MAGNESIUM

Magnesium (Mg) is an essential nutrient for plant growth. It is classified as a macronutrient, as it is needed in relatively large amounts, along with nitrogen, phosphorus, potassium, calcium, and sulphur. It plays an important part in the formation of chloroplasts and photosynthesis in plants, and in animal nutrition. Magnesium also has an influence on the structure of clay soils.

1. MAGNESIUM IN THE SOIL

1.1. Forms

Most of the magnesium in the soil exists in non-exchangeable forms which are not directly available to plants, i.e. the minerals from which the soil is formed, e.g. biotite, olivine, chlorite, and dolomite, and in clay minerals such as montmorillonite and vermiculite. Some magnesium, usually less than 1% of the total, is held in organic complexes. About 5% of the total magnesium is present in exchangeable forms. This consists of magnesium held on clay and organic particles in the soil, and any magnesium in water-soluble forms.

Exchangeable magnesium levels are likely to be lower on well drained sandy soils in areas of high rainfall, where magnesium and other cations, e.g. calcium, have been leached from the topsoil. Soils that are low in calcium and magnesium tend to be acid, i.e. they have a low pH.

Availability of magnesium to plants is affected by soil acidity. It is most available in neutral to alkaline soils. Magnesium availability decreases sharply as soil pH falls below 6.0. At the other end of the scale, magnesium becomes less available as soil pH rises above 8.5.

1.2. Effect on soil structure

Soils in which the exchange sites on clay particles are dominated by calcium have good structure and internal drainage. They are friable and easy to cultivate.

As the amount of sodium and/or magnesium increases, soil structure declines. Rather than aggregate together to form crumbs or peds (a characteristic of a friable self-mulching soil) soil particles disperse on wetting. Infiltration rates are low, the soil sets hard on drying, and it is difficult to cultivate.

Soils that are poorly structured and drained may also be saline, due to the accumulation of soluble salts in the surface soil.

2. MAGNESIUM IN THE PLANT

2.1. Uptake

Magnesium is taken up by plants as magnesium ions (Mg^{2+}). Magnesium plays a key role in the photosynthetic process, being an important constituent of chlorophyll, the green pigment in leaves and stems. It is also important in the formation of seeds with a high oil content. Once absorbed, magnesium is quite mobile within the plant, i.e. it is readily relocated from old to young plant tissue.

2.2. Competitive effects with other cations

Plant uptake of magnesium (Mg^{2+}) may be depressed by the presence of other positively charged ions (cations), e.g. calcium (Ca^{2+}), potassium (K^{+}), sodium (Na^{+}) and ammonium (NH_4^{+}) in the soil, or their application in fertilisers. For example, high rates of potassium (K) at planting on light sandy soil can induce magnesium deficiency (orange freckle) in sugarcane. Such effects are more pronounced at low soil pH, and in fast growing short season horticultural crops.

2.3. Symptoms of magnesium deficiency

Given magnesium's mobility within plants, deficiency always begins in the older leaves and then moves to the younger leaves. Symptoms of deficiency generally appear during the latter part of the growing season. However, it may be induced earlier, e.g. following the application of potassium at planting.

Early symptoms of magnesium deficiency include the loss of healthy green colour between veins. This is usually followed by yellowing (chlorosis), which starts at the leaf tips and margins and progresses inward until the entire leaf if chlorotic, curling of the leaf margins, death of these areas and premature defoliation. Brilliant colours develop in some plants, e.g. bright orange, red and purple tints in strawberries.

2.4. Magnesium toxicity

Symptoms of magnesium toxicity are rare, since there are few soils where magnesium is the dominant cation. In many cases what is suspected magnesium toxicity is simply a nutrient imbalance, i.e. an induced deficiency of some other nutrient.

3. CRITICAL LEVELS OF MAGNESIUM

3.1. Soil analysis

To identify magnesium responsive sites, soil tests are required that measure the amount of exchangeable magnesium in the soil, i.e. that which is adsorbed onto clay particles and humus, and that present in water-soluble forms. The ammonium acetate test used by the Incitec Pivot Laboratory is one such test.

