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Characterization, Appraisal of Soil Salinity, Fertility and Amelioration of Non-Saline/Sodic and Saline/Sodic Soils at District Chiniot, Punjab: Pathways for Agricultural Sustainability and Farmers Community Well-being

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Abstract

Evaluation of soil fertility consists of estimating the nutrient supplying power of soil. In this regard, a total of 4758 advisory soil samples were received directly from farmers or collected from the agriculturists' countryside with geolocation data from all over Chiniot district for soil fertility evaluation. To categorize the soil of district Chiniot as normal, saline, saline-sodic, sodic and their ultimate solution, if any; the recommendations were also provided to the farmers in the light of soil samples analyzed reports. The results showed that 92.8% soil samples were found normal, while 4.89% saline, 1.11% saline-sodic and 1.15% sodic of the entire collected soil tester from tehsil Chiniot. However, 92.03% samples were surrounded by definite normal salts decisive limits, while 3.74% saline, 2.57% brackish-sodic and 1.63% sodic of whole assembled tester from tehsil Bhowana. Moreover, 93.73% samples were found normal, while 4.08% saline, 0.86% saline-sodic and 1.32% sodic of entire gathered trials from tehsil Lalian. Also, 50.3% of soil samples were found poor (i.e., <0.86%) in OM, while 40.5% samples were medium (i.e., 0.87 - 1.29%) ranged OM and 9.1% samples had adequate (i.e., > 1.29%) OM of the total collected soil samples from district Chiniot. However, 56.6% of soil samples were established poor in available P (i.e., < 7.0 mg kg^{-1}), while 39.6% samples were medium (i.e., 7.1 - 14.0 mg kg^{-1}) ranged P and 3.8% samples had tolerable (i.e., > 14.0 mg kg^{-1}) soil P of the total collected samples under study. Moreover, 22.9% of soil samples were found poor (i.e., < 80 mg kg^{-1}) in

available K, while 64.1% samples were intermediate (81-180 mg kg^{-1}) ranged K and 12.8% samples had adequate (i.e., >180 mg kg^{-1}) soil K of the total collected samples. In squat, depending upon the soil analysis, farmers were guided for fertilizer recommendations according to climate suitability, crop/orchard/vegetable and water/rainfall conditions as being implemented right through the suitable conditions of the Punjab following guidelines of the Directorate of Soil Fertility, Thokar Niaz Baig Lahore.

Keywords: Chiniot, Bhowana, Lalian, Soil Salinity, Fertility, Community Based Rehabilitation & Development

Introduction

The total geographical area of district Chiniot is 2,643 km2 (1,020 sq mi). It is 38 kilometers north of Faisalabad and 158 kilometers northwest of Lahore. With a moderate elevation of 179 meters (587 feet), Chiniot City has an area of 10 square kilometers. Chiniot City is situated on a tiny rocky hill on the left-hand side of the Chenab waterway. Around Chiniot, stony arising of slate and brickwork that may grow up to 400 feet in altitude are scattered across the most alluvial plains that make up the surrounding area. Chiniot has a hot semi-arid climate (Köppen climate classification BSh). The weather in Chiniot is variable. The important products of Chiniot include silk, wheat, sugar, rice, cotton, milk, pottery, wooden furniture, etc. Fishing and tourism also play an important role in economy. The "canal colonies" that were created during British control when extensive networks of canals were constructed to irrigate Punjab are a major source of the city's agricultural economy. Because of its closeness to the Chenab River, where lumber from Kashmir would float down the river into Chiniot, the city became a center for woodworking and is well-known for its wooden furniture. Madina, Ramzan and Safina Sugar Mills are positioned at Faisalabad Road, Jhang Road and Sargodha Road, respectively. The biota of the district Chiniot include: Jand trees (Prosopis spicigera), Karir (Capparisaphylla), Beri (Ziziphus jujuba), Van (Salvadora abeoides), Kikar (Acacia arabica), Shisham (Dalbergia sissoo) and Aak (Calotropis hamiltoni) are found inside the locality (Sultana et al., 2024).

