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Short communication: Indexing of physico-chemical variables and fertility status of district Sahiwal soils, Punjab, Pakistan

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Abstract

Rapid urbanization and industrialization are leading cause of food security issue in modern days, so there is dire need to efficiently utilize the scarce resources. Increased food per unit area is an indispensable factor to tackle food security. Therefore, a research survey was carried out to evaluate the salinity and fertility status of district Sahiwal to execute balanced and environment friendly fertilizer recommendation to the farmers to gain maximum output from different crops of this area. A total of 14490 soil samples were collected from two tehsils of Sahiwal (Tehsil Chichawatni and Tehsil Sahiwal) and analyzed for physico-chemical properties in Soil and Water Testing Laboratory, Sahiwal. About 81% soils had EC values (≤ 4.0 dSm-1) which were non-saline in nature and 74% of total soil samples exhibited normal pH value < 8.5. Organic matter status of 90% soil samples was deficient < 1%. The available phosphorus in 45% samples were poor (i.e., ≤7.0 mg kg-1), Potassium contents of most (70%) of the soils were satisfactory having 80-180 mg K kg-1 soil. The results of this study indicated that the most of soils of district Sahiwal are good for agricultural crops production but with low fertility status.

Keywords: Electrical conductivity, organic matter, pH, soil analysis, soil fertility

From agriculture point of view, Sahiwal is considered as one of the main districts of the Punjab (Farah *et al*., 2019). In past it was known as Montgomery on historical foundation by Sur Robert Montgomery in 1865. Harappa is very historical place that backed about 3000-5000 BC, which is located almost 20 km in west of Sahiwal city and in north of Indus valley civilization. It comprises 2 tehsils, with 88 union councils, if we take its global position it lies between 30.4^0 N to73.6^0 E and almost 150m above sea level (Feilden and Hawthorne.1998).

Climate of district Sahiwal is semi-arid, temperature varies from mild winter to hot summer. In summer season temperature may rise to 50˚C and in winter season temperature may decrease up to 5˚C. In monsoon or rainy season precipitation is maximum and the average annual rainfall is almost 200 mm (Choudhary, 2017). Sahiwal district has multi-cropping area, almost all main crops are grown in this district including wheat 37.1%, corn 22%, cotton 17.2%, fodder 9.8%, potato 9.1%, rice 0.7%, vegetables 1.3% and fruits 0.8% including citrus, mango, guava, dates lemon, orange and mulberry (GOP, 2018). Sandy areas along the river side is used for growing of cotton and peanut while the area of Yousuf Wala and Arif Wala are specific for growing of maize (Amir *et al*., 2019).

Soil analysis is a tool through which farmer community comes to know about the availability of nutrients in the soil and they get the maximum yields on fertilizer recommendation basis. On the other hand it will also be very beneficial for manufacturers, planners (associated with fertilizer marketing and distribution), farmers and soil fertility to determine the level of requirement of different fertilizers for a specific season/ year and for forecasting in increase/decrease of fertilizers on the basis of cropping pattern and cropping intensity of that area (Ahmed and Rashid, 2003). Due to increased population, poor management practices and inefficient use of fertilizers, the

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production is not at satisfactory level which is probably getting reduced due to converting agricultural land for non-agricultural purposes (Laishram *et al.*, 2012). In Pakistan, the main threat for sustainable agriculture is soil degradation and poor quality of groundwater because it affects both soil fertility and productivity (Kausar *et al*., 2016). Soil fertility is directly influenced by numerous physico-chemical characteristics of soil. One of possible way to increase the sustainable agriculture production is to assess macro and micro-nutrient contents of soil so that fertilizer recommendations can be made based on soil fertility status for profitable production (Abdul *et al*., 2015). Net agricultural production can be maximized by precise input application based on soil analysis report (Manan, *et al*., 2016). Nearly all Pakistani soils are deficient in respect of availability of nutrients for plant growth, so they are unable to fulfill nutrients requirements which are essential for plant growth to obtain highest crop production (Ahmed and Rashid, 2003). Fluid transmission, soil strength and storage properties especially in rhizosphere are termed as soil physical quality (Gulser *et al*., 2010), Soil physical properties play a key role in germination of seeds and emergence of young seedlings, besides affecting the movement of water within the soil. Thus, indirectly influence plant available nutrients (Davoud *et al*., 2015). Farmers and research workers having comprehensive information of physico-chemical soil characteristics at hand can increase the probable yield estimation. Important soil nutrient management decisions are based on the knowledge of soil physical properties. In the same way chemical properties affects the bioavailability of necessary plant nutrients and a powerful correlation exists between nutrients availability and production of crops. For sustainable agriculture it is chief principle that inputs must be used according to the fertility position of a particular region (Singh and Mishra 2012). Therefore soil test basis application of nutrients is highly recommended to increase their use efficiency and protect the environment from there excessive use.

