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Review

Soil fertility evaluation: a potential tool for predicting fertilizer requirement for crops in Nigeria

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In most developing countries including Nigeria, fertilizers are applied to the soil by uneducated farmers without particularly making reference to the specific need of the plant or soil. Therefore, intended efficiency/replenishment is not maximized and fertilizer use is not rationalized. This paper critically reviews the three basic approaches to soil fertility evaluation: Visual symptoms of nutrient deficiency, Plant tissue analysis and soil testing. The implications of these methods are examined in terms of predicting fertilizer requirements for crops in Nigeria. Furthermore, the paper discusses the methods of Soil fertility evaluation available. Focus is then shifted primarily to the soil testing method, describing in detail the main objectives behind carrying out soil testing, including the proper soil sampling tools, sound sampling techniques and handling of the samples.

Key words: Soil fertility evaluation, fertilizer, soil sampling, Nigeria.

INTRODUCTION

Soil, being the natural medium for plant growth has a direct impact on yield and quality of crops growing on it. Measurement of the fertility of an agricultural soil tells much about the productive potential. Fortunately, producers can control fertility by managing the plant's nutritional status (Flynn et al., 2004). Nutrient status is an unseen factor in plant growth, except when imbalances become so severe that visual symptoms appear on the plant (Flynn et al., 2004). In Nigeria, a recent general reduction in the yield of common crops has drawn attention of stakeholders in the agricultural sector to this serious trend. Therefore, at present, the greatest challenge before Nigerian agriculture is to boost food production and productivity as well as sustainability of agriculture as a whole (FAO Handbook, 2004). There are problems that impose limits on these objectives or goals which raise serious concerns about national food security. These include deterioration of soil fertility, increase in cost of production, and low diversity of production systems (Arifalo and Mafimisebi, 2011). However, the need for improved crop productivity is more now than ever because the increasing rate of population growth at about 3% in Nigeria (CIA, 2012) and the consequent pressures from competing demands for land over time have resulted in cultivatable land being drawn from its traditional agricultural uses. With resultant reduction in the land-man ratio and this has drastically reduced the average size of farm land and invariably leads to soil fertility depletion through continuous or intensive cropping along with short, unfertilized fallow (Ruthernberg, 1980; Adesimi, 1988)

Low fertility of Nigerian soils is the major constraint in achieving high productivity goals. In both rain-fed and irrigated systems, nutrient replenishment through fertilizers and manures remains far below the crop removal, thus causing mining of native reserves over the years. Soil nutrient depletion has grave implications in terms of:

(1) Wide spread deficiencies of macro and micro nutrients; N, P, K, Cu, Zn, B, Ca and S deficiencies were observed (Julio and Carlos, 1999).

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(2) Declining nutrient use efficiency and returns from money spent on nutrient and other inputs (Sanchez et al., 1997).
(3) A weakened foundation for high yielding sustainable farming (Agboola and Ayodele, 1987).
(4) Escalating remedial costs for rebuilding depleted soils (Arifalo and Mafimisebi, 2011).

Site-specific estimates of the nutrient fertility status of the soils are therefore very important to rational fertilizer use. Reliable site-specific information can only be accomplished through an orderly program of soil fertility evaluation.

Soil fertility evaluation is the process of estimating the amount of native and residual nutrient elements which could be available for use by growing crops in particular soil and the amount of fertilizer to be supplemented for profitable crop production (Sanchez et al., 1997). Soil fertility evaluation, therefore is a tool for:

(a) Determining the fertilizer needs of specific crops and soils;
(b) Achieving reliable and economic fertilizer recommendations, that is, ensuring that right types and quantities of fertilizers are applied;
(c) Checking wastage of fertilizers; and
(d) Minimizing soil and water pollution through the addition of excessive amounts of chemical fertilizers.
Although soil fertility evaluation is a powerful tool to support high productivity by way of rationalizing nutrient use, its current impact on farm practice is presently not visible. In order to make it an effective and farmer oriented service, it is imperative to
(1) Expand the arena of soil fertility evaluation beyond NPK, and as well as the pH of the soil.
(2) Develop fertilizer recommendations for high yield targets, involving all deficient nutrients and exploiting important positive nutrient interactions.

METHODS OF EVALUATING SOIL FERTILITY

There are three basic tools for evaluating soil fertility. They are listed below based on their relevancies, starting with the least useful:

(1) Visual symptoms of nutrient deficiency
(2) Plant tissue analysis
(3) Soil analysis

Using visual symptoms of nutrient deficiency to determine fertilizer needs

Visual nutrient deficiency symptoms can be a very powerful diagnostic tool for evaluating the nutrient status of plants. One should keep in mind, however, that a given individual visual symptom is seldom sufficient to make a definitive diagnosis of a plant's nutrient status. Wade (2010) argued that many of the classic deficiency symptoms such as tip burn, chlorosis and necrosis are characteristically associated with more than one mineral deficiency and also with other stresses that by themselves are not diagnostic for any specific nutrient stress. However, their detection is extremely useful in making an evaluation of nutrient status.

