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DISTRIBUTION PATTERN OF AVAILABLE NUTRIENTS AND BIOLOGICAL PROPERTIES OF SOIL IN DIFFERENT LOCATION OF MEERUT AND BULANDSHAHR DISTRICT UNDER RICE – WHEAT CROPPING SYSTEM

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ABSTRACT
The depth wise soils of rice- wheat farming system from different locations were analysed to find the physico – chemical properties like soil texture, bulk density, pH, EC, CEC, organic carbon, total nitrogen, macro- micronutrients. The soil samples collected from different locations of rice- wheat farming system. The pH of soil samples varied from 7.4 to 9.0. The range of electrical conductivity of 1:2 soil water extraction was 0.105 to 0.744 d Sm^{-1} at 25 ^{0}C. None of the soil was found in saline category. CEC of soil varied from 12.08 to 25.21 cmol (p^{+}) kg^{-1} soil. Generally CEC was positively and significantly correlated with clay content. The organic carbon content which decline with soil depth varied from 1.8 to 7.5 g kg^{-1} soil. Organic carbon was correlated positively and highly significantly with available nitrogen, total nitrogen, positively with available P, K, micronutrient and microbial biomass carbon and negatively with Bulk density and CEC in all the cropping sequences soil. The available nitrogen ranged from 47.9 to 134.05 kg ha^{-1}. It decline with soil depth. Total nitrogen in soil decline with increasing soil depth and ranged from 522.27 to 2924.78 kg ha^{-1}. The available phosphorus and potassium ranged from 2.16 to 18.87 and 84.47 to 317.51 kg $ha^{-1}$and declined with increasing soil depth. Among the different cationic micronutrients with exception of zinc the availability of rest micronutrients was in sufficiency range. In some case the availability of zinc was in deficient range. DTPA extractable Cu ranged from 0.350 to 1.349, Fe 3.687 to 16.923, Mn 2.150 to 5.091 and Zn 0.113 to 1.621 mg kg $^{-1}$ soil. The availability of these micronutrients declined with increase in soil depth. Except Mn and available potassium others nutrients were significantly and positively correlated with organic carbon. The biological properties of soil, the range of bacteria varied from 3.6 to 5.5 x 10^{6}, Fungi 1.8 x $10^{4}$to 2.2 x 10^{4} and actinomycetes 1.5 x 10^{4} to 2.7 x10^{4} count g^{-1} soil, microbial biomass carbon 281-298 µg g^{-1} soil and dehydrogenase activity 55 to 69 µg TPF $g^{-1}day^{-1}$.

KEY WORDS: Rice-wheat, cropping system, macro& micronutrient, microbiological properties.

INTRODUCTION
Rice- wheat cropping system occupy 24 million hectares of cultivated land in Asia, of this 13.5 million hectares are in South Asia extending from the Indogangetic planes to Himalayan foot hills. Rice- wheat cropping system covers about 32% of the total rice area and 42% of the total wheat area in these countries: India, Pakistan, China, Bangladesh and Nepal. In India major rice – wheat growing states are Punjab, Haryana, Uttar Pradesh, Himachal Pradesh, Bihar and West Bengal. However, majority of the 10.5 million hectares rice wheat cropping system are concentrated in Punjab, Haryana and western Uttar Pradesh. In India rice-wheat cropping system account for about three fourth of the total food grain production. Rice- wheat cropping sequence are exhaustive feeder of plant nutrient, the nutrient removal by the system for exceeds the amount replenished through fertilizers causing much greater strain on native soil recourse. Cultivation of two cereals for a year on the same piece of land had lead to soil fertility problem and the yield of both crop are decline. Recently stagnation or declining tread in rice- wheat productivity at same location has been reported (Singh *et al*., 1992), which may be associated with declining in soil organic matter content and other edaphic factors. On the other hand crop residues in machine harvested area are being burnet to clear the field for planting the next crop this practice results in loss of valuable organic matter and nutrients particularly nitrogen and sulphur, and caused environmental problem. Nutrients are being mined and transported long distance and lost permanently for the sub region. The water table has reduces at several places in the region. Also there is a reduction in biodiversity due to larger area coverage by a single cultivar . The crop residue potential of rice wheat cropping system in India is presently estimated at about 276 million tones annually which may add 1.55 million tones of nitrogen (N) 0.48 million tones of phosphorus (P_2O^5) and 3.67 million tones of potassium (K_2O) besides considerable amount of secondary nutrients and micronutrients and decomposable organic matter. The incorporation of crop residue in rice – wheat cropping system is therefore desirable under integrated plant nutrient management system but its impact on soil fertility and productivity is not well understood. Continuous cropping of rice- wheat sequence for several decades as well as contrasting need of these two crops has resulted in increased

pest pressure, nutrient mining and declining yield in some area.

