Nutrient Management

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ELEMENT	ROLE in PLANT	DEFICIENCY SYMPTOM	DEFICIENCY CAUSES
Boron (B) Micronutrient Deficient* 0.0 – 0.3 Adequate** 1.2 High 2.0 Hot water extraction (ppm)	Essential for normal plant growth canola and legume crops in particular. Promotes crop maturity, water balance, flower set and yield.	• Leaf distortion and leaf texture changes • Death of growing points • Cracking and rotting • Poor fertilization and seed set	• Low soil B • High soil pH • Excessive rainfall • Dry weather • Sandy soils with low organic matter
	ROLE in SOIL	Soil organic matter is the major reserve of boron (B) in most agricultural soils. It is released as the soil organic matter decomposes, its availability fluctuating according to soil microbial activity. In the soil solution, boron is present in a non-ionic form and is not attracted to soil colloids. It is among the most mobile nutrients in the soil, and can be rapidly leached once released from soil minerals and organic matter. Light textured soils in high rainfall areas are often low in boron, while boron can accumulate in the sub-soil in semi-arid regions, particularly on heavier textured clay soils, and may reach toxic concentrations.	
ELEMENT	**ROLE in PLANT**	**DEFICIENCY SYMPTOM**	**DEFICIENCY CAUSES**
Calcium (Ca) Macronutrient Ca, Mg, K and H cation ratio's important	Cell wall structure component. No specific recommendation other than liming low pH soils, 5.5 or less. Acts as a catalyst for nitrogen uptake. An important part of soil C.E.C. ideal base saturation level is 65-75%	• Low storage potential of seed • Blossom end rot of tomatoes • Cavity spot in carrots • Hollow heart in potatoes	• High nitrogen • Hot, dry weather • High potassium • High magnesium • High phosphate
	ROLE in SOIL	Calcium is an important plant nutrient and plays an important role in determining soil physical and chemical parameters, i.e. structure and pH. 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 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. Exchangeable calcium levels and soil acidity are usually closely related. Calcium is most available in the pH range 7.0 to 8.5. Under low pH or acid soil conditions, exchangeable calcium levels in the soil are usually low, and the solubility of manganese and aluminium increase and may become toxic.	
ELEMENT	**ROLE in PLANT**	**DEFICIENCY SYMPTOM**	**DEFICIENCY CAUSES**
Copper (Cu) Micronutrient Deficient < -0.6 Adequate 0.9 – 2 High 2.5 + DTPA extraction (ppm)	Wheat, barley and flax crops are very sensitive to deficient Cu levels. Very important in plants reproductive growth stage and indirect role in chlorophyll production. Deficiency results in major yield and quality losses.	• Spiralling of leaves, especially the flag leaf, of cereals • Chlorosis of leaf tips • Stunted plants • Poorly filled heads	• Low soil Cu • High soil pH • High soil organic matter (peat or muck) • High Fe • High manure applications
	ROLE in SOIL	Copper (Cu) is present in relatively small amounts in soils, with sandy soils low in organic matter having the lowest concentrations. Copper is most available for plant uptake in acid soils. As the soil pH increases above 7.0, copper availability declines due to stronger copper adsorption. Elevated soil concentrations of copper are found in regions where copper rich ores, e.g. of silver, lead or zinc, are found, and where copper fungicides have been routinely used. Copper is held very tightly on clay and organic exchange sites in the soil. Consequently, copper is very immobile. Low copper concentrations are found in the soil solution, and it is not easily lost by leaching.	