In the vast majority of cases, nutrient deficiencies can substantially reduce production *without showing any clear symptoms*. This problem is referred to as "*hidden hunger*" whereby a deficiency is having a negative effect without being recognised, though if an early diagnosis is made, effective action can usually be taken (Wade, 2010). The principal advantages of visual diagnostic symptoms are that they are readily obtained; can provide an immediate indication of nutrient status (Wade, 2010; Wallace, 1943) and where the symptoms do not require confirmation no apparatus of any kind is necessary (Wallace, 1943). Its main drawbacks are that the visual symptoms do not develop until after there has been a major effect on yield, growth and development (Wade, 2010); symptoms may be complicated or suppressed by other factors, such as salinity and non-uniformity of nutrients, weather conditions and pests or disease organisms (Wallace, 1943) and the complications may lead to forming an entirely wrong conclusion. Nevertheless, with experience, an observant farmer can learn to use the visual method quickly and with great advantage. Such farmer must be very familiar with the basic theoretical knowledge of nutrients deficiencies as described in Table 1 as well as the practical knowledge of recognizing the symptoms when spotted on the field. Examples of such visible symptoms are as shown in Figures 1 and 2.

Plant tissue analysis

Plant tissue analysis is a laboratory determination of the total elemental content of plants or of certain plant parts (Steinhilber and Salak, 2010; Reuter and Robinson, 1997). It is used for a variety of purposes including monitoring the nutrient status of crops and troubleshooting problem areas. It also serves as the basis for nutrient recommendations for perennial fruit crops (Steinhilber and Salak, 2010). It is the only way to know whether or not a crop is adequately nourished during the growing season (Flynn et al., 2004). Plant tissue analysis should not be confused with tissue testing. Tissue testing typically refers to a field test that involves taking sap samples from fresh plant tissue and analyzing the samples on site. Plant tissue analysis is performed on dried plant tissue that has been processed in a laboratory (Steinhilber and Salak, 2010).

Plant tissue analysis can detect unseen deficiencies (Flynn et al., 2004; Cleveland et al., 2008; Steinhilber and Salak, 2010; Walsh and Steinhiber, 2005), confirm visual symptoms of deficiencies and detect toxic levels of

Table 1. Description of nutrient deficiency symptoms in crops.

Nutrient element	Deficiency symptoms in crops
Nitrogen	General chlorosis (appearance of light-green to pale-yellow colour starting from the older leaves). The tips are first affected. Older leaves scorch or drop depending on the degree of deficiency. Growth becomes stunted and plant may have etiolated appearance. In acute case, flowering is greatly reduced. Deficient crops have lower protein content
Phosphorus	The mature leaves have characteristic dark-green to blue-green coloration. The root development is restricted, plant is spindly and stunted. In acute case, red, purple or brown leaf coloration develops and maturity is delayed. There is poor development of seed and fruit
Potassium	Slow and stunted growth of plants. Chlorosis along the leaf margins followed by scorching and browning of tips of older leaves. These symptoms gradually progress inward. Stalks are weak and plants lodge easily. Terminal and lateral buds may die ("dieback"). Shriveled seeds of fruits
Calcium	These are first noticed in the meristematic regions and the young leaves. The young leaves of new plants are often distorted, small and abnormal. Leaves may be cup-shaped and crinkled and the terminal buds deteriorate with some breakdown of petioles. Root growth is severely impaired. Roots get rotten. Buds and blossoms shed prematurely. Stem structure weakened
Magnesium	Inter-veinal or marginal chlorosis, mainly of older leaves often accompanied by development of a variety of pigments. Chlorosis may also begin in patches or pouches which later merge and spread to the leaf margins and tips. With acute deficiency, the affected tissue may dry up and die. Leaves are usually small, brittle in final stages and curve upwards at margin. Twigs weak and prone to fungus attack, usually premature leaf drop
Sulfur	Younger leaves turn uniformly yellowish or chlorotic. Plants are spindly and grow poorly. Flower production is often indeterminate. Stems are stiff, woody and small in diameter
Zinc	Deficiency symptoms mostly appear on the 2nd or 3rd fully mature leaves from the top of plants. In some species, leaves may be dark-green or blue-green. Flowering and fruiting are much reduced under conditions of severe zinc deficiency, and the entire plant may be stunted and misshapen
Boron	Growing tips are often damaged and may die. The leaves may become distorted, curling and becoming brittle. Stems become rough and cracked; often with corky ridges of spots. Flowers do not form. Roots are stunted and prone to bacterial infection. Brown heart in root crops characterized by dark spots on thickest part of the root or splitting at center. Fruits such as apples develop" internal and external cork" symptoms
Copper	Leaves may become chlorotic (yellowing) or deep blue-green. Curling of leave blades or rolling up of margins. Flowering and fruiting are curtailed. Ear production in cereals restricted and grains poorly set. Young shoots often die back, whereupon new shoots emerge from multiple buds further back, making for a bushy appearance. Annual plants may fail to develop and may die at the seedling stage.

