CALCIUM

Along with nitrogen (N), phosphorus (P), potassium (K), sulphur (S) and magnesium (Mg), calcium (Ca) is classified as a macronutrient, i.e. it is needed in relatively large amounts for healthy plant growth. Calcium is also required in relatively large amounts by animals and plays an important role in determining soil physical and chemical characteristics, i.e. structure and pH.

The choice of calcium products and the rate and how they are applied depends on whether they are being applied as a plant nutrient or as a soil ameliorant. Higher rates and different application strategies are required for soil amelioration.

1. CALCIUM IN THE SOIL

1.1. Forms

Calcium exists in the soil as:

- Primary minerals, e.g. feldspar;
- Secondary minerals, e.g. silicate clays;
- Calcium compounds such as calcium phosphate (e.g. apatite), calcium carbonate (lime) and calcium sulphate (gypsum);
- Organic matter;
- Exchangeable calcium, adsorbed on to clay particles or organic matter; and
- Free divalent cations (Ca^{2+}), i.e. water-soluble calcium in the soil solution.

More calcium is present in heavy-textured clay soils than in sandy soils. Calcium is usually the dominant cation on the exchange complex of clays and affects both the physical and chemical properties of soil. Soil calcium is normally lower in high rainfall areas, where calcium has been leached (washed through the soil), than in areas of low rainfall. In arid areas, gypsum (calcium sulphate) may accumulate in the sub-soil.

1.2. Soil pH

Low exchangeable calcium levels and soil acidity (low pH) usually go hand in hand. Calcium is most available in the pH range 7.0 to 8.5. Where soil pH is below 6.0, soluble and exchangeable calcium is usually lower than in soils of higher pH. Under low pH or acid soil conditions, the solubility of manganese (Mn), aluminium (Al), copper (Cu) and heavy metals increases to levels that can be toxic to plant growth. Low pH reduces the solubility of molybdenum (Mo) and phosphorus making these nutrients less available for plants. Below pH 5.5, conditions are detrimental to nitrifying organisms, and the lowered calcium availability may slow down the nodulation of certain legumes, e.g. lucerne.

1.3. Loss through leaching

Leaching of calcium (and other nutrients) below the root zone of crops and pastures is most likely to occur on light - textured sandy soils, and at low pH. In acid soils hydrogen (H^+) ions can replace calcium (Ca^{2+}) and other ions on exchange sites. The displaced calcium can then be leached or lost from the soil under high rainfall conditions.

Under the process of acidification, not only are calcium (Ca^{2+}) ions leached from the topsoil, but so too are hydrogen (H^+) ions. This in turn can make the sub-soil more acidic. If the sub-soil becomes acid, root growth, nutrient uptake and the utilisation of stored soil moisture can be restricted.

Hydrogen ions are only leached in appreciable quantities from the topsoil when it is acidic. If the pH of the topsoil is maintained above 5.5, acidification of the sub-soil will be stopped or only occur slowly. In high value intensive cropping situations, it is generally recommended that pH in topsoil be maintained in the range of 6.0 to 7.5.

While soil acidification is a natural process under high rainfall conditions the rate at which it occurs is accelerated in productive agricultural systems. Cultivation (which increases the rate of decomposition of soil organic matter), nitrogen fixation by legumes, and the use of nitrogen fertilisers all contribute to acidification.

Straight nitrogen fertilisers, such as anhydrous ammonia (Big N), urea and ammonium nitrate are equal in their acidifying effort, at the same rate of nitrogen. Ammonium sulphate (Sulphate of Ammonia), which supplies nitrogen and sulphur, has a much greater acidifying effect. Nitrate fertilisers, such as calcium nitrate, are non-acidifying.

1.4. Soil structure

Calcium ions cause soil colloids (clay platelets) to bond or aggregate together, forming crumbs or peds. Soils dominated by calcium are friable and well structured, have good internal drainage, and are easy to cultivate. They are often described as self-mulching.

In contrast to calcium, sodium, and to a lesser extent magnesium, cause clay platelets to disperse. Soils dominated by sodium and/or magnesium have low infiltration rates, crust after rain, are puggy when wet, set hard on drying and are difficult to cultivate.

