Incitec Pivot Fertilisers

AGRITOPIC

March 2022

ZINC

1. INTRODUCTION

Zinc (Zn) is an important micronutrient in plant, animal and human nutrition. In Australia, zinc deficiency is one of the most common micronutrient (trace element) deficiencies in agricultural crops. It occurs on a wide range of soil types varying from acid sands to alkaline clay soils.

2. ZINC IN SOILS

The total amount of zinc in soils is related to the parent material. Basaltic soils are high, whereas sandy soils are low in zinc. Ionic zinc is found on the exchange sites of clay minerals and organic matter. It may be adsorbed as the divalent cation Zn^{2+} and, as $ZnOH^{+}$ and $ZnCl^{+}$ to a lesser extent. Up to 60% of the total soluble soil zinc is associated with soluble zinc organic complexes. Zinc held by organic matter is fairly immobile and very little is lost through leaching. Factors affecting zinc availability to plants include:

Soil texture

Sandy soils are often low in available zinc. Their labile (exchangeable) zinc content is generally much lower than finer-textured clay soils. Even when water-soluble zinc in the immediate vicinity of growing roots is high, it is likely to be depleted quickly.

Soil pH

The availability of zinc (mainly Zn^{2+}) is highly pH dependent and on alkaline soils decreases 100 fold for each unit increase in pH. Zn^{2+} is most available within a pH range of 5.5 to 6.5. On acid soils, zinc deficiency is mostly caused by a low total zinc content, whereas on alkaline soils, the total zinc level may be high but, a deficiency occurs due to low plant availability.

Organic matter

There is a high correlation between available zinc and soil organic matter content.

Organic matter can interact with zinc in two important ways. Firstly, zinc can be mineralized and made available to plants from organic matter. Secondly, zinc interacts with soil organic matter forming both insoluble and soluble zinc organic complexes. Zinc bound or fixed in insoluble organic complexes is not readily released.

The availability of zinc also depends on the content of chelating agents in the soil, which can be exuded by plant roots or result from the decomposition of organic matter. Chelating agents increase the solubilization of zinc from soils and facilitate its movement to plant roots.

Topsoil removal

Land leveling (or soil erosion) often results in zinc deficiency in areas where the topsoil is removed, leveling the subsoil exposed. The subsoil is low in organic matter, in which most of the plant - available zinc is to be found. In semi-arid areas, e.g., the clay soils where cotton is grown, the sub-soil is also typically more alkaline than the topsoil. This is generally caused by higher concentrations of sodium and/or lime accretions.

Climatic conditions

Zinc availability may be related to climatic conditions. Cool temperatures and a wet winter-spring season may result in zinc deficiency in plants. This may be due to reduced microbiological release of zinc from organic matter and/or restricted root development. Waterlogging tends to increase zinc deficiency e.g., in paddy rice where zinc deficiency is often accompanied by visible symptoms of iron toxicity.

3. ZINC IN PLANTS

3.1 Uptake

Zinc is taken up by plant roots as Zn^{2+}. Other cations, e.g., Ca^{2+}, Mg^{2+}, and Cu^{2+}, may depress zinc (Zn^{2+}) uptake. Factors which may affect zinc uptake include:

Restricted Root Growth

Any factor that affects root development or the rates of diffusion of zinc in the soil may cause zinc deficiency, e.g., soil compaction, high water tables, container grown plants.

VAM

VAM (vesicular arbuscular mycorrhiza) is a beneficial fungi which infects the roots of most crops plants (canola is an exception). The mycelium (fungal threads) act like fine root hairs, effectively increasing the root surface area and greatly increasing plant uptake of immobile nutrients such as phosphorus and zinc.

VAM are dependent on growing plants for survival. If land is fallowed for a long period, e.g., 12 months, soil is frequently cultivated or non-host crops are grown, VAM populations will decline, increasing the likelihood that responses to zinc will be obtained. Phosphorus and zinc deficiencies are less likely to occur where short fallows are used.

Note. Some herbicides may also affect VAM and root growth.

