Original Research Article   https://doi.org/10.20546/ijcmas.2020.902.103

Effect of Long Term Application of Imbalanced and Balanced Fertilization on Soil Physical Properties in *Vertisol* under Rice Wheat Cropping System

TilKumari Limboo[*], Alok Tiwari and Vinay Bachkaiya

Indira Gandhi KrishiVishwavidyalaya, Raipur, Chhattisgarh, India

**Corresponding author*

A B S T R A C T

An investigation was carried out at LTFE, Farm, IGKV, Raipur(C.G) in order to study the influence of long term application of balanced and imbalanced fertilization on different soil physical properties under rice-wheat cropping system during kharif-2018. BD, hydraulic conductivity, soil moisture content (gravimetric and volumetric), total porosity and soil temperature significantly improved with the combined use of inorganic fertilizer along with FYM. The soil (cone) penetration resistance was found higher at the maturity stage than flowering stage of rice. The lowest value of BD $1.13m^{-3}$ was achieved at depth of 0-5cm due to application of 100% NPK+FYM, while the application of 100% NPK + FYM resulted in highest HC (1.2 cm hr^{-1}), gravimetric moisture content (23.5%) and the total porosity (57.2%). The volumetric moisture was found highest in 100% NPK + FYM and 150%NPK treatment at the depth of 15-20cm (32.8%).The lowest soil temperature was found in treatment 100%NPK + FYM (16.40C). The PR was significantly lower 2.26 kN cm^{-2} in 100%NPK+FYM at the depth of 5cm in the flowering stage of rice crop. The positive significant correlations were observed between various soils physical properties, whereas BD was found negatively correlated except with soil temperature. Similarly, soil temperature is negatively correlated with all physical indices but BD. The present investigation shows the significance of balanced use of fertilizers along with FYM for improving various soil physical properties over long term conditions.

Introduction

India is the 2nd most populated country in the world after China with a population of 17.74% of the total world population (www.worldmeters.info//). By 2025, India is going to be the world most populated country. In India, Rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L.) cropping system covers about 12 million hectares (Tripathi *et al.,* 2011) and it is the backbone of country's food security with a yield potential of 8-12 t/ha/year (Ladha *et al.,* 2012). Kumar *et al.,* (2016), by 2030, the demand of total food grain will reach 311Mt involving 122 Mt of rice, 115 Mt of wheat, 47 Mt of coarse grains and 27 Mt of pulses. The use of unbalanced fertiliser leads to an unhealthy plants. Therefore, use of balanced proportions of fertilizer and in sufficient quantity is necessary. Application of balanced fertilisation improves HC, soil moisture

content, porosity and decreases bulk density and soil strength (cone penetration). Observing all the negative impact of chemical fertilizers on soil health arouse an idea of using organic materials as a nutrient source to conserve the physical, chemical and biological properties of soil from further deterioration.

The result of uncontrolled use of mineral fertilizer poorly affected physicochemical properties of soil, which resulted in decreasing productivity of rice-wheat cropping system (Kakraliya *et al.,*2017). The soil physical, chemical and biological properties improve by organic manure application and also enhance the crop productivity vis-à-vis maintain soil health.

The combined application of manures and compost resulted in higher SOC content than the application of the same amount of inorganic fertilizers. Several studies have reported that inorganic N application along with FYM in irrigated systems resulted in reduced bulk density, higher hydraulic conductivity and SOC and also improved soil structure and microbial communities.

In general, the continuous cultivation of crops leads to the reduction in SOC and soil physical properties. A combination of organic amendments and inorganic fertilizers is considered as strategy of INM in order to sustain agronomic productivity and to improve soil fertility.

The combine use of organic and inorganic nutrient source in INM has supplied higher nutrients than the use of each component separately (Palaniappan and Annadurai, 2007). Long term experiments is more advantageous for reviewing the changes in soil properties and finding information on agricultural sustainability developing future strategies to maintain soil health.