High sodium (and/or magnesium) is not the only causes of poor soil structure. Other causes include low organic matter content, over-cultivation and soil compaction. Where high concentrations of sodium (and/or magnesium) are the primary cause, the addition of a soluble source of calcium, e.g. calcium sulphate (gypsum) provides calcium ions (Ca^{2+}) to replace sodium (Na^+) and/or magnesium (Mg^{2+}) ions on the surface of clay particles, helping improve the soil structure.

2. CALCIUM IN THE PLANT

2.1. Uptake

Plants take up calcium in the ionic form (Ca^{2+}). Calcium is required for cell elongation and cell division. Adequate calcium helps delay leaf senescence and slows down or prevents leaf and fruit fall (abscission). Calcium uptake by plants is not as efficient as for other plant nutrients. Uptake occurs just behind the root tip, in contrast with potassium where uptake occurs along most of the length of the root. Consequently, anything that affects new root growth may prevent calcium uptake and induce a deficiency. This includes adverse weather conditions such as drought, low temperatures, high humidity, poor soil aeration and water logging. For example, “blossom-end” rot in tomatoes, which is attributed to inadequate calcium, can be induced by a period of moisture stress, even though the soil may have adequate calcium levels.

Within plants, calcium is not mobile. Once calcium is deposited in leaves, it cannot be remobilised from them to the growing tips. Seeds and storage organs which develop in the soil, like peanuts, sub-clover burrs and potato tubers are not supplied with calcium by the transpiration stream in the plant, but directly from the soil.

2.2. Interactions with other nutrients and competitive ion uptake effects

Anions

As calcium is a cation (a positively charged ion), uptake is enhanced by the presence of anions (negatively charged ions). Plants fed with nitrate nitrogen (NO_3^-) generally contain more calcium than those fed with ammonium (NH_4^+) nitrogen.

Cations

The relationship between the four cations, calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and sodium (Na^+) is important, as there is competition between them for entry into plant roots. Increasing the supply of one cation can lower the level of the other cations in the plant. For example, the application of potassium can reduce magnesium or calcium uptake and may cause a deficiency in one of these nutrients.

Boron

Boron and calcium behave similarly in their transport around the plant. Both are relatively immobile. The efficient uptake and transport of calcium depends on boron availability.

Early boron sprays can sometimes reduce calcium deficiency (Bitter Pit) in apples. As boron availability is reduced at high pH, boron sprays should be considered when applying lime in horticultural crops that are susceptible to boron deficiency.

2.3. Deficiency symptoms

Since plants are unable to utilise calcium from older leaves for growth, a deficiency is often first observed in the growing points and youngest leaves. Roots are usually affected before the tops; with both roots and tops exhibiting die back of the growing point. Where calcium deficiency is moderate to acute, root growth is markedly impaired, and plants become susceptible to root-rot infection. Deficiency symptoms also occur in fruit or storage tissues. Some specific symptoms are:

- "Bitter pit" in apples – small brown necrotic spots (2 – 3 mm deep and 2 – 3 mm in diameter) over the surface of the fruit.
- "Blossom-end rot" in tomatoes – breakdown at the flower end of the fruit, with depressed blackened patches which may be up to 3 – 5 cm across.
- "Black heart" in celery – deformed and chlorotic (yellow) growth. At a more advanced stage the leaf margins become necrotic (dead patches).
- "Pops" in peanuts – empty shells or small kernels in the pods.

3. CRITICAL LEVELS OF CALCIUM

3.1. Soil analysis

pH

In assessing the need to apply calcium and the form in which it is best applied, the soil pH should be considered in addition to the soil's calcium status. In very acid soils, calcium will need to be applied in a form which will raise the soil pH, e.g. lime, and at higher rates than are normally required to correct calcium deficiency alone.

While useful in assessing the suitability of soil for plant growth, soil pH tests do not reliably indicate the amount of lime required to raise the soil pH to a more acceptable level, as soils differ in their buffering capacity. At the same pH, a clay soil will require more lime than a sand, as it has a greater buffering capacity.

"Buffer pH" tests have been developed and are used in some (but not all) Australian states to provide a "liming estimate" on the amount of lime required to raise the soil pH to a more acceptable level. These tests take into consideration the reserve acidity or buffering capacity of the soil.

