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Soil Testing Scenario in India and Its Significance in the Balanced Use of Fertilisers

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Authors' contributions

This work was carried out in collaboration between all authors. Author HMM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors HMM and RPS managed the analyses of the study. Author Roohi managed the literature searches. All authors read and approved the final manuscript.

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Short Communication

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ABSTRACT

Soil testing is employed for quick characterisation of the inherent fertility status of soils and predicting the nutrient requirements of crops. Soil testing is guiding the farmers regarding the balanced and judicious use of the fertilisers, which ultimately reduces the overall costs and finally mitigate the consequences of the global warming. Proper soil sampling techniques must be demonstrated to the farmers for having more meaningful results by adopting which more desirable results will be achieved. Soil sampling will be the ultimate gadget which surely improves the livelihoods of the farmers by reducing the dose of fertilisers as we have to feed the crop but not the soil.

Keywords: Soil testing; fertility status of soil; soil health and balance nutrition.

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1. INTRODUCTION

Soil testing refers to the chemical analysis of soils and is well recognised as a scientific means for quick characterisation of the inherent fertility status of soils. It also includes testing of soils for other properties like texture, structure, pH (depending on Organic carbon (%), available phosphorus and potash), Cation Exchange Capacity, water holding capacity, electrical conductivity etc. and parameters for amelioration of chemically deteriorated soils for recommending soil amendments, such as gypsum for alkali soils and lime for acid soils. The basic purpose of the soil-testing programme is to give farmers a service leading to better soil, soil testing helps in soil management in various ways. Like for example pattern of soil justifies the type of cropping or more precisely soil specific cropping. It helps in soil reclamation and helps to know the gypsum requirement etc. and more economical use of fertilisers and better soil management practices for increasing agricultural production.

1.1 Objectives of Soil Testing

a. To provide an index of inherent nutrient availability in soil.
b. To predict the probability of obtaining a profitable response to lime and fertiliser.
c. To provide a basis for recommendations on the amount of fertiliser, that is applied in fields, mostly for orchards and salt-affected soil.
d. Such summaries are helpful in developing both farm level and nutrient management programmes.

1.2 History of Soil Testing in India

The soil testing programme started in India during the year 1955-56 with the setting-up of 16 soil testing laboratories under the Indo-US Operational Agreement for "Determination of Soil Fertility and Fertilizer Use". In the early 50's when soil testing work started scientists (mainly at IARI) were concerned with the development/adoption/calibration of suitable soil test methods, and by far the most attention was paid to soil tests for phosphorus.

Early work on soil testing owes a great deal too late Dr N.P. Datta and his associates at IARI [1]. Goswami and co-worker's attempted soil test-crop response correlation work from a large volume of field data from the All India Coordinated Agronomic Research Project (1968) under cultivator's fields (simple fertiliser trials) for rice and wheat. In 1965, five of the existing laboratories were strengthened, and nine new laboratories were established under the Intensive Agricultural District Programme (IADP) in selected districts. To meet the increasing requirement of soil testing facilities, 25 new soil-testing laboratories were added in 1970 and 34 mobile soil testing vans were established under the joint auspices of the Technical Cooperation Mission (TCM) of USA, IARI (Indian Agricultural Research Institute) and Govt. of India.

The number of soil testing laboratories (STLs) has increased progressively from 1971 to 2000 exhibiting an annual growth rate of 6.94 % over a period of thirty years. During 11th Five Year Plan, a National Project on Management of Soil Health and Fertility (NPMSHF) scheme provides for setting up of 124 and 118 new static and mobile soil testing laboratories, respectively and strengthening of the existing 170 labs with micronutrient testing facilities.

1.3 Soil Testing Laboratories in India

The number of soil testing laboratories increased to 1,049 of which 896 are static, and 153 are mobile with a total analysing capacity of 107 lakh sample annually. These laboratories were analyzing pH, EC, major plant nutrients, i.e. N, P and K and quality of irrigation water and some of the laboratories have started analysing secondary and micro-nutrients.

