

Trace Elements – Importance

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Take Home Messages

- Trace elements are important in particular situations but are not miracle workers.
- Deficiencies are not uncommon, but when they occur can give large yield penalties.
- Diagnosis by soil test and tissue test is difficult, but in most cases, the potential for deficiencies can be assessed by reviewing soil types, crop type and seasonal conditions.
- Products vary in their efficiency and growers should look for evidence for the efficacy of products in their region.

Most growers and agronomists are fully aware of the nitrogen and phosphorus demands of crops, and meeting those demands is a major investment in crop production. Sulphur and potassium have are also important in some regions as have calcium and magnesium. These six nutrients – the macronutrients – are complemented by a set of nutrients required in smaller amounts – the micronutrients or trace elements. Even though needed in small quantities, Copper (Cu), Manganese (Mn), Iron (Fe), Zinc (Zn), Boron (B) and Molybdenum (Mo) are all essential for plant growth, although the demand is small relative to nitrogen and phosphorus.

The diagnosis of plant nutrient status requires information about the nutrient stores available for redistribution within the plant, the supply of nutrient from the soil and the nutrient requirement for growth and yield. This discussion aims to review these issues relative to micronutrients.

Diagnosis of the *RIGHT* problem

Just because the macro nutrient demands are met does not always mean that the next limit on yield is on one of the micro nutrients. Moisture is still a limit in most situations and if growers are to invest in micronutrients then correct diagnosis and treatment is critical – and the 4R's (Right Source, Right Rate, Right Time, Right Place) concept applies, and these four aspects need to be addressed. Micronutrients work with macronutrients but are not substitutes for them nor will they give responses unless they are a limiting factor.

Table 1 shows the results of a survey of wheat grain nutrient contents taken from the NVT sites in 2009 from Victoria and New South Wales. This shows the likely removal of these micronutrients, as well as showing the sorts of variation within and between regions. Molybdenum levels are not given as they were virtually all less and 0.4 mg/kg.

Table 1. Wheat grain nutrient concentrations (Norton, 2011) and critical nutrient concentrations (Reuter and Robinson, 1997)

		Fe mg/kg	Mn mg/kg	B mg/kg	Cu mg/kg	Zn mg/kg
NSW	South East	42.1±2.2	57.6±3.6	1.6±0.3	3.9±0.4	23.0±2.4
	South West	39.5±2.2	54.4±3.6	1.7±0.3	4.1±0.4	23.5±2.4
Vic	Mallee	34.9±1.5	36.8±2.6	3.4±0.2	5.1±0.3	18.9±1.7
	North Central	41.0±3.0	55.8±5.1	1.7±0.5	4.7±0.5	25.5±3.4
	North East	44.3±3.0	53.3±5.1	1.4±0.5	5.1±0.5	28.8±3.4
	Wimmera	36.2±1.9	49.2±3.2	4.6±0.3	4.8±0.3	27.3±2.2
Total	Mean	36.8±6.9	43.5±13.8	2.2±1.3	4.8±1.2	23.0±7.3
Grain Critical Values		-	20	2.0	1.0	23

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There is also regional variation in the soil test levels for these nutrients. The values in Table 2 are taken from the Nutrient Advantage laboratory soil analyses from 2011. While these soil test values indicate that low zinc and copper levels across all regions, the most common deficiency indicated is zinc in the Mallee – associated particularly with high soil pH. Soil tests for micronutrients generally have a lower reliability than soil tests for the macronutrients. As well as the uncertainties associated with seasonal conditions, rooting depth and nutrient demand, micronutrient availability is often derived from a number of soil pools that may not necessarily be extracted in the soil tests. Soil organic matter, texture and soil pH are all moderating influences on nutrient availability and often need to be considered in association with the soil test values measured. The difficulty with assessing the availability of metal cations (like Cu, Zn, Mn and Fe) is affected by redox state as well as the formation of metallo-organic ligand complexes and they can also precipitate (usually as hydroxides) depending on concentration and pH. Boron is present either as boric acid or as dissociated ions depending on pH, while molybdenum is present as an oxyanion (molybdenate). This chemistry is complex and soil tests generally struggle to provide a full picture of bioavailability from simple extractants.