Calcium as a plant nutrient

The Incitec Pivot Laboratory measures plant - available calcium in the soil using ammonium acetate as the extractant.

Different crops require different levels of plant-available calcium for healthy growth. For high value fruit and vegetable crops, levels over 5 meq/100 g Ca (1,000 mg/kg Ca) are usually required, whereas for cereal crops or pastures, levels of 2.5 meq/100 g Ca (500 mg/kg Ca) or less may be adequate.

The concentration of other nutrients is also of importance. Plants can grow satisfactorily with very low levels of calcium in the nutrient medium provided other divalent cations are also at low concentrations. On the other hand, if the concentration of other cations is high, higher levels of calcium are required, i.e. the balance between the cations is of importance.

Effect on soil structure

Clay soils that are dominated by calcium have good structure. They are friable, self-mulching, easy to cultivate, and display good water infiltration rates. Soil structure is adversely affected if sodium is present in excessive amounts. The soil will have poor internal drainage, the clay particles will disperse when wet, and on drying the soil will set hard and crust at the surface.

Magnesium-dominant clays affect the soil's physical structure in a similar way but to a lesser extent than sodium clays.

3.2. Plant tissue analysis

Within a plant, there are variations in calcium levels between plant parts, and the levels depend on the age of the tissue and vigour of plant growth, but usually range between 0.3 and 2.0% Ca of dry matter.

4. CALCIUM FERTILISERS AND SOIL AMENDMENTS

There are many products available that contain calcium. Some are low-priced bulk commodities, e.g. lime and gypsum, which are applied at high rates as soil ameliorants. In others, the calcium is present as a companion nutrient, e.g. to phosphorus and sulphur in single superphosphate.

Few calcium compounds are readily soluble in water. Calcium nitrate and calcium chloride are exceptions. These come at a higher price. The solubility of various calcium compounds is shown in the following table, as this is an important consideration in choosing which product to use. Some calcium compounds, e.g. lime, correct soil acidity (raise the soil pH). Others, e.g. gypsum, supply calcium without affecting the soil pH. Gypsum is used to improve the structure of sodic soils.

Table 1.

Compound	**Formula**	**Solubility (kg/100L) @ 20°C**
Calcium Carbonate (Lime)	$CaCO_3$	0.0013
Calcium Oxide (Burnt or Quick Lime)	CaO	0.13 (at 25 deg C)
Calcium Hydroxide (Slaked or Hydrated Lime)	$Ca(OH)_2$	0.17
Calcium Sulphate (Gypsum)	$CaSO_4.2H_2O$	0.26
Monocalcium Phosphate (Superphosphate)	$Ca(H_2PO_4)_2.H_2O$	1.8
Calcium Chloride	$CaCl_2.6H_2O$	75
Calcium Nitrate	$Ca(NO_3)_2.4H_2O$	129

4.1. Lime

Lime is primarily used to lime the soil or correct soil acidity. Acid soils are characterized by an excess of hydrogen (H^+) ions in the soil solution and on exchange complexes in the soil.

Limestone or calcium carbonate ($CaCO_3$) is very insoluble (150 to 200 times less soluble than gypsum in water). It dissolves slowly to release calcium ions (Ca^{2+}) and carbonate ions (CO_3^{2-}), as depicted in the following equation.

$$CaCO_3 \rightarrow Ca^{2+} + CO_3^{2-}$$

In acid soils, the calcium ions displace hydrogen (H^+) ions from soil colloids, which are then neutralized according to the following equation. Soil acidity is reduced in the process.

$$2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$$

The sorption of the calcium ions onto soil colloids and removal of the carbonate ions from the soil solution allows the first reaction to continue to proceed, i.e. the lime will continue to dissolve slowly in the soil. It will continue to do so while ever hydrogen ions are present in sufficient quantity in the soil.

The dissolution of the lime will be blocked once the pH has been raised to around neutral (or should lime be applied to alkaline soils in which few hydrogen ions are present).

The effectiveness of lime is very dependent on its particle size. Fine particles react more quickly than coarse particles on account of the larger surface area they provide. In general, lime that is coarser than 250 microns (0.25mm) has little value in raising soil pH, at least in the short term.