To meet the food demand of an increasing population, tremendous pressure is being put on land resources to fulfill there potential. The capacity of new cultivars to give high yield must be exploited without causing any deterioration in soil quality. However continuous application of excessive amount of fertilizer in intensive cropping system harms the soil. With improvement in irrigation techniques and the introduction of high yield variety: rice – wheat cropping system become popular in India. Continuous cultivation of same crop on same field by the farmers coupled with inadequate replenishment on nutrients from the external sources has led to severe depletion of soil available nutrients in this area. Soil characterization in relation to evaluation of fertility status of the soil of an area or region is an important aspect for sustainable crop production because of imbalance and inadequate fertilizer use efficiency of chemical fertilizer has decline tremendously under intensive cropping system in recent year (Chandra *et al.*, 2008). Information on soil fertility status of macro and micro nutrients of these study area in not available therefore present study was carried out to evaluate the soil fertility status of rice – wheat cropping system of Meerut and Bulandshar district of Uttar Pradesh. An attempt was also made to correlate soil available nutrients content with other soil properties.

MATERIALS & METHODS

The experiment was conducted during the year 2009-2010. The soil samples of 0-15, 15-30 and30-45 cm depth were collected from four different locations of Meerut district under fallow –potato cropping sequence. Soil samples of 0-15, 15-30 and 30-45 cm depth were collected from four different locations of Meerut district under rice – wheat cropping sequence with the help of auger and stored in plastic box. Collected samples were air dried in shade, crushed gently with a wooden roller and pass through 2.0 mm sieve to obtain a uniform representative sample. The processed soil samples were analyzed for physico– chemical properties using standard method for pH and electrical conductivity (1:2 soil water suspensions), organic carbon (Walkley and Black, 1934), available nitrogen (Subhiah and Asija, 1956), available phosphorus (Olsen *et al*., 1954), available potassium (Jackson, 1973) and cationic micronutrients (Fe, Mn, Cu and Zn) in soil samples extracted with a diethylene triamine penta acetic acid (DTPA) solution (0.005M) DTPA +0.01 M $Cacl_2$ + 0.1 M triethanolamine , pH 7.3 as outlined by Lindsay and Norvell (1978). The concentration of micronutrients was determined by atomic absorbtion spectrophotometer (GBC Avanta PM). For the biological properties Soil samples were incubated at 25 ±1°C for 7 days. Soil moisture content during incubation was adjusted to field capacity for all the microbial counts and biochemical properties were studied as described by Wollum (1982). All the analysis of soil samples was carried out in laboratory of department of soil science, SVPUA&T, Modipuram Meerut (U.P.) India.

RESULTS & DISCUSSION

Chemical properties

Soil Reaction (pH)

Soil samples collected from surface and sub surface of four different locations of Meerut and Bulandshare district Soil pH estimated for soil of various depths was usually found normal to alkaline in reaction (table-1). It was observed that soil pH ranged from 7.4 to 8.9 for surface soil (0 -15 cm) while 7.5 to 9.0 in subsurface soil (30 - 45 cm). The soil EC ranged from 0.169 to 0.500 dSm^{-1} for surface soil while 0.105 to 0.744 dSm^{-1} in subsurface soil with an average value of 0.270 and 0.290 dSm^{-1}. The CEC ranged from 13.30 to 22.20 cmol (p^+) kg^{-1} for surface soil (0-15 cm) while 13.60 to 25.21 cmol (p^+) kg^{-1} in subsurface soil (30-45cm) with an average value of 17.25 and 17.92 cmol (p^+) kg^{-1} soil.

TABLE 1: Physico-chemical properties of soil under rice –wheat cropping sequence Meerut and Bulandshahr districts.