Table 2. Percentage of samples with DTPA zinc, DTPA copper and hot water extractable B values (top 10 cm) below critical values for four regions in Victoria.

Nutrient	Wimmera	Mallee	Western	Central
zinc (<0.5 mg/kg)	22%	61%	37%	40%
copper (<0.3 mg/kg)	30%	7%	31%	9%
boron (<0.5 mg/kg)	8%	*	*	*

* insufficient samples available

Soil tests for zinc, copper and boron are available but the caution with these tests (other than chemistry) are that often subsoil nutrient supplies can be more than topsoil, particularly with mobile nutrients (eg B). While soil tests have been correlated to crop responses in properly conducted trials, the trials have been limited and the confidence limits can be quite large. This then reflects on the critical levels developed, which are often very low in absolute terms and sampling errors and analytical reliability make them difficult to confidently apply. For example zinc critical soil test value is 0.75 mg/kg and while this can be accurately measured, the critical values are at the lower levels of confidence for predicting responses. In some cases, such as boron, the deficiency value is not very different to the toxicity value. As with all soil testing, it is important to use accredited laboratories that use ASPAC accredited methods for assessing nutrients – these tests are ones that have critical values established for Australian conditions. Copper and Zinc are usually tested using the DTPA extractions method but the critical values Cu vary for different species. Boron is tested from hot water or KCl extracts. There are no Australian data for soil test calibrations for Mo or Mn status. For all tests, often soil pH, organic C levels and clay contents may need to be included to make an assessment of the likelihood of deficiencies from a soil test.

Trace elements are often chemically similar to other elements and so there can be interactions among nutrients – where excess of one will induce a deficiency of another. Well documented examples are between phosphorus and zinc (Zhu et al. 2001), and between sulphur and molybdenum (Shinmachi *et al.* 2010). The literature is full of these types of interactions that may affect the response under certain conditions.

Despite this considerable complexity, soil conditions can be a good guide to the potential for low availability of particular micronutrients. Soil pH is particularly important, as this affects the plant availability of the nutrient. Water logging and drought, soil texture and organic matter content can

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also affect potential micronutrient availability. Table 3 gives a useful summary to check off particular nutrients under various soil and environmental conditions.

Table 3 Soil factors affecting micronutrient availability. + indicates the factor increases bioavailability, and – indicates a reduction in bioavailability.

	Cu	Fe	Mn	Zn	B	Mo
pH > 7.0	---	---	--	---	**	++
pH < 5.5	++	+++	+++	+	--	--
water-logged soil	+	--	+	+		
drought	---	---	---	-	---	--
high humus content	---	++	++	++	++	-
high P-content	-	---	-	---	-	+++
sand	---	---	--	---	--	-
compaction	+	++	+	+	+	+

** boron availability decreases at very high pH.

Tissue Testing

Testing plant tissue for the concentration of nutrient relies on a known relationship between the tissue in question and the degree of limitation that concentration places on crop performance (yield). These relationships are developed between tissues that have consistent responses and at time when nutrient supply is likely to be most limiting. For example, sampling old leaves for N is likely to be of little value as N is mobile and rapidly moved to areas of demand. Figure 1 gives a general view of the types of tissues to sample for nutrient assessment.

Figure 1 Tissues to sample for nutrient testing, symptoms occur in the older leaves first with mobile nutrients and the younger leaves first with less mobile nutrients (Price 2006).