As magnesium requirements and the ability to extract magnesium from the soil vary with different plant species, critical values also vary. A critical value for highly productive horticultural crops is 1.6 meq/100g Mg (ammonium acetate extract), while values greater than 0.4 – 1.25 meq/100g Mg are usually satisfactory for improved pastures and grain crops. For sugarcane the critical value is 0.25 meq/100 g Mg.

As there are competitive effects at the root surface for plant uptake, the ratio of magnesium to other cations can be just as important as the exchangeable magnesium concentration, in predicting where responses to magnesium might occur. A balance of all major nutrients (especially potassium) is important.

Magnesium concentrations often increase with depth. If magnesium is low in the topsoil but high in the sub-soil, magnesium deficiency is less likely to occur, or may be temporary.

The relative amounts of calcium and magnesium also influences soil structure. Once the magnesium percentage of exchangeable cations exceeds 20%, the soil will become increasingly difficult to work, as magnesium causes clay particles to disperse.

3.2. Plant tissue analysis

The content of magnesium (Mg) in plant tissues is usually about 0.5% of the dry matter. The optimum magnesium content of plant tissue for most plants is between 0.2 and 1.5% Mg on a dry matter basis.

Most plants will only show symptoms of magnesium deficiency when the magnesium content of leaf tissue drops below 0.1% Mg in the dry matter. However, as the requirement for grazing animals in forage is at least 0.2% Mg, the critical level in pasture and forage crops is taken as 0.2% Mg of the dry matter.

4. CORRECTING MAGNESIUM DEFICIENCY

Magnesium can be applied as an:

i) Insoluble magnesium compound, e.g. magnesium carbonate or magnesium oxide; or

ii) In a water-soluble form, e.g. magnesium sulphate.

Insoluble magnesium fertilisers cost less per kg of magnesium than the water-soluble products. They do, however, need to be applied early, to give them time to react in the soil, and they are only effective in acid soils. In annual crops, they should be applied early in the fallow period. In perennial crops, they should be applied in advance of the main growing season.

Soluble magnesium fertilisers can be used where a quick response is required, e.g. at planting or during the growing season. They can be applied dry to the soil, or in solution, either in fertigation programs or as foliar sprays. These products are more costly, and their use is largely confined to high value horticultural crops.

In horticultural crops that are sensitive to magnesium deficiency, a combination of these products is often used to get the best results. The bulk of the magnesium can be applied early, in an insoluble form, and supplementary magnesium applied in a water-soluble form, at lower rates, during the growing season.

Should magnesium deficiency occur on high pH calcareous soils, broadcast applications of magnesium are unlikely to be effective, particularly if an insoluble magnesium compound such as dolomite or magnesium oxide was to be used. In this situation, the magnesium needs to be applied as a foliar spray, or applied to the soil where roots are actively foraging, or will grow into in the future, in a water-soluble form. Options include banding or side-dressing the fertiliser, or its use in fertigation programs through drip or trickle irrigation systems or under-tree sprinklers.

5. MAGNESIUM FERTILISERS

5.1. Magnesite, dolomite, and dolomitic limestones

Magnesite is magnesium carbonate ($MgCO_3$). In its pure form it contains 27% Mg. Dolomite is calcium magnesium carbonate [$CaMg(CO_3)_2$]. In its pure form it contains 20.8% Ca and 12.5% Mg. Commercial grades of magnesite and dolomite contain some impurities and have a lower nutrient content than this. Dolomite typically contains from 8 – 12.5% Mg.

As well as supplying magnesium, magnesite and dolomite help correct soil acidity. Soils that are low in magnesium are usually low in calcium as well, and acid. Hence products are required that supply both nutrients and raise the soil pH.

Various commercial blended products are available for this purpose, containing a mixture of lime and magnesite or dolomite.

Magnesite, dolomite, and other liming materials are insoluble, and slow to react in the soil. To be effective, they must be finely ground, i.e. have a fine particle size. They are broadcast applied at high rates, e.g. 2.5 – 7.5 t/ha. Such applications may remain effective for several years before repeat applications are necessary.

