

1.4 | SOIL ANALYSIS

Soil analysis is an extremely valuable aid for determining the optimum level of fertilization required for agronomic and horticultural crops, pastures, trees, gardens and turf. It is one of the key components of sound crop production practices and has been used by commercial farmers in developed countries for over 50 years. Extensive research programmes conducted abroad as well as in South Africa have resulted in the development of reliable and rapid soil analysis methods, promoting optimum fertilization of key crops and the effective use of fertilizers.

Due to the development of reliable soil analysis methods and calibrated norms for certain plant nutrients and other soil factors influencing plant growth in the main cropping areas of South Africa, farmers and advisers accept soil analysis as a tool to predict crop responses to applied fertilizer with an acceptable degree of reliability. Soil analysis results form the basis on which fertilization recommendations are made.

Soil analysis provides the only objective means of assessing the fertility status of soil; there is no alternative for soil analysis. By taking soil samples several months before planting, it is possible to correct fertility problems before yield losses are incurred.

AIM

Soil is analysed in order to

- (i) Determine the soil fertility status with a view to making fertilizer recommendations;
- (ii) Determine whether there are any deficiencies, excesses or imbalances that can influence plant growth;
- (iii) Determine whether liming is required;
- (iv) Divide soils into capability categories for planning purposes.

COST EFFECTIVENESS OF SOIL ANALYSES

The use of soil analysis has increased worldwide and is accepted as an essential tool for decision making in crop production. If done properly, soil analysis provides invaluable information and is the only practical method to determine the lime and fertilizer requirements of a soil.

The cost of a soil sample analysis is less than half of the average cost of a 50 kg bag of fertilizer. Considering that one soil sample can be used to represent 25 to 50 ha, the cost per hectare is negligible, approximately the cost of 1 kg of fertilizer; especially when considering the potential benefits. A reliable service for soil analysis and fertiliser recommendations will reduce risks and improve the economic effectiveness of the fertilizer programme, which should lead to higher crop yields and improved profitability.

THE PARTIES INVOLVED

To be of value, soil analyses must be correlated with fertilization and crop responses. Soil analyses can therefore not be used in isolation, neither are they the prerogative of only the laboratory analyst. The following people are involved in the soil analysis process:

1. **Farmer**

The process starts with the farmer, who must know what type of fertilizer he requires as well as the quantity to achieve the most economic yield. It is the farmer's prerogative to obtain advice so that he can solve his problems but it is also his responsibility to ensure that soil samples are indeed representative of the associated field. To make the most of the service he must ultimately make use of the advice based on the soil analysis.

2. **Sampler**

Soil samples are either taken by the farmer himself, an employee, consultant or fertilizer company representative. The sampler and the farmer are jointly responsible for ensuring that the sample is practical and representative in terms of a workable field unit, soil type and soil variability.

3. **Soil scientist**

The soil chemist and soil scientist are responsible for the choice of the extraction method. Combined with the agronomist, the methods used in crop production trials must be correlated with crop yield and fertilization. There are various extractants that are available which can be used to determine the so-called plant available nutrients in the soil.

Most of these are suitable if they have been scientifically calibrated and are used under appropriate conditions, for example acid extractants on acid soils. However, what is important is that it has limited value if an extractant is not in general use. Correlation then becomes difficult and even impossible because conversion between extractants is very subjective.

4. **Laboratory analyst**

The task of the laboratory analyst is to receive, prepare and analyse the sample. In this respect not only is the reliability (bias and variability) important, but also the extraction method used to extract the plant nutrients in the sample. The soil analysis service to farmers for fertilizer recommendations includes the following (often topsoil samples only):

