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OCTOBER 2005 PRIMEFACT 85

Apple and pear nutrition

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Most pome fruit orchards need some fertiliser, lime, or a trace element to achieve and maintain optimum tree growth and fruit production. Even very fertile soil which may need little extra nutrient for years, eventually develop nutrient problems.

Modern pome fruit production calls for greater attention to plant nutrition because of:

- higher density plantings,
- the need for higher fruit production from young plantings,
- replanting of old orchards due to a shortage of good new land,
- increased demand for better quality fruit and ever-longer storage times.

Essential chemical elements

These chemical elements are essential for the healthy growth of all higher plants:

Table 1.

From air and water			
Oxygen	O	Hydrogen	H
Carbon	C		
From the soil			
Nitrogen	N	Phosphorus	P
Sulphur	S	Potassium	K
Calcium	Ca	Magnesium	mg
Boron	B	Chlorine	Cl
Copper	Cu	Iron	Fe
Manganese	Mn	Molybdenum	Mo
Zinc	Zn		

Carbon, hydrogen and oxygen are obtained from air and water, but the other 13 elements must come from the soil.

To grow and produce well, pome fruit trees require an adequate supply of all of these nutrients, but only a few are commonly lacking in orchards of the main apple and pear districts of NSW.

They are nitrogen, potassium, calcium, zinc and boron. Occasionally magnesium deficiency occurs, especially in trees where the soil has been limed.

Nitrogen

Adequate nitrogen is essential for tree growth, leaf cover, blossom formation, fruit set and fruit size, all of which combine to determine crop yield.

A shortage of nitrogen is:

- Usually first noticed in the leaves, which become pale and small. As nitrogen is mobile (readily transferred from older to newer leaves) within the plant, symptoms of yellowing will be seen first in the older leaves.
- Leaves may develop yellow and red autumn colours as early as late summer and fall prematurely.
- Shoot growth is poor.
- Fruit tends to be small, it matures early and is highly coloured.

Too much nitrogen may cause excessive vegetative or shoot growth and poorly coloured fruit, with delayed ripening, poor quality and a short storage life.

Phosphorus

Mature fruit trees rarely show deficiency symptoms or respond to phosphorus fertilisers in tree growth or in cropping. However, growers commonly apply superphosphate to stimulate clover growth in the ground cover or sod. This in turn can boost nitrogen to the tree and increase organic matter return to the soil, improving its structure.

Sometimes young trees in very deficient soils respond to phosphorus fertiliser during their first few years of growth. Phosphorus is mobile in the plant which means symptoms generally will be seen first on older leaves. These deficient symptoms consist of dull/ dark green leaf colour, bronze or purple tints and generally poor growth.

Potassium

Potassium is generally not a common deficiency. Some mature orchards, particularly those on light, heavily leached granite or sandstone soils, may benefit from potassium fertiliser.

Young plantings in new soil do not usually need potassium fertiliser before cropping starts, but replant trees put into such soils which have not been fertilised with potassium, could be at risk.

In apple trees-the margins of older leaves of a potassium deficient apple tree turn yellow and then brown as potassium is a mobile element. The leaf edges become tattered, curl inwards and the leaf becomes boat-shaped.

In pear trees-the older basal leaves are also the first to show symptoms but the colour of the scorched leaf edges is dark brown to black and the leaf is strongly rolled inward. Shoot growth is poor and fruit is small. Excess potassium can increase susceptibility to bitter pit.

Calcium

Calcium is not very mobile in the plant which results in symptoms usually developing in the fruit and new shoots. Foliar symptoms are rarely noticed. It is not until the fruit develops problems that the symptoms of calcium deficiency are noticed. Low calcium in the soil rarely affects tree growth or fruit yield, but a shortage in the developing apple fruit causes bitter pit.

Bitter pit begins as slight indentations in the skin towards the calyx end-away from the stem. These become brown spots in the flesh and on the skin. A similar, but less common, condition has been seen in pears.

Bitter pit may develop before the fruit is picked but more often it develops during storage. Adequate calcium in the fruit at harvest is essential for good keeping qualities. Fruit which is low in calcium is more susceptible to a range of breakdown conditions in storage:

- internal breakdown,
- low temperature breakdown,
- watercore and lenticel breakdown.

Calcium deficient fruit are also more susceptible to sunburn.

(For more detail see [Agfact H4.AC.1 - Bitter Pit in Apples])

Magnesium

Magnesium deficiency is a less common problem. Symptoms are first seen in late summer in the older basal spur leaves. These become yellow and then scorched around the margin and between the main veins and they tend to drop early. Excessive use of potassium fertilisers will aggravate this problem.

