Advice Sheet 5: Interpreting basic Soil Analysis – pH, Available P, K and Mg

Why pH, Phosphorus, Potassium and Magnesium?

The four soil properties, pH (acidity-alkalinity), plant available phosphorus, plant available potassium and plant available magnesium are some of the most routinely measured. Why? – Because they are relatively straightforward to measure, they are stable in time and they are key for making fertiliser recommendations with the DEFRA guidelines in RB209[1].

Soil pH

When considering soil and plant nutrition it is essential to know the soil pH. The pH scale ranges from 1 (strong acid), through 7 (neutral) to 14 (strong alkali). Typically, soils range between 4 and 8.7 but there are rare exceptions and pH's of 2 or 9+ have been observed. The ideal pH varies with soil type and crop/plant grown. The two headline values are 6.5 for Arable and 6.0 for grassland, below these values the addition of liming products is recommended. Reason for maintaining these pH values is because it is within this range that most elements are most available to the plant.

The natural trend is for soil pH to lower over time, this is because rain and fertilisers are naturally acidic. As pH lowers, nutrients such as Phosphorus, Potassium, Iron and others become 'locked up' in the soil and less available to the plant. In addition elements such as Aluminium become available in phyto-toxic[2] concentrations. In addition, beneficial soil microbes find it more difficult to exist at low soil pH.

On soils which are formed from chalk or limestone, higher pH's occur and whilst these are less of a problem, sometimes nutrient availability can be restricted and additional amounts of fertiliser are required or certain crops which require acid soils cannot be grown.

The standard method for measuring pH is to extract an air-dried, 2mm sieved soil in a ratio of 1 to 2.5 in water. Other extraction ratios and extractants are available for analysis at NRM, but the liming calculations are based upon 1:2.5 in water.

Available Phosphorus

The amount of phosphorus available to the plant is measured using the Olsen method. This weak extracting solution simulates the amount of phosphorus available to the plant and only extracts a small fraction of the total amount in a soil, the majority of which is unavailable to plants. The phosphorus content of the extract solution is then measured by colorimetry and is reported as mg/l. This can be converted to an index by reference to RB209.

After nitrogen, phosphorus is one of the most important nutrients, and phosphorus deficiency is the second most common crop nutrient deficiency worldwide. Fertilising soils for phosphorus is difficult. Phosphorus binds easily with other elements in the soil to create mineral forms, such as apatite, which are unavailable to the plant – particularly at low or high pH. This means that in certain situations it is necessary to apply large amounts of phosphorus fertiliser, before any plant benefit is seen. However, in the UK where phosphorus has been used in large amounts, a lot of agricultural land only requires plant-targeted amounts of fertiliser as the soils cannot fix any more P.

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[1] Nutrient Management Guide (RB209). AHDB Agricultural & Horticulture Development Board.

[2] Phyto-toxic means toxic to the plant (not necessarily animal/human toxicity).

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CDA-005-TBA-V3
Issued: 11th August 2021

Phosphorus is an essential nutrient because it is required by the plant to synthesise adenosine tri-phosphate (ATP), which is the key energy form in plants and photosynthesis. It is also essential for the formation of nucleic acids and phospholipids used in forming cell walls. Where P is abundant, root growth is encouraged and it is therefore commonly applied with seed at establishment.

Plant deficiency symptoms vary from plant to plant but are typically stunted growth – short plants that are dark green in colour (can be masked by N application). P is mobile within the plant and easily moved from old cells to new, therefore deficiency symptoms appear first in older leaves. The oldest leaves will show a dark brown colour as they die. Maturity (ripening) will be delayed, which can affect harvest dates etc.

Phosphate is also responsible for the eutrophication of fresh and coastal waters. Eutrophication (explosion of algae in the water reducing the oxygen content and killing aquatic flora and fauna) is a significant environmental problem in the UK and excess fertiliser application and soil erosion are, in-part, to blame.

For these reasons it is very important to analyse soil for available phosphorus regularly and to follow the fertiliser recommendations in RB209 to ensure the correct amount is applied.

Available Potassium

The amount of potassium available to the plant is extracted from the plant by using ammonium nitrate. The potassium content of the extract solution is then measured by atomic adsorption flame photometry and is reported as mg/l. This can be converted to an index by reference to RB209.

Potassium is an extremely mobile element in soil. It is highly water soluble and is easily leached so deficiencies are common (depending upon soil type, cropping and rainfall). Plants need potassium to activate enzymes for photosynthesis, respiration, starch forming and protein building. Potassium is also essential for the control of osmosis in plants and therefore their turgor pressure (stiffness from water content).

Like phosphorus, potassium is mobile in the plant and again, deficiencies are seen first in the older parts of the plant. Symptoms include some chlorosis (yellowing in colour) and spots of dead tissue on the leaves. In cereals, leaf tips die first and this is a common diagnosis tool for potassium deficiency.

Available Magnesium

The amount of magnesium available to a plant is determined in the same way as for potassium and it is perhaps for this reason that magnesium is included in a standard soil analysis package because magnesium deficiencies are less common, and less yield limiting than for nitrogen, phosphorus and potassium. Like potassium it is an enzyme activator but it also a facilitator for ATP.

Interveinal (between the veins in the leaf) chlorosis (yellowing or whitening) of the oldest leaves is a diagnostic indicator of magnesium deficiency in plants. This should not be confused with the interveinal chlorosis seen in younger leaves which is an indication of iron deficiency.

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Why not NPK like fertiliser?

Nitrogen is the most important element in soil and plant nutrition and yet it is not included in the standard soil analysis. The reasons why nitrogen is not included in the standard package are outlined in the NRM Advice Sheet 'Understanding Soil Nitrogen'. Essentially it is because it is much more difficult to analyse nitrogen in soils because nitrogen content fluctuates throughout the year and soil samples need to be taken with extra care because the amount of 'available' nitrogen can change whilst the sample is in transit to the laboratory if the appropriate precautions are not taken.

How are the results interpreted?

The pH value is entered into the Genfer lime equation, which is used to calculate the amount of lime required per hectare. More information about this can be found in the NRM Advice Sheet 16.

The amount of available phosphorus, potassium and magnesium is converted to an index value (0-9) by reference to RB209. Indices 0 and 1 indicate deficiency, 2 borderline deficiency and 3-9 sufficiency. Typically soils range from 0-3, depending upon soil type, crop rotation and other factors.

Once the index has been calculated – fertiliser recommendations are made depending upon the crop specified on the analysis request form – that is why accurately completing the paperwork submitted with the sample is so important.

Beyond pH, P, K, Mg

It is essential to conduct the standard soil analysis and to know about these soil properties when growing plants, and whilst pH plays an important role in nutrition and P and K (+ N) deficiencies are common, there are other 'trace element' nutrient deficiencies, which also limit yield and quality of crops. See the NRM advice sheet 'Interpreting Soil Trace Analysis'.

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