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Seasonal analysis of physico-chemical parameters of agricultural soil samples collected from banks of rivers Beas and Sutlej, Punjab, India

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ABSTRACT

Physico-chemical parameters are among the basic attributes for the study of soil, as they play an important role in the health of soil and crops. In the present study, an attempt was made to study the seasonal changes in physico-chemical parameters of 24 soil samples collected from agricultural fields of 6 villages situated on the banks of rivers Beas and Sutlej during two consecutive seasons (October 2012 and April 2013). The physico-chemical parameters analyzed in this study included pH, bulk density (BD), water holding capacity (WHC), total organic carbon (TOC), total nitrogen (TN), total available phosphorous (TAP), total potassium (TK^+) and total sodium (TNa^+). Difference in the content of these parameters was statistically analyzed using student's T-test. In the present study, pH of different soil samples ranged from 7.33 to 8.05 and 7.53 to 8.06, for 1st and 2nd sampling, respectively, indicating the alkaline nature of the soil. Overall range of BD was from 0.968 to 1.324 g/cc. Total Organic Carbon (TOC) content varied from 0.41% to 4.18% for sampling 1, while it ranged from 0.34 to 6.21% for 2nd sampling. Total nitrogen content ranged from 0.05% to 0.23% and 0.05% to 0.219% for samplings 1 and 2, respectively. TAP ranged from 0.64 to 2.44% for sampling 1 and 0.36 to 2.42% for sampling 2. The content of Potassium ranged from 2.20 to 3.91% and 1.66 to 3.96%, while that of sodium ranged from 0.56 to 1.57% and 0.57 to 1.11% for samplings 1 and 2, respectively. Results of T-test showed that, water holding capacity was found to vary in fields which were situated near the banks of rivers in consecutive samplings. The content of K^+ and Na^+ was found to vary in maximum number of fields (83%) studied in sampling 1 and 2. Except two agricultural fields the content of total nitrogen remained same in all the samples studied.

Keywords: pH, Bulk Density, Total Organic Carbon, Total Nitrogen, Total Available Phosphorous

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INTRODUCTION

Soil is a thin layer on the surface of the earth constituting weathered rock particles, decaying plant and animal matter along with varying proportions of minerals, air and water [1]. Soil plays a critical role in delivering a variety of ecosystem services e.g., it act as a medium that supports plant growth; and modulates water, nutrients, and pollutants transport [2-3]. At microscopic level also, it performs important ecological functions that help in sustaining a diverse and dynamic microbial community. It is the main source and sink for many biogeochemical cycles [4].

A healthy soil consists of roughly 40% mineral, 23% water, 23% air, 6% organic material and 8% living organisms [1]. From the ancient times, the oldest and the most commonly used criteria to judge the quality of soil is its suitability to sustain crop production [5-6]. While the modern concept of the soil quality is its ability to support ecosystem functions, to sustain biological productivity, to maintain environmental quality, and to promote plant, animal, and human health [7].

There are reports pertaining to changes in physico-chemical properties of soil like pH, soil texture, conductivity, nitrogen, phosphorous and potassium contents, etc., because of changes in place, time and land use [8,9]. The understanding of various soil physico-chemical properties is very crucial for the planning of land use, management of water resources and development of water harvesting structures [10-11]. Soil organic carbon plays a significant role in the functioning of agro-ecosystem as it influences the physical structure of the soil, the ability of soils to store water, availability of nutrients for crop production, and overall sustainability of soil [12]. The physico-chemical properties of soil play an important role in crop productivity [13].

The soil can be classified into various types depending upon the proportions of mineral particles of various sizes [14]. The state of Punjab has spectrum of soil types in its different regions. The southeastern parts of Punjab have loamy soil and it becomes clayey towards northwestern side, while southwestern sides of Punjab have sandy and desert soil. One more category of soil in Punjab is Khadar soil found in the flooding plains which get periodically inundated due to heavy rains. This soil is usually found along the banks of the rivers and is composed of sediments of the Shiwalik and Himalyan hills brought down and laid by the rivers.

Punjab is a land of perennial and seasonal rivers. The Beas and Sutlej are the two important rivers of Punjab. There are very few reports on the physico-chemical parameters of agricultural fields situated on the banks of these rivers [14]. A large-scale and multiple-attribute field survey is required to evaluate quality of soil of Punjab on the banks of rivers of Punjab. Keeping this in mind the present study was planned to analyze the various physico-chemical parameters of additional soil samples collected from agricultural fields along the banks of these rivers. The analysis also includes an account of seasonal variations among them. The different physico-chemical parameters considered in the present study are pH, bulk density, water holding capacity, soil organic carbon, soil total nitrogen, total available phosphorous, total potassium and total sodium.

EXPERIMENTAL SECTION

Study Area

The area of the present study extends from 31˚8'5.0310"N to 31˚59'42.5856"N latitude to 74˚53'15.2981"E to 75˚33'31.5644"E longitude alongside the rivers. Six villages were selected on the banks of rivers Beas and Sutlej (Fig. 1). The population residing in these villages mainly depends on agriculture for their livelihood spread over two main crop seasons, Kharif and Rabi. The climate of the present study area varies from semi-arid to sub-humid with an average annual rainfall of 435.6 mm. In monsoon season these villages also face flash floods.

