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Shiv Sing Meena
Ph.D., Research Scholar, Department of Soil Science, GBPUA&T, Pantnagar, Uttarakhand, India

Ajay Shrivastava
Professor, Department of Soil Science, GBPUA&T, Pantnagar, Uttarakhand, India

BR Meena
Assistant Professor, Department of Agronomy, SKNAU, Jobner, Rajasthan, India

Vijay Kant Singh
Assistant Pedologist, Department of Soil Science, PAU, Ludhiana, Punjab, India

Vinit Kumar
Ph.D., Research Scholar, Department of Soil Science, GBPUA&T, Pantnagar, Uttarakhand, India

Corresponding Author:
Shiv Sing Meena
Ph.D., Research Scholar, Department of Soil Science, GBPUA&T, Pantnagar, Uttarakhand, India

Long term impacts of organic manures and chemical fertilizers on different physical properties of soil in *Tarai* region of India

Shiv Sing Meena, Ajay Shrivastava, BR Meena, Vijay Kant Singh and Vinit Kumar

Abstract
Agriculture has been the backbone of the Indian economy. In India around 70 per cent of the population earns its livelihood from agriculture. It fulfils the basic need of human beings and animals. It is an important source of raw materials for many agro-based industries. All physical properties of the soil are the key factor of soil fertility. Different physical properties in soil *viz*., bulk density, particle density, hydraulic conductivity of soil and mean weight diameter etc. However the magnitudes of the impact at 0-15 and 15-30 cm soil depth are varies and alterations in the physical properties of soil are not well defined. Therefore, the present trial was conducted on long term impacts of organic manures and chemical fertilizers on different physical properties of a *Tarai* soil at the N.E. Borelog crop research centre, GB Pant University of Agriculture and Technology Pantnagar, Uttarakhand (India). The experiments plot comprising of six treatments were laid out in simple randomized block design with four replications. Treatments were i. Control, ii. 100% NPK (LTFE), iii. 100% NPK + FYM (LTFE), fallow field, poplar based agro-forestry system and eucalyptus based agro-forestry system. The particle density was lowest with plots receiving 100% NPK+FYM @ 15 t ha^{-1} (T_3) and highest PD was observed in the control plot (T_1). The values were statistically significant in both the surface and sub surface soil. The highest mean weight diameter of soil aggregates at surface and sub surface soil was observed in FYM along with 100% NPK fertilizer treated plot (T_3). This might be due to the application of FYM and chemical fertilizer significantly enhanced organic carbon status in soil and increases the MWD of soil aggregates. With respect to surface soil, saturated hydraulic conductivity varied from 0.168 to 0.344 (cm hr^{-1}). In the sub surface soil layer (15-30 cm) saturated hydraulic conductivity ranged from 0.136 to 0.257 (cm hr^{-1}). The data obtained from this experiment enhanced the understanding of long term impacts of organic manures and chemical fertilizers on different physical properties of soil in the *Tarai* region soil of UK in India.

Keywords: Bulk density, particle density, mean weight diameter, carbon

1. Introduction

Agriculture has been the backbone of the Indian economy. In India around 70 per cent of the population earns its livelihood from agriculture. It fulfils the basic need of human beings and animals. It is an important source of raw materials for many agro-based industries. Indian geographical condition is unique for agriculture because it provides many favourable conditions. There are plains, fertile soil and long growing seasons and wide variations in climatic conditions *etc.* Apart from unique geographical conditions, India has been consistently making innovative efforts with the help of science and technology to increase production. In India, various types of farming and cropping patterns are used by farmers. India has one of the largest plain areas of the world in the form of Indo-Gangetic plain. Central part of India is dominated by plateau area.

In the country, rice-wheat cropping system is very popular in Indo-Gangetic plains, occupies about 13.5 million hectares. Rice-wheat cropping system dominated mostly in Punjab, Haryana, Uttar Pradesh and Madhya Pradesh and contributes 75 per cent of the national food grain production (Sapkota *et al.*, 2017and Jat *et al.*, 2014) [15, 10]. The intensive tillage in rice- wheat croppingsystems requires much labour, water and energy, which are becoming more expensive, thus increasing the cost of production resulting in decreased profitability (Aryal *et al.*, 2015).

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. (FAO, 2015) [8]. Agroforestry system interventions provide diversified range of product from a given area leading to higher income and improved standards of life, enhanced self-sufficiency and reduced risk from climatic, biological, and market impacts, better use of underutilized land enhance food and nutritional security and increased fulfilment of social and cultural needs through product sharing and exchange (Kumar and Nair, 2004) [13].

Soil organic matter (SOM) are intrinsic and essential components of soil which act as a storehouse for nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and all essential micro and trace nutrients. It also improves various other chemical properties such as cation exchange capacity and buffering capacity of soils and also improves soil physical properties *viz.* soil structure, porosity, water holding capacity and soil drainage.

