Physico-chemical and Enzymatic Analysis of Rhizospheric and Non-rhizospheric Soils from Middle Indo-Gangetic Plain Region

Chapter · June 2019

DOI: 10.1007/978-981-13-6846-2_2

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Physico-chemical and Enzymatic Analysis of Rhizospheric and Non-rhizospheric Soils from Middle Indo-Gangetic Plain Region

2

Ashish Tiwari, Shikha Devi, Nand Kumar Singh, and Shivesh Sharma

Abstract

Indo-Gangetic plain (IGP) is one of the largest agricultural region in the world feeding large population of the country. Nutrient mining, lack of crop rotation and excessive use of agrochemicals has resulted into severe loss in soil fertility and slowdown in the crop productivity in Middle IGP. Farmers are compelled to apply higher fertilizer input per hectare (ha) every year to maintain or increase crop productivity. The soil fertility status of the MGP appears to be low to medium for various soil parameters. Soil pH is mostly in normal range with some samples showed increased salinity in the region. Nitrogen and soil organic carbon (SOC) content were deficient in the region's soil. Phosphorus (P) and Potassium (K) content were also found to be deficient in most of the sampling sites. Soil enzymatic activity was found greater in rhizospheric soil as compare to non-rhizospheric soil due to presence of rhizospheric microbial activity.

Keywords

Indo-Gangetic plain · Physico-chemical analysis · Soil fertility and soil nutrients

2.1 Introduction

Indo-Gangetic Plain (IGP) region is most fertile and productive agricultural region formed by the Indus, Ganga and the Brahmaputra river basin systems. IGP constitute large geographical area (15%) of the country with four major sub regions i.e. Trans IGP (TGP), Upper IGP (UGP), Middle IGP (MGP) and Lower IGP (LGP) extending from 73° latitude and 32° longitude to 89° East latitude and 21° North longitude

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R. Kundu et al. (eds.), *Environmental Biotechnology For Soil and Wastewater Implications on Ecosystems*, https://doi.org/10.1007/978-981-13-6846-2_2

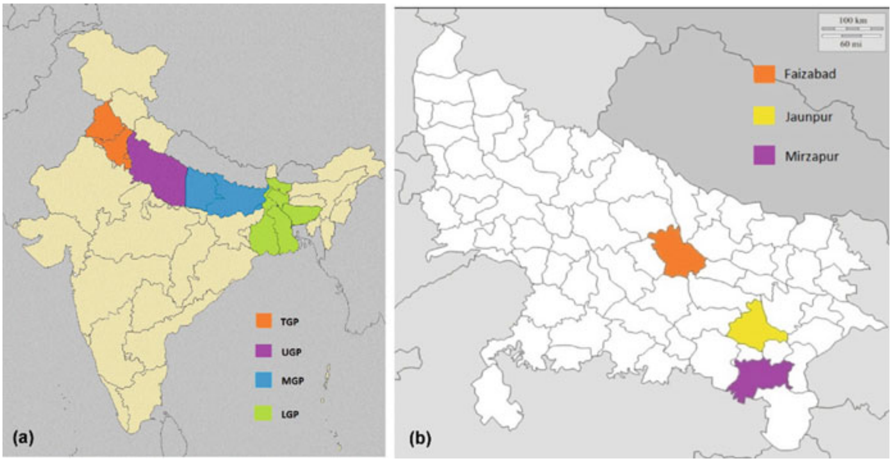

Fig. 2.1 (**a**) Indo-Gangetic Plain region, (**b**) Middle Indo-Gangetic plain

(Fig. 2.1a) [1, 2]. Indo-Gangetic Plain is known as food bowl or basket of the country by producing 50% of total food grain production [3]. IGP is mostly dominated by the alluvial, loam and sandy loam soils that subjected to alkalinity, wetness and soil erosion [4]. Rice (*Oryza sativa)*-Wheat (*Triticum aestivum*) cropping system (RWCS) is major cropping pattern of IGP with 53% of the total area [5]. RWCS transforms soil environment from anaerobic to aerobic, remove significant amount of nutrients (nutrient mining) that causes loss of soil fertility [6].