- If the pH (H₂O) is < 5.5 or the pH (KCl) is < 4.5, exchangeable acid, acid saturation, lime requirement assessment and phosphate adsorption must be carried out.
- If the pH (H₂O) is > 7 or the pH (KCl) is > 6.0, tests for free lime must be conducted. If free lime is present, an alkaline extractant, such as Olsen or Ambic must be used, instead of an acid extractant such as Bray 1.
- The cations Ca, Mg, K and Na are mainly determined with 1N ammonium acetate.
- S determinations are sometimes requested and two basic methods of extraction are used, namely acidified ammonium acetate and calcium phosphate.
- Colour, texture, and
- in some cases also resistance if the Na is > 100 mg kg⁻¹, and conductivity if the resistance is < 250 ohm, are recommended.
- Sometimes Zn, B, NO₃⁻, NH₄⁺, CEC and organic C are also determined.
- Analysis of micro-elements, such as Fe, Mn and Cu, must preferably be performed on plant samples and not on the soil.
- In the report, it is important that the laboratory indicates the analytical methods used.

5. **Agronomist**

The agronomist, in conjunction with the soil scientist, is responsible for the interpretation of the soil analysis results.

Making use of the supporting information that accompanies the sample, combined with research data, a fertilization programme must be drawn up to assist the farmer in achieving his/her crop yield target. In this regard, the nutrient requirements of the crop must be taken into consideration. Appropriate plant analyses are used with great success in the fertilization of perennial crops such as vineyards, citrus, subtropical and deciduous fruit, and may also be used meaningfully in annual crops for diagnostic purposes by comparing plants that exhibit deficiency symptoms with healthy plants in the same field. It is not advisable to base fertilization recommendations for annual crops on the previous season's leaf analyses.

SOIL ANALYSIS METHODS

Soil samples are subjected to a wide range of determinations with a view to making fertilizer recommendations, as well as for other purposes.

The Non-Affiliated Soil Analysis Work Committee, in conjunction with the Soil Science Society of South Africa, published a manual, *Handbook of Standard Soil Testing Methods for Advisory Purposes*, in 1990. Laboratories use this publication to ensure that soil analyses are performed in a uniform manner. At present these methods are being updated by AgriLASA (Agri Laboratory Association of Southern Africa), which has also published handbooks on fertilizer, plants and animal feed.

South African laboratories currently use the following analytical methods:

- a) **pH:** A 1:2.5 mass of soil to water, or 1 mol dm⁻³ potassium chloride solution is used. Other ratios, such as 1:1 soil to water, used notably by foreign laboratories, must be used with caution because the wrong deductions can be made as adequate correlations have not been done in South Africa.
- b) **Phosphorus (P):** Various laboratories use the following extractants/methods:
 - Bray 1: 0.025 mol dm⁻³ hydrochloric acid + 0.03 mol dm⁻³ ammonium fluoride in a 1:7.5 extraction ratio (mass), shaken for 60 seconds. This method is used by most laboratories, but only on soils with pH (KCl) < 6.
 - Bray 2: 0.1 mol dm⁻³ hydrochloric acid + 0.03 mol dm⁻³ ammonium fluoride in a 1:7.5 extraction ratio (mass), shaken for 40 seconds. This method is only used on soils with pH (KCl) < 7.
 - Olsen (NaHCO₃): 0.05 mmol dm⁻³ sodium bicarbonate, 1:20 extraction ratio. This method is recommended for soils with a pH (KCl) > 7 and if free lime is present.
 - Mehlich 3: 0.2 N acetic acid + 0.25 N ammonium nitrate + 0.013 N hydrochloric acid + 0.015 N ammonium fluoride + 0.001 M EDTA. Mehlich 3 is used for precision farming where multiple samples are taken in order to determine soil chemical variation. On the single extract P, Ca, Mg, K, Na and micro-elements are determined. As no such calibration studies have been conducted in South Africa, they are only used meaningfully for precision analysis where the purpose is to observe spatial variation over a field. The fact that a single extraction is done from which all the important elements can be determined, makes it extremely suitable for precision sampling.

The methods below are also used, but due to the limited number of laboratories and users, they are not recommended as standard.