Soil salinity and sodicity represent significant challenges to agricultural productivity in arid and semi-arid regions worldwide, with Pakistan facing particularly severe impacts on its agricultural lands. An estimated 6.67 million hectares of land in Pakistan are affected by salinity and sodicity, with Punjab province alone accounting for 1.234 million hectares of salt-affected soil (Abdulah et al., 2022). These soil conditions are characterized by elevated levels of sodium (Na^+) that lead to deteriorated physical properties, fertility problems, and ultimately threatened agricultural productivity in affected regions (Qadir et al., 2005). The accumulation of soluble salts and exchangeable sodium significantly impairs soil structure, reduces water infiltration, limits nutrient availability, and creates hostile environments for plant growth and development, thereby compromising agricultural sustainability and food security in the region.

District Chiniot, situated in Punjab province, represents an area of significant agricultural importance facing soil fertility challenges. According to a survey, the soil in Chiniot is predominantly alluvial and classified as sandy soil, containing approximately 78% sand, 7% silt, and 15% clay, with moderate organic matter content (0.78%) and slightly alkaline pH ranging between 7.8 and 7.9 (Bakhsh et al., 2015). While these alluvial soils possess inherent fertility, continuous cultivation without proper management practices has led to degradation of soil quality, exacerbated by issues of salinity and sodicity in certain areas. Farmers in this region have expressed concerns regarding multiple constraints affecting their agricultural productivity, including canal water shortages (95%), energy issues (91%), and fertilizer availability (80%) (Bakhsh et al., 2015). These challenges, coupled with soil fertility degradation, necessitate comprehensive characterization and amelioration strategies tailored to the specific conditions of Chiniot district.

Despite significant advances in understanding soil salinity and sodicity management, there remains a critical need for location-specific characterization and tailored amelioration strategies that account for the unique soil properties and environmental conditions of District Chiniot. The present research aims to address this gap by conducting a comprehensive characterization of saline/sodic and non-saline/sodic soils in Chiniot, assessing their fertility status, and developing effective amelioration techniques suitable for local conditions. The study will evaluate various physical, chemical, and biological properties of these soils to understand their limitations and potentials, followed by the formulation of practical and economically viable strategies for soil improvement. Additionally, the research will explore the integration of chemical amendments with biological approaches to enhance soil quality and agricultural productivity in a sustainable manner.

By generating location-specific knowledge and practical interventions, this research seeks to contribute significantly to agricultural sustainability in District Chiniot, with potential applications to similar agro-ecological zones experiencing soil salinity and sodicity challenges. The present study findings will guide farmers, agricultural extension workers, and policymakers in implementing effective soil management practices that enhance crop productivity while preserving the region's natural resources for future generations.

Materials and Methods

A research review was regulated to assess the soil salinity and fertility status of 3 tehsils of Chiniot district Punjab Pakistan during fiscal year 2016-17. Soil (0-15 cm and 15-30 cm depths) samples were collected from three tehsils (Chiniot, Bhowana and Lalian) sites using soil auger following the standard procedures of soil sample collection. The soil samples were analyzed at Soil and Water Testing Laboratory, Chiniot during the year 2016-2017.

Table-I Profile of District Chiniot

Sr. No.	Tehsil	Markaz	Union Council (No.)	Villages (No.)	Area (Acres)	Population
1	Chiniot	1	18	115	201209	Males: 0.739 Million (53.98%) Females: 0.630 Million (46.02%)
2	Bhowana	2	13	109	185214	
3	Lalian	3	13	138	241978	
TOTAL	3	6	44	362	628401	965124 1.369 Million

Table-II Land Utilization Statistics

Sr. No.	Item Description	ACRES
1	Total Area	628401
2	Cultivated area	533034
3	Irrigated area	528634
4	Un irrigated area	4400
5	Uncultivated area	95367

Prior to their physical-chemical and textural investigation, a composite of three samples was combined at each location, allowed air dry, ground, and then sieved through a 2 mm sieve.

Using the following formula, saturated soil paste was made in order to calculate the saturation %, and soil texture was classified according to the saturation percentage *(Kargas et al., 2018)*.

Using a pH meter and the soil water ratio (1:1), the pH of the soil was determined (Schofield and Taylor, 1955) and in accordance with the specified requirements the soil electrical conductivity of a 1:10 soil-water ratio using an EC meter (US Salinity Lab Staff, 1954*)*.