Keeping the above all facts in view, the present study was conducted with the objectives, to diagnose the nature and extent of salinity and classify the area into low, satisfactory and high fertility status for the better nutrient management.

This work was carried out by Soil and Water Testing Laboratory Sahiwal, Pakistan to assess the physico-chemical properties and fertility level of district Sahiwal, (Table 3). Composite soil samples (i.e., Chichawatni 6872 and Sahiwal 7618) were collected from two depths (0- 15 cm and 15-30 cm) for crops and vegetables, mixed properly by following the guidelines of soil sampling and sample preparation (Andreas and Micheal 2005).

Samples were dried in shade, pulverized softly and passed through 2.0 mm sieve to get invariable sample. Later on standard soil analysis methods were used to analyze physico-chemical characteristics of soil. Saturated soil paste was prepared to determine saturation percentage by using the following formula and categorization of soil texture with respect to saturation percentage was categorized (Kargas *et al*., 2018) as mentioned in Table 2.

$$\text{Saturation Percentage} = \frac{\text{Loss in Wheight of Soil}}{\text{Wheight of Wet Soil}} \times 100$$

The pH was measured in soil: water (1:1) solution by pH meter (HANNA-HI 2210) and electrical conductivity (EC) was measured in 1:10 soil : water ratio by using EC meter (HANNA-edge^{ec}) according to criteria described by Malik et al. (1984) as illustrated in Table 3. Soil organic matter was measured by titration method (Nelson and Sommers, 1982), available phosphorus was extracted by using 0.5 *M* $NaHCO_3$ solution (Olsen and Sommers, 1982) and then spectrophotometer (PD-303S) was used to measure it. Potassium was measured on flame photometer (JENWAY PFP-7) using 1 *M* NH_4-acetate at normal pH. i.e. 7.0 (Helmkeand Sparks, 1996). Gypsum requirement was determined by following Schoonover' s method (1952). The data was analyzed for standard deviation and mean values of all physico-chemical properties of the soil by using SPSS 16 computer base statistical software.

Many soil properties rely on soil texture and depend directly or indirectly on it just like organic matter, water holding capacity, porosity, infiltration rate, cations exchange capacity and soil aggregation (Pardo *et al*., 2000). Soil texture also handles the preservation and removing of nutrients in soil plant environment. Soil texture also influences on germination and emergence of young seedlings, root penetration and plant growth (Jalota *et al*., 2010).

The saturation percentage ranges from 24 to 52 in Tehsil Chichawatni having the mean value of 36.55 (Table 1). The 3% of the soil samples were coarse textured while 95% soil were medium textured and only 2% were fine in texture (Figure 1a). While in tehsil Sahiwal the saturation percentage ranges from 22 to 50 with mean value 34.11 (Table 1), the texture of Tehsil Sahiwal soils was similar to Tehsil Chichawatni soils. The soils having clayey texture in nature are considered good from fertility point of view as they have sufficient amount of nutrients such as nitrogen, phosphorus and potassium. The coarsed textured soil on the other hand have low cation exchange capacity are considered low from fertility point of view (Chakraborty

and Mistri, 2015) along with limited water holding capacity so needs some amendments just like application of farm yard manure which will improve soil physical properties, antagonistic and osmotic pressure. Uptake rate of all nutrients increased with increasing nutrients concentration solution (EC). Nutrients which are high in concentration are