Phosphorus

The application of phosphorus fertiliser may induce zinc deficiency by affecting the physiological availability of zinc in plant tissues. It was once thought that this was due to the precipitation of zinc phosphate in the soil, but this is now known not to be the case.

More recently, it has been found that VAM colonization of plant roots is reduced in crops growing in soils high in phosphorus. This may also contribute to the high incidence of zinc deficiency in these soils. Plants may be able to take up adequate phosphorus under lower VAM populations, but if soil zinc is low, plants may become zinc deficient.

Zinc has a low mobility within plants. The ease with which zinc is transferred to younger tissue is depressed further in zinc deficient plants.

3.2 Zinc deficiency symptoms

Zinc is the most common trace element deficiency in Australian agriculture with the exception of molybdenum deficiency in legume-based pastures.

Plants suffering from zinc deficiency often show chlorosis in the interveinal areas of the leaf. These areas are pale green to white in colour. In monocotyledons (cereals and grasses), chlorotic bands develop on either side of the midrib of the leaf. Symptoms are usually most marked in the seedling stages and tend to disappear as the crop matures.

Specific crop symptoms are:

- **Maize** - Bands or lines of pale green coloured tissue on either side of the leaf midrib (most severe at the base of the leaf). Some varieties show red and/or purple discolouration, while others exhibit no deficiency symptoms apart from stunting and slow growth.

- **Sorghum** - Symptoms are similar to those expressed by maize. Sometimes whole or portion of the leaf turns a purplish-red. Many varieties show no readily identifiable deficiency symptoms yet respond to zinc.

- **Linseed** - Symptoms appear at about three weeks after seedling emergence. Brown or white spots appear on the older leaves, a rosetting of terminal growth occurs, followed by branching of the plant from the base.

- **Oats** - Premature death of older leaves with twisting and blackening.

- **Wheat** - Small spray-burn type spots may develop on the leaves and leaf tips may die back. With many varieties however, no clear symptoms apart from a general unthrifty growth occurs.

- **Fruit Trees** - Leaf development is affected with unevenly distributed clusters or rosettes of small, stiff leaves being formed at the end of young shoots. Deficiency symptoms are more developed on the plant parts most exposed to sunlight.

- **Avocado** - The earliest symptoms are mottled leaves developing on a few terminals. The areas between the veins are light green to pale yellow. As deficiency progresses, the yellow areas become larger and the new leaves produced are smaller. In advanced stages, a marginal burn develops on these stunted leaves, shoot die-back occurs and the distance between leaves and stems is shortened, giving a crowded, feather-duster appearance. Yield is reduced and some of the fruit may be rounder than is normal for the pear-shaped varieties.

3.3 Zinc deficiency is increasing

The incidence of zinc deficiency and demand for zinc fertilisers has increased in Australia in recent decades. There are several reasons for this including:

- Higher crop yields (improved varieties and cultural practices), increasing the demand on the soil for nutrients including zinc.

- Declining soil fertility. Soil zinc concentrations have fallen as a result of nutrient depletion i.e., removal in crop and animal products.

- Expansion onto poorer classes of land.

- Reduced zinc availability in some soils and districts due to increases in soil pH e.g., as a result of the use of lime, irrigation with alkaline water and, cultivation, land leveling or erosion exposing or bringing more alkaline sub-soil to the surface.

- Increased cultivation in fallows. Tillage breaks up VAM hyphae and decreases the rate of survival during fallow period. Bare fallows reduce soil VAM populations.

- Finally, zinc has unintentionally been applied as an impurity in phosphorus fertilisers. The phosphate rock currently used to manufacture phosphorus fertilisers used in Australia contains appreciably less zinc than in the past, e.g., from ocean sources such as Banaba, Christmas Island and Nauru. Where fertilisers made from these rocks were used, sufficient zinc was often applied to meet crop and pasture requirements.

Some examples of typical zinc concentrations found in various phosphate rocks are listed below.

Source	mg/kg Zn
Nauru	760
Duchess (Qld)	150

Florida	90
Bucraa	80

Nauru phosphate rock was commonly used in the manufacture of superphosphate and high analysis phosphorus fertilisers in Australia until 1990. The current use of Nauru phosphate rock has been less frequent and in smaller quantities and/or, blended with other phosphate rocks in the manufacture of superphosphate to reduce the cadmium content of the finished product. Phosphate rocks that are high in zinc are also high in cadmium.