Source: Marschner (1995).

nutrients. Though usually used as a diagnostic tool for future correction of nutrient problems, plants tissue analysis from young plants will allow a corrective fertilizer application that same season (Flynn et al., 2004; Cleveland et al., 2008). The most important use of plant analysis is to monitor nutrient status and diagnose existing nutrient problems (Flynn et al., 2004; Cleveland et al., 2008) as well as to keep an excellent yearly record of crop nutrient use and needs under different environmental conditions.

However, it is a tool which must be used with caution. The tissue sampling method is critical for success. The procedure is unique to each crop. The plant must be at specific stage of growth, and specific tissue must be selected (Flynn et al., 2004; Cleveland et al., 2008; Steinhilber and Salak, 2010; Walsh and Steinhiber,

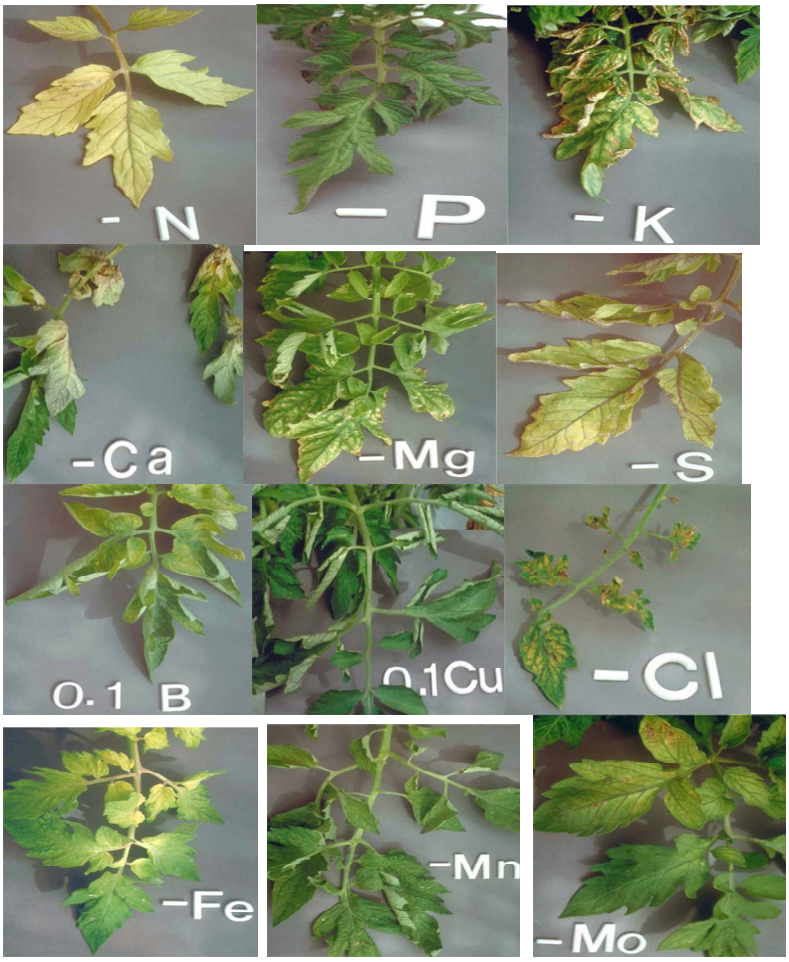


Figure 1. Some visual systems of selected nutrient defiencies in tomato (Epstein and Bloom, 2004).

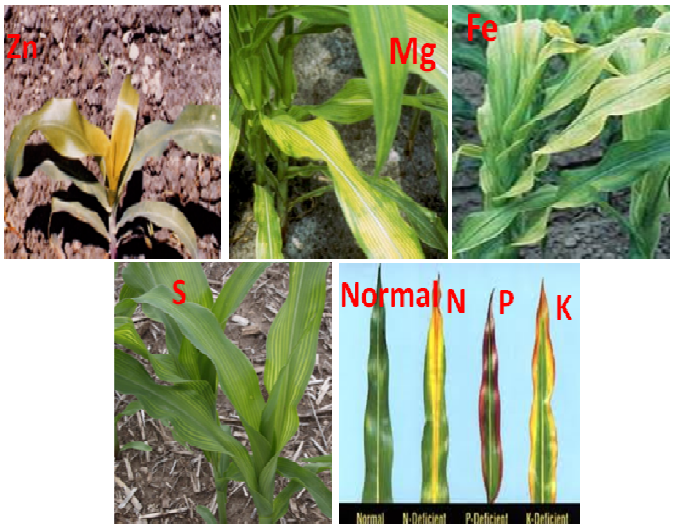


Figure 2. Some visual systems of selected nutrient deficiencies in cereals (maize). Zinc defiency (photo culled from Food and Fertilizer Centre, 2001); Magnessium, sulphur and iron (photo from Nutrico, 2011); N, P and K defiencies (photo from publication 12 of Agriculture food and rural affairs 2007).

