Importance of Soil pH in Crop Production

Determination of pH

There are 2 basic methods of determining the soil pH viz (1) colorimetric and (2) potentiometric method

In either method, the sample has to be prepared. The soil sample is weighed, then decision on the type of slurry to prepare (water slurry (distilled water)) or salt solution (KCl or $CaCl_2$) 0.01m conc. of the salts are used. Decision on the ratio of water to soil or salt solution to soil, usually 1:1 or 2:1 (salt or water: soil). It is recommended that slurry should be shaken and read immediately because if allowed to settle, the potential difference as a result of the junction is avoided when settling is not allowed the actual reading is gotten.

Colorimetric Method of pH Measurement

This entails the formation of colour with soil : H_2O or salt solution mixture. The colour formation is made possible by the addition of a universal indicator (indicator with large pH range), the colour is then matched with colour charts of known pH. (Demerit – slower, less precise colour blindness and eye fatique.)

Potentiometric Method

This is an instrumental method and involves measurement of potential. It is based on the principle that if we use pH sensitive electrode (selective or specific electrode), the potential generated is proportional to the H^+ concentration. i.e. $E = K(H^+)$

It is based on the Nerst equation.

pH

$E = E^0 \pm 0.059/n \log [H+]$ ie $E^0 \pm 0.059/n = K$, holds only at 25^oC.

E

pH is also known to be equal to $(E - K) / 0.059$ @ 25^0C

hence the temperature should be adjusted to 25^{o}C.

The pH is directly related to E. To establish this straight line, a minimum of two or more points is required. To establish this straight line, you have to calibrate the pH meter with standard buffers. There are 3 standard buffers pH 4, 7 and 9. The choice of buffer is a function of the experience, if acid soil use pH 4, 6 or 7 if alkaline use 6 or 7 and 9. If no knowledge of soil pH use 4 and 9.

Factors Affecting pH Measurement

1) Suspension effect
2) Dilution effect
3) Sodium effect

Lime Requirement

This is the amount of lime required to neutralize the acidity of the soil to a desired pH. There are several methods of determining lime requirement, out of which five are very common: (1) Field plot techniques (2) Titration with a base (soil/base titration) (3) Incubation studies (4) Use of buffer (5) Green house techniques

1) Field plot techniques/green house
2) Titration with a base
3) Incubation studies
4) Use of buffer

Soil Organic Matter

Determination of SOM

SOM is the plant and animal remains or debris at all stages of decomposition. Decomposed parts are called humus.

1) Measurement of CO_2 evolved during decomposition.

2) Determination from the total Nitrogen values.

3) Weight loss

4) Estimation of the oxidizable carbon

Walkley and Black Procedure

This is a chromic acid oxidation procedure; it involves the oxidation of the SOM by chromic acid. In practice the chromic acid is generated insitu by the reaction between $K_2Cr_2O_7$ and conc. H_2SO_4 then you back titrate with ferrous solution because the $K_2Cr_2O_7$ and H_2SO_4 is added in excess. By this we determine the oxidizable organic carbon, however not all the Organic Carbon is oxidizable, but we know that about.

1) 75 % of the organic carbon in organic matter is oxidizable hence to convert org. carbon = 100 / 75 = 1.33

2) Only about 58% of total organic matter is organic carbon. So to convert org. carbon to org. matter = 100/58 = 1.724

3) Milli-equivalent weight of carbon in (g) = 0.003

12/4 = 3/1000 = 0.003g

$$\therefore \textbf{ \% org C} = \frac{(A) - (B) \textbf{ X} \text{ Normality of titrant X } 100 \textbf{ X } 0.003 \textbf{ X } 1.33}{\text{Weight of soil taken}}$$

Where: Titre value of blank (A)

Titre value of sample (B)

$\therefore$ **Org. matter** = Total Org. C **X** 1.724

$$\textbf{Org. matter} = \frac{(A) - (B) \text{ X N X } 100 \textbf{ X } 0.003 \textbf{ X } 1.33}{\text{Weight of sample}}$$

Testing for Available Nutrients

Available nutrient is that portion of soil nutrient, whose variations (increase or decrease) are reflected in the growth/yield of the crop. The major nutrients of interest in this course are nitrogen, P, K, Ca, Mg, Na, Mn, Fe, etc.

Soil Nitrogen

This is perhaps the most needed nutrient element in most soils. About 90% of total N in the soil is in organic combination. In most soil, N content ranges as low as 0.01% to as high as 0.5%. Total N content of Nigerian soil is around 0.02 – 0.2% and the critical level is 0.15%.

Methods of Determining N Levels in Soil

Plant take N as NO_3^- and NH_4^+, hence both are important in plant uptake. There is however, the interconversion of both in the soil to different forms. In recent time, attention is focused on NO_3^- for many reasons.

1) The possibility of leached NO_3^- polluting the underground water i.e. NO_3^- going below root zone of plants.

2) From point of view of crop need.

However, so far in Nigeria, total nitrogen is used mainly as the index of N availability to crops.

