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SPATIAL DISTRIBUTION OF PHYSICO-CHEMICAL PROPERTIES AND MACRONUTRIENTS IN RICE GROWING SOILS OF HARYANA

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ABSTRACT

Rice growing soils in Kaithal, Kurukshetra and Karnal were neutral to slightly alkaline in reaction and loamy sand to clay loam. In surface soil, organic carbon ranged from 0.35 to 0.68, 0.27 to 0.67 and 0.36 to 0.69 % and 0.28 to 0.63, 0.21 to 0.56 and 0.27 to 0.61% in sub-surface soil in Kaithal, Kurukshetra and Karnal, respectively.Available nitrogen, phosphorus, potassium and sulphur varied from 112 to 194, 86 to 180 and 115 to 193; 9 to 37, 6 to 37 and 9 to 46; 100 to 454, 54 to 306 and 126 to 456; 8 to 71, 4 to 60 and 6 to 108 kg/ha in surface soil while in sub-surface soils varied from 88 to 145, 67 to 141 and 86 to 140; 5 to 26, 4 to 27 and 7 to 38; 92 to 426, 38 to 278 and 118 to 359; 4 to 49, 3 to 42 and 3 to 72 kg/ha correspondingly in district Kaithal, Kurukshetra and Karnal. Mostly samples were medium in OC, low in nitrogen, medium to high in phosphorus, potassium and sulphur. Nitrogen, phosphorous and potassium were positively correlated with OC. Soil pH was negatively correlated with P and K.

KEY WORDS
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Soil pH
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INTRODUCTION

Rice is the staple food crop for more than 60 percent of the world population and dominant crop cultivated in large parts of Asian agriculture regions, where about 90% of the world's rice is produced and consumed. Rice-wheat cropping system is the dominant cropping system of Indo-Gangetic Plains (IGP) and occupies 13.5 million hectares in the IGP of India, Bangladesh, Nepal and Pakistan (Benbi and Senapati, 2010). In context of India, IGP occupies nearly 15 % of its geographical area. The contribution of IGP percentage area in India is 48.4 % for rice and 74.7 % for wheat (Koshal, 2014).

Haryana is the second largest producer of rice in India after Punjab but the production of rice in Haryana has broken all the records during the year 2013-14 with the highest production at 39.98 lakh million tons of total rice production (DOAH, 2014). Soil fertility is one of the important factors controlling yield of the crops. Macronutrients (N, P, K and S) are important soil elements which control its fertility. The knowledge of physico-chemical properties is crucial for characterizing and/or improving soil health to attain optimal productivity for each soil/climatic condition. Soil characterization in relation to evaluation of fertility status of the soils of an area or region is an important aspect in context of sustainable agriculture production.Because of adoption of highly intensive rice-wheat cropping system along with imbalanced and inadequate fertilizer use, tillage practices coupled with low use of other inputs such as organic manures and crop residues, the production efficiency of chemical fertilizer nutrients has declined tremendously under intensive agriculture in recent years in rice growing soils of Haryana. This resulted in decline of soil quality at an alarming rate ensuing not only the fast depletion of macronutrients but also micronutrient deficiencies in soils**.** The results of numerous field experiments in different parts of India have, therefore indicated "fertilizer-induced unsustainability of crop productivity"(Yadav, 2003).

Many researchers have revealed that soil properties vary across agricultural fields, causing spatial variability in crop yields. Therefore, their proper management is necessary to avoid deteriorating the soil while meeting the requirement of high crop productivity and farmers must be advocated for balanced fertilization. Earlier, Celik, (2005) reported that soils under cultivation have higher bulk density as compared to the adjacent soils under forest and pasture land. Lv *et al.*(2011) observed that after 18 years of inorganic and organic fertilizer application to an infertile paddy field under subtropical conditions resulted in higher available N in organic manure containing treatment as compared with the organic manure omitted treatments. The concentration of available phosphorus both in surface and subsurface increased significantly with time and depth after 68-100 years of rice cropping (Zhang and He, 2004). Sepehya *et al*. (2012) observed that over 18 years there was significant decrease in available K of the soil under continuous cropping and manuring under all treatments as compared to the initial value of 221 kg ha^{-1}. Singh (2004) concluded that about 30, 21 and 11 per cent soil samples were deficient in the available sulphur in Sonipat, Panipat and Rohtak district, respectively. Overall, 23 per cent soils were found to be deficient in soils of Yamuna river basin of Haryana state. Hence it is necessary to evaluate the fertility status of the soil and promote the recommendations of soil test for balanced nutrition in order to maintain the soil quality. Keeping in view the aforementioned facts, an attempt has been made to assess the spatial distribution of physico-chemical properties and macronutrients in rice growing soils of Haryana.