Crushed limestone is known as **Pulverized Lime**. Apart from crushing, limestone can also be treated in other ways to improve its reaction rate:

- **Burnt Lime** or **Quick Lime** is calcium oxide (CaO). It is produced by heating limestone. Carbon dioxide (CO_2) is liberated as a gas in the process. Burnt Lime is caustic and needs to be handled with care.

- **Slaked Lime** or **Hydrated Lime** is produced by allowing burnt lime to absorb water (H_2O) to form calcium hydroxide [$Ca(OH)_2$].

The oxides (burnt lime) and hydroxides (slaked lime) are more reactive than calcium carbonate (lime). Their solubility is one hundred times that of calcium carbonate and approaches that of gypsum. In addition, they typically have a finer particle size, higher calcium content and higher neutralizing value.

Being naturally occurring, liming materials vary greatly in composition and purity. Calcium (Ca) levels range from 64% Ca in burnt lime to 13% Ca in dolomite. Magnesium (Mg) levels range from trace levels in true limestone to 8% Mg in dolomite.

4.2. Gypsum

Gypsum (calcium sulphate) may be used as a calcium fertiliser, e.g. over the row in peanuts after planting, and as a sulphur fertiliser, e.g. in pastures on high phosphorus soils. The major use of gypsum, however, is at higher rates as a soil amendment (or ameliorant), to improve soil structure and reduce surface crusting in alkaline sodic soils.

Lime is unsuitable for such use on high pH (alkaline) soils as it is insoluble. Lime will not dissolve and react in the soil unless the soil is acid. Gypsum is more soluble, allowing its use on a wider range of soil types, but it has little or no effect on soil pH, i.e. it will not correct soil acidity.

4.3. Superphosphate

Incitec Pivot SuPerfect® (granulated Single Superphosphate) contains 8.8% P, 11% S, and 19% Ca. About two-thirds of the calcium is present in the form of gypsum, one-third in the form of monocalcium phosphate. SuPerfect is primarily used to top-dress legume-based pastures, in which both phosphorus and sulphur are usually required. The calcium it contains is generally not of importance. Pasture soils that are low in calcium are generally acidic as well, necessitating the use of lime.

The use of superphosphate in planting fertilisers can be beneficial in soils low in calcium. Incitec Pivot SuPerfect, however, is high in cadmium (Cd), containing up to 300 mg Cd/kg P. It should not be used as the sole source of phosphorus in formulating NPK planting fertilisers for vegetables. Fertilisers with a lower cadmium content (< 150 mg Cd/kg P) should be used for this purpose.

4.4. Calcium nitrate

Various grades of calcium nitrate are available, for dry application to the soil, or application in solution. Pure calcium nitrate is classified as a Dangerous Good (Oxidizing Agent) and is not normally traded as a fertiliser. Fertiliser grade calcium nitrate has the chemical formula $5Ca(NO_3)_2.NH_4NO_3.10H_2O)$ and is essentially the hydrated ammonium calcium nitrate double salt. It contains 15.5% N and 19% Ca and is not classified as a Dangerous Good.

The presence of the ammonium nitrate enhances the fertiliser's solubility in water, the commercial product having a solubility of 250 kg/100 L at 20°C. The dissolution of calcium nitrate in water, like urea and other nitrate fertilisers, is endothermic. It causes the temperature to fall.

Compared to products such as lime and gypsum, calcium nitrate is costly. It is used where a quick response to calcium is required during the growing season in horticultural crops. Calcium nitrate is normally applied in solution, e.g., as a foliar spray or through fertigation systems (dissolved in the irrigation water) but may also be applied dry to the soil (though this tends to be less effective than fertigation and foliar sprays).

Calcium nitrate is also used as a non-acidifying nitrogen fertiliser through drip and trickle irrigation systems and under tree sprinklers. Calcium nitrate will not acidify the soil around the emitters like straight nitrogen fertilisers do, e.g. urea and ammonium nitrate. Calcium nitrate has a low Critical Relative Humidity (CRH), just below 40% at 25°C. It readily absorbs atmospheric moisture. This makes it unsuitable for use in dry blends with other fertilisers. Urea, by comparison, has a CRH of about 75%.

4.5. Calcium chloride

Calcium nitrate is the preferred product in most situations where a soluble calcium fertiliser is required, as it is chloride free. Calcium chloride is more likely to burn plant foliage if used in foliar sprays. An exception to this rule is red apple varieties, in which the nitrogen in calcium nitrate may affect the colour of the fruit.