Table 1: Minimum, maximum, and mean values of different soil parameters of District Sahiwal

Estimation	Tehsil Chichawatni			Tehsil Sahiwal		
	Range	Mean	Standard Deviation	Range	Mean	Standard Deviation
Saturation %	24-52	36.55	4.27	22-50	34.11	4.02
EC (dS/m)	0.7-32	3.28	8.4	0.6-43	2.75	6.9
pH	7.6-10.5	8.03	1.47	7.7-10.3	8.14	1.34
Organic Matter %	0-1.20	0.55	0.21	0.30-1.1	0.59	0.26
Available Phosphorus (mg kg^{-1})	1.6-28	8.12	5.4	2.5-32	7.84	5.7
Extractable Potassium (mg kg^{-1})	20-560	200.46	110.23	30-620	205.13	116.28
Gypsum Requirement (kg/acre)	250-4500	1050.45	125.78	250-4250	1100.85	131.26

Table 2: Comparison of different parameters in percentage of district sahiwal

	pH		EC (dSm^{-1})		Saturation %			Organic Matter (%)		Available P (mg kg^{-1})			Extractable K (mg kg^{-1})		
	Normal	Sodic	Normal	Saline	Sandy	Loam	Clay	Poor	Adequate	Poor	Adequate	Fertile	Poor	Adequate	Fertile
Sahiwal	70	30	83	17	4	94	2	90.4	9.6	44.8	51.3	3.9	2.2	69.4	28.4
Chichawatni	76	24	79	21	3	95	2	89.8	10.2	45.5	50.2	4.3	1.9	70	28.1

Table 3: Detail of soil samples collection annually and their fertility status

Status of Samples		Sahiwal			Chichawatni		
		Available P (mg kg^{-1})	Extractable K (mg kg^{-1})	Organic Matter (%)	Available p (mg kg^{-1})	Extractable K (mg kg^{-1})	Organic Matter (%)
2014	Poor	735	44	1543	706	21	1337
	Satisfactory	879	1150	142	749	1091	179
	Fertile	71	491	0	61	404	0
2015	Poor	497	24	973	354	15	730
	Satisfactory	536	737	105	406	550	81
	Fertile	45	317	0	51	246	0
2016	Poor	666	29	1332	712	32	1416
	Satisfactory	743	1038	149	802	1099	156
	Fertile	72	414	0	58	441	0
2017	Poor	765	36	1509	642	27	1310
	Satisfactory	854	1169	165	740	1023	148
	Fertile	55	469	0	76	408	0
2018	Poor	750	31	1527	696	33	1366
	Satisfactory	898	1193	173	747	1057	149
	Fertile	52	476	0	72	425	0

ultimately water holding capacity will be enhanced of these soils.

Hindrance in normal uptake of nutrients is produced by dissolved salts by misbalancing of salts or by affecting on taken in high quantity on the other hand the nutrients which are small in quantity are depressed (Bugbee, 2004). Normally for research purpose EC is exploited for soluble chemicals meanwhile for counseling plans it is used for salinity and is determined by using a soil water solution

