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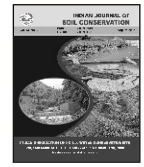

An assessment of soil fertility status of the rainfed region of Chhattisgarh and Madhya Pradesh

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ABSTRACT

There are large yield gaps between farmers' current and achievable yields in Chhattisgarh and Madhya Pradesh. Lack of awareness about soil health is leading to indiscriminate or imbalanced use of chemical fertilizers exposing farm based livelihoods to soil health related risks. Soil fertility assessment of crop fields showed Madhya Pradesh soils relatively poor in terms of soil organic C and available P. All fields in both the states were sufficient in K and majority of the fields in Madhya Pradesh had adequate N and P. Results showed scope to cut use and cost of current N, P and K fertilizers. However, widespread deficiencies were recorded for S (52 to 90% fields), B (67 to 100% fields) and Zn (20 to 52% fields) in the selected sites for the study. Results showed that the deficiencies of S, B and Zn are apparently the stumbling block for realizing higher yields, and declining response to N, P and K fertilizers.

1. INTRODUCTION

Sustainable production of more food from limited and scarce land and water resources to feed the projected world population of 9.1 billion people in 2050 is one of the greatest challenge of the 21st century (Selvaraju *et al.,* 2011). In India, per capita arable land availability has decreased from 0.39 ha in 1951 to 0.12 ha in 2011 mainly due to increased population from 359 million in 1951 to 1.21 billion in 2011 (DoA, GoI, 2012), which is further expected to rise to 1.58 billion by 2050 (Amarasinghe *et al.,* 2007) with associated decrease in per capita land availability to 0.09 ha by 2050. Within existing land constraints, India must increase the current food production to about 380 m t in 2050 (Amarasinghe *et al.,* 2007) to meet the growing food demand. Green revolution in India increased the food production through intensified use of fertilizer, dwarf genotypes of wheat and rice mainly from 40% of irrigated area in India, and now those regions has reached a productivity plateau and so there is little scope to increase the productivity. The rainfed cropped area (89 m ha) which were bypassed during green revolution era, today offer the hope to meet increasing demand of food (Wani *et al.,* 2008) by increasing current low crop productivity (Wani *et al.,* 2012).

In rainfed semi-arid and dry sub-humid regions, the yields of important crops range from as low as 0.5 to 2 t ha^{-1}, with an average of 1 t ha^{-1} in sub-Saharan Africa, and 1-1.5 t ha^{-1} in Asia and North Africa (Rockström and Falkenmark, 2000; Wani *et al.,* 2003 and 2011). The large gap between actual farmer's practice yield and attainable yield due to improved management, suggest an untapped potential for yield increase to feed the burgeoning population. In the semi-arid tropics (SAT), soil degradation along with water scarcity are the main cause for low crop yields and inefficient utilization of existing water resources resulting in low water use efficiency. Rainfed soils are multi nutrient deficient and need proper nutrient management strategies to bridge the existing gap between farmers' current yields and achievable potential yields (Sahrawat *et al.,* 2010). In view of observed secondary and micronutrient deficiencies, the applications of major nutrients *viz.* nitrogen (N), phosphorus (P) and potassium (K) only will not be sufficient enough for the SAT soils (El-Swaify *et al.,* 1985; Rego *et al.,* 2003; Sharma *et al.,* 2009) to explore full productivity potential of these regions. Hence, attention has to be paid to diagnose and take corrective measures for deficiencies of secondary and micro nutrients in various crop production systems (Rego *et al.,* 2005; Sahrawat *et al.,* 2007, 2011; Manna *et al.,* 2011) being followed in millions of small and marginal farmers' fields in the SAT.

We hypothesized that soil fertility related risks can be managed through soil test based balanced nutrition to bring in sustained intensification and resilience building. Therefore, the study focused to explore the soil fertility status of rainfed areas in Chhattisgarh and Madhya Pradesh to find out the current soil health status to bring in more informed decisions by the farmers to improve productivity and livelihood.