Materials and Methods

The present study was conducted in kharif-2018at Long Term Fertilizer Experiment (LTFE) Farm, I.G.K.V, Raipur, Chhattisgarh which was initiated in 1999. The experimental site lies at 22° $33^{'}$ N to 21° $14^{'}$ N latitude and 82° $6^{'}$ E to 81° $38^{'}$ E Longitude with the altitude of 293m above MSL.

The field experiment has been laid in Randomized Block Design (RBD) in three replications with ten treatments comprising control, N, NP, NPK at varying doses alone and with $ZnSO_4$ (10 kg ha^{-1}), FYM(5 t ha^{-1}), BGA(10 $kgha^{-1}$ dry culture) in kharif crop only and GM (sown in site and mixed in soil in kharif season only). The N, P and K were provided as per treatment details through urea, single super phosphate and muriate of potash, respectively.

Soil sampling and analysis

Soil samples were collected from four depths (0-5, 5-10, 10-15 and 15-20cm) from all the replications at the maturity stage of rice in 2018. The soil bulk density at desired depths was determined by core sampler method (Blake, 1965). Soil moisture content was determined by gravimetric method whereas volumetric moisture content was calculated by using the formula $(\theta v\%) = \theta w \ X \ BD$. The hydraulic conductivity was measured in the field at the depth of 0-20cm with the constant head in-situ method using the Guelph permeameter.

The soil strength (Penetration resistance) was measured with the instrument soil static penetrometer at the depth of 5, 10 and 15cm. Soil temperature was measured with the instrument called soil digital thermometer and the soil total porosity was estimated from the bulk density and the particle density by using the equation:

$$\text{Total porosity (\%)} = 1 - \frac{\text{Bulk density}}{\text{Particle density}} \times 100$$

Where, particle density was taken constant *i.e.,* 2.65 Mg m^{-3}.

Results and Discussion

The bulk density (BD) samples were taken at the maturity stage of rice crop at four depths (0.0-5, 5-10, 10-15 and 15-20cm). Significant differences in BD values between different treatments at all the depths were observed. In general, BD increased with increase in soil depth. The lower value of BD 1.13, 1.16, 1.19 and 1.23Mg m^{-3}at depth of 0-5, 5-10, 10-15 and 15-20 were recorded in 100% NPK+FYM treatment and the control plot showed the highest i.e., 1.33, 1.36, 1.4 and 1.48 Mg m^{-3},respectively that was on par with imbalanced inorganic fertilized treated plots (Table 1). Significant influence on bulk density of soils was observed under different organic sources over control. Suwara *et al.,* (2016) found that the application of farm yard manure lead bulk density to decrease from 0.03–0.09 Mg/m^3 compared to unfertilised and mineral fertilized soil. Kumar *et al., (*2017) also reported the significant reduction in BD in the plot treated with bulky organic manures over in-situ green manuring and concentrated organic manures. Bhatt *et al., (*2017) found a significant improvement in BD with the combined use of inorganic fertilizers along with FYM in surface and sub-surface layer by 7.71-8.55 and 7.31-8.12 percent, respectively over the control.

At the depth of 0-5cm 100%NPK + FYM treatment showed the highest gravimetric moisture content (23.5%) followed by 150%NPK (22.2%).The gravimetric moisture content increased with the increase of depths (Table 2). So, the highest moisture content was found at 15-20cm depth in treatment 100%NPK+FYM (26.6%) followed by 150%NPK (25.2%). Gedaya *et al., (*2018) also reported the high soil moisture retention with the application of FYM as well as fertilizers. Similar finding was revealed by Yang *at al.* (2011) where the MNPK treatment retained more water than NPK and CK treated soil for 0-5cm layer at the tension ranges from 0 to 0.25 kPa and from 8 to 33 kPa.

The lowest gravimetric moisture was found in the control for all the four depths i.e., 15.7, 17.3, 18.1 and 18.7 %, followed by 100%N (17.4, 18.0, 18.3 and 18.7%), respectively. The similar trend was also found in volumetric moisture content. Volumetric moisture was found highest in 100% NPK + FYM and 150 % NPK treatment at the depth of 15-20cm (32.8%) whereas at the upper soil layer 100% NPK + FYM treated plot has higher moisture than 150%NPK treatment (Table 3). The lowest volumetric moisture was observed under control at all the four depths of soil (21.2, 23.5, 25.4 and 27.6 %), respectively. Singh *et al.*(2000) also reported the advantage of FYM in increasing the moisture content. From the above results it gave the idea that the application of soil organic matter continuously into the soil retains more available water at deeper layer.

