Plant Archives Vol. 26, No. 2, 2026 pp. 2628-2632 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.2.360

EFFECT OF DIFFERENT LONG-TERM NUTRIENT MANAGEMENT PRACTICES ON DEPTH-WISE DISTRIBUTION OF SOIL CHEMICAL PROPERTIES

Sonali Harinkhere*, Vinay Bachkaiya, K. Tedia, Vinay Kumar Samadhiya and Monika Tikariha

Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh-492 012, India.

*Corresponding author E-mail : harinkheresonali@gmail.com

(Date of Receiving-23-08-2026; Date of Revision-20-10-2026; Date of Acceptance-23-10-2026)

ABSTRACT

Long-term application of inorganic fertilizers is essential for supplying nutrients such as nitrogen, phosphorus, and potassium to enhance crop yields; however, it poses significant risks to soil health and sustainability. Prolonged use leads to depletion of soil organic carbon (SOC), which is vital for maintaining soil structure, nutrient retention, and microbial activity. This depletion primarily affects surface soils, reducing carbon sequestration and impairing soil physical properties like water retention. Extended inorganic fertilization also alters soil pH and electrical conductivity (EC) profiles. Surface soil acidification, especially under nitrogen-only treatments, results from urea hydrolysis and nitrification, lowering pH values. In contrast, organic amendments such as farmyard manure and green manure help stabilize pH due to their buffering capacity. EC increases slightly with fertilizer intensity because of salt accumulation but remains below harmful levels. Elevated EC in subsurface layers is linked to salt leaching. In a rice-wheat system study, soil samples at 0-15 cm and 15-30 cm depths showed that pH and EC variations were statistically insignificant among treatments. However, SOC content significantly increased with combined organic and inorganic fertilizer use, while nitrogen-only and unfertilized plots exhibited SOC depletion. Higher SOC concentrations consistently appeared in surface layers due to organic inputs and microbial activity.

Key words : Soil organic carbon (SOC), Long-term fertilization, Carbon sequestration.

Introduction

The application of inorganic fertilizers plays a crucial role in enhancing soil fertility and improving crop yields by supplying essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K). However, despite their short-term benefits, the long-term reliance on inorganic fertilizers raises significant concerns regarding soil health and sustainability. One of the primary issues is the decline in soil organic carbon (SOC) content, which is essential for maintaining soil structure, nutrient retention, microbial activity and overall soil ecosystem functionality. Continuous depletion of SOC through prolonged inorganic fertilization may reduce soil resilience, lower nutrient use efficiency and impair long-term agricultural productivity.

In addition, long-term application of inorganic fertilizers has been shown to significantly alter the depth-wise distribution of key soil chemical properties, including pH, electrical conductivity (EC) and SOC. For instance, numerous studies have reported that inorganic fertilization leads to a marked decrease in soil pH, particularly in the surface layers (0-15 cm), where most fertilizers are applied. Acidification tends to be more pronounced in the topsoil due to the accumulation of acidic residues such as nitrates and ammonium-based compounds. In contrast, the subsoil layers may exhibit a more buffered pH response, although long-term nutrient leaching can gradually lead to acidification at deeper depths as well. Soil acidification can adversely affect nutrient solubility and microbial dynamics, leading to reduced nutrient availability for plants. Soil electrical conductivity, an indicator of soil salinity and ionic concentration, also tends to increase under prolonged inorganic fertilizer use, particularly in the surface horizons. The accumulation of

soluble salts from fertilizer inputs especially under conditions of insufficient leaching or poor drainage can elevate EC values in the topsoil. Over time, these effects may extend into deeper soil layers depending on irrigation practices and rainfall patterns. Elevated EC can impair plant root function, reduce water uptake and increase the risk of salt stress, ultimately affecting crop growth and yield.