Bucraa phosphate rock from Morocco in the Western Sahara has been one of the more commonly used phosphate rocks in the manufacture superphosphate.

The high analysis phosphorus fertilisers such as DAP and MAP available for use in Australia today are either made from Duchess phosphate rock at the Incitec Pivot plant at Phosphate Hill in north west Qld or are imported. The imported products are mostly made from Florida rock.

3.4 Zinc toxicity

High levels of zinc may adversely affect some crops. In tomatoes, excess zinc increases susceptibility to "grey mould", especially in low calcium soils. However, some plant species are zinc tolerant and are able to grow in soils abnormally high in available zinc.

In acid soils with toxic zinc levels, liming to pH 7 is the usual treatment as zinc availability is reduced when pH rises above 6.5. High zinc levels may induce manganese deficiency.

4. CRITICAL LEVELS OF ZINC

4.1 Soil analysis

Total soil zinc concentrations are usually in the range of 10-300 mg/kg Zn. However, the amount of water soluble and exchangeable zinc in the soil is a better measure of plant available zinc than total soil zinc.

Various tests are available to measure plant available zinc. In Australia, zinc soil tests have generally been better researched and can be used with greater confidence than tests for the other trace elements. However, local factors need to be taken into consideration when interpreting the results, e.g., soil type and pH, length of fallow, type of crop to be grown and district experience with the use of zinc fertilisers.

Some general guidelines for the DTPA method used by the Incitec Pivot Laboratory are:

- In many cereal and oilseed crops, soils with levels less than 0.3 mg/kg Zn are likely to require zinc fertiliser. Where the soil pH is greater than 7.0, the critical level is 0.8 mg/kg Zn.

- For high value, highly productive, or crops with a high zinc requirement, e.g., vegetables and fruit crops, it is suggested that the soil level should be above 2 mg/kg Zn.

- Zinc is seldom toxic to crops but levels over 20 mg/kg Zn may cause nutrient imbalances.

A specific zinc soil test for use in sugarcane using hydrochloric acid as the extractant has been developed by the BSES for use on acid soils.

4.2 Plant tissue analysis

The ranges for optimum growth can vary widely for different plant species. Generally, most plants require levels in leaf tissue higher than 20-25 mg/kg Zn and lower than 100 mg/kg Zn.

Zinc deficiency levels in leaf tissue of plants usually range from 0-15 mg/kg Zn.

5. ZINC FERTILISERS

Zinc can be applied in many ways, either on its own or in combination with other nutrients and either to the soil or crop foliage. Zinc compounds used as fertilisers include:

5.1 Zinc Oxide

Zinc oxide (ZnO) contains 80% Zn. Zinc oxide is insoluble. To be effective, zinc oxide must be applied as a fine powder or dust. This makes application on its own difficult and requires the use of a carrier. Zinc oxide is added to other fertilisers during their manufacture. It can be used as a seed coating and is available as micro-fine suspension grade products that can be applied as a foliar through a boom spray.

5.2 Zinc Sulfate Monohydrate

Zinc Sulfate Monohydrate ($ZnS0_4.H_20$) contains 33-35% Zn. Incitec Pivot Fertilisers markets a granulated grade of the product (33% Zn) that can be applied on its own dry to the soil or used in blends. It is not used in the preparation of solutions.

5.3 Zinc Sulfate Heptahydrate

Zinc sulfate heptahydrate ($ZnS0_4.7H_20$) contains 22.7% Zn. Both zinc sulfate monohydrate and zinc sulfate heptahydrate are water soluble. The fully hydrated zinc sulfate heptahydrate dissolves more readily and is used where zinc is applied as a liquid solution. Fine crystalline grades are available for this purpose and can be either sprayed on the soil through a boom-spray, used in fertigation programs and water injection equipment, or sprayed onto plant foliage.