The saturated hydraulic conductivity was significantly improved by the organic and inorganic fertilizers but the more evident effect was found when organic manures integrated along with inorganic fertilizers than inorganic fertilizers alone. The highest hydraulic conductivity (HC) was found in 100% NPK + FYM (1.2 cm hr^{-1}) and the control showed the lowest hydraulic conductivity (0.78 cm hr^{-1}) (Table 4). Increase in HC may be due to increase soil organic carbon content of higher root biomass with application of fertilizer and more aggregate formation with the presence of FYM (Nandapure *et al.,* 2014 and Dhaliwal *et al.,* 2015). Kumar *et al.,* (2017) also reported the

improvement of hydraulic conductivity in Vertisol with the plant nutrient provided through organic manures. Pant *et al., (2018)* also witnessed the increase in hydraulic conductivity with an application of fertilizer and addition of FYM further indicated the constructive effect on soil properties. Kaje *et al., (2018)* and also witnessed the similar finding. Katkar *et al., (2012)* recorded the higher hydraulic conductivity in soil treated with NPK + farm yard manure @ 10 tonnes/ha than 150% NPK and 100% NPK through chemical fertilizers without organics. Xin *et al., (2016)* also observed the use of balanced fertilizer enhanced the hydraulic conductivity than the application of unbalanced fertilizers.

Soil strength, as measured penetration resistance (PR), increased with soil depth under balanced as well as imbalanced fertilization in soil (Table 5). The PR value was found greater at maturity stage than the flowering stages showing that the PR increases with increase in the root proliferation. At the depth of 5cm in the flowering stage of crop, PR was significantly lower 2.26 kN cm^{-2} in 100%NPK + FYM followed by 2.46 kN cm^{-2} in 50%NPK + GM and 2.51 kN cm^{-2} in 150%NPK. At the depth of 10 cm, the PR was significantly lower 2.95 kN cm^{-2} in 100 % NPK + FYM and 3.63 kN cm^{-2} in100%NPK + FYM at 15cm of depth. PR increased in the same fashion at all the depths amongst various treatments. The highest PR value was recorded in Control plot 3.9, 4.59 and 6.25 kN cm^{-2} at respective depths. The values significantly increased near maturity than the flowering stage. Similarly, the lowest PR value was found in 100%NPK+FYM that was at par with 50%NPK+GM and 150%NPK for all the depths. The lowest PR value was 2.6kN cm^{-2} in 100%NPK+FYM for 5cm and 3.9 and 4.0 kN cm^{-2} for the depth of 10 and 15 cm,

respectively were observed at maturity stage. The control plot had shown the highest PR value *i.e.,* 4.2, 5.6 and 6.4kN cm^{-2} at all the depths, respectively. Celik *et al.,* (2010) reported the low penetration resistance in the soil amended with manure and compost. Agarwal *et al., (*2010) also reported the significant reduction in PR due to application of manures whereas the increase in PR with depth of 25cm, then at 25-40cm it decreased and again increased below 40cm was observed by (Quang *et al.,* 2012). The similar findings were reported by Bhogal *et al., (2018).*

The lowest soil temperature was found in treatment 100%NPK + FYM i.e., 16.4^{0}C and 15.8^{0}C followed by 50%NPK+GM (17.6^{0}C and 16.5^{0}C) for 0-5 and 5-10cm, respectively (Table 6). The highest soil temperature was observed under control for both the depths (0-5 and 5-10cm) i.e., 24.2 and 23.7^{0}C, respectively. Nwankwo *et al.,* (2012) also concluded the decrease in soil temperature with increasing depth and thereafter started to increase with depth.