2. MATERIALS AND METHODS

Study Sites and Soil Sampling

The study sites include farmers' fields in 30 villages of 4 districts *viz.,* Durg, Kwardha, Raipur and Rajnanadgaon in Chhattisgarh and 52 villages of 4 districts *viz*., Damoh, Jabalpur, Rewa and Satna in Madhya Pradesh (Fig. 1 and Table 1).

Composite surface (0 to 0.15 m) soil samples were collected to address variations that may arise due to topography, soil color, texture, cropping system and agronomic management. Ninety one samples were collected from Chhattisgarh and 100 samples from Madhya Pradesh. We adopted participatory stratified soil sampling method (Sahrawat *et al.,* 2011). Under this method, we divided target eco-regions in the districts into three topo-sequences. At each topo-sequence location, samples were taken proportionately from small, medium and large farm-holding sizes to address the variations that may arise due to different management because of different economic status in each farm size class. Within each farm size class in a topo-sequence, the samples were chosen carefully to represent all possible soil fertility variations as judged from soil colour, texture, cropping system and agronomic management. Eight to ten cores of surface (00.15 m) soil samples were collected and mixed together to make a composite sample. The samples were processed and analyzed for pH, organic C, available- sulphur (S), boron (B), zinc (Zn), P and K in Charles Renard Analytical Laboratory, ICRISAT.

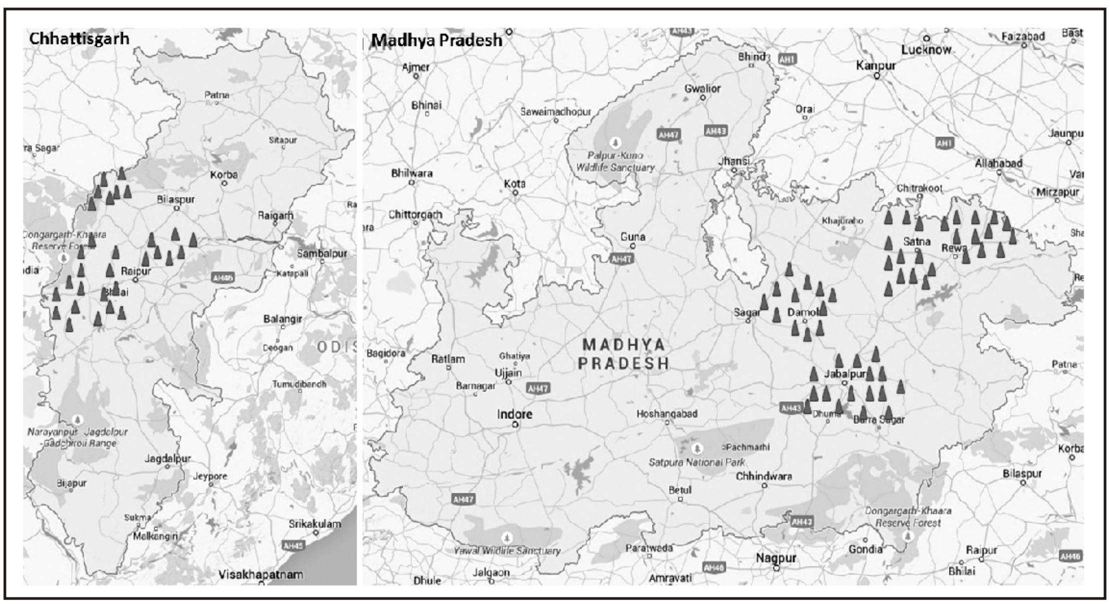

Fig. 1. Sites selected for soil sample analysis in Chhattisgarh and Madhya Pradesh