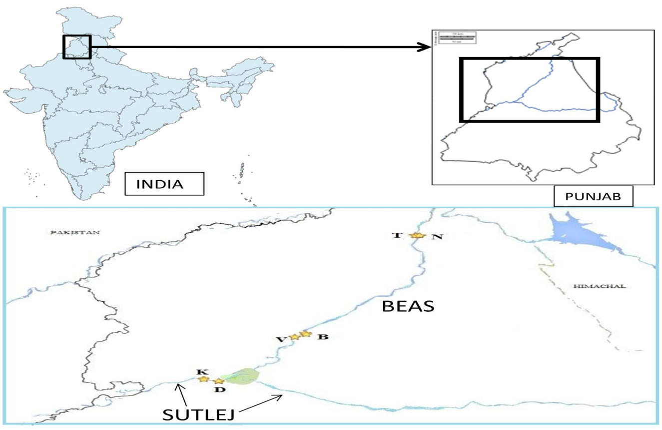

Fig. 1 Map showing the location of sampled villages
N- Naushera Pattan; T- Tanda; V- Verowal; B- Baguana; K- Kutianvala; D- Deneke.

Soil Sampling

Two soil samplings were done, first during October 2012 and the second during April 2013 at the time of harvest of rice and wheat respectively. From each village, 4 agricultural fields were selected (two under rice and two under sugarcane cultivation at the time of first sampling). At the time of second sampling, samples were collected from the same sites from where the first sampling was done but at this time instead of the rice crop the fields had the wheat crop ready for harvesting. The other two fields which earlier had sugarcane crop in the harvesting stage had sugarcane crop in the juvenile stage, now. Twenty four composite surface soil samples were collected from horizon 'A' of the soil (i.e. 5-15 cm depth). Horizon 'A' was particularly chosen because the roots of these crops generally do not penetrate beyond this horizon [15]. Samples were collected using a plastic spatula, transferred to clean polythene bags to avoid all possible contaminations and coded as per (Table 1). The precise location, i.e. the exact longitude and latitude were determined using GPS Garmin (eTrex 10).

Table 1. Description of codes of agricultural soil samples collected during sampling 1 and sampling 2

S. No.	Village (Code)	Sample Codes for first sampling (October, 2012)	Sample Codes for second sampling (April, 2013)	Description of sample code	Geographical co-ordinates
1	Naushera Pattan (NA)	NS1	NS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated near the river	31˚59’32.4648” N; 75˚33’22.8385” E
		NG1	NG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated near river	31˚59’32.5696” N; 75˚33’24.4272” E
		FS1	FS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated far from the river	31˚59’26.0514” N; 75˚33’31.5644” E
		FG1	FG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated far from river	31˚59’23.6807” N; 75˚33’31.1157” E
2	Tanda (TA)	NS1	NS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated near the river	31˚59’35.7390” N; 75˚32’49.3869” E
		NG1	NG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated near river	31˚59’34.7529” N; 75˚32’52.0532” E
		FS1	FS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated far from the river	31˚59’42.5856” N; 75˚32’36.6583” E
		FG1	FG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated far from river	31˚59’42.5044” N; 75˚32’41.1548” E
3	Verowal (VE)	NS1	NS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated near the river	31˚23’43.8230” N; 75˚10’9.9788” E
		NG1	NG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated near river	31˚23’45.8628” N; 75˚10’12.2902” E
		FS1	FS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated far from the river	31˚23’40.4274” N; 75˚10’10.5702” E
		FG1	FG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated far from river	31˚23’40.4479” N; 75˚10’10.1140” E
4	Baguana (BA)	NS1	NS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated near the river	31˚25’8.6172” N; 75˚12’7.6782” E
		NG1	NG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated near river	31˚25’6.5030” N; 75˚12’8.3179” E
		FS1	FS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated far from the river	31˚24’42.7042” N; 75˚12’18.8058” E
		FG1	FG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated far from river	31˚24’43.7580” N; 75˚13’1657” E
5	Kutianvala (KU)	NS1	NS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated near the river	31˚8’43.7565” N; 74˚53’17.3428” E
		NG1	NG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated near river	31˚8’43.5795” N; 74˚53’17.5805” E
		FS1	FS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated far from the river	31˚9’10.2321” N; 74˚53’15.5606” E
		FG1	FG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated far from river	31˚9’10.1993” N; 74˚53’15.2981” E
6	Deneke (DE)	NG1	NG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated near river	31˚8’14.9172” N; 74˚56’4.7136” E
		NS1	NS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated near the river	31˚8’14.1871” N; 74˚56’4.9170” E
		FG1	FG2	Soil samples from agricultural field under rice and wheat cultivation during sampling 1 and 2, situated far from river	31˚8’5.0310” N; 74˚56’4.9761” E
		FS1	FS2	Soil sample from agricultural field under sugarcane cultivation during sampling1 and 2, situated far from the river	31˚8’10.3169” N; 74˚56’4.6234” E

Sample Preparation

The method as reported in earlier studies [9, 16-18] was used. The collected soil samples were taken to the laboratory and air dried by placing soil on filter paper on a steel mesh. Stones and other debris were removed from the soil samples. The samples were ground, passed through 2-mm sieve and stored in new clean polythene bags until further analysis.

Physico-chemical analysis

Physico-chemical parameters such as pH, bulk density, water holding capacity, total organic carbon, total nitrogen, total available phosphorus, total potassium and total sodium were analyzed. A core cylinder was used for bulk density (BD) analysis [19]. Water holding capacity was computed following method given by [20]. Total organic carbon (TOC) concentration was determined by protocol of Bhat *et al.* [21]. Total nitrogen (N) was determined by Kjeldahl method [22]. Total available phosphorous (P) was estimated spectrophotometrically using Spectrophotometer- 2202 (Ahmadabad, Gujarat, India) after extraction with sodium bicarbonate [23]. Systronics

Flame Photometer-128 was used to measure Potassium (K) and sodium (Na), after digesting the samples in a diacid mixture (HClO4/HNO3 in a 4:1 ratio) [21].