2005) avoiding rains and soil contaminations (Cleveland et al., 2008). Failure to follow the prescribed method for that crop will produce misleading results. The analysis may be of little importance if plants come from field that are infested with weeds, insects, disease organisms; if the plants are stressed for moisture; or if plants have some mechanical injury (Flynn et al., 2004). As posited by Steinhilber and Salak (2010) and other earlier researchers that there are rules that must be followed for an analysis to be successful, a simple mistake can be deleterious for the crops concerned. Table 2 shows some of the complex but important techniques of when, where and number to sample of a large varieties of crops including field, vegetable, ornamental, fruit and nut crops.

Once the analysis is done, the nutrient contents are compared with known minimum values for that crop (critical values) or sufficiency ranges and nutrient deficiencies or excesses are identified. The critical values and sufficiency ranges for several crops are shown in Table 3. The lower limit (of sufficiency range) represents the critical level below which appropriate fertilizer rates should be applied. The upper level indicates the level

Table 2. Tissue sampling techniques for specific plants.

Field crops			
Crop	**When to sample**	**Where to sample**	**Number to sample**
Alfalfa	Early bloom	Top 6 inches or upper third of plant	12-30
Canola	Before seed set	Recently mature leaf	60-70
Clover	Before bloom	Upper 1/3 of plant	30-40
Corn/sweet corn	Seedling stage or before tasseling or tasseling to silking	All above-ground portions first fully developed leaf from the top of the plant Leaf opposite and below ear	15-20 15-20 12-20
Cotton	Full bloom	Recently mature leaf from main stem	40-50
Grasses/forage mixes	Stage of best quality (before seed emerges)	Upper 4 leaves	30-40
Peanuts	Before or at bloom	Recently mature leaves	40-50
Small grains (barley, oats, wheat, rye, rice)	Seedling stage before heading	All above-ground portions 4 uppermost leaf blades	25-40 25-40
Sorghum (milo)	Before or at heading	2nd leaf from top of plant	20-30
Soybeans	Before or at bloom	Recently mature, trifoliate leaves from the top of the plant	20-30
Sugar beets	Midseason	Recently mature leaf at center of whorl	25-30
Sunflowers	Before heading recently mature leaf	Before heading recently mature leaf	20-30
Vegetable crops			
Crop	**When to sample**	**Where to sample**	**Number to sample**
Asparagus	Maturity	Fern, 18-30 inches above ground line	10-30
Beans	Seedling stage or before or at bloom	All above-ground portions Recently mature leaf	20-30 20-30
Broccoli	Before heading	Recently mature leaf	12-20
Brussels sprouts	Midseason	Recently mature leaf	12-20
Celery	Midseason	Outer petiole of recently mature leaf	12-20
Cucumbers	Before fruit set	Recently mature leaf	12-20
Head crops(cabbage, cauliflower)	Before heading	Recently mature leaf at center of whorl	12-20
Leaf crops(such as lettuce, spinach)	Midseason	Recently mature leaf	12-20
Melons	Before fruit set	Recently mature leaf	12-20
Peas	Before or at bloom	Leaves from 3rd node from top	40-60
Peppers	Midseason	Recently mature leaf	25-50
Potatoes	Before or at bloom	3rd to 6th leaf from growing tip	25-30
Sweet potatoes	Midseason or before root enlargement	3rd to 6th leaf from tip center or mature leaves	20-30 25-35
Root/bulb crops(such as carrots, beets, onions)	Midseason before root or bulb enlargement	Recently mature leaf	20-30
Tomatoes (field)	Midbloom	3rd to 4th leaf from growing tip	15-20
Tomatoes (trellis or indeterminate)	Midbloom from 1st to 6th cluster stage	Petiole of leaf below or opposite top cluster	12-20

Table 2. Contd.