Titration was used to determine the amount of organic matter in the soil. After weighing around 1.0 g of dirt

in a 500 ml conical flask, 5 ml of $K_2Cr_2O_7$ was added, and everything was thoroughly mixed. 10 ml of H2SO4 was added. 30 minutes were spent keeping the flask. 50 milliliters of distilled water, three milliliters of phosphoric acid, five to ten drops of indicator, and standardized ferrous sulphate were used to titrate the mixture until the green end point became blue (Walkley, 1947).
50 milliliters of the $NaHCO_3$ extraction solution were applied to 2.5 grams of soil. After 30 minutes of shaking, filter through Whatman (No. 42). 5 ml of the aliquot was taken, filled with a 250 ml volumetric flask with 5 ml of color-developing reagent. Permitted to stand for approximately fifteen minutes adjusted the volume appropriately. The color turned bluish. A measurement was made using a spectrophotometer at a wavelength of 880 nm (Olsen et al., 1954). A flame photometer (PFP-7 Jenway) was used to assess the amount of potassium that was available using 1 M NH4-acetate at standard pH. i.e. 7.0 (Helmke and Sparks, 1996).
Gypsum requirement was determined by following Schoonover's method (1952), if required and necessary.
The criteria used to categorize the soil samples for various classes of texture, salinity/sodicity and nutrients were according to classification of Malik et al. (1984) (Table-III).

Table-III. Standards Followed for Categorizing Soil Properties

Sr. No.	Standards	Remarks
1.	**Saturation %age**	**Soil Class**
	0-19 %	Sandy
	20-29 %	Sandy Loam
	30-45 %	Loam
	46-60 %	Clay Loam
	> 60 %	Clayey
2.	**Electrical Conductivity (dS m^{-1})**	
	0- 4	Normal /Slightly Saline Soil
	4.1-8	Saline Soil
	> 8	Highly Saline Soil
3.	**Sodicity (Soil pH)**	
	< 8.5	Normal Soil
	> 8.5	Sodic Soil
4.	**Fertility**	
	I - Organic Matter (%)	
	<0.86	Poor Soil
	0.87 - 1.29	Satisfactory Soil
	> 1.29	Adequate Soil
	II - Available Phosphorus (ppm)	
	> 7.0	Poor Soil
	7.1 - 14.0	Satisfactory Soil
	> 14.0	Adequate Soil
	III - Available Potassium (ppm)	
	< 80	Poor Soil
	81-180	Satisfactory Soil
	>180	Adequate Soil

Using SPSS 16 computer-based statistical software, the data was examined for mean values and standard deviations of all the analyzed soil's physio-chemical characteristics.

Results

During the year 2016-17, a total of 4758 soil samples from District Chiniot were received, collected and tested for physico-chemical analysis (Table-IV & V). These advisory soil samples were received directly from farmers as well as collected from the fields of farmers of Chiniot district during the fiscal year 2016-17. Then these were analyzed in Soil and Water Testing Laboratory Chiniot for physio-chemical analysis to assess their fertility status and to find out soil problems and their solution, if any. Recommendations were given particularly to the farmers in the light of soil analysis reports. Among the tested 4758 soil sample tested of District Chiniot, 4429 soil samples were found normal whereas 214, 55 and 60 were found saline, saline-sodic and sodic respectively.

Table-IV: Salinity/sodicity Status (Texture, pH and TSS) of Soils in Three Tehsils of District Chiniot

Sr. No.	Tehsil	Total No.	Texture			pH			TSS (%)			
			Light	Medium	Heavy	< 7.5	7.5-8.5	> 8.5	*Normal*	Saline	*Saline-Sodic*	*Sodic*
1	Chiniot	2592	39 (1.5%)	2501 (96.4%)	52 (2%)	___	2406 (92.8%)	186 (7.1%)	2406 (92.8%)	127 (4.8%)	29 (1.1%)	30 (1.1%)
2	Bhowana	427	16 (3.7%)	382 (89.4%)	29 (6.7%)	___	393 (92%)	34 (7.9%)	393 (92%)	16 (3.7%)	11 (2.5%)	07 (1.6%)
3	Lalian	1739	21 (12.1%)	1687 (97%)	31 (1.7%)	___	1630 (93.7%)	143 (8.2%)	1630 (93.7%)	71 (4%)	15 (0.86%)	23 (1.3%)
	TOTAL	4758	76	4570	112	___	4529	363	4429	214	55	60
OVERALL % AGE			*1.60%*	*96.05 %*	*2.35%*	___	*95.18 %*	*7.62%*	*93.09%*	*4.50%*	*1.16%*	*1.25%*
Mean			*25.3*	*1523.3*	*37.3*		*1509.6*	*121*	*4429.3*	*71.3*	*18.3*	*20*