Statistical analysis

The physico-chemical characteristics of different soil samples analyzed in the present study was done in triplicate, and the data is presented graphically as mean ± SE. The statistical analysis of the data obtained was done with the help of IBM SPSS version 16.0 (Chicago, IL, USA) and Minitab version 14.0 (Pennsylvania, USA) computer software. Oneway ANOVA followed by Tukey's HSD test as post hoc was used to compare the means of physico-chemical properties of different soil sample. To study the seasonal variations in the physico-chemical parameters of the same field under different cultivation practices T-test was used. Differences at $p \leq 0.05$ were considered statistically significant.

RESULTS AND DISCUSSION

Various physico-chemical properties of soil naturally change across the countryside due to variations of pedogenic processes or alterations caused by the agricultural practices such as wheel spacing of farm machinery, crop rotation cycles and irrigation patterns which ultimately affect the plant growth [24-27]. The results of various physico-chemical parameters are presented in Fig. 2 to 9. Tables 2 and 3 summarize the Pearson's correlation matrix for all the physico-chemical parameters studied in samplings 1 and 2, respectively.

pH

pH is an important physico-chemical characteristic of soil as it helps in activity of micro-organisms. Verstrate *et al.* [28] reported that optimal activity of microbial degradation occurs at pH 7.4. Results of pH of various soil samples during sampling 1 and sampling 2 are presented in Fig. 2 (a and b). The value of pH in sampling 1 ranged from 7.37 to 8.01, indicating alkaline nature of the soil samples. The soil samples during 2nd sampling were also of alkaline nature and pH ranged from 7.54 to 8.02. Tukey analysis revealed a significant difference in the pH among samples from the fields which were situated far from the banks of the rivers and were under sugarcane cultivation during sampling 1. T-test showed that value of pH in 58% of soil samples from all the fields studied showed a significant difference in consecutive sampling. The Pearson Correlation analysis (Tables 2 and 3) showed that pH is negatively correlated with WHC, TOC, TN and TAP. A significant negative correlation was observed between pH and TOC (Table 3) during sampling 2. Rashidi and Seilsepour [29] reported the pH of soil samples to range from 7 to 8.10. Earlier reports of our lab also reported the pH of agricultural soil samples in alkaline range [30, 14].

Table 2. Pearson correlation matrix of physico-chemical characteristics of agricultural soil samples during sampling 1

	pH	WHC	BD	TOC	TN	TP	TK
WHC	-0.400						
BD	0.318	-0.758**					
TOC	-0.184	0.003	-0.209				
TN	-0.218	0.215	-0.154	0.084			
TAP	-0.160	0.223	-0.306	0.274	0.345		
TK^+	0.250	0.214	-0.083	0.260	0.358	0.162	
TNa^+	0.375	-0.042	-0.149	0.152	-0.136	0.114	0.275

*** Correlation is significant at 0.01 level (two tailed)*

Table 3. Pearson correlation matrix of physico-chemical characteristics of agricultural soil samples during sampling 2.

	pH	WHC	BD	TOC	TN	TP	TK
WHC	-0.152						
BD	0.291	-0.708**					
TOC	-0.429*	0.549**	-0.487*				
TN	-0.399	0.430*	-0.351	0.356			
TAP	-0.360	0.267	-0.463*	0.118	0.269		
TK	-0.225	0.027	-0.436*	-0.069	-0.093	0.476*	
TNa	0.142	0.268	-0.334	-0.323	-0.323	0.055	0.419*

** Correlation is significant at 0.05 level (two tailed)*

*** Correlation is significant at 0.01 level (two tailed)*

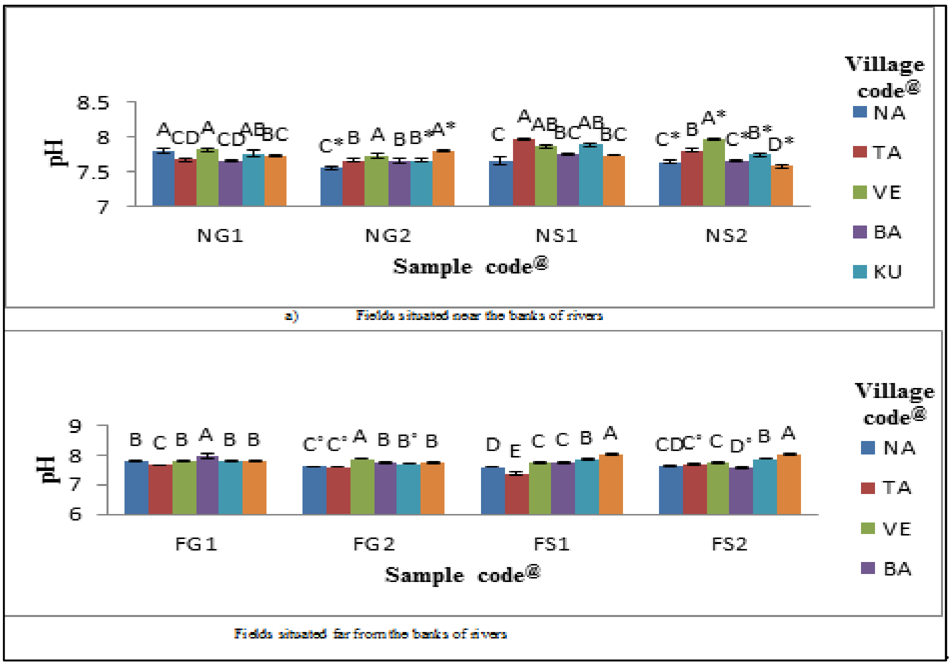

Fig. 2 pH of soil samples collected from agricultural fields under rice/wheat/sugarcane cultivation

@: sample and village codes as described in Table 1

Bars show Mean ±SD, different letters on the bars indicate statistically significant difference among samples belonging to each group analyzed by one way ANOVA; Tukey test p≤0.05.