Zinc

Zinc is a common trace element deficiency of pome fruit, and the most damaging to tree health and fruit yield. It affects orchards in all districts and soils including acid soils. Zinc is not very mobile in the plant so symptoms will appear on the younger leaf terminals.

The most characteristic symptoms are:

- Small narrow and irregularly shaped leaves with wavy margins-'little leaf'. These are bunched together near the shoot tips to form rosettes.
- Leaves are sometimes mottled but yellowing between the veins-in the absence of the other symptoms-could be caused by other disorders such as manganese deficiency.
- When the deficiency is severe, branches become almost bare behind the rosetted tip due to a delay or even failure of buds to shoot.
- Many of the branches die back and wood-rotting fungi often attack these weak limbs. Growth may be normal in the lower parts of the tree.
- Yield will be greatly reduced by severe deficiency, and the fruit can be small and misshapen.

Boron

Boron deficiency is another common trace element disorder of apples and pears. It causes a variety of fruit and growth abnormalities. It may be found in all districts and soils but is usually worst on granite soils.

Boron deficiency is more widespread in some seasons than in others, especially in years when very wet periods fluctuate with dry conditions.

Where boron deficiency is severe, symptoms may be seen on fruit, shoots and leaf growth but with most varieties, it is the fruit symptoms which are usually noticed first.

The most common fruit symptom begins as small, clear water-soaked areas in the flesh.

These turn brown later and dry out, forming spongy lesions in the flesh-internal cork. The skin may show no markings with the **internal cork** symptom, but in another form described as **superficial cork**, the skin becomes brown, rough and russetted, often with deep cracks extending into the flesh. Fruit may be misshapen with irregular depressions developing as it ripens.

Trees with severe boron deficiency can suffer from die-back in spring because buds fail to develop. Dieback may also show up in late summer on current season shoots, or a type of rosette of thickened brittle leaves may develop around shortened shoots.

Fruit set can be reduced. A more detailed description of boron deficiency is given in Agfact H4.AC.2 - Boron Deficiency (cork) in Pome Fruit.

Less Common Nutritional Disorders

Manganese deficiency

With manganese deficiency faint light green areas develop between the veins, starting near the margins of mature leaves. Usually the affected mature leaves are normal in size and shape, which distinguishes the symptoms from those caused by zinc deficiency's little leaf.

Manganese deficiency is less common in the main pome fruit districts than zinc deficiency and its effects are far less damaging. It is more common in alkaline or recently limed soils.

Manganese toxicity

This is mostly a problem of acid soils which can be made worse by periodic waterlogging. It affects both apple and pear trees with a condition described as internal bark necrosis or **measles**. Delicious apples are most commonly affected especially in replant blocks.

The measles condition in trees is believed to be caused by a complex of problems involving high manganese associated with low calcium. Sometimes low boron can be involved. Onsets of symptoms are often triggered by moisture stress.

Measles first develops as pimples on the bark of two year old shoots. These enlarge and erupt producing sunken spots surrounded by callus. As these affected areas merge, the bark becomes rough. When the surface bark is scraped away, dark brown spots are seen in the green part of the bark. Die-back often develops in the two year old wood and growth is poor.

Iron deficiency

This causes yellowing of all the leaf tissue between the veins of the youngest leaves-only the main veins remain green. It is not a major problem of the main districts but it can be serious in calcareous high pH soils or soils which have been over-limed.

Using Fertilisers

The key to a successful fertiliser program lies in getting the nutritional balance right. Nodulated legumes in a sod which is well fertilised with superphosphate and other nutrients, such as molybdenum, can make a very useful nitrogen contribution. However, this potential nitrogen supply is reduced by shading from trees, grass and weeds, by mowing and herbicide strips. Because of these factors, supplementation with fertilisers is usually necessary.

The principal inorganic nitrogenous fertilisers are:

- ammonium nitrate (34 per cent N),
- urea (46 per cent N), and
- ammonium sulphate (21 per cent N)

Table 2 gives detailed information of available fertilisers for use in apples and pears. Nitrogen is also supplied in a wide variety of mixed N-P-K fertilisers such as 10-4-6 or 15-6-5.* Generally these mixes can be made to order at the grower's request.

Ammonium nitrate has half of its nitrogen in the nitrate form which can move readily to the roots to give a quick response. This greater mobility brings a greater risk of loss through leaching.

Urea is the most concentrated source of nitrogen but some loss of gaseous ammonia can occur if it is left on the surface. Early incorporation into the soil by shallow cultivation or irrigation will minimise losses.