5.4 Zinc Oxysulfate

Zinc oxysulfate is manufactured by partially acidulating zinc oxide with sulfuric acid and granulating the end product. Zinc oxysulfate contains zinc in the oxide and sulfate forms. On application of the granules to the soil, the zinc sulfate dissolves, releasing fine particles of zinc oxide. Zinc oxysulfate products are variable in analysis and often contain around 18% Zn. They are not fully soluble and are therefore unsuitable for application in liquid solution.

5.5 Zinc Chelate

Zinc chelate fertilisers are available as either a micro-granule or a liquid formulation. Analysis of microgranule products range from 12%-15% and liquids products range from 7%-9%. Zinc chelate solutions can be either directly applied to the soil surface, subsurface banded, fertigated or as a foliar spray. Chelates are less subject to fixation in water or soil than other zinc formulations. They are more compatible with commonly used ag-chem products than zinc sulfate and have a higher market price.

6. GRANULOCK FERTILISERS

Incitec Pivot manufactures two zinc enriched fertilisers. The analysis is shown Table 1.

Table 1: Analyses of Incitec Pivot Granulock Fertilisers.

PRODUCT	% N	% P	% S	% Zn
Granulock Z	11	21.7	4	1
Granulock Big Z	16.1	4.3	16.1	10

Granulock Z

Granulock Z is a zinc enriched MAP (monoammonium phosphate) fertilizer which contains 1% Zn. Granulock Z is used in place of MAP (or DAP) at planting in grain and cotton crops where zinc is required.

The application of Granulock Z at planting provides available zinc to the small, poorly developed root system of young seedlings. It provides more point sources and a better distribution of zinc in the plant row than blended fertilisers, as zinc is present in each granule. This is of importance in crops planted at narrow row spacings such as. winter cereals.

Granulock Big Z

Granulock Big Z contains 10% Zn. Incitec Pivot Fertilisers only use Granulock Big Z as a blend ingredient. It is not sold as a straight. Situations where Granulock Big Z is used in blends include:

- Where a higher zinc concentration than the 1% in Granulock Z is required in grain and cotton. Granulock Big Z can be added to Granulock Z to increase the zinc content.
- In SuPerfect and SuPerfect Potash blends for use in pastures on sandy soils, where a typical application rate for zinc is 2 kg/ha Zn. Adding 20 kg/ha of Granulock Big Z (10% Zn) to the blend will provide more point sources of zinc in the field than 6 kg/ha of Zinc Sulfate Monohydrate (33% Zn).

Note:

Incitec Pivot Zinc Sulfate Monohydrate (33% Zn) is used in blends where zinc is applied at high rates e.g., 10 kg/ha Zn. Applications include planting fertilisers for sugarcane, crops planted at wide row spacings and, in tree plantations and vine crops.

7. PREVENTION/CORRECTION OF ZINC DEFICIENCIES

7.1 Soil Application

Soil application rates for zinc vary depending on such factors as the soil's texture, soil pH and the crops to be grown. High rates of zinc are required on alkaline clay soils as zinc can be fixed and become unavailable for plant uptake. Sandy soils are likely to be low in total and available zinc but require lower rates compared to alkaline clays soils as zinc is less likely to be fixed in the soil. Zinc application rates also depend on how frequently zinc is to be applied.

Zinc is generally regarded as being immobile in most soils, with very little movement from the point of application. Leached is not regarded as being an issue in most situations. Zinc can be applied at a high rate intended to last several years, which is a common practice in pastures, cotton and sugarcane.

Zinc can also be applied at lower rates on a more frequent basis. In annual crops zinc can be applied at planting. In the case of tree, plantation and vine crops, once a year in the spring or in combination with other fertilisers throughout the growing season. Typical rates (kg/ha Zn) at which long term applications of zinc are made, i.e. at intervals of about 5 years, are shown below.

<u>Pasture</u>

- 2 kg/ha Zn on lighter-textured soils,

- 4 kg/ha Zn on clays.

Zinc is best applied as Granulock Big Z in pasture as a blend with SuPerfect (plus Muriate of Potash where it is required as well).