Cereal based repetitive cropping pattern with discriminate use of fertilizer and pesticides are major cause of decline in crop productivity and soil fertility in the region over the year [7]. Current increasing input of chemical fertilizer causes a number of health and environmental related issues with poor soil health [8]. Soil enzyme activity is an important indicator of soil fertility, soil quality and soil microbial activity [9]. Soil enzymes are involved in organic matter decomposition, nutrient mineralization and release of available nutrients for maintaining soil fertility [10]. Chemical fertilization, tillage, irrigation and grazing practices affect soil microbial diversity and its enzymatic activity [11].

2.2 Materials and Methods

2.2.1 Study Area and Study Crop

Study area constitutes different locations of Middle Indo-Gangetic plain (MGP) region *viz.,* Faizabad (latitude 26°78′ N, longitude 82°13′ E), Jaunpur (latitude 25°44′ N, longitude 82°41′ E) and Mirzapur (latitude 25°18′ N, longitude 88° 18′ E) in Uttar Pradesh (Fig. 2.1b). Pigeon pea *(Cajanus cajan),* known as red gram, is major source of protein diet in India. Pigeon pea is drought tolerant plant that can survive wide range of temperature (18–35 °C), pH (4.5–8.5) and can be grown on less irrigated land or semi-arid climate conditions.

2.2.2 Soil Sample Collection

Rhizospheric and non-rhizospheric soil samples were collected from pigeon pea grown fields using standard procedure [12]. Soil samples from different locations were collected in triplicates, mixed thoroughly and stored in sterile polythene bags. Soil samples were properly labelled, brought to the laboratory and stored at 4 °C for the further analysis.

2.2.3 Physico-chemical Analysis

Soil physico-chemical properties *viz.*, soil pH, electrical conductivity (EC), Soil organic carbon (SOC) and macronutrients (N, P and K) of soil samples were analysed using standard soil test methods [13]. Soil pH was measured by using electrode pH meter and soil electrical conductivity (EC) was measured by using conductivity meter in the supernatant solution of 1:5 soil/water ratios (w/v) [14]. SOC (%) content was determined by using walkley black rapid titration method [15, 16]. Soil nitrogen (N) content was measured by the alkaline permanganate method [17]. Soil Phosphorus (P) content was extracted by using sodium bicarbonate and measured using ascorbic acid-ammonium molybdate method or Olsen's Method [18]. Soil Potassium (K) content was extracted by 1 N ammonium acetate [19] and determined by flame photometry [20].

2.2.4 Nutrient Index

Soil nutrient index was calculated to evaluate the soil fertility status based on following formula. On the basis of nutrient index value, Soil fertility status is categorized as low (< 1.67), medium (1.67–2.33) and high (> 2.33) for different soil parameters (Table 2.1).

$$\text{Nutrient} \quad \text{Index} = \frac{N_L + 2 \times N_M + 3 \times N_H}{N_L + N_M + N_H}$$

Where, N_L = Number of soil sample with low nutrient value; N_M = Number of soil sample with medium nutrient value; N_H = Number of soil sample with high nutrient value.

Table 2.1 Rating chart for soil physico-chemical parameter

1.	Soil pH	Acidic (Ac)	Neutral (N)	Alkaline (Al)
		<6.5	6.5–8.0	>8.0
2.	Electrical conductivity (cS/cm)	Normal	Critical	Injurious
		<0.1	0.1–0.2	>0.2
		Low (L)	Medium (M)	High (H)
3.	Soil organic carbon (%)	<0. 5	0.5–0.75	>0.75
4.	Nitrogen (N) (kg/ha)	<272	272–544	>544
5.	Phosphorus (P) (kg/ha)	<22	23–56	> 56
6.	Potassium (K) (kg/ha)	<120	123–280	> 280

2.2.5 Soil Enzymatic Activity

Soil enzymatic activities viz., dehydrogenase, polyphenol oxidase and catalase activity were estimated for assessment of soil quality, microbial activity and soil health status [21].