Ammonium sulphate is a less concentrated and usually more expensive source of nitrogen than either ammonium nitrate or urea and it has a strong soil acidifying effect.

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* The first number indicates the percentage of nitrogen (N) in the fertiliser, the second number is the percentage phosphorus (P) and the last number is the percentage of potassium (K).

Animal and poultry manures can meet the nitrogen needs if used in sufficient quantity and they also contain useful quantities of phosphorus and potassium. Composition is often variable, for example nitrogen levels of poultry manure can range from less than 2 per cent to over 3.5 per cent nitrogen. This makes it difficult to accurately determine how much nitrogen and other nutrients the trees are actually getting. An added bonus of these manures is that they add valuable organic matter to the soil and by increasing organic matter, good soil and plant health generally follow meaning that the plant is more tolerant to potential pest and disease attack.

Remember that even the best poultry manure contains only about one-tenth as much nitrogen as ammonium nitrate. When using animal based manures, ensure that they are well composted. When applying them, ensure low hanging fruit does not come into contact with manures, reducing the risk of microbial contamination.

The most commonly used simple fertiliser source of phosphorus is single superphosphate. For potassium it is potassium chloride-muriate of potash.

Compound or mixed N-P-K fertilisers provide a convenient but expensive means of supplying all three major elements in one application. They are wasteful unless both phosphorus and potassium are needed as well as nitrogen. Comparisons of different fertilisers are given in Table 2.

Table 2 - Fertilisers for apple and pear orchards

Fertiliser	Nutrient content	KG of fertiliser needed to supply 1kg of N, P or K	Advantages	Problems
Urea	46% N	2.17kg Urea	High analysis - low freight, low cost.	Losses if left on surface. Water or cultivate in.
Ammonium nitrate	34% N	2.94kg Ammonium nitrate	Low cost. Quick response Half N as nitrate which moves quickly to the roots.	Nitrate can leach easily.
Ammonium sulphate	21% N	4.76kg Ammonium sulphate	Not recommended for orchards.	Expensive source of nitrogen. Highly acidifying.
Di ammonium phosphate (DAP)	18% N 20% P	5.55kg for N 5.00kg for P	Supplies both N and P.	Strongly acidifying. Concentrated source of N and P but lacks calcium.
Single Superphosphate	8.8% P	11.36kg single super	Supplies phosphorus, calcium and sulphur for both sod and trees.	Relatively low analysis.
Double Superphosphate	17% P	5.88kg double super	Concentrated source of P giving savings in freight and handling.	
Potassium chloride (muriate of potash)	50% K	2.00kg potassium chloride	Cheapest form of K.	Has high chloride content. Do not use where soil salinity is a problem.
Potassium sulphate	41% K	2.44kg potassium sulphate	Free of chloride.	Its higher cost compared to muriate of potash is not usually warranted.
N-P-K mixtures	Various proportions of N, P and K		A convenient way of supplying N, P and K in one application.	More expensive than single element fertilisers. Wasteful unless P and K are needed.

Fertiliser Application

For most efficient uptake fertiliser dressings should be applied to the area of greatest root activity. This will vary with tree spacing, rootstock and irrigation management but as a guide, place it no closer than 20cm from the butt and out to the drip line of the tree. Most orchards use microsprinkler irrigation. A good rule is to place the fertiliser in the wetted zone of these systems. In most cases fertiliser can be applied via the irrigation system (fertigation) which ensures accurate delivery and is very cost effective.

Since phosphorus, and to some extent potassium, can be held in the surface soil, relatively large applications and deep placement are common means of getting these elements down to the root zone. Deep placement is often not favoured because of root damage it can cause in an established orchard.

Time of Application

Timing is critical when applying nitrogen fertilisers. These fertilisers are quite soluble in water and will not remain in the soil for long. This means that delivery of the nutrients through fertigation needs to be precise otherwise the nutritional program will suffer. If the soil is over irrigated, water and fertiliser will be lost past the active rootzone. If the soil is under irrigated, water and nutrition will not reach the active root zone. Growers seeking further information should contact their local NSW Agriculture District Horticulturist or Irrigation Officer.

Efficient uptake with minimum losses is best achieved when applications coincide with periods of high root activity. The timing should also provide adequate nitrogen for the peak seasonal demands of the tree and its crop, that is:

- in early spring for flowering and fruit set, and
- during spring and early summer for leaf growth.

Nitrogen for flowering and fruit set comes mainly from reserves stored in the tree from the previous season, highlighting the need for good nutrition in the previous season.

