GrowPlus

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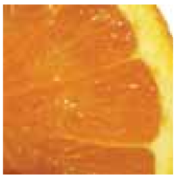

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A HORTICULTURAL NEWSLETTER FROM BALLANCE AGRI-NUTRIENTS LIMITED ISSUE 3

Nitrogen for apples - foliar, soil, or both?

Recent developments in the international apple market have seen some New Zealand apple growers choose to exit the industry lately. For those who have decided to persevere, the challenge remains the production of high-quality fruit at lowest feasible cost.

Many factors impact on the yield of an apple crop and the costs associated with growing it. Some, such as the weather, are impossible to control. Others, such as cultivar choice, nutrition, spraying and irrigation programmes, are more easily influenced by the grower.

Although all plant nutrients have a specific part to play in the healthy development of horticultural crops, nitrogen is the element most closely associated with crop yield. This relationship has, in some instances, led to the use of nitrogen in large quantities, almost as an insurance policy against reduced productivity.

However, there are two negative side effects with this approach. The first is economic: although much cheaper than some other nutrients, nitrogen still costs $464 per tonne (Ballance bulk urea price on 11 October 2005). On top of this must be added the costs of transport and application. As markets tighten, growers will be looking to save money wherever possible, and excess nitrogen applications might be one area to investigate.

The second side effect is environmental: across New Zealand, there is increased attention on the deleterious effects of nitrogen entering waterways and contributing to aquatic pollution (see panel). Much of this nitrogen comes from pastoral farming systems, but the horticultural industry must also look to its practices with a view to improving them if needed.

Soil-applied nitrogen

Before making any changes to nutrient application techniques, it's vital to have an understanding of the potential impact this might have on production. It is also important to know the extent of any nitrogen loss to the environment from soil-applied fertiliser.

In the USA, Shufu Dong and colleagues investigated the fate of ammonium nitrate applied to the soil as fertiliser for bench-grafted Fuji/M.26 apple trees.[1] In order to assess how much nitrogen was taken up by plants, how much remained in the soil and how much was lost to the environment, the researchers grew the apple trees in pots. Trees were grown for one season with one of three different levels of nitrogen applied during the summer months of June to August. This gave them trees with low, medium or high nitrogen status. When they evaluated the trees, they found that those that had received the highest level of nitrogen had the greatest fresh weight of roots and stem; trees that had got the least nitrogen had the lowest weight of roots and stem. In addition, the actual amount of nitrogen in plant tissues increased in line with the amount of nitrogen that had been supplied to the plant as dry fertiliser. This was particularly true for the root tissues.

At the end of the first part of the experiment trees were left to defoliate naturally, then stored in a simulated winter environment before being planted in a nitrogen-free medium in early spring.

Seventy-three days after transplanting the trees, nitrogen (ammonium nitrate) was applied by fertigation. So that they could measure the fate of the nitrogen that was applied (as opposed to the nitrogen that was already present in the plants or soil), the researchers used radioactively labelled nitrogen (^{15}N). When they examined the growth of the trees through this second season, they found that the amount of new growth was dependent upon the nitrogen status of the tree in the previous season. So, trees that had received low levels of nitrogen in the first season had the least growth in the second season; trees that had received higher levels of nitrogen in the first season showed the best growth the following season. This did not alter when additional nitrogen was supplied in the second season - all trees grew more, but the relative amounts

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of growth were still determined by the nitrogen status of the tree at the end of the first season.

When tracking the ^{15}N applied to the soil in the second season, the researchers found that after four weeks, 62-69% of this had been taken up by the trees. Of the remainder, half could still be found in the soil, but half was unaccounted for, possibly lost through volatilisation or denitrification. Compared to other experimental systems, this represents quite a high recovery of applied nitrogen, because none was lost through leaching. This work shows that the use of fertiliser nitrogen on commercially grown trees is important, because it helps determine their growth potential, and that this effect is not limited just to one season. It also shows that not all soil-applied nitrogen is taken up by the plant.

Foliar applications

Orchardists also use foliar applications of urea to promote plant growth - and sometimes to control plant diseases. The question is whether foliar-applied nitrogenous fertilisers are more effective than the dry-applied equivalent. To investigate this, Dong and colleagues conducted another experiment, this time with Fuji/M.9 trees.[2] Again using ^{15}N, they applied urea three times over the growing season, either as a foliar spray or as a soil application and tracked it to see where in the plant it went.

The results were revealing and are shown in Figure 1. Early in the season, the majority of the foliar-applied ^{15}N went into new shoots, with little going into the roots and about 20% going into the previous-year stem wood. The pattern in the summer application was similar, though around 10% of the nitrogen went into the roots, more than double in the earlier application. In the early autumn application, even more of the foliar-applied ^{15}N went into the roots, but even so this still only amounted to 20% of the ^{15}N absorbed by the tree.

In contrast, the soil-applied nitrogen was more evenly distributed around the plant in the spring application, with approximately half going into the new shoots and about 13% entering the root system. For the summer and autumn applications, though, the amount of soil-applied nitrogen used in the root system increased significantly, to more than 30% (summer) and around 60% (autumn application). Little of the autumn-applied dry nitrogen fertiliser reached new shoots.

