Original Research Article

Impact of long-term nutrient management practices on physical properties in a *Vertisol* of central India

Abstract

Health of any soil is influenced by its physical properties to greater extent which has been more prominent in Vertisols due to their self-till behavior. Differential application of nutrients in long-term may alter the soil properties at temporal and spatial scales. Inventory on effect of different long-term nutrient management practices on physical properties across the soil depths, especially on *Vertisols* of central India, is insufficient. Present study examined the long-term (48 years) effect of different combinations of organic and inorganic nutrient management practices under soybean-wheat cropping system on various physical properties (Bulk density, Particle density, Porosity and Water holding capacity) of a *Vertisol* in of central India. In the present study, soil sample were collected at four depths (0-15, 15-30, 30-45 and 45-60 cm) in triplicate from seven treatments (Control, 100% NP, 100% NPK, 100% NPK+FYM, 100% N, 50% NPK and 150% NPK) of permanent plots of AICRP on LTFE (initiated in 1972), Jabalpur. By differential nutrient management practices the bulk density and porosity affected significantly up to 30 cm soil depth and beyond that up to 60 cm non-significantly. At all selected soil depths, water holding capacity were significantly affected, on contrary, a non-significant effect was observed on particle density by various nutrient managements. This study indicated a positive impact of balance fertilizer application and integrated approach of nutrient management on physical properties of soil.

Key words: Long-term nutrient management, bulk density, particle density, porosity, water holding capacity, *Vertisol*.

INTRODUCTION

Clay-dominant *Vertisols* have a characteristic potential of swell-shrink mechanism. These soils occupy approximately 2.5 percent of the world's total land area. Vertisols together with soils having vertic features cover about 72.9 million hectares in India (Hati *et al*. 2006). These soils are known for their swell- shrink property as a well as for becoming very hard when dry and sticky in wet conditions enhances the role of physical properties in crop production process. Maintaining balanced physical properties is must for good soil health. Fertilizer application in agricultural fields has increased in a rapid manner as they are playing an unprecedented role in enhancing crop production in India as well as Madhya Pradesh. On one side use of high nutrient responsive cultivars increased the consumption of inorganic fertilizer, other side it has replaced on-farm beneficial practices like use of manures or FYM and recycling of crop residues (Hati *et al.* 2008). Source of nutrient alters the physical properties of soils, organic sources like FYM or manure enhances the porosity and water holding capacity etc. In central India, soybean-wheat is a dominant cropping system practiced on 4.5 million hectare area of *Vertisol*. Imbalanced use of fertilizer in this region is predominant cause of declining yield and deterioration of soil health (Behera *et al.* 2007). The impact of continuous cropping and intensive fertilizer application on the yield of different crops and the characteristics of the soil are effectively shown by long-term fertilizer trials. The objective of the present study were to evaluate the effects of different nutrient management on physical properties under soybean-wheat cropping system after end of 48^{th} cycle in a *Vertisol.*

MATERIALS AND METHODS

Experimental site

A long-term fertilizer experiment (AICRP-LTFE) started during 1972–73 at the experimental farm of the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, India (23°10´N, 79°57´E) 393 m above mean sea level by Indian Council of Agricultural Research (ICAR) was selected for this study. The climate of experimental site is semi-arid and subtropical with average annual mean rainfall of the area is 1274 mm. Recommended rates of N-P-K through fertilizer application for soybean and wheat were 20:80:20 kg/ha and 120:80:40 kg/ha, respectively. Farmyard manure (FYM) (15 Mg/ha/year up to 2012-13; 5 Mg/ ha/year from 2013-14) was applied to soybean crop only during kharif season.

Soil sampling and analysis

The soil of experimental field was a clayey *Vertisol* (Haplustert), characterized as a medium-deep black soil. It is classified as very fine, belonging to Kheri series of fine montmorillonitic hyperthermic family of *Typic* Haplustert. Soil samples were collected after the harvest of *Rabi* crop (wheat) in April 2021 in triplicates from seven treatments (Control, 100% NP, 100% NPK, 100% NPK+FYM, 100% N, 50% NPK and 150% NPK) at four depths (0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm) with the help of screw auger and kept in separate polythene bags after processing.

The bulk density of soil was estimated by core method (Jamison et al. 1950), particle density by pycnometer method, water holding capacity by keen box method and the porosity was calculated from bulk density and particle density (Mujumdar and Singh, 2005) using equation:

$$\text{Porosity (f)} = \left(1-\frac{\rho b}{\rho s}\right) x100$$

Porosity (f) = Porosity of soil expressed in percent.
ρb = Bulk Density of soil expressed in Mg/m^3
ρs = Particle Density of soil expressed in Mg/m^3

Statistical analysis

The data were analyzed by carrying out Analysis of Variance (ANOVA) using randomized block design (RBD). To test the differences between means of different treatments critical difference (C.D.) were computed at *P=0.05* (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Bulk density (BD)

Bulk density of soils from different treatments belonging to long-term fertilizer experiment were analyzed (Table 1.). At 0-15cm, BD varied from 1.31 Mg m^{-3} to 1.38 Mg m^{-3} and at lower depths (15-30, 30-45, and 45-60 cm) from 1.34 to 1.40, 1.40 to 1.42, and 1.42 to 1.43 Mg m^{-3} respectively. Lower values of BD was evident in surface soil (0–15 cm) than in the deeper layers (15-30, 30-45, and 45-60 cm). Among the treatments, at the surface and subsurface soil, application of 100% NPK along with FYM has resulted significantly lower bulk density (1.31 Mg m^{-3} and 1.34 Mg m^{-3}) compared to control (1.38 Mg m^{-3} and 1.40 Mg m^{-3}) and was at par to 150% NPK (1.32 Mg m^{-3}) and 100% NPK (1.33 Mg m^{-3}). At the depth of 30-45 cm and 45-60 cm, different nutrient management practices had similar bulk density with no significant difference. The lower value of bulk density in 100% NPK+FYM treatment might be attributed to the higher quantity of soil organic matter contributed by FYM application (Kusro *et al*., 2014) and in treatments receiving balance fertilizer (NPK) might be due to high biomass production subsequently leads to increase in soil organic matter (Nandapure *et al.* 2011). Similar findings were observed by sharma *et al.* (2016).

