

1. ROLE OF SOIL TESTING IN SUSTAINABLE AGRICULTURE

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Declining natural resources and rapidly increasing population have resulted in building up a pressure on our ecosystem. To feed the estimated population, our production has to be increased significantly. The limited availability of land for crop production, along with declining yield growth of major food crops has raised concerns about agriculture’s ability to feed the population. Stagnation in crop yields, increased cost of fertilizers and imbalanced nutrition and decline in soil fertility has pushed Indian agriculture to be at cross roads.

The year 2025 could be foreseen as a “Watershed year” by when Indian population would overtake the population of China and the availability of land to every child born will be negative. The solution to this lies in increasing the food production per unit area per unit time. India is using about 17.5 million tonnes of plant nutrients (NPK) and is likely to need about 45 million tonnes by 2025. For this the soil health needs to be cared. Mismanagement and neglect of the soil can ruin the fragile resource and become a threat to human survival.

Long term projections have indicated that agriculture is pushing itself towards stagnation with severe damage to eco-systems. Imbalanced nutrition, adverse soil reaction due to use of fertilizers, build up of phosphorus antagonizing zinc uptake, deleterious effect on microorganisms, soil degradation and affecting the soil quality are the reasons for decrease in the growth rate of crops. To overcome these problems, we have to increase soil productivity. This is linked to soil health and soil quality. Maintenance of soil health and soil quality is essential to sustainable agriculture. Hence, in recent years a concept of sustainable agriculture is developed in order to ensure that the agro-eco-systems are stabilized and sustained crop yields are assured on long term basis.

Sustainability means keeping an effort going continuously, or the ability to last out and keep from falling. So, sustainable agriculture means successful management of resources for agriculture to satisfy the changing human needs, while maintaining or

enhancing the quality of environment and conserving natural resources. Sustainable agriculture refers to agriculture - where the agro-eco-systems function on self sustaining basis of nutrient supply and crop protection in order to stabilize the crop yields. Sustainable agriculture involves practices such as organic farming, biological and natural control of pests, and emphasis of watershed approach to conserve the soil and water, buildup of micro flora in close harmony with beneficial soil - inhabitants and complete restricting the use of synthetic chemicals. It is sustainable agriculture - which ensures pollution free food production and which ensures continuation of agriculture with least damage to eco-system.

Here comes the importance of soil testing. To maintain the soil health as well as quality, protecting the degradation of soil due to excess use of fertilizers and saving our soils from residual contamination. Soil testing is done to understand the quantity of plant available nutrients present in the soil and to determine the fertilizer recommendation based on it. Before analysis, it becomes important to understand the available forms of nutrients and their movement in the soil leading to their uptake.

Essential Nutrients, Forms of availability and their movement in soil

Essential nutrients are elements needed by the plant without which it will not be able to survive. For an element to be regarded as an essential nutrient, it must satisfy the following criteria as propounded by Arnon and Stout (1939).

1. A deficiency of an essential nutrient element makes it impossible for the plant to complete the vegetative or reproductive stage of its life cycle.
2. The deficiency is specific to the element and can be prevented or corrected only by supplying that element.
3. The element is involved directly in the nutrition of the plant, quite apart from its possible effects in correcting some microbiological or chemical conditions of the soil or other culture medium.
4. Most plants need this element to survive.

There are sixteen essential nutrients for plants including major, secondary and micro nutrients. These are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo) and nickel (Ni).

Training Manual on "Soil Testing and Fertilizer Recommendation"

Certain nutrients like Si and Co are considered as beneficiary nutrients. The major forms in which these nutrients are taken up by plants are given in the table.

Nutrient	Form
N	Nitrate (NO_3^-), Ammoniacal (NH_4^+)
P	Phosphate (PO_4^{3-})
K	K^+
Ca	Ca^{2+}
Mg	Mg^{2+}
S	SO_4^{2-}
Fe	Fe^{2+}
Mn	Mn^{2+}
Zn	Zn^{2+}
Cu	Cu^{2+}
B	H_3BO_3
Mo	MoO_4^{2-}
Ni	Ni^{2+}

Nutrient movement in the soil

There are three ways by which nutrients reach the root surface.

1. Mass flow

The movement of nutrients through the soil to roots is in the convective flow of water caused by the plant water absorption. The rate of nutrients transfer by mass flow (J) is given by the rate of water flux into the root (V) and the concentration of the ion in solution (C_1).

$$J = V \cdot C_1$$

2. Diffusion

Nutrients move from higher concentration in the bulk soil solution to lower concentration at the root. As roots absorb nutrients from the surrounding soil solution, the nutrient concentration at the root surface decreases compared with the bulk soil solution concentration that causes ions to diffuse toward the root. Ion diffusion in soils can be quantified by Fick's law which can help in understanding factors influencing diffusion in soil

$$dC/dt = D_e \cdot A \cdot dC/dX$$

Where, dC/dt = rate of diffusion

dC/dX = concentration gradient

D_e = effective diffusion coefficient

A = cross-sectional area through which the ions diffuse

3. Root interception

Roots obtain nutrients by physically contacting nutrients in soil solution or on soil surfaces. Root interception represents exchange of ions through physical contact between the root and mineral surfaces. Ion absorption by root interception is enhanced by increasing the quantity of absorbing roots in a given volume of soil. As root develop, contact between soil and roots increases. Ions such as H^+ adsorbed to the surface of root hairs may exchange with ions held on the surface of clays and OM because of the intimate contact between roots and soil particles. The ions held by electrostatic forces at these sites oscillate within a certain volume. When the oscillation volumes of two ions overlap, ion exchange occurs. Root interception of nutrients can be exchanged by mycorrhiza, a symbiotic association between fungi and plant roots.

Objectives of soil testing

1. Provide an index of nutrient availability (or supply) in a given soil. A soil test measures a portion of a nutrient from a "pool" that is used by plant.
2. Predict the probability of obtaining a profitable response to lime and fertilizer
 - On low testing soils, a response to applied nutrients may not always be obtained because of other limiting factors (moisture, pH, other nutrients)
 - BUT the probability of a response to nutrient additions on low testing soils is greater than high testing soils
 - Correlation
3. Provide a basis for recommendations on the amount of lime and fertilizer to apply
 - Relationships obtained through laboratory, greenhouse, and field studies

Soil Test Interpretation Categories

Soil Test Level	Relative Supply of Nutrients From Soil and Fertilizer	Probability of Yield Increase
Very High	Soil	<5%
High	Soil Fert.*	5-30%
Optimum	Soil Fertilizer	30-60%
Low	Soil Fertilizer	60-90%
Very Low	Soil Fertilizer	>90%

Nutrients available from soil
Nutrients required

* Fertilizers used at high soil test levels are for starter or maintenance purposes

An understanding on the forms of available nutrients would help in soil analysis and in interpreting the soil test results. Soil test results would aid in determining the fertilizer recommendation. Application of fertilizer based on the nutrient status of soil is a must as it would help in maintaining the soil health, controlling the issue of fertilizer residual contamination. This would also benefit the farmers in monetary terms as the quantity of fertilizer to be added may be lesser than the blanket application. In the long run, this could sustain the fertility and productivity of soil by maintaining the soil health and quality which is a component of sustainable agriculture.