Journal of Soil Salinity and Water Quality 17(1), 68-75, 2025
DOI: https://doi.org/10.56093/jsswq.v17i1.166601

Effect of Dominant Cropping Systems on the Soil Properties in Sirsa District, Haryana

Vijendra Kumar Verma[1]*, Devender Singh Jakhar[1], Dev Raj[1], Supriya Ranjan[1], Dileep Meena[2], Sawan Kumar[1], Ram Kishor Fagodiya[3], Saloni Yadav[1] and Ashish Kumar Patel[3]

[1]*Chaudhary Charan Singh Haryana Agricultural University, Hisar 125004, Haryana, India*
[2]*ICAR-Indian Agricultural Research Institute, New Delhi-110012, India*
[3]*ICAR-Central Soil Salinity Research Institute, Karnal 132001, Haryana, India*
**Corresponding author's Email: vermavijendra378@gmail.com*

Abstract

Lack of information about site-specific nutrients for various cropping systems has been a major challenge in addressing declining soil fertility and improving crop productivity in the Sirsa district, Haryana, India. Therefore, the study was aimed to evaluate and quantify soil properties across cropping systems (CS), including cotton-wheat (C-W), rice-wheat (R-W), groundnut mustard (GN-M), pearl millet-wheat (PM-W), Guar-Mustard (G-W), mungbean-wheat (MB-W), guava orchard, and cotton-mustard (C-M). A total of 140 georeferenced soil samples were collected using a random survey approach, and the samples were analyzed for soil texture, pH, electrical conductivity (EC), organic carbon (OC), available nitrogen percentage (AvN), phosphorus (AvP) and extractable potassium (ExK). The Sulfur Availability Index (SAI) and Soil Nutrient Index (SNI) were also developed. Guava orchard showed the maximum mean value of EC (0.60 dS/m), organic carbon (0.71%), available N (161.70 kg ha^{-1}), AvP (33.91 kg ha^{-1}), available K (325 kg ha^{-1}), and available S (48.52 kg ha^{-1}). Nutrient index values of the all the cropping systems for available N were low, medium for OC except cotton-wheat (low) and available K except guava (high), high for available P except cotton-mustard and guar-mustard (medium) and S except cotton-wheat (medium). Highest SAI was observed in guarva orchard (3.00) whereas minimum was observed in cotton-wheat (2.15). Our findings indicate that cropping systems have huge impact on soil properties.

Key words: Cropping system, Soil properties, Nutrient index, Sulfur Availability Index.

Introduction

Soil is one of the most valuable natural resources, essential for sustaining life on Earth, both living and non-living. All living organisms depend on soil either directly or indirectly for food, shelter, and other needs. It act as the primary medium for plant growth by providing physical support and supplying essential nutrients (Pande, 2008). Therefore, maintaining soil health is critical for robust plant development. Soil health is determined by its physical, chemical, and biological characteristics. Alterations in these properties within agricultural zones can adversely affect plant growth and overall crop productivity (Dutta and Dutta, 1995). Given that agriculture relies heavily on extracting nutrients from the soil, sustainable practices that minimize nutrient loss and replenish them are essential for maintaining crop yields and ensuring long-term agricultural sustainability (Gruhn *et al.*, 2000). Intensive farming and multi-cropping systems without adequate soil management often deplete nutrients from the root zone, reducing their availability. Hence, conserving soil quality is key to boosting food production to meet the demands of a growing global population.

Soil fertility encompasses a combination of physical, chemical, and biological factors that influence soil structure, porosity, nutrient availability, and biological activity. These factors collectively impact crop growth and yield potential (Rowell, 1996). Properties such as soil texture, pH, nutrient levels, organic matter, and microbial activity are central to determining fertility.

Understanding soil texture is crucial, as it affects a wide range of characteristics including water retention, nutrient dynamics, decomposition rates, and cation exchange capacity (Brady and Weil, 1999). Soil pH governs important soil processes such as ion exchange and nutrient availability (Bohn *et al*., 2001; Rowell, 1996). Organic matter, composed of living organisms, decomposed residues, and metabolic by-products, plays a vital role in integrated soil fertility management (Brady and Weil, 1999).