2.2.5.1 Dehydrogenase Activity

Dehydrogenase activity (DHA) was estimated by TTC (2, 3, 5-triphenyl tetrazolium chloride) reduction method and reaction product i.e. triphenyl formazan (TPF) was extracted using methanol [22]. DHA activity is indicated by production of red colour and measured as μg TPF gm^{-1} dry soil/hr by spectrophotometer at 485 nm.

2.2.5.2 Polyphenol Oxidase Activity

Polyphenol oxidase (PPO) activity was determined by formation of purpurigallin from pyrogallic acid as substrate [23]. The appearance of yellow colour indicated the formation of purpurigallin in test tubes. Further, PPO activity was evaluated by spectrophotometer at 430 nm in mg purpurigallin/(gm.dry soil.2hr).

2.2.5.3 Catalase Activity

Soil catalase activity was measured by $KMnO_4$ titration method with H_2O_2 as substrate [24]. Catalase activity was expressed in ml 0.1 mol/litre $KMnO_4$ solution titrated/(gm dry soil.20 min) for the remaining H_2O_2.

2.3 Results and Discussions

A total of thirty (30) soil samples of both rhizospheric (15) and non-rhizospheric (15) soil were collected from pigeon pea fields (Fig. 2.2). Collected soil samples were labeled on the basis of location viz., Faizabad (F), Jaunpur (J) and Mirzapur (M) and soil sample type viz., pigeon pea rhizosphere (PR) and non-rhizospheric (NR). Soil samples were examined at soil testing laboratory for physico-chemical and macronutrients analysis.

Fig. 2.2 Collection of rhizospheric and non- rhizospheric soil samples

2.3.1 Soil Physico-chemical Analysis

Soil physico-chemical properties and macronutrients (N, P, K) values were measured for collected soil samples. The measured soil parameter values were categorised as low (L), medium (M) and high (H) based on rating (Table 2.1). Soil pH of rhizosphere soil samples ranged between 6.8 and 8.4 and ranged between 6.7 and 8.2 for non- rhizospheric soil samples. Few soil samples show slightly alkaline pH that may be due to application of chemical fertilizers. The result indicates that pH value of rhizospheric soil samples were in optimal range (6–7.5), whereas non-rhizospheric soil samples showed variation from slightly acidic to slightly alkaline (Table 2.2).

Electrical conductivity (EC) is measure of current carrying capacity and represents the soluble salts present in the soil that ranged from 0.08 to 0.20 cS/cm. EC is directly proportional to the soil salinity with highest EC value (0.20 cS/cm) in FNR-4 sample and the lowest EC value (0.08 cS/cm) for JNR-2 soil sample (Table 2.2). Soil organic carbon content is major determinant of soil structure, moisture content and soil fertility [25]. In present study, SOC percentage range (0.12–1.2) showing low carbon content over the region. Majority of the soil samples (40%) showed low percent organic carbon (i.e., < 0.40), while 33% soil samples represent medium percent of organic carbon content. SOC buffers soil against strong pH changes and soil with higher SOC value can prevent soil from erosion.

Nitrogen content was measured as nitrate (NO_3^-) and observed to be in low to medium nitrogen content (198–345 kg/ha) in most of the soil samples (Table 2.2). Phosphorus (P) is the second most important macronutrient affecting plant growth (pulse crop production). Phosphorus content of the region ranged between 4.5 and 38 kg/ha. Majority of the soil samples in the region have deficient (72.60%) and medium (27%) supply of phosphorus content. Potassium (K) is third most important macronutrient element required by the plant for growth. The potassium content value of the region ranges from 75 to 278 kg/ha. Majority of the soil samples (60%) showed medium potassium content, while some samples (40%) showed low level of potassium content (Table 2.2).