Organic matter in the soil can affect soil physical properties and the supply of plant nutrients and is often considered the determining indicator of soil quality and productivity. Long-term field experiments have been used to study the influence of crop management, fertilizer application and tillage practices on organic matter content (Schulten and Leinweber, 1991; Paustian *et al*., 1992; Aref and Wander, 1998; Ellmer *et al*., 2000; Hernanz *et al*., 2002). Under intensive cultivation, deterioration of soil physical properties is very often associated with a decrease in organic matter (Anderson *et al*., 1990 and Schjønning *et al*., 1994).

Organic matter content is the most frequently used indicator to discuss properties such as water retention, soil porosity and aggregate stability (Tisdall and Oades, 1982; Haynes and Swift, 1990; Chenu *et al*., 2000). Little research has been carried out, in long-term experiments, on physico-chemical influences on soil properties and especially at pH close to neutrality. However, long-term intensive cultivation can cause considerable changes in soil pH, cation exchange capacity and cation environment, mainly by fertilizer additions (Schjønning *et al*., 1994; Hera, 1996; Blake *et al*., 1999; Ellmer *et al*., 2000; Noble *et al*., 2000; Pernes-Debuyser and Tessier, 2002a). Furthermore, the distribution of SOC is highly influenced by the nature and duration of fertilizer inputs. In systems dominated by inorganic fertilization, SOC levels typically decline in the top-soil due to reduced organic matter inputs and increased microbial decomposition rates. In contrast, manure or compost amendments tend to increase SOC levels, particularly in the upper soil layers. Long-term inorganic fertilization without organic supplementation leads to a shallow SOC profile, with lower carbon content in both surface and subsoil layers. This not only reduces carbon sequestration potential, but also weakens soil structure and water retention capacity across soil depths.

Materials and Methods

Soil analysis

After the harvest of wheat crop, soil samples were collected from selected treatments of rice-wheat systems during 2022 and 2023 from all the replicates of each treatment at two soil depths surface layer (0-15 cm) and sub surface layer (15-30 cm) from the experimental field. Soil samples from each plot at two depths were also collected for analysis of soil chemical properties. All these collected samples are brought to the laboratory and dried under shade, ground to mix to pass through a 2 mm sieve and then stored for determining various chemical properties (pH, Electrical conductivity, organic carbon). The following standard methods were used for the chemical analysis of the soil samples.

pH

Soil pH was determined in 2.5:1 water-soil suspension after stirring for 30 minutes, by glass electrode pH meter as suggested by Piper (1967).

Electrical conductivity (EC)

The soil sample used for pH determination was allowed to settle down for overnight then conductivity of supernatant liquid was determined by Solu-bridge as described by Black (1965).

Organic carbon (OC)

Wet oxidation method (Walkley and Black, 1934) was followed for determining organic carbon in the soil. The soil was ground in a mortar and pestle to make it into a fine powder. From this, 0.5 g of soil sample was taken and transferred to a 500 mL conical flask. 10 mL of 1 N K2Cr2O7 (49 g in 1000 mL water) was added and swirled to disperse the soil in solution. Then, 20 mL of concentrated $H2SO_4$ was rapidly added to the solution. The mixture was swirled again and was allowed to stand for 30 minutes. A blank (without soil) was also prepared. The solution in the flask was diluted to 200 mL with distilled water to stop the reaction. Then 3-4 drops of ferroin indicator were added. The solution in the flask was then back titrated with 0.5 N FAS solution (196g / 980 mL water + 20 mL conc. H_2SO_4) taken in a burette. The colour of the solution turns from dark green to wine red at the end point.

Results and Discussion

The long-term application of various nutrient management practices significantly influenced the soil chemical properties, particularly organic carbon (OC) content, while the effects on soil pH and electrical conductivity (EC) were relatively minor and statistically non-significant. The data presented in Table 1 illustrate the depth-wise distribution of soil pH, EC and OC under different treatments at 0–15 cm and 15–30 cm soil layers.