Cropping systems refer to the spatial and temporal arrangement of crops and associated management practices on agricultural land over time. These systems aim to maximize productivity to meet human needs for food, fiber, and economic benefits (FAO, 2016). A detailed understanding of how continuous cropping affects the physical, chemical, and biological attributes of soil is essential for promoting sustainable agro-ecosystems (Aparicio and Costa, 2007). The amount and type of organic inputs such as crop residues, FYM, and compost combined with management practices that influence decomposition rates, directly affect organic matter dynamics in the rhizosphere and thus soil quality (Bunemann *et al*., 2018). While regional-scale soil properties are primarily shaped by climate and geology, land use becomes the dominant influence at smaller scales (Wang *et al*., 2014). Research has shown that cropping system treatments significantly alter topsoil characteristics (Wang *et al*., 2014).

Repeated cropping depletes plant nutrients in the rhizosphere and diminishes soil organic matter unless replenished through organic amendments or allowed to regenerate during fallow periods (FAO Bulletin). In South Asia, declining yields in rice-wheat systems have been linked to soil degradation, nutrient depletion, and water pollution caused by unbalanced use of fertilizer and intensive cultivation, and poor irrigation practices (Patil *et al*., 2018). Adoption of improved practices like no-tillage, residue incorporation, cover cropping, rotation, and balanced nutrient applications can enhance soil organic carbon (SOC), benefiting microbial activity, root development, nutrient and water retention, and aggregation (Lal *et al*., 2015). Methods like continuous no-till, solid manure application, high-residue rotations, and cover cropping enhance soil buffering capacity and reduce pH fluctuations (Penn and Camberato, 2019). Incorporating legumes in crop rotation supports nitrogen recycling and boosts soil nitrogen levels.

Nutrient over-mining needs to be ceased when soil health is to be maintained, which is urgently needed to sustain the nation's food and nutritional security. (Raj *et al*., 2020). Soil health has declined as a result of intensive agriculture, which relies on the production of high-yielding cereals and other crops has led to nutrient depletion from the soil and use of chemical fertilizers and pesticides without proper dosage guidelines (Singh *et al*., 2019). This shift toward monoculture for profit, coupled with limited resources, has had detrimental effects on soil health. However, actual changes in soil fertility under various cropping systems need to be assessed by periodical monitoring the availability of nutrients in the soil. The creation of site-specific nutrient limit standards for various crops will increase nutrient use efficiency and prevent yield losses, and have a negative influence on the environment by fertilizers (Fairhurst *et al*., 2012). The primary aim of this study is to evaluate the impact of different cropping systems on soil properties in Sirsa district of Haryana.

Material and Methods

Description of the study area

Sirsa is the north western district of Haryana State and located between 29°14′ to 30°0′ N latitude and 74°29′ to 75°18′ E longitudes. It has a total geographical area of 4276 km^2 and a total cultivated area of 4050 km^2. The study area includes all seven blocks of the district viz. Nathusari Choupta, Rania, Sirsa, Baragudha, Odhan, Ellenabad and Dabwali (Fig. 1).

Major cropping systems growing in the area were cotton- wheat, rice – wheat, groundnut – mustard, pearl millet – wheat, guar – mustard, mungbean – wheat and guava. The climate of Sirsa district is tropical desert type arid and hot. The mean maximum and minimum temperature