'' shows significant difference for independent T-test for consecutive samplings (NG1-NG2; NS1-NS2)*

'°' shows significant difference for independent T-test for consecutive samplings (FG1-FG2; FS1-FS2)

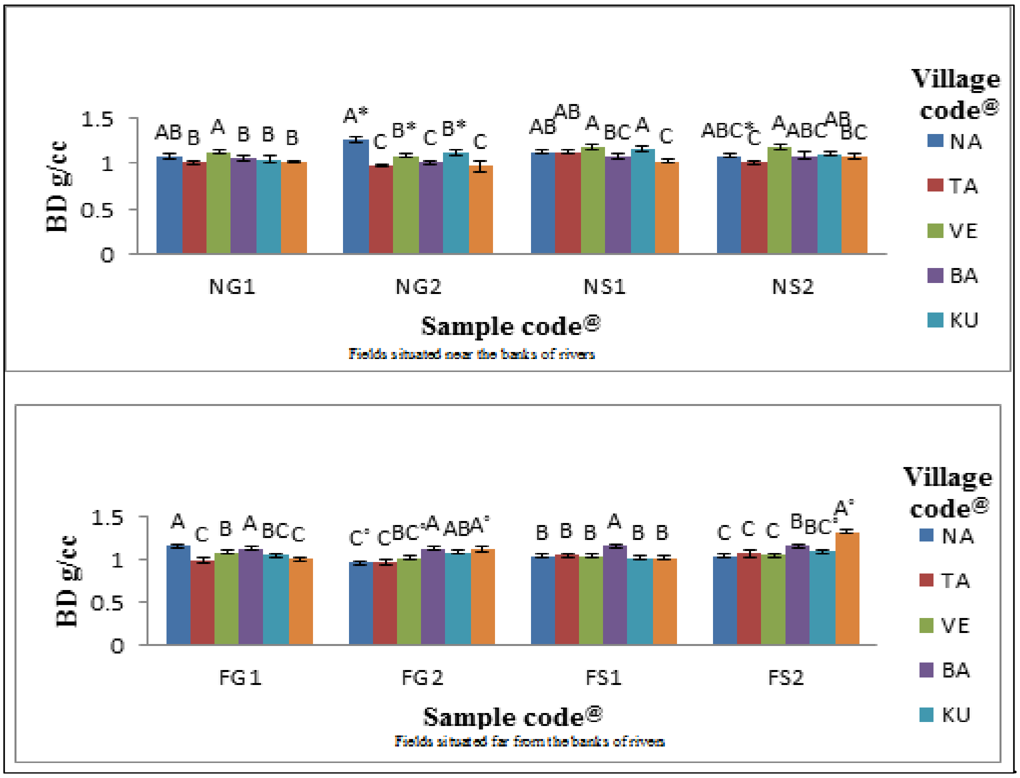

Fig. 3. Bulk Density (BD) of soil samples collected from agricultural fields under rice/wheat/sugarcane cultivation

@: sample and village codes as described in Table 1

Bars show Mean ±SD, different letters on the bars indicate statistically significant difference among samples belonging to each group analyzed by one way ANOVA; Tukey test p≤0.05.

'' shows significant difference for independent T-test for consecutive samplings (NG1-NG2; NS1-NS2)*

'°' shows significant difference for independent T-test for consecutive samplings (FG1-FG2; FS1-FS2)

Bulk Density

It is important parameter for the growth of plants as high bulk density can reduce the root penetration in soil [31]. Fig. 3 (a and b) shows the bulk density (BD) of agricultural fields under rice, wheat and sugarcane cultivation cycle. Bulk density of different soil samples ranged from 1.007 to 1.1846 g/cc and 0.9784 to 1.3241 g/cc for sampling 1 and 2, respectively. The mean value of BD for all the soil samples studied in sampling1 and sampling 2 was 1.081 and 1.089 g/cc, respectively. This difference can be attributed to the compaction of the topsoil due to repeated ploughing and other agricultural practices [32]. Bulk Density remained same in 62% fields studied in both the samplings. Maximum variations were observed in rice fields. The Pearson Correlation matrix revealed a significant negative correlation between the BD and TOC, TAP and TK^+ during 2nd sampling (Table 3). Earlier the agricultural soil samples were tested by Chahal *et al.* [33] and Kaur *et al.* [30] and they reported the bulk density in a range of 0.75 to 0.84% and 1 to 1.88%, respectively.

