Asian Journal of Chemistry; *Vol. 28, No. 1 (2016), 216-220*

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2016.19351

Evolution of Block Level Sulphur Status and their Relationship with Some Physico-Chemical Properties of Soil of Raipur District, Chhattisgarh, India

R.G. GOSWAMI*, V.N. MISHRA, L.K. SHRIVASTVA, A.K. SINGH and THANESHWAR KUMAR

Department of Soil Science and Agricultural Chemistry, Indira Gandhi Agricultural University, Raipur-492 012, India

*Corresponding author: E-mail: rakeshgoswami57@gmail.com

Received: 15 May 2015; *Accepted*: 25 July 2015; *Published online*: 5 October 2015; AJC-17578

A study on the evolution of block level sulphur status and their relationship with some physico-chemical properties of soil of Raipur district, Chhattisgarh, India was performed during 2014. Grid based soil samples from surface soils of Dharsiwa (54), Abhanpur (48), Tilda (54) and Arang (42) were collected using GPS and were analyzed to assess the status of available S and their relationship with some physico-chemical properties. The available sulphur (S) varied from 16.24 to 80.24 kg ha^{-1} with an average of 39.90 kg ha^{-1}, found 7.40 % samples under low, 14.81 % in medium and 77.77 % in high status of sulphur and organic carbon level ranged from 0.24-0.96 (mean 0.60 %) at Dharsiwa block. Similarly, from Abhanpur block, available sulphur varied from 12.07 to 79.80 kg ha^{-1} with an average 43.94 kg ha^{-1} falls under low, medium and high categories as 8.33, 12.5 and 79.16 %, respectively and organic carbon varied from 0.23-0.96 (mean 0.60 %). In Tilda block, available sulphur varied from 8.68 to 97.72 kg ha^{-1} with an average 41.59 kg ha^{-1} and the per cent samples tested under low, medium and high status sulphur were found as 14.81, 11.11 and 74.07 %, respectively and organic carbon ranged from 0.23-0.96 (mean 0.75 %). In Arang block, available sulphur varied from 8.96 to 98.84 kg ha^{-1} with an average 38.83 kg ha^{-1} and the per cent samples tested under low, medium and high status sulphur were found as 14.28, 9.52 and 76.19 %, respectively and Arang organic carbon varied from 0.23-0.96 (mean 0.59 %). The analyzed data on sulphur level from Dharsiwa and Abhanpur block was correlated with soil pH and organic carbon levels indicated positive correlation with soil pH and positive with organic carbon status. Similarly Arang and Tilda block was recorded negative correlation with soil pH and positive correlation with organic carbon except Arang block. Soil nutrient index of all four selected blocks were found in high fertility classes for available sulphur, respectively.

Keywords: Available organic carbon level, Available sulphur, Kriging, Variability, Nutrient index, Sulphur status.

INTRODUCTION

A comprehensive knowledge of the basic soil resources is a fundamental importance for efficient land use planning. Now a day's fast depletion of natural resource of sulphur is becoming widespread due to use of high yielding crop varieties (HYVs), intensive multiple cropping system, high sulphur requiring crops and continuous use of sulphur free fertilizers as well as restricted use of organic manure coupled with its leaching from root zone are largely responsible for increasing sulphur deficiency in Inceptisol soil [1]. The subcontinent possesses widely divergent spectra of changing physiography, climate and vegetation and their combined influence, accentuated by the action of water and wind on the weathering of different type of parent material, has obviously resulted in soil showing appreciable variation in morphological, physical, chemical and biological characteristics. Thus, the soil representing a continuum of diversified genetic process and being one of the biggest natural heritages of mankind deserves greater consideration than Marely as an inert medium for plant growth. The tremendously growing population in the country is an acute problem that demands maximum possible output of food, fuel and fiber from each unit of cultivated land area per unit time. The soil fertility undergoes change due to cropping, manure and fertilizer application. Soil test results of one form need to have scope to be connected with the border population. But we may not be able to sample each farm in the population, because it is so coastaly, troublesome and time consuming, especially multiple small farm holding in many developing countries. We, thus, need to generalize results of sample farms to get information of entire area [2].