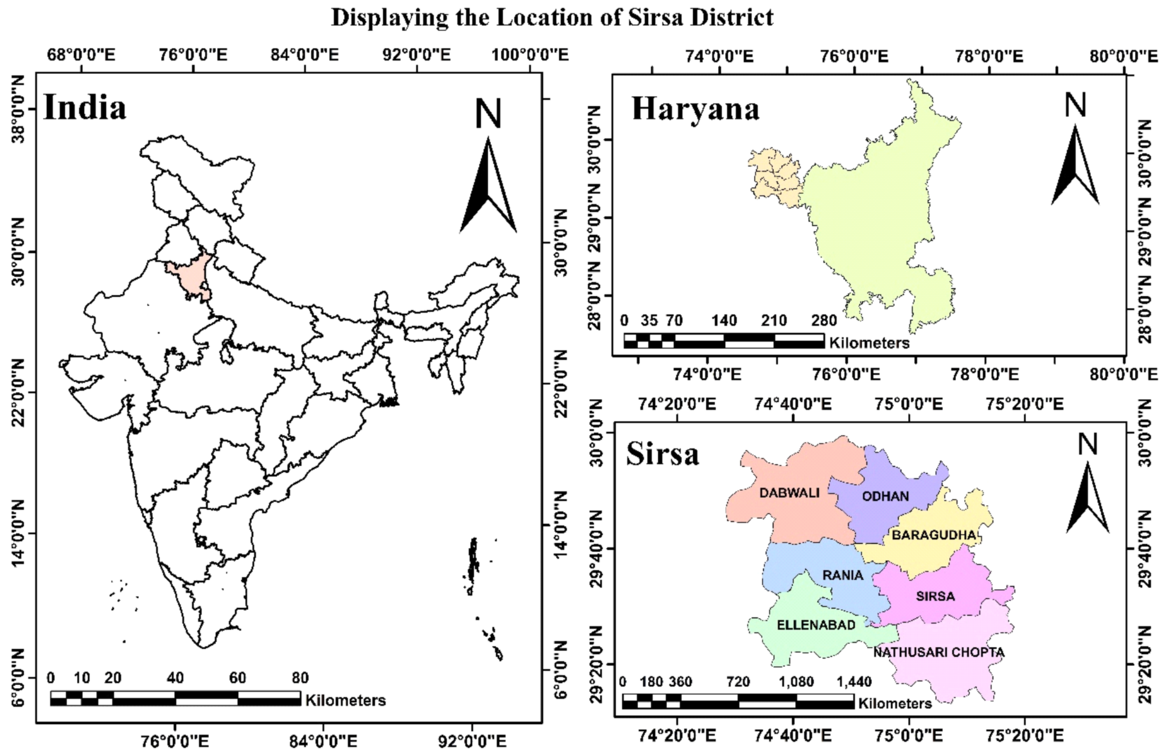

Fig. 1 Location map of study area

is 41.1°C (May-June) and 5.1°C (January), respectively. The annual average rainfall of the district is 318 mm and the monsoon rainfall is 253 mm. The soils of the district are sandy (S) to sandy loam (SL) in texture.

Soil sampling and laboratory analysis

A total 140 surface soil samples (0-15 cm) were collected randomly from all (seven) blocks of Sirsa district (20 samples from each block). These 140 sites were divided in eight groups based on cropping systems. The information regarding crop management practices and fertilizer use pattern of sampling sites were also collected (Table 1). In order to prevent the effects of recent fertilization during the crop growing season, the samples were taken (in 2022) after harvest and before the following cropping season. All of the samples were brought into the lab, air-dried, manually crumbled to remove the root materials, and then passed through 2 mm sieve. The samples were passed through 100 mesh sieve (0.5 mm) for evaluating organic carbon (OC). The pH and electrical conductivity of soils were measured using 1:2 soil-water suspension with standard protocol outlined by Jackson (1973). Organic carbon (OC) was determined through the rapid titration method developed by Walkley and Black (1934). Available nitrogen (N) was estimated by alkaline permanganate method (Subbiah and Asija, 1956). Available phosphorus (Olsen P) was measured using sodium bicarbonate ($NaHCO_3$) as an extractant following the method of Olsen *et al.*, 1954. Available potassium (K) was through the ammonium acetate method. Available Sulfur (S) was measured using 0.15% calcium chloride ($CaCl_2$) as an extractant following the procedure described by Chensin and Yien (1950).

