

Paradigm shift in soil fertility ratings

for sustainable crop production and environmental quality

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Evaluation of soil fertility status of a region is important for sustainable agricultural production. Nutrients in soil govern its fertility and control the crop yield. However, in recent years, partial factor productivity and crop yields are declining. This revealed that there are shortcomings in our soil fertility ratings, fertilizer recommendations and management which lead to loss of costly chemical fertilizers. Therefore, there is an urgent need for improving soil testing, interpretations and fertilizer recommendations, and also innovations in nutrient management for sustainable use of resources to attain nutritional goals. The recommended doses of fertilizers which are currently in practice were developed back in 1970s and it may not meet nutrient requirement of high yielding varieties that have been developed recently. Further, three level soil fertility rating and nutrient indexing is vague, because there is a large variation (range) within a fertility category. Therefore, this review suggests nine level soil fertility rating and nutrient indexing based nutrient recommendations to the crops. Further, it emphasizes on innovative advanced nutrient management practices for efficient and sustainable crop production.

Keywords: Crop production, Nutrient management, Nutritional security, Soil testing

AGRICULTURE continues to be mainstay for livelihood of rural Indian population. Fertilizers continue to play an important role in achieving the total food grain production worldwide to feed the ever-increasing population. Around 50% of the enhanced food production globally comes from use of chemical fertilizers. In our opinion it is difficult to determine exactly how much crop yield is due to the use of commercial fertilizers because of inherent soil fertility, climatic conditions, crop rotations, management and the crop itself. Some crops (*e.g.*, legumes) are not responsive to N fertilization and crops differ in their nutrient requirements. Our responsibility is to develop and employ management practices that use fertilizer effectively and efficiently. Existing soil testing and fertility rating related nutrient recommendations need to be modified according to the need of high yielding varieties being grown

now days.

With increasing global food demand for feeding the increasing population and diversion of resources used for producing food grains to non-agricultural activities, it becomes imperative to have a relook at the strategies on efficient use of soil resource. This review critically analyzes the status and usefulness of the current soil testing and fertility ratings and nutrient management practices and their lacunae, highlights the modifications that are needed in soil fertility rating and management, and suggests future course of actions needed to achieve country's food security goals.

National scenario of nutrient use efficiency of fertilizer inputs

Compilation and computation of nutrient use efficiencies from fertilizer inputs based on 207 trials across 15 states carried out under All India Coordinated Research Project

on Soil Test Crop Response Correlation (ICAR-STCR) revealed that average use efficiency of fertilizers – N, P and K was 46.6 ± 17.7 , 35.1 ± 17.2 and $112.4 \pm 62.6\%$, respectively. Lower N use efficiencies were observed in Chhattisgarh (29.9%) and West Bengal (39.5%). Relatively higher N use efficiencies were observed in Tamil Nadu (51.2%), Bihar (51.3%), New Delhi (52.5%) and Rajasthan (62.9%). Relatively low P use efficiencies were observed in Bihar (20.8%), New Delhi (25.7%), Himachal Pradesh (28.4%), Uttarakhand (29.1%) and Chhattisgarh (31.6%) while Karnataka (53.4%) and Punjab (62.9%) had higher P use efficiencies. Low K use efficiencies were observed in Tamil Nadu (64.1%), Karnataka (71.9%) and Odisha (75.8%). Relatively higher K use efficiencies observed in Madhya Pradesh (128.5%), Chhattisgarh

Table 1. Crop wise average nutrient use efficiency from fertilizer inputs

Crop	Number of trials	Nutrient use efficiency (%)		
		Nitrogen	Phosphorus	Potassium
Rice	50	42.9±16.2	36.2±23.8	120.8±76.4
Wheat	58	42.8±12.3	28.4±18.2	121.8±97.4
Maize	26	43.9±15.8	43.5±25.4	121.6±60.2
Sugarcane	13	50.8±19.2	28.8±10.9	102.4±54.6
Cotton	6	36.7±4.5	47.2±19.8	40.1±11.2
Millets	22	47.9±20.4	33.9±19.1	145.6±73.5
Vegetables	32	58.0±23.9	39.2±23.9	104.9±77.8

Note: Data are compiled and calculated from 207 trials across fifteen states carried out under All India Coordinated Research Project on Soil Test Crop Response Correlation (ICAR-STCR)