In annual crops, these products should be applied early in the fallow period and be thoroughly incorporated into the soil. In perennial tree crops, they are normally applied at the start of the main growing season, e.g. late winter.

Magnesite and dolomite react in acid soils to release magnesium and correct acidity (raise the pH). Such reactions are slowed considerably in neutral and alkaline soils. Magnesite and dolomite are relatively ineffective in soils with a pH of 6.5 and above.

The magnesium status of alkaline soils is typically high, so magnesium application is usually unnecessary. If magnesium is required on alkaline soils, it needs to be applied in a water-soluble form.

5.2. Magnesium oxide

Magnesium oxide (MgO) contains around 55% Mg. It is often used where lime (calcium carbonate) has been applied, to supply additional magnesium.

Granular grades of magnesium oxide are available that can be applied through conventional fertiliser boxes. Magnesium oxide, like lime, dolomite, and magnesite, is insoluble and slow to react in the soil.

In annual crops, magnesium oxide should be broadcast applied early in the fallow period. It is best to wait for a few weeks to allow the granules to weather and disperse before working the magnesium oxide into the soil. Magnesium oxide should be applied in advance of the main growing season in trees, vines, and plantation crops.

Suggested application rates for magnesium oxide, which may remain effective for several years, are:

- Pasture, forage, grain and oilseed crops 50 – 200 kg/ha
- Sugarcane (for a crop cycle) 150 – 300 kg/ha
- Horticulture - vegetables, tree crops and vines 200 – 400 kg/ha

In perennial horticultural crops, granular magnesium oxide may be added to NPK blends, to supply maintenance applications of magnesium on an ongoing basis. A suggested annual application rate is 50 – 100 kg/ha.

Magnesium oxide is not recommended where a quick response to magnesium is required, i.e. in planting fertilisers for annual crops, or during the growing season.

5.3. Potassium magnesium sulphate

Potassium magnesium sulphate, sold under the brand names of Sul-Po-Mag and K-Mag, contains 18% K, 22% S and 10.8% Mg. It is not widely used in Australia, due to logistical difficulties in importing the product, and the low overall demand.

Potassium magnesium sulphate has excellent storage and handling characteristics and is an ideal blend ingredient for use in NPK fertilisers for horticulture, e.g. planting fertilisers for vegetable crops. It is generally not used as the sole source of magnesium, but rather to provide supplementary magnesium at critical growth stages, complementing that applied prior to planting as liming materials.

Incitec Pivot does not stock potassium magnesium sulphate.

5.4. Magnesium sulphate

Magnesium sulphate may be applied as:

1. Magnesium Sulphate Monohydrate ($MgSO_4.H_2O$) or Kieserite;
2. Magnesium Sulphate Heptahydrate ($MgSO_4.7H_2O$), also known as Epsomite or Epsom Salts.

The magnesium in these products is readily available for plant uptake. They can be used to provide supplementary magnesium in high value horticultural crops, and where a quick response is required during the growing season to correct magnesium deficiency.

Kieserite is applied dry to the soil, while Epsom Salts is generally applied in solution, e.g. in fertigation programs and foliar sprays. A typical rate at which Kieserite is applied to the soil is 100 – 150 kg/ha /annum. Kieserite typically contains 15% Mg and 20% S. Epsom Salts typically contains 9.7% Mg and 12.9% S.

Magnesium sulphate is hygroscopic. It readily absorbs atmospheric moisture. The Critical Relative Humidity (CRH) of magnesium sulphate at 25^{O} C is in the region of 50%. By comparison, the CRH of Urea is around 75%. Consequently, magnesium sulphate fertilisers have poor storage and handling characteristics. Blends in which Kieserite is used can deteriorate rapidly in quality and must be used quickly.

Incitec Pivot does not stock Kieserite for use as a blend ingredient at Distribution Centres on the east coast of Australia, i.e. Port Kembla, Newcastle, Brisbane, Mackay, Townsville, and Cairns, where the atmospheric humidity, particularly over summer, is higher than in southern Australia.