Statistical analysis

Descriptive statistics of the analysed soil data viz., minimum, maximum , mean value and standard deviation were determined using SPSS software (29.0.1.0). The nutrient index was developed by Parker *et al.* (1951) to provide a single value to each nutrient and enable the comparison of soil fertility levels in one region with levels of another region.

$$\text{Nutrient index} = \frac{(N1\times1) + (Nm\times2) + (Nh\times3)}{Nt}$$

Table 1 Fertilizers management practices in various cropping system of Sirsa district

Cropping system	Fertilization (kg ha^{-1})
Cotton- Wheat	Cotton = 160.5 N+ 57.5 P_2O_5 + 37.5 K_2O
	Wheat = 177 N+ 57.5 P_2O_5 + 0 K_2O
Rice – Wheat	Rice = 149.25 N+ 28.75P_2O_5 + 37.5 K_2O
	Wheat = 177 N+ 57.5 P_2O_5 + 0 K_2O
Groundnut - Mustard	Groundnut = 63 N+ 28.75 P_2O_5 + 37.5 K_2O
	Mustard = 63 N + 28.75 P_2O_5 + 0 K_2O
Pearl millet - Wheat	Pearlmillet = 51.75 N+ 0 P_2O_5 + 0 K_2O
	Wheat = 177 N+ 57.5 P_2O_5 + 0 K_2O
Guar - Mustard	Guar = 0 N+ 0 P_2O_5 + 0 K_2O
	Mustard = 63 N+ 28.75 P_2O_5 + 0 K_2O
Mungbean - Wheat	Pulse = 0 N+ 0 P_2O_5 + 0 K_2O
	Wheat = 177 N+ 57.5 P_2O_5 + 0 K_2O
Guava	Guava = 203.62 N+ 57.5 P_2O_5 + 75 K_2O
Cotton-Mustard	Cotton = 160.5 N+ 57.5 P_2O_5 + 37.5 K_2O
	Mustard = 63 N + 28.75 P_2O_5 + 0 K_2O

N: Nitrogen; P: Phosphorus; K: Potassium

where,

Nt = total number of samples analyzed for a nutrient in given area;

Nl = number of samples with low nutrient status (low category);

Nm = number of samples with medium nutrient status (medium category); and

Nh = number of samples with high nutrient status (high category)

Additionally, according to NI, the soil fertility level was divided into three categories: low (1.67), medium (1.67–2.33), and high (>2.33).

The formula described by Donahue *et al.* (1977) was used to calculate the Sulfur Availability Index (SAl) as follows:

SAI = (0.4 × $CaCl_2$ extractable SO_4^{2-}in mg kg^{-1} soil + % organic matter)

Results and Discussion

Physico-chemical properties of soil

The soil pH was influenced significantly under different cropping systems viz. cotton-wheat, cotton-mustard, rice-wheat, guar-mustard, groundnut-mustard, pearl millet-wheat and guava. Lowest soil pH was observed in rice-wheat (8.27) system (Table 2). This was might be due to higher organic matter in prolonged reduced condition during rice crop and release of organic acids that lowers the soil pH (Benbi *et al.*, 2014). Highest electrical conductivity was observed in guava orchard (0.60 dS m^{-1}) (Table 2). This was might be attributed to higher application of fertilizers. In a similar manner, SOC content was highest under guava (0.71%) orchard followed by rice-wheat cropping system (0.65%) whereas lowest under cotton-mustard (0.49%) cropping system (Table 2). The higher SOC in guava orchard probably due to trees continue to drop litter, which keeps adding organic matter to the soil and is recognized as the main source of organic carbon (Kaushik *et al.*, 2018). Similarly, the slower rate of organic matter decomposition in puddled rice soil under anaerobic conditions, which might results in greater organic carbon storage, may account for the higher SOC content in the rice-wheat cropping system (Pan *et al.*, 2004).