Locations	Depth (cm)	pH	EC (dSm^{-1})	CEC (cmol (p^+) kg^{-1})	O.C. g/kg	Available macronutrients		
						N ($kgha^{-1}$)	P ($kgha^{-1}$)	K ($kgha^{-1}$)
Nai Basti (B)	0-15	7.4	0.254	13.30	6.2	134.05	18.87	128.70
	15-30	7.5	0.188	12.95	5.9	111.51	17.52	100.97
	30-45	7.5	0.123	14.21	3.3	105.62	11.43	95.17
ZRS (B)	0-15	7.8	0.169	13.69	7.5	129.09	15.33	90.71
	15-30	7.9	0.138	12.08	3.8	69.02	11.31	84.47
	30-45	7.9	0.115	13.60	1.8	67.62	10.70	99.00
CRC (M)	0-15	8.9	0.500	22.20	6.3	99.65	11.67	317.51
	15-30	9.0	0.655	22.34	2.4	49.46	4.48	219.84
	30-45	9.0	0.744	18.96	2.1	47.90	2.53	168.66
Mavana (M)	0-15	8.2	0.246	19.82	6.9	112.70	3.75	147.50
	15-30	8.2	0.134	16.56	5.5	92.20	2.65	154.90
	30-45	8.2	0.105	25.21	3.1	78.86	2.16	187.30
Mean	0-15	-	0.290	17.25	6.72	118.87	12.40	171.10
	15-30	-	0.270	15.98	4.40	80.54	8.99	140.04
	30-45	-	0.270	17.92	2.57	76.50	6.70	137.53

In parentheses B denotes Bulandshahr and M for Meerut.

Organic Carbon content

The organic carbon in surface (0-15cm) and subsurface soil (30-45cm) varied from 6.2 to 6.9 and 2.1 to 3.3 g kg^{-1} soil with an average value of 6.72 and 2.57 g kg^{-1}, respectively. The Maximum organic carbon content 7.5 g kg^{-1} at surface (0-15 cm) was found in soil of Zonal research Station Bulandshahr while minimum 6.2 g kg^{-1}in Nai Basti. In the sub surface soil maximum organic carbon content 3.3 g kg^{-1} was found in Nai Basti and minimum 1.8 g kg^{-1} Zonal research Station Bulandshahr. Lower organic carbon in the area may be due to prevailing high temperature and good aeration in the soil which increase the rate of oxidation of organic matter content. Aggarwal *et al.* (1990) reported that the organic carbon content of some Aridosols of western Rajasthan ranged from 0.14 to 0.40 % in surface soil. Organic carbon was low and generally decreases with depth.

Nutrients status and soil fertility

Nitrogen

Soil fertility exhibits the status of different soils with regard to the amount and availability of nutrients essential for plant growth. The available nitrogen content in surface (0-15cm) and subsurface soil (30-45cm) varied from 99.65 to 134.05 and 47.9 to 105.62 with an average value of 118.87 and 76.50 kg ha^{-1} (Table-1) suggesting that all soils were low in available nitrogen. Available nitrogen was found to be maximum134.05 kg ha^{-1} in Nai Basti and minimum 99.65 kg ha^{-1} in CRC in surface soil (0-15 cm) while in sub surface soil 30-45cm) the highest available nitrogen 105.62 kg ha^{-1} in Nai Basti and minimum 47.90 kg ha^{-1} in CRC. The available nitrogen content was low and generally decreases regularly with increasing depth which is due to decreasing trend of organic carbon with depth and because cultivation of crops is mainly confined to the surface soil only at regular interval the depleted nitrogen is supplemented by the external addition of fertilizers during crop cultivation (Prasuna Rani et al. 1992). Walia *et al*. (1998) reported that available nitrogen in the soils of Bundelkhand region accounted for 12 to 40 % of total N in the range of 95 to 159 N kg^{-1} in surface soil and 51 to 159 mg N kg^{-1} in sub surface horizon. The continuous mineralization if organic matter in surface soils was responsible for the higher values.

Phosphorus

In rice- wheat cropping sequence the available phosphorus in surface (0-15 cm) and sub surface soil (15-30 & 30-45cm) varied from 2.65 to 17.52, 2.65 to 17.52 and 2.16 to 11.43 kg ha^{-1} with an average value of 12.40, 8.99 and 6.70 kgha^{-1}, respectively. The mean value of available phosphorus for 0-45 cm depth varied from 2.85 to15.94 kg ha^{-1}. The highest available phosphorus was observed in the surface soil and decrease with increasing depth. It might be due to the confinement of crop cultivation to the rhizosphere and supplementing the depleted P by external sources. The lower P content in sub surface soil could be attributed to the fixation of released phosphorus by clay minerals (Leelavathi *et al*., 2009).