There was a greater total porosity in the 100 % NPK + FYM and 50% NPK + GM treatments compared to the control and 100% alone inorganic fertilizers plots in all the depths. The significant higher porosity was observed under 100%NPK+FYM treatment (57.2, 56.1, 55.0, 53.5%) at all the four undertaken depths i.e., 0-5, 5-10, 10-15 and 15-20cm, respectively, over other treatments (Table 7). The control plot showed the lowest porosity percentage that was on par with imbalanced inorganic treated plots 100% NP and 100% N in all the depths. Yang *et al.,* (2011) reported the increase in total porosity in the plot treated with MNPK with a lower bulk density than NPK and CK treated plots (p ≤ 0.1 at 0–5cm and p ≤ 0.01 at 10–15cm).

Table.1 Effect of inorganic fertilizer and organic manure on bulk density at various depths at maturity stage of rice

Treatments	Bulk density (Mg m^{-3})			
Depths (cm)	0-5	5-10	10-15	15-20
Control	1.33	1.36	1.40	1.48
50% NPK	1.29	1.33	1.37	1.41
100%NPK	1.21	1.25	1.26	1.30
150% NPK	1.20	1.22	1.25	1.29
100% NPK + ZnSO$_4$	1.24	1.26	1.28	1.32
100% NP	1.29	1.31	1.33	1.34
100% N	1.30	1.33	1.39	1.45
100% NPK + FYM	1.13	1.16	1.19	1.23
50 % NPK + BGA	1.26	1.28	1.29	1.33
50% NPK + GM	1.16	1.18	1.22	1.27
CD (5%)	0.11	0.16	0.17	0.17

Table.2 Gravimetric moisture content as affected by the continuous application of fertilizers and organic manure at maturity stage of rice

Treatments	Gravimetric moisture content (θ_w%)			
Depths (cm)	0-5	5-10	10-15	15-20
Control	15.7	17.3	18.1	18.7
50% NPK	18.5	19.3	20.0	20.4
100%NPK	21.2	21.3	22.4	22.9
150% NPK	22.2	23.6	23.8	25.2
100% NPK + ZnSO$_4$	20.8	20.8	21.4	22.1
100% NP	20.7	20.8	20.9	21.3
100% N	17.4	18.0	18.3	18.7
100% NPK + FYM	23.5	24.5	25.4	26.6
50 % NPK + BGA	18.9	19.4	20.2	20.5
50% NPK + GM	21.2	23.3	23.5	24.0
CD (5%)	3.6	3.75	3.86	3.56

Table.3 Volumetric moisture content as affected by the continuous application of fertilizers and organic manure at maturity stage of rice

Treatments	Volumetric moisture content (θ_v %)			
Depths (cm)	0-5	5-10	10-15	15-20
Control	21.2	23.5	25.4	27.6
50% NPK	24.3	25.8	27.5	28.7
100%NPK	26.1	26.4	28.4	29.8
150% NPK	26.7	28.8	29.8	32.8
100% NPK + ZnSO$_4$	25.6	26.4	27.5	29.3
100% NP	27.0	27.0	28	28.6
100% N	23.4	23.9	25.5	27.0
100% NPK + FYM	27.0	28.5	30.0	32.8
50 % NPK + BGA	24.0	24.9	26.0	27.4
50% NPK + GM	24.6	27.4	28.7	31.0
CD (5%)	4.8	4.5	5.7	7.3

Table.4 Effect of balanced and imbalanced application of fertilizer on Hydraulic conductivity at flowering stage of rice

Treatments	Hydraulic conductivity (cm hr^{-1})
Depths (cm)	0-20
Control	0.78
50% NPK	0.92
100%NPK	1.0
150% NPK	1.03
100% NPK + ZnSO$_4$	1.01
100% NP	0.85
100% N	0.75
100% NPK + FYM	1.2
50 % NPK + BGA	1.08
50% NPK + GM	1.13
CD (5%)	0.14

Table.5 Effect of continuous application of balanced and imbalanced fertilizer on soil strength