Available nutrients

Among the cropping systems, the mean available N was significantly higher under guava orchard (161.70 kg ha^{-1}) followed by rice-wheat (148.28 kg ha^{-1}) copping system while it was significantly lower under pearl millet-wheat (136.84 kg ha^{-1}) cropping system (Table 2). The reason behind the higher N content in guava orchard and rice-wheat cropping system might be due to the frequent

Table 2. Descriptive statistics of soil chemical properties in various cropping systems of Sirsa district

Indicators	pH	EC (dS m^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})	SAI
				Cotton – Wheat (N=60)				
Minimum	7.4	0.16	0.27	116.75	5.61	96	8.15	1.78
Maximum	8.7	0.75	0.76	191.25	45.8	437	67.8	2.66
Mean	8.29	0.40	0.49	142.11	23.74	244.07	35.55	6.98
SD	0.21	0.16	0.11	15.51	7.08	83.16	14.47	2.65
				Cotton-Mustard(N=10)				
Minimum	7.94	0.15	0.38	122.24	12.58	120	10.4	2.24
Maximum	8.61	0.91	0.61	159.23	31.61	320	65.26	12.12
Mean	8.32	0.49	0.52	139.20	20.34	241.38	39.55	7.56
SD	0.18	0.21	0.07	11.38	6.37	54.05	14.52	2.63
				Rice-Wheat(N=54)				
Minimum	7.5	0.12	0.37	109.75	5.59	115	8.9	1.96
Maximum	8.90	0.76	0.82	212.62	51.71	530.00	84.37	15.81
Mean	8.27	0.41	0.61	148.28	29.58	247.68	44.87	8.62
SD	0.23	0.18	0.11	18.29	9.29	96.62	15.96	2.92
				Guava(N=2)				
Minimum	8.3	0.35	0.68	159.65	31.66	320	40.78	7.96
Maximum	8.40	0.84	0.74	163.75	36.16	330.00	56.25	10.49
Mean	8.35	0.60	0.71	161.70	33.91	325.00	48.52	9.23
SD	0.07	0.35	0.04	2.90	3.18	7.07	10.94	1.79
				Guar-Mustard(N=8)				
Minimum	8.2	0.19	0.45	121.62	9.76	124	13.34	2.83
Maximum	8.60	0.69	0.76	160.52	28.56	330.00	63.06	11.91
Mean	8.33	0.37	0.65	143.58	21.06	224.63	40.63	7.91
SD	0.13	0.17	0.12	12.28	5.83	75.39	14.02	2.56
				Groundnut-Mustard(N=2)				
Minimum	8.3	0.15	0.51	135.26	15.25	124	34.5	6.82
Maximum	8.40	0.48	0.66	142.49	24.48	409.00	42.77	8.15
Mean	8.35	0.32	0.59	138.88	22.17	266.50	38.64	7.49
SD	0.07	0.23	0.11	5.11	6.53	201.53	5.85	0.94
				Pearl millet-Wheat(N=2)				
Minimum	8.4	0.34	0.41	107.84	10.13	125	29.25	5.63
Maximum	8.48	0.57	0.76	165.84	34.21	230.63	41.54	8.18
Mean	8.44	0.46	0.59	136.84	19.87	177.82	35.40	6.91
SD	0.06	0.16	0.25	41.01	17.03	74.69	8.69	1.80
				Mung bean-Wheat(N=2)				
Minimum	8.25	0.25	0.61	135.87	16.58	221	35.87	7.06
Maximum	8.40	0.38	0.65	137.54	26.51	270.00	46.60	8.93
Mean	8.33	0.33	0.63	137.71	21.55	245.50	41.24	8.00
SD	0.11	0.09	0.03	1.18	7.02	34.65	7.59	1.32

EC: Electrical Conductivity; OC: Organic Carbon; N: Available Nitrogen; P: Available Phosphorus; K: Available Potassium; S: Available Sulfur; SAI: Sulfur Availability Index

application of nitrogenous fertilizers, and higher biomass contributed to soil which had significant positive correlation with organic carbon. (Chesti *et al.*, 2015; Dhaliwal *et al.*, 2015; Kharche *et al.*, 2013; Sepehya *et al.*, 2012; Sharma *et al.*, 2015).