Table: 1
Study sites in Chhattisgarh and Madhya Pradesh in India

District	Villages (Number and name)	No. of composite samples
Chhattisgarh		
Durg	7 (Arjuni, Deori, Devgahan, Dhour, Mohandi, Mundpar, Semariya)	21
Kwardha	7 (Amera, Baijaalpur, Boda, Dullapur, Silli, Tarsingh,Charbhata)	22
Raipur	7 (Beltukari, Budera, Elda, Khaprideehkhurd, Kumhari, Nahardih, Parsada)	25
Rajnanadgaon	9 (Antyanawagaon, Bharragaon, Dhamansari, Khapari, Kohka, Kumhalori, Makrandpur, Nathunawagaon, Saltigari)	23
Madhya Pradesh		
Damoh	12 (Aanu, Bamhori, Bandakpur, Golapati, Gunji, Hindoria, Jamenera, Khejar, Nonepani, Parswaha, Patinandlal, Surkhi)	25
Jabalpur	16 (Andar, Barkhera, Cheedi Baroda, Chedi, Dunda, Ghorakoni, Gidhora, Gwari, Imlai, Jamgaon, Kastara, Paroda, Pondi, Salliya, Turka, Urdwa)	28
Rewa	12 (Amilki, Bahoribhand, Bidwa, Govingarh, Khokham, Kothi, Laxmanpur, Puraini, Raura, Sannwbhodi, Tikiya, Veerkham)	22
Satna	12 (Bachera, Bathiya, Ganesha, Gora, Gunchahai, Katha, Magraj, Matha, Parsiya, Puranibastijamudi, Ramasthan, Saajanpur, Satri)	25

Soil Chemical Analysis

The samples were processed and analyzed for pH, organic C, available-sulphur (S), boron (B), zinc (Zn), P and K in Charles Renard Analytical Laboratory, ICRISAT. The soil samples were air dried, ground and passed through 2-mm sieve. For organic carbon, the soil samples were ground to pass through 0.25 mm sieve. Soil pH was measured by glass electrode using soil to water ratio of 1:2, organic C was analyzed as per procedure laid out by Walkley-Black (Nelson and Sommers, 1996). Available P, K, S, B and Zn were extracted from soil using the sodium bicarbonate for P (Olsen and Sommers, 1982), ammonium acetate for K (Helmke and Sparks, 1996), 0.15% Calcium Chloride for S (Tabatabai, 1996), hot water for B (Keren, 1996) and diethylenetriaminepentaacetic acid (DTPA) reagent for Zn (Lindsay and Norvell, 1978). Available P was determined using colorimetric method, while K by Atomic Absorption Spectrophotometer (AAS). Analyses of S, B and Zn were made using the Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES).

The critical values considered for delineating deficiency were: 5.0 g kg^{-1} for organic C, 5 mg kg^{-1} for P, 50 mg kg^{-1} for K, 10 mg kg^{-1} for S, 0.58 mg kg^{-1} for B and 0.75 mg kg^{-1} for Zn (Sahrawat *et al.,* 2010).

3. RESULTS AND DISCUSSION

Soil Fertility Status in Chhattisgarh

Majority of the farmers' fields had adequate levels of available P and only 4 to 10% fields tested were deficient in P across the districts (Table 2). Soil levels of K were also adequate in all the districts and no deficiency was detected in any single field, 40 locations. Soil organic C deficiency ranged between 0 to 5% which indicates sufficient N content also. The adequate levels of primary nutrients namely N, P and K may be expected due to the current practice of farmers where fertilization practices are primarily focused on application of these three nutrients only, and inherent capacity of soils in case of K. However, widespread deficiencies were recorded for S (52 to 90% fields) and B (78 to 100%) across all four districts in Chhattisgarh. Zinc deficiencies also ranged between 20 to 52%, and were critical in Durg district where majority fields had low levels of Zn. The deficiencies of S, B and Zn are apparently due to accelerated removal due to crop intensification in the recent past, while ignoring their addition into the soil. The use of high analysis straight chemical fertilizers and decreasing use of organic manures has probably exaggerated the problem. The deficiencies of S, B and Zn may be apparently the reason for the declining response to N and P fertilizers (Sahrawat *et al.,* 2010; Chander *et al.,* 2012 and 2013; Prabhavathi *et al.,* 2013).