Potassium

In rice - wheat cropping sequence the available potassium in surface (0-15 cm) and sub surface soil (15-30 & 30-45cm) varied from 90.71 to 317.51, 84.47 to 219.84 and 95.17 to 187.30 kg ha^{-1} with an average value of 171.10, 140.04 and 137.53 kg ha^{-1}, respectively. The available potassium was higher in surface soil and it's declined with increasing soil depth.

Micronutrients

Copper

In rice - wheat cropping sequence the DTPA extractable Cu varied from 0.825 to 1.349 mg kg^{-1} soil in surface (0-15cm) while 0.517 to 1.213 and 0.350 to 0.775 mg kg^{-1} in sub surface soil (15-30 & 30-45cm) with an average value of 1.140, 0.870 and 0.560 mg kg^{-1} soil, respectively. All the soil sample in rice-wheat farming system were found to be sufficient in available Cu content by considering the critical limit of 0.20 mg kg^{-1} soil suggested by Lindsay and Norvell (1978). A decreasing trend in available Cu with increasing depth was noticed in all locations. The available Cu was more in surface layer and decreased with depth.

Iron

In rice – wheat cropping sequence the DTPA- extractable iron in surface (0-15cm) and sub surface soil (15-30 & 30-45cm) varied from 6.783 to16.923, 3.961 to 8.273 and 3.687 to 5.245 mg kg^{-1} soil with an average value of 11.560, 6.150 and 3.740 mg kg^{-1} soil, respectively. According to critical limit of 4.5 mg kg^{-1} soil as proposed by Lindsay and Norvell (1978) all the surface soil (0-15cm) was sufficient in available Fe. A decreasing trend with depth in available Fe was noticed in all locations of rice – wheat farming sequence.

Mn

In rice – wheat cropping sequence the DTPA- extractable Mn content in surface (0-15cm) and subsurface soil (15-30 & 30-45cm) varied from 2.667 to 5.091, 2.632 to 3.901 and 2.150 to 3.251 mg kg-1 soil with an average value of 3.490, 3.180 and 2.670 mg kg^{-1} soil, respectively.. According to critical limit of 1.0 mg kg^{-1} as proposed by Lindsay and Norvell (1978) all the soil was sufficient in available Mn.

Zn

In rice - wheat cropping sequence the DTPA -extractable Zn ranged from 0.423 to 1.621 mg kg^{-1} in surface (0-15cm) While 0.233 to 1.305 and 0.113 to 0.428 mg kg^{-1} soil in sub surface soil (15-30 & 30-45cm) with an average value of 1.110, 0.660 and 0.320 mg kg^{-1} soil for surface and subsurface soil, respectively. Considering 0.6 mg kg^{-1} as critical level (Lindsay and Norvell 1978) all the surface soil sample with exception of CRC (M) was sufficient in available Zn content.

Microbiological Properties

In rice-wheat cropping sequence the no. of viable bacteria varied from 3.6 X 10^6 to 5.5 X 10^6, 4.1×10^4 to 5.6×10^4 and 2.1 X 10^2 to 4.8 X 10^2 count g^{-1} soil for surface (0-15 cm) and sub surface soil (15-30 & 30-45cm) with an average value of 4.62 X 10^6, 4.62×10^4 and 3.4 x 10^2 count g^{-1} soils, respectively.

In rice –wheat cropping sequence the fungi population in surface (0-15cm) and sub surface soil (15-30 & 30-45cm) varied from 1.8 x 10^4 to 2.2 x 10^4 , 1.3 x 10^2 to 2.3 x 10^2 and 1.0 x 10^2 to 1.7 x 10^2 count g^{-1} soil with an average value of 2.07 x 10^4 , 1.87 x 10^2 and 1.5 x 10^2 count g^{-1} soil, respectively. In rice-wheat cropping sequence actinomycetes population of surface (0-15cm) and sub surface soil (15-30 & 30-45cm) varied from 1.5x 10^4 to 2.0 x10^4 , 1.2 x 10^2 to 2.3 x 10^2 and 1.0 x 10^2 to 1.8 x 10^2 count g^{-1} soil with an average value of 2.0 x 10^4, 1.77 x 10^2 and 1.27 x 10^2 count g^{-1} soil respectively.