5.5. Magnesium nitrate

Magnesium nitrate, $Mg(NO_3)_2.6H_2O$, is another soluble magnesium fertiliser, that can be used in fertigation programs and foliar sprays. It typically contains 9.4% Mg and 10.9% N. Application rates for magnesium nitrate will be similar to those for magnesium sulphate heptahydrate (9.7% Mg), given that their magnesium content is much the same.

6. FERTIGATION

Fertigation is a convenient way to apply supplementary magnesium during the growing season in high value horticultural crops.

On calcareous soils, fertigation may be the most effective way to apply magnesium to the soil, targeting it in a readily available soluble form to where roots are actively foraging, through drip and trickle irrigation systems and under tree sprinklers.

A suggested application rate for magnesium sulphate heptahydrate (Epsom Salts) or magnesium nitrate in fertigation programs is 25 - 30 kg/ha per application. Three or more applications may be required at fortnightly intervals during peak growth periods.

Fertigating with magnesium avoids the risk of leaf burn from foliar sprays.

7. FOLIAR SPRAYS

Magnesium is not a trace element. It is taken up by plants in large amounts. Consequently, foliar sprays can only be used to supplement, but not replace soil applications of magnesium. If magnesium were to be foliar applied at the concentrations and rates required to meet crop needs, it would burn the foliage.

Magnesium sprays are used in high value fruit and vegetable crops, and to help correct a deficiency where symptoms are evident. Fertigation and foliar sprays are the quickest ways in which this can be achieved.

Magnesium can be foliar applied as magnesium sulphate heptahydrate (Epsom Salts) or magnesium nitrate. Foliar application rates for either product is typically in the range of 2 – 5 kg/ha, though up to 10 kg/ha may be recommended in some circumstances. The amount applied per application, and the concentration at which it is applied can be reduced if regular sprays are made throughout the growing season.

Recommended spray concentrations for magnesium sulphate and magnesium nitrate show considerable variation. In horticultural crops, up to 1% w/v (1 kg/100L) spray solutions are recommended, applied to the point of run-off, with repeat applications being made if needed.

Spray concentrations are adjusted according to the spray volume, e.g.

- 2 – 5% w/v (2 – 5 kg/100 L) in field crops
- 0.25 – 1% w/v (250 g – 1 kg/100 L) in vegetables
- 0.25 – 0.5% w/v (250 – 500 g/100 L) in trees and vines

In field crops, spray volumes of up to 100 L/ha are used. In horticultural crops, spray volumes are typically around 500 L/ha in vegetables, and 1 000 L/ha or more in tree crops.

Spray volumes in vegetables increase as the crop matures and there is more foliage to spray, e.g. from 250 L/ha up to 1,000 L/ha late in the growing season. Nutrient sprays are mostly applied in the early growth stages, a typical spray volume being 400 – 500 L/ha. If using equipment delivering higher or lower spray volumes, adjust the spray concentration to apply around the same rate of nutrient.

Some suggested spray programs are shown in the Table 1. In general, these are representative of the upper limit at which magnesium sulphate is recommended.

If deficiency symptoms persist, e.g. in newly matured and young leaves, be prepared to continue with the spray program.

Table 1: Suggested spray programs for Magnesium Sulphate Heptahydrate

Crop	Concentration	Comments
Field crops	2 kg/100 L	Use for quick correction of an existing deficiency. Several sprays may be required. Direct supplementation of livestock with a suitable magnesium product will be required where hypomagnesaemia (grass tetany or staggers) occurs.
Vegetables, e.g. Tomato, Capsicum	1 - 2 kg/100 L	In young, affected crops, apply fortnightly.
Potatoes	1 kg/100 L	Two sprays in first 30 days after emergence. Continue spraying at two-week intervals if required.
Strawberry	1 kg/100 L	Apply every 4 weeks from April to September (Qld).
Apple, Pear	1 - 2 kg/100 L	Apply fortnightly during spring. A late summer spray before the leaves fall is recommended where magnesium deficiency is evident.
Grape	2 kg/100 L	Apply 5 sprays at fortnightly intervals from post-flowering through to veriason (berry colouring)
Citrus	1 kg/100 L	Apply in late spring when spring flush leaves are two-thirds expanded. Spraying is the only effective treatment for deficient citrus on calcareous soils.
Custard apple	1 kg/100 L	Apply 2 - 3 sprays