The amount of available P was found to be statistically different under different cropping systems with highest amount in guava orchard (33.91 kg ha^{-1}) followed by rice- wheat (29.58 kg ha^{-1}) cropping system than other cropping systems while it was lowest under pearl millet- wheat (19.87 kg ha^{-1}) cropping system (Table 2). In guava orchard and rice-wheat cropping systems there were higher amount of humic acids in soil which leads to large numbers of negative charges, carboxyl and hydroxyl groups which are

Table 3. Nutrient index value under different cropping systems of Sirsa district

Cropping systems	OC	N	P	K	S
Cotton-Mustard	1.70	1.00	2.20	2.00	2.40
Cotton-Wheat	1.52	1.00	2.37	2.10	2.15
Guava	2.00	1.00	3.00	3.00	3.00
Guar-Mustard	2.13	1.00	2.13	2.13	2.38
Grounnut-Mustard	2.00	1.00	2.50	2.00	2.50
Mungbean-Wheat	2.00	1.00	2.50	2.00	2.50
Peral millet-Wheat	2.00	1.00	2.50	2.00	2.50
Rice-Wheat	1.93	1.00	2.65	2.20	2.52

OC: Organic Carbon; N: Available Nitrogen; P: Available Phosphorus; K: Available Potassium; S: Available Sulfur

responsible for desorption or release of available P in soil (Sekhon *et al.*, 2009). Also, higher levels of organic matter contain significant amounts of organic P, such as phospholipids and nucleic acids, which can be released to enhance soil inorganic P concentrations through mineralization (Turner and Leytem, 2004).

Among the cropping systems, the available K content of 325 kg ha^{-1} was significantly higher under guava orchard than other cropping systems, while it was lowest in pearl millet-wheat (177.82 kg ha^{-1}) cropping system (Table 2). Addition of inorganic potassium fertilizer and high potassium bearing parent materials like feldspar and illite in the soils might have increased the K availability in guava orchard and rice-wheat cropping systems (Shen *et al.*, 2007).

The available S content and SAI were found to be statistically different under different cropping systems and these were found highest in guava orchard (48.52 kg ha^{-1} and 10.54) in contrast to other cropping systems (Table 2). However, higher amount of organic matter in these cropping systems leads to release of organic acids which keep binding sulfur fertilizers and slow release of sulfur in the soils (Lemanowicz *et al.*, 2014; Sharma and Subehia, 2014).

Nutrient index value (NI)

Nutrient index (NI) value was determined to assess the overall nutritional status of OC, available nutrients (N, P, K, and S) under different cropping systems (Table 3). The soils of the different cropping systems were medium in OC status except cotton-wheat (low) cropping. Similarly, all the cropping systems were low in available N. Cotton-mustard and guar-mustard cropping systems were medium in available P whereas all other cropping systems were high In a similar fashion, available K was high under guava orchard while all other cropping systems were medium in available K status. Besides, cotton-wheat (medium) cropping system, available S was high under all the cropping systems.

Conclusion

Effects of cropping system on soil properties was assessed at Sirsa district of Haryana. Soil across all five cropping systems were found to be non-saline and slightly to moderately alkaline in the reaction. The highest soil organic carbon was recorded in guava orchard while the lowest was observed under cotton-mustard system. The nitrogen content was low across the cropping systems. The maximum available phosphorus was recorded in guava orchard and lowest value of phosphorus was obtained from pearl millet cropping system. The available potassium was also varied with cropping systems. The maximum potassium content was found in guava orchard and lowest potassium content was found in pearl millet cropping system. The available S content and SAI were found highest in guava orchard (48.52 kg ha^{-1} and 10.54) in contrast to other cropping systems. The availability of soil nutrients also influenced by the pattern of fertilizer and manures application trend and fertility management practices. Thus, for sustainable soil resources management, effective nutrient management technique should be integrated with appropriated cropping sequence.