1.4 Functions of Static soil Testing Laboratory

i. Analysis of soil samples which are collected by farmers or from the farmers by the Assistant Agricultural Officers.
ii. Analysing irrigation water samples for EC, pH, cations and anions; Assessing their quality based on different parameters; and suggesting suitable ameliorative measures for different soil condition and crops.
iii. Based on the soil test value for the soil samples collected during the particular year they are rated as low, medium and high; and village fertility indices will be prepared.
iv. Conducting trials related to soil fertility to solve the site-specific problems.

1.5 Functions of Mobile Soil Testing Laboratory

i. The staffs of the mobile soil testing laboratory visit the villages to collect and analyse the soil and irrigation water samples in the village itself and give recommendations immediately.
ii. Show the audio-visual programmes through projectors in the villages to educate the importance of soil testing, plant protection measures and other practices related to crop production.

1.6 Constraints in Functioning of STLs

i. Inadequate technical staff.
ii. Weak and inadequate linkages of STLs with SAUs and other research organizations.
iii. Poor level of training support from research organizations to STL personnel.
iv. Lack of new equipments and lack of laboratory automation.
v. Attainment of poor targets on farmer's fields particularly on small and marginal farmers is also one of the constraints that need consideration which may be due to improper selection of testing methods.

1.7 Soil Nutrient as an Index of Soil Fertility

Soil testing laboratories use organic carbon as an index of available N, Olsen's and Bray's method for available P and neutral normal ammonium acetate for K.

Available nutrient status in the soils is generally classified as low, medium and high which are generally followed at the National level in Table 1 [2].

1.8 Nutrient Status – N P K

Singh [3] computed nutrient index values and prepared a soil fertility map for nitrogen, phosphorus and potassium using 3.65 million soil analysis data collected from 533 soil testing labs representing 450 districts in the country (Fig. 1).

Table 1. Soil fertility categories

Sr. no.	Soil Nutrients	Soil fertility ratings		
		Low	Medium	High
1.	Organic carbon as a measure of available Nitrogen (%)	< 0.5	0.5-0.75	>0.75
2.	Available N as per alkaline permanganate method (kg/ha)	< 280	280-560	>560
3.	Available P by Olsen's method (kg/ha) in Alkaline soil	< 10	10-24.6	>24.6
4.	Available K by Neutral N, ammonia acetate method (kg/ha)	< 108	108-280	>280

(Source: Muhr et al., 1965)

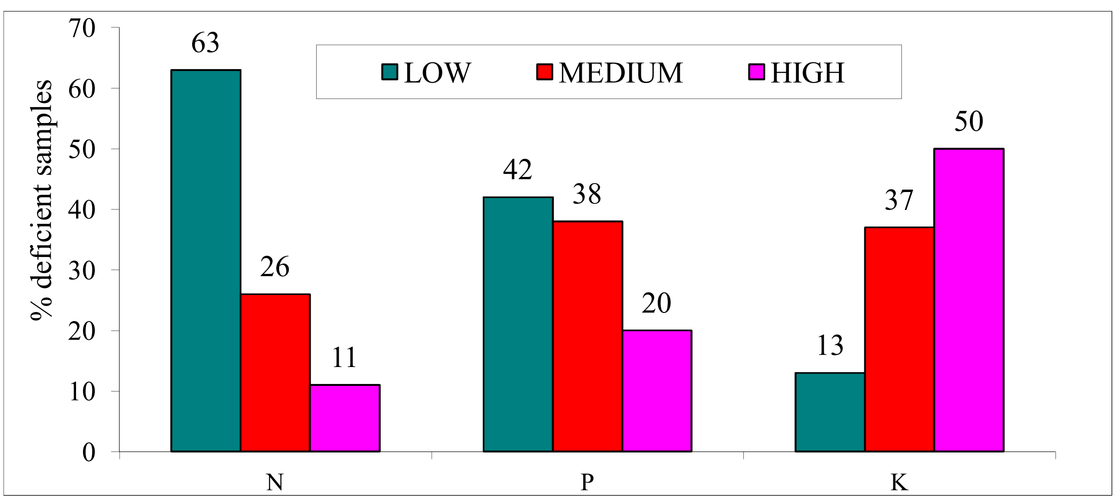

Fig. 1. Primary nutrients (N, P and K) status in Indian soils
(Source: Singh, 2010)