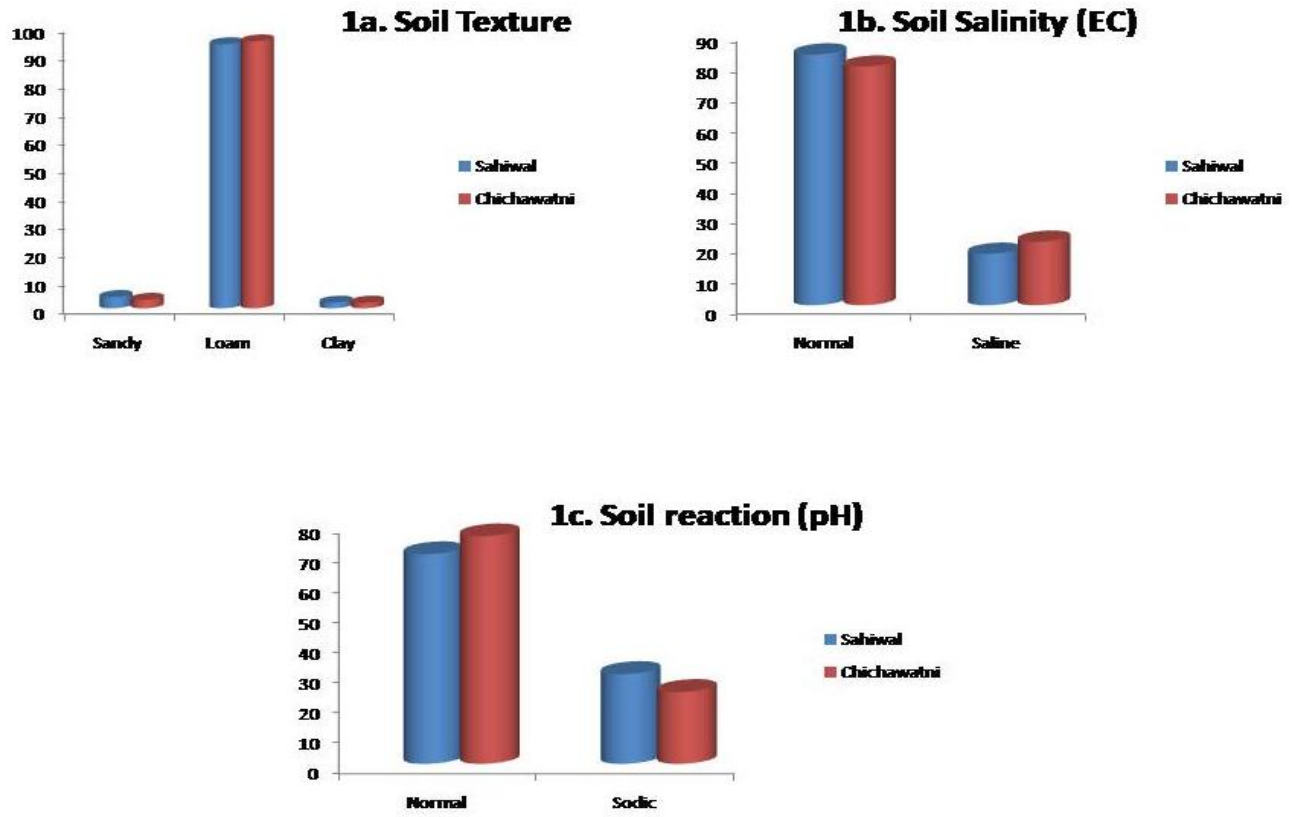

Figure 1. Indicating the soil texture, salinity and pH status of district Sahiwal

(1:10). The data (Figure 1b) showed that 83% of analyzed samples were non-saline and approximately 17% were saline in Tehsil Sahiwal (Table. 1). The minimum EC value was 0.6 dS m^{-1} while maximum value was 43 dSm^{-1} having the average value 2.75 dS m^{-1}, in the same way 79% samples were normal and 21% were saline in Tehsil Chichawatni. The highest value was 32 dS m^{-1} and minimum was 0.7 dS m^{-1} with the mean value of 3.28 dS m^{-1}. It was very interesting that salinity was not a serious issue where soils were sodic in nature. Thus, in such soils special management practices should be adopted to increase the production level (Suriyan *et al*., 2011).

Nutrients availability and solubility depends upon the pH of a soil. The NO_3 and NH_4 are available relatively vide rang of pH (6.0-8.5). If a soil has high $CaCO_3$ contents as well as pH then the availability of P is decreased to the plants (Belkheir and Mulas, 2013). The ability to dissolve P is at peak in a very small range of pH (6.5-7.5), the nutrients which required plants in small amount like copper, zinc, iron and boron are highly soluble in pH ranging from 5.0 to 6.0, but their availability is affected by different factors such as temperature, moisture and microbial number (Saha *et al*., 2019).