ELEMENT	ROLE in PLANT	DEFICIENCY SYMPTOM	DEFICIENCY CAUSES
Iron (Fe) Micronutrient Deficient 5.0 Adequate 11 – 16 High 25 + DTPA extraction (ppm)	Critical for chlorophyll formation and photosynthesis. Important in enzyme systems and respiration in plants.	• Yellowing (chlorosis) of youngest leaves	• High pH soils • High copper levels • Poor drainage • Calcareous soils • High Zn, Mn, or Cu levels
	ROLE in SOIL	Of all the elements plants derive from the soil, iron (Fe) is the most abundant, total iron concentrations often being around 2.5%. It is ranked fourth in abundance after oxygen, silicon and aluminium in the earth's crust. As far as plant nutrition is concerned, iron is classified as a micronutrient or trace element, as it is only required in small amounts. Any problem with iron supply to plants is therefore one of its availability in the soil, not the amount present.	
ELEMENT	**ROLE in PLANT**	**DEFICIENCY SYMPTOM**	**DEFICIENCY CAUSES**
Magnesium (Mg) Macronutrient	The key element in the chlorophyll molecule. There would be no greening in the absence of Mg. First shows up as yellowing on older leaves. Important component of C.E.C. base saturation levels ideally are in 10-20% range.	• Interveinal chlorosis • Symptoms appear first on older leaves • Reduced crop growth	• Low soil Mg • Low soil pH • High soil K • Poor drainage or compaction
	ROLE in SOIL	Most of the magnesium in the soil exists in forms that are not directly available to plants. About 5% of the total 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. Magnesium also has an influence on the structure of clay soils. Once the magnesium percentage of exchangeable cations exceeds 20%, the soil will become increasingly difficult to work, as magnesium causes clay particles to disperse. Magnesium concentrations often increase with depth. If magnesium is low in the top-soil but high in the sub-soil, magnesium deficiency is less likely to occur, or may be temporary.	
ELEMENT	**ROLE in PLANT**	**DEFICIENCY SYMPTOM**	**DEFICIENCY CAUSES**
Manganese Micronutrient Deficient < -4.0 Adequate 9 – 12 High 30 +	Important for all cereals on high pH mineral (alkaline) and organic soils. Enzyme systems involved with carbohydrate and nitrogen metabolism.	• Interveinal chlorosis (marbling) of younger leaves • Pale striping and brown spots on cereals • Floppy plants (cereals) • Upright growth habit and triangular leaves on Sugar Beet	• Low soil Mn • High soil pH • High soil organic matter • Poor drainage • High Fe
	ROLE in SOIL	Manganese (Mn) is present in the soil in greater quantities than other trace elements, with the exception of iron. Its concentration typically exceeds that of macronutrients such as phosphorus and sulphur, and often that of nitrogen. Consequently, where plant deficiencies occur, it is not because the soil is low in total manganese, but because most of it is present in forms which are not available for plant uptake. The total amount of manganese in soils is typically around 0.25%, and is normally in the range of 0.02 - 1%. It can be as high as 13% in some volcanic soils.	
ELEMENT	**ROLE in PLANT**	**DEFICIENCY SYMPTOM**	**DEFICIENCY CAUSES**
Molybdenum (Mo) Micronutrient Deficient < -0.05 Adequate 0.11 – 0.2 High 0.40 + Hot water extraction (ppm)	Essential for nitrogen fixation in legumes and nitrogen metabolism in crucifers (canola). Mo deficiency resembles iron chlorosis. Forages range from 0.1 to 3 ppm/kg of dry matter.	• Reduced plant growth (symptoms of N deficiency) • Reduced leaf area (whiptail in cauliflowers)	• Low organic matter • Low soil pH (acidic soils)
	ROLE in SOIL	Molybdenum (Mo) is the least abundant of the trace elements in soils, and very little is present in forms that are available to plants. Sandy soils, and those which are inherently infertile in their natural state, e.g. soils low in phosphorus, are typically low in molybdenum. Peats tend to be high in molybdenum. Availability in the soil is influenced by the pH. Acid soils, i.e. pHw less than 6.0, and the presence of iron and aluminium oxides greatly reduce the availability of molybdenum. Molybdate is quite strongly sorbed, or attached to clay particles or organic matter in soils, and is therefore not readily leached. Of the anions (negatively charged ions) which are of importance as plant nutrients, molybdate is second behind phosphate in this respect, and much more strongly sorbed (resistant to leaching) than nitrate or chloride.	

ELEMENT	ROLE in PLANT	DEFICIENCY SYMPTOM	DEFICIENCY CAUSES
Nitrogen (N)	Important for synthesis of amino acids and production of chlorophyll. Essential for protein and nucleic acid formulation.	• Lack of growth or stunted growth • General yellowing of foliage, older leaves first • Loss of leaves under severe deficiency • Purplish colouration due to accumulation of anthocyanin pigments	• Poor drainage (denitrification) • Leaching (low CEC and/or excess moisture) • Dry weather • Poor nodulation caused by low fertility, low pH, poor drainage or dry weather
	ROLE in SOIL	Nearly all the nitrogen (N) present in the soil originates from the atmosphere, which is made up of about 80 % nitrogen. The rocks and minerals from which soils are formed do not contain nitrogen. Most of the nitrogen present in the soil is in the form of organic matter. Organic nitrogen, however, is not available for plant uptake. It must first be converted to simple inorganic forms, i.e. ammonium (NH+4) and nitrate (NO3-). Nitrogen can be lost from the soil in various ways, through volatilization and denitrification to the atmosphere, and leaching below the root zone following heavy rain.	

ELEMENT	ROLE in PLANT	DEFICIENCY SYMPTOM	DEFICIENCY CAUSES
Phosphorus (P) Macronutrient	Essential for all plant growth, i.e. energy transfer.	• Reduced growth • Production of dark green foliage • Reduced tillering in cereals • Reddening or yellowing of leaf margins and necrosis of older leaves • Reduced fruit quality and storage potential	• Low soil pH • Cool soil temperature • High soil pH • Poor root system caused by wet soil, chemical or mechanical injury
	ROLE in SOIL	Australian soils are characteristically low in phosphorus in their native state, with the exception of a few soils of basaltic origin and some alluvial soils. Agriculture can further deplete soil fertility, even in soils that initially are high in phosphorus. Most of the phosphorus in soils is associated with organic matter. Even in mineral soils, between 20% and 80% of the total phosphorus will be present in organic forms. Phosphorus is most available for uptake by plants in the pH range 6.5 - 7.5. At pH below 5.5, slowly soluble oxides of iron, aluminium and manganese form, reducing phosphorus availability, while at pH above 7.0, slowly soluble calcium phosphate is formed. Phosphorus in the soil is relatively immobile. Phosphorus applied as fertiliser rarely moves any great distance in the soil without some form of physical mixing, e.g. cultivation. The distance that the phosphorus front moves in the soil from fertiliser granules is rarely much more than 4 - 5 cm.	