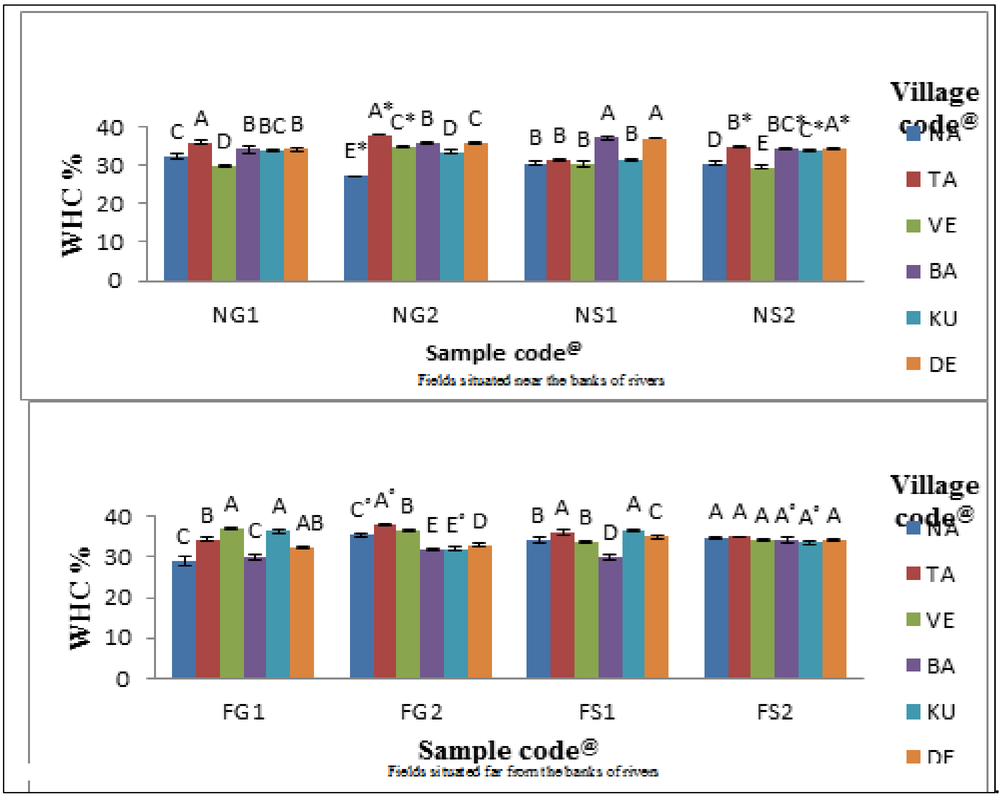

Fig. 4. Water Holding Capacity (WHC) of soil samples collected from agricultural fields under rice/wheat/sugarcane cultivation

@: sample and village codes as described in Table 1

Bars show Mean ±SD, different letters on the bars indicate statistically significant difference among samples belonging to each group analyzed by one way ANOVA; Tukey test p≤0.05.

'' shows significant difference for independent T-test for consecutive samplings (NG1-NG2; NS1-NS2)*

'°' shows significant difference for independent T-test for consecutive samplings (FG1-FG2; FS1-FS2)

Water Holding Capacity

In both the samplings, the average water holding capacity (WHC) was found to be more in fields situated far from the banks of rivers in all the sites studied. During sampling 1, minimum value (29.0199 %) of WHC was found in Naushera Pattan village in a field, which is situated far from the bank of river Beas and was under rice cultivation [Fig. 4(a)], while the maximum (37.4724 %) value was observed for soil of sugarcane field of Baguana village situated near bank of river Beas. During 2nd sampling, the WHC ranged from 27.1323 to 37.8426 %. T-test revealed a significant difference in the WHC capacity in 50% of agricultural fields which were situated along the banks of rivers Beas and Sutlej in samplings 1 and 2. WHC was found to be negatively correlated with BD at $p \leq 0.01$ level of significance in both samplings, while a positive correlation was observed between WHC, TOC and TN at $p \leq 0.01$ and $p \leq 0.05$, respectively (Tables 2 and 3). Bharadwaj *et al.* [34] reported the WHC in a range of 21.6 to 24.5 % of saline-alkali soils. Chahal *et al.* [33] evaluated the physico-chemical parameters of the agricultural soil samples of Amritsar and found that the WHC of agricultural soil samples ranged from 50.54 % to 57.12 %. The result of WHC of the present study was also in line with the previous reports by different scientists from the length and breadth of country [30, 35, 16) who worked upon different kinds of soil samples.

Total Organic Carbon:

Organic matter content of the soil samples of the long-term cultivated lands and pastures has been reported to be significantly lower as compared to native ecosystems, because cultivation increases aeration of soil which enhances decomposition of soil organic matter [36]. In addition, most of the soil organic matter produced in cultivated lands is removed with harvest and the leftover crop residues are placed under the soil with plough. Total Organic Carbon (TOC) content varied from 0.4120 % to 4.1870 % in sampling 1, while in sampling 2, it ranged from 0.3495 to 6.2104 %. The average TOC content in sampling 1, was higher in the fields situated far from the banks of rivers under sugarcane cultivation [Fig. 5(b)]. This greater TOC in fields under sugarcane cultivation may be due to year round cropping practice for sugarcane. Moreover, residues from sugarcane crop fields *viz.* trashes and greater root biomass from a long duration crop might have positively contributed to the higher organic carbon content in these soils. In sampling 2, the average content of TOC was more in fields situated near the banks of rivers as compared to sampling 1, this may be because of extensive root systems i.e., formation of new roots and decay of old roots added considerable amount of organic matter to the soil in consecutive years. Tukey analysis showed a significant difference in the content of TOC of soil from rice fields situated near the banks during sampling 1. In sampling 2 also, a significant difference in the content of TOC of soil from fields under rice cultivation but were situated far from the bank of river. T-test showed that value of TOC was not different statistically among 75% of agricultural fields studied during sampling 1 and 2. The seasonal change in the content of TOC was observed mainly in the fields which were situated near the banks of rivers. TOC showed a positive correlation between TN and TAP in both the samplings. Masakorala *et al.* [37] analyzed the TOC in soil samples contaminated with petroleum hydrocarbon and reported the content of TOC to range from 2.13 to 4.43 %. The results of present study are in line with others reports [29, 38, 16, 39].