In rice-wheat cropping sequence microbial biomass carbon in surface (0-15cm) and sub surface soil (15-30 & 30-45cm) varied from 280 to 298, 150 to 172 and 77 to 90 µg g^{-1} soil with an average value of 288.25, 160.50 and 81.50 µg g^{-1} soil, respectively . The mean value microbial biomass carbon for 0-45cm depth varied from 153.00 to 178.33 µg g^{-1} soil.

In rice – wheat cropping sequence dehydrogenase enzyme activity in surface (0-15cm) and subsurface soil (15-30 & 30-45) varied from 55 to 69, 25 to 31 and 12 to 15 µg TPF g $^{-1}$soil day^{-1} with an average value 62.75, 27.50 and 13.25 µg TPF g $^{-1}$soil day^{-1}.

Correlation study

Correlation coefficient among the different soil properties of seven different cropping sequences of various locations of Meerut and Bulandshahr district at 3 soil depth *viz.* 0-15, 15-30 and 30-45 cm were work out Simple correlation coefficient of soil properties with various elements revealed that the soil organic carbon under rice- wheat cropping sequence was significantly and positively correlated with total N (r = 0.621*) and Fe (r = 0.697*) which positively and highly significant with available N (r = 0.856**), Cu (r = 0.809**), Zn (r = 0.754**) and microbial biomass carbon (r = 0.846**) although available P (r = 0.433), available K (r = 0.0156) and Mn (r = 0.238) were positively correlated with organic carbon but not to the any significance level. Organic carbon is negatively correlated with bulk density (r = - 0.226) and CEC (r = - 0.171). Similar relationship between organic carbon and CEC has been reported by Sarade and Jagdish (2008).

The soil pH is negatively correlated with Cu (r = - 0.171), Fe (r = - 0.367) and significantly & negatively with Zn (r = - 0.676*) a positive correlation with Mn (r = 0.375) was found. CEC of soil is significantly & negatively correlated with sand (r = - 0.612*) and negatively correlated with silt (r = - 0.555) but positively and significantly with clay (r = 0.632*). Available soil nitrogen is positively and significantly correlated with total N (r = 0.600*) and microbial biomass carbon (r = 0.656*).

TABLE 2: DTPA extractable micronutrient (mg kg^{-1}) at various soil depths under rice – wheat cropping sequence

Locations	Depth (cm)	Available micronutrients			
		Fe mgkg^{-1}	Mn mgkg^{-1}	Cu mgkg^{-1}	Zn mgkg^{-1}
Nai Basti (B)	0-15	16.923	3.350	0.825	1.561
	15-30	8.273	3.333	0.781	1.305
	30-45	4.250	3.251	0.775	0.428
ZRS (B)	0-15	10.769	2.869	1.349	1.621
	15-30	6.925	2.843	1.213	0.681
	30-45	5.245	2.325	0.350	0.391
CRC (M)	0-15	11.761	5.091	1.273	0.423
	15-30	3.961	3.901	0.517	0.233
	30-45	3.687	2.967	0.393	0.113
Mavana (M)	0-15	6.783	2.667	1.123	0.845
	15-30	5.450	2.632	0.980	0.460
	30-45	4.753	2.150	0.697	0.352
Mean	0-15	11.560	3.490	1.140	1.110
	15-30	6.150	3.180	0.870	0.660
	30-45	3.740	2.670	0.560	0.320

In parentheses B denotes Bulandshahr and M for Meerut.

TABLE 3: Bacteria(Countg^{-1}soil), Fungi (Countg^{-1}soil), Actinomycets microbial biomass carbon and Dehydrogenase activity (Mg TPF g^{-1} soil) at various soil depths under rice– wheat cropping sequence

Location	Depth, cm	Bacteria (Countg^{-1}soil),	Fungi (Countg^{-1}soil),	Actinomycetes (Countg^{-1}soil),	Microbial biomass carbon µg g^{-1} soil	Dehydrogenase activity Mg TPF g^{-1} soil
Nai Basti (B)	0-15	3.6×10^6	1.8×10^4	1.5×10^4	290	69
	15-30	4.1×10^4	1.3×10^2	1.2×10^2	150	25
	30-45	2.1×10^2	1.0×10^2	1.1×10^2	90	15
ZRS (B)	0-15	4.8×10^6	2.2×10^4	2.7×10^4	285	55
	15-30	4.3×10^4	2.0×10^2	2.3×10^2	170	28
	30-45	2.6×10^2	1.7×10^2	1.8×10^2	80	12
CRC (M)	0-15	4.6×10^6	2.2×10^4	2.0×10^4	280	65
	15-30	4.5×10^4	2.3×10^2	2.1×10^2	172	26
	30-45	4.1×10^2	1.7×10^2	1.2×10^2	79	12
Mavana (M)	0-15	5.5×10^6	2.1×10^4	1.8×10^4	298	62
	15-30	5.6×10^4	1.9×10^2	1.5×10^2	150	31
	30-45	4.8×10^2	1.6×10^2	1.0×10^2	77	14
Mean	0-15	4.62×10^6	2.07×10^4	2.0×10^4	288.25	62.75
	15-30	4.62×10^4	1.87×10^2	1.77×10^2	160.50	27.50
	30-45	3.4×10^2	1.5×10^2	1.27×10^2	81.50	13.25