In some districts post harvest application is used to provide extra nitrogen for the following season. However always wait until the crop has been picked because too high a level of nitrogen in late summer adversely affects fruit quality and storage.

Phosphorus and potassium can be applied at any time. Both are retained and not easily leached from most soils and it takes some time before they are taken up by the tree. When phosphate is being used to stimulate a winter legume ground cover, March-April is the preferred time.

Fertiliser Rates

The quantities of nutrients that need to be applied depend on many factors including the level and consistency of production. The following general suggestions should be modified for individual orchards taking into account leaf analysis, soil analysis, tree growth, fruit yield and quality, the level of irrigation, whether the ground cover is predominantly grass or clover, and whether the fertiliser is banded along the row or broadcast over the whole area or injected into the irrigation system.

Nitrogen-Fully Bearing Trees

The annual application rates listed are suggested as average for mature bearing trees in medium and high density blocks:

Apple 70 kg N/ha

Pear 100 kg N/ha

Nitrogen-Young Trees

For medium and high density plantings:

Apple 30 g N/tree/year for each year of tree age after the year of planting* until the rate (per hectare) for fully bearing tree is reached.

Pear 40 g N/tree/year for each year of tree age after the year of planting[*]* until the mature tree rate is reached

For maximum quality, storage and shelf life in apples, avoid excessive nitrogen applications. Aim to maintain moderate levels of leaf nitrogen-about 2.0-2.3 per cent N. Pears often respond to slightly higher rates of fertiliser nitrogen than red apples but evidence suggests that the pear quality can also be lowered by too much nitrogen which may reduce flavour and soluble solids.

Foliar nitrogen sprays

Urea sprays can be used to supplement soil applications when fruit set is heavier than expected. Sprays provide a small amount of nitrogen rapidly to the leaves and may be conveniently added to many pesticide sprays.

Up to four post-bloom sprays of 500 g urea/l00L with surfactant may be used at 14 day intervals.

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[*] In the year of planting a light dressing of 15-20 g N/tree may be applied during summer.

Such urea sprays should only be regarded as a supplement to normal soil applied fertilisers.

A post-harvest **high concentration** urea spray of 5 kg/100 L in April-May, for scab control, also provides a nutritional benefit in the following season. Always use low (less than 0.4 per cent) biuret urea for foliar application to avoid damage to buds, spurs and bark.

Phosphorus

Mature pome fruit trees rarely respond to phosphorus fertilisers. However, young trees during the first four years may benefit from up to 90 g P-equal to 1 kg super / tree / year. Because surface applications of phosphorus do not usually move far down through the soil a generous rate of single superphosphate-0.5 to 1 tonne per hectare-should be worked into the soil when preparing for a new planting. At planting, 1 kg of superphosphate may be mixed thoroughly with the soil in the planting hole. It is always a good idea to cover the mixed super in the hole with about 5 cm of soil at planting to prevent root burn to the young plant.

Note: Other fertilisers such as ammonium phosphates, mixed fertilisers, other nitrogenous or potassium fertilisers, poultry manure or blood and bone, should never be used in the planting hole because of the risk of root injury.

Legume cover crops or clover-based sod will benefit from an annual application of about 250 kg super per ha in March-April.

Potassium

A survey of the major districts found potassium levels were adequate in most orchards. Too much potassium can be harmful as it can depress calcium and magnesium uptake (nutritional imbalance) and lead to Bitter Pit and other problems. Potassium is not leached from the soil, so continued application of N-P-K mixtures over several years can build up potassium to excessive levels. However with a regular soil and leaf analysis this will not occur as there will be an annual update of potassium levels and over a longer time trends will develop which will become easier to anticipate giving the grower better control of fertilizing practices.

When potassium deficiency does occur, a single heavy dressing of 200-300 kg K/ha applied as muriate of potash once every three to four years is usually more effective and economical than small annual applications or the use of N-P-K mixtures. Timing is not critical for potassium fertiliser application. Surface banding near the drip ring of the trees improves uptake. Alternatively, potassium nitrate injected through the system will address both the potassium and nitrogen issues in the one application. As the elements are in a soluble form their uptake will be much quicker and the results more immediate.

Fertigation

Many modern under-tree irrigation systems lend themselves to fertigation-applying nutrients as well as water to the orchard. This is a simple and efficient way of delivering precise amounts of nutrients at the best times to suit tree and crop needs. Advantages include:

- Fertiliser is applied to the irrigated part of the root zone which usually is the area of greatest root activity. This can lead to a more efficient use of fertiliser.
- Rapid availability of nutrients.
- Savings in labour, time, equipment and fuel costs.
- Less traffic in the orchard and so less soil compaction.
- Greater flexibility with timing of fertiliser applications to suit growth stage and crop demand.
- Easier adjustment of fertiliser application rates to meet the needs of an unexpectedly large or small crop.