4.6. Calcium ammonium nitrate (CAN)

Incitec Pivot Cal-Am® contains 27% N and 8% Ca. It is mostly used in blends, at concentrations up to 55%, with other fertilisers. Above this concentration, the fertiliser is classified as Security Sensitive, and is only supplied to customers who are licensed to use it.

Cal-Am is used as a source of nitrogen to top-dress rain-grown crops where ammonia volatilization losses may be excessive, and where a quick response is required to nitrogen applied during the growing season, e.g. in winter forage crops and short season vegetable crops.

While Cal-Am contains 8% calcium, it should not be thought of as a calcium fertiliser. The calcium in Cal-Am is present as carbonate, the same form as in lime. It is insoluble and will be of no immediate benefit to crops and pasture when side or top-dressed during the growing season.

Calcium carbonate is added to Cal-Am as a dilutant, so that the end product can be declassified as being a Dangerous Good, and not for its nutritive value to plants.

Pure ammonium nitrate fertilisers are classified as Oxidizing Agents. Cal-Am, which contains 80% ammonium nitrate and 20% calcium carbonate, is not.

5. CALCIUM APPLICATION

Calcium compounds are used as soil ameliorants, and as calcium fertilisers. The time and rates of application for these are entirely different. Soil ameliorants, such as lime and gypsum, are applied early, e.g. at the start of the fallow period in annual crops, or before the main growing season, e.g. late winter, in perennial crops, and at high rates. Lime is used to correct soil acidity, while gypsum is used to improve the structure of sodic soils. Their use improves the soils calcium status, often negating the need to apply additional calcium as a fertiliser.

Calcium deficiency can occur in rapidly growing new plant tissue and fruit, e.g. “blossom-end rot” in tomatoes, “bitter-pit” in apples, even in soils well-endowed with calcium. This often calls for strategic applications of calcium at critical growth stages in fruit and vegetable crops that are susceptible to calcium deficiency. Calcium nitrate is commonly used for this purpose, in fertigation programs and foliar sprays. In summary, the main uses of calcium compounds are:

- Lime – to correct soil acidity;
- Gypsum – to improve the structure of sodic soils;
- Calcium Nitrate – to prevent calcium deficiency in susceptible horticultural crops through fertigation programs and foliar sprays at critical growth stages.

5.1. Lime

The soil’s calcium status, pH, buffering capacity, exchangeable aluminium and manganese levels and the types of crops or pasture to be grown are important considerations in determining the need for lime, and the rate at which it should be applied.

Lime is likely to be required where soil calcium is low, and the soil is acid (pH below 6.5). Despite the apparent need, there may be circumstances where the investment in lime cannot be justified. The final decision will depend on such factors as the soils buffering capacity, the crop or pasture being grown and its tolerance of acidity, rainfall, and the potential yield and returns, e.g. low carrying capacity native pastures.

In more intensive farming systems, lime application rates, where required, generally range from 1 to 10 t/ha, more typically being in the range of 2.5 to 7.5 t/ha.

Repeat applications are necessary, the frequency (anything from one to ten years) depending on the crop or pasture, soil type, climate, irrigation and other management factors, including rate and type of fertiliser use, and the rate at which the lime itself is applied.

In annual crops, and when preparing to sow a new pasture, lime should be applied several months before planting and be incorporated into the soil, to give it time to react.

Lime is insoluble and relatively ineffective in neutral and alkaline soils. In the unlikely event that soil calcium is low and the pH is high, a more soluble source of calcium such as gypsum will need to be used. However, it should not be automatically assumed that lime is unsuitable should a soil test show that soil calcium is low but the pH is in the optimum range. If this is the natural pH of the soil, then a more soluble product than lime needs to be used.

Should the soil be inherently acid, and the current pH is a direct consequence of recent and regular applications of lime, this indicates that the liming program is maintaining the pH in the desired range, and that lime will continue to be required on an ongoing basis.

5.2. Gypsum

Gypsum can be used to improve the structure of clay soils that are high in sodium (sodic) and/or magnesium. Such soils are normally alkaline and typically have a pH above 8.4. The intensity of production and likely returns are important considerations in determining whether gypsum should be applied. An important consideration, in determining the rate of application, is the depth of incorporation.