Sulphur is one of the essential nutrients required for the plant growth. It is not only an often growth-limiting plant nutrient but also indirectly affects the use efficiency of other plant nutrients, such as nitrogen [3]. It is now assuming importance next to major nutrient *i.e.*, nitrogen, phosphorus and zinc for Indian agriculture. Its deficiency has become wide spread in India and it is now rightly called fourth major nutrient. In

India, nearly 57 m ha of arable land suffers from various degress of sulphur deficiency [4]. The availability of sulphur is largely dependent on its fraction. About 90 % of plant sulphur is present in these amino acids. Sulphur deficiencies in India are found in almost 40 % of the cultivated area. Several soil factors influence the availability of sulphur and hence the status of different forms of sulphur in soils varies widely with soil type. Again high annual rainfall (> 2000 mm) in Assam enhances leaching of SO_4, leaving these soil deficient in sulphur [5]. Form of sulphur and their interrelationship with soil properties, on other hand; determine the sulphur supplying power of the soil through their influence on release and dynamics of sulphur in soil [1]. Geographic information system arc (GIS) 9.3 based soil fertility mapping has appeared as a promising alternative. Limiting sulphur availability has been shown to favour the synthesis and accumulation of sulphur-poor or low-sulphur storage proteins at the expense of sulphur-rich proteins [6]. It has been widely used for determination of available soil sulphur. However, the amount of sulphur extracted by this method is affected by the extraction time and temperature and the potential resorption of sulphur during the cooling period [7]. The present research work was taken as efforts to evaluate the Block level sulphur status of Raipur district of Chhattisgarh with the help of GIS and GPS techniques and their inter-relationships with some physico-chemical properties of soil.

EXPERIMENTAL

Raipur lies between 22°33′ N to 21° N latitude and 82°6′ to 81°38E′ longitude. The total geographical area is 13,083 km^2 north to south. The climate of the district is Moist sub-humid with annual rainfall of 1233 mm. 198 Surface soil samples were collected from four selected blocks of Raipur district *viz.* Dharsiwa (54), Abhanpur (48), Tilda (54), Aarang (42) in which total 33 villages were selected based on stratified multistage random sampling method covering all the blocks and a total of 198 surface soil samples (six from each village) were collected using GPS and represented small, medium and large resources framers' category. The selected samples were analyzed for soil pH (1:2.5) soil:water suspension after stirring for 0.5 h by glass electrode pH meter as suggested by Piper [8], organic carbon as referred by Walkley and Black's rapid titration method [9] and the most suitable and widely used method for estimation of available sulphur was done as suggested by Williams and Steinberg [10], using 0.15 % $CaCl_2{\cdot}H_2O$ as an extractant and measured using turbid metrically. These samples were analyzed for available sulphur status to categories them into low, medium and high and correlated with pH and organic carbon level. Standard statistical procedure for correlation study was followed. The categorization of the soils of the individual blocks as a whole in to the three fertility classes was done according to the nutrient index values calculated from the soil test summarized giving their percentage distribution into low, medium and high categories. The nutrient index [11] was given by:

$$\text{Nutrient index} = [\%\ \text{samples in high category} \times 3 + \%\ \text{in medium category} \times 2 + \%\ \text{in low category} \times 1]/100$$

In this per cent assessment, a nutrient index less than 1.65 denotes low category and that falling between 1.65 and 2.33 represents the medium fertility class. Value of 2.34 and above (maxi 3.00) signifies a high fertility class in respect of the particular nutrient [12].

Actual soil sampling using multistage stratified random sampling was carried out in the selected blocks. The topo sheet containing selected blocks were digitized and geo-referenced with known features. Thus, digitized map might used for preparation of soil fertility map using Kriging technique to interpolate the information. Here, global positioning system (GPS) was used to identify actual locations (latitude longitude data of collection) of sample points.

RESULTS AND DISCUSSION

54 Soil samples out of 198 were collected from Dharsiwa block using GPS. Available sulphur ranged from 16.24 to 80.24 (mean 39.90 kg ha^{-1}), organic carbon % ranged from 0.24-0.96 (mean 0.60 %) and pH ranged from 6.7-8.1 (mean 7.50) are presented in Tables 1 and 2. Considering the soil test rating for available sulphur (< 20 as low, 20-30 as medium, > 30 kg ha^{-1} as high status), the distribution of sulphur status of Dharsiwa block under different soil sulphur rating can be classified as in the range from 16.24- 18.20 with mean value of 17.49 kg ha^{-1}, 20.72-29.40 with mean value of 25.55 kg ha^{-1} and 33.60-80.92 with mean value of 45.23 kg ha^{-1} under low, medium and high soil sulphur rating, respectively (Table-3). The per