Table 2.2 Physico-chemical analysis of rhizospheric and non- rhizospheric soil samples

Soil sample	pH	Electrical conductivity (cS/cm)	SOC (%)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
FNR-1	8.2_{Al}	0.14_{M}	0.28_{L}	248_{L}	4.5_{L}	78_{L}
FPR-1	7.5_{N}	0.16_{M}	0.45_{L}	282_{M}	12.5_{L}	90_{L}
FNR-2	8.1_{Al}	0.12_{M}	0.30_{L}	250_{L}	9.0_{L}	101_{L}
FPR-2	8.0_{Al}	0.14_{M}	0.42_{L}	280_{M}	14.2_{L}	125_{M}
FNR-3	8.4_{Al}	0.12_{M}	0.63_{M}	271_{L}	13.0_{L}	89_{L}
FPR-3	8.2_{Al}	0.13_{M}	0.60_{M}	292_{M}	17.0_{L}	94_{L}
FNR-4	6.8_{N}	0.20_{M}	0.75_{M}	212_{L}	18.2_{L}	252_{M}
FPR-4	6.8_{N}	0.19_{M}	0.65_{M}	240_{L}	20.2_{L}	270_{M}
FNR-5	7.1_{N}	0.15_{M}	0.65_{M}	198_{L}	19.5_{L}	165_{M}
FPR-5	7.9_{N}	0.17_{M}	0.70_{M}	212_{L}	22.0_{L}	172_{M}
JNR-1	7.0_{N}	0.14_{M}	0.45_{L}	207_{L}	8.2_{L}	205_{M}
JPR-1	7.5_{N}	0.15_{M}	0.50_{M}	224_{L}	16.4_{L}	212_{M}
JNR-2	7.1_{N}	0.08_{L}	0.90_{H}	265_{L}	26.1_{M}	260_{M}
JPR-2	6.9_{N}	0.10_{L}	0.78_{M}	282_{M}	28.2_{M}	282_{M}
JNR-3	7.4_{N}	0.15_{M}	1.20_{H}	280_{M}	35.4_{M}	272_{M}
JPR-3	7.3_{N}	0.12_{M}	1.10_{H}	302_{M}	37.6_{M}	265_{M}
JNR-4	6.7_{N}	0.09_{L}	0.30_{L}	305_{M}	7.8_{L}	212_{M}
JPR-4	7.0_{N}	0.15_{M}	0.47_{L}	308_{M}	15.7_{L}	232_{M}
JNR-5	6.9_{N}	0.14_{M}	0.47_{L}	246_{L}	15.5_{L}	195_{M}
JPR-5	7.9_{N}	0.12_{M}	0.55_{M}	274_{L}	19.7_{L}	214_{M}
MNR-1	7.2_{N}	0.11_{M}	0.75_{M}	285_{M}	19.3_{L}	255_{M}
MPR-1	7.0_{N}	0.13_{M}	0.47_{L}	315_{M}	18.2_{L}	260_{M}
MNR-2	7.1_{N}	0.17_{M}	1.20_{H}	315_{M}	36.5_{M}	278_{M}
MPR-2	7.4_{N}	0.14_{M}	0.52_{M}	322_{M}	39.8_{M}	284_{M}
MNR-3	7.9_{N}	0.12_{M}	0.12_{L}	322_{M}	13.5_{L}	112_{L}
MPR-3	7.6_{N}	0.14_{M}	0.12_{L}	314_{M}	19.5_{L}	176_{L}
MNR-4	8.2_{Al}	0.15_{M}	0.42_{L}	345_{M}	4.5_{L}	75_{L}
MPR-4	7.5_{N}	0.18_{M}	0.42_{L}	335_{M}	12.5_{L}	134_{L}
MNR-5	7.4_{N}	0.16_{M}	0.50_{M}	260_{L}	38_{M}	85_{L}
MPR-5	7.8_{N}	0.16_{M}	0.50_{M}	290_{M}	42.0_{M}	175_{L}

Al Alkaline, *N* Neutral, *H* High, *L* Low, *M* Medium

2.3.2 Nutrient Index

Nutrient index values for soil physical-chemical parameters i.e. Soil pH, EC, SOC, N, P and K were calculated based on nutrient index formula. Further, fertility status for sampling areas was determined on the basis of nutrient index value as enlisted (Table 2.3).