Soil Fertility Status in Madhya Pradesh

All fields across the four districts in Madhya Pradesh had sufficient levels of K (Table 3). However, Madhya Pradesh soils were more degraded in terms of available P and soil organic C. Deficiency in soil organic C and P varied from 14-64% in the tested fields. Satna district was critical for low levels of soil organic C and P in majority of fields. In other 3 districts (Jabalpur, Rewa and Damoh), majority of fields had adequate level of soil organic C and P. The results suggest that there is a scope to cut use and cost of chemical fertilizers in these 3 districts by just having a maintenance dose. Similar to Chhattisgarh, the micronutrient deficiencies were rampant across the districts. Boron deficiency was critical across all the districts and ranged between 59 to 79%. Zinc deficiency ranged between 32 to 80% with more critical in Damoh and Satna districts. Sulphur deficiency was also found in Damoh (32%) and Jabalpur (71%) districts.

Correlation among Soil Parameters

Interrelationship among the nutrients offers a better understanding of the soil system. Correlation among soil parameters showed a significant and positive effect of soil organic C on the availability of P, S, B and Zn contents in both the states (Table 4a and 4b). The correlation between soil organic C and available K or Fe was also positive, but found significant only in Madhya Pradesh. These results

Table: 2
pH, organic C and available nutrient status of farmers' fields in Chhattisgarh state in India

District	Farmers (No)	PH	% deficiency (Range of available contents#)						
			Organic C	P	K	S	B	Zn	Fe
Durg	21	5.93-8.10	5 (0.50-1.07)	10 (2.80-15.8)	0 (129-262)	86 (2.30-16.6)	86 (0.26-0.74)	52 (0.32-2.28)	0 (10.3-37.5)
Kwardha	22	5.90-7.79	0 (0.68-1.20)	10 (1.50-27.7)	0 (123-578)	90 (3.10-24.4)	100 (0.20-0.93)	20 (0.44-2.98)	0 (10.9-117)
Raipur	25	5.90-8.20	0 (0.60-1.77)	12 (2.50-130)	0 (109-273)	72 (3.10-23.3)	84 (0.12-0.69)	40 (0.32-4.22)	0 (18.5-103)
Rajnanadgaon	23	5.70-8.00	0 (0.55-1.14)	4 (2.10-33.7)	0 (105-233)	52 (2.00-32.7)	78 (0.28-0.74)	48 (0.24-3.10)	0 (10.1-117)
4 districts (Chhattisgarh)	91	5.70-8.20	1 (0.50-1.77)	9 (1.50-130)	0 (105-578)	75 (2.00-32.7)	87 (0.12-0.93)	40 (0.24-4.22)	0 (10.1-117)

#Values in parentheses indicate the range of available nutrient contents (mg kg^{-1}) except organic C (%).

clearly point to the need to manage optimum amounts of soil organic C to regulate adequate supplies of essential plant nutrients. Soil reaction in general is another soil property which influences availability of plant nutrients. In the both states, a positive significant relationship was found between soil pH and available B and a negative significant relationship between soil pH and Fe. The soil pH and Zn had a negative relationship, but significant only in Madhya Pradesh. Amongst available nutrients in both the states, a positive significant relationship was found between S and B and B and Zn. The correlation between P × S, P × B were also positive and that between B and Fe was a negative one, but significant in Chhattisgarh only. Similarly, there were positive interactions between P × K, P × Zn, P × Fe, K × Zn, Zn × Fe, and negative interaction between S × Fe, but found significant in Madhya Pradesh only.