This is a useful study, because it shows the way different sources of nitrogen are spread through Fuji apple trees during a typical growing season and indicates that a combination of dry-applied and foliar sprays of nitrogen may best serve the tree during this time.

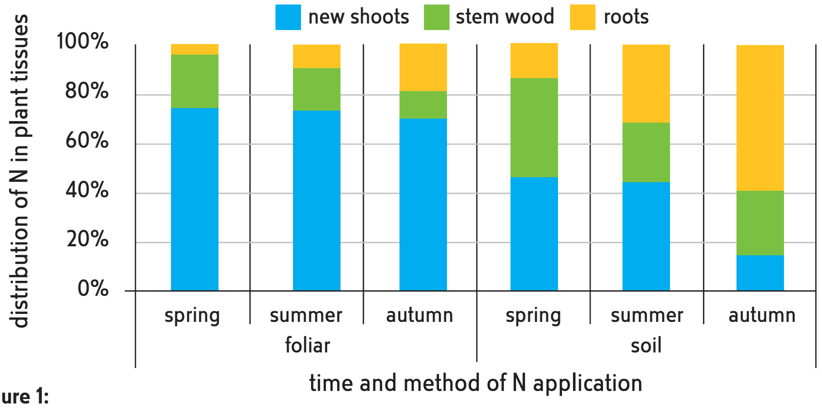


Figure 1:
The fate of soil- and foliar-applied nitrogen in Fuji/M.9 apple trees grown under controlled conditions

Supplying sufficent nitrogen

Nitrogen is needed by all parts of the plant - the rapid and healthy development of leaves in spring is essential for growth as this helps determine the rate of photosynthesis, which in turn governs the accumulation of sugars in the plant. Indeed, two other researchers in America, Li-Song Chen and Lailiang Cheng, have looked at what happens when you limit the nitrogen supply to Gala apple trees, studying in particular the levels of the plant cell enzymes that are involved in the formation of sugars and starches.[3] They found that the nitrogen content of leaves influenced the activity of many of these enzymes, with the result that leaves with low nitrogen tended to have lower levels of soluble sugars and higher levels of starch. Sugars such as sorbitol, glucose, fructose and sucrose are mobile and translocated through the plant to so-called 'sink' regions, such as roots and fruit. Starch is not mobile, although it can be degraded into sugars during the night and then moved around the plant. With low levels of nitrogen, then, plants are not likely to get maximum benefit from photosynthesis, so growth is further constrained.

Clearly, having sufficient nitrogen in the leaves is important, and research has shown that this may be best achieved by using foliar applications of urea. However, it is also vital that the roots are not denied. Roots support the above ground portion of the tree, take up water and nutrients, and are the place where some plant growth hormones are synthesised. Supplying the root system with adequate and available nitrogen leads to healthy growth and increased biomass, with the growth occurring particularly between spring and summer. In spring, little foliar-applied urea reaches the root system, so dual applications of foliar and soil-applied nitrogen may be advisable. Taking this approach may permit lower amounts of soil-applied urea to be used, and thus reduce the risk of losses through nitrate leaching (particularly in early spring) and volatilisation (particularly in summer).

Nitrate leaching

How does nitrogen applied to the land end up entering waterways and causing damage? Fertiliser nitrogen may be applied in one of three forms - urea, ammonium or nitrate. Regardless of the starting point, once in soil it is all fairly quickly converted to nitrate. Biochemical reactions change urea to ammonium, a positively charged ion that can bind to soil particles (like a magnet to a fridge) or be taken up by plants.

Specific bacteria in soil then convert ammonium to nitrate, a negatively charged ion that can also be taken up by plants. However, the surfaces of soil particles are also negatively charged, so the nitrate is repelled - it's just like trying to push together the negative poles of two magnets; they won't stick.

As a result, the nitrate stays in soil solution, the water that surrounds soil particles. When it rains, this soil solution gets flushed further down the soil profile, taking the nitrate with it. If the rain is heavy enough, the nitrate gets into the groundwater and from there enters streams, rivers and lakes, where it is used as a nutrient source by algae and weeds. The growth of these plant forms gradually 'chokes' the life out of the water body by depleting it of oxygen.

[1] Dong, S., Cheng, L, Scagel, C. and Fuchigami, L.H. (2004) N uptake, soil retention and loss of soil-applied $^{15}NH_4{}^{15}NO_3$ in young Fuji/M.26 apple trees with different N status, *Journal of Horticultural Science & Biotechnology*, 79 (3): 395-399.

[2] Dong, S., Cheng, L., Scagel, C. and Fuchigami, L.H. (2005) Timing of urea application affects leaf and root N uptake in young Fuji/M.9 apple trees, *Journal of Horticultural Science & Biotechnology*, 80 (1): 116-120.

[3] Chen, L-S. and Cheng, L. (2004) Photosynthetic enzymes and carbohydrate metabolism of apple leaves in response to nitrogen limitation, *Journal of Horticultural Science & Biotechnology*, 79 (6): 923-929.