TABLE-1
BLOCK WISE RANGE AND MEAN VALUES ON SOIL AND DISTRIBUTION OF AVAILABLE SULPHUR AND ORGANIC CARBON IN THE SOILS OF SELECTED BLOCKS OF RAIPUR

Blocks	Number of sample	Organic carbon (%)			Available sulphur (kg/ha)			Samples (%)			S.D.
		Range	Mean	S.D.	Min.	Max.	Mean	Low (< 20)	Medium (20-30)	High (> 30)	
Dharsiwa	54	0.24-0.96	0.60	± 0.17	16.24	80.24	39.90	4 (7.40 %)	8 (14.81 %)	42 (77.77 %)	± 13.21
Abhanpur	48	0.23-0.96	0.60	± 0.19	12.07	79.80	43.94	4 (8.33 %)	6 (12.5 %)	38 (79.16 %)	± 19.62
Tilda	54	0.29-0.96	0.75	± 0.14	8.68	97.72	41.59	8 (14.81 %)	6 (11.11 %)	40 (74.07 %)	± 16.61
Arang	42	0.23-0.96	0.59	± 0.16	8.96	98.84	38.83	6 (14.28 %)	4 (9.52 %)	32 (76.19 %)	± 17.95
Total	198	0.23-0.96	0.64	± 0.18	8.12	89.15	41.06	22 (11.20 %)	24 (12.48)	152 (76.79 %)	± 16.84

The values in the parenthesis indicate the per cent sample distribution.

TABLE-2
CATEGORY OF SOIL SAMPLES UNDER DIFFERENT pH RATING OF SELECTED FOUR BLOCKS

Blocks	Total number of soil samples	Number of sample					Sample (%)				
		Strongly acid (< 5.5)	Moderately acid (5.5-6.5)	Slightly acid (6.5-7.5)	Neutral (7.5-8.5)	Slightly alkaline (> 8.5)	Strongly acid (< 5.5)	Moderately acid (5.5-6.5)	Slightly acid (6.5-7.5)	Neutral (7.5-8.5)	Slightly alkaline (> 8.5)
Dharsiwa	54	0	0	31	23	0	0	0	57.40	42.59	0
Abhanpur	48	0	9	21	18	0	0	18.75	43.75	37.50	0
Tilda	54	0	7	34	13	0	0	0	12.96	62.96	0
Arang	42	0	6	21	15	0	0	14.26	50	35.71	0
Total	198	0	22	107	69	0	0	11.11	54.04	34.84	0

cent samples distribution under soil test rating can be stated that majority of soil sample of Dharsiwa block contained 77.77 % high sulphur level, 14.81 % under medium level and 7.40 % falls under low sulphur level (Table-1). Similarly, the per cent samples distribution under soil test rating can be stated that majority of soil sample of Dharsiwa block contained 20.37 % high organic carbon level, 55.55 % under medium level and 24.70 % falls under low organic carbon level. The calcium chloride extractable-sulphur showed non-significant positive correlation with organic carbon (r = 0.218) and (r = 0.238) with soil pH at 5 and 1 % level of significant (Table-4). These results confirmed the finding as reported by Isitekhal *et al.* [13] in soils of Edo Central Nigeria, Kundu and Mukhopadhyay [14] from Haringhata block of Nadia district (India) and Mali and Syed [15] in soil of 240 districts of the India including Maharashtra.

TABLE-3
IMPORTANT PROPERTIES AND AVAILABLE SULPHUR STATUS IN SELECTED SOIL SAMPLES OF DHARSIWA BLOCK (RANGE AND MEAN)

Particular	pH	Organic carbon (%)	Available (sulphur) (kg ha^{-1})
Soils low in available sulphur	6.8-7.9 (7.3)	0.38-0.49 (0.45)	16.24-18.20 (17.49)
Soils medium in available sulphur	7.4-7.6 (7.4)	0.43-0.88 (0.63)	20.72-29.40 (25.55)
Soils high in available sulphur	7.1-7.9 (7.52)	0.24-0.96 (0.61)	33.60-80.92 (45.23)

The values in the parenthesis indicate the mean value of the respective properties.