Where gypsum is used on poorly structured clay soils to improve the tilth of the plough layer, e.g. irrigated cotton, vegetables, sugarcane, typical application rates, are of the order of 7.5 – 10 t/ha. The gypsum should be applied well ahead of planting and be incorporated into the soil. Rainfall or irrigation is then required to allow the calcium in the gypsum to replace excess sodium and/or magnesium on clay colloids in the soil, and then wash or leach the displaced sodium and magnesium below the root zone. If gypsum is applied too close to planting, or leaching does not occur, plant growth may be worse after applying gypsum, despite the apparent improvement in soil structure.

Gypsum (calcium sulphate) is sparingly soluble in water. In contrast, the sodium sulphate that is formed in the soil after gypsum is applied is highly soluble and adds to soil salinity. Successful soil amelioration is dependent on it being leached out of the topsoil and deeper into the soil profile. Do not use gypsum if the electrical conductivity is already high.

Lower application rates, e.g., 2.5 t/ha, are required where gypsum is used in rain grown grain crops to reduce surface crusting under minimum tillage. Here, the gypsum is being targeted at the surface layers of the soil, not the entire plough layer. Its use can improve water infiltration, reduce run-off, and improve seedling emergence and crop establishment if rain falls shortly after planting. Such applications remain effective for several years and remain effective for longer where the soil is subjected to minimal disturbance (reduced tillage).

Gypsum may be used as a calcium fertiliser. Where gypsum is used to supply extra calcium to the developing kernels of peanuts on sandy soils, gypsum is broadcast along the rows at 400 – 600 kg/ha within 4 – 6 weeks of emergence.

Low rates of gypsum are required if gypsum is used as a sulphur fertiliser, e.g. 100 – 200 kg/ha/annum.

5.3. Lime plus gypsum

While lime and gypsum have specific uses for which they are best suited, there are circumstances where the two products may give better results if used together, i.e. in acid sodic soils with poor drainage.

The more soluble calcium from the gypsum exchanges with aluminium and manganese, and releases hydrogen ions into solution to react with the less soluble calcium carbonate in the lime. Together, they improve the soil's structure and pH. Lime can be used on its own on acid sodic soils but is likely to take longer to work. Gypsum alone is unsuitable, as it will not correct soil acidity.

5.4. Calcium nitrate

On acid soils low in calcium, the pre-plant application of lime early in the fallow period will raise soil calcium levels. This, however, may not always be enough to prevent calcium deficiency.

Calcium is immobile in plants, i.e. it is not readily relocated from old to young leaves and developing plant parts. Plants are therefore dependent on a continuous supply of calcium. If plant root uptake is inadequate, calcium deficiency can be induced in new plant growth and fruit. This can occur on soils well supplied with calcium, particularly if the crop is allowed to become moisture stressed, e.g. in hot dry weather.

Many horticultural crops are susceptible to calcium deficiency. If there is a need to apply calcium at critical growth stages to help prevent calcium deficiency in rapidly growing new plant tissue and fruit, e.g. "blossom-end rot" in tomatoes, "bitter-pit" in apples, it must be in a soluble form. Lime is unsuitable at this stage.

Calcium nitrate is the product most recommended under these circumstances. It can be side-dressed dry (in vegetable crops), applied in the irrigation water (fertigation), as a foliar spray, or a combination of these methods.

Calcium deficiency is very difficult to correct if soil moisture is inadequate. Ensure horticultural crops are properly irrigated at all stages of growth.

Fertigation

Fertigation is an effective way of supplying calcium in a soluble form that is readily available for plant uptake on a regular basis during critical growth stages. Placing the calcium nitrate into wetted soil where the roots are most active maximises utilization and uptake and is usually more effective than applying calcium nitrate or other calcium fertilisers dry to the soil.

Suggested application rates are:

- For trickle irrigation in **tomatoes** in warm weather when and where blossom-end rot may be a problem, apply calcium nitrate at 65 kg/ha once a week, or at 30 kg/ha twice a week from first fruit set onwards.

- In other **vegetable crops**, a suggested application rate is 20 – 50 kg/ha per week for the first three to four weeks after transplanting for leaf vegetables, from the onset of flowering for fruit, and after tuber initiation in potatoes.