Timing: Fertigation, in split applications, should be timed to provide sufficient nitrogen during demand periods of rapid vegetative growth but not too much nitrogen which will create unwanted excessive growth, and limit nitrogen when the fruit is ripening.

Fertigation gives a quicker uptake of nutrients than surface broadcast fertilisers.

Nitrogen applications should start shortly before flowering and be followed by two or more nitrogen fertigations. For example, treatments may occur mid-September and mid-October and mid-November with variations depending on the earliness or lateness of the particular cultivar, district and season.

A review of your nitrogen program should be established where trees are growing vigorously and require lots of pruning. Reducing nitrogen can assist in controlling tree vigour and reducing time spent on annual pruning. There is as much a need to investigate fertiliser under/ over use as there is a need to look into thinning regimes. In the end they will both save money.

Rates: Current evidence on whether fertiliser rates can be significantly reduced when compared to surface applied fertilisers is conflicting. If less than standard fertiliser rates are tried, leaf analysis should be used to ensure that the trees are being adequately fed.

Fertigation procedures: Fertigation is carried out in three stages:

- irrigation to wet the soil,
- fertigation-the injection of nutrients, and
- flushing with water alone.

Fertiliser injection should not begin for at least half an hour after the start of watering and be cut off in sufficient time before the end of the irrigation to allow complete flushing of the lines.

Fertilisers used in fertigation: Materials must dissolve easily, remain stable in the pipes and not react with pipes or drippers or cause blockages. Table 3 lists some of the fertilisers more commonly used for fertigation.

Table 3 - Fertigation-solubility and composition of some fertilisers used in fertigation

Fertiliser	Solubility kg per 1000L*	Nutrient N %	P %	Content K
Urea	840	46	-	
Ammonium Nitrate**	1580	34	-	
Urea-Ammonium nitrate solution (Easy N®)	-	32***	-	
Calcium nitrate	910	15.5	-	-
Potassium nitrate	210	13	-	38
Potassium chloride	310	-	-	50
Mono ammonium phosphate & trace (MAP)****	290	12	26	-

* Values are the maximum quantity which will dissolve at 10°C

** 2004 has seen limited sources of Ammonium Nitrate being available.

*** Sold as liquid-323b W/V, 100 L supplies 42.5 kg N.

**** Applications of phosphorus fertilisers through irrigation systems can cause problems of precipitation in the lines and blocked drippers.

Fertiliser grade MAP contains insoluble residue which can also block drippers.

Nitrogen and potassium are the elements most suited to fertigation. Usually phosphorus application by this method is not recommended because phosphates can react with calcium and magnesium in irrigation waters causing precipitation in the lines or drippers.

Trace elements can also cause clogging problems and some remain localised in the soil preventing effective uptake. Most nitrogen and potassium fertilisers are compatible and can be used together if required. **Calcium and phosphorus fertilisers should never be used together in fertigation systems**. Nitrate has greatest mobility and will move to the edge of the wetted zone. Excess irrigation can therefore result in leaching beyond the roots. The ammonium form of nitrogen is initially held in the soil near the drippers but later, as soil bacteria change it to the mobile nitrate form, it moves outward.

Urea is briefly mobile, moving through the soil until it is changed to the ammonium form which is held in the soil until it also is converted to nitrate. Potassium tends to be held in most soils and does not usually leach under fertigation.

Long term fertigation with ammonium fertilisers or urea can cause localised acidification of soil within the wetted zone. Liming the surface soil is ineffective in correcting the problem, but calcium nitrate, substituted as the source of nitrogen, will help counteract this form of soil acidification.

Correction of other Nutrient Disorders

Many deficiencies are best corrected by sprays which overcome several problems:

- fixation in the soil of some trace elements such as zinc,
- delayed response of magnesium, or
- poor mobility of the element to the fruit-calcium for example.

Deficiencies of boron or magnesium can be corrected either by a soil application or foliar spray. Soil applications are slower to take effect but they give more lasting results.

Calcium

Calcium sprays to the fruit during the growing season are recommended to control Bitter Pit on trees carrying pit-liable fruit. An additional post harvest dip can be given to fruit to be stored. Although lime used to correct soil acidity also adds calcium to the soil, it will not prevent Bitter Pit from developing in the fruit.