TABLE-4
CORRELATION BETWEEN SOIL CHARACTERISTICS AND AVAILABLE SULPHUR (kg ha^{-1})

Blocks	pH	Organic carbon (%)
Dharsiwa	0.2387	0.218
Abhanpur	0.0937	0.119
Tilda	-0.0411	0.079
Arang	-0.1106	-0.0169

Similarly, 48 soil samples out of 198 were collected from Abhanpur block using GPS. Available sulphur ranged from 12.07 to 79.80 (mean 43.94 kg ha^{-1}), organic carbon % ranged from 0.23-0.96 (mean 0.60 %) and pH ranged from 5.7-8.2 (mean 7.19) are presented in Tables 1 and 2. The distribution of sulphur status of Abhanpur block under different soil sulphur rating can be classified as in the range from 12.07-18.20 with mean value of 15.06 kg ha^{-1}, 23.24-28.28 with mean value of 34.36 kg ha^{-1} and 30.80-79.80 with mean value of 49.86 kg ha^{-1} under low, medium and high soil sulphur rating, respectively (Table-5). The per cent samples distribution under soil test rating can be stated that majority of soil sample of Abhanpur block contained 79.16 % high sulphur level, 12.5 % under medium level and 8.33 % falls under low sulphur level (Table-1). Similarly, the per cent samples distribution under soil test rating can be stated that majority of soil sample of Abhanpur block contained 22.91 % high organic carbon level, 43.75 % under medium level and 33.33 % falls under low organic carbon level. The calcium chloride extractable-sulphur showed non-significant positive correlation with organic carbon (r = 0.119) and (r = 0.0937) with soil pH at 5 % and 1 % level of significant (Table-4). These results confirmed the finding as reported by Isitekhal *et al.* [13] in soils of Edo Central Nigeria and also in soils of Udham Singh Nagar district [2] and Jaipur district [16], India.

TABLE-5
AVAILABLE SULPHUR STATUS IN SELECTED SOIL SAMPLES OF ABHANPUR BLOCK (RANGE AND MEAN)

Particular	pH	Organic carbon (%)	Available (sulphur) (kg ha^{-1})
Soils low in available sulphur	6.7-7.7 (7.17)	0.58-0.73 (0.64)	12.07-18.20 (15.06)
Soils medium in available sulphur	6.3-7.9 (7.46)	0.25-0.78 (0.55)	23.24-28.28 (24.36)
Soils high in available sulphur	5.7-8.2 (7.11)	0.23-0.96 (0.59)	30.80-79.80 (49.86)

The values in the parenthesis indicate the mean value of the respective properties.

54 Soil samples out of 198 were collected from Tilda block using GPS. Available sulphur ranged from 8.68 to 97.72 (mean 41.59 kg ha^{-1}), organic carbon % ranged from 0.23-0.96 (mean 0.75 %) and pH ranged from 6.3-7.9 (mean 7.12) are presented in Tables 1 and 2. Considering the soil test rating for available sulphur (< 20 as low, 20-30 as medium, > 30 kg ha^{-1} as high status), the distribution of sulphur status of Tilda block under different soil sulphur rating can be classified as in the range from 8.68-23.24 with mean value of 16.69 kg ha^{-1}, 23.24-31.08 with mean value of 28.18 kg ha^{-1} and 31.08-97.72 with mean value of 49.86 kg ha^{-1} under low, medium and high soil sulphur rating, respectively (Table-6). The per cent samples distribution under soil test rating can be stated that majority of soil sample of Tilda block contained 74.07 % high sulphur level, 11.11 % under medium level and 14.81 % falls under low sulphur level (Table-1). Similarly, the per cent samples distribution under soil test rating can be stated that majority of soil sample of Tilda block contained 51.85 % high organic carbon level, 42.59 %

TABLE-6
AVAILABLE SULPHUR STATUS IN SELECTED SOIL SAMPLES OF TILDA BLOCK (RANGE AND MEAN)

Particular	pH	Organic carbon (%)	Available (sulphur) (kg ha^{-1})
Soils low in available sulphur	6.5-7.9 (7.05)	0.54-0.93 (0.74)	8.68-23.24 (16.69)
Soils medium in available sulphur	6.7-7.9 (7.17)	0.42-0.93 (0.74)	23.24-31.08 (28.18)
Soils high in available sulphur	6.3-7.9 (7.12)	0.29-0.96 (0.77)	31.08-97.72 (49.86)

The values in the parenthesis indicate the mean value of the respective properties.

under medium level and 5.55 % falls under low organic carbon level. The calcium chloride extractable-sulphur showed non-significant positive correlation with organic carbon (r = 0.079) and (r = -0.0411) negative correlation with soil pH at 5 % and 1 % level of significant (Table-4). These results confirmed the finding as reported by Isitekhal *et al.* [13] in soils of Edo Central Nigeria, and Kundu and Mukhopadhyay [14] from Haringhata block of Nadia district, India.