Fruit and nut crops			
Crop	**When to sample**	**Where to sample**	**Number to sample**
Apples, pears, almonds, apricots, cherries, prunes, plums	Midseason(June-July)	Leaves from current season's nonfruiting, nonexpanding spurs	50-100
Peaches and nectarines	Midseason (June-July)	Midshoot leaflets/leaves	25-100
Grapes	At bloom	Petioles or leaves adjacent to basal clusters at bloom	50-100
Pecans	Midseason	Midshoot leaflets/leaves	25-60
Pistachios	Mid- to late season (August)	Terminal leaflets from nonfruiting shoots	25-60
Raspberries	Midseason	Recently mature leaves from laterals of primocanes	30-50
Strawberries	Midseason	Recently mature leaves	25-40
Walnuts	(June-July)	Terminal leaflets/leaves from nonfruiting shoots	25-40

Source: Flynn et al., 2004.

Table 3. Sufficiency range of nutrient elements in some crops.

S/N	Crop	Source/amount of fertilizer (bags)						
		Nitrogen (N)	**Phosphorus (P)**	**Potassium (K)**	**Calcium (Ca)**	**Magnesium (Mg)**	**Zinc (Zn) (ppm)**	**Boron(B) (ppm)**
1	Maize (whole plants, less than 30 cm tall)	3.5-5.0	0.30-0.50	2.50-4.0	0.30-0.70	0.15-0.45	20-60	5-25
2	Maize (leaf below the whorl prior to teaseling. Ear leaf at teaseling collected before silks turn brown)	Leaf below the whorl:3.0-3.50	0.25-0.45	Leaf below the whorl:2.0-0.50 Ear Leaf: 1.75-2.25	0.25-0.50	0.13-0.30	15-50	4-25
3	Cotton: (upper mature leaves on vegetative stems taken prior to bloom or when first squares appear).	3.50-4.50	0.30-0.50	1.50-3.0	2.0-3.0	0.30-0.90	20-200	20-60
4	Groundnut (upper mature leaves taken prior to or at boom stage)	3.50-4.50	0.25-0.50	1.70-3.00	1.25-2.00	0.30-0.80	20-60	20-60

Source: Plank and Kisse (2008).

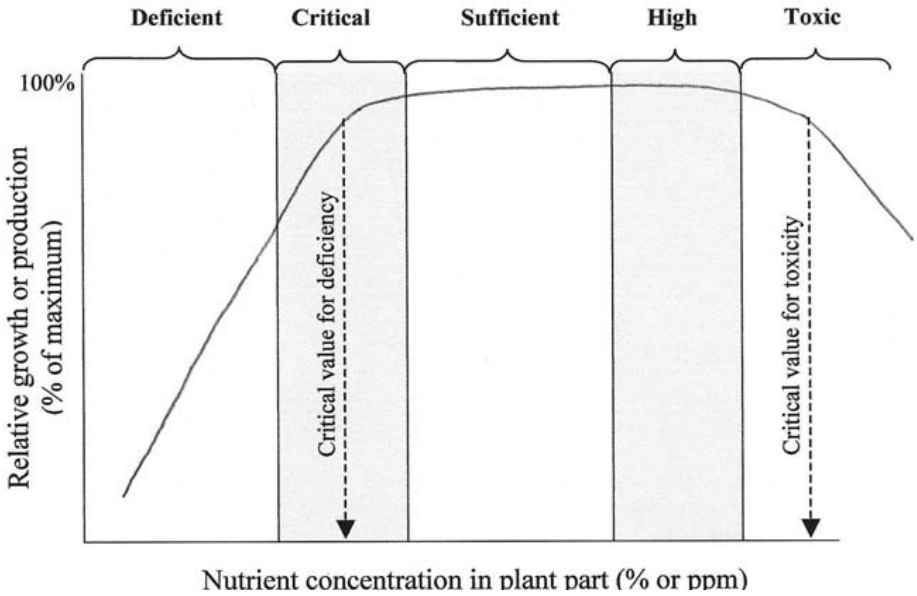


Figure 3. Australasian Soil and Plant Analysis Council Inc. 1997; Modified from p.78 in Plant Analysis: an Interpretation Manual (DJ Reuter et al.), with permission from CSIRO PUBLISHING, Melbourne Australia – http://www.publish.csiro.au/pid/437.htm).

above which toxicity sets in. Figure 3 is a graphical depiction of interpretive guidance for a generic crop. The nutrition concentration ranges (% or ppm) for each nutrient status category and the shape of the growth curve differ from crop to crop.

Although very detailed, plant tissue analysis results cannot be used as a sole determinant for generating nutrient recommendation for crops. It is therefore pertinent to look at the primary source of the nutrient - the soil, rather than the tissue. The result of the soil test will be very important in determining nutrient needs of crops.

Soil testing/soil analysis

Soil testing is used to determine both the amount of each nutrient that is immediately available and the amount that can become available during the life of a crop. Various methods have been developed and the key to success is that the methods must be calibrated. Soil test calibration implies establishing relationship between soil test values and relative crop response (Agboola and Ayodele, 1987). Soil sampling done properly forms the basis of a successful long-term soil and crop nutrient management plan (Potash and Phosphate Institute, 2004).