Agroforestry has great potential for restoration of degraded lands and forests and mitigating the release of carbon as CO_2 in the atmosphere by increasing land based carbon sinks. Owing to all above points the present investigation ‘‘Long term impacts of organic manures and chemical fertilizers on different physical properties of soil in *Tarai* region of India” was carried out with the objective assessment of physical properties in rice- wheat cropping systems and poplar and eucalyptus based agroforestry systems under long term use of chemical fertilizers, organic manure (FYM)

2. Materials and methods

The field experiment was conducted during the crop season, 2016-17 at Norman E. Borlaug Crop Research Centre of GBPUA&T, Pantnagar, four treatments were taken in an ongoing Long Term Fertilizer Experiment, which is being carried out at since *Kharif* 1971 and Agroforestry Research Centre of GBPUA&T, Pantnagar in which two treatments were taken from Poplar and Eucalyptus based agroforestry systems. Experiment location represents the *Tarai* belt of Uttarakhand and is situated at 29˚N latitude, 79.5˚ E longitude and at an altitude of 243.83 m above mean sea level in the foot hills of *shivalik* range of the Himalayas. The soil of experimental area is fined loamy in texture. These soils are originated from alluvial sediments. The climate of the region is humid subtropical. The average annual precipitation is 1020 mm. During summer, maximum temperature exceeds 40^0 C while in winters the minimum temperature occasionally touches 0^0 C. the experimental treatments were laid out in RBD and replicated fourth times. Six treatments combination including two field conditions were (1) Long term fertility experiments; (a.) Control (no manures and fertilizers), (b.) 100% NPK to rice and wheat both (c.) 100% NPK to both crops + FYM @ 15 t ha^{-1} (to wheat only) (d.) Fallow (without crop) (2) Agro-forestry system; (a.) 100% NPK to soybean-wheat and under Poplar trees (b.) 100% NPK to wheat under eucalyptus trees. The details of experiments are presented in Table 1.

2. 1 Experimental Site

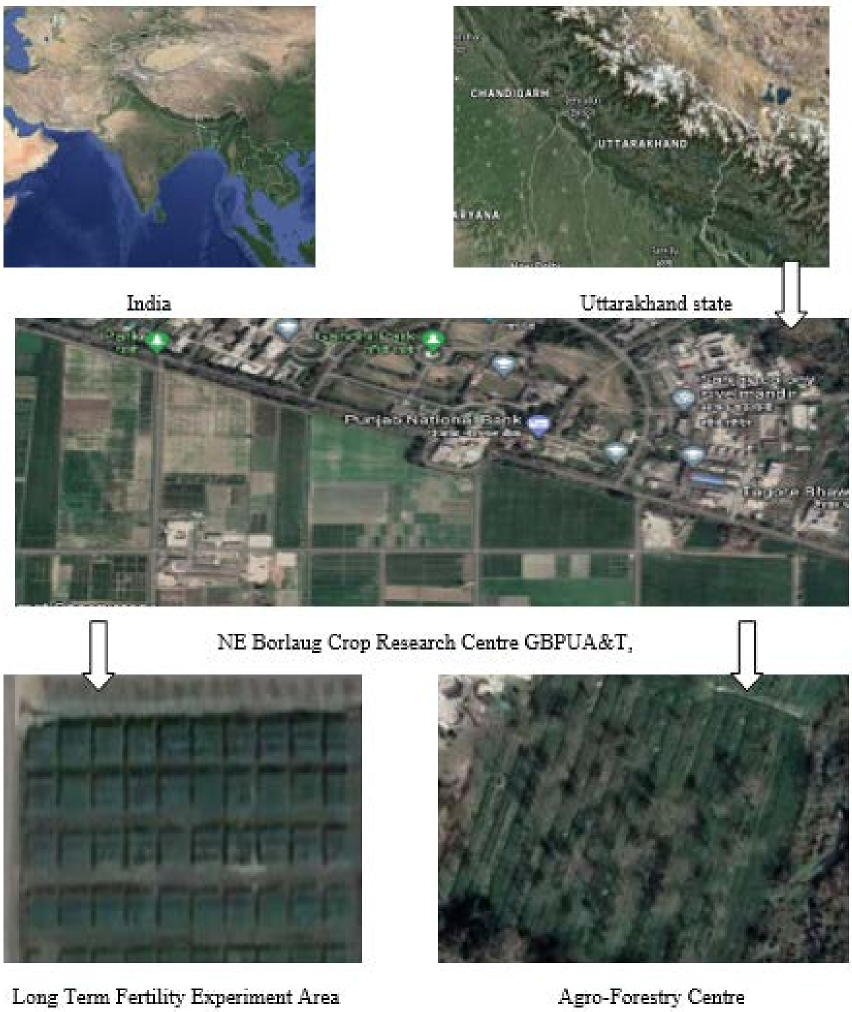

Table 1: Experimental details

S. N.	Experimental site details	GB Pant University of Agriculture and Technology, Pantnagar, UK, India
1	Duration	49 year of LTFE and 10 year of Agro-forestry
2	Tillage	Conventional tillage
3	Crop history	Rice-wheat cropping system follows from last 20 years in LTFE and Fallow-wheat cropping sysetm in AF
4	Types of soil	Fined loamy, High base saturation, developed from alluvial sediments
5	Experiment analysis design	Randomized block design (RBD) to test differences among the treatment means as described by Gomez and Gomez (1984). Correlation coefficients were computed using SPSS programme.
6	Replications	Four
7	Treatments	Six

2.2 Observations
2.2.1 Soil sampling
Soil samples were taken by the help of core sampler from two soil depths i.e. 0-15 and 15-30 cm to the experimental field after *Kharif* and *Rabi* seasons. The core and samples were weighed before and after drying in oven at 105ºC temperature for 25 hr (Gardner *et al.*, 2001). Then the soil samples air dried, broken the clods and removed the roots and other material from the sample. Thereafter the soil samples were passed through 0.2 to 0.5 mm sieve for organic fractions and 2-mm sieve for other parameters. The sieved soil samples were stored in air tight plastic beg for further analysis of Physico-chemical and biological properties.