Table 2. Soil fertility rating followed in India (Adopted from Dhyani-Singh *et al.* 2005)

Fertility category	Organic carbon (%)	Phosphorus (kg/ha)	Potassium (kg/ha)	Nitrogen (kg/ha)	Nutrient index
Low	<0.50	<10	<120	<280	1.0-1.67
Medium	0.50-0.75	10-25	120-280	280-560	1.68-2.33
High	>0.75	>25	>280	>560	2.34-3.0

Table 3. Modified nine level soil fertility rating

Category	Organic carbon (%)	Phosphorus (kg/ha)	Potassium	Nitrogen	NI ₉
Very Low	<0.15	<5	<50	<100	1.0-1.8
Low	0.15-0.3	5-10	50-100	100-150	1.9-2.7
Moderately Low	0.3- 0.45	10-15	100-150	150-200	2.8-3.6
Slightly Medium	0.45-0.6	15-20	150-200	200-250	3.7-4.5
Medium	0.6-0.75	20-30	200-250	250-350	4.6-5.4
Highly Medium	0.75-0.9	30-40	250-300	350-450	5.5-6.3
Moderately High	0.9-1.05	40-50	300-350	450-550	6.4-7.2
High	1.05-1.20	50-60	350-400	550-650	7.3-8.1
Very High	>1.20	>60	>400	>650	8.2-9.0

(130.5%), Haryana (134.2%), Uttarakhand (166.8%) and Punjab (244.7%). The crop-wise nutrient use efficiencies across the fifteen states are given in Table 1.

Soil fertility rating

Currently in all the soil testing laboratories across India, the three level fertility rating of low, medium and high is followed. Nutrient index (NI) is commonly used to assess the fertility status of a farm or a region (village, block, district or state level). Nutrient index (NI) is calculated using equation given by Parker *et al.* (1951).

The range of nutrient index value is from 1.0 to 3.0 and based on the NI values soils are categorized into three classes as low (1.0-1.67), medium (1.68-2.33) and high (2.34-3.0) fertility status (Table 2). But there is a large variation within the category. Therefore, it is necessary to narrow down the cap within a

category for correct fertility rating along with appropriate fertilizer recommendations.

Modified fertility rating

In view of the lacunae in current soil fertility ratings, it is suggested to adopt nine classes of soil fertility rating, viz. very low, low, moderately low, slightly medium, medium, highly medium, moderately high, high and very high (Table 3) instead of three levels to narrow down the variations within the fertility level. For efficient management of costly fertilizer, these nine fertility ratings will be very useful. Further this classification might help in grouping the soils having similar nutrient supplying capacity in a particular category. Equation for computation of nutrient index (NI₉) will be:

$$NI_9 = (1 \times N_{vl} + 2 \times N_l + 3 \times N_{ml} + 4 \times N_{sm} + 5 \times N_m + 6 \times N_{hm} + 7 \times N_{mh} + 8 \times N_h + 9 \times N_{vh})/N_{\dots}$$

Where N_x denotes number of soil samples in 'x' category and the 9 categories are vl (very low), l (low), ml (moderately low), sm (slightly medium), m (medium), hm (highly medium), mh (moderately high), h (high) and vh (very high). N denotes total number of soil samples. Here, the range of nutrient index is from 1.0-9.0 and the soils are categorized into nine classes.

Fertilizer recommendations

General fertilizer recommendations

These recommendations are based on multi-location trials conducted with graded dose of N, P and K. Yield responses to applied nutrients are worked out and an optimum dose of fertilizers is recommended for individual crops in a given agro-ecological region. The major drawback with this approach is that the variation in soil fertility is not taken into consideration. Obviously under high or low fertility conditions, the applied nutrients prove to be either wasteful or remain insufficient. Hence, the use efficiency of fertilizer nutrients often remains low with the adoption of these recommendations. Despite these limitations, general recommendations are being used extensively in India and many other Asian countries because of their simplicity and exclusion of costs involved in soil testing. As the present day globally competitive agriculture strives for enhancement in the input use efficiency, this fixed-rate approach needs to be discouraged. Further these recommendations are based on very old practices established in 1970s or 80s. Current intensive agriculture involves cultivation of high fertilizer-responsive hybrids and high yield varieties of crops across the country. Hence, the general fertilizer recommendations have to be revisited and modified to meet the nutrient requirements of current intensive and exhaustive high yielding production systems.

