	5.3	3.0	3.8	3.3
"Excess" supplied	-2	-2	1	8	1
Soil status pre-season	Medium	High	Low-medium	High	High

Sulphur

- Deficiencies are not common, so this nutrient is seldom applied except as part of mixed fertilisers or in combination with other elements.

Sulphur	Red Del Orange	PL Orange	PL Stanthorpe	PL Batlow	PT Pears Cobram
Kg/Ha Applied	28.0	21.0	4.6	60.0	52.0
Kg/Ha Removed	3.2	3.6	2.1	2.6	4.5
"Excess" supplied	25	17	2	57	48
Soil status pre-season	Medium	Low	Low	Low	High

Boron

- A wide range between the "deficits" and "excesses".
- The boron supplied in standard mixed fertilisers is insufficient to supply enough boron to replace that removed by the crop.

Boron	Red Del Orange	PL Orange	PL Stanthorpe	PL Batlow	PT Pears Cobram
g/Ha Applied	60	1458	545	2356	300
g/Ha Removed	337	486	213	239	176
"Excess" supplied	-277	972	332	2117	125
Soil status pre-season	Medium	Low	Low	NA	Low

The discussions on pages 2 to 14 have concentrated on the removal of nutrients from the orchard and their replacement by fertilising. The approach taken was one of budgeting; aiming for a surplus if soils were deficient and living with a deficit if soils were well supplied.

But what about the nutrient levels in the product – the harvest fruit ? How did they stack up for storability ? The data I have collected is interesting, but can be misleading if taken out of context.

Note the following;

- The data is on a dry matter basis and is after the water has been extracted.
- For simplicity I have averaged the 4 apple samples as there won't huge differences between them.
- The reference levels are from Col Little's storage textbook.
- However Col's figures are only for apple flesh (excluding stalks, seeds and core) and my samples were the whole apple. I used the whole apple as the focus of my inquiry was removal of minerals from the orchard and the stalk, seeds and cores are part of the removal.

I would expect higher nitrogen and phosphorus levels in the whole apple as the seeds, stalk and core would have more proteins (that contain N and P) than the flesh.

I would expect higher potassium levels in the whole apple as the seeds, stalk and core would have more lignified matter (that contain potassium) than the flesh.

In discussions with Col in years past he emphasised the ratios of calcium to nitrogen, potassium and phosphorus were just as important as the overall levels.

	Average of 4 apple orchards surveyed 2013	**Adequate range per Col Little guidelines 2000**
Potassium %	1.0	0.66-0.9
Nitrogen %	0.50	0.25 - 0.35
Phosphorus %	0.07	0.21-0.07
Calcium %	0.05	0.025 - 0.035
Magnesium %	0.04	0.02-0.03
Sulphur %	0.03	0.02
Boron ppm	29	15
Copper ppm	2.5	2
Zinc ppm	4.3	8
Iron ppm	30	8
Manganese ppm	5	12
Sodium ppm	0.02	<0.1
Ca:N ratio	10	10
Ca:P ratio	1.4	2.2 or lower
Ca:K ratio	20	30 or lower
Ca:Mg ratio	0.8	0.8

Fertiliser Checklist

1. Fertilising should be based on a soil test. You should sample where the roots mainly are – which is usually along the tree line. The depth of sampling should be 20 – 30 cm, which is deeper than many reseller agronomists will sample (0 -15cm). Late winter is the best time to sample as it allows time for the fertilisers applied after the soil test to be washed into the soil.
2. Mid-season leaf tests can confirm if the program is on track. The main messages will be whether to apply more nitrogen or potassium. Be careful when interpreting as reference standards are based on late season leaf levels. Nitrogen and potassium levels fall during the season and calcium and boron levels rise. Deficiencies can also be diagnosed with leaf tests.
3. Leaf tests at the end of the season are a good review of the tree's status and your fertiliser program, but are too late to do anything about it for this year !
4. Sap tests are of little use; there are not good standards to interpret them, the nutrient levels vary based on time of day of sampling and irrigation status, they don't test for the full range of elements and they are measuring just a portion of the tree's tissues.
5. Just enough nitrogen should be applied to keep the tree healthy, leaves green, and replace what is removed with fruit. Excess nitrogen causes growth and fruit quality problems.
6. Potassium should be available in the soil at high levels. High yielding and later harvested varieties are going to need a longer supply and at higher levels.
7. Adequate phosphorus is important in establishing young trees. Annual replacement needs are easily met.
8. It's hard to get become deficient in the trace elements quickly unless the soil is being planted for the first time, or no fertilisers have been applied for several years. The exception is boron which is easily leached and is very important for all horticultural crops. Too much boron is toxic so a little bit should be applied often.