42 Soil samples were collected from Arang block using GPS. Available sulphur ranged from 8.96 to 98.84 (mean 38.83 kg ha^{-1}), organic carbon % ranged from 0.23-0.96 (mean 0.59 %) and pH ranged from 5.7-8.2 (mean 7.19) are presented in Tables 1 and 2. Considering the soil test rating for available sulphur (< 20 as low, 20-30 as medium, > 30 kg ha^{-1} as high status), the distribution of sulphur status of Arang block under different soil sulphur rating can be classified as in the range from 8.96-17.36 with mean value of 13.39 kg ha^{-1}, 21.28-35.76 with mean value of 24.36 kg ha^{-1} and 30.24-98.84 with mean value of 45.40 kg ha^{-1} under low, medium and high soil sulphur rating, respectively (Table-7). The per cent samples distribution under soil test rating can be stated that majority of soil sample of Arang block contained 76.19 % high sulphur level, 9.52 % under medium level and 14.28 % falls under low sulphur level (Table-1).The per cent samples distribution under soil test rating can be stated that majority of soil sample of Tilda block contained 23.80 % high organic carbon level, 47.61 % under medium level and 28.57 % falls under low organic carbon level (Table-2). Table-2 shows that the soil pH range were neutral to slightly acidic and 50 % soil was comes under slightly acidic fallowed by 35.71 % neutral and 14.26 % moderately acidic. The calcium chloride extractable-sulphur showed non-significant negative correlation with organic carbon (r = -0.0169) and (r = -0.1106) negative correlation with soil pH at 5 % and 1 % level of significant (Table-4). These results confirmed

TABLE-7
AVAILABLE SULPHUR STATUS IN SELECTED SOIL SAMPLES OF ARANG BLOCK (RANGE AND MEAN)

Particular	pH	Organic carbon (%)	Available (sulphur) (kg ha^{-1})
Soils low in available sulphur	6.9-7.6 (7.36)	0.46-0.81 (0.62)	8.96-17.36 (13.39)
Soils medium in available sulphur	6.7-8.2 (7.4)	0.25-0.79 (0.57)	21.28-35.76 (24.36)
Soils high in available sulphur	5.7-8.1 (7.16)	0.29-0.88 (0.59)	30.24-98.84 (45.40)

Values in the parenthesis indicate the mean value of the respective properties.

the finding as reported by Kundu and Mukhopadhyay [14] from Haringhata block of Nadia district, India. Ashoka *et al.* [17] from different agro-climatic zones of Karnataka, India.

Nutrient index value: Using the model of Ramamurthy and Bajaj [18] for nutrient index values to categorize the fertility class as low, medium and high, the analyzed data on soil sulphur status were put under the different nutrient index values. Based on the nutrient index values Dharsiwa, Abhanpur, Tilda and Arang blocks can be categorized under high fertility status of sulphur (Table-8). The nutrient index value for sulphur status of Dharsiwa, Abhanpur, Tilda and Arang blocks were estimated as 2.70, 2.70, 2.53 and 2.63, respectively against the nutrient index values < 1.65 for low, 1.65-2.33 for medium and > 2.33 for high fertility status [19].

TABLE-8
MEAN VALUE OF SOIL FERTILITY INDEX AND SOIL FERTILITY CLASSES IN SOILS OF FOUR SELECTED BLOCKS OF RAIPUR DISTRICTS

Blocks	Mean value of fertility index	Soil fertility class
Dharsiwa	2.70	High
Abhanpur	2.70	High
Tilda	2.53	High
Arang	2.61	High
Overall	2.65	High

There was a negative correlation of available sulphur ($CaCl_2$ extractable SO_4^{2-}-S) with soil pH and $CaCO_3$ contents in the soils. According to Biswas *et al.* [20], SO_4^{2-} retention capacity of soils decreases with increasing soil pH and becomes almost negligible [21] at pH values above 6.5. Thus under high soil pH conditions, SO_4^{2-} retention in soils is minimum which favours its leaching losses. In calcareous soils, SO_4^{2-} may react with $CaCO_3$ to get converted into insoluble forms unavailable to plants [21,22]. Soils in low organic carbon are possibly because of high temperature and good aeration in the soil which increased the rate of oxidation of organic matter [23].