- Ambic 1: 0.25 mol dm^{-3} ammonium bicarbonate + 0.01 mol dm^{-3} ammonium fluoride + 0.01 mol dm^{-3} ammonium EDTA, in a 1:10 extraction ratio by mass, shaken for 30 minutes.
- Ambic 2: as for Ambic 1, but on a volume basis, stirred for 10 minutes.
- Citric acid (1%): 1:10 extraction ratio.
- Modified Truog: $0.025 \text{ mol dm}^{-3}$ sulphuric acid.

The fact that there are still different extraction methods is not conducive to meaningful communication. Because practically every method gives a different analysis value, it causes confusion among users. Concerted efforts are still being made to solve this problem and to ensure the rationalisation of the number of analytical methods.

c) **Cations** (K, Ca, Mg and Na). Using the following is recommended:

- Ammonium acetate: 1 mol dm^{-3} at pH 7, an extraction ratio of 1:10 and shaken for 30 minutes.

Some laboratories also use the undermentioned but these are not recommended as standard:

- KCl: 1 mol dm^{-3} , on both a mass and a volume basis.
- Ambic 1: ammonium bicarbonate, ammonium fluoride and ammonium EDTA on a mass basis (see above).
- Ambic 2: as for Ambic 1, but on a volume basis.

d) **Sulphur (S)**, as stated above, is determined by two methods, namely acidified ammonium acetate extract and calcium phosphate extract.

e) **Microelements** (Fe, Mn, Cu and Zn). The following methods are used:

- HCl: 0.1 mol dm^{-3} . This method is only recommended on acid soil with $\text{pH} < 6$ (KCl). (Bray 1 is increasingly being used for Zn as it eliminates the need for additional extraction.)
- EDTA: ammonium.
- Ambic 1.

- Ambic 2.
 - Mehlich 3: 0.2 N acetic acid + 0.25 N ammonium nitrate + 0.013 N hydrochloric acid + 0.015 N ammonium fluoride + 0.001M EDTA. Used for precision farming where multiple samples are taken in order to determine soil chemical variation. On the single extract P, Ca, Mg, K, Na and micro-elements are determined.
 - DTPA: 0.005 M DTPA + 0.01 M calcium chloride + 0.1 M TCA (triethanolamine). Used to determine Fe, Zn, Cu, Mn and B.
- f) **Boron (B)**: extractable in hot water or in $0.02 \text{ mol dm}^{-3} \text{ CaCl}_2$.
- g) **Aluminium (Al)**: extractable in $1.0 \text{ mol dm}^{-3} \text{ KCl}$.
- h) **Exchangeable acidity**: with $1 \text{ mol dm}^{-3} \text{ KCl}$ on a mass or volume basis or with the modified Eksteen method (Western Cape).
- i) **Nitrogen (N)**: extractable inorganic nitrogen (NH_4^+ or NO_3^-) in $1 \text{ mol dm}^{-3} \text{ KCl}$.
- j) **Organic matter (C)**: readily oxidisable organic matter is determined by oxidation with potassium dichromate (Walkley Black).
- k) **Stone fraction**: estimated or determined and expressed as volume per volume.
- l) **Cation exchange capacity (adsorption ability) (CAC or CEC)**: the following is used to exchange the cation: 1 mol dm^{-3} ammonium acetate, pH7; 0.2 mol dm^{-3} ammonium acetate, pH7; $0.5 \text{ mol dm}^{-3} \text{ LiCl}$.

As a standard, laboratories also state a calculated CEC in reports. This can lead to incorrect deductions, especially if, for example, free lime is present.

- m) **Texture**: is determined according to the pipette method. Any other methods must be calibrated against this method. Most laboratories, however, use the Bouyoucos method for routine determinations.

The well-known finger test method is often used to get a general idea of the soil texture. This method is, however, subjective.

- n) **Colour**: is assessed using the Munsell colour chart (international colour standards), dry and wet. The cheaper Japanese equivalents (standard colour charts of the Fujihara Industry Company) are also used.

- o) **Other methods:** several other methods, mainly for more specific requirements, are described in the *Handbook of Standard Soil Testing Methods for Advisory Purposes*.

All analyses must be done by means of recognised methods, and the method used must always be accompanied by an acceptable reference.