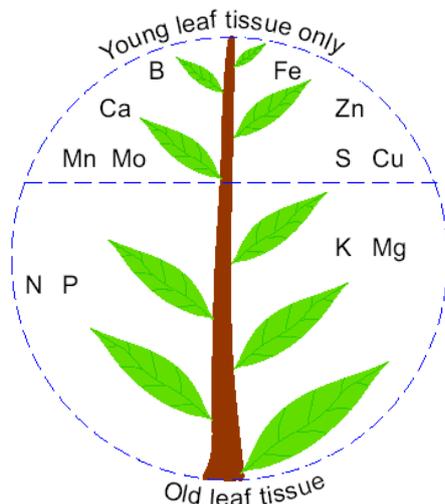
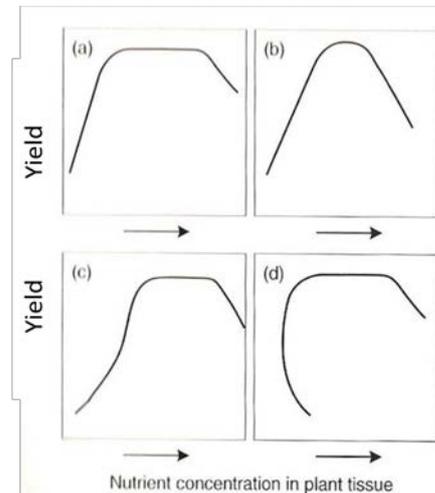


Figure 2 Relationships between yield and nutrient concentrations in plant parts frequently found in plants as nutrient supply increases from deficient to toxic.



A difficulty with interpreting tissue concentrations is that there are at least four relationships seen between yield and nutrient concentration (Figure 2, adapted from Smith and Loneragan, 1997). The most common form is as shown in 2a, which is similar to the soil test and yield relationship. There may be several different yield and nutrient concentrations and examples are shown in figure 2, including 2d (Piper-Steenbjerg effect) which shows that a particular tissue concentration can decline

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when more nutrient is added such as with Cu. Another major caution with tissue testing is that when the plant samples are taken, other reserves (*eg* deeper in the soil) may not yet be accessed and so that a false low tissue content can result. In 2011, there were several reports of low tissue B in canola, but few responses were seen to added B because the crop eventually accessed subsoil B and so solved its own problem.

Micronutrient supplements

Micronutrients can be applied either as supplements to macronutrient fertilizers and/or as in-crop treatments. Because of the potential for soil reactions reducing nutrient availability, it may be necessary to protect the micronutrients such as by the use of chelating agents such as EDTA. There have been some new chelating agents developed (Stacey et al. 2008) that can enhance Zn and Cu uptake, particularly on alkaline soils. There have been several product comparisons, such as for copper (Brennan 1990), zinc (Brennan and Bolland 2006) and manganese (Brennan 1996) and these should be considered when selecting an appropriate product as well as referring to some general texts such as Price (2006).

The use of foliar micronutrient is useful when root uptake is reduced and a rapid response is required. The disadvantages of foliar application are that there is little residual activity and to avoid foliar damage only low concentrations can be used. Uptake is limited because only small quantities can be taken up through the stomata, leaf cuticles or parts of the epidermis, but if the nutrient (such as copper) is rapidly fixed in soils, it may be an effective strategy. While there is also considerable interest in the use of adjuvants and other materials to enhance micronutrient uptake and effectiveness, there is little evidence in the literature.

Boron:

- Essential for germination and sugar metabolism
- Lucerne is more susceptible than canola and wheat is lower than canola
- Symptoms include stem splitting, poor seedset,
- Liming can induce B deficiency.
- Critical tissue levels <2 mg/kg in youngest mature leaf blade at mid-late tillering. Leaching can reduce tissue levels.
- B sources are Borax, Boric acid, solubor, Ulexite, sodium, pentaborate.
- Even application is critical.

Copper:

- Essential for chlorophyll formation and pollen production as well as baking quality.
- Wheat and barley are more responsive to copper than lucerne and canola
- Symptoms are rolling and curling of new leaves, white tipped leaf and poor seed set.
- Organic soils and sandy low organic matter soils deficiency common, as well as where there is high Fe, Mn or Al in the soil.
- Critical tissue levels reported as <1.5 mg/kg youngest expanded blade in wheat (Brennan et al. 1986).
- Cu can be applied as an additive to fertilizers, or foliar as copper sulphate, copperoxychloride or chelated copper. Also has a fungicidal effect.