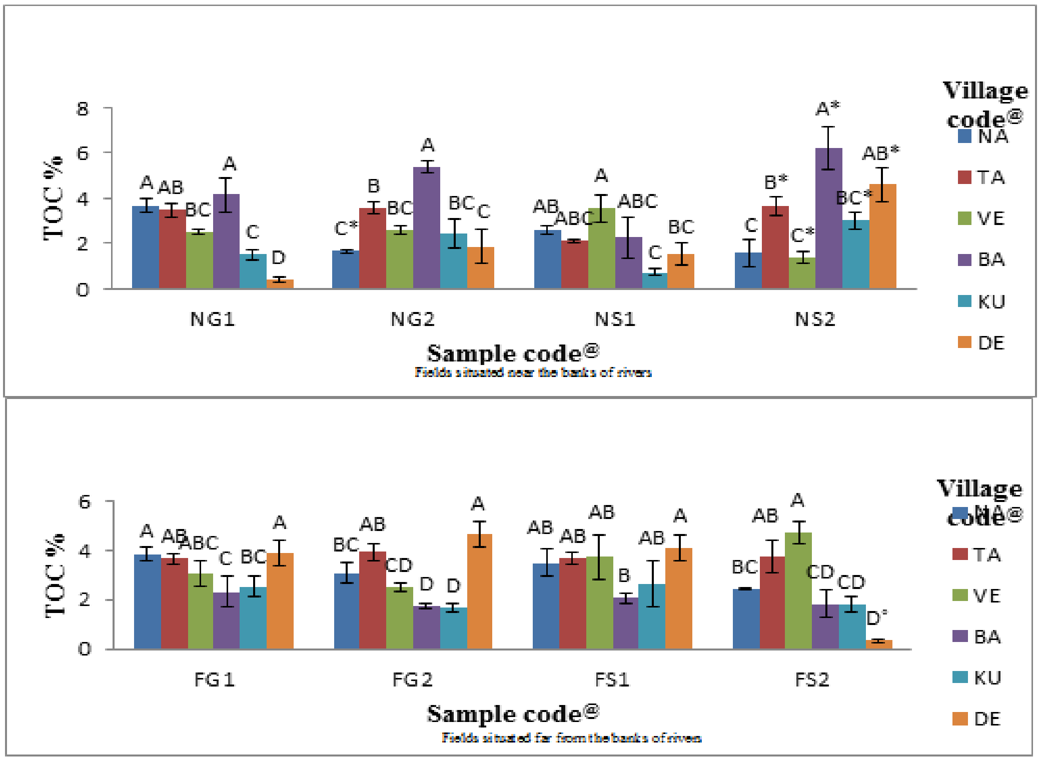

Fig. 5. Total Organic Carbon (TOC) of soil samples collected from agricultural fields under rice/wheat/sugarcane cultivation

@: sample and village codes as described in Table 1

Bars show Mean ±SD, different letters on the bars indicate statistically significant difference among samples belonging to each group analyzed by one way ANOVA; Tukey test p≤0.05.

'' shows significant difference for independent T-test for consecutive samplings (NG1-NG2; NS1-NS2)*

'°' shows significant difference for independent T-test for consecutive samplings (FG1-FG2; FS1-FS2)

Total nitrogen

Nitrogen is one of the necessary elements for the growth of plant [2]. During sampling 1, total nitrogen content was minimum (0.05 %) in field under sugarcane cultivation situated near the bank of river Beas in village Verowal [Fig. 6(a)] and was maximum (0.23 %) in field under rice cultivation in village Naushera Pattan village, which was far from the bank of river Beas. During sampling 2 total content of nitrogen varied from 0.05 % to 0.21 %. The low level of nitrogen may be because of significant activity of microbial biomass which leads to release of N to the soil through their easily decomposable compounds. Tukey analysis revealed that there was no significant difference in the content of nitrogen in all the fields during sampling 1, while in sampling 2 significant differences were observed in some wheat fields situated near the banks of rivers. T-test revealed a significant difference in the content of TN only in two agricultural soil samples- one from village Naushera Pattan which was under rice and wheat cultivation cycle during samplings 1 and 2 and the other was from village Tanda which was under sugarcane cultivation. Both these fields are situated near the banks of river Beas. This may be because of the injudicious use of nitrogen fertilizer mainly urea in all the agricultural fields from the beginning of green revolution. Rashidi and Seilsepour [29] analyzed one hundred and three samples and reported a minimum content of TN as 0.04% and maximum as 0.13%. Calalang *et al* [38] investigated top soil samples from different agricultural fields that were under potato, carrots and corn cultivation and reported that total nitrogen content in potatoes, carrots and corn fields ranged from 0.39 to 0.75%, 0.3 to 0.8% and 0.39 to 0.75%, respectively. Bharadwaj *et al.* [34] analyzed control and saline soils amended with different proportions of farmyard manure for their total nitrogen content and reported that the content of nitrogen in control soil was 0.018 % and other soil samples amended with different ratios of farmyard manure ranged from 0.07 to 0.25%.

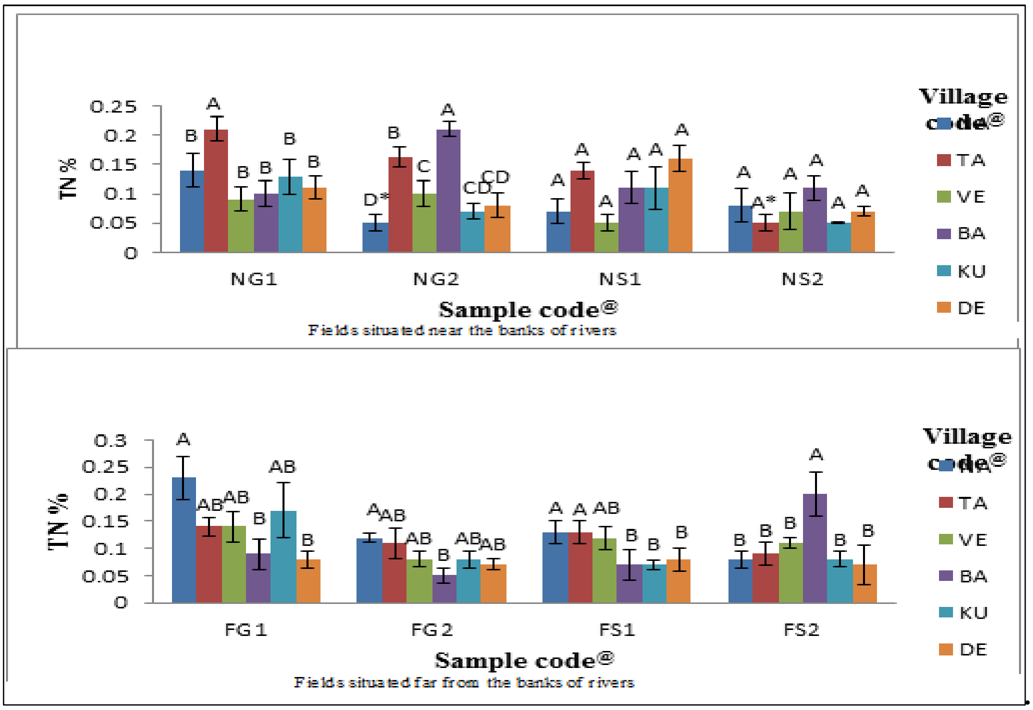

Fig. 6. Total Nitrogen (TN %) of soil samples collected from agricultural fields under rice/wheat/sugarcane cultivation

@: sample and village codes as described in Table 1

Bars show Mean ±SD, different letters on the bars indicate statistically significant difference among samples belonging to each group analyzed by one way ANOVA; Tukey test p≤0.05.

