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Impact of Continuous Application of Fertilizer and Organic Manure on Soil Physical Properties of a Vertisol in Central India

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ABSTRACT: The field experiment was conducted during rabi season during 2017-18 and 2018-19 at the AICRP-LTFE project of Research Farm, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, India chosen for this study. The impact of continuous application of fertilizer and organic manure on physical properties of a Vertisol. The experiment was conducted in a randomized block design with ten treatments in four replications. The treatments viz., 50% NPK, 100% NPK, 150% NPK, 100% NPK+Hand weeding, 100% NPK+Zn, 100% NP, 100% N, 100% NPK+FYM, 100% NPK-S and Control. The response of various treatment on physical properties of soil at harvest of wheat crop were studied. The representative soil samples were collected at crop harvest from surface soil (0-15 cm) depth and analysed for soil bulk density, soil moisture content (0.33 and 15 bar), mean weight diameter and water stable aggregates. The results revealed that, the soil water retention at 0.33 and 15bar, MWD and WSA were significantly influenced under combined application of balanced fertilizer (100% NPK) and FYM. However, the soil bulk density did not show any significant change in surface soil. The study indicates that sole application of balanced fertilizers in combination with farm yard manure improve the soil physical properties of a Vertisol. Similarly, the application of balanced application of fertilizer showed higher moisture content, MWD and WSA as compared to imbalanced nutrition.

Keywords: continuous fertilizer application, bulk density, soil aggregation, Vertisol, soil moisture retention.

INTRODUCTION

Sustainable agriculture mainly depends on the soil quality. Soil quality integrates with the soil properties. Long term experiments are the best way to change in soil quality. Fertilizers are the key inputs for increasing agricultural production but their continuous and imbalanced application deteriorates the soil health (NAAS, 2009; Rajput *et al*., 2016). Organic carbon management improves the soil health and sustainability (Aher *et al*., 2018). long term fertilizer and manure application to the soil significantly affected the soil physical properties of viz., soil bulk density, aggregates distribution, water stable aggregates, mean weight diameter, soil moisture content (Hati *et al*., 2007; Karami *et al*., 2012). Various factors contribute to loss of soil organic matter (SOM) levels such as lower level of carbon to the soil, imbalanced fertilizer application, removal crop residues, tillage induced aggregates disruption, more favourable condition for decomposition and greater losses of surface soil by water erosion (Manna *et al*., 2012). Organic matter inputs are key element which increase the soil organic carbon for agricultural management. Integration of manures and compost either sole or in combinations with the inorganic fertilizers increase crop productivity and improvement in soil physic-chemical properties throughout the world including diverse Indian soils and crops (Raghuveer *et al.*, 2016).

Application of continuous and higher quantity of inorganic fertilizers will increase the crop yield in preliminary years but influence the capacity of soil to supply plant nutrient and induces the deficiency of micronutrients (Bangre *et al.*, 2020). The optimum crop yield has been limited by many factors such as quality of seed, irrigation water availability, weather, agronomic practices, type of soil, soil nutrient status etc. Among them, deterioration in soil fertility due application of imbalanced fertilizers has been identified as most important factor (Indoria *et al.*, 2018; Dotaniya *et al*., 2020). The loss of organic carbon content is the main reasons for loss of soil fertility and it can be prevented by balanced fertilizer application and external addition of organic carbon to the soil (Aher *et al*., 2012; Aher *et al*., 2015).

Changes in soil properties, health and nutrient supply capacity of soil are slow processes and hence require long-term monitoring. Long-term monitoring allows both the identification of current changes in the soil and prediction of future changes (Antil and Singh, 2007). The capacity of the plant to produce higher yields is based on the availability of adequate plant nutrients. Use of one or two major nutrients will not be sufficient for maintaining the sustainability of crop production technology for long term bases (Bangre *et al*., 2020). Also, the information on the relationship between allocation of long-term chemical fertilizers in varied magnitudes and with organic manures and important physical properties of a Vertisol of Central India is lacking. Hence, the present study was conducted in a Vertisol of Central India with different combinations of chemical fertilizers with the objective to examine the changes in important soil physical properties