Soil pH

The soil pH ranged from 7.02 to 7.30 at the surface layer (0–15 cm) and from 7.31 to 7.58 at the sub-surface layer (15–30 cm). The lowest pH value was observed

Table 1 : Effect of different treatment on depth-wise distribution on pH, electrical conductivity and soil organic carbon.

Treatment details		pH		EC (dS m^{-1})		SOC (g kg^{-1})	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1	Control	7.30	7.54	0.18	0.21	4.27^{d}	4.11^{d}
T_2	50% NPK	7.17	7.31	0.21	0.23	5.49^{c}	5.4^{c}
T_3	100% NPK	7.22	7.37	0.22	0.26	6.42^{ab}	6.33^{b}
T_4	150% NPK	7.25	7.35	0.24	0.25	7.08^{a}	6.99^{a}
T_5	100% NPK+ Zn	7.16	7.38	0.21	0.23	6.33^{b}	6.24^{b}
T_6	100% NP	7.11	7.36	0.20	0.21	5.31^{c}	5.15^{c}
T_7	100% N	7.02	7.38	0.17	0.20	4.48^{d}	4.43^{d}
T_8	100%NPK+FYM	7.23	7.58	0.22	0.24	7.12^{a}	7.03^{a}
T_9	50% NPK+BGA	7.20	7.52	0.20	0.23	5.6^{c}	5.51^{c}
T_{10}	50%NPK+GM	7.23	7.44	0.22	0.23	6.41^{ab}	6.32^{b}
	Sem±	**0.08**	**0.11**	**0.01**	**0.01**	**0.22**	**0.17**
	CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**0.66**	**0.49**

under the 100% N treatment (7.02), whereas the highest was recorded in the control (7.54). Notably, the differences in soil pH among treatments at both depths were statistically non-significant. The decrease in pH under treatments applied with nitrogen alone can be attributed to the acidifying effects of continuous urea application. Urea hydrolysis and subsequent nitrification lead to the formation of nitric acid, resulting in acidification of the soil over time. In contrast, the relatively higher pH values in the control and balanced fertilization treatments (*e.g.*, 100% NPK) suggest that the absence of acid-forming fertilizers and the buffering capacity of soil organic matter helped maintain near-neutral soil conditions.

Treatments involving the addition of farmyard manure (FYM) and green manure (GM) also contributed to pH stabilization. Organic amendments generally possess a liming effect and increase the soil's buffering capacity due to their high cation exchange properties. The minimal variation in pH between the two depths further indicates a relatively uniform distribution of soil reaction, potentially due to leaching and mixing of surface-applied amendments over time.

Electrical Conductivity (EC)

Soil EC ranged between 0.17 and 0.24 dS m^{-1} in the 0-15 cm depth and between 0.20 and 0.26 dS m^{-1} in the 15-30 cm depth. The highest EC values were recorded in treatments receiving 150% NPK and 100% NPK, while the lowest were observed under the 100% N and control treatments. Similar to pH, differences in EC were found to be statistically non-significant.

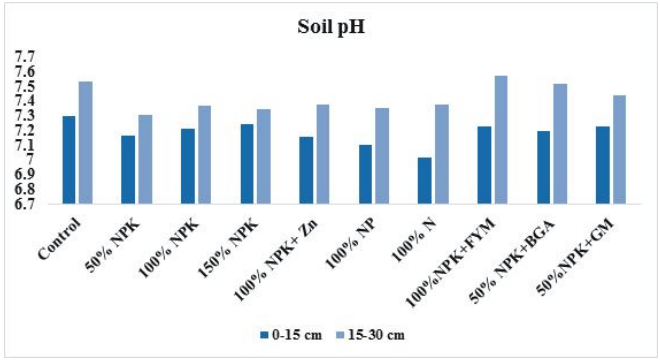


Fig. 1 : Effect of long-term nutrient management on depth-wise distribution on soil pH.