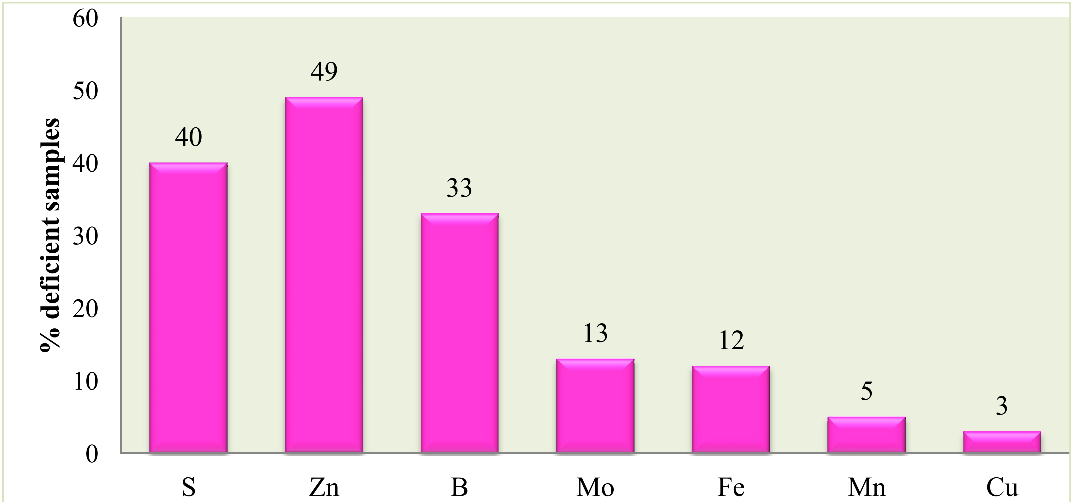

Fig. 2. Secondary and micro-nutrients status in Indian soils
(Source: Singh and Behera, 2011)

Table 2. Soil tests methods and critical levels of nutrients in soils and plants

Element	Soil test method	The critical level in the soil	The critical level in plant
Sulphur	Hot water, CaCl2 or phosphate	Usual 10 ppm	< 0.15-0.2%
Calcium	Ammonium acetate	< 1.5 me Ca/100 g	< 0.2%
Magnesium	Ammonium Acetate	< 1 me Mg/100 g	< 0.1-0.2%
Zinc	DTPA	0.6 ppm	< 15-20 ppm
Manganese	DTPA	2 ppm	< 20 ppm
Copper	DTPA or Ammonium acetate	0.2 ppm	< 4 ppm
Iron	DTPA, Ammonium acetate	2.5-4.5 ppm	< 50 ppm
Boron	Hot water	0.5 ppm	< 20 ppm
Molybdenum	Ammonium oxalate	0.2 ppm	< 0.1 ppm

1.9 Secondary and Micro-nutrients Status in Indian Soils

Singh and Behera [4] Three lakh soil samples were analysed from different sites and reported that 49 % soil samples were deficient in Zn, 40 % in S, 12 % in Fe, 3 % in Cu, 5 % in Mn, 33 % in B and 13 % in Mo (Fig. 2).

Suitable testing methods are being standardized under the All India Coordinated Research Project on Micronutrients.

2. APPLICATIONS OF SOIL TESTING

1. Generalized Fertilizer recommendation (GRD)
2. Integrated nutrient management
3. Site-specific nutrient management
4. Soil test based fertilizer recommendation
5. Fertilizer recommendation for a targeted yield of the crop
6. Preparation of soil maps
7. Soil health cards

2.1 Generalized or State Level Blanket Fertilizer Recommendation

The state-level fertilizer recommendations for a particular crop are given from time to time in the package of practices for *Kharif* and *ravi* crops. It is most commonly advocated and followed method and ideally suited to soils of medium fertility.

