Aluminium Soil Test Interpretation

Introduction

Aluminium (Al) is a very abundant element making up on average 7% of the weight of the earth crust as alumino-silicate minerals; however aluminium is not an essential element for plant growth or animal production.

It is well known that high levels of aluminium in soil can be harmful to plant roots but what is less well known is that there are several different forms of aluminium in soil and not all are harmful. There are also different test methods reporting soil aluminium that need to be interpreted correctly to be useful.

Soil pH or acidity is the most important factor that influences the form of aluminium present in the soil and whether this is potentially ‘soluble’ and damaging to sensitive plant roots or not. Soil type and clay content are also significant factors - medium to high ASC (or P Retention) soils with a significant clay content having increased risk of aluminium toxicity at low pH.

Some components of Organic Matter can form complexes with Al in the soil solution, thus making it unavailable to plants. For this reason, Al toxicity may not be such an issue in peat soils even when pH is low.

In general for mineral soils with medium to high ASC:

- pH below 5.0, soluble aluminium is almost certainly a problem
- pH between 5.0 and 5.5, soluble aluminium may be a problem
- pH between 5.5 and 6.0, soluble aluminium not likely to be a problem
- pH above 6.0, soluble aluminium is almost certainly not a problem

On average, New Zealand soils range from <0.1 – 20 mg/kg Al (0.02M $CaCl_2$) but generally levels are less than 3 mg/kg if soil pH is above 5.5. Most soils used for agricultural purposes have a pH higher than 5.5.

Effects of aluminium toxicity:

- Stunted roots and reduced root zone of susceptible plant species such as clover, brassica, ryegrass and most crop plants. This leads to reduced drought tolerance[3]
- Dominance of tolerant species such as browntop in pastures and low clover content
- Reduced availability of phosphorus through formation of Al-P complexes
- Reduced availability of other cation nutrients (K, Mg, Ca) through competitive interaction[1]

N.B. Leaf analysis for Al toxicity is not valid as high soil-Al levels will stunt roots to the degree that nutrient (and Al) uptake is severely restricted. Also, soil and dust contamination of the herbage will elevate Al measurements.

Soil tests for soluble aluminium:

There are several extraction procedures in use for measuring plant available Al, the two most common in NZ being the 0.02M $CaCl_2$ or the 1M KCl extraction procedures.

1. The measurement of soil Aluminium (Al) using 0.02M $CaCl_2$ gives an indication of the "Plant Available Al". This is a standard method (Methods of Soil Analysis, 1996)[4] for measuring soil Al and is the preferred method for the measurement of soil Al to determine plant Al toxicity in New Zealand (Edmeades et al.)[2]

2. The measurement of soil Aluminium (Al) using 1M KCl, which displaces the aluminium from the cation exchange sites with potassium; providing a measure of "Exchangeable Al".

N.B. The Mehlich3 Al test has no relationship with "plant available" aluminium. As the M3 test is an acid extraction, it is not measuring plant available Al, but the dilute acid soluble Al. This tends to be the amorphous, non-crystalline Al, i.e. that Al likely to fix applied soluble P. In-house investigations have shown reasonable correlation between M3-Al and the Phosphate Retention (PR) test. High M3-Al can be taken to indicate high phosphate fixation and consequently good sulphate retention. Conversely, a low M3-Al indicates a lower phosphate fixation and the potential for greater leaching losses of sulphate.

Relationship between soil Al (0.02M $CaCl_2$ or 1M KCl) and pH

The relationship between soil Al (0.02M $CaCl_2$ and 1M KCl) and pH was examined for 110 samples. These were commercial samples which requested measurement of soil Al. The amount of soil Al extracted by both extractants increases exponentially below soil pH 5.5 (Figure 1). The critical Al concentration deemed to inhibit plant (root) growth is > 3 mg/kg for Al (0.02M $CaCl_2$). Figure 1 shows the increase in solution Al as soil pH approaches 5.5.