Acknowledgements

The authors are thankful to the Chaudhary Charan Singh Haryana Agricultural University, Hisar 125004, Haryana, India for providing platform for research work and internal manuscript review.

References

Aparicio V and Costa JL (2007) Soil quality indicators under continuous cropping systems in the Argentinean Pampas. *Soil and Tillage Research* **96 (1–2)**: 155–165. DOI:

Benbi DK, Brar K, Toor AS, and Singh P (2015) Total and labile pools of soil organic carbon in cultivated and undisturbed soils in northern India. *Geoderma* **237**: 149-158.

Bohn HL, McNeal BL and O'Connor GA (2001) Acid soils. Soil Chemistry Third Edition John Wiley and Sons New York NY **303**: 48-66.

Brady NC and Weil RR (1999) The nature and properties of soil. 13th Edition. Prentice hall, Upper Saddle River, London.

Bünemann EK, Bongiorno G, Bai Z, Creamer RE, De Deyn, G de Goede R, and Brussaard, L (2018) Soil quality – A critical review. *Soil Biology and Biochemistry* **120**: 105–125.

Wang B, Zeng C, Chen W, and Peng C (2014) Soil pH and associated properties in relation to land use and topography in a typical karst region of southwest China. *Environmental Earth Sciences* **71**: 1713–1723

Chesnin L and Yien CH (1950). Turbidimetric determination of available sulphates. *Proceedings of the Soil Science Society of America* **14**: 149-151.

Chesti MH, Kohli A, Mujtaba A, Sofi JA, Qadri TN, Peer QJA, Dar MA and Bisati IA (2015) Effect of integrated application of inorganic and organic sources on soil properties, yield and nutrient uptake by rice (*Oryza sativa* L.) in intermediate zone of Jammu and Kashmir. *Journal of the Indian Society of Soil Science* **63(1)**: 88-92.

Dhaliwal MK, Dhaliwal SS, Thind HS and Gupta RK (2015) Effect of integrated nutrient management on physico-chemical parameters of soil in rice-wheat system. *Agricultural Research Journal* **52(2)**: 130-137

Donahue RL, Miller RW and Shickluna JC (1977) *Soils: An Introduction to Soils and Plant Growth*. Prentice-Hall, Upper Saddle River.

Dutta TC and Dutta AC (1995) *Botany for degree students*. Oxford university press.

Fairhurst T (2012) *Handbook for Integrated soil Fertility Management*. 151.

FAO (2016) *Properties of dryland cropping systems*. Chapter 1.

Gruhn P, Goletti F and Yudelman M (2000) Integrated nutrient management, soil fertility, and sustainable agriculture: current issues and future challenges. *Food Policy* ISBN 0- 89629-638-5

Jackson ML (1973). *Soil Chemical Analysis*. Prentice Hall, New Jersey, USA.

Kaushik U, Raj D, Rani P and Antil RS (2018). Effect of cultivation on available nutrients and organic carbon content in soil under different land use systems of Haryana. *International Journal of Communication System* **6(3)**: 2522-2527.

Kharche VK, Patil SR, Kulkarni AA., Patil VS and Katkar RN (2013) Long-term integrated nutrient management for enhancing soil quality and crop productivity under intensive cropping system on vertisols. *Journal of the Indian Society of Soil Science*, **61(4)**: 323-332.

Lal, R (2015). Restoring Soil Quality to Mitigate Soil Degradation. *Sustainability* **7(5)**: 5875–5895.

Lemanowicz J, Ziomek AS and Koper J (2014) Effects of farmyard manure and nitrogen fertilizers on mobility of phosphorus and Sulfur in wheat and activity of selected hydrolases in soil. *International Agrophysics of Polish Academy of Sciences* **28**: 49-55.