Limitations:

1. Due to variation in soil fertility, it does not ensure economy and efficiency of applied fertilizer.

2. Wastage in high fertility and sub-optimal use in low fertility soils.

2.2 Soil Test Based Fertilizer Recommendations

Generalized recommendation of fertilizers is suitable for soils of medium fertility. If soil test value comes under high rating then recommended a dose of fertilizer is reduced by 25-50 per cent and if the rating is low then recommended a dose of chemical fertilizer is increased by 25-50 per cent.

Limitations:

- Same dose for extremely low and moderately low soils.
- Same dose for extremely high and moderately high soils.

2.3 Soil Test Based Fertilizer Recommendation for a Targeted Yield of the Crop

The method of fertilizer recommendations thus developed, is called "Prescription Based Fertilizer Recommendations", and is specific to a given type of soil, crop and climate situation. The requirement of nutrients is different for different crops and the efficiency of soil available nutrients as well as those added through fertilizers is also not same for a different type of soils under a particular set of climate conditions. Keeping this in view, the following tree parameters are worked out for the specific crop and area for development of prescription based fertilizer recommendations:-

1. Nutrient requirement (N, P and K) in kg/quintal grains (NR)
2. The percentage contribution from soil available nutrient total uptake (CS).
3. The percentage contribution from applied nutrient (fertilizer) to total uptake (CF).

Development of fertilizer adjustment equation:

$$\text{Fertilizer nutrient dose} = \frac{\text{NR}}{\text{\% CF}} X\ 100\ \frac{\text{\% CF X STV}}{\text{\% CF}}$$

After calculating these three basic parameters from the yield and uptake data from the well-conducted test crop response experiment, these basic parameters, in turn, are transferred into simple, workable fertilizer adjustment equations of the type:

$FN = XT – Y\ SN$
$FP_2O_5 = XT – SP$
$FK_2O = XT – SK$

Where,

X and Y = constants
T = Yield target in quintal per hectare
FN = Nitrogen dose in kg/ha which is to be added to fertilizer
FP_2O_5 = P_2O_5 dose in kg/ha which is to be added to fertilizer
FK_2O = K_2O dose in kg/ha which is to be added to fertilizer
SN = Soil test value in kg/ha for available N
SP = Soil test value in kg/ha for available P (not P_2O_5)
SK = Soil test value in kg/ha for available K (not K_2O)

2.4 Integrated Nutrient Management

The combined use of chemical fertilizers and organics becomes essential to meet the nutrient requirement and reduce the negative balance. Also sustaining of the soil productivity and soil health becomes easier with the inclusion of organic sources along with inorganic fertilizers. Technologies have been generated at different locations across the country for the integrated supply of plant nutrients involving fertilizers, organic manures and bio-fertilizers. In this technique, the fertilizer nutrient doses are adjusted not only to that contributed from soil but also from various organic sources like FYM, green manure, compost, crop residues and bio-fertilizers like *Azospirillum* and *Phosphobacteria*.

2.5 Site-specific Nutrient Management

Site-specific nutrient management (SSNM) should be followed to apply the required amount of fertilizers for optimizing the supply and demand of nutrients according to their variation in time and space for achieving the high yield targets. The SSNM approach aims at increasing farmer's profit by achieving the goal of maximum economic yield (MEY) of crops on a sustainable basis, maintaining soil fertility and protecting the environment.

Site-specific nutrient management provides an approach for “feeding” the crops with the nutrients as and when they are needed.

2.6 The Main Features of SSNM are

- ✓ Application of nitrogen, phosphorus and potassium fertilizers is adjusted to the location and season-specific needs of the crop.
- ✓ Site-specific application of secondary and micronutrients based on soil tests are ensured.
- ✓ This approach advocates wise and optimal use of existing indigenous nutrient resources such as crop residues, manures, etc.