MATERIALS AND METHODS

The present investigation was undertaken in Kaithal, Kurukshetra and Karnal districts of Haryana; the part of the Great Indian Plains. The plains are remarkably homogenous with little variation in relief features.The climate is subtropical, semiarid, continental monsoonal having prolonged hot summer with annual precipitation of 300 - 670 mm. The maximum rainfall occurs during monsoon *i.e.*, July to September. The soil moisture regime is ustic and udic and soil temperature regime is hyperthermic. The relative humidity increases from June to September and gradually decreases reaching the minimum during January. The fields were selected randomly where the farmers were growing rice for about last fifteen years.One hundred fifty representative soil samples (75 surface and 75 sub-surface) were collected from rice growing soils of Kaithal, Kurukshetra and Karnal districts. The samples were air dried, ground and passed through 2-mm sieve to remove coarse fragments and used for analysis. The soil reaction (pH) and electrical conductivity (EC) were determined in saturation extract as per the procedure described by Jackson (1973). Soil texture was determined by international pipette method (Piper, 1966) whereas the soil bulk density was determined by core method.The soil organic carbon (OC) was estimated by wet digestion method (Walkley and Black, 1934) and available N by alkaline potassium permanganate method (Subbaiah and Asija,1956). Available P in the soil was extracted by employing Olsen extractant (0.5M $NaHCO_3$) as described by Olsen *et al*. (1954), available K by neutral normal ammonium acetate and measured by flame photometer (Jackson, 1973) and available sulphur (S) was extracted by 0.15% $CaCl_2.2H_2O$ solution as described by Chensin and Yien (1950). The correlation was determined among physicochemical properties and available nutrients by using SPSS.

RESULTS AND DISCUSSION

Physico-chemical properties of surface and sub-surface soil

Organic carbon

The organic carbon content varied from 0.35 to 0.68, 0.27 to 0.67 and 0.36 to 0.69 per cent with mean values of 0.51, 0.45 and 0.52 per cent in surface soil samples of Kaithal, Kurukshetra and Karnal districts, respectively. In sub-surface layer, organic carbon content ranged from 0.28 to 0.63, 0.21 to 0.56 and 0.27 to 0.61 per cent with mean values of 0.42, 0.36 and 0.42 per cent in Kaithal, Kurukshetra and Karnal districts, respectively. Based on the critical limits of organic carbon (Table 1), it was deduced that 77% soil samples were under medium category, whereas, only 23 % were classified under low category. The subsurface soils had lower organic carbon than the surface soils. The probable reason for low to medium organic carbon content in these areas may be attributed to good aeration of soil and high rate of organic matter decomposition under hyperthermic temperature regime which led to extremely high oxidizing conditions (Kameriya, 1995). Similar results were also reported by Singh *et al.* (1997) and Gora (2013) in their earlier studies in soils of Haryana. Moreover, farmers in rice growing soils of Haryana apply fertilizers and manures to increase the rice production which also helps in build up of the soil organic carbon. Similar results have been reported by Benbi *et al*. (2012) in his experiment. Singh *et al*. (2014) while ascertaining soils of Chambal region reported that 63, 56 and 91% of soils were low, 37, 44 and 9% in medium in organic carbon content in alluvial, medium black and ravenous land, respectively.

pH

The pH of the surface soil varied from 7.39 to 8.53, 7.38 to 8.85 and 7.30 to 9.25 whereas that of sub-surface soil ranged from 7.31 to 8.50, 7.22 to 8.70 and 7.35 to 8.91 in Kaithal, Kurukshetra and Karnal districts, respectively. Most of the soil samples have the alkaline pH and showed decrease in pH with depth. Similar results were found by Vijaykumar *et al.* (2011) and Singh and Mishra (2012). The alkaline pH may be attributed to the reaction of applied fertilizers with the soil colloids, which resulted in the reaction of basic cations on the exchangeable complex of the soil.