Total Nitrogen Determination

There are 2 classical methods of determing total Nitrogen.

***1) Dumass (1831)*:-** This is a dry oxidation procedure.

***2) Kjeldahl method*:-** The two step Kjeldahl system does not take into consideration the following compounds N-O compounds and the N-N compounds therefore, the two way system has to be modified in order to include N-O compounds as NO_3^-, NO_2^-. One of the modification is the salicylic (e.g. aspirin) acid modification.

Determination of Phosphorus

Chemistry of P in the Soil

Plant takes their P in form of HPO_4^{2-} and $H_2PO_4^-$. Unfortunately the soluble form of P in the soil at any particular time is very small that it will not satisfy the crop yield.

Labile P is the pool of P that replenishes soil P immediately the soluble P is depleted. Therefore available P = labile P + solution P. Labile P varies from soil to soil, hence the extractant varies too from soil to soil.

Criteria for Selecting Extractant for P

1) The extractant should rapidly dissolve or desorb P and it should be time independent after 30 minutes.

2) It should maintain O.M. and soil clays in a flocculated form (no dispersion of OM or soil minerals).

3) It should not precipitate after dissolution.

4) It should not contain excess salts, buffers, or ions that will interfere with the analytical determination.

5) It should be easy to prepare, store or disposed of.

In practice some of the commonly used extractant include: Bray 1, Bray 2, Olsen, Hunter, Mehlich[1], Egner, Ambic I, Citric acid, 0.01M $CaCl_2$

Determination of Extracted P

There are several methods of doing this, but the most common is the molybdate method. The classical molybdate method involves the use of certain reagents like Na vernadate and NH_4MoO_{10}. When these reagents react with P in solution, yellow phosphomolybdate is formed and the intensity of the yellow colour is determined colorimetrically. However, the yellow

colour is not very sensitive and there is a limit to its detection, hence to enhance the sensitivity of the colour, it is reduced to blue colour buy the addition of stannous chloride (tin chloride). Another common method is the use of antimony potassium tartrate and ascorbic acid solution to generate a blue colour, whose intensity is a function of the P concentration.

Exchangeable Cations

Two principal methods used in determining total CEC are:

1) NH_4^+

Ca^{2+}

Mg^{2+}

K^+

Al^{3+}

H^+

***Summation method*:-** All the cations are displaced by a saturated solution of the displacing ion, usually a monovalent ion. NH_4^+ (ammonium) ion is often used. The salt widely used id NH_4OA_c, by adding this NH_4^+ is furnished and all other cations will have been displaced. The cations will then be determined and summed up to give the total CEC.

Colloids $+ NH_4^+$ **Colloids** $+ Ca^{2+}, Mg^{2+}, K^+$

colloid

usually the Ca^{2+} and Mg^{2+} is determined using atomic absorption spectrophotometer (AAS) while Na^+ and K^+ are determined using flame photometer, H and Al by AAS and by NaOH titration.

2) ***Displacement method*:** here we figure out (i) Displacing ion (ii) Index ion

NH_4^+

Ca^{2+}

Mg^{2+}

K^{+}

Al^{3+}

H^{+}

e.g. NH_4^{+} as Index ion

Colloids + NH_4^{+} + Ca, Mg, K

Na^{+}

NH_4^{+}

+ Na^{+} $^{+ NH}{}_4$

With soil and NH_4, shake for 1 hour filter, the filtrate has cations, residue (solid) has NH_4^{+} return the residue to the beaker, then look for a displacing ion (monovalent cation) usually Na^{+} in form of acetate. Hence NH_4^{+} in solution is equivalent to all the cations.

Determination of Available Sulphur

The best extractant for S is Ca $(H_2PO_4)_2$, it must contain about 500 ppm PO_4^{3-}. Phosphorus is more specifically fixed whereas S is not specifically fixed i.e. the adsorption energy is higher in P than in S (P is more tightly held than S). Therefore P can easily displace S on the adsorption site.

Extract and determine S by colorimetry, gravimetry but most common is turbidemetric method, here $BaCl_2$ is added to the extract.

$BaCl_2 + SO_4^{2-}$ $BaSO_4 + 2Cl^-$, $BaSO_4$ is formed, this is a turbid suspension, the rabidity of the solution is determined, hence to make it stay, a stabilizer is added e.g. Gelatin/Cum acacia, the resulting solution is determined by use of a spectrophotometer at 420nm wavelength.

- To remove any colour (to ascertain that only turbidity is measured and not colour), this is achieved by adding a decolorizer e.g. activated charcoal; this is added to the filtrate and then refilter before adding $BaCl_2$ and measuring.
- Turbidimeter functions even in the presence of colour because it records reflection and refraction.

Micro-Nutrients

They are Cu, Zn, Co, Mo, B, Fe, Mn. They are essential to crop growth but needed in small amount as far as fertilizer need is concerned, however they have equal importance as the macro elements. Micronutrient analysis is not common in most analysis because of severl reasons as:

1) Since their presence is in trace levels, hence the instrument used for the analysis must be highly sensitive; this is not only very costly but also not available in most laboratories.

