

1. INTRODUCTION

The idea that one could test or analyze a soil and obtain some information about its properties—especially its acidity or alkalinity and its nutrient status—is long established, and can be traced back to the beginning of scientific inquiry about the nature of soil. Analysis of plant to reflect fertility status of the soil in which it grew is more recent, although visual crop observations are as old as the ancient Greeks, if not older. In the last few decades, spurred on by commercialization of agriculture and the demands for increased output from limited — and even diminishing — land resources, both soil and plant analysis procedures have been developed, and are still evolving.

With the advent of chemical fertilizers, the need to know nutrient status of a soil in order to use these expensive and limited inputs more effectively became all the more crucial. However, if soil testing is to be an effective means of evaluating fertility status of soils, correct methodology is absolutely essential. A soil or a field may be assessed for its capability of providing a crop with essential nutrients in several ways:

1. Field Plot Fertilizer Trials;
2. Greenhouse Pot Experiments;
3. Crop Deficiency Symptoms;
4. Plant Analysis;
5. Rapid Tissue or Sap Analysis;
6. Biological Tests, such as Growing Microorganisms; and
7. Soil Testing prior to Cropping.

While all approaches can be used in research, the latter one is most amenable, and one upon which recommendations for farmers can be based. On the other hand, plant analysis is a *postmortem* approach and one that should be interpreted in the light of soil test results.

Soil testing is now an intrinsic part of modern farming in the West. Tests primarily focus on the elements in most demand by crops which are supplied by fertilizers: *nitrogen* (N), *phosphorus* (P), and *potassium* (K). Depending upon the soil types, in some regions tests are also conducted for secondary nutrients: *calcium* (Ca), *magnesium* (Mg), and *sulfur* (S). In drier areas, micronutrients such as iron (Fe), *zinc* (Zn), *manganese* (Mn), *copper* (Cu), and *boron* (B) are often measured, since deficiencies of these elements are more frequently associated with calcareous soils. Indeed such areas may also have excessive or toxic levels of some elements, like B and Sodium (Na).

As nutrient behavior in soils is governed by soil properties and environmental conditions, measurement of such properties is often required. These include *pH*, *salinity*, *organic matter* (OM), *calcium carbonate* (CaCO_3), and *texture*. In drier areas, the presence of *gypsum* ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is also of concern.

Soil testing involves four distinct phases:

1. **Sample Collection:** This should be such that it reliably reflects the *average* status of a field for the parameter considered.
2. **Extraction or Digestion and Nutrient Determination:** The reagent used and the procedures adopted should quantify all or a portion of the element in the soil which is related to the availability to the plant, i.e., it should be correlated with plant growth.
3. **Interpreting the Analytical Results:** The units of measurement should reliably indicate if a nutrient is deficient, adequate, or in excess.
4. **Fertilizer Recommendation:** This is based upon the soil test calibrated for field conditions, and considers other factors such as yield target, crop nutrient requirement, management of the crop, soil type, and method of fertilizer application, etc.

It should be emphasized, however, that a soil test, even if very *reliable* or *accurate*, is only one *factor* in making decisions about the need for *fertilization*. There are many other factors affecting crop growth and yield, such as soil type and environmental conditions, i.e., moisture, temperature, etc.

Because of varying and different forms of nutrients in soils, e.g., calcareous vs. acid soils, soil tests are equally varied, particularly for available P and micronutrients, and to a lesser extent for N (Walsh and Beaton, 1973). Being mobile in soils and subject to mineralization - immobilization, N poses particular problems to establish a reliable test. Tests for K, pH, OM, and CaCO_3 are more straightforward.

Since the development of the DTPA test of Lindsay and Norvell (1978) and adoption of azomethine-H as a color-developing reagent for B (Gaines and Mitchell, 1979), micronutrient (Fe, Mn, Zn, Cu, B) tests for alkaline soils have become more useful. Though tests for gypsum are developed (Richards 1954; FAO, 1990), there are unique problems for CEC measurement in such soils (Rhoades and Polemio, 1977).