Three tehsils wise (Chiniot, Bhowana and Lalian) advisory soil samples during the fiscal year 2016-17 are described as follows:

Tehsil Chiniot

Out of 2592 soil samples analyzed in the laboratory, it was found that 2406 soil samples were normal, 127 were saline, 29 were saline sodic and 30 were sodic in nature (Table-IV). A total of 106 beneficiaries were given advisory service during this year in tehsil Chiniot.

The analyzed results showed that 54.3% soil samples were found poor (i.e., <0.86%) in OM, while 42% samples were medium (i.e., 0.87 - 1.29%) ranged OM and 3.5% samples had adequate (i.e., > 1.29%) OM of the total collected soil samples from tehsil Chiniot. However, 65.5% of soil samples were established poor in available P (i.e., < 7.0 mg kg^{-1}), while 32.9% samples were medium ranged P and 1.5% samples had passable (i.e., > 14.0 mg kg^{-1}) soil P of the collected samples in tehsil Chiniot. Moreover, 29.7% soil samples were found poor (i.e., < 80 mg kg^{-1}) in available K, while 62.5% samples were intermediate ranged K and 7.7% samples had tolerable (i.e., >180 mg kg^{-1}) soil K of the collected samples from tehsil Chiniot (Table-V).

Table-V: Fertility Status (Organic Matter, P and K) of Soils in Three Tehsils of District Chiniot

Sr. No.	Name of Tehsil	Total No. of Soil Samples	Organic Matter (%)			*Soil Available P (mg Kg^{-1})*			*Soil Available K* (mg Kg^{-1})		
			Poor	Medium	Adequate	Poor	Medium	Adequate	Poor	Medium	Adequate
1	Chiniot	2592	1410 (54.3%)	1090 (42.0%)	92 (3.5%)	1699 (65.5%)	853 (32.9%)	40 (1.5%)	772 (29.7%)	1620 (62.5%)	200 (7.7%)
2	Bhowana	427	234 (54.8%)	172 (40.2%)	21 (4.9%)	229 (53.6%)	167 (39.1%)	31 (7.2%)	54 (12.6%)	284 (66.5%)	89 (20.8%)
3	Lalian	1739	750 (43.1%)	666 (38.2%)	323 (18.5%)	760 (43.7%)	866 (49.7%)	113 (6.4%)	266 (15.2%)	1149 (66%)	324 (18.6%)
	TOTAL	4758	2394	1928	436	2688	1886	184	1092	3053	613
OVERALL % AGE			*50.32%*	*40.52%*	*9.16%*	*56.49%*	*39.64%*	*3.87%*	*22.95%*	*64.17%*	*12.88%*
Mean			*798*	*642.6*	*218*	*896*	*628.6*	*61.3*	*364*	*1017.6*	*204.3*

Tehsil Bhowana

Out of 427 soil samples analyzed in the Laboratory, it was found that 393 soil samples were normal, 16 were saline, 11 samples were saline-sodic and 07 soil samples were sodic in nature (Table-IV). A total of 31 beneficiaries were provided advisory service during this year in tehsil Bhowana.

The analyzed results showed that 54.8% soil samples were found poor (i.e., <0.86%) in OM, while 40.2% samples were medium (i.e., 0.87 - 1.29%) ranged OM and 4.9% samples had adequate (i.e., > 1.29%) OM of the collected soil samples from tehsil Bhowana. However, 53.6% of soil samples were established poor in available P (i.e., < 7.0 mg kg^{-1}), while 39.1% samples were medium ranged P and 7.2% samples had passable (i.e., > 14.0 mg kg^{-1}) soil P of the collected samples in tehsil Bhowana. Moreover, 12.6% soil samples were found poor (i.e., < 80 mg kg^{-1}) in available K, while 66.5% samples were intermediate ranged K and 20.8% samples had tolerable (i.e., >180 mg kg^{-1}) soil K of the collected samples from tehsil Bhowana (Table-V).