It is most useful before planting to predict lime or fertilizer needs (Reisenauer et al., 1983). Also, it measures levels of specific nutrients in a soil. However, it cannot indicate whether plants growing in that soil are able to take up the nutrients. Soil test are the best way to assess soil pH (Kidder, 1993).

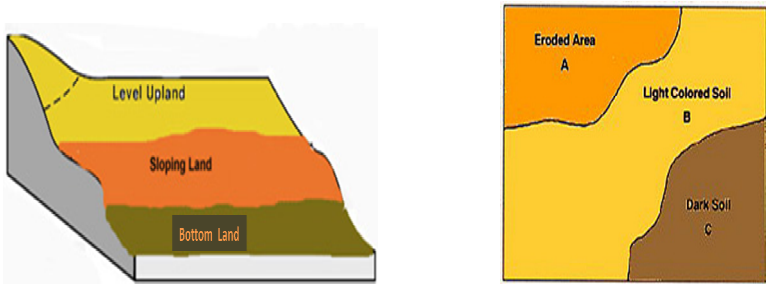
Objectives of soil testing

(1) To accurately determine the status of available nutrients in soils (P, K, Mg, pH, Zn, B)
(2) To clearly indicate to the farmer the seriousness of any deficiency or excess that may exist in terms of various crops
(3) To form the basis on which fertilizer needs are determined
(4) To express the results in such a way that they permit an economic evaluation of the suggested fertilizer recommendation

How to sample soils

It is not possible to move the entire soil of the farm to the laboratory for analysis. Only a small sample is required. A good sample is the first requirement for a reliable soil test. This sample should be a true representative of the farm/plot/field, that is, it should contain all the characteristics of the soil on this farm/plot/field. The proper methods of collecting and handling samples are determined by certain factors (Canadian Society of Soil Science, 2008).

(1) Accuracy and precision
(2) Sample areas that are representative of the farm
(3) Effect of farm size on accuracy
(4) When, how deep and how often to sample
(5) The use to be made of the analyses



(a) Based on land shape and topography (b) Based on drainage and soil colour

Figure 4. Divided plots based on uniformity.

Figure 5. Some soil sampling tools.

(6) The pattern and ease of recognition of soil variability
(7) Previous and proposed management practices.

Although many types of sampling designs exist (Gilbert 1987; Mulla and McBratney, 2000; de Gruijter 2002) only two main types (random and systematic) are commonly used in the soil and earth sciences. Simple Random gives opportunity to all samples to be involved in the final selection while in stratified simple sampling; points are assigned to predefined groups or strata and a simple random sample chosen from each stratum. Stratified sampling (correctly applied) is likely to give a better result than simple random sampling (Williams, 1984).

Soil sampling could be done before or after preparing the land for planting (that is, to estimate pre-plant fertilizer needs). The farm operator must decide what level of detail is relevant to his or her field operations. Are there parts of the field that have different fertility patterns? Are these areas large enough to be relevant? Does the operator want to engage in site- specific management? Has the operator the ability to vary fertilizer application rates to accommodate the field subsections identified (Canadian Society of Soil Science, 2008)?

The farm should be divided into small units of 1 hectare in size. Each unit should have uniform observable properties. Subsections of a field would commonly be identified by differences in topography (termed landscape -directed soil sampling), parent material, management history, or yield history. It may be impossible to subdivide a field into smaller units if the farm operator has no prior knowledge of the field, or if there is no obvious topographic or parent material differences (Janzen, 1993). A composite sample consisting of 10 to 20 spot (core) samples collected using approved sampling techniques is obtained for each unit of the farm.

Tools

The best tool is the metal tube called “sampling tube”. If this is not available, cutlass, shovel, hand trowel and auger could be used (Figure 5). Do not use brass, bronze, or galvanized tools because they will contaminate samples with copper and/or zinc.

Soil test kit: This is a compact soil testing equipment with full complement of devices and reagents for the determination of the pH, electrical, conductivity, nitrogen, phosphorus and potassium in soil, fertilizer and water. Carbon, which is a good index of nitrogen content in soil, can also be determined. The equipment is robust and cost saving in terms of laboratory space.

Method of soil testing

To sample a farm: A rough map of the farm dividing it into sampling units as shown in Figures 4a and b was made. A composite soil sample is taken from each soil-sampling unit. The farm was then sampled as indicated in the following illustrations:

(1) Use the right sampling tool: The best tool is a metal tube called a sampling-tube. However, if this is not available, any of the materials illustrated below could be used (Figure 5). These include cutlass, shovel, hand trowel and augur.
(2) The sample: A composite sample; comprising of 10 to

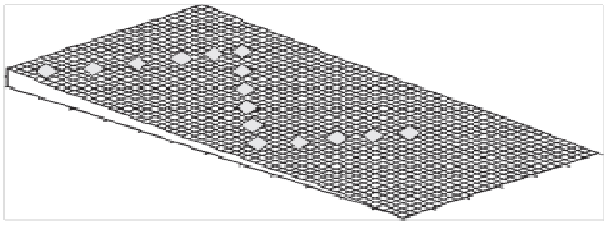


Figure 6. Example of a zigzag sampling layout on a near-level surface. Soil samples would be taken at each point labeled with a diamond shape (Canadian Soc. Of Soil Sci., 1993).