MATERIALS AND METHODS

Experimental site, climate and soil characteristics: This investigation was showed as a part of a continuing project All India Coordinated Research Project (AICRP) on Long Term Fertilizers Experiment (LTFE) of the Indian Council of Agricultural Research (ICAR). It is situated in the Kymore Plateau and Satpura Hills agricultural region of Madhya Pradesh, at 23.90N latitude and 79.60E longitudes, at an altitude of 411.8 m above mean sea level. Jabalpur is in the semi-arid region of India and has a sub-tropical climate with hot, dry summers, and cold winters. The average annual rainfall is about 1350 mm. maximum and minimum temperatures are respectively over 35°C and 5.3°C. The average relative humidity was 62%. This soil was neutral in reaction (pH 7.6), (EC 0.18 dS m^{-1}), medium in organic carbon (0.57%) and low in available N (193 kg ha^{-1}) and P (7.6 kg ha^{-1}) and 370 kg ha^{-1} soil available K.

Treatment details: The field experiment has been in continuance since 1972 with 10 different treatments with each replicated four times in a randomized block design consist of gross plot size 17m × 10.8m with 1m spacing between plots and 2m spacing between the replication with wheat (cv.GW-366). The treatments comprised were 50% NPK, 100% NPK, 150% NPK, 100% NPK+Hand weeding, 100% NPK+Zn, 100% NP, 100% N, 100% NPK+FYM. The recommended dose of fertilizers applied to the wheat crop (120:80:40 $kgha^{-1}$) N, P_2O_5 and K_2O. N was applied through urea, P was applied through SSP (single super phosphate) except in treatment 100% NPK-S P was applied through DAP (Diammonium phosphate) and K was applied through murate of potash. The FYM was applied @ 5t ha^{-1} year-1 to soybean crop only.

Soil sampling, analysis and statistics: Soil samples were collected after harvesting of wheat crop during 2017-2018 & 2018-19 from the surface soil (0-15cm) of all the four replications of ten treatments. The composite soil samples were prepared by quartering technique. The soil samples were mixed to get a composite sample and finally the processed samples were used for analysis of physical properties. The soil moisture determined was determined by the difference between the water retained at field capacity and permanent wilting point using pressure plate apparatus (Richards, 1954). The bulk density was determined by core method as given by (Blake and Hartge 1986). The water stable soil aggregates determined by wet sieving using the Yoder apparatus (Yoder, 1936) and mean weight diameter (MWD) was calculated as per Kemper and Rosenau (1986) as follows:

$$MWD = \sum_{i=1}^{n} wi\bar{X}i$$

Where, MWD represents mean weight diameter, sum of products of I, the mean diameter $\bar{X}i$, of each size fraction and wi is the proportional of the total sample mass, occurring in corresponding size fraction, and the summation was carried out over all *n* size fractions, including the one that passes through the finest sieve.

The data obtained was compiled and analysed by statistical procedure appropriate for randomized block design at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The data affecting to the influence of long term2w application of inorganic fertilizer with organic manure on soil bulk density, soil moisture content at field capacity (0.33 bar) and permanent wilting point (15 bar), mean weight diameter and water stable aggregate recorded during 2017-18, 2018-19 and pooled of two years is presented in Table 1, 2 and 3, respectively.

Table 1: Impact of continuous application of fertilizer and organic manure on soil physical properties in 0-15 cm depth (2017-18).

Treatments	BD (Mg m^{-3})	Soil Moisture Retention (%)		MWD (mm)	WSA (%)
		at 0.33 bar	at 15 bar		
50% NPK	1.35	23.0	13.4	1.06	52.8
100% NPK	1.36	25.6	16.1	1.16	58.1
150% NPK	1.36	28.7	18.3	1.26	63.1
100%NPK+HW	1.34	23.8	15.5	1.18	59.3
100% NPK+Zn	1.36	24.2	16.4	1.19	59.7
100% NP	1.37	23.3	15.7	1.08	55.2
100% N	1.37	20.6	12.5	0.93	50.8
100% NPK+FYM	1.29	29.0	18.5	1.28	64.0
100% NPK-S	1.36	24.5	16.1	1.15	56.4
Control	1.38	20.3	12.2	0.92	49.7
SEm±	0.02	0.8	0.62	0.03	1.47
CD (0.05)	NS	2.33	1.79	0.08	4.26

Table 2: Impact of continuous application of fertilizer and organic manure on soil physical properties in 0-15 cm depth (2018-19).