Recommendations based on soil fertility rating

Most of the recommendations prescribed by soil testing laboratories

in India are based on soil fertility ratings, the medium soil fertility being equated with general recommended dose of fertilizers. In low or high categories, the fertilizer doses are raised or lowered by 25% of general recommended doses, respectively. However, there is a large variation in particular fertility category. For instances, in case of N, low fertility category ranges from 0 to 280 kg/ha, but the recommendation is same for all across this range and it seems to be vague. Therefore, this gap has to be narrowed down to accurately meet the crop requirements. Similarly, in case of K, soil with more than 280 kg/ha is rated high, but some soils like Vertisols have more than 500 kg K/ha, so it also warrants attention as it may be of no use to apply K-fertilizer. Since nutrient recommendations with this approach are irrespective of yield goal and variation in soil type, these may perform well for moderate yield levels under optimal soil conditions. For high yield expectations as under commercial farming, however, the approaches considering target yield are more suitable.

Recommendations based on modified soil fertility rating

The current fertilizer recommendations based on soil fertility ratings suffer from lacunae of having similar recommendations due to large variations being covered within the broad fertility category. Though soil test based target yield approach is more suitable, its application at field level has been low due to more complications. The nine level soil fertility rating based fertilizer recommendations may be very useful for efficient use of fertilizers. In this approach also the medium soil fertility category is managed with RDFs. Further, 15, 30, 50 and 75% of RDFs may be increased or lowered for slightly medium, moderately low, low and very low or highly medium, moderately high, high and very high soil fertility levels, respectively. But it is suggested that the acutely degraded soils belonging to very low and low categories should first be restored

with suitable remediation practices and then the fertilizers should be applied to the crops. It will help in reduction of losses of applied fertilizer-nutrients which might otherwise cause pollution to the environment.

Recommendations based on targeted yield approach

Since inception of soil testing in India, two prominent approaches, viz. multiple regression approach of Colwell (1978) and targeted yield approach of Ramamoorthy *et al.* (1967) have been successfully used for making fertilizer recommendations. Now-a-days, targeted yield approach is being extensively used for fertilizer prescription based on pre-decided yield target. Parameters needed in this approach include nutrient requirement in kg per quintal (kg/q) of grain production; per cent contribution from soil available nutrients (CS) and per cent contribution from fertilizer nutrients (CF). Such basic data on number of crops/varieties have been generated under the AICRP-STCR for different soil and climatic conditions for the purpose of making fertilizer recommendations. Recommendations based on this approach are quantitative, precise and meaningful because these involve both soil and plant analysis and have a scientific basis for making balanced fertilization. Advantage of this approach is that a farmer can select a suitable target according to his resources and management conditions. The experience gained from the experimental farms and farmers' fields indicate that with this approach the yield targets can be achieved with $\pm 10\%$ deviation. These recommendations have the potential to meet the needs of soil and crop production strategies such as efficient use of fertilizers according to soil fertility status and crop species; choice of fertilizer recommendation under the fertilizer credit shortage; maintenance of soil fertility in the cropping system; identification of suitable crop rotations from the point of view of relative ability of crop and crop

varieties to utilize soil/fertilizer nutrients and area-wise fertilizer recommendations based on yield targeting and soil nutrient index.

Nutrient management practices

Research efforts are being made to develop efficient nutrient management strategies for producing higher yields and sustaining the soil health. Balanced fertilization of NPK and inclusion of other deficient nutrients in different crops have helped in harnessing higher crop yields and arresting nutrient mining under intensive cropping systems. Of late, emphasis has been to utilize all available organic and inorganic nutrient sources, legumes, biofertilizers, etc. in integrated plant nutrient supply (IPNS) system mode to overcome wide negative nutrient balance in different production systems. Data from the long-term fertilizer experiments across the country have proved that integrated nutrient management comprising 100% NPK + 10 t FYM/ha is the best management practice for sustaining crop productivity as well as maintaining soil health. Further, response of crops to application of 150% NPK under some situations matches the above-mentioned INM treatment. It suggests the need for upward revision of RDFs to meet the requirement of the high yielding varieties and hybrids. This will cater to the demand of the production system, reduce the mining of excess nutrient from soil, and restore soil health.