2) Since they are present in trace amount, containers used for them may contaminate the sample to the extent that the error level could be very high (e.g. 90%) and therefore it requires well-trained personnel to handle micronutrient analysis.

Extraction

by EDTA + HCl, DTA + HCl, Acid etc. for boron we can use hot-water and immediately they are extracted, we can use AAS to determine them, depending on the availability of lamp as every element has its own lam.

PLANT ANALYSIS

a. **Definition**

Plant analysis can be defined as the quantitative determination of the concentration of an element or extractable fraction of an element in a sample from a particular part or portion of a crop.

b**. Principles and Practices**

Plant analysis is used as an index of available nutrient element supply. Plant growth or yield are compared with the elemental concentrations contained in the dry matter of the entire plant or plant structures such as leaves, petioles, fruit or grain sampled at different times during their development. Plant analysis gives the overall picture of the nutrient levels within the plant at the time the nutrient was taken. The use of plant analysis is based on the principle that the nutrient level present is as a result of all factors affecting the growth of the plant.

2. **Some uses of Plant Analysis**

i. It is used to determine if an element is essential for plant growth, development and maturation.

ii. It is used to verify the element associated with a phenotypic or nutrient deficiency or toxicity symptom

iii Establishment of optimum concentrations or critical values for elements associated with optimum or maximum economic yields

iv. Determining the total elemental uptake by a crop which could be used to estimate the nutrient element requirement per unit of production

v. Determining the availability and recovery of an applied element in fertilizer in crop response experiments

3. **Sampling and Analyzing tissue samples**

A. Factors to be considered before sample collection:

i. Nutrient element heterogeneity

ii. Statistical considerations

B. Sampling Techniques

Factors on which the number of plants to sample are dependent:

i. General condition of the plants

ii. Soil homogeneity

iii. Purpose for sampling

C. Sample Preparation

Plant samples are to be subjected to the following preparatory steps before the actual chemical analysis:

1. Storage and transport of the fresh material prior to cleaning and drying
2. Cleaning the material to remove surface contamination or Decontamination
3. Drying to stop enzymatic reactions and prepare the material for grinding
4. Mechanical grinding to reduce the material to a fineness suitable for analysis
5. Storage of the tissue powder prior to analysis

D **Plant Analysis**

Most of the elements contained in plant tissue are present as constituents of the plant tissue rather than as water soluble inorganic anions or cations. Consequently, organic matter of plant tissue must be destroyed before the mineral elements can be determined.

i. Methods of organic matter destruction:

a. Wet Ashing- Decomposition of plant tissue by digesting in strong acid solutions

b. Dry Ashing- Heating plant samples to a temperature sufficiently high to burn off the

carbon

ii. Methods of determining elements in plant samples:

- Total Nitrogen

  Method: Micro-Kjeldahl

- Phosphorus

  Method: Vanado-Molybdate

- Potassium

  Method: Flame emission

- Calcium, magnesium, manganese, Zinc and copper determination

Method: Atomic absorption

4. Plant Analysis as an aid in fertilizing crops

   This is based on the concept of critical nutrient concentration.

   Definition : Critical level is defined for a given form of nutrient and plant part as that concentration above which sufficiency occurs and below which deficiency occurs.

   There are established critical or sufficiency ranges for specific crops and elements, when nutrient concentrations are below the established sufficiency range, additional nutrients would be required.

- Students would be provided with established critical or sufficiency ranges of some common crops

5. **Operation and management of a soil testing and plant analysis laboratory**

5.1 Types of laboratories:

- University or educational Institute laboratory

Objectives: Data acquisition to support or confirm research or to acquire information useful in designing educational programs for students and other persons concerned with soil fertility and plant nutrition

- Industrial laboratory

Objectives: Promoting the use or sale of the product manufactured or distributed by the company owning or operating the laboratory

- Commercial laboratory

Objectives: To operate in a manner as to return a profit for the investment required to provide the service

5.2 Facilities:

- Receiving dock: Used for receiving chemical supplies, soil and plant samples
- Soil grinding or crushing room: Where soils are prepared for analysis
- Soil sterilization area: Used for heat treating soils
- Plant and feed samples preparation room: Where plant samples are prepared for analysis
- Vibration free benches: On which analytical balances and delicate instruments would be placed
- Equipment room: Where laboratory equipments would be kept
- A lockable room or cabinet: For safe storage of chemicals
- A well defined area for disposing of laboratory wastes, washing and drying glassware

5.3 Safety: Ready access should be provided to protective and first aid supplies

5.4 Electricity Supply: There should be reliable electricity supply since most analytical procedures involves the use of equipment powered by electricity

5.5 Water Supply and quality: Water is the wellspring of laboratory performance hence the laboratory should be supplied with regular and clean water

5.6 Management: This includes technicians, supervisory personnel, technical director and the manager

5.7 Record keeping: Data must be recorded in specific laboratory record books. Records which contain primary data should not leave the laboratory.