Potassium and potatoes

The New Zealand potato market has undergone some subtle changes over the past decade or so. Deregulation has given growers more mastery over their own destiny, with all the benefits and challenges that presents. The export market has slowly grown, from 30,632 tonnes in 1994 to some 91,774 tonnes in 2004. At the same time, the process market has diversified, with greater variety in the snack food industry increasing demand for potatoes with defined characteristics. The fresh market, too, is evolving, as customers seek specific varieties of potato that offer the taste and colour they desire, along with enhanced cooking and storage characteristics.

All of these factors combine to put yet more importance on the need to produce a crop that meets the criteria of the purchaser. Cultivar selection, site selection, soil preparation, planting time, irrigation strategy, pest and weed control and fertiliser use all play a part in determining a successful high-yielding, high-quality crop.

The role of potassium

Of all the plant nutrients, potassium is the one that is removed in greatest quantities in a potato crop. Research in Holland showed that over 6 kg of potassium can be removed per tonne of potato tubers harvested.

Potassium has many roles in plants - it is needed for the correct functioning of many enzymes in the plant, it is involved in the transport of sugars around the plant, and it helps control the water status of plant tissues.

Potassium is a highly mobile nutrient within the plant, moving through the phloem and xylem. Plants can take up more potassium than they actually need to function; this phenomenon is called luxury consumption and can occur when available soil potassium is in excess. Excess potassium can sometimes be taken up to maintain electrical neutrality in the plant. For instance, if nitrogen is taken up as nitrate (which carries one negative charge), the plant may take up potassium (which carries one positive charge) to ensure the internal electrical status remains neutral.

Potassium and tuber yield

Potassium is generally thought to be critical to achieving high yields of potatoes. In part, this may be due to the direct effects of potassium on plant health, and in part due to indirect impacts. These indirect effects include the relationship between potassium uptake and nitrate-nitrogen uptake. If potassium is deficient, and the main source of nitrogen is nitrate, plants may not take up enough nitrogen to support maximum growth. If potassium is in excess, then this risk is obviated.

However, one of the key criteria in the commercial production of potatoes is the dry matter content of the tubers. The target dry matter content varies with use: for instance, a high dry matter in fresh potatoes is associated with an increased risk of tuber disintegration during cooking. If potatoes are to be turned into crisps (chips), a high dry matter content is desirable, since it reduces the amount of oil absorbed during processing, so minimising costs.

If a potato plant takes up excess potassium, one outcome is a lower dry matter content in the tubers. This is because the extra potassium is translocated to the tuber, where it causes the water content to be raised. For fresh potatoes this might not be a problem, but for some processing markets it may be an issue. On the other hand, high applications of potassium fertiliser are also thought to reduce tuber bruising and to improve the colour of the final fried product.

In an extensive experiment in the UK, researchers examined the effect of potassium fertiliser on potato yield and quality over a 10-year period.[1] Crops were grown in a range of soil types, including sandy loams, clay loams and silty clay loams. Potato varieties tested included Estima, Russet Burbank, Maris Piper, Nadine and Pentland Dell. More than half of the sites tested had low exchangeable K levels and would have been expected to show a response to fertiliser potassium. The average fresh weight tuber yield was 48 tonnes/ha, with a low of 22 tonnes/ha and a high of 79 tonnes/ha. Experimental results showed that the optimum rate of potassium fertiliser to achieve a significant yield response varied between 105 kg K/ha and 250 kg K/ha, with the largest increase in yield being 3.7 tonnes dry matter/ha.

In ten of the experiments the researchers found that potassium had an effect on tuber dry matter content. In two cases (Nadine, clay loam, K responsive soil, and Russet Burbank, silty clay loam, soil with high potassium reserves), the tuber dry matter increased by an average of 0.9 g DM/100 g fresh weight. In the other eight experiments the tuber dry matter decreased by 0.7-1.4 g DM/100 g fresh weight, but only when 170 kg K/ha or greater was applied. Tuber dry matter content was not altered when the optimal rate of potassium for plant growth was used. In some experiments different forms of potassium were evaluated: when potassium applications were made at the optimal rate, the form of potassium did not affect dry matter content of the tubers. Where excess potassium was applied, potassium chloride resulted in lower dry matter content than potassium sulphate or potassium nitrate.

The authors concluded that the soil potassium status was not the key factor determining yield responses to potassium. Other management practices, such as irrigation and varietal choice appear to play a more important role in determining whether or not a potato crop will show a significant dry matter yield response to potassium fertiliser.

[1] Alllison, M.F., Fowler, J.H. and Allen, E.J. (2001) Responses of potato *(Solanum tubersum)* to potassium fertilizers, *Journal of Agricultural Science*, Cambridge, 136: 407-426.