'' shows significant difference for independent T-test for consecutive samplings (NG1-NG2; NS1-NS2)*

'°' shows significant difference for independent T-test for consecutive samplings (FG1-FG2; FS1-FS2)

Total Available Phosphorus (TAP)

Phosphorus (P) is a necessary element for maintaining a balance between the other plant nutrients and ensuring the normal growth of the crop. The content of P reported to show a positive correlation with mineral particles of the soil which differ in their susceptibility to cause release of P during weathering [40]. The average content of TAP in 1st sampling was found to be higher in fields under sugarcane cultivation situated near and far from the banks of rivers. The overall range of TAP in all the fields studied during sampling 1 ranged from 0.64 to 2.44 %. From statistical investigation, no significant difference was observed in the content of TAP in fields which were under sugarcane cultivation and situated near the banks of rivers at all the sites during sampling 1. During sampling 2, TAP ranged from 0.36 to 2.42 %. T-test analysis revealed that the content of TAP varied in 41 % of the fields studied during the consecutive sampling [Fig. 7(a) and 7(b)]. The result of the present study was in line with various reports [16, 41]. The Pearson correlation analysis showed a significant positive correlation between TAP and TK^+ (Table 3).

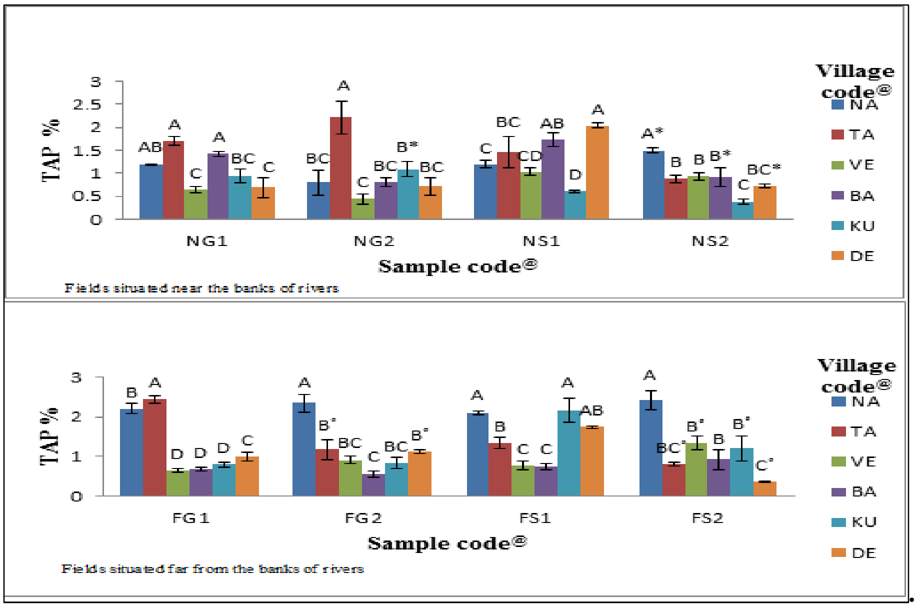

Fig. 7. Total Available Phosphorous (TAP) of soil samples collected from agricultural fields under rice/wheat/sugarcane cultivation
@: sample and village codes as described in Table 1
Bars show Mean ±SD, different letters on the bars indicate statistically significant difference among samples belonging to each group analyzed by one way ANOVA; Tukey test p≤0.05.
'' shows significant difference for independent T-test for consecutive samplings (NG1-NG2; NS1-NS2)*
'°' shows significant difference for independent T-test for consecutive samplings (FG1-FG2; FS1-FS2)

Total Potassium (TK^+)

Potassium (K) is an essential nutrient and plays an important role in the growth of plants, synthesis of amino acids and proteins [42]. The content of Potassium is presented in Fig. 8 (a and b) and ranged from 2.20 to 3.98 % during sampling 1 and from 1.66 to 3.96 % during sampling 2. Tukey analysis showed that the content of TK^+ was statistically different in all the soil samples collected from agriculture fields under rice cultivation which were situated far from the banks during sampling 1. Same trend was found in fields during 2nd sampling where the fields were under wheat cultivation and situated near the banks of rivers in all the sites studied.

