Advice Sheet 8: Interpreting Soil Trace Element Analysis

Why analyse for Trace Elements in Soil?

Whilst the majority of yield limiting nutrient deficiencies in crops are related to nitrogen (N), phosphorus (P) and potassium (K), deficiencies in other elements can be limiting for both yield and quality of some crops.

Trace elements, often called micronutrients, are required by plants in very small, but significant amounts. Some of the elements discussed on this sheet are not trace elements and are macro nutrients which are required in larger amounts (e.g. sulphur). Essentially, this advice sheet applies to elements that are not included in the standard analysis package (A001) of pH and available P, K and Mg (see Advice Sheet 5).

How do I spot deficiencies?

Often trace element deficiencies are indicated by the plant, in 'deficiency' symptoms. There are a number of books which show photographs of deficiencies, some of which are described in the table overleaf. Whether it is the plant or the soil that is limiting the uptake of trace elements is often difficult to determine, it is common therefore to combine soil trace element analysis with plant tissue analyses (see below).

Available vs. Total Nutrients

As with the standard elements in soil, when determining plant nutrient requirements it is important to investigate the fraction of the total amount of an element in a soil that is available to plants. For that reason, different elements will be analysed using different extraction and measurement methods – this provides the most accurate representation of the plant soil system.

Deficiency, Sufficiency and Toxicity

Your soil report will indicate whether the level of a nutrient in the soil is low, medium or high. Depending on other factors, including the plant itself and pH, these levels will manifest themselves in the plant as deficient, sufficient or toxic. In other words, the plant will be lacking in the nutrient and yield or quality will be limited (deficiency); the plant will not be adversely affected by the nutrient supply (sufficient); or yield/quality will be adversely affected by too much of the nutrient (toxicity).

Beware, deficiency/sufficiency/toxicity can only be determined by a combination of plant tissue and soil analysis because different plants have different sensitivities to different elements and have different mechanisms for managing uptake and soil concentrations.

Note that this discussion of toxicity concerns phytotoxicity (toxicity to the plant) not zootoxicity (toxicity to animals, including humans). Zootoxicity is a different concern and is important in human food chain supply and in animal nutrition. Plant tissue analysis is more appropriate for determining zootoxicity as it is the plant, not the soil that is eaten (assuming food is appropriately cleaned/prepared). Please note also that the elements that cause toxicity to plants (and indeed deficiency) are not necessarily those that are zootoxic.

However in practice only a few micronutrients are known to be present in such small amounts in soil that there is a risk of deficiency in plants and animals. Deficiency is most frequently related to soil type, soil pH, soil structural conditions and their effect on root growth and crop susceptibility.

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The role of pH

pH is critical in determining the availability of nutrients to plants. This is because, generally, nutrients must be taken up in solution but changes in pH determine the concentration of different nutrients in solution vs. precipitated salts.

The target pH for liming (see Advice Sheet 16) is not arrived at by accident; this is the pH when most elements are available to the plant in appropriate amounts. The pH-availability of nutrients can be generalised as:

- Nutrients that become increasingly more available at higher pH (and less available at low pH)
- Nutrients that become increasingly more available at lower pH (and less available at high pH)
- Nutrients that become less available at lower and higher pH.

Treatment of deficiency

Trace element deficiencies can be treated with specialist fertilisers or by selection of different salts in fertilisers (for example Ammonium Sulphate rather than Ammonium Nitrate). Animal manures are also a good source of trace elements – depending on the types of feed used. Consult your agronomist/advisor for advice.

Plant tissue analysis and trace element deficiencies

As has been discussed above, availability of a nutrient in a soil does not mean that the plant is taking it up. For this reason it is often best to accompany trace element soil analysis with plant tissue analysis to diagnose whether the plant or the soil is responsible for the deficiency. Note that plant analysis can tell you whether the plant is deficient (or toxic) in a particular nutrient but not definitively whether this is caused by soil deficiencies, although this is often the case.

Additional elements including Iodine, Selenium, Cobalt and Sodium are essential in animal nutrition, but are often 'luxury uptake' for plants, i.e. they are not taken up by the plant for a specific function but they are of benefit to the animal. As discussed above, animals eat tissue not soil, so these elements are more appropriately analysed in analysis of the grass.

How do I sample for trace elements?

The answer to this question is – the same as for standard soil analysis (see Advice Sheet 4). The analyses can be requested in addition to the standard analysis. If requested on their own it is best to combine with an analysis of pH for the reasons discussed above.