Tehsil Lalian

During the fiscal year under report 1739 soil samples were collected from farmers' fields. After putting into different physic-chemical determination, it was found that out of 1739 samples analyzed in the Laboratory, 1630 soil samples were normal, 71 were saline, 15 were saline sodic and 23 were sodic in nature (Table-IV). A total of 72 beneficiaries were given advisory service during this year in tehsil Lalian.

The analyzed results showed that 43.1% of soil samples were found poor (i.e., <0.86%) in OM, while 38.2% of samples were medium (i.e., 0.87 - 1.29%) ranged OM and 18.5% samples had adequate (i.e., > 1.29%) OM of the collected soil samples from tehsil Lalian. However, 43.7% of soil samples were established poor in available P (i.e., < 7.0 mg kg^{-1}), while 49.7% samples were medium ranged P and 6.4% samples had passable (i.e., > 14.0 mg kg^{-1}) soil P of the collected samples in tehsil Lalian. Moreover, 15.2% of soil samples were found poor (i.e., < 80 mg kg^{-1}) in available K, while 66% samples were intermediate ranged with K and 18.6% samples had tolerable (i.e., >180 mg kg^{-1}) soil K of the collected samples from tehsil Lalian (Table-V).

Discussion

The availability of phosphorus to plants is reduced in soil with higher calcium carbonate and pH values

because phosphorus precipitates as di-calcium phosphate. The pH range of 6.5 to 7.5 is when plants are most able to absorb phosphorus. Low pH leads to micronutrient availability (Shah and Fry, 2019).
Nutrient retention and root penetration are issues in these types of soils. Therefore, gypsum should be administered in accordance with the soil's gypsum needs for reclamation of such soil (Schofield and Taylor, 1955). Raising the field's borders and filling it with sweet water after applying gypsum will allow the sodium salts to seep below the root zone (Hopkin, 2015: Schofield and Taylor, 1955).
The soil textural class determines the chemical and physical characteristics of the soil, including its porosity, organic matter levels, root penetration, water infiltration, aggregation, and CEC (Singh and Mishra, 2012). Compared to coarse-textured soils, fine-textured soils (clay) may store more water and nutrients (Chakraborty and Mistri. 2015). Applying organic amendments, such as green manure, poultry manure, and yard manure, can develop the physical and chemical properties of soil, increasing its ability to retain water and nutrients.
The local farmers don't employ green manure techniques or organic additives like farmyard or chicken manure. Therefore, in order to increase the soil's organic matter contents in a sustainable manner, organic amendments must be applied (Mondini & Sequi, 2008). By keeping vital nutrients in the soil, the use of organic modifications can enhance soil physical condition (Dhaliwal et al., 2021). Organic material has elevated cation exchange capacity (CEC) which helps in the switch over of diverse fundamental nourishment which successively progress soil health as well as productiveness of soil (Hosseinzadeh et al., 2021).
The reason for the low-down plant accessible phosphorus contents in the region is because of alkaline and calcareous soils of the area where fixation of P occurs due to high calcium carbonate filling. Additionally, the area's farmers are impoverished, own little land, and cannot afford the expensive phosphoric fertilizers (Dawar et al., 2022). Our results are in line with the prior conclusion of researchers as soils of the area are in poor range of plant available phosphorus contents.
The amelioration of salt-affected soils traditionally involves providing soluble sources of calcium (Ca^{2+}) to change overloaded sodium on the cation exchange complex, followed by leaching the displaced sodium from the root zone (Qadir et al., 2005). Chemical amendments such as gypsum, calcium chloride, sulfuric acid, and various sulfates have been widely employed for this purpose. However, these approaches often require significant financial investments that may be prohibitive for resource-poor farmers. Alternative strategies such as phytoremediation have emerged as cost-effective interventions that not only address soil sodicity but also provide economic benefits through crop cultivation during the amelioration process (Qadir et al., 2005). The continuous cultivation of appropriate crops has demonstrated positive effects on soil properties, as evidenced by long-term studies in Punjab showing decreases in soil pH and increases in organic carbon content and nutrient availability (Singh et al., 2023).