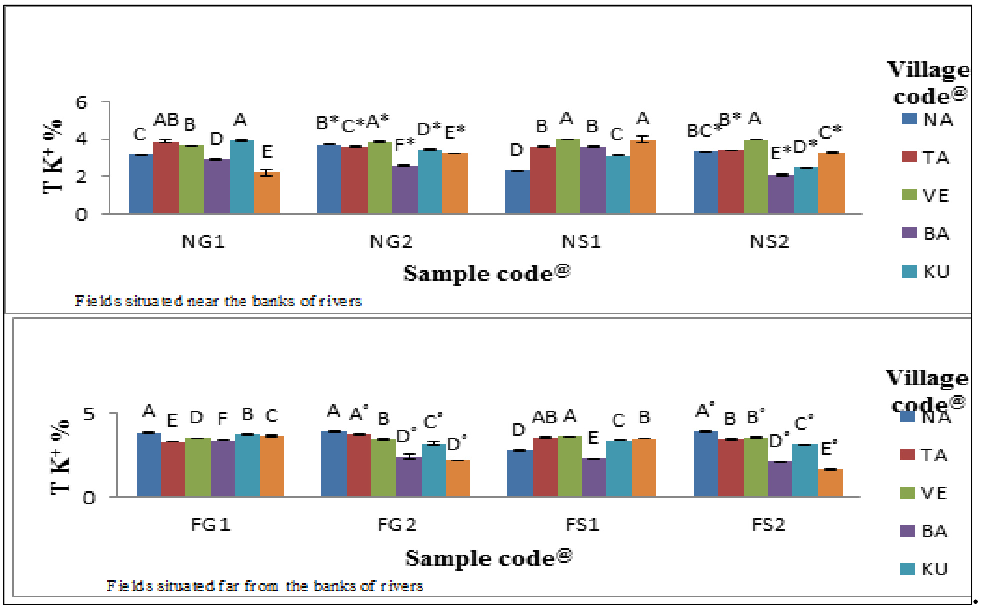

Fig. 8. Total Potassium (TK^+%) of soil samples collected from agricultural fields under rice/wheat/sugarcane cultivation
@: sample and village codes as described in Table 1
Bars show Mean ±SD, different letters on the bars indicate statistically significant difference among samples belonging to each group analyzed by one way ANOVA; Tukey test p≤0.05.
'' shows significant difference for independent T-test for consecutive samplings (NG1-NG2; NS1-NS2)*
'°' shows significant difference for independent T-test for consecutive samplings (FG1-FG2; FS1-FS2)

Total Sodium (TNa^+)

The content of sodium (Na) ranged from 0.56 to 1.57% and 0.57 to 1.11% during sampling 1 and 2, respectively. Tukey analysis revealed that at the time of 1st sampling, the soil samples from sugarcane fields situated near the banks of rivers in all the sites studied showed significant difference in the content of TNa^+. The same trend was found in fields near banks of rivers under wheat cultivation in sampling 2. From the T-test it was observed that the content of Na^+ was significantly different in 79 % of fields studied during sampling 1 and 2 [fig. 9(a) and 9(b)]. The content of potassium TK^+ was also found to be significantly different in 83 % of the fields studied during the consecutive samplings which may be because of significant positive correlation as is revealed from pearson correlation matrix (Table 3). The results of present study are in line with studies by [14, 16, 41].

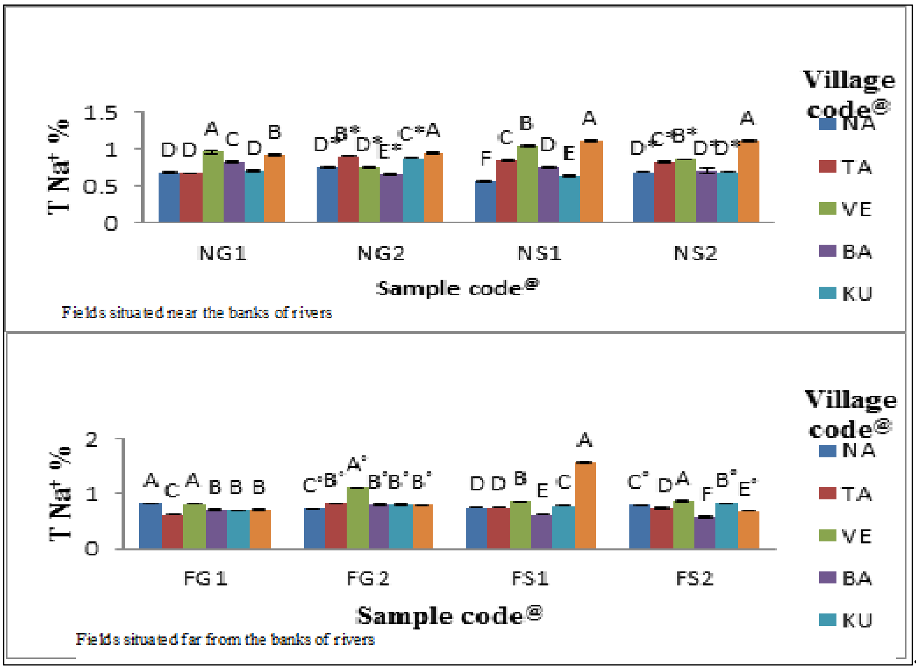

Fig. 9. Total Sodium (TNa^+%) of soil samples collected from agricultural fields under rice/wheat/sugarcane cultivation

@: sample and village codes as described in Table 1

Bars show Mean ±SD, different letters on the bars indicate statistically significant difference among samples belonging to each group analyzed by one way ANOVA; Tukey test p≤0.05.

'' shows significant difference for independent T-test for consecutive samplings (NG1-NG2; NS1-NS2)*

'°' shows significant difference for independent T-test for consecutive samplings (FG1-FG2; FS1-FS2)

CONCLUSION

Various physico-chemical parameters like pH, bulk density (BD), water holding capacity (WHC), total organic carbon (TOC), total nitrogen (TN), total available phosphorous (TAP), total potassium (TK^+) and total sodium (TNa^+) of the agricultural soil samples from fields situated along the banks of rivers Beas and Sutlej were studied. The pearson correlation analysis showed a negative correlation of pH with TOC and TN. WHC showed significant negative correlation with BD and a significant positive correlation with TOC and TN. Water holding capacity was found to vary in fields which were situated near the banks of rivers. The content of TK^+ and TNa^+ was found to vary in maximum number (83 % and 79 %) of fields studied during sampling 1 and 2. Except two agricultural fields the content of total nitrogen remained same in all the samples studied.

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