Treatments	Cone resistance (kN cm^{-2}) Flowering stage			Cone resistance (kN cm^{-2}) Maturity stage		
Depths (cm)	5	10	15	5	10	15
Control	3.91	4.59	6.25	4.2	5.6	6.4
50% NPK	3.51	4.16	5.93	3.6	5.3	6.0
100%NPK	2.62	3.43	4.83	3.0	4.5	4.9
150% NPK	2.51	3.33	4.77	2.9	4.4	4.8
100% NPK + ZnSO$_4$	2.81	3.88	4.83	3.2	5.0	5.1
100% NP	2.89	4.0	5.25	3.3	5.1	5.3
100% N	3.61	4.31	6.18	3.7	5.4	6.2
100% NPK + FYM	2.26	2.95	3.63	2.6	3.9	4.0
50 % NPK + BGA	3.18	4.12	5.56	3.4	5.2	5.5
50% NPK + GM	2.46	3.13	4.47	2.9	4.4	4.5
CD (5%)	0.57	0.67	0.89	0.6	0.88	0.9

Table.6 Effect of balanced and imbalanced fertilizer on soil temperature at maturity of rice

Temperature (^{o}C)		
Depths (cm)	0-5	5-10
Control	24.27	23.7
50% NPK	23.0	22.7
100%NPK	19.2	18.2
150% NPK	18.9	17
100% NPK + ZnSO$_4$	19.9	19.5
100% NP	20.7	20
100% N	23.2	23.1
100% NPK + FYM	16.4	15.8
50 % NPK + BGA	21.4	21
50% NPK + GM	17.6	16.5
CD (5%)	3.3	3.7

Table.7 Effect of long term application of balanced and imbalanced fertilizer on porosity at different depths at maturity of rice

Treatments	Porosity(%)			
Depths (cm)	0-5	5-10	10-15	15-20
Control	49.1	48.6	47.1	44.2
50% NPK	50.6	49.8	48.3	46.7
100%NPK	53.4	52.9	52.5	50.9
150% NPK	54.7	54	52.9	51.4
100% NPK + ZnSO$_4$	53.2	52.3	51.5	50.1
100% NP	50.8	50.5	49.9	49.4
100% N	49.6	49.8	47.6	45.4
100% NPK + FYM	57.2	56.1	55	53.5
50 % NPK + BGA	52.2	51.7	51.1	49.8
50% NPK + GM	56.3	55.6	53.9	51.9
CD (5%)	4.6	6.1	6.4	6.7

The application of organic manures along with inorganic fertilizers decreased the soil bulk density, increased soil moisture content and saturated hydraulic conductivity (K_{sat}) as well as decreased soil penetration resistance, soil temperature and increased soil porosity. Hence the integrated application of organic manures and inorganic fertilizers are recommended in order to improve the soil physical properties.

References

Bhatt, M.K., Raverkar, K.P., Labanya, R. and Chandola, J.C., 2017. Effect of inorganic fertilizers and FYM for twenty-nine years in rice-wheat cropping system improves physical soil quality indices after wheat. *IJCS*, 5(6): 152-155.

Bhogal, A., Nicholson, F.A., Rollett, A., Taylor, M., Litterick, A., Whittingham, M.J. and Williams, J.R., 2018. Improvements in the quality of agricultural soils following organic material additions depend on both the quantity and quality of the materials applied. *Frontiers in Sustainable Food Systems*, 2, 9.

Celik, I., Gunal, H., Budak, M. and Akpinar, C., 2010. Effects of long-term organic and mineral fertilizers on bulk density and penetration resistance in semi-arid Mediterranean soil conditions. *Geoderm*, *160*(2): 236-243.

Dhaliwal, M.K., Dhaliwal, S.S, Thind, H.S, and Gupta, R.K 2015.Effect of integrated nutrient management on physico-chemical parameter of soil in rice-wheat system. Agri. Res. J. 52 (2): 130-137,

Gediya, S.P. and Rajani, A.V., 2018. Long term effect of balance nutrient management on dynamics of important physical properties of a calcareous under AICRP-LTFE soils. *International Journal of Chemical Studies*, 6(5), 288-291.