Fertiliser burn may occur at these concentrations, particularly if other nutrients are applied at the same time, or if the water is of poor quality. If foliar 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 magnesium sulphate for the first time or to new crop, or applications 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 entire crop. Some crops, e.g. strawberry, French bean, and navy bean are more susceptible to fertiliser burn than others. Spray concentrations may need to be reduced in sensitive crops.

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. Suggested addition rates for urea are 1 kg/100 L in field crops, 500 g/100 L in vegetables, and 100 g/100 L in tree crops. Add a wetting agent at label recommended rates.

Apply in the early morning or late afternoon or evening. Avoid spraying in the heat of the day. Do not spray under hot, dry, or windy conditions, when the humidity is low.

8. COMPATIBILITY IN SOLUTION

Magnesium sulphate and magnesium nitrate are compatible in solution (dissolved in water) with urea), ammonium nitrate, potassium nitrate, potassium sulphate and potassium chloride, metallic sulphates,

metallic chelates and sodium molybdate. They should not be mixed with phosphate, calcium or boron fertilisers, as an 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 minimise sediment formation and settling in tanks.

Check the labels of all agricultural chemicals that are to be added to the spray mixture for compatibility advice before use. Magnesium salts add to the hardness of water, which may affect their efficacy.

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.

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

9. CORRECTING SOIL STRUCTUAL PROBLEMS CAUSED BY MAGNESIUM

Soils in which the exchange capacity is largely saturated with magnesium have a poor physical structure. The clay particles tend to disperse resulting in poor water infiltration rates. Calcium has the opposite effect, causing clay platelets to aggregate together, giving a friable soil of good structure. Calcium sulphate (gypsum) is used as a soil ameliorant where soils have a poor physical structure resulting from high magnesium or sodium.

High gypsum application rates are likely to be required, which may make treatment uneconomical, particularly where low value crops or pasture are grown.

10. MAGNESIUM IN WATER

If water is high in magnesium or is high in magnesium relative to calcium, e.g. some bore waters in the Bundaberg area, its long-term use may affect soil structure (by replacing calcium on the exchange sites of clay particles with magnesium). Magnesic water may also affect animals if used for drinking, i.e. it may cause scouring. Note. The addition of magnesium fertiliser to water used for irrigation or foliar sprays will make the water harder.

11. MAGNESIUM IN ANIMALS

If magnesium is low in forage (less than 0.2% Mg in dry matter), grass tetany or staggers (hypomagnesaemia) may occur in grazing animals. Grass tetany most commonly occurs on lush fast-growing crops or pasture, e.g. in the spring on temperate pastures, and in high producing animals e.g. pregnant animals and lactating dairy. Specialist advice from a veterinarian or animal nutritionist should be sought as to the best way to prevent or treat magnesium deficiency in animals.

Improving the soil's fertility and magnesium status may be of benefit. By applying a magnesium fertiliser to the soil, the magnesium content of forage can be increased. Alternatively, or in addition to applying magnesium to the soil, it may be better to supplement the animal. This can be achieved in

various ways, e.g. spraying magnesium sulphate on the pasture, direct supplementation through licks or feeds, or the use of rumen pellets.

Finely ground magnesium oxide is often used as a magnesium supplement for livestock. The granulated fertiliser grades of magnesium oxide are unsuitable for this use, as they are too coarse.

12. FURTHER READING

Agritopics are available on “Soil Acidity”, “Lime and Dolomite”, “Fertigation” and “Foliar Fertilisers”, should more detailed advice be required on these topics.

13. 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.

14. 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.

15. 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.

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