Conclusion

It can be concluded from the analysis of the soils of four selected blocks of Raipur districts that highest per cent samples analyzed in the range of high sulphur status was recorded in Abhanpur block (79.16 %), followed by Dharsiwa (77.77 %), Arang (76.19 %) and Tilda (74.07 %).The overall 22 % area categorized under low sulphur status requires its correction by applying sulphur fertilizer to avoid the crop yield limiting factor due to sulphur deficiency. The available sulphur increased with decline in pH and reverse in case with organic carbon level except Arang and Tilda block. The deficiency of available sulphur in surface soils of different blocks could be arranged in the order: Tilda (14.81 %) > Arang (14.28 %) > Abhanpur (8.33 %) > Dharsiwa block (7.40 %).

REFERENCES

1. K.S. Reddy, A.K. Tripathi, M. Singh, A.S. Rao and S. Anand, *J. Indian Soc. Soil Sci.*, **49**, 74 (2001).
2. S.P. Singh, R. Singh, P.C. Shrivastava and P. Singh, *Agropedology*, **19**, 68 (2009).
3. F.D. De Bona and F.A. Monteiro, *Soil Sci. Soc. Am. J.*, **74**, 1248 (2010).

4. N. Tripathi, *Fertilizers News*, **48**, 111 (2003).
5. B. Borkotoki and K.N. Das, *J. Indian Soc. Soil Sci.*, **56**, 186 (2008).
6. N.E.S. Flaete, K. Hollung, L. Ruud, T. Sogn, E.M. Faergestad, H.J. Skarpeid, E.M. Magnus and A.K. Uhlen, *J. Cereal Sci.*, **41**, 357 (2005).
7. R.G. Goswami, V.N. Mishra and L.K. Srivastava, *Res. J. Agric. Sci.*, **5**, 1000 (2014).
8. C.S. Piper, (1966). *Soil and Plant Analysis*, Hans Publisher, Bombay. pp. 85-102.
9. A. Walkley and C.A. Black, *Soil Sci.*, **37**, 29 (1934).
10. C.H. Williams and A. Steinbergs, *Aust. J. Agric. Res.*, **10**, 340 (1959).
11. G.R. Muhr, N.P. Datta, H. Sankarasubramoney, V.K. Leley and R.L. Donahve, Soil Testing in India, USAID Mission to India, New Delhi, edn 2 (1965).
12. A.B. Ghosh and R. Hasan, *Bull. Indian Soc. Soil Sci*., **12**, 1 (1976).
13. H.H.E. Isitekhale, S.I. Aboh and E.S. Oseghale, *Int. J. Sci. Technol. Res.*, **2**, 91 (2013).
14. M.C. Kundu, S. Chakrabortty and P. Mukhopadhyay, *Environ. Ecol.*, **23**, 922 (2005).
15. C.V. Mali and I. Syed, Characterization and Fertility Status of Marathwada Soils Sulphur and Micro-Nutrients in Soil Resource Inventory of Marathwada, Department of Agricultural Chemistry and Soil Science, Vasantrao Naik Marathwada Agricultural University, Parbhani, India, pp. 72-87 (2002).
16. J.R. Jat and B.L. Yadav, *J. Indian Soc. Soil Sci.*, **54**, 208 (2006).
17. K.B. Ashoka, M.Sc. (Agric.) Thesis, Sulphur Status of Selected Soil Series of Karnataka and Studies on Direct and Residual Effect of Graded Level of Sulphur on Crop, University of Agricultural Sciences, Dharwad, India (2001).
18. B. Ramamoorthy and J.C. Bajaj, *Fert. News*, **14**, 25 (1969).
19. H.B. Meena, R.P. Sharma and U.S. Rawatn, *J. Indian Soc. Soil Sci.*, **54**, 508 (2006).
20. H. Biswas, R.K. Rattan, S.P. Datta and A.K. Singh, *J. Plant Nutr. Soil Sci.*, **166**, 519 (2003).
21. C. Srinivasarao, A.N. Ganeshamurthy, M. Ali, K.K. Singh and K.K. Singh, *Commun. Soil Sci. Plant Anal.*, **35**, 1713 (2004).
22. J.L. Havlin, J.D. Beaton, S.L. Tisdale and W.L. Nelson, Soil Fertility and Fertilizers, An Introduction to Nutrient Management, Pearson Education, Singapore (2004).
23. R.P. Singh and S.K. Mishra, *Indian J. Soc. Res.*, **3**, 97 (2012).