- p) **Units:** the well-known unit in soil analysis is parts per million (ppm). However, this is ambiguous because it can mean mass parts per million volume parts, or mass parts per million mass parts (this being the “general” meaning). These two differ substantially because the bulk density of soil can vary between 0.9 and 1.8 with an “average” of approximately 1.4 for most soils. Sandy soils are “heavier” than clayey soils, while organic or humic soils are “lighter”. The bulk density of the prepared sample in the laboratory is obviously not necessarily the same as that of the soil in the field.

Instead of ppm, the following units should be used, depending on the method of extraction: milligram per kilogram (mg/kg, or mg kg^{-1}), or milligram per litre (mg l^{-1} , or mg dm^{-3}).

CHALLENGES

When interpreting soil analysis results, the following should be borne in mind:

- (i) In the laboratory an attempt is made to simulate the plant’s ability to take up plant nutrients from the total volume of soil available to the plant, over the entire growing season and under varying climatic conditions by taking a soil sample from mainly the top 15 to 30 cm;
- (ii) The concentrations of the extractable plant nutrients, for example, P, K, Ca, Mg and Zn, are very low to extremely low. For example, 15 mg P kg^{-1} soil means 0.0015% P, but in the soil extract in which the determination is actually done in the laboratory it is only 0.0002% P (some laboratories report concentrations in mg dm^{-3});
- (iii) The danger of contamination during soil analysis, for example, from reagents;
- (iv) The selectivity of the method and the equipment used must be precise, and these are often accompanied by sensitivity, which, if too high, will lead to inconsistency;

- (v) Only 5 grams of soil is measured off in the laboratory (approximately one teaspoonful), to be representative of and to provide answers for the 50 000 000 000 grams of soil in a field of 20 ha to a depth of 20 cm. This naturally places demands not only on the analyst in the laboratory, but in particular on the person taking the soil sample.

RELIABILITY

The ultimate reliability of a soil analysis service is dependent upon the combined efforts of all the participating parties. To ensure that the analytical work in the laboratory is as reliable as possible and that there is satisfactory agreement between the different laboratories, Fertasa instituted a soil analysis test and control scheme several years ago; which is currently being administered as an accreditation scheme by AgriLASA. Some 28 laboratories are voluntarily participating in the scheme.

Laboratories receive unidentified samples for analysis every month. The results of all participating laboratories are processed statistically. It is the responsibility of each laboratory to ensure that the quality of its work is acceptable. As mentioned previously, certificates are issued annually by AgriLASA.

Laboratories strive to ensure that the quality of soil, plant and fertilizer analyses are beyond reproach as well as being comparable to those of leading international laboratories and quality control schemes. Consequently, several AgriLASA laboratories also participate in international proficiency schemes for soil, leaf, fertilizer and animal feed analysis.

RELATIONSHIP BETWEEN METHODS

Considering that a variety of extractants are used in South Africa, it is sometimes useful for agronomists to be aware of the relationship between different methods. In some cases it facilitates the interpretation of the analyses, especially if field calibration has not yet been done with a particular method. Such relationships, however, are not always straightforward and may be dependent on pH and soil type.

Taken from overseas literature, as well as local comparative studies, the general relationships, as set out in the Table 1.5.1, can serve as examples.

Table 1.5.1. General relationships

Acid extractants	Alkaline extractants	
Bray 2	Bray 1	Olsen
10	6	4

Please note: Relationships such as those listed in the table serve only as an indication to facilitate interpretation. When making recommendations, they cannot be used to relay values obtained from one method to another. Ideally, research should provide guidelines based on independent field calibrations of each method, together with fertilizer application and crop yield. The ultimate objective is to also communicate internationally. Consequently, standard international extraction methods should be used.

For the interpretation of soil analysis, see Chapter 5.2.

REFERENCE

Handbook of Standard Soil Testing Methods for Advisory Purposes, 1990. Non-Affiliated Soil Analysis Work Committee, Soil Science Society of South Africa.

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