Treatments	BD (Mg m^{-3})	Soil Moisture Retention (%)		MWD (mm)	WSA (%)
		at 0.33 bar	at 15 bar		
50% NPK	1.34	23.6	13.3	1.08	53.1
100% NPK	1.35	26.1	16.2	1.18	59.3
150% NPK	1.35	28.8	18.8	1.28	64.5
100%NPK+HW	1.33	24.4	15.8	1.19	60.2
100% NPK+Zn	1.35	25.3	16.4	1.21	60.6
100% NP	1.36	24.8	15.9	1.10	56.8
100% N	1.37	22.0	12.6	0.95	51.5
100% NPK+FYM	1.28	29.1	19.0	1.29	65.0
100% NPK-S	1.35	25.1	16.4	1.16	58.4
Control	1.37	21.1	12.4	0.89	50.2
SEm±	0.02	0.71	0.73	0.03	1.74
CD (0.05)	NS	2.07	2.11	0.09	5.05

Table 3: Impact of continuous application of fertilizer and organic manure on soil physical properties in 0-15 cm depth (pooled of two years).

Treatments	BD (Mg m^{-3})	Soil Moisture Retention (%)		MWD (mm)	WSA (%)
		at 0.33 bar	at 15 bar		
50% NPK	1.35	23.3	13.3	1.07	53.0
100% NPK	1.36	25.9	16.2	1.17	58.7
150% NPK	1.36	28.7	18.6	1.27	63.8
100%NPK+HW	1.34	24.1	15.7	1.19	59.8
100% NPK+Zn	1.36	24.8	16.4	1.20	60.2
100% NP	1.37	24.1	15.8	1.09	56.0
100% N	1.37	21.3	12.5	0.94	51.1
100% NPK+FYM	1.29	29.0	18.8	1.29	64.5
100% NPK-S	1.36	24.8	16.3	1.16	57.4
Control	1.38	20.7	12.3	0.91	50.0
SEm±	0.02	0.76	0.68	0.03	1.61
CD (0.05)	NS	2.20	1.95	0.09	4.66

Bulk density: The pooled data of bulk density (0-15 cm) under different treatment combinations showed that it was varied from 1.29 to 1.38 Mg m^{-3}. The highest bulk density was recorded in control (1.38 Mg m^{-3}) followed by 100% N (1.37 Mg m^{-3}) and 100% NP (1.37 Mg m^{-3}). The lowest bulk density was observed under 100% NPK+FYM (1.29 Mg m^{-3}). However, the changes in BD under these treatments were not found statistically significant. Generally, the soil decreases by the addition of FYM within organic fertilizers and increases with the use of imbalanced fertilizers, the present study also revealed the similar findings; however, the differences in the results were marginal and non-significant.

The change in soil BD upon organic matter application might be due to build up and decline of soil structure (Bellaki *et al.*, 1997). Continuous application of inorganic fertilizers along with organics manure for 47-year cropping cycles caused highest decrease in the BD of soil due to addition of higher organic carbon that resulted in more pore space and good soil aggregation (Chaudhary and Thakur 2007). The present findings are in good agreement of those reported by Walia and Dhaliwal (2010) who noticed integrated nutrient application reduced the bulk density of soil as compared to the treatments using inorganic nutrients alone and control treatment as well. The BD of soil changes very slowly and showed marginal variations during long period.

Soil moisture content at 0.33 bar and 15 bar: The soil moisture content at field capacity (0.33 bar) was significantly influenced by various treatment. The soil moisture content at (0.33bar) varied from 20.7 to 29.0% among the treatments. The maximum moisture content was observed in the treatment receiving 100% NPK +FYM (29.0%) followed by 150% NPK (28.7%) and 100% NPK (25. 9%). The lowest value was recorded in control (20.7%) followed by 100% N (21.3%). The long-term application of inorganic nutrient along with organic manure significantly increased the soil moisture content at field capacity. Similarly, the soil moisture content at permanent wilting point (15 bar) varied from 12.3 to 18.8% among the studied treatments. The data showed that the application of 100 % NPK + FYM had the highest moisture content at permanent wilting point followed by 150% NPK (18.6%) and 100% NPK+Zn (16.4%). The lowest value was recorded in control (12.3 %) followed by 100% N (12.5%). The data showed the effect of long-term application of integrated nutrients on soil moisture content at the harvest of wheat crop. The addition of organic manure along with inorganic nutrients significantly increased the soil moisture content which is attributed to the build-up of organic carbon, good aggregation and better porosity which promoted the adhesive force of soil matrix that enhanced the moisture holding capacity of soil. Findings of Chesti *et al.*, (2013) have also emphasized that continuous application of organic manures along with balance fertilizers increases soil moisture content with depth under soybean-wheat cropping system.