In Tehsil Sahiwal the pH value ranges from 7.7 to 10.3 with an average value of 8.14 (Table 1). The results (Figure 1c) further revealed that 70% soils had pH value 7.5-8.5 and 30% soil samples were either sodic or saline sodic but on the other hand in Tehsil Chichawatni range of pH was 7.6 to 10.5 with the mean value of 8.03 and in this area 76% soils were normal with respect to pH and 24% soils were sodic or saline sodic. Agriculture can be carried out successfully on these soils , however soils having high pH (> 8.5) have a bit constraints for good quality crops, soils having high pH need unusual concentration for some worthy amendments (sulphur, sulphuric acid) that can be used for their reclamation as per their gypsum requirements (Schofieldand Taylor, 1955). If the sodium content is high and pH > 8.5 than for the reclamation of such soils gypsum, sulphur and acid are usually recommended (Sherry, 2007). After the application of such amendments heavy irrigation of good quality water is required to leach down the sodium salts from the root zone area (Horneck *et al.*, 2007).

Soil Testing Laboratories usually recommend the nitrogen requirements estimating the nitrogen that can be released from organic portion of soils. This organic portion

of soils positively effect on biological yield as well as grain yield (Arif *et al*., 2017). The data (Figure 2a) showed that 90.4 % of soils of Tehsil Sahiwal were poor (i.e. ≤ 0.86%) in organic matter contents and only 9.6% were acceptable in respect of organic matter and in Tehsil Chichawatni were also same trend i.e. 89.8% soils were poor and 10.2% were