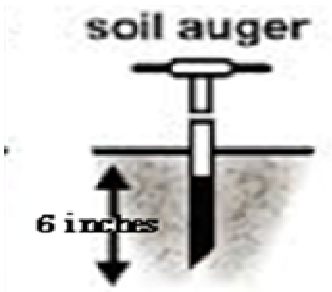


Figure 7. Collecting soil sample using sampling tube.

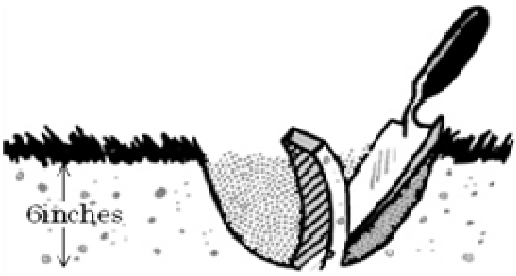


Figure 8. Collecting soil samples using a shovel, spade or cutlass (Sonon and Kissel, 2009).

20 core (single location) (However 15 sub-samples may be the minimum number required to give sufficiently low variance, especially for P) samples that have been taken randomly in a zigzag fashion across the same soil area (land unit) is obtained (Figure 6). The land unit or soil area from which each composite sample is obtained is about one hectare. Sampling fertilizer bands, terrace channels, dead furrows, roads and other unusual areas should be avoided.

(a) Sample the soil from the surface to about 15 cm (6 inches) depth with a sampling tube, or any of the tools stated above. For a sampling tube, the process is as illustrated in Figure 7.
(b) If the tool available is a spade, a shovel, or a cutlass,

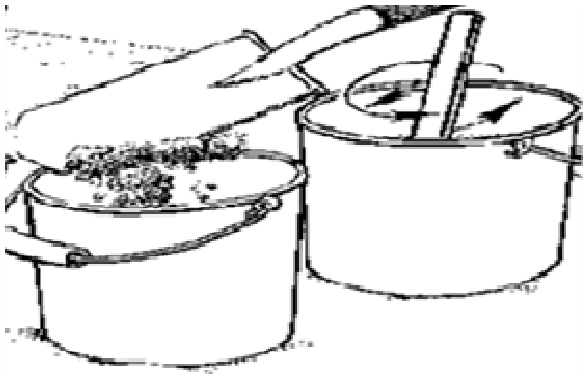


Figure 9. Mixing of soil samples after collection. (Sonon and Kissel, 2009).

Figure 10. Getting the sample ready for laboratory test.

proceeds as follows:

(i) Dig a v-shaped hole, 15 cm (6 inches) deep
(ii)Then take one-and a –quarter centimeter (1/2 inch) slice of soil sample from the smooth side of the v-shaped hole illustrated in Figure 8.

(3) Put all the core samples taken from the soil area together in a clean plastic bucket, as a composite sample.
(4) Mix the sample well with a clean rod or with your hand in the bucket (Figure 9).
(5) Pour the soil sample into a clean plastic bag and tie it securely (Figure 10).
(6) Label each plastic bag of sample properly.
(7) Fill out the information requested as accurately as possible and send the sample to laboratory for analysis (Figure 10).

Soil test result interpretation

The figures on the soil analysis report (Figure 11 and Table 4) do not indicate the exact amount of nutrients