Calcium and citrus quality

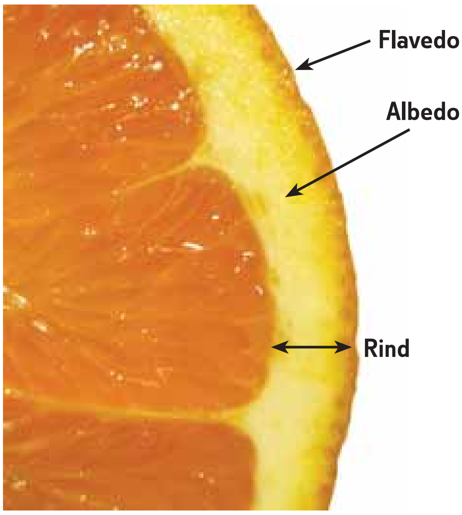
With an average of 21,000 tonnes of fruit grown in New Zealand annually, the citrus sector occupies a significant niche in this country's horticultural market. For fruit destined for the fresh market, appearance and flavour are paramount. The taste and flavour of fresh citrus is largely determined by the ratio of total soluble sugars to acids, a high ratio and a high Brix reading delivering the sweetest taste. The ideal appearance of fruit depends on the variety involved, but good colour and blemish-free skin is the ideal.

One nutrient that plays an important role in the healthy development of citrus fruit is calcium. Plants with an adequate supply of calcium benefit in many ways: fruit set is better, disease resistance is higher, root mass is greater. One of the reasons for such a widespread effect is the key role that calcium plays in the cell walls of plants.

Plant cell walls

The walls of any plant cell are quite complex, made up of celluloses, cross-linking glycans, pectic polysaccharides, protein, lignin, waxes and water. The way that each of these compounds is bound to others contributes to the strength of the cell. For instance, celluloses bind to each other through relatively weak hydrogen bonds. However, there are so many of these bonds, that together they create a very strong structure - it's a bit like combining strands of twine to make rope. In contrast the cross-linking glycans don't join on to each other, but they do bind on to celluloses, essentially 'sewing' a net together.

The pectic polysaccharides are different again, and these are joined together by calcium. The two positive charges on calcium mean it can bind to two negatively charged sites, and it finds these on the chains of pectic polysaccharides. It's a bit like a toddler walking between two adults, holding tightly on to one hand of each. When enough of the polysaccharides are joined together, they form a gel. The correct binding of pectic polysaccharides by calcium is essential, because this component of the cell wall determines how porous the cell is and helps other fractions of the cell wall adhere together. The sugars in the pectic polysaccharides also play a role in helping cells recognise other cells (which is an important function in controlling growth) and they also help the plant recognise when a pathogen is present (pathogens typically invade cells by binding first onto sugars on the cell wall).



Calcium deficiencies can result in breaks developing in the albedo. As the fruit expands, these defects appear as crease marks on the fruit surface

Calcium and crease

Plants that have sufficient calcium have strong cell walls and thus tend to resist the diseases and quality problems that can affect the market value of crops. In citrus crops, this includes crease, a defect that impacts primarily on the visual appeal of the fruit. Crease, also known as albedo breakdown, occurs during the expansion phase of the fruit, when small breaks develop in the albedo. As the fruit continues to grow, the albedo separates further and the outer skin develops undulations where it 'falls' into the crevice created by the faulty albedo. It has been suggested that the reason for the fractures occurring is a breakdown in cell to cell adhesion, a function that is mediated by calcium.

However, many factors are thought to be associated with crease, including rootstock, nutrition, irrigation practices, climate and crop size. In terms of plant nutrition, effects have been noted for nitrogen, phosphorus, potassium and calcium.

With so many variables associated with the onset of crease, a systematic analysis of the situation was needed to tease out valid relationships between cause and effect. CSIRO scientist Richard Storey and his team have conducted experiments on the incidence of crease in oranges for many years now, and recently published a summary of their findings.[1]

To determine if there was a relationship between calcium concentration and incidence of crease, Storey analysed the albedo, flavedo and rind portions of navel oranges with and without crease. Without exception, calcium concentrations were significantly higher in tissue from fruit without crease. Regardless of whether or not fruit showed symptoms of crease, the concentration of calcium was significantly higher in the flavedo than in the albedo or rind. The levels of calcium in rind and albedo were similar, and as it is easier to remove the rind than to isolate the albedo, Storey suggested that this fruit section would be best for routine analysis.

Uptake of calcium from soil is affected by the presence of other cations, such as potassium and magnesium. To investigate these effects, Storey supplied 'Leng' navel trees with varying levels of these nutrients by fertigation. Raising the amount of potassium supplied decreased the amount of calcium in the leaves and fruit tissues by 50 percent, compared to control plants. Lowering the amount of potassium supplied increased the amount of calcium in the leaves and albedo by 1.3 times that of the control.

Raising the potassium and decreasing the calcium levels both caused the plant K:Ca ratios to increase. In previous work, Storey had shown that this ratio was an even better predictor of crease than the absolute amount of calcium in the albedo, flavedo or rind; the higher the ratio, the more likely the development of crease. The K:Ca ratio at the beginning of the season was a good indicator of the ratio at the end of the season. Early assessment of the ratio could allow for remedial action to be taken, such as using calcium sprays on fruit. Sprays of calcium chloride or calcium nitrate can increase the population of unaffected fruit from 11 percent (in the untreated sample) to 65-85 percent (in the treated samples), and at the same time reduce the severity of creasing in affected fruit.