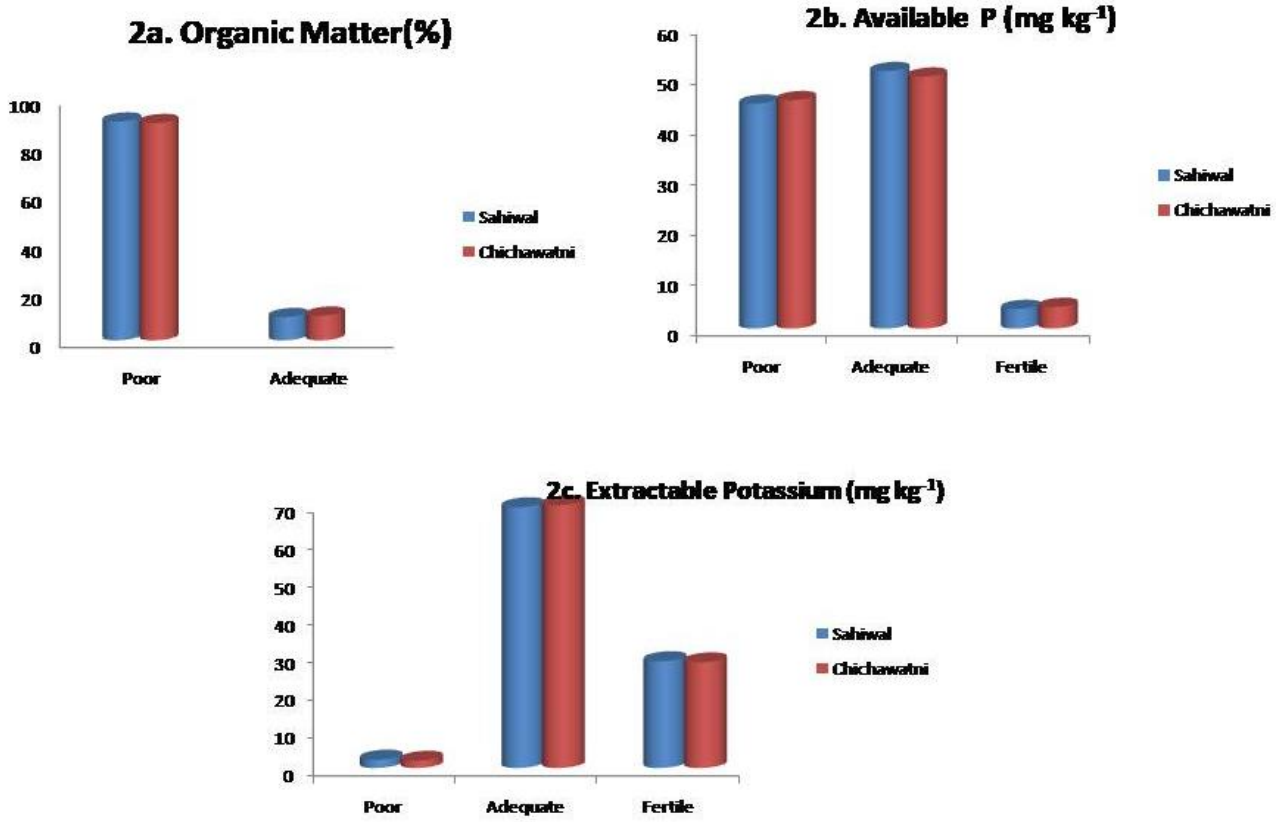

Figure 2. Indicating the fertility (organic matter, available phosphorus and extractable potassium) status of district Sahiwal

satisfactory with respect to organic matter. The main factor of low organic matter content is temperature of the region increased up to 50°C in summer that speeds up its decomposition. Most of the farmers don't like to use poultry manure or farm yard manure in their fields and remove the crops totally from them as a result left them fallow. The concept of green manuring among farming community is also negligible. Due to which there is immense need to adopt such practices which will increase the soil organic matter otherwise soils are deteriorating rapidly in these areas (Sieglinde, 2011).

The data in Figure 2b indicates that 44.8% soils of Tehsil Sahiwal were poor (i.e., ≤7 mg kg^{-1}), 51.3 % were satisfactory (i.e., 7-14 mg kg^{-1}) and only 3.9 % were adequate (i.e., ≥14 mg kg^{-1}) with respect to available phosphorus to plants. Two factors are involved regarding less availability of phosphorus to plants , one is the fixation of P in calcareous soils due to high contents of $CaCO_3$, and 2nd is high price of phosphatic fertilizers (Ray von wandruska. 2006). These results coincide with the finding of the previous scientists according to which the soils of this area are poor in available phosphorus.

As the material varies from which soil particles forms and soil texture changes along with its rate of weathering so potassium (K) availability changes. Generally clayey soils have more available K than the silty and sandy soils (Wakeel *et al*., 2017). The K contents ranged from 20 mg kg^{-1} to 560 mg kg^{-1} with a mean value of 200.46 mg kg^{-1} in Tehsil Chichawatni (Table 1). The data (Figure 2c) indicates that only 1.9 percent soils were deficient, 70 percent were satisfactory and remaining 28.1 percent were adequate in available K, on the other hand in Tehsil Sahiwal the value of K varies from30 mg $kg^{-1}$to 620 mg kg^{-1} with the mean value of 205.13 mg kg^{-1}, in this Tehsil 2.2 percent soils were poor, 69.4 percent soils were satisfactory and 28.4 percent were adequate in available K. The K content had consistently

reported as enough in Pakistan apart from windswept or sandy textured soils (Aamer *et al*., 2015).

The results showed that texture of Sahiwal soils is almost loam in nature, 19% and 26% soils are saline and sodic in nature. Almost all the soils in this district are low in organic matter. Phosphorus contents are from satisfactory to poor while potassium contents vary from satisfactory to adequate. Farming community may increase their yield by applying recommended inputs according to the soil analysis reports.

These soils are also good for agriculture but as the pH value increase (i.e. >8.5) it has some limitation for high value crops. Soils having pH>8.5 needs some special attention and some suitable amendment (gypsum or acid) is to be applied for their reclamation according to gypsum requirements.

While soils having EC >4.0 dS m^{-1} need some special practices for their reclamation e.g. deep ploughing followed by heavy canal irrigation.

Inorganic Fertilizers must be applied according to the recommendations of the Laboratory in a balanced form, and in line sown crops band placement is very effective. By using farm yard manure / poultry manure and/ or green manuring of leguminous crops can increase organic matter contents. With this practice sufficient moisture can be preserved for next crops.

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