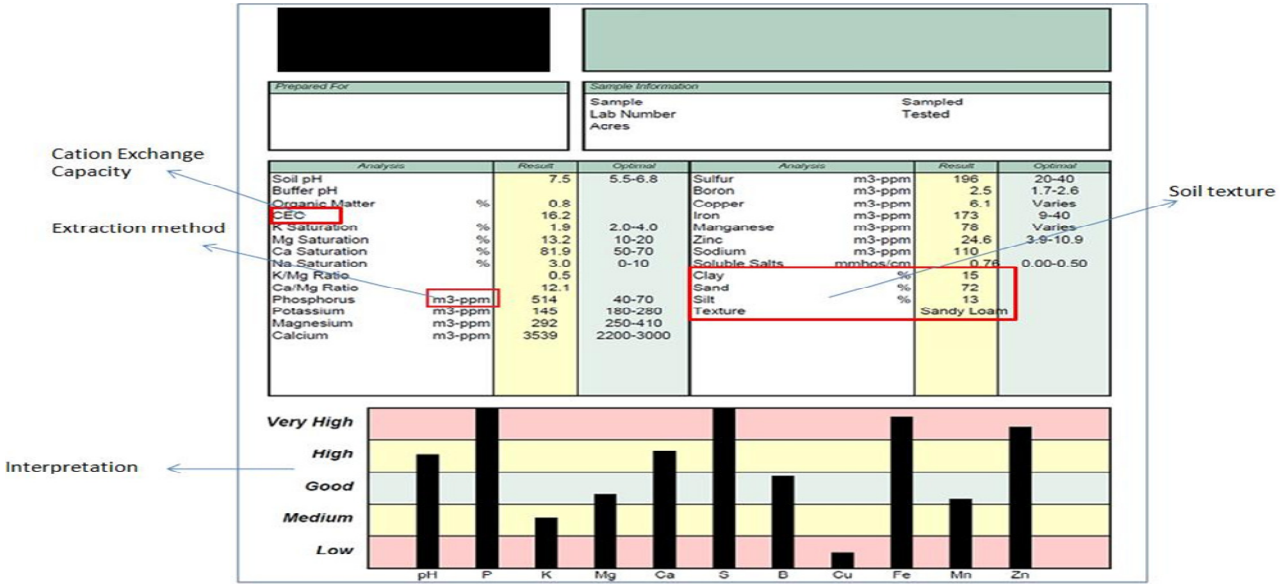


Figure 11. Sample of soil test result. (SMART, 2010).

Table 4. Physical and chemical properties of soils of selected fadama sites in FCT, Nigeria.

RVA	Name of farmer	(g kg^{-1})			Text class	pH ratio 1:2.50		g kg^{-1}		mg kg^{-1}	< ---------- (Cmol kg^{-1}) ---------- >						%
		Sand	Silt	Clay		H_2O	1N KCl	OC	N	Available P	Ca	Mg	K	Na	H + Al	CEC	BS
Pukafa	Abdullahi Yusuf	720	140	140	SL	6.5	5.2	4.4	0.35	15.6	1.8	1.2	0.16	0.14	0.1	4.3	79.07
Pukafa	Mallam Hamidu	540	320	140	SL	6.4	5.3	6.4	0.53	18.9	3.2	2.4	0.19	0.52	0.1	7.1	90.28
Pukafa	Abdu Rahman Serki	740	140	120	SL	6.3	5.5	2.4	0.35	16.9	3	2.2	0.13	0.23	0.1	6.4	88.44
Pukafa	Dauda Madaki	520	320	160	SL	6.2	5.4	8.8	0.35	32.2	4.4	3.1	0.08	0.17	0.1	9.3	84.41
Pukafa	Ibrahim Dauda	760	100	140	SL	6.1	5.4	7.6	0.7	69	3.6	2.3	0.1	0.17	0.1	7.1	88.31
Pukafa	Ali Ayuba	370	420	210	L	6	5.2	18.8	1.23	22.2	8	5.2	0.16	0.29	0.1	17.3	79.48
Pukafa	Adamu Yau	280	500	220	SiL	6	5.4	15.2	0.7	32.8	7	4.3	0.18	0.78	0.1	14.2	87.04
Pukafa	Muhammed Isiaka	330	480	190	L	6.1	5.4	18.8	1.75	31.5	7	4.4	0.18	0.61	0.1	13.7	89.71
Pukafa	Mallam Yahaya	570	280	150	SL	6.1	5.4	6.8	0.53	34.4	3.6	2.2	0.08	0.35	0.1	8	79.13
Pukafa	Mallam Idris	680	200	120	SL	6	5.5	4.8	0.35	19.5	2.4	1.3	0.11	0.7	0.1	6	76.83
Pukafa	Yunisa Ibrahim	370	420	210	L	6	5.3	18.4	1.75	21.5	7	4.2	0.2	0.87	0.1	13.6	90.96
Pukafa	Muhammed Ibrahim	720	160	120	SL	6.1	5.6	14	0.53	16.9	2.4	1.6	0.1	0.26	0.1	5.5	81.09

Culled from Report of Soil and Water Baseline Survey for National Fadama III Project (2010).

available to a crop but when interpreted correctly give a description of the soil fertility status. The analytical result is used to suggest how much nutrient should be applied. The exact amount needed will depend on the crop to be grown and must be modified to suit the conditions under which it is grown.

CONCLUSION

Continuous removal of nutrients from the soil via different means requires continuous replacement to maintain productivity. This replacement (fertilization) requires specific knowledge in order to truly maximize yield, minimize cost and to reduce adverse effect on soil/crops. Of the methods available, soil test seems to be the easiest to predict fertilizer requirement for Nigerian farmers. At a certain level, the complex tissue analysis may be used as a tool but it must be combined with soil test result.

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