Mean weight diameter: The mean weight diameter in surface soil varied from 0.91 to 1.29 mm between the treatments under study. The highest MWD value of 1.29 mm was recorded in treatment receiving 100% NPK+FYM followed by 150% NPK (1.27 mm). The lowest MWD was observed under unfertilized control (0.91 mm). Aher *et al.,* (2019) also observed higher MWD under organic manure application as compared to the sole chemical fertilizer application and unfertilized control. The MWD of soil aggregates was significantly affected by different treatments combination which might be the result of binding ability of organic carbon which facilitated the building of larger soil aggregates. The accumulation of organics sources improves the binding ability of organic carbon, which facilitated the formation of larger soil aggregates. It was due to higher organic carbon content and organic acid secretion in surface soil from the added organics from the fresh organic residue resulting in the production of microbial polysaccharides that increase aggregate cohesion, as reported by Aulakh *et al.*, (2013). The continuous application of inorganic fertilizers did not show any improvement in the MWD ultimately indicating enormous need of organics to enhance such a critical soil physical property which is ponded within the remedies of INM. For development in soil shape, soil aggregates are a fundamental element that is prompted through different factors, like addition of organic sources, their fabricated from decomposition, crop impact of balanced fertilization on soil aggregates can be due to the position played via phosphate ion in bindings of soil particle or because of larger number of natural residues formed. The organic remember stabilizes the aggregates through forming and strengthening bonds among quartz debris and clay domain names (Emerson, 1977). The beneficial impact of the lengthy-time period utility of balanced dose of chemical fertilizers on my own or in mixture with organic manures on the development of aggregation said by using Acharya *et al.,* (1988).

The improvement in physical properties of soil and extended organic carbon content is probably liable for stabilization of aggregates and therefore higher MWD with the application of 100% NPK and organic manure have been noticed. The findings of Bandyopadhyay *et al*., (2010). The consequences of the present examine are nicely supported with the findings of Samahadthai *et al*., (2010) found that MWD of soil aggregates has multiplied due to application of inorganic fertilizers together with natural source (FYM) below soybean-wheat cropping system. The outcomes further confirmed that imply weight diameter of soil aggregates after harvest of wheat was better than those obtained on the harvest of soybean crop which may be due to decomposition of FYM and plant biomass of soybean in soil.

Water stable aggregates: Two-years pooled data showed that the water-soluble aggregates (WSA) varied from 50.0 to 64.5% among different treatment combinations. The highest water stable aggregates were found under the treatment balanced application of nutrient with organic manure followed by super optimal dose of fertilizer i.e.150% NPK (63.8%). The lowest water stable aggregate percentage was observed in treatment control (50.0%). It was also observed that balanced dose of fertilization and excess of balanced dose (150%NPK) maintained greater WSA values over the sub-optimal doses of nutrients. Soil aggregation is characterized by MWD and percent water stable aggregates (%WSA). It is also evident from the results that per cent larger sized water stable soil aggregates in surface soil were improved due to integrated use of FYM &inorganic fertilizers as compared to imbalance application of inorganic fertilizers alone. However, the effect of treatments of balanced (100% NPK and 150% NPK) use of inorganic nutrients on different size fractions of water stable aggregates was on par to those obtained in balance fertilizer with organic manure treatment. It might be due to cementing behaviour of organic carbon which promotes the size of soil aggregates. The findings are in good agreement of those reported by Gathala *et al*., (2007) and Mahmood-ul-Hassan *et al.,* (2013). They were found higher fraction of water stable aggregates under integrated nutrient management as compared to imbalanced use of chemical fertilizer treatments in the wheat crop.

The soil moisture content at 0.33bar and 15bar, MWD & WSA were significantly influenced under continuous application of balanced 100% NPK + FYM. However, the soil bulk density did not show any significant change in surface soil. The sole application of balanced fertilizers also showed positive influence on physical properties of a vertisol. Thus, the physical health of the vertisol can be achieved by balanced application of chemical fertilizers along with periodic FYM application. The improvement in physical properties of soil leads to long term sustainability of crop yield & sustenance of soil health.

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