If zinc sulfate heptahydrate is applied in a liquid solution through a boom-spray to established pasture, apply it when the pasture is short and withhold stock until after rainfall has occurred. This helps ensure the maximum amount of zinc reaches the soil and minimises the amount ingested by livestock.

Grain, Cotton and Forage Crops

- 2 kg/ha Zn on light-textured sandy soils,
- 5 kg/ha Zn on loams, and
- 10 kg/ha Zn on clays.

The zinc fertiliser should be applied pre-plant and drilled into the soil. If spread or sprayed on the soil surface, the zinc should be incorporated afterwards. Ideally, cultivate twice before planting. Surface applications without incorporation are relatively ineffective as the zinc is left at the soil surface where plants cannot utilize it.

Minimum tillage practices currently utilised in crop rotation systems limit the opportunity to incorporate zinc into the cultivation layer of soils. Zinc can be annually applied at planting with Granulock Z. Where opportunity tillage occurs or deep placement of nitrogen, phosphorus or potassium is planned, blending these fertilisers with Granulock Big Z allows zinc to be applied deeper in the soil profile.

Vegetables

- Up to 10 kg/ha Zn

Apply pre-plant and incorporate into the soil.

Tree, Plantation and Vine Crops

- 7-10 kg/ha Zn

For new orchards, plantations, vineyards, apply while the land is being prepared for planting and incorporate into the soil. Once established, apply in one of the following ways:

- To the whole floor area of the orchard.
- Uniformly over the entire root zone of the trees i.e., under the whole canopy and just beyond the canopy but not within 30 cm of the trunk.

- Concentrated in a band at least 30 cm wide around the drip-line i.e., where the roots are most active.
- Concentrated in a band at least 30 cm wide along the canopy edge of the hedgerow if the canopies have met.
- Fertigate at key crop develop stages.

For young trees, treat the area that the roots will be growing into as well as the area where most roots are now present.

Trees may be slow to respond to soil applied zinc. Where zinc deficiency is evident in the foliage, it is recommended that foliar sprays of zinc be applied as well in the first year after applying zinc to the soil, or until such time that deficiency symptoms are no longer apparent.

Sugarcane

- Apply 10 kg/ha Zn in the drill with the planting fertiliser.

This should last a complete crop cycle (plant plus ratoons).

Annual Soil Applications

Soil applications at the above rates may remain effective for longer than 5 years in some circumstances and less in others. Rather than apply zinc every five or so years, zinc is commonly applied annually at lower rates in combination with other fertilisers.

Typical annual application rates in perennial horticultural crops are 1-2kg/ha Zn. This can be applied once a year at the start of the main growing season e.g., in the spring or split into a number of smaller applications. Similar rates i.e., 1-2 kg/ha Zn are used when planting annual crops such as grain and vegetables. In grain crops, this rate may be reduced to 0.5-1 kg/ha after a number of years of application.

Granulock Z is the recommended way to apply zinc where it is required in forage, grain and oil seed crops, including cotton. Zinc may also be applied to the soil annually with solutions in fertigation programs and though water injection equipment at planting:

Fertigation

In tree, plantation and vine crops, zinc sulfate heptahydrate can be applied at 5 kg/ha per annum through drip and trickle irrigation systems and under tree sprinklers.

Fertigation with zinc should only be contemplated in annual crops where sub-surface emitters are placed under the crop row e.g., in permanent beds. Here, zinc sulfate heptahydrate can be applied at 2 - 3 kg/ha within two weeks of planting. Application should not be delayed, given that zinc needs to be applied early in the life of a crop.

Zinc should not be applied through overhead sprinkler systems in annual crops, as the zinc will remain at or near the soil surface and be positionally unavailable to the crop's root system.

Water Injection

Zinc can be applied with the seed in wide row crops such as sorghum and cotton using water injection equipment. A typical application rate for zinc sulfate heptahydrate is 1-4 kg/ha.

If planning to mixed zinc with technical MAP, it is best to select a zinc chelate based product. Adjusting the pH of the fertilizer solution to below 5 may to reduce the formation of precipitate (sediment) when technical MAP and zinc sulfate are mixed together but can still be problematic.