Conclusion

Before planting a crop, a thorough assessment of the soil productiveness aids in the adoption of suitable corrective actions to address deficiencies and guarantee a high crop yield. As a result, 4758 consultative soil models were gathered from farmers' fields in the district of Chiniot, coupled with GPS coordinates by the experts of Soil and Water Testing Laboratory Chiniot. According to the overall findings, 7.6% of the soil samples had a pH greater than 8.5, while 92.3% of the samples had a pH between 7.5 and 8.5. Of the total samples obtained, 4.5% were saline, 2.07% were saline-sodic, and 2.18% were sodic; nonetheless, 91.2% of the trials were within the threshold ranges of recognized normal salts. Similarly, 94.9% of soil samples had medium texture, 2.4% had heavy texture, and 2.6% had light texture. In addition, 55.5% of soil testers were deprived (i.e., < 0.86%) in OM, while 37.7% standard (i.e., 0.87 - 1.29%) ranged and 6.6% were adequate (i.e., > 1.29%) OM. However, 54.1% soil selected trials were unfortunate in existing P (i.e., < 7.0 mg kg^{-1}), while 43.1% average (i.e., 7.1 - 14.0 mg kg^{-1}) ranged and 2.7 percent had satisfactory (i.e., > 14.0 mg kg^{-1}) top soil P. Likewise, 19.9 percent soil models were unfortunate (i.e., < 80 mg kg^{-1}) in available K, while 69.5% were intermediate (81-180 mg kg^{-1}) ranged and 10.5 percent had satisfactory (i.e., >180 mg kg^{-1}) top soil K.

Recommendations

The site-specific plant food recommendations using soil test-based plant food prediction model were also given to the farmers. The reclamation of the saline soils to be carried out by canal water or good quality groundwater and growth of crops like Kallar grass, Swank, Sesbania, Atriplex, salt-tolerant varieties of barley, wheat, rice etc. For sodicity problem, add farm manure with deep ploughing or add gypsum 0.5 tons per acre depending upon the extent of soil hazard.

The 4Rs stewardship approach i.e. right fertilizer with right rate at right time in right place may also be helpful in low fertility soil for optimum growth and yield.

Various efforts were made to share and transfer the importance and knowledge of soil and water testing laboratory Chiniot to various shareholders and agricultural community through all feasible means. Through lectures/talks on the importance of soil water testing and laboratory owing to farmers issues related conferences, seminars, workshops, and meetings conducted in various locations of district Chiniot, awareness was raised among agri-educators, researchers, extension specialists, and the fertilizer industrialists. Training in soil sampling was given to the Agriculture Extension workers. Advertisements in print and electronic media, TV shows and clips, social media, farmers' field days, and brochure distribution, among other methods, were used to raise awareness among farmers.

References

Abdullah, M., A. Mahmood, M. Shah, U. Qamar, M.T. Abdullah, M. Iqbal, T. Naz, K. Mahmood, K.S. Baig, B. Akhtar, M. Idrees, N. Iqbal, W. Abbas, N. Akhtar and M. Jamil. 2022. Soil macro-nutrients appraisal and indexing for salinity/sodicity and fertility status of soils in Tehsil Athara-Hazari of District Jhang, Punjab, Pakistan: A precision agricultural approach. *Plant Cell Biotechnology and Molecular Biology*, 23: 19-27.

Bakhsh, A., Muhammad Ashfaq, Aamir Ali, M. Hussain, Ghulam Rasool, Zain Haider and R.H. Faraz. 2015. Economic evaluation of different irrigation systems for wheat production in Rechna Doab, Pakistan. *Pakistan Journal of Agricultural Sciences,* 52: 821-828.

Chakraborty, K. and B. Mistri. 2015. Importance of soil texture in sustenance of agriculture: a study in Burdwan-I CD Block, Burdwan, West Bengal. *Eastern Geographer,* 21(1): 475-482.