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[1] Storey, R., Treeby, M.T. & Milne, D.J. (2005) Crease: another Ca deficiency-related fruit disorder?, *Journal of Horticultural Science & Biotechnology*, 77: 565-571.

Tomato crop quality and the calcium effect

Tomatoes - whether greenhouse or field-grown - are a significant horticultural crop in New Zealand. Statistics New Zealand report that in 2004, some 85,000 tonnes of tomatoes were grown in this country. Tomatoes may be grown for the fresh market, either as individual fruit or as the increasingly popular truss tomatoes, or they may be produced specifically for processing, destined for canning, pureeing, juicing or other products, such as soup.

The end use of the tomato in part determines the qualities most desired by growers - fresh tomatoes, for instance, must have good colour, form and flavour; tomatoes for canning require a thick, firm wall so they retain their shape when cooked.

Regardless of the growing medium or the end use of the fruit, a well-designed nutrition programme is essential for maximising quality and quantity of commercially grown tomatoes. In addition, tomatoes require a constant supply of water during their growing season, so the irrigation programme is also important.

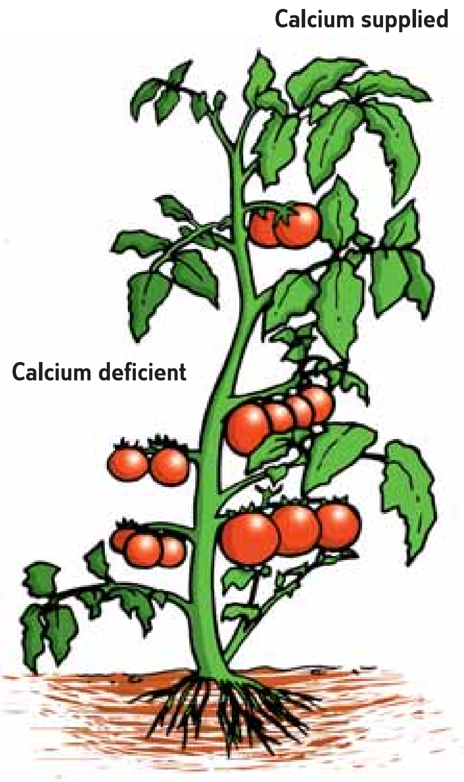
The role of calcium

Calcium is an integral element in plant health - in tomatoes it plays a key role in the structure of cell walls and cell membranes, and so helps the fruit retain firmness as it develops. It also enhances pollen germination, regulates some intracellular enzyme systems and has a specific influence on the development of blossom end rot. A constant supply of calcium is needed through the plant's life in order to ensure vigorous leaf and root development, and canopy growth.

What happens without calcium?

The impact of nutrient deficiencies is best illustrated in an experimental setting, where all other factors - such as levels of other nutrients, water availability, temperature, hours of sunlight, humidity - can be controlled. Using such a setting, two Dutch scientists revealed the dramatic effects of denying tomato plants calcium, even for a relatively short time.[1] Using the 'Capita' variety of tomato, they germinated seeds in a controlled environment and cultivated them for 28 days, by which stage the plants were growing in 12-litre containers. At this point they changed the nutrient supply so that plants received no calcium for either 0 (the control), 1, 3 or 7 days. After the appropriate amount of time without calcium had passed, some plants in each group were harvested and the rest were resupplied with calcium for a further 7 days, before they, too, were harvested.

After just one day without calcium, the level of photosynthesis in the plant decreased (as measured by the assimilation of carbon dioxide). The longer the plants were in calcium-free nutrient solution, the greater the reduction in photosynthesis. When plants were resupplied with calcium for 7 days, those that had only been without calcium for one day returned to their pre-treatment levels of photosynthesis. However, plants deprived of calcium for 3 or 7 days did not recover to the same extent.



Less than adequate calcium supplies can have multiple effects on tomato plants, from reduced root mass, to fewer and smaller leaves with raised dry matter levels

This reduced rate of photosynthesis would no doubt have an effect on plant growth, and this is exactly what the study revealed. Plants that had been calcium-deprived for 7 days accumulated less dry matter over that time than did the controls. More disturbingly, even after the 7-day recovery period with calcium, these plants failed to accumulate dry matter at the same rate as the controls.

The effects of removing calcium from the nutrient supply were seen across the plant - after 7 days without calcium total leaf area was reduced, leaf numbers were lower and the percentage of dry matter in leaves increased. Some of these factors were overcome after supplying the plant with calcium again, but total leaf number and total leaf area never recovered when the nutrient deficiency had lasted 7 days.

The effect of withdrawing calcium was not only seen above ground, though. With just one day of calcium-free nutrition, the amount of dry matter partitioned into the roots decreased dramatically - root growth almost completely stopped when calcium was withheld. This situation was reversed once the plants were given access to calcium again.