Spray: at 500 g/100 L of calcium nitrate with surfactant. Apply three sprays spaced evenly between the end of November and a few weeks before harvest. Extra sprays can be used for highly susceptible fruit such as light crops, heavily pruned trees or in dry seasonal conditions. The sprays can be combined with some pesticide sprays. Over the last 10 years we have seen a number of calcium foliar sprays come onto the market. The realization that calcium is a crucial factor to the development of the fruit has meant that there is a wide range of products for the grower to choose from.

Post-harvest dip: Use 1.5-3 kg/100 L of calcium chloride-the flaked commercial product. There is a slight risk of skin injury, so small trial lots should be treated initially. Use the lower concentration for red fruit varieties and fruit from older or low vigour trees which are more susceptible to lenticel spotting or other slight injury. Drain the fruit thoroughly immediately after dipping and place in cool store without delay.

Magnesium

A foliar spray is the only way to quickly correct an existing deficiency. One spray per season is usually enough unless the problem is severe. A liberal application of dolomite or magnesite to the soil will last for several years but it may take up to four years before the deficiency is controlled.

For an existing block of trees, the best strategy comprises sprays for two to three years until the soil application becomes effective. In preparing any new block where the soil is known to be deficient in magnesium, work dolomite or magnesite deeply into the soil before planting.

Ground application: Good quality Dolomite at 1 to 2 tonne/ha, or Magnesite 500 kg/ha, or Magnesium oxide 250 kg/ha.

Foliar spray: 2 kg/100 L magnesium sulphate (Epsom salts) with surfactant.

Be aware of not only sufficient Magnesium levels in the soil but that there is also a sufficient Calcium Magnesium ratio. Ideally calcium should be 3-4 times the magnesium levels. These factors should be taken into account when planning and reviewing the fertiliser program.

Zinc

Zinc deficiency is usually corrected by applying annual sprays of zinc sulphate heptahydrate to the bark when the trees are dormant. Zinc applied to the soil is usually ineffective for fruit trees because it is not mobile in the soil and does not reach the roots.

Dormant spray: Use 5 kg/100 L zinc sulphate-(22 per cent Zn) heptahydrate. Spray in June or July when trees are fully dormant, preferably before pruning or at least three weeks after pruning. For mild deficiency, the dosage may be halved.

Foliar spray for Non-bearing trees only: 150 g/100 L zinc sulphate with surfactant applied in November.

The dormant spray is the only safe treatment for bearing trees as foliar zinc sprays applied in spring may cause russeting of the fruit. If the deficiency is mild, a zinc-based fungicide used for scab control-zineb, ziram, mancozeb or metiram-and applied up to three times during the growing season, may correct the deficiency.

Boron

Boron deficiency can be corrected by a soil application or a foliar spray. **BUT boron spray treatments should not be used in the same season as a soil application because of the risk of toxicity.**

Ground application: apply 80 g to 300 g borax per tree, depending on tree size, usually in winter or early spring. Halve these rates if using polyborate powder. Carefully break up all borax lumps and spread evenly around whole root area to avoid toxicity. This treatment should last for three to five years, but watch for symptoms to re-appear earlier than this.

Foliar spray: Use 125 g/100 L of Solubor or 250 g/100 L of borax. One spray annually in late November is usually sufficient. Solubor dissolves easily in the tank. Solubor is not compatible with any sulphate fertilisers.

Iron

Fortunately iron deficiency is not a serious problem in the main pome fruit districts. Corrective treatments are either ineffective or too expensive. Avoid over-liming the soil and correct areas of poor drainage.

Manganese

Usually no corrective treatment is necessary. Manganese sulphate 250 g/100 L may be used as a foliar spray. If mancozeb is used for scab control, this may also correct manganese deficiency.

Manganese Toxicity: Measles

Examine soil drainage and correct if necessary. If the soil is very acidic - below pH 5.0, 1:5 Calcium Chloride - apply lime or dolomite.

Liming

Most orchard soils in the main pome fruit districts were acid in their natural state. After several years of orchard cultivation, irrigation and fertiliser use they have become even more acid. Apples and pears prefer a soil which is only slightly acid. That is, where the pH is about 5.5-6.0 (1:5 Ca C12) or 6.0-6.5 if the pH is measured in water.

If the soil becomes more acid than this, plant nutrients such as phosphorus may become less available, calcium and magnesium can be leached out, or harmfully high levels of soluble manganese can develop. The growth of roots and their capacity to absorb nutrients from soil and fertilisers is also reduced in strongly acid soils.

Conversely, as soil pH rises above 6.5, the availability of trace elements boron, zinc, manganese and iron, are reduced and may become deficient.