Iron

- Essential component of chlorophyll and in respiratory enzymes
- Legumes are more responsive to iron than cereals.
- Chlorosis of the youngest part of the plant is the most common symptom.
- Problem is worst in high pH and low organic matter soils, especially if there is a lot of free bicarbonate (soil or irrigation water origin).

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- Soil analysis is not able to provide critical values, and tissue samples can be easily contaminated with iron from soil. Levels of 70 mg/kg or more in tissue seem adequate.
- Foliar sprays are useful as iron sulphate or side dressings with iron chelates.

Manganese

- Common enzyme cofactor for chlorophyll and photosynthesis.
- Deficiency symptoms often preceded by wilting and then chlorosis of younger leaves, often at the base of the leaf.
- Mainly a problem on high organic matter soils, and those with free lime present. It may be toxic at low pH (<5)
- For cereals, tissue concentrations of less than 12 mg Mn/kg in the youngest mature leaf are considered deficient.
- Foliar Mn can be more efficient than soil applied Mn, as the latter can result in iron or phosphate precipitates. Chelated formulations are also available.

Molybdenum

- Important for nitrate reductase activity in all plants.
- Deficiency symptoms similar to N deficiency.
- Availability increases with high soil pH, deficiencies on acid soils especially in high rainfall areas.
- Tissue levels of 0.28 to 0.55 mg Mo/kg in youngest mature leaf adequate for canola, and <0.1 mg/kg mid-late tillering in wheat is considered deficient.
- Very small quantities (50 g/ha) applied with fertilizer are usually sufficient, usually in the form of molybdenum trioxide. Sodium or ammonium molybdate can be used as sprays.

Zinc

- Essential for protein shape and so enzyme function in many different tissues.
- Symptoms appear as oily grey green patches in the centre of leaves. Young leaves most affected.
- Typically associated with alkaline soils over a wide range of textures. Lime and gypsum can reduce zinc availability.
- Critical tissue concentrations in youngest expanded blade of wheat 8-10 mg/kg but the response curve is very steep.
- Zinc supplements can be applied with fertilizer as zinc oxide, chelated zinc or zinc sulphate. The latter products are soluble and can also be used for foliar applications. Product efficacy varies with the time and placement of application.

Summary

Trace elements are important and can be limiting factors under certain conditions. Diagnosis of the disorder can be done through a combination of situation, selected crop, soil tests and tissue tests, allied with careful observations. Treatment options are either to use supplemented fertilizers which can give long term increases or the use of foliar sprays to treat growing crops. There are many products on the market, and demand the evidence of their efficacy from properly run experiments.

References:

- Brennan R 1990. Aust J. Exp. Agric. 30, 687-691.
 Brennan R. 1996. Journal of Plant Nutrition, 19, 293-304.
 Brennan R, M Bolland. 2006. 46, 1615-1620.
 Brennan R, et al. 1986 Aust. J. Exp. Agric. 37,115-124
 Norton R. 2011. <http://anz.ipni.net/articles/ANZ0073-EN>
 Piper CS 1942. J. Agr. Sc. 32, 143-178.

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Norton R, J Laycock, C Walker (2012). Trace elements. Proceedings of the Grains Research and Development Corporation Advisor Updates, Ballarat, February 9 & 10. p 169-174.

Price G (ed) 2006. Australian Soil Fertility Manual. CSIRO Publishing, Collingwood, Victoria, Australia.
Reuter DJ, JB Robinson, 2005. Plant analysis: an interpretation manual. CSIRO Publishing, Collingwood, Victoria, Australia.
Smith FW, JF Loneragan, 1997, In (Eds). DJ Peverill KI, LA Sparrow, DJ Reuter 1999. Soil analysis: an interpretation manual. CSIRO Publishing, Collingwood, Victoria, Australia.
Shinmachi F, et al. 2010. Plant Physiol. 153, 327-336
Steenbjerg F. 1951. Plant Soil 3, 97-109.
Stacey SP, D Oosterhuis, MJ McLaughlin. 2008. Americas J. Plant Sci. Biotech. 2, 69-73.
Zhu Y-G, SE Smith, FA Smith. 2001 Annals of Botany, 88, 941-945.

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