Out of the laboratory

In real-life situations, of course, it is unlikely that plants would suffer from a complete lack of calcium. However, transient shortages of calcium may very well occur, and these could have a detrimental effect on plant growth and fruit yield. Tomatoes require large quantities of calcium - around 1.7 kg of calcium is removed per tonne of crop produced. How much is taken up by the plant depends on three factors - how

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Nitrogen and calcium uptake

One factor that affects calcium uptake is the concentration of other cations (positively charged ions) in the soil solution. If there are a lot of cations in solution they compete for uptake by the plant. Nitrogen can be taken up by the plant as either ammonium (a cation) or nitrate (an anion - a negatively charged ion). If nitrogen is supplied as ammonium, then it competes with calcium for uptake by the plant, so calcium uptakes decreases. Supplying nitrogen in the nitrate form prevents this happening, and helps maximise calcium uptake.

much available calcium is present in the soil; the rate of water movement into the plant; and soil acidity (which partly influences the availability of calcium).

Field-grown tomatoes are usually planted into soil with a pH of between 6 and 6.5, but it is possible to grow them in more acidic conditions. However, as soil pH declines, the availability of calcium drops off, especially below pH 5.5. In this situation, plants have smaller soil reserves of calcium to draw on, so uptake can be restricted.

Much of the calcium that is taken up by plants enters as part of mass flow, along with the water that is used in transpiration. If soil water levels are low, less enters the plant, and so less calcium is taken up. A well-designed irrigation strategy helps minimise this. For field-grown tomatoes, mulching helps prevent water loss, while in greenhouses, humidity control serves the same purpose.

Calcium can be supplied in fertiliser in several ways. Dry-applied fertiliser worked in before planting provides a reserve of calcium and other nutrients, and this can be supplemented by fertigation throughout the growing season. If specific nutrient deficiencies become apparent as the plant matures, foliar applications may be appropriate. Fruit sprays to maximise fruit quality can also be used; in particular, spraying fruit with calcium helps minimise blossom end rot. Given the high demand for calcium and the need for it throughout the entire growing season, a multi-faceted approach such as this is undoubtedly best for optimising crop quality and yield.

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[1] Del Amor, F.K. and Marcelis, L.F.M. (2003) Regulation of nutrient uptake, water uptake and growth under calcium starvation and recovery, *Journal of Horticultural Science &*

Asparagus, acidity and nitrate leaching

At a production mass of 6000 tonnes for 2004, asparagus rates as a relatively low-volume crop in New Zealand, especially when compared to the likes of potatoes and onions. However, for many consumers, asparagus is an extremely important crop, marking the arrival of spring, better weather and a greater diversity of horticultural produce.

Asparagus growers face a number of challenges, not least of which is the time delay between planting and generating a return on investment. Once established, however, asparagus plants remain productive for up to 15 years, so effort extended in the early days can be well rewarded.

Asparagus is generally regarded as a crop that requires a relatively high pH soil to thrive, with a pH above 5.8 recommended. For some New Zealand soils, this means applying large quantities of lime to overcome soil acidity. As asparagus roots are mainly 15 to 30 cm below the soil surface, it's this soil section that needs to be at the desired pH. Planting asparagus at optimum pH is said to result in better crop development, a lower risk of fusarium infection and improved spear quality. In addition, there are two nutrient-related benefits of increasing soil pH: the first is increased availability of magnesium and the second is less availability of aluminium.

Magnesium is a key constituent of the chlorophyll molecule and is also involved in a number of other cellular processes. In acidic soils, magnesium ions detach from the cation exchange sites on soil matter and enter the soil solution. Once here, they are vulnerable to leaching, so an acidic soil that has experienced a significant rainfall event will have lowered levels of magnesium. In a neutral to alkaline soil, magnesium ions only detach from the cation exchange sites to replace soil solution magnesium that is taken up by plants.

Aluminium is also released into soil solution in acid soils; if aluminium concentrations are high, it can become toxic to plant growth. As the pH rises, aluminium forms complexes on the surface of clay particles and cannot be taken up by plants.

Managing nitrogen

The two nutrients most closely associated with yield of asparagus are nitrogen and potassium. Of these, nitrogen is the one that comes under most scrutiny, because of the potential for environmental damage from excessive or inappropriate use.

How much nitrogenous fertiliser is required by a crop depends on the plant density and growth rate, the amount of available nitrogen already in the soil, and the amount of nitrogen that is removed in crop harvest.

If asparagus is planted into cultivated ground previously in high-producing pasture, levels of available nitrogen are likely to be high, and little fertiliser nitrogen will be required. On the other hand, if the land has been used to grow crops such as maize or cereals, some of the available nitrogen will have been exhausted and more fertiliser nitrogen will be required to establish the plants.

As asparagus plants become older, the amount of available nitrogen in the soil decreases and fertiliser nitrogen takes on greater importance. The actual amount that needs to be added will depend on the crop's needs - international fertiliser specialists Yara recommend the following:

- 70 kg N/ha in the first year
- 180 kg N/ha in the second year
- 100 kg N/h in year three
- 120 kg N/ha thereafter.