A regular program of liming is necessary to stop orchard soils from becoming too acid. Agricultural lime-calcium carbonate-is usually the cheapest form of lime for correcting soil acidity. For acid soils low in magnesium as well as calcium, dolomite calcium magnesium carbonate-is preferred.

Movement of lime down through the root zone of an orchard is very slow, particularly in heavier textured soils. Liming programs should therefore aim at preventing serious acidity rather than allowing the problem to develop before liming is commenced.

Pre-plant Liming

The best opportunity to get lime down through the soil profile is to apply it before planting. When land is being prepared for planting, the soil pH should be tested. If it is below 6.0, some lime should be worked in deeply, preferably to a depth of 15-20 cm, and thoroughly mixed with the soil. The quantity will depend on how low the pH is and the texture of the soil. For a very acid loamy soil-pH below 5.0-an application of up to 6 tonnes/hectare may be required, whereas an application of 1-2 tonnes/ha before planting may be all that a sandy soil of pH 5.8 needs.

Consider the following applications:

Low pH, low calcium and low magnesium	Use dolomite
Low pH, low calcium and high magnesium	Use Aglime
Low pH, high calcium and low magnesium	Use Aglime
High or OK pH, low calcium and low magnesium	Use gypsum and magnesium sulphate
High or OK pH, low calcium and high magnesium	Use gypsum
High or OH pH, high calcium and high magnesium	Use acid fertilisers such as superphosphate and ammonium sulphate etc.

Maintenance liming

Nitrogenous fertilisers are essential for continued high production, but most acidify the soil after prolonged use. For every kilogram of nitrogen that has been applied as sulphate of ammonia or diammonium phosphate, about 5kg of lime is required to maintain the soil pH. If urea or ammonium nitrate are used, about 2kg of lime are needed for every kilogram of nitrogen applied to the orchard.

Maintenance liming should be carried out every two to three years, preferably during winter, using enough lime to keep the soil pH at around 5.5 to 6.0. Apply most of the lime along the tree row strip where fertilisers are spread and acidification is greatest.

Restoration Liming

Correcting a severe acidity problem throughout the root zone of an established orchard is difficult. A single large application of lime to an acid orchard soil will not be very effective because the lime cannot be worked down around the feeder roots. Its effect will be restricted to the surface few centimeters while the soil 10-20 cm below, remains acid.

Apply a moderate rate of about 1 tonne/ha annually for several years. If possible, lightly cultivate the lime into the surface soil without causing root injury. Monitor the soil pH over several years, ideally at various depths through the root zone.

Chemical Analysis: fine-tuning the program

Several commercial laboratories provide chemical analyses services. Leaf analysis is the best method of determining the nutrient status of fruit trees.

Soil analysis is useful for measuring soil acidity but soil tests for 'available' nutrients have not been calibrated locally for fruit trees and do not give a reliable guide to what a fruit tree can take up. A soil sample, however, can reveal much about relative levels of Ca, P, K, and Mg in the soil. It can reveal whether liming is justified and depending on the soil pH, also indicate the availability of certain elements. An example may be when soil pH is less than 6, then Mg, P,and K are less available to the plant (locked up in the soil). Soil analysis can also reveal the cation exchange capacity (CEC) which is the availability of the soil to absorb exchangeable cations. Briefly a soil with low CEC will require less fertiliser than a soil with high CEC to get the same nutritional availability.

Soil Analysis

A soil analysis should be planned thoroughly. Before collecting a sample determine whether the soil type is uniform across all blocks. If it is not it may mean several samples will be required to accurately represent the different soil types. Soil samples are particularly useful were problem areas may arise. Sampling from the problem area and the "normal area' may reveal what is causing the problem. Depending on the size of the block a number of sub-samples may be required. These typical samples are then combined and mixed together. From this bulk sample a final sample is extracted and tested. Generally samples should be collected from the top 40 cm around the root zone. Soil samples are extremely useful in conjunction with leaf samples and may indicate reasons elements are not being taken up etc. Soil and leaf analysis are extremely useful as a tool to identify what is happening to the fertiliser being applied. In many cases these simple easy to perform tasks have saved many dollars on fertiliser expenses and improved yields.

Quick sap tests of leaves or other tissues have not been calibrated for fruit trees and do not give a reliable guide to crop nutrient needs.

Fruit analysis is useful for diagnosing calcium and boron deficiencies in pome fruits and also to monitor other nutrients such as nitrogen, phosphorus, potassium and magnesium which influence fruit quality.