In parentheses B denotes Bulandshahr and M for Meerut.

CONCLUSION

The study of soil samples of Meerut and Bulandshar district revealed that the soil are normal to moderately alkaline in reaction, low to medium in organic carbon. As far as nutrient status in concerned on the bases of mean value, the soils were low in available nitrogen, low to medium in available phosphorus and potassium and in general sufficient in available Cu, Fe, Mn and Zn in

surface soil and declined with soil depth. Among the biological properties of soil, the range of bacteria varied from 3.6 to 5.5 x 10^6, Fungi 1.8 x $10^4$to 2.2 x 10^4 and actinomycetes 1.5 x 10^4 to 2.7 x10^4 count g^{-1} soil. Microbial biomass carbon 281-298 µg g^{-1} soil and dehydrogenase activity 55 to 69 µg TPF $g^{-1}day^{-1}$. All the microbial population, microbial biomass carbon and dehyrogenase activity decline as the soil depth increases.

REFERENCES

Aggarwal, R.K., Kumar, P. and Sharma, B.K. (1990) Distribution of nitrogen in some Aridisols. *Journal of the Indian Society of Soil Science* 38, 430-433.

Chandra, R., Rana, N.S., Kumar, S. and Panwar, G.S. (2008) Effect of sugarcane, residue and green manure practices in sugarcane- ratoon–wheat sequence on productivity, soil fertility and soil biological properties. *Archives of Agronomy and Soil Science* 54 (6) 651 - 664

Fertilizer Association of India (FAI) (2005) Fertilizer Statistics 2004-2005. *New Delhi: FAI.*

Jackson, M.L. (1973) Soil chemical analysis prentice hall of India, New Delhi, 498.

Leelavathi, G.P. Naidu, M.V.S., Ramavatharram, N. and Karuna Sagar, G. (2009) Studies of genesis, classification and evaluation of soil for sustainable land use planning in Yerpedu Mandal of Chittoor District, Andhra Pradesh. *J. Indian society of soil science* 57 (2) 109-120.

Lindsay, W.L. and Norvell, W.A. (1978) Development of DTPA soil test for zinc, iron, manganese and coper. *Soil Science Society of America Journa*l 42, 421-428.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Deen, L.A. (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA CIRC. 939. United State Dept. of Ag. Wasignton, D.C.

Rani, Prasuna, Pillai, R.N., Prasad, Bhanu and Subbaiah, G.V. (1992) Nutrient status of some red and associated soil of Nellore district under Somasila Project in *Andhra Agriculture Journal* 39, 1-5.

Singh, J.P., Dahiya, D.J., Kumar, V. and Singh, M. (1992) Distribution and status of different forms of N in soils of Haryana. *Journal of the Indian Society of Soil Science* 40, 698-704.

Subbiah, B.V. and Asija, G.L. (1956) A rapid procedure for the determination of available nitrogen in soil. *Current Sci.* 25, 259-260.

Walkley, A.J. and Black, I.A. (1934) Estimation of soil organic carbon by the chromic acid titration method. *Soil Sci.* 37, 29-38.

Walia, C.S., Ahmed, N., Uppal, K.S. and Rao, Y.S. (1998) Studies profile distribution of various forms of total nitrogen and C: N ratio in some lands of Bundelkhand region of U.P. *Journal of the Indian Society of Soil Science* 46, 193-198.

Wollum, A.G. (1982) Cultural methods for soil microorganism. In A.L., Page, R.H. Miller, and D.R. Keeney (ed.) method of soil analysis, part 2. Chemical and microbiological properties, Agronomy monograph No. 9, ASA-SSSA, Publisher Madison, Wisconsin, USA, pp. 781-814.