Particle density (PD)

Data pertaining to particle density of soil influenced by long-term application of integrated nutrients is given in Table 1. indicated that long-term application of different nutrient management practices had no significant effect on particle density of soil, however heading towards deeper soil layers it slightly increased. In surface soil (0-15 cm), particle density ranged between 2.56 Mg m^{-3} to 5.58 Mg m^{-3} and at 15-30, 30-45, and 45-60 cm depths, it varied from 2.57 to 2.59, 2.58 to 2.59, and 2.59 to 2.60 Mg m^{-3} respectively. Mean value of particle density across 0-60 cm did not show any noticeable change under different nutrient management practices (Fig.1). The mere differences in particle density might be due to addition of organic matter which contributes more in volume compared to mass (Neupane *et al.* 2020).

Porosity

Data related to porosity of soil under different nutrient management practices has been revealed the significant differences among various treatments in surface and sub-surface soil, on contrary no significant difference found in the deeper layers (30-45 and 45-60 cm) (Table 1.). In surface and sub-surface soil, the maximum porosity observed in 100% NPK+FYM (48.82% and 47.75%) and the minimum in control (46.28% and 45.64%). Porosity of 100% NPK+FYM found at par to 150% NPK, 100% NPK and 100% NP at both soil depth. Furthermore, in deeper soil layers (30-45 cm and 45-60 cm), the significantly higher porosity recorded in 100% NPK+FYM (45.76% and 45.38%) and the lower in control (44.87% and 44.58%). It is important to note that consistent use of organic manure not only changed the bulk density but also improved the soil's porosity and other physical characteristics. Thangasamy *et al*. (2017) in a long-term field experiment and Arya *et al*. (2022) obtained similar findings.

Water holding capacity (WHC)

Perusal of the data expressed the significant effect of different nutrient sources on water holding capacity of soil (Table 1.). Water holding capacity of soil at depth 0-15, 15-30, 30-45, and 45-60 cm varied from their minimum values of 43.03, 40.09, 39.22 and 38.70 per cent under control to maximum values of 47.68, 46.34, 44.10 and 41.71 per cent under treatment 100% NPK+FYM. In surface soil (0-15 cm), the WHC obtained in 100% NPK+ FYM was at par to 150% NPK and minimum value obtained under control treatment at depth 30-45 cm was at par to 50% NPK, 100% N, and 100% NP. Continuous application of organic matter increases macro and micro pores, which retains more water in soil and decrease in WHC with increase in soil depth might be due to more compaction of deeper layers (Bhavya *et al*. 2018) Similar results were obtained by Karikatti *et al.* 2020.

Conclusion

Present study concluded that long-term application of organic and inorganic sources in combinations had significantly improved the physical properties like bulk density, porosity, and water holding capacity of soil. However, a non-significant effect of differential nutrient management on particle density was evident and supports it as an intrinsic property of soil.

Table 1 Effect of different long-term nutrient management practices on physical properties.

Soil Depth (cm) Treatment	Particle Density (Mg m^{-3})				Bulk Density (Mg m^{-3})			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
CONTROL	2.58	2.58	2.58	2.59	1.38	1.40	1.42	1.43
100% NP	2.57	2.58	2.59	2.60	1.34	1.35	1.41	1.43
100% NPK	2.58	2.59	2.59	2.59	1.33	1.35	1.41	1.42
100% NPK + FYM	2.56	2.57	2.58	2.60	1.31	1.34	1.40	1.42
100% N	2.57	2.57	2.58	2.59	1.37	1.38	1.42	1.43
50% NPK	2.57	2.58	2.59	2.59	1.36	1.37	1.42	1.43
150% NPK	2.58	2.58	2.59	2.60	1.32	1.35	1.41	1.43
SEm±	0.010	0.009	0.005	0.006	0.009	0.006	0.010	0.007
C.D. ($p=0.05$)	NS	NS	NS	NS	0.028	0.019	NS	NS

Soil Depth (cm) Treatment	Porosity (%)				Water holding capacity (%)			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
CONTROL	46.28	45.64	44.87	44.58	43.03	40.09	39.22	38.70
100% NP	47.92	47.54	45.35	44.89	44.23	42.53	41.10	40.85
100% NPK	48.44	47.67	45.61	44.96	44.47	43.40	41.27	38.72
100% NPK + FYM	48.82	47.75	45.76	45.38	47.68	46.34	44.10	41.71
100% N	46.79	46.19	45.03	44.88	43.25	42.62	39.04	38.75
50% NPK	47.07	46.90	45.00	44.62	43.55	42.30	40.42	39.07
150% NPK	48.66	47.75	45.61	45.17	45.22	43.28	41.34	40.97
SEm±	0.352	0.239	0.401	0.264	0.866	0.852	0.612	0.672
C.D. ($p=0.05$)	1.086	0.736	NS	NS	2.668	2.625	1.884	2.069

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