7.2 Foliar Application

In many crops, foliar sprays of zinc may be used in place of or to supplement soil applications. Foliar zinc sprays are not used in pasture or sugarcane.

In annual crops, preventative sprays should be applied from soon after emergence. Zinc deficiency should not be allowed to develop before corrective sprays are applied.

In tree crops, zinc should be sprayed onto a new growth flush e.g., spring. Late season sprays i.e., approaching harvest are usually ineffective.

Zinc sulfate heptahydrate (22.7% Zn) is typically applied at 1 kg/ha/application. One or two sprays may be required in grain and tree crops and up to four sprays in vegetable crops.

In horticultural crops, zinc can be applied in combination with crop protection sprays provided no compatibility problems exist. Typical spray volumes in horticultural crops are around 500 L/ha in vegetables and 1,000 L/ha or more in tree crops.

Zinc is often sprayed on its own in grain crops.

Typical spray programs, where foliar sprays are used to meet the crop's zinc requirements i.e., zinc has not been applied to the soil are discussed on the following page:

Grain

Apply two to three sprays of zinc sulfate heptahydrate at 1 kg/ha at 3, 5 and 10 weeks after emergence. Spray volumes of up to 100 L/ha are used though typically this is lower e.g., 30-50 L/ha.

Vegetables

Where seedlings are grown, apply an initial spray of zinc sulfate heptahydrate at 100g/ 100L (0.1% w/v) in the seedbed before transplanting. After planting and in crops grown from seed, apply three to four sprays of zinc sulfate heptahydrate at 200-250 g/100L (0.2-0.25% w/v) at two-week intervals in the early stages of growth.

Lower concentrations may be required in sensitive crops. In **Strawberry**, restrict the zinc sulfate heptahydrate concentration to 100 g/100L.

Spray volumes will increase as the crop matures e.g., starting around 250 L/ha then increasing up to about 500 L/ha when the last spray is applied.

Tree and Plantation Crops

Apply zinc sulfate heptahydrate at 100 g/100L (0.1% w/v) in the spring to an expanding flush of growth. More than one spray may be required. The spray volume may be 1,000L /ha or more.

If zinc deficiency becomes apparent at any stage, apply a foliar spray as soon as it is practical.

Notes

Zinc recommendations and application rates vary. If specific crop and district advice is available, it should be used in preference to the general advice in this Agritopic.

The spray concentration of zinc needs to be adjust depending on the target spray volume (high or low) in order to apply the correct rate of zinc.

Add a wetting agent at label recommended rates.

The addition of urea to the spray mixture can assist leaf uptake of the zinc. Rates to use are:

- 1 kg/100 L (1% w/v) in field crops.
- 500 g/100 L (0.5% w/v) in vegetables.
- 100 g/100 L (0.1% w/v) in tree crops.

Nutrient sprays may burn plant foliage. Refer to the Incitec Pivot Agritopic on "Foliar Fertilisers" for further information.

7.3 Compatibility of Zinc Sulfate in solution

Zinc sulfate heptahydrate is compatible in solution with urea, ammonium nitrate, potassium chloride (Muriate of Potash), potassium nitrate and other metallic sulfate fertilisers.

Do not mix with ammonium sulfate, phosphorus fertilisers (MAP and MKP), potassium sulfate (Sulfate of Potash), calcium nitrate, magnesium sulfate or boron fertilisers, as insoluble precipitates will form.

Zinc may also be precipitated as zinc hydroxide or carbonate if the spray mixture is alkaline i.e., pH is above 7. This can be overcome by slowly adding a little sulfuric (battery) acid to the mixture while stirring. Ideally the pH should be in the range of 5.0 to 6.5.

8. FUNGICIDAL SPRAYS

Fungicides such as zineb and mancozeb contain zinc. Where these are used on a routine basis e.g., in some horticultural crops, there may not be a need to apply additional zinc to the soil and/or foliage (depending on the severity of any deficiency).

WARNING

This information is for use as a guide only. The use of fertilisers is not the only factor involved in producing a top yielding crop or pasture. Local soil, climatic and other conditions should also be taken into account as these could affect crop or pasture responses to applied fertiliser.

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