Srinivasan and Angayarkanni [5] observed that the fertilizer requirement decreased with the conjoint application of fertilizers + FYM + *Azospirillum* for a specific yield target at the same soil test value. Hence there will be a balanced supply of nutrients coupled with organics and bio-fertilizers avoiding either under or over usage of fertilizers.

Santhi et al. [6] observed that fertilizer requirement decreased with the conjoint application of fertilizers + FYM for a specific a specific yield target at the same soil test value due to a balanced supply of nutrients coupled with FYM avoiding over the use of fertilizers.

Soman et al. [7] observed that the superiority of site-specific nutrient management (SSNM) over farmer's fertilizer practice (FFP) in increasing the root yield of cassava and uptake of N and P in SSNM plot significant increase compared to farmer's fertilizer practice plot.

Tiwari et al. [8] reported that nutrient application by site-specific nutrient management principles resulted in significantly higher grain yields over farmers' practices (FP) and recommended a dose of fertilizer (RDF).

Katharine et al. [9] observed that seed cotton yield numerically higher in the STCR-IPNS treatments compared to STCR-NPK alone treatments and also the seed cotton yield significantly higher under STCR-NPK alone and STCR-IPNS treatments compared to general recommendation of fertilizers and farmer's practice.

Nagegowda et al. [10] observed the grain and straw yield of rice was significantly higher in SSNM-major + secondary + micronutrient treatments compared to Farmers' Fertilizer Practice (FFP).

Deshmukh et al. [11] reported that the application of balanced fertilizer dose of N, P and K as per STCR treatment with or without farm yard manure @ 2.5 t ha^{-1} helped to maintain the organic carbon status and available N, P and K in soil thereby sustaining the soil health.

2.7 Preparation of Soil Fertility Maps

An attempt was made with a joint venture of IISS, Bhopal and NBSSLUP, Nagpur to create spatial fertilizer recommendation maps using available validated fertilizer adjustment equations (STCR's generated) and Geographic Information System (GIS). The maps can also be updated from time to time based on the soil test result data base. It can be further narrowed down to block/village level depend on the availability of information. These fertility maps can also be used to study the changing trends in the fertility status of nutrients and can be correlated with fertilization practices of farmers of a particular region.

Scientists in this regard approach to many other technically advanced methods that can explore the better way of soil renovation. Several technologies are involved in the formation of better soil or crop-specific soil that inherits all the useful nutrients to it. Numerous agricultural universities have taken a step ahead to built better agro-economic ventures for the enrichment of agriculture not only in Indian aspects but also in the platform of the world.

2.8 Soil Health Cards

The soil analysis basically aims at assessing the fertility status of the soil. This information along with the additional information on the farmer's land may be presented to the farmers in the form of soil health cards. The additional information may relate to the relevant revenue record of farmer's field. This card may also be useful to the farmers in getting loans for agriculture purposes where the agricultural value of the land may be one of the factors.

5th December is celebrated as World Soil day" throughout the world, which is said to be importance for soil as a critical component of the natural system and as a vital contributor to the human commonwealth through its contribution to food, water and energy security and as a mitigator of biodiversity loss and climate change.

2.9 Objectives of Soil Health Cards

1. Provide direct advice to farmers.
2. The soil health card so issued to the farmers may be periodically updated so as the farmers are aware of the changing fertility status of their land.
3. Soil analysis for all villages in the state.
4. Provide guidance to farmers regarding fertilizer usage and alternative crop patterns.
5. Provide Soil Health Cards to every farmer

3. CONCLUSION

Soil testing is employed for quick characterization of the fertility status of soils and is to give farmers a service leading to better and more economic use of fertilizers and better soil management practices for increasing agricultural production. Balance nutrition through soil testing helps in maintained soil fertility and soil health. Targeted yield fertilizer recommendations provide balanced nutrition to crops, thus, are able to sustain the crop productivity. GIS-based soil fertility maps are used as a decision support tool for nutrient management will not only be helpful for adopting a rational approach compared to farmer practices or blanket use of state recommended fertilization but will also reduce the necessity for elaborate plot-by-plot soil testing activities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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