Electrical Conductivity

The mean values of EC of surface soil samples were 0.85, 0.48 and 0.48 dS/m with range from 0.35 to 2.57, 0.21 to 0.90 and 0.15 to 1.63 dS/m in Kaithal, Kurukshetra and Karnal districts, respectively. Similarly, the electrical conductivity of sub-surface soil samples varied from 0.26 to 1.42, 0.18 to 0.82 and 0.11 to 1.52 dS/m with mean values of 0.71, 0.47 and 0.46 dS/m in Kaithal, Kurukshetra and Karnal districts, respectively. Most of the soil samples were non saline. There was decrease in electrical conductivity of soil with increase in depth. The probable reason for low electrical conductivity with depth may be attributed to the fact that the climate of the study area is sub-tropical due to which soluble salts rise up by capillary action. In case of surface soil, the electrical conductivity was found to be non saline by several workers (Vijaykumar *et al.,* 2011; Singh and Mishra, 2012; Gora, 2013). The pH and the electrical conductivity values indicated that the most of the soil sampling sites were normal for crop growth.

Bulk density

The bulk density of the surface soils varied from 1.12 to 1.61, 1.14 to 1.70 and 1.18 to 1.70 g/cc in Kaithal, Kurukshetra and Karnal districts with mean values of 1.29, 1.36 and 1.49 g/cc, respectively. With increase in depth there was increase in the soil bulk density since sub-surface layers are more compacted and have less organic matter, less aggregation, and less root penetration compared to surface layers and soil bulk density of sub-surface ranged from 1.18 to 1.66, 1.20 to 1.74 and

Table 1: Critical limits of organic carbon and available N, P, K and S in Haryana soils

Parameter	Category		
	Low	Medium	High
Organic carbon (%)	<0.40	0.40-0.75	>0.75
Available N (kg/ha)	<250	250-500	>500
Available P (kg/ha)	<10	10-20	>20
Available K (kg/ha)	<104	104-249	>249
Available S (mg/ha)	<10	10-20	>20

Table 2: Range and mean values of physico-chemical properties of surface and sub-surface soil samples in rice growing soils of Haryana

Soil properties	Rice growing soils of Haryana					
	Kaithal	Kurukshetra	Karnal			
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
pH (1:2)	7.39-8.53	7.31-8.50	7.38-8.85	7.22-8.70	7.30-9.25	7.35-8.91
EC (1:2) dS/m	0.35-2.57(0.85)*	0.26-1.42(0.71)	0.21-0.90(0.48)	0.18-0.82(0.47)	0.15-1.63(0.48)	0.11-1.52(0.46)
Bulk density	1.12-1.61(1.29)	1.18-1.66(1.33)	1.14-1.70(1.36)	1.20-1.74(1.41)	1.18-1.70(1.49)	1.22-1.74(1.53)
Texture	Loamy sand to Clay loam		Sandy loam to Clay loam		Loamy sand to loam	

*- Values in parenthesis are the mean values

Table 3: Total organic carbon in surface and sub-surface soils of rice growing soils of Haryana

Soil Depth (cm)	District					
	Kaithal		Kurukshetra		Karnal	
	Range g/kg	Mean	Range	Mean	Range	Mean
0-15	3.50- 6.80	5.10	2.70-6.70	4.50	3.60-6.90	5.20
15-30	2.80- 6.30	4.20	2.10-5.60	3.60	2.70- 6.10	4.20

Table 4: Range and mean of macronutrients of surface and sub-surface soil samples of rice growing soils of Haryana

Macronutrients	Rice growing soils of Haryana					
	Kaithal		Kurukshetra		Karnal	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Nitrogen (kg/ha)	112-194(157)*	88-145(122)	86-180(140)	67-141(111)	115-193(157)	86-140(119)
Phosphorus (kg/ha)	9-37(23)	5-26(15)	6-37(20)	4-27(15)	9-46(28)	7-38(20)
Potassium (kg/ha)	100-454(246)	92-426(216)	54-306(176)	38-278(148)	126-456(226)	118-359(198)
Sulphur(mg/kg)	8-71(34)	4-49(25)	4-60(21)	3-42(14)	6-108(56)	3-72(41)