Olsen SR, Cole CV, Watanabe FS and Dean LA (1954) Estimation of available phosphorus in soils by extracting with sodium bicarbonate. *Circular of United States Department of Agriculture* **939**:1-19.

Pan GX, Li LQ, Wu LS, Zhang XH (2004). Storage and sequestration potential of topsoil organic carbon in China's paddy soils. *Global Change Biology* **10(1)**: 79-92.

Pande KR (2008) *A Text Book on Fundamentals of Soil Science and Geology*. Asian Publications Ltd, Kathmandu.

Parker FW, Nelson WL, Winters E, Miles JE (1951) The broad interpretation and application of soil test summaries. *Agron J.* **43(3)**: 103–112.

Patil MM, Singh P, and Wani SP (2018) Soil organic matter dynamics and management. In R Lal and BA Stewart (Eds.), *Soil Health and Intensification of Agroecosytems* (pp. 125–150).

Penn CJ, and Camberato JJ (2019) *Soil Acidity and Liming for Agricultural Soils*. Purdue University Extension AY-267-W.

Raj D, Antil RS, Garg R, Dahiya DS, Arora VK, Yadav SS and Singh JP (2020) Impact of Intensive Cropping Systems on Crop Productivity and Changes in Soil iv Fertility: A Case Study on Benchmark Sites of Haryana. *Indian Journal of Fertilisers*, **16(10)**: 988-996.

Rowell DL (1996) Soil science: methods and applications. Routledg

Sekhon KS, Singh JP and Mehla DS, (2009) Soil organic carbon pools after seven years of manures and mineral fertilizers application in a rice-wheat rotation, *Archives of Agronomy and Soil Science* **55(2)**: 197-206.

Sepehya S and Subehia SK (2012) Nitrogen dynamics as influenced by long-term fertilization and amendments under rice-wheat system in a north-western himalayan soil. *Crop Research* **44(1-2)**: 94-101.

Sepehya S, Subehia SK, Rana SS and Negi SC (2012) Effect of integrated nutrient management on rice-wheat yield and soil properties in a north western Himalayan region. *Indian Journal of Soil Conservation* **40(2)**: 135-140.

Sharma GD, Thakur R, Chouhan N and Keram KS (2015). Effect of integrated nutrient management on yield, nutrient uptake, protein content, soil fertility and economic performance of rice (*Oryza sativa* L.) in a Vertisol. *Journal of the Indian Society of Soil Science* **63(3)**: 320-326.

Sharma U and Subehia SK (2014) Effect of long term integrated nutrient management on rice (Oryzasativa L.)-wheat (*Triticum aestivum* L.) productivity and soil properties in northwestern Himalaya. *Journal of the Indian Society of Soil Science* **62(3)**: 248-254.

Shen MX, Yang LZ, Yao YM, Wu DD, Wang J, Guo R and Yin S (2007) Long-term effects of fertilizer managements on crop yields and organic carbon storage of a typical rice–wheat agroecosystem of China. *Biology of Fertiliser Soils* **44**: 187-200.

Shen W, Ni Y, Gao N, Bian B, Zheng S, Lin X, and Chu H (2016) Bacterial community composition is shaped by soil secondary salinization and acidification brought on by high nitrogen fertilization rates. *Appl. Soil Ecol* **108**: 76–83.

Singh M, Wanjari RH, Kumar U and Chaudhary SK (2019) AICRP on long term fertilizer experiments: salient achievement and future directions. *Indian Journal of Fertilisers* **15 (4)**: 356-372.

Subbiah BV and Asija GL (1956) A rapid procedure for the determination of available nitrogen in soil. *Current Science* **25**: 259-260.

Turner BL and Leytem AB (2004) Phosphorus compounds in sequential extracts of animal manures: chemical speciation and a novel fractionation procedure. *Environmental Science and Technology* **38**: 6101-6108.

Walkley AJ and Black CA (1934) Estimation of soil organic carbon by chromic acid titration method. *Soil Science* **37**: 29-38.

Received: May 13, 2025; Accepted: June 25, 2025