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Interpretation – General Guideline Limits

Status	Sulphate (mg/l)	Copper (mg/l)	Zinc (mg/l)	Boron (mg/l)	Manganese (mg/l)	Iron (mg/l)	Sodium (mg/l)	Cobalt (mg/l)
Very Low	0-10	0-1.8	0-0.5	0-0.3	0-4	0-5.0	0-10	0.02-0.30
Low	11-22	1.8-2.3	0.5-1.0	0.4-0.6	5-8	5.1-10.0	11-24	0.31-1.00
Risk	23-37	2.3-3.0	1.1-3.0	0.7-1.2	9-12	11.0-16.0	25-40	1.10-4.00
Normal	38-51	3.1-4.5	3.1-6.0	1.3-2.0	13-30	17-25	100-800	4.10-10.0
Very High/ Excessive	> 51	> 10	> 6.0	> 2.0	> 30	> 25	> 800	> 10

Extractions used in above interpretation

Sulphur	- Phosphate buffer	Manganese	- DPTA
Copper	- EDTA	Iron	- DPTA
Zinc	- EDTA	Sodium	- Ammonium nitrate
Boron	- Hot Water Soluble	Cobalt	- Acetic acid

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What do Trace Elements do?

NRM can analyse for all sorts of elements in soil, but the trace elements discussed here are typical for cereal, vegetable and grassland production.

Element	Taken up by the plant as	Function etc.	Deficiency symptoms
Sulphur (S)	SO_4^{2+}	Forms proteins (important in bread wheat), vitamins and coenzyme A. Soil S increasingly rare due to improved fossil fuel emissions.	General chlorosis[1] of the leaf and crop stunting. Low mobility in the plant so deficiencies seen in young leaves first. In oil seed rape, middle and upper leaves can show interveinal yellowing, and flower petals are unusually pale. The best guide for assessing the risk of sulphur deficiency is soil type & field location. Oilseed rape and grass grown for silage are particularly sensitive to sulphur deficiency. Leaf analysis is a useful guide for diagnosing deficiency in cereals, oilseed rape and grass but interpretative criteria have not been established for other crops.
Calcium (Ca)	Ca^{2+}	Important for cell division and membrane function in cells. Enzyme activator. Ca abundant in UK soils.	Twisted and deformed leaves (youngest first). It can also affect flowering on some fruit plants.
Iron (Fe)	Fe2+, Fe3+	Essential for enzyme and protein formation. Involved in photosynthesis.	Deficiency occurs commonly in fruit crops grown on calcareous soils but is not a problem in annual field crops. Symptoms in fruit are yellowing of the young leaves with veins remaining green. Deficiency cannot be reliably diagnosed using soil or plant analysis.

[1] Yellowing of the plant due to lack of chlorophyll (which creates the green colour of plants)

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Element	Taken up by the plant as	Function etc.	Deficiency symptoms
Manganese (Mn)	Mn^{2+}	Chloroplast membrane structure and enzyme activator.	Manganese is the micronutrient most commonly deficient in field crops. Deficiency occurs in many crops on peaty, organic and sandy soils at high pH but can occur less severely on other soils when over limed. Susceptible crops include sugar beet, cereals and peas. In cereals deficiency often shows as patches of pale green, limp foliage. Sugar beet leaves develop interveinal mottling and leaf margins curl inwards. Dried peas show internal discolouration when the pea is split (marsh spot). Soil analysis is not a reliable guide to deficiency.
Zinc (Zn)	Zn^{2+}	Enzyme formation.	Zinc deficiency is rarely found in field crops. In the few cases where deficiency has been found, it has been on sandy soils, with a high pH and phosphate status. Top fruit and nursery stock are most likely to be affected.
Boron (B)	B(OH)3	Limited data.	Deficiency can affect sugar beet, brassica crops and carrots on light textured soils with a pH above 6.5, particularly in dry seasons. Symptoms include death of the apical growing point and growth of lateral buds. In sugar beet, there is a blackening at the leaf base and beneath the crown (heart-rot). Carrots can show a darkening of the rot surface (shadow). Soil analysis prior to growing a susceptible crop is recommended. Leaf analysis is also a useful tool.

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Element	Taken up by the plant as	Function etc.	Deficiency symptoms
Copper (Cu)	Cu^{+}, Cu^{2+}	Present in redox enzymes. Soil deficiency rare.	Deficiency is not widespread in crops but can occur mainly in cereals on sands, peats, reclaimed heathland and shallow soil over chalk. Sugar beet may also be affected. In cereals, symptoms are yellowing of the tip of the youngest leaf followed by spiralling and distortion of the leaf. Ears can be trapped in the leaf sheath and those that emerge have white tips. Barley awns can become white. Soil analysis is a useful tool for identifying whether deficiency is likely.
Nickel (Ni)	Ni^{2+}	Essential in urease, a vital enzyme in plants.	Deficiency best determined by plant tissue analysis.
Sodium (Na)	Na^{+}	Deficiencies rare. Important for palatability of grasses for animals.	Applications of sodium are recommended for certain crops (sugar beet and carrots).
Molybdenum (Mo)	MoO_4^{2-}	Limited information on function. Mo in soils is more available at higher pH – so liming is advised for Mo sensitive crops.	Usually soil supply exceeds demand but where deficiencies do occur it takes the form of chlorosis or twisted growth such as whiptail in cauliflower or broccoli

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