Table 2.3 Nutrient index value of different sampling area

Soil parameter	Range	Sampling area			Nutrient index	Fertility status
		Faizabad	Jaunpur	Mirzapur		
pH	6.7–8.4	7.72 ± 0.72	7.02 ± 0.26	7.56 ± 0.47	2.14	Medium
Electrical conductivity (cS/cm)	0.08–0.20	0.15 ± 0.03	0.12 ± 0.03	0.15 ± 0.03	1.87	Medium
Soil organic carbon (%)	0.12–1.20	0.52 ± 0.20	0.65 ± 0.38	0.60 ± 0.41	1.64	Low
Nitrogen (kg/ha)	198–345	235.80 ± 29.94	251.0 ± 46.63	293.0 ± 57.27	1.40	Low
Phosphorus (kg/ha)	4.5–38	12.84 ± 6.27	18.60 ± 11.90	18.45 ± 13.40	1.26	Low
Potassium (kg/ha)	75–278	137 ± 72.61	228.8 ± 34.35	161.60 ± 96.94	1.60	Low

Table 2.4 Soil enzymatic activity of different soil samples

Soil sample	Dehydrogenate activity (μg TPF gm^{-1})	PPO activity (mg purpurigallin/gm drysoil.2 hr)	Catalase activity (ml/gm dry soil.20 min)
FNR	12.33 ± 2.08	0.25 ± .03	1.97 ± .40
FPR	17.45 ± 2.6	0.49 ± .02	3.57 ± .45
JNR	11.0 ± 3.50	0.23 ± .02	2.54 ± .35
JPR	20.0 ± 3.0	0.50 ± .03	8.8 ± .35
MNR	20.67 ± 2.08	0.21 ± .03	4.53 ± .41
MPR	50.00 ± 2.5	0.32 ± .03	9.36 ± 3.05

2.3.3 Soil Enzyme Activity

Soil enzymes are secreted by inhabitant soil microbes that determine biochemical status of the soil plant system [26]. Soil enzyme activities were analyzed for collected six (6) rhizospheric and non-rhizospheric soil samples from different location *viz.*, Faizabad (F), Jaunpur (J) and Mirzapur (M) (Table 2.4).

Dehydrogenase activity indicates oxidative activity of soil samples and ranged from 11 to 50 μg TPF gm^{-1}. DHA activity was also found to be low in less polluted soil than polluted soil samples that consistent with previous findings [27]. Polyphenol oxidase is lignolytic enzymes that degrade humus to gain carbon and other nutrients by the oxidation of phenolic compound. PPO activity ranged from 0.21 to 0.50 mg purpurigallin/(gm drysoil.2 hr) in rhizospheric soil samples. PPO activity gives the indication of a healthy soil i.e. free from toxic effect of phenol molecules and metal ions as reported in previous work [28]. Catalase enzyme decomposes plant litter and counteract to damaging of cells by H_2O_2 [29]. Catalase activity ranged from 1.98 to 9.34 ml/(gm dry soil.20 min). The higher catalase activity in soil samples indicates the higher microbial population. Soil enzyme activity can be affected by various abiotic conditions like moisture, oxygen content, soil pH, temperature and chemical structure of the organic matter [30].

2.4 Conclusion

Crop productivity is heavily dependent upon chemical fertilizers and pesticides in Middle IGP (MGP) region. Farmers apply approximately 30–50 kg/ha fertilizer input for maintaining crop productivity over the year. The soil fertility status of the region appears to be low to medium for various soil parameters. Soil pH is mostly in normal range (6.7–8.4) in the region, but some samples reported deviation (6.0–7.5) due to excess application of fertilizer. Physico-chemical analysis revealed the deficiency of nitrogen (N), phosphorus (P) and SOC content throughout the region. Phosphorus (P) and potassium (K) were also found deficient in most of the sampling sites. The soil enzyme activity show greater enzyme activity in rhizospheric soil with comparison to non-rhizospheric soil indicates the presence of high microbial activity in rhizosphere soil. Rhizospheric soil containing rhizobacteria indicated improved soil quality with increasing organic carbon, total nitrogen and total phosphorus. Legume crop can improve physico-chemical property of soil by nitrogen fixation, nutrient recycling, increase in soil organic matter and minimizing soil compaction without requirement of additional fertilizers. Thus, Legume crops such as pigeon pea are very useful as intercrop between cereals crops to increase soil fertility and macronutrients availability.

Acknowledgements The authors greatly acknowledge Department of Biotechnology (DBT), India for providing financial assistance.

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