ELEMENT	ROLE in PLANT	DEFICIENCY SYMPTOM	DEFICIENCY CAUSES
Potassium (K) Macronutrient	The major ion inside every living plant and animal cell. Component of C.E.C. base saturation level is ideally 5 - 10%	• Mottled chlorosis, necrosis (especially at tips and margins between veins). • Older leaves most affected • In cereals, weak stalks, roots more susceptible to disease	• Low soil K • Leaching of K (low CEC) • Dry weather • Poor drainage or compaction
	ROLE in SOIL	Potassium (K) is quite abundant in soils, typically ranging from 0.5 to 4.0%. Of this, only a small part is present in water-soluble and exchangeable forms, and readily available for plant uptake, usually less than 1% of the total. Sandy soils have the lowest potassium content, clay and alluvial soils the highest. However, even clay soils can become depleted in potassium where considerable quantities are removed in farm produce, e.g. hay, silage, sugarcane. Potassium that is dissolved in the soil solution is subject to leaching. It is more readily leached than phosphorus, less so than nitrate nitrogen.	

ELEMENT	ROLE in PLANT	DEFICIENCY SYMPTOM	DEFICIENCY CAUSES
Silicon (Si) Micronutrient Deficient unknown Adequate unknown	The most abundant element on earth. Plays a role in disease resistance in crop plants. A structural component of some plant species.		

ELEMENT	ROLE in PLANT	DEFICIENCY SYMPTOM	DEFICIENCY CAUSES
Sodium (Na) Micronutrient Deficient unknown Adequate unknown	Many cultivated crops, such as beets, were originally sea shore plants. Sugar beets will respond to sodium fertilization.		• High water table • Manure applications • Runoff water • Low soil calcium levels

ELEMENT	ROLE in PLANT	DEFICIENCY SYMPTOM	DEFICIENCY CAUSES
Sulphur (S) Macronutrient	Absolutely essential for plant growth. Deficiency causes yield loss in all crops, especially canola.	• Purplish colourations • Cupping of leaves • Slow stunted growth	• Low soil S • Leaching of S on low CEC soils • Low soil organic matter
	ROLE in SOIL	70 - 90% of the soil Sulphur is present in the organic matter. This sulphur is not available for plant uptake until it has been converted to sulphate (SO_4^{2-}) by soil bacteria, a process known as mineralization. Mineralization occurs more rapidly when the soil is warm and moist, and has been cultivated. Consequently, sulphur fertiliser is more likely to be needed in pasture than in crops. Some sulphur is also received in rain (near industrialised areas and the sea). In Australia, this can exceed 10 kg/ha/annum S; but in inland areas, e.g. the New England Tableland, is often no more than 1-2 kg/ha S per year. The use of low sulphur fuels and added emphasis on air pollution control has reduced the amount of atmospheric sulphur reaching agricultural land through rainfall in many parts of the world. Compared to phosphate and ammonium ions, sulphate is not as strongly adsorbed onto clay and organic colloids. Consequently leaching losses can be appreciable on light textured soils in areas of high rainfall. In drier areas and in soils of a heavier texture, leaching is less significant. In these situations, crystalline calcium sulphate (gypsum) may accumulate in the sub-soil. Where this occurs, sulphur is seldom limiting as a plant nutrient, provided it is accessible by plant roots.	

ELEMENT	ROLE in PLANT	DEFICIENCY SYMPTOM	DEFICIENCY CAUSES
Zinc (Zn) Micronutrient Deficient < -0.5 Adequate 1.0 – 3.0 High 6.0 + DTPA extraction (ppm)	Very important in potato, flax, cereals and bean production. Deficiencies usually occur on eroded soils low in organic matter with high pH. Essential for sugar regulation and enzymes that control plant growth.	• Stunted plants • Pale stripes parallel to the leaf mid rib (maize) • Formation of rosettes (fruit trees) • Formation of small leaves • Chlorosis of young leaves	• Low soil Zn • High soil pH • High soil P • High soil Fe
	ROLE in SOIL	Zinc is present in higher amounts in clay soils, while sandy soils are low in zinc. Its availability for plant uptake is affected by pH, being most available in acid soils, and less available at high pH. On acid sandy soils, zinc deficiency is mostly caused by low total zinc content; whereas on alkaline clay soils, the total zinc level may be high but deficiency occurs due to low availability. Deficiency is also more likely to occur on soils low in organic matter. Zinc is not mobile in the soil. It tends to stay where it is placed. Plant roots therefore have to grow to the zinc, rather than have the zinc move in the soil solution to the roots.	