4. CONCLUSIONS

Widespread deficiencies of S, B and Zn were diagnosed in the semi-arid regions in Chhattisgarh and Madhya Pradesh. The findings are of interest for farmers of target districts in context of current practice of adding indiscriminate amounts of N, P and K which in general were adequate in most of the fields. Going by essentiality of the nutrients, it is apparent that the deficiencies of S, B and Zn might be a constraint to harvest full yield potential and thus responsible for declining response to N, P and K fertilizers. The study provides a site specific basis for farmers to plan balanced nutrient applications.

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Table: 3
pH, organic C and available nutrient status of farmers' fields in Madhya Pradesh state in India

District	Farmers (No)	PH	% deficiency (Range of available contents#)						
			Organic C	P	K	S	B	Zn	Fe
Damoh	25	6.40-8.28	32 (0.36-1.17)	40 (2.50-28.1)	0 (79-320)	32 (2.80-29.2)	76 (0.03-1.30)	56 (0.22-1.70)	0 (4.84-54.6)
Jabalpur	28	6.00-8.30	14 (0.36-1.61)	32 (1.70-50.3)	0 (52-738)	71 (2.10-37.8)	79 (0.12-0.78)	39 (0.31-1.86)	0 (5.25-82.5)
Rewa	22	5.59-8.10	46 (0.36-1.84)	14 (3.40-83.2)	0 (97-928)	0 (13.8-488)	59 (0.12-1.70)	32 (0.16-1.54)	0 (4.04-33.1)
Satna	25	7.06-8.45	64 (0.23-0.92)	64 (0.71-84.5)	0 (57-560)	0 (10.4-172)	76 (0.10-1.26)	80 (0.14-5.72)	0 (3.98-33.3)
4 districts (Madhya Pradesh)	100	5.59-8.45	38 (0.23-1.84)	38 (0.71-84.5)	0 (52-928)	28 (2.10-488)	73 (0.03-1.70)	52 (0.14-5.72)	0 (3.98-82.5)

#Values in parentheses indicate the range of available nutrient contents in mg kg^{-1} for all parameters except organic C (%).

Table: 4a
Correlation among different soil parameters in Chhattisgarh state in India

Soil parameter	Organic C	Available P	Exchangeable K	Available S	Available B	DTPA-Zn	DTPA-Fe
pH	-0.1677^{ns}	0.0354^{ns}	-0.1448^{ns}	0.0399^{ns}	0.2562*	-0.1140^{ns}	-0.5261*
Organic C	-	0.3806*	0.1531^{ns}	0.2839*	0.4244*	0.4259*	0.0932^{ns}
Available P		-	0.1305^{ns}	0.2852*	0.2035^{ns}	0.1735^{ns}	0.1355^{ns}
Exchangeable K			-	-0.1048^{ns}	-0.0741^{ns}	0.0612^{ns}	0.0889^{ns}
Available S				-	0.4573*	0.1572^{ns}	-0.0971^{ns}
Available B					-	0.2123*	-0.2402*
DTPA-Zn						-	0.1123^{ns}

*Significant at 0.05 level of significance; nsNon-significant at 0.05 level of significance

Table: 4b
Correlation among different soil parameters in Madhya Pradesh state in India

Soil parameter	Organic C	Available P	Exchangeable K	Available S	Available B	DTPA-Zn	DTPA-Fe
pH	-0.1545^{ns}	-0.4216*	-0.0181^{ns}	0.1629^{ns}	0.2721*	-0.2108*	-0.6801*
Organic C	-	0.2168*	0.6077*	0.2867*	0.5455*	0.4038*	0.2941*
Available P		-	0.2621*	0.0155^{ns}	0.1077^{ns}	0.4712*	0.3636*
Exchangeable K			-	0.2289*	0.3314*	0.3247*	0.1373^{ns}
Available S				-	0.5261*	-0.0518^{ns}	-0.2174*
Available B					-	0.2553*	-0.1738^{ns}
DTPA-Zn						-	0.3316*

*Significant at 0.05 level of significance; nsNon-significant at 0.05 level of significance

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