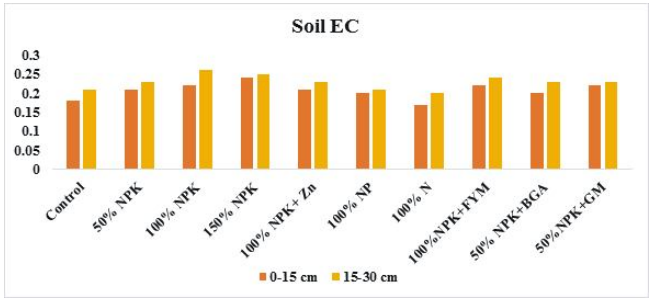


Fig. 2 : Effect of long-term nutrient management practices on depth-wise distribution of soil electrical conductivity.

The increased EC in the high-input chemical fertilizer treatments (*e.g.*, 150% NPK) may be attributed to the accumulation of soluble salts resulting from prolonged application of mineral fertilizers. However, all EC values remained well below the critical threshold for salt injury, suggesting that salt accumulation has not reached levels detrimental to plant growth under the prevailing agroclimatic conditions.

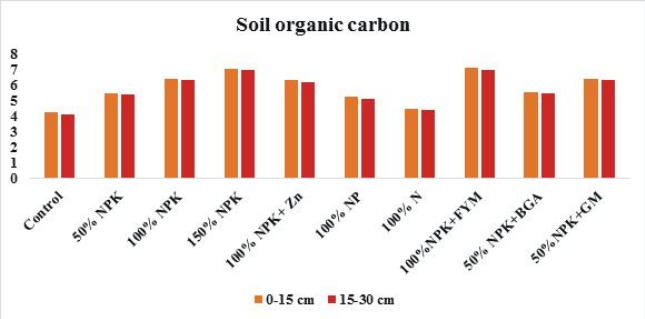


Fig. 3 : Effect of long-term nutrient management practices on depth-wise distribution of soil organic carbon.

In sub-surface soil layer electrical conductivity was slightly higher than that in the surface layer, which may be explained by the downward movement of soluble salts through leaching, especially during the monsoon season. Nonetheless, the overall low EC values across all treatments suggest minimal risk of secondary salinization due to long-term fertilizer use.

Organic Carbon (OC)

Soil organic carbon content varied significantly among treatments, with values ranging from 4.27 to 7.12 g kg^{-1} at the surface layer and from 4.11 to 7.03 g kg^{-1} at the sub-surface layer. The highest OC was observed under 100% NPK + FYM (7.12 and 7.03 g kg^{-1}), followed closely by 150% NPK and 100% NPK + GM. In contrast, the lowest OC was recorded in the control and 100% N treatments. The significant enhancement of OC in treatments involving FYM and GM can be attributed to the direct input of organic residues into the soil, which enhances soil organic matter (SOM) accumulation and microbial activity. Organic amendments not only contribute carbon directly but also improve the stabilization of organic matter through microbial synthesis and the formation of organo-mineral complexes.

In treatments with balanced fertilization (*i.e.*, 100% NPK) also contributed to increased OC levels, likely due to enhanced crop growth and greater root biomass return to the soil, indirectly augmenting the organic matter pool. On the other hand, treatments involving nitrogen alone (100% N) and the control (no fertilizers) exhibited the lowest OC values. This trend reflects the depletion of soil carbon reserves due to nutrient mining and minimal residue return in the absence of sufficient nutrient inputs.

A consistent pattern of higher OC concentration in the 0-15 cm layer compared to the 15-30 cm layer was observed across all treatments. This is expected, as the majority of organic inputs such as FYM, crop residues, and green manure are applied on or near the soil surface, resulting in higher microbial activity and organic matter accumulation in the topsoil.