Soil pH

I want to revisit some basics of soil health and pH is a very important measure as at low or high pH's many undesirable things happen.

pH is a measure of the acidity or alkalinity of the soil. pH's of 0 to 7 are acid, pH's of 7 to 14 are alkaline. A pH of 7 is neutral. Fruit trees grow best at a pH of about 6.5. Agricultural soils typically range from 4.5 to 8.5, but as horticultural soils need to be well drained they contain less clay than cropping soils, so they are more commonly naturally acidic.

Soil pH can be lowered by

- use of fertilisers
- rainfall and irrigation
- flooding & lack of aeration
- erosion of surface soil
- build up of organic matter (roots/leaves etc, manures)
- cropping and removal of nutrients (magnesium, calcium, potassium)

Sandy soils will become acid quicker than clay soils.
Soils with low organic matter can become acid quickly.

Why is a an acid (low pH) soil undesirable ?

1. Nutrients become unavailable
   - applied fertiliser is less effective (nitrogen, phosphorus, potassium)
   - trace element deficiencies occur (calcium, magnesium, boron)
2. Acidity affects plant roots directly
3. Induced toxicities of manganese and aluminium
   - excess aluminium stunts root growth
   - excess manganese contributes to apple bark measles
4. Affects on soil microbial activity
   - unhealthy soil and less conversion of ammonia to nitrate for plant uptake

The pH within soil profiles

Because nitrogen fertilisers are one of the main causes of low soil pH and nitrogen readily leaches in sandy soils it is common for pH to be lower in deeper parts of the soil. Also lime and dolomite are slow to move down into soil, so most pH correction occurs in the surface soil.

Also the pH along herbicide strips is usually lower than in grassed alleyways. This is because the fertiliser is usually applied more to the under-tree strip. This example from New Zealand demonstrates that changes in pH down the soil and across the rows.

Soil Depth (cm)	pH in herbicide strip	pH in grassed alley
0 - 5	4.6	6.3
5 - 10	5.3	6.3
10 - 20	5.7	6.1
20 - 30	5.9	6.0

Source: *Soil Science* (1981) 132:274.

Correcting low pH

Lime and dolomite are the cheapest and easiest ways to raise soil pH. Rates to apply depend on the soil pH and the expected reaction of the soil and range from 0.75 tonnes to 7 tonnes/ha.

Lime is insoluble so it moves very slowly into the soil with rainfall. Hence lime applied during dry years may only affect the soil surface. It is best mixed into the soil prior to planting tree crops – its the only chance to apply lime directly below trees. The best strategy is to test soil regularly and apply lime before the soil pH drops too far.

The effectiveness of lime and dolomite also depends on its fineness. Finer lime reacts with the soil quicker. Lime is sometimes rated by its neutralising value. This is expressed as a % value. These commonly range from 75% to 140 %.

Product	Content	Neutralising Value	Characteristic
Ag. lime	Calcium carbonate	100 %	Relatively inexpensive
Ag. dolomite	Mix of lime and 8-10% mag. carbonate	102 %	More expensive than lime
Hydrated lime	Calcium hydroxide	135 %	Very expensive More reactive than ordinary lime
Burnt or quick lime	Calcium oxide	178 %	Very expensive More reactive than ordinary lime Dangerous to use as so reactive
Grow Mag	Mix of lime & mag oxide	110%	Slow release Mg. Good neutralising value
Gypsum	Calcium sulphate	nil	Breaks up clay soils. Supplies calcium Can displace sodium from salty soils.

Hydrated lime is used in cold stores to absorb CO_2 . The chemical reaction is;

$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$ or hydrated lime + carbon dioxide = lime + water

Cold store lime is as effective as agricultural lime in raising soil pH, however its main drawback is that it has got wet and formed lumps and rocks that need to be physically broken up.