Using large quantities of nitrogen fertiliser greatly increases the risk of nitrogen loss by nitrate leaching and may also not be the best economic practice. Timing of fertiliser applications is important - nitrogen uptake is at its greatest during fern growth, so this is the ideal time to apply nitrogenous fertilisers. Split applications of nitrogen mean that plants are more likely to take up a greater proportion of the nitrogen applied. By matching supply to demand, less fertiliser may be required, and less will certainly be lost to the environment. However, split applications may not be practical, in which case applying fertiliser at close-up is the best option.

Magnesium - getting to the heart of the matter

Magnesium is the eighth most abundant element in the earth's crust. Its strength and lightness - it has two-thirds of the density of aluminium - make it a useful alloy in the construction of missiles and airplanes. Finely divided, it burns with a ferocious white light, making it a top choice for pyrotechnics. Yet in other forms it has medical uses, for instance in the indigestion remedy, milk of magnesia. And it also plays a crucial role in horticulture.

At the heart of every chlorophyll molecule is a single atom of magnesium, held firmly in place by four atoms of nitrogen and encircled by what is known as a porphyrin ring. The entire structure is very similar to haemoglobin, the oxygen-carrying compound in blood, although this has an iron atom at its centre. The chlorophyll molecule performs a similarly vital role in plants, capturing the energy of the sun and converting it into a form that can be used for growth.

As well as this role in photosynthesis, magnesium activates certain plant enzymes, is involved in the production of nucleic acids and plays a role in the metabolism of carbohydrates and their movement from the leaves where they are produced to other parts of the plant where they may be stored or utilised. 'Normal' concentrations in plants vary with species and growth stage; for example, for an asparagus fern the range is 0.15-0.2%, but for a courgette leaf it is 0.3-1.5%.

Deficiency symptoms show up first on the older leaves, as magnesium may be mobilised and transported from these to younger, growing parts of the plant. Leaves first start to lose their healthy green colour; as the deficiency increases, leaves turn yellowish, although the veins remain green. Grapes, however, develop purple coloured leaves as a result of magnesium deficiency, while potato leaves develop small, brown, dead spots between the veins. Other symptoms include mottling, curling or scorching of leaves, and poor fruit development.

Correcting magnesium deficiency

Magnesium in soil is largely derived from the minerals that are present in the parent rock. This magnesium is only slowly released through the weathering process. Of more immediate relevance to plant nutrition, though, are exchangeable and soil solution magnesium. Exchangeable magnesium is that held on the surface of soil and organic matter particles. Though it is bound on, it can be released into soil solution, where it is available for uptake by plants. This readiness to detach from soil particles is a double-edged sword - it means that, in the absence of a deficiency, there's an easily accessible supply of magnesium in the soil, but it also makes that magnesium vulnerable to loss by leaching.

Magnesium fertilisers come in two forms - rapidly dissolving sulphates and slow-release substances such as dolomite lime, serpentine super and calcined magnesite (Calmag). In the horticultural industry, both forms of magnesium serve a purpose.

In the case of acute magnesium deficiency, foliar sprays of magnesium may be recommended. This allows rapid uptake over the entire plant and avoids the need for an already stressed plant to transport magnesium to deficient zones. In these situations it's helpful to have a highly soluble form of magnesium, and Epsom salts may be used. Its highly hydrated state means that it dissolves quickly and completely.

However, where remediation of soil magnesium levels is required, something less soluble is preferred. One choice is to use magnesium sulphate, also known as kieserite. This can be either mined or synthesised (see panel on page 8).

Recent public discussion has focused on the relative merits of these two forms of magnesium sulphate, specifically the solubility of each and the benefits this offers. Research funded by the German company that mines kieserite is frequently cited to support pro-'natural' kieserite claims.

Standard hot water analysis of Ballance's manufactured kieserite revealed that it contains 12.1% water-soluble magnesium. This is 75% of the total amount of magnesium in the product. The remaining magnesium was in the form of magnesium oxide and magnesium carbonate.

While some claim that magnesium oxide is 'near-insoluble', the truth is that it is soluble in the soil environment, where the acidic conditions make it available to plants. Indeed, the use of Calmag (magnesium oxide) in both pastoral and field crop situations is widespread.

As a result, the mixed magnesium forms in Ballance kieserite can be to the benefit of the horticulturalist, since the water-soluble portion is available for rapid plant uptake and the acid-soluble portion (the magnesium oxide) provides a sustained supply of magnesium. One of the advantages of having this dual supply is that, following significant rainfall or after prolonged irrigation, there is a persistent source of fertiliser