Conclusion

The results of the long-term experiment clearly demonstrate that while soil pH and EC remained relatively stable and unaffected by nutrient management practices, organic carbon content was significantly influenced. The incorporation of organic amendments such as FYM and GM, either alone or in combination with chemical fertilizers, proved most effective in enhancing and maintaining soil organic carbon levels over time. Treatments with balanced fertilization (NPK) also contributed positively to soil OC, whereas exclusive nitrogen application or the absence of nutrient inputs resulted in significant degradation of soil carbon status. These findings underscore the importance of integrated nutrient management (INM) in sustaining soil fertility and ensuring long-term agricultural productivity. Maintaining adequate organic carbon through the addition of organic matter and balanced nutrient supply is essential for enhancing soil physical, chemical, and biological properties and supporting sustainable crop production systems.

References

Anderson, S.H., Gantzer C.J. and Brown J.R. (1990). Soil physical properties after 100 years of continuous cultivation. *J. Soil Water Conser.*, **45**, 117-121.

Aref, S. and Wander M. (1998). Long-term trends of corn yield and soil organic matter in different crop sequences and soil fertility treatments on the Morrow plots. *Adv. Agron.*, **62**, 153–197.

Black, C.A. (1965). Method of soil analysis American Agronomy Inc., Madison, Wisconsin, USA. 131-137.

Blake, L., Goulding K.W.T., Mott C.J.B. and Johnston A.E. (1999). Changes in soil chemistry accompanying acidification over more than 100 years under woodland and grass at Rothamsted Experimental Station, UK. *Europ. J. Soil Sci.*, **50**, 401-412.

Chenu, C., Le Bissonnais Y. and Arrouays D. (2000). Organic matter influence on clay wettability and soil aggregate stability. *Soil Sci. Soc. America J.*, **64**, 1479-1486.

Ellmer, F., Peschte H., Kohn W., Chmielewski F.-M. and Baumecker M. (2000). Tillage and fertilizing effects on sandy soils. Review and selected results of long-term experiments at Humbolt-University Berlin. *J. Plant Nutr. Soil Sci.*, **163**, 267-272.

Haynes, R.J. and Swift R.S. (1990). Stability of soil aggregates in relation to organic constituents and soil water content. *J. Soil Sci.*, **41**, 73-83.

Hera, C. (1996). The role of inorganic fertilizers and their management practices. *Fertilizer Res.*, **43**, 63-81.

Hernanz, J.L., Lopez R., Navarrete L. and Sanchez-Giron V. (2002). Long-term effects of tillage systems and rotations on soil structural stability and organic carbon stratification in semiarid central Spain. *Soil Tillage Res.*, **66**, 129-141.

Noble, A.D., Gillman G.P. and Ruaysoongnern S. (2000). A cation exchange index for assessing degradation of acid soil by further acidification under permanent agriculture in the tropics. *Europ. J. Soil Sci.*, **51**, 233-243.

Paustian, K., Parton W.J. and Persson J. (1992). Modeling soil organic matter in organic-amended and nitrogen-fertilized long-term plots. *Soil Sci. Soc. Amer. J.*, **56**, 476-488.

Pernes-Debuyser, A. and Tessier D. (2002a). Influence de matières fertilisantes sur les propriétés des sols: cas des 42 parcelles de l'INRA à Versailles. *Etude et Gestion des Sols*, **9**, 177-186.

Piper, C.S. (1966). *Soil and Plant Analysis*. Hans. Pub. Bombay. Asian Ed. pp. 368-374.

Schjønning, P., Christensen B.T. and Carstensen B. (1994). Physical and chemical properties of a sandy loam receiving animal manure, mineral fertilizer or no fertilizer for 90 years. *Europ. J. Soil Sci.*, **45**, 257-268.

Schulten, H.-R. and Leinweber P. (1991). Influence of long-term fertilization with farmyard manure on soil organic matter: characteristics of particle-size fractions. *Biology and Fertility of Soils*, **12**, 81-88.

Tisdall, J.M. and Oades J.M. (1982). Organic matter and water-stable aggregates in soils. *J. Soil Sci.*, **33**, 141-163.

Walkey, A. and Black C.A. (1934). An examination of the degtjareff method for determining the soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, **37**, 29-38.