Dawar, K., Z. Khalil, I.A. Mian, B. Khan, S. Ali, A.A. Rahi and R. Datta. 2022. Effects of farmyard manure and different phosphorus inorganic fertilizer application rates on wheat cultivation in phosphorus-deficient soil. *Sustainability,* 14(15): 9030.

Dhaliwal, S., S. Sharma, V. Sharma, A.K. Shukla, S.S. Walia, M. Alhomrani, A. Gaber, A.S. Toor, V. Verma and M.K. Randhawa. 2021. Long-term integrated nutrient management in the maize–wheat cropping system in alluvial soils of North-Western India: Influence on soil organic carbon, microbial activity and nutrient status. *Agronomy,* 11: 2258.

Helmke, P.A. and D.L. Sparks. 1996. Lithium, sodium and potassium. pp. 551-575. In: *Methods of Soil Analysis. Part 2. Chemical and Microbial Properties*. A.L. Page, O.L. Helmke, P.N. Sultnanpur, M.A. Tabatabai and M.E. Summer (eds.). Soil Science Society of America, Madison, Wisconsin, USA.

Hosseinzadeh, M.H., A. Ghalavand, M.M.A. Boojar, S.A.M. Modarres-Sanavy and A. Mokhtassi-Bidgoli. 2021. Application of manure and biofertilizer to improve soil properties and increase grain yield, essential oil and ω3 of purslane (*Portulaca oleracea* L.) under drought stress. *Soil and Tillage Research,* 205: 104633.

Kargas, G., I. Chatzigiakoumis, A. Kollias, D. Spiliotis and P. Kerkides. 2018. An investigation of the relationship between the electrical conductivity of the soil saturated paste extract ECe with the

respective values of the mass soil/water ratios 1:1 and 1:5 (EC1:1 and EC1:5). *Proceedings,* 2: 661-668.
Malik, D.M., M.A. Khan and D.A. Choudhary. 1984. *Analysis Manual for Soil, Water and Plants*. Director Rapid Soil Fertility Survey, Lahore, Pakistan.
Qadir, M., A.D. Noble, S. Schubert and A. Ghafoor. 2005. Phytoremediation of sodic and saline-sodic soils. In: *The International Salinity Forum – Managing Saline Soils and Water: Science, Technology, and Social Issues*, Riverside, California, USA. 25-27 April 2005.
Mondini, C. and P. Sequi. 2008. Implication of soil C sequestration on sustainable agriculture and environment. *Waste Management,* 28: 678-684.
Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean. 1954. *Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate*. USDA Circular 939. US Department of Agriculture, Washington, DC.
Schofield, R.K. and A.W. Taylor. 1955. The measurement of soil pH. *Soil Science Society of America Journal,* 19(2): 164-167.
Schoonover, W.R. 1952. *Examination of Soil for Alkali*. University of California Extension Service, Berkeley, California.
Shah, N.N. and T.J. Fry. 2019. Mechanisms of resistance to CAR T cell therapy. *Nature Reviews Clinical Oncology,* 16(6): 372-385.
Singh, Kuldip, Dhanwinder Singh, A.S. Toor, O. Choudhary and Sumita Chandel. 2023. Improvement in soil fertility under long-term intensive irrigated agriculture Punjab (North-west India) scenario. *Journal of Environmental Biology,* 44: 229-237.
Singh, R.P. and S.K. Mishra. 2012. Available macronutrients (N, P, K and S) in the soils of Chiraiga on block of district Varanasi (U.P) in relation to soil characteristics. *Indian Journal of Scientific Research,* 3(1): 11-21.
Sultana, R., N. Ahmad, T. Ahmed, B. Sarwar, Mahnoor, F.S. Butt, H.M. Hina, B. Kaynat and T. Nayab. 2024. Mapping and assessment of soil properties for sustainable agriculture with an application of GIS in District Chiniot, Punjab, Pakistan. *FUUAST Journal of Biology*, 13: 87-95.
US Salinity Laboratory Staff. 1954. *Diagnosis and Improvement of Saline and Alkali Soils*. USDA Handbook 60. US Department of Agriculture, Washington, DC.
Walkley, A. 1947. A critical examination of a rapid method for determining organic carbon in soils – effect of variations in digestion conditions and of inorganic soil constituents. *Soil Science,* 63: 251-264.