Leaf Analysis

Leaf analysis can help diagnose a deficiency symptom or provide a guide in developing a sound fertiliser program. By monitoring the leaf nutrient levels in a representative block over a number of seasons, a grower can build up a useful record for managing the nutrition program.

The analyses for each season should be compared and considered in relation to previous fertiliser applications, fruit yield and quality, as well as general tree health and vigour.

Nutrient levels will vary from season to season depending on crop size, pruning and environmental effects, so the clearest picture will come from examining trends over several seasons.

All of the sampled trees should be of the same age, cultivar, growth characteristics and be growing on the same soil type. Both the leaves and trees should be free of disease and insect or mechanical damage.

Leaf Sampling

The concentration of nutrients in leaves changes during the season and will vary with the position on the shoot and with the type of shoot on which it is growing. Therefore careful sampling, taking the correct type of leaf at the right time of year, is essential.

Leaves should be taken between late January and mid-February. Collect a total of 100 leaves - including leaf stalk - at about shoulder height from a mid-shoot position on medium vigour current season extension growth from 20 randomly chosen trees throughout one block in the orchard ie 5 leaves per tree. Avoid collecting leaves that are not whole or that have been damaged in some way. Aim to keep separate different varieties and blocks so that they represent each rather than mixing the lot. This will give a better understanding of the different needs of each sample. Information on preparation of the sample for analysis to avoid accidental contamination is available from analytical laboratories or District Horticulturist.

Interpretation of leaf analysis results

Standards for apples and pears are shown in Table 4. The standard ranges are defined as follows:

Deficient:	symptoms present-too low for optimum performance.
Low:	no symptoms but nutrient may be too low for optimum crop performance.
Normal:	no symptoms-level is adequate.
High:	no symptoms-level higher than necessary and may cause imbalance or loss of quality.
Excess:	level too high for optimum performance-toxicity symptoms may be present.

Adjusting the Fertiliser Program

Any adjustment to the fertiliser program following a leaf analysis report should be cautious, well-considered and wherever possible, undertaken in association with sound impartial advice.

Do not make drastic changes to a program on the basis of just one year's analysis.

A single low or high value, unless supported by symptoms or other information, could be an aberration caused by unusual seasonal conditions such as drought, by heavy pruning or the crop load.

Fluctuations in nitrogen, potassium, calcium and some other elements are often observed in orchards subject to alternate bearing. Be cautious in reacting to a high trace element levels. They may be due to spray contamination of the leaves.

However, where the leaf analyses, monitored over a few seasons, indicate consistent low values for a particular nutrient or a steady decline towards deficiency, seek the advice of your District Horticulturist before modifying your program.

Develop a consistent program, not one that is changed drastically each year with each season's leaf analysis-otherwise monitoring becomes impossible.

Above all, recognise that chemical analysis is only a tool. Don't let any analysis of leaf, soil or fruit, override common sense and your knowledge of other factors based on sound experience.

Acknowledgements

This Primenote replaces Agfact H4.AC.3.

ISSN 1832-6668

JOB NUMBER 5144

Updates of this Primefact are available at **www.dpi.nsw.gov.au/primefacts**

Table 4 - Leaf nutrient standards for apples and pears

Crop	Nutrient % or parts per million	Deficient less than	Low range	Normal range	High range	Excess more than
Apple	Nitrogen %	<1.6	1.6 - 1.9	2.0 - 2.4	2.5 - 3.0	>3.0
Pear	Nitrogen %	<1.8	1.8 - 2.2	2.3 - 2.7	2.8 - 3.5	>3.5
Apple and pear	Phosphorus %	<0.10	0.10 - 0.14	0.15 - 0.20	0.21 - 0.30	>0.30
	Potassium %	<0.8	0.8 - 1.0	1.1 - 1.5	1.6 - 2.0	>2.0
	Calcium %	<0.7	0.7 - 1.0	1.1 - 2.0	2.1 - 2.5	>2.5
	Magnesium %	<0.18	0.18 - 0.24	0.25 - 0.35	0.36 - 0.50	>0.50
	Sodium %	-	-	<0.02	0.02 - 0.50	>0.50
	Chloride %	-	-	<0.4	0.4 - 1.0	>1.0
	Zinc ppm	<10	10 - 15	16 - 50	>50*	
	Manganese ppm	<20	20 - 24	25 - 100	101 - 200*	>200*
	Copper ppm	<4	4 - 5	6 - 20	21 - 100*	
	Boron ppm	<15	15 - 19	20 - 60	61 - 200	>200

*** High values containing a trace element should be disregarded if leaves have been sprayed with a nutritional spray or fungicide-such as ziram or mancozeb.**