In potatoes, the basal roots or main root system do not contribute to calcium accumulation in the tubers. This is done directly by the roots arising from the stolons and tubers. Calcium fertiliser, where required, should be positioned in this area, in a soluble form.

The rate at which any other nitrogen fertiliser is applied should be adjusted, taking into consideration how much nitrogen is applied as calcium nitrate (15.5% N), to apply the correct rate of nitrogen.

Foliar sprays

Routine foliar sprays of calcium are often recommended in horticultural crops that are susceptible to calcium deficiency, to supplement plants during critical growth stages. In some crops, e.g. tomatoes, calcium deficiency may occur where calcium has been applied to the soil, e.g. as lime, or the soil is naturally high in calcium, particularly if the crop is moisture -stressed.

Calcium deficiency should not be allowed to develop before commencing the spray program. Repeat sprays are often required, as calcium is not mobile within plants, i.e. once incorporated into plant tissue, it is not readily relocated to the growing points. Calcium sprays should be directed at the plant parts affected by calcium deficiency.

Foliar sprays are not effective for hearting vegetables, e.g. lettuce, as the solution will not reach the young, enclosed leaves; nor are they recommended in tuber crops.

In potatoes, calcium is not translocated from the leaves to the tubers. It is taken up directly from the soil into the tubers.

A typical foliar application rate for Calcium Nitrate in tree and vegetable crops is 5 kg/ha/application. A typical spray concentration for calcium nitrate is 500 g/100 L. Examples of spray programs are detailed in the table on the next page.

Concentrations are given in g/100 L, as is the custom for crop protection sprays, on the assumption the same spray equipment will be used. These spray concentrations are based on a spray volume of around 1 000 L/ha. Lower volumes (at similar spray concentrations) are used in the early growth stages in vegetables. Spray concentrations can be reduced if higher volume spray equipment is used, and increased if low volume sprays are applied.

If urea is not already being used in the spray program, it is recommended that a small amount be added to the spray mixture. Urea helps promote leaf uptake of other nutrients. Addition rates for urea are:

- 500 g/100 L in vegetables, or
- 100 g/100 L in tree crops.

Add a wetting agent at label recommended rates.

Foliar burn may occur at the concentrations shown in the table, particularly if other nutrients are applied at the same time, or water is of poor quality. If burn occurs or experience indicates it is likely, reduce the concentration, e.g. to half the above rates, and be prepared to spray on a more regular basis.

If applying Calcium Nitrate for the first time, or applying to a new crop, or should application procedures and equipment change, test spray on a few plants or trees first, and observe for three to four days for signs of phytotoxicity, before spraying the rest of the crop.

Some crops, e.g. strawberry, are more susceptible to fertiliser burn than others. Spray concentrations may need to be reduced in sensitive crops. Apply in the early morning or late afternoon. Avoid spraying in the heat of the day, or under hot, dry windy conditions.

Table 2: Suggested foliar spray concentrations for calcium nitrate in horticultural crops.

Crop	**Concentration**	**Comments**
Tomato, Capsicum	500-800 g/100 L	Apply weekly over the fruit development period, i.e. for 2 - 6 weeks from the time the first fruit set reach 20 mm in diameter. The fruit must be wetted. Where “blossom-end” rot is prevalent, spray twice a week.
Temperate fruit	500-800 g/100 L	Apply 3 or more sprays from early summer to within a few weeks of harvest. For green apple varieties, spray in December, January and February (Qld). Calcium chloride is preferred on red apples, as excess nitrogen can affect fruit colour, and as a post-harvest dip for apples which are to be stored. In grapes, apply at pre-bunch closure.
Tropical fruit & nut crops	500 g/100 L	Direct spray at the fruit. In bananas, apply at 1 kg/100 L to the leaves.
NOTE. Calcium Nitrate is often applied more frequently at lower concentrations, e.g. 250 g/100 L at 1- to 2-week intervals, during the fruit-filling period in tree crops.		

Compatibility in solution

Do not pre-mix calcium nitrate with chlorite or hypochlorite before addition to water. Cleaning agents should be added separately to the water, not mixed beforehand with calcium nitrate.