Apart from this, the method of nutrient supply to meet the crop need is given much attention in recent times. The concept of right time, right dose, right place and right method should be effectively followed. Application of more N, P to some extent and low/nil K is general practices in the majority of the regions in the country. Further, all P and K fertilizers are applied as basal and N is applied in two or three splits. This might be due to reactivity of applied nutrients in the soil. But these lead to low use efficiency and loss of costly fertilizer inputs. Therefore, modified innovative and crop need based nutrient

management strategies are need of the hour to improve crop productivity and reduction of fertilizer nutrient loss.

Innovative strategies in nutrient management practices

Physiological needs of the crops have often been ignored while making fertilizer recommendations. Currently some of the advanced nutrient management practices are evolving based on physiological demand of the crops and are discussed. Site-specific nutrient management (SSNM) and soil test crop response (STCR) based prescriptions are gaining popularity due to their superiority over blanket nutrient recommendations. In addition, precision agriculture and micro-fertigation systems are being given more attention to make efficient use of the available resources. Chlorophyll meter readings (SPAD meter, green seeker and leaf colour chart value) based N-management in rice and wheat system that takes into account the inherent variability in N-supplying capacity of soils, assured high yields consistent with efficient N use and enhanced farmer's profit. Application of NPK complex fertilizers in split doses have also been reported to improve the use efficiencies of applied nutrients and reduced their losses. Moreover, time and doses of split application of fertilizers have been modified. It is claimed that application of fertilizers after germination of seedlings might be effective. Further, the doses of split also need to be clarified based on the physiological needs of the crops. The doses should be 25-50-25% of RDFs for consecutive splits. Because in initial stages plants may not requires more fertilizer, therefore more amount of nutrients during peak

vegetative growth will be useful to the crops and later the nutrients present in the vegetative parts will be translocated and stored in reproductive parts particularly in fruits/grains. Some studies claim that 0-50%-of RDFs for crops might be sufficient as native soil could supply all the nutrients to the crops provided the soil fertility status is medium to high. However, applicability of this kind of innovations should be studied through many numbers of field trials across the country before recommending the same to the farmers. Further, farming system approaches based best nutrient management modules should be developed considering socio-economic status and livelihood of the farmers in various regions of the country.

Future scope

But the current practice of applying recommended doses of fertilizers for various crops is very old one and may not supply adequate nutrients to the high yielding varieties and hybrids. This needs to be revised according to the nutrient demand of the intensive production systems. Moreover the optimum doses of N, P and K need to be computed by fitting response of various crops and using soil fertility status. The application time, doses of splits and method of applications need more attention so as to meet the physiological requirement of the crop as well as to attain nutritional security. Fertilizer-irrigation water interaction studies are to be undertaken. Further modified fertilizers like coated fertilizers, slow releasing super granules, customized fertilizers, organic-mineral multi-nutrient complexes, nutrient blends and micronutrient mixers based on soil-

test-crop response studies for different regions of the country are to be developed with low cost indigenous available materials and studied for enhancing the nutrient uptake of the crops. Liquid fertilizers formulations/soluble fertilizers that are suitable for micro-fertigation systems should be developed and promoted among the farmers. Also applications of nanotechnology principles to use native nutrient containing minerals as nutrient sources for crops can be explored. Moreover, crop growth stage specific nutrient requirement and customized fertilizer products need to be developed for enhancing crop yield and reducing fertilizer loss.

SUMMARY

Fertilizers are one of the key inputs for enhancing crop production. However, improper and inadequate application of fertilizers leads to decline in crop productivity and loss of costly fertilizer inputs. Therefore, a paradigm shift in current soil fertility rating and management is need of the hour to overcome these problems. Use of soil fertility ratings with nine classes is being recommended for a particular farm and for a region through modified nutrient index (NI_9) to narrow down the variation in the particular fertility category. Further, fertilizer recommendations based on this modified ratings will help in judicious use of fertilizers as well as meet the nutrient demand of the crops. This can be used as alternative to STCR based recommendations, because of the complications experienced during practical field applications of the later.

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