The literature on soil testing is rich and varied. Some salient examples include:

1. Monographs from the American Society of Agronomy for Physical (Klute, 1986) and Chemical Analysis (Page, 1982) which give detailed descriptions of all available soil tests and their modifications.
2. Soil Science Society of America Publications (Walsh and Beaton, 1973; Westerman, 1990) that take a broader look at the philosophy, procedures, and laboratory operations for soil and plant analysis, with interpretation criteria for specific crops.
3. Soil Testing with a Textbook Format (Hesse, 1971).
4. University Publications which range from those that deal with all Soil, Water and Plant Tests (Chapman and Pratt, 1961) to more narrowly based ones (Reisenaur, 1983).
5. Publications that deal with theoretical considerations involved with sampling, correlation, and calibration, to interpretation (Brown, 1987).
6. Those that are commercially oriented and reflect "**State of the Art**" instrumentation and computer-assisted data analysis and handling (Jones, 1991; Jones *et al.*, 1991).
7. Finally, publications that are written in "**Recipe/Cook-book**" style with little or no discussion; only listed are the equipment and chemicals used and the general steps involved in the procedure (Quick, 1984).

While most soil testing sources emanate from the West, publications such as those of the Food and Agriculture Organization of the United Nations (FAO, 1970; 1980) are more international in scope and assume a developing country perspective. In such countries, *soil testing is often less developed* and, in some cases, does not exist. Similarly, research pertaining to soil testing and plant analysis is often fragmentary.

This leads to a consideration of the Central and West Asia - North Africa region, which is served by the International Center for Agricultural Research in the Dry Areas (ICARDA). In this region, the development of the Soil Test Calibration Network at ICARDA served as a catalyst to promote soil testing and thus eventually lead to more efficient use of soil and fertilizer resources in the region. Its evolution and potential impact can be seen from scrutiny of the papers presented at the various workshops in Aleppo, 1986 (Soltanpour, 1987), Ankara, 1987 (Matar *et al.*, 1988), Amman, 1988 (Ryan and Matar, 1990), and in Agadir, 1991 (Ryan and Matar, 1992).

Central to the Network, and indeed ICARDA's operations, has been its Soil-Plant Analysis Laboratory. Though its facilities have been designed and developed without some of the constraints experienced by other governmental and educational laboratories in the region, some of the procedures adapted by the laboratory are based on *validated regional research*, e.g., N and P.

A key element in any worthwhile laboratory is a list of appropriate tests presented in such a manner that it can be readily followed routinely by those who actually do soil testing and plant analysis, i.e., *the laboratory technicians*. Therefore, the target audience for this manual is the cadre of technical staff throughout the region.

A brief introduction to each test is given, so that the technician should have an *elementary understanding of the importance of the work he/she is doing*. He/she should also know the range of *values to be expected* for soils and plants in the region, and therefore more readily identify gross errors. We have attempted to select the most appropriate method for each test and present it in a clear, stepwise manner.

While the manual primarily deals with soil testing, a number of important plant tests are presented, since they may complement the soil tests and are frequently needed for soil fertility and plant nutrition studies. Similarly, due emphasis has been given to physical properties; describing the tests routinely done along with chemical analysis. The importance of proper soil and plant sampling has been highlighted, and guidelines of sample collection, processing, and storage provided.

We have also presented material on *laboratory organization* and *safety-aspects* which are often *overlooked* by technical staff, but which impinge greatly on their work output and its reliability. Additionally, the appendices contain very useful information on related practiced aspects like abbreviations, conversion factors, atomic weights, solution concentrations, pH effect on soil conditions, summarized soil test methodologies, plant sampling guidelines, criteria for interpreting soil and plant analysis data, soil salinity, and boron toxicity interpretations.

Although the manual is written in English, the language of ICARDA's publications, only an elementary knowledge of English is required to follow the procedures listed. As ICARDA's mandate area is diverse in terms of languages, it is intended that French, Arabic, and Russian versions will be produced.