Calcium nitrate is compatible with urea, ammonium nitrate, potassium chloride, potassium nitrate, and metallic chelates.

Do not mix calcium nitrate with phosphate, sulphate, boron or molybdenum fertilisers, as insoluble precipitate will form.

Fill the tank to near capacity, leaving space for the added fertiliser, which should then be added slowly while agitating. Do not pre-mix, as is the practice with many pesticides, e.g. wettable powders. The fertiliser will not dissolve completely if added to a small amount of water.

Fertiliser solutions should be prepared just prior to use, and not allowed to stand for an extended period, to minimize sediment formation and settling in tanks.

Calcium salts, including calcium nitrate, add to the hardness of water. This may affect compatibility with agricultural chemicals in foliar sprays. Check the labels of all agricultural chemicals with which the calcium nitrate is to be mixed before use.

If compatibility information is not available, mix a small batch in a glass jar, and observe for signs of stability (settling or phase separation). It may also be necessary to spray a few plants and wait a few days to observe for signs of phytotoxicity and/or efficacy, before spraying the entire crop.

Chemicals should be added to the spray tank first, followed by the fertilisers.

6. CALCIUM IN WATER

If water is hard, i.e. high in calcium (and magnesium), it will not harm the soil, or be detrimental to livestock, but may cause problems with scale in pumps and equipment, the formation of precipitate and blockages in fertigation systems, affect the efficacy and life in the tank of agricultural sprays, and be of nuisance value in households. Soap will not lather in hard water. The addition of calcium fertiliser to water used for irrigation or foliar sprays will make the water harder.

7. CALCIUM IN ANIMALS

Calcium is important in animal nutrition. It is an important constituent of bones and teeth, and in milk. It is present in larger amounts in the body's mineral ash than any other mineral. Calcium supplementation is not usually necessary under grazing conditions, i.e. deficiency is unlikely to occur, but it is important in feedlots. Where cattle are fed a diet consisting largely of grain, it is necessary to add limestone (calcium carbonate) to the ration to supply extra calcium.

8. FURTHER READING

Agritopics on Soil Acidity, Lime and Dolomite, Gypsum, Fertigation and Foliar Fertilisers are available and should be read in combination with this Agritopic.

9. SAFETY DIRECTIONS

Refer to the Safety Data Sheet (SDS) for more detailed safety advice. Before use, read the Product Label and the SDS. Use safe work practices and avoid contact with the eyes and skin. Avoid ingestion and inhaling dust. Protective clothing, eyewear and dust masks should always be used when dealing with this product. Observe good personal hygiene, including washing hands after use. Avoid loss of fertiliser to waterways.

10. WARNING

This document contains information of a general nature. Before using fertiliser seek independent agronomic advice. Fertiliser programs may need to be varied depending on the plants being grown, climatic and soil conditions, application methods, irrigation, agricultural and livestock management practices, the soil's fertility, and cultural practices. ('Unforeseen Elements')

Fertiliser may burn and/or damage crop roots or foliage. Foliar burn to the leaves, fruit or other plant parts is most likely to occur when fertilisers are foliar applied at high concentrations and/or on a regular basis, different products are mixed and sprayed together at cumulatively high rates, the water is of poor quality, or the spray is applied under hot dry conditions, e.g. in the heat of the day.

Fertiliser and supplements may affect animal health. Seek independent advice before using any supplements in livestock rations.

11. DISCLAIMER

As Unforeseen Elements are beyond the control of Incitec Pivot Limited, in no event Incitec Pivot Limited and its related bodies corporate be liable or accept any responsibility whatsoever for any direct, indirect, punitive, incidental, special or consequential damages (including but not limited to loss of revenue, crops and livestock), in respect of the illness, injury or death of a person, damage to property (including of a third party), or any other loss whatsoever arising out of or connected with the use or misuse of this fertiliser, or its transport, storage, handling or application. Where Incitec Pivot Limited and its related bodies corporate's liability cannot be lawfully excused, it and its related bodies corporate's liability shall be limited to the replacement of, or cost of the fertiliser supplied. The buyer accepts and uses this product subject to these conditions.

12. COPYRIGHT

Copying or reproduction in whole, or in part, by any means, or transmission, or translation into a machine language without the written permission of Incitec Pivot Limited, is strictly prohibited.