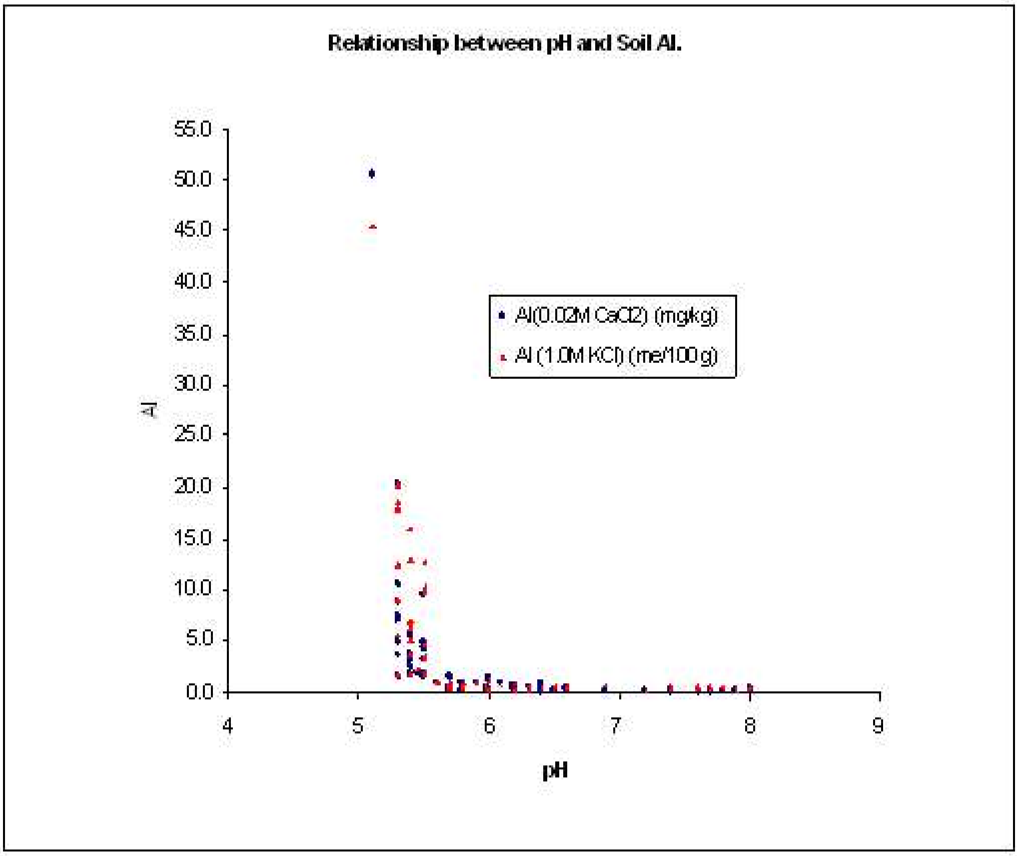

Figure 1: Relationship between soil pH and soil Al extracted using 0.02M $CaCl_2$ and 1M KCl

When to Request a Soil Aluminium Test

Aluminium (Al) is not present in a plant-available form in soils with a pH above 5.5 and therefore tests for extractable aluminium need only be done on distinctly acid soils. In New Zealand, soils with a pH range of 4.5 - 5.5 are those most likely to be affected by aluminium toxicity. Up until recently, Hill Labs has reported Al measured from a 1M KCl extract. A recent change means the 0.02M $CaCl_2$ extractable method is now in use; with this lower ionic strength extractant giving different interpretive levels.

It is highly recommended that sub-soils are tested for Aluminium prior to crop establishment to allow soil management for plants to develop a deep rooting zone.

Plants such as grass, cereals, maize, tree and vine crops all have potential to extend roots down to 750mm if not deeper, most other plants to at least 300mm so restriction of root zone depth affects ‘plant available water’ which has a knock on effect on plant nutrition and growth.

Interpretive Levels for Soil Al tests

Level	1M KCl Extractable Aluminium (me/100g)	0.02M $CaCl_2$ Extractable Aluminium (mg/kg)
Low	< 0.5	<1
Medium	0.5 - 1.0	1.0 - 3.0
High*	1.0 - 2.5	3.0 – 10.0
Very High (toxic to plants)	> 2.5	> 10.0

*Toxicity more likely in low organic matter soils.

Note: The Soil Aluminium test now offered by Hill Labs Agriculture Division is the 0.02M $CaCl_2$ Extraction. The 1M KCl method has been discontinued as from April 2010.

References:

1. The Nature & Properties of Soils, 13th Ed, 369-376

2. Edmeades D.C, Smart C.E and Wheeler D.M. 1983. Aluminium toxicity in New Zealand soil. New Zealand Journal of Agricultural Research.Volume 26; pages 493-501.

3. Jamieson, PD, Martin, RJ, Francis, GS. Drought Influences on Grain Yield of Barley, Wheat and Maize. NZ Journal of Crop and Horticultural Science, 1995, Vol. 23: 55-66.

4. Methods of soil analysis. Part 3 – Chemical Methods.1996. Editor: Sparks D.L. Published by the Soil Society of America Book. Chapter 18: Aluminium; pages 517-550.