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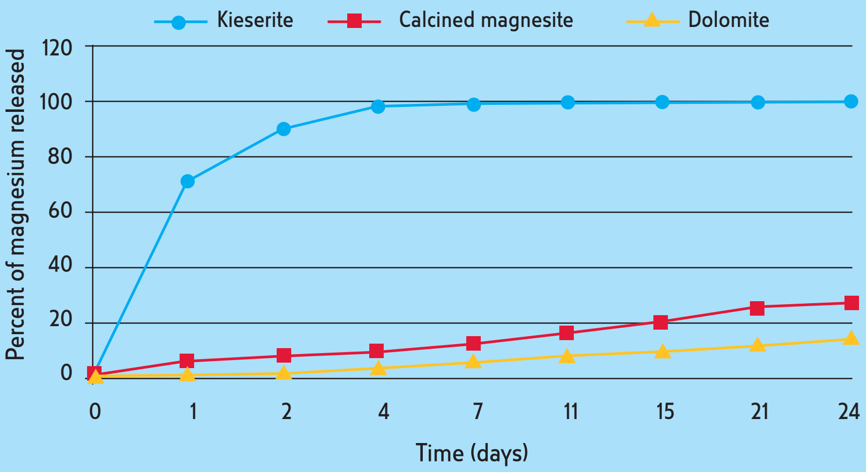

Release of magnesium from three fertilisers, determined over a 24-day period.

Magnesium release

In early 2001 AgResearch conducted an experiment to compare the release of magnesium from various types of fertilisers. Among the fertilisers tested were a kieserite, a dolomite and a calcined magnesite (magnesium oxide). Tests were carried out to determine how much magnesium was released from each fertiliser over a 24-day period with samples taken at regular intervals.

The results in the graph show that nearly all of the magnesium from the kieserite was released within seven days, whereas both the dolomite and calcined magnesite samples released magnesium slowly over the 24-day timeframe. By day 24, 26 percent of the magnesium had been released from the calcined magnesite and 14 percent from the dolomite.

magnesium in the soil. In these circumstances, the more highly soluble forms of magnesium may be subject to losses by leaching.

It's important, therefore, to consider your needs when choosing a magnesium fertiliser. If plants are suffering from an acute deficiency, a foliar spray will bring quick results. Less severe deficiencies can be corrected by soil applications of soluble magnesium. Yet the soil deficits that led to the deficiency must also be addressed and in this case a slow-release magnesium fertiliser may be more desirable, since it will provide a sustained supply of magnesium, so reducing the potential for loss by leaching.

Synthesising magnesium sulphate

Although kieserite (magnesium sulphate monohydrate - $MgSO_4{\cdot}H_2O$) occurs in natural deposits in Germany, it can also be manufactured from other naturally occurring compounds. To do this, an ore containing mainly magnesium carbonate ($MgCO_3$) is first mined then heated to convert it to calcined magnesite (MgO). When this is treated with sulphuric acid the reaction produces magnesium sulphate.

This magnesium sulphate is first dried to a powder then sprayed with water to form prills, which are then dried. No coating or binding materials are required.

The reactions involved in this process can't be controlled with absolute certainty, so the final product - like many 'natural' products - has a mixture of components. The manufactured kieserite that Ballance imports has a magnesium content of 16%. This is mainly made up of hydrated $MgSO_4$, but it also contains some residual $MgCO_3$ and MgO.

$$MgCO_3 \xrightarrow[\uparrow\ \text{heat}]{} MgO \xrightarrow[\uparrow\ \text{sulphuric acid}]{} MgSO_4{\cdot}n\,H_2O \quad (\text{where } n = 1 \text{ to } 7)$$

Ballance Agri-Nutrients horticultural specialists

Ballance Agri-Nutrients has a strong team of technical representatives throughout the country. Yet with approximately a hundred times more land in New Zealand being given over to pastoral farming than horticultural use, it's not surprising that most Ballance technical reps have to focus on sheep, beef and dairy issues. The horticultural industry, though small in area, is of great importance to the economy and products such as kiwifruit, apples and wine grapes have helped reaffirm New Zealand's standing on the international stage.

To help support this industry, Ballance has two horticultural specialists on its team. Peter Buckingham, who has been with the company since 1999, is based in Pukekohe, and Jo Honey, who joined Ballance in 2005, is based in Mount Maunganui.

Peter has a Bachelor of Commerce (Horticulture) and extensive experience, having spent over ten years working in the fertiliser industry before joining Ballance. Although his main focus is vegetables, particularly onions and potatoes, Peter is also well qualified to provide advice on other crops.

Jo has a Bachelor of Resource Studies and has spent time developing and implementing sustainable land management schemes. She was brought up in a farming environment, including the family avocado and kiwifruit orchards.

Both Peter and Jo take an active interest in research developments in their respective fields and in this they benefit from contact with scientists from Yara, which supplies many of the specialist horticultural fertilisers recommended by Ballance. Their wide experience means both are able to assist with plant nutrient requirements for a range of horticultural crops.

Contact details:
Peter Buckingham
Ballance Agri-Nutrients
Hart Road
PO Box 260
Pukekohe
Phone: 027 479 5861
Free phone: 0800 222 090
Email: pbuckingham@ballance.co.nz

Jo Honey
Ballance Agri-Nutrients
Hull Road
Mt Maunganui
Phone 027 444 4083
Free phone: 08000 222 090
Email: jhoney@ballance.co.nz

Peter Buckingham

Jo Honey

agri-nutrients
Ballance

For customer services phone 0800 222 090
WEB. www.ballance.co.nz

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