*- Values in parenthesis are the mean values

1.22 to 1.74 g/cc with mean values of 1.33, 1.41 and 1.53 in Kaithal, Kurukshetra and Karnal districts, respectively. Higher bulk density was observed in Karnal followed by Kurukshetra and Kaithal which may be ascribed to relatively higher organic matter and clay content. Moreover, relatively higher bulk density of some surface soils was observed because soil samples were taken from rice fields which have been flooded for long period of time for production of rice, which causes slaking of soil aggregates. Similar results have been reported by Motschenbacher *et al*. (2011). Divya and Belagali (2012) reported that the bulk density varied from 1.24 to 1.32, 1.16 to 1.46 and 0.92 to 1.32 mg/m^3 in rain-fed, irrigated and garden soil samples, respectively.

Soil Texture

The soils of the Karnal district were having slightly lighter texture ranging from Loamy sand to Loam whereas the soils of rice growing areas of the Kaithal and Kurukshetra district varied from loamy sand to clay loam and sandy loam to clay loam, respectively. The variation in soil texture may be ascribed to difference in parent material and influence of pedogenesis.

Available Nitrogen

The available nitrogen of surface soil ranged from 112 to 194, 86 to 180 and 115 to 193 kg/ha with mean values of 157, 140 and 157 kg/ha soil, whereas, in sub-surface soil from 88 to 145, 67 to 141 and 86 to 140 kg/ha with mean values of 122, 111 and 119 kg/ha in Kaithal, Kurukshetra and Karnal districts, respectively. The results indicated that there was decrease in the available nitrogen content in soil with increase in the soil depth in all the districts. All the surface and sub-surface soils of Kaithal, Kurukshetra and Karnal districts were in low category, because of loss of applied nitrogenous fertilizers due to leaching and volatilization processes. Similar results were observed by several other workers (Meena *et al.*, 2006; Singh *et al.*, 2011; Singh *et al.*, 2014). A significant positive correlation ($r = 0.93^{**}$) was found between organic carbon and available nitrogen (Table 5). Similar results were observed by several workers (Pathak, 2010; Singh *et al.* 2011 and Singh and Mishra, 2012). Available N showed negative and non-significant correlation ($r = -0.15$) with pH. This might be due to increased rate of

Table 5: Correlation coefficient between some physico chemical properties, organic carbon and macronutrients of surface and sub-surface soil samples of rice growing soils of Haryana

	OC	EC	pH	Bulk density
Nitrogen	0.93**	0.11	-0.15	-0.18*
Phosphorus	0.53**	0.10	-0.20*	-0.09
Potassium	0.24**	0.21*	-0.35**	-0.33**
Sulphur	0.09	0.07	0.18*	0.23**

*- Significant at the 0.05 level (2-tailed) and **. Significant at the 0.01 level (2-tailed), n=150

denitrification at lower pH values (Tisdale, 1997). Available nitrogen showed negative and significant correlation (r=-0.18*) with bulk density. Similar result were obtained by Chandel *et al.* (2015).

Available Phosphorus

The available phosphorus of surface soil ranged from 9 to 37, 6 to 37 and 9 to 46 kg/ha with mean values of 23, 20 and 28 kg/ha, while that of sub-surface soil varied from 5 to 26, 4 to 27 and 7 to 38 with mean values of 15, 15 and 20 kg/ha in Kaithal, Kurukshetra and Karnal districts, respectively. Based on the critical limits of available phosphorous (Table 1), it was deduced that 17 per cent soils were low and 23 % soils were medium in available phosphorus, while majority of the soils were under high status (60 %) of available phosphorus. However, earlier report indicated the almost reverse trend of available phosphorus in these soils (Singh and Poonia, 1982). The changes in the status of available phosphorus in these soils were due to continuous addition of phosphatic fertilizers. The range of available phosphorus in rice growing soils was considerably large which might be due to change in soil properties *viz*., pH, organic carbon content, texture and various management practices which affects the availability/fixation/transformation of phosphorus in the soil. With the increase in the soil depth, there was decrease in the phosphorus content and the soil samples shifted from high category to either medium or low. According to the site information about the history of fertilizer application, DAP fertilizer has been used repeatedly in fertilization of different crops (mainly rice and wheat) and this may be a major reason for the higher values of available P in some rice growing areas of Haryana. A significant positive correlation (r= 0.53**) was found between organic carbon and available phosphorus. Available phosphorus was significantly and negatively correlated with pH (r= -0.20*) because at higher pH calcium precipitate with phosphorus as Ca-phosphate and reduce phosphorus availability (Tisdale *et al*., 1997). Similar results were also noted by Singh (1988) and Singh *et al.* (2014). Available phosphorus showed non-significant and negative correlation with bulk density (r = -0.09). Similar results were obtained by Chandel *et al.* (2015).