Kaje, V.V., Sharma, D.K., Shivay, Y.S., Jat, S.L., Bhatia, A., Purakayastha, T.J., Bandyopadhyay, K.K. and Bhattacharyya, R., 2018. Long-term impact of organic and conventional farming on soil physical properties under rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system

in north-western Indo-Gangetic plains. *Indian Journal of Agricultural Sciences*, *88*(1): 107-113.

Kakraliya, S.K., Jat, R.D., Kumar, S., Choudhary, K.K., Prakash, J. and Singh, L.K., 2017. Integrated nutrient management for improving, fertilizer use efficiency, soil biodiversity and productivity of wheat in irrigated rice wheat cropping system in Indo-Gangetic Plains of India. *International Journal of Current Microbiology and Applied Sciences*, *6*(3): 152-163.

Katkar, R.N., Kharche, V.K., Sonune, B.A., Wanjari, R.H. and Singh, M., 2012. Long term effect of nutrient management on soil quality and sustainable productivity under sorghum-wheat crop sequence in Vertisol of Akola, Maharashtra. *Agropedology*, *22*(2): 103-114.

Kumar, M.S., Bhoyar, S.M. and Deshmukh, P.W., 2017. Influence of organic manures on soil physical properties in cotton under rainfed conditions. *IJCS*, *5*(5): 832-835.

Kumar, P., Joshi, P.K. and Mittal, S. 2016. Demand vs supply of food in India-Futuristic Projection. *Proc Indian NatnSciAcad,* 82(5): 1579-1586.

Ladha, J.K., Hill, J.E, Duxbury, J.D, Gupta, R.K and Buresh, R.J 2012.Improving the productivity and sustainability of ricewheat systems: Issues and impact. Am. Soc. of Agron, Special Publication 65. Madison, Wis. (USA): ASA, CSSA, SSSA. 211.

Mina, A., Nand, R. and Shri, R., 2010. Long-term effect of inorganic fertilizers and manure on physical and chemical properties of soil after 35 years of continuous cropping of rice-wheat. *Pantnagar Journal of Research*, *8*(1): 76-80.

Nandapure, S.P., Sonune, B.A and Patil, R.T., 2014. Long-term effects on integrated nutrient management on soil physical properties and crop productivity in sorghum-wheat cropping sequence in a vertisol. Indian J. Agric. Res. 45(4): 336-340.

Nwankwo, C. and Ogagarue, D., 2012. An investigation of temperature variation at soil depths in parts of Southern Nigeria. *American journal of environmental engineering*, *2*(4): 142-147.

Palaniappan, S.P. and Annadurai, K. 2007. Organic Farming: Theory and Practices. Scientific Publishers, Jodhpur, 169.

Pant, P.K. and Ram, S., 2018.Long-Term Manuring and Fertilization Effects on Soil Physical Properties after Forty Two Cycles under Rice-Wheat System in North Indian Mollisols. *Int. J. Curr. Microbiol. App. Sci*, *7*(7): 232-240.

Quang, P.V., Jansson, P.E. and Khoa, L.V. 2012. Soil Penetration resistance and its dependence on soil moisture and age of the raised beds in the Mekong delta, Vietnam. International Journal of Engineering Research and Development. 4(8): 84-93.

Suwara, I., Pawlak-Zaręba, K., Gozdowski, D. and Perzanowska, A., 2016.Physical properties of soil after 54 years of long-term fertilization and crop rotation. *Plant, Soil and Environment*, *62*(9): 389-394.

Tripathi, J., Adhikari, C., Lauren, J.G., Duxbury, J.M. and Hobbs, P.R. 2011. Assessment of farmer adoption of surface seeded wheat in the Nepal Tarai rice-wheat consortium paper series 19. RWC, New Delhi, India.

Xin, X., Zhang, J., Zhu, A. and Zhang, C., 2016. Effects of long-term (23 years) mineral fertilizer and compost application on physical properties of fluvo-aquic soil in the North China Plain. *Soil and Tillage Research*, *156*,

166-172.

Yang, X., Li, P., Zhang, S., Sun, B. and Xinping, C., 2011. Long-term-fertilization effects on soil organic carbon, physical properties, and wheat yield of a loess soil. *Journal of Plant Nutrition and Soil Science*, *174*(5): 775-784.