Available Potassium

The available potassium varied from 100 to 454, 54 to 306 and 126 to 456 kg/ha with mean values of 246, 176 and 226 kg/ha in surface soils while in sub-surface soil it ranged from 92 to 426, 38 to 278 and 118 to 359 kg/ha with mean values of 216, 148 and 198 kg/ha in Kaithal, Kurukshetra and Karnal districts, respectively. The available potassium content decreased with increase in soil depth. Based on the critical limits of available potassium (Table 1), it was deduced that majority of surface soils in these areas were in medium category (60 %) followed by high (37 %) and low category (8 %).The medium to high amount of available potassium in soil could be most probably due to its potassium rich parent material like feldspar and illite (Sharma *et al.,* 2012). As compared to earlier report by Singh and Poonia, (1982) the available potassium in soil was low due to continuous uptake of potassium by field crops as the farmers' field has been intensively cultivated for a long period of time without potassium fertilization. Similar results were observed by Singh *et al.* (2011). A significant positive correlation (r= 0.24**) was found between organic carbon and available potassium (Table 5). This might be due to creation of favourable soil environment with presence of high organic matter. Similar results were also reported by Meena *et al.* (2006). Available potassium showed negative and significant correlation (r= -0.35**) with pH. Similar results were reported by Sheoran (2015). Available potassium showed negative and significant correlation (r= -0.33**) with bulk density. Similar result was obtained by Chandel *et al.* (2015).

Available sulphur

The available sulphur ranged from 8 to 71, 4 to 60 and 6 to 108 mg/kg with mean values of 34, 21 and 56 mg/kg in surface soils, whereas, it varied from 4 to 49, 3 to 42 and 3 to 72 mg/kg with mean values of 25, 14 and 41 mg/kg in Kaithal, Kurukshetra and Karnal districts, respectively. Based on the critical limits of available sulphur (Table 1), it was deduced that 70 % soils of these areas were high in available sulphur status followed by medium (15 %) and low (15 %) category. The results indicated that with increase in the soil depth, there was decrease in the content of available sulphur in the soil due to greater plant and microbial activity, mineralization of organic matter and application of fertilizers takes place on the soil surface. Almost similar trend were also observed by Narwal *et al.* (2011). The higher status of available sulphur in these rice growing areas was due to sulphur rich parent material and application of zinc sulphate as a common practice for correcting zinc deficiency in rice-wheat cropping system. Kumar and Sahu (2015) reported that sulphur varied from 7.56 to 89.32 kg ha^{-1} with mean value of 38.43 kg ha^{-1} in soils of Malkharouda block, Chhattisgarh irrespective of soil samples of different orders. A positive but non-significant correlation (r=0.09) was observed between organic carbon and available sulphur content. This relationship existed because most of the sulphur is associated with organic matter. The result obtained are in line as observed by Nor (1981) and Singh and Mishra (2012). Available sulphur was positively and significantly correlated with pH (r= 0.18*). Singh (2004) also observed the significant positive relationship between pH of the soil with available sulphur content in Yamuna river basin of Haryana state. Available sulphur showed positive and significant correlation (r=0.23**) with bulk density.

The physico-chemical properties of the soil indicated that most of the soils, in general, were neutral to slightly alkaline in reaction, non saline, normal in bulk density and loamy sand to clay loam in soil texture. Soil pH and electrical conductivity mostly decreased with increase in soil depth while bulk density increased with increase in soil depth in these rice growing soils of Haryana. The soils were low to medium in organic carbon and decreased with the increase in the soil depth. The available nitrogen was under low status, while other macronutrients viz., phosphorus, potassium and sulphur were under medium to high in status in majority of the samples. Moreover, available macronutrients decreased with increase in soil depth.

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