2.2.2 Bulk density (Veihmeyer and Hendrickson, 1948)
The processed soil samples of desired depths (0-15 and 15-30 cm) were used to determine bulk density by core method. The mass of air dry soil andvolume was determined. Bulk density was calculated as the ratio of mass of oven dry soil to itstotal volume. Bulk density measurements can be done if you suspect your soil is compacted or as part of fertiliser or irrigation management plans. To account for variability, it is useful to take several measurements at the same location over time and at different depths in the soil, for example at 10, 30 and 50 cm depths to look at both the surface soil and subsoil.

$$\text{Bulk Density } (g/cm^3) = \frac{\text{Oven dry wieght of soil (g)}}{\text{Volume of soil } (cm^3)}$$

2.2.3 Particle density (Baver, 1956)
The particle density (ρ_s) also called density of soil solids, is the ratio of total mass of soil solids to total volume of soil solids and expressed in g/cm^3 or Mg/m^3. 50 mL of water take into the 100 mL graduated cylinder and addition of 20 g oven dry soil. The contents in cylinder was stirred and allowed to stand for 15 minutes. The difference between initial volume of water and final volume of soil solution (soil plus water) was recorded which represent the volume of water displaced and now occupied by the soil particle.

$$\text{Particle Density } (g/cm^3) = \frac{\text{wieght of soil solids(g)}}{\text{Volume of soil solids } (cm^3)}$$

2.2.4 Saturated hydraulic conductivity (Klute, 1965)
To determine hydraulic Conductivity, soil samples were collected in brass cylindrical rings with the help of core sampler (0.08 m diameter ring). It was determined as per constant head method (Kulte, 1965) by using following equation.

$$K_s = \frac{Vx}{At\ (\Delta H + x)}$$

Where,
K_s = saturated hydraulic conductivity (cm/sec)
V = Volume of water collected (cm^3)
A = Cross sectional area (cm^2)
(ΔH+x) = Difference in head at inlet and outlet (cm)
t = time (hr)

2.2.5 Mean weight diameter (Bavel, 1949)
The procedure used for aggregate analysis was Modified Yoder's wet sieving method. Soil samples were collected in between from 0 to 15 cm and 15-30 depth segments after *Kharif*and *Rabi* in the year of 2016-17 and 2017-2018. At the time of sampling the sample were broken gently at their natural cleavage and air dried in the laboratory. These samples were cleaned by removing roots, lime, concentration etc. The nest of five sieve having 8,2,1,0.5,0.25 and 0.125 mm opening were mounted on sieve holders in the Yodder type wet sieving machine. Air dried triplicate soil samples were used for analysis.
Out of them one sample was kept for moisture content estimation and the remaining two samples were used for aggregate analysis. In the sieve set the soil sample was placed at top sieve. Immediately prior to sieving, water level was raised rapidly to a point where it fairly covers the sample when sieve set at its highest position. Subsequently the Yodder's wet sieving standard procedure was followed.

2.2.6. Water holding capacity (Piper, 1950)
It was determined by using Hilgard apparatus in laboratory. For calculating water holding capacity of soil air dry processed soil was uniformly packed in the keen box lined with filter paper. After filling the boxes, the dry weight was taken. Soil was saturated from below by water keeping below these boxes on the tray for about 12 hrs. Then the moist weight was taken and the soil was dried in oven for 24 hrs at 105 ºC. Water holding capacity was calculated on dry weight basis.

3. Result and Discussion
3.1 Bulk density (Mg m^{-3})
A glance of the data (Table 1) revealed that bulk density slightly decreased in all over treatments except control (T_1) and 100% NPK treated plot (T_2). Soil bulk density of 0–15 cm layer varied from 1.26 to 1.51 Mg m^{-3}. The lowest bulk density of 0–15 cm layer was recorded in 100% NPK + FYM @ 15 t ha^{-1} treated plot (T_3). Soil bulk density in 15–30 cm layer it varied from 1.35 to 1.60 Mg m^{-3}. The lowest bulk density of 15-30 cm layer was recorded in 100% NPK + FYM @ 15 t ha^{-1} treated plot (T_3).
Application of 100% NPK with FYM @ 15 t ha^{-1} slightly decrease in soil bulk density at surface soil might be due to

high amount organic carbon which produces more micro and macro pore and batter soil aggregation by Singh *et al.* (2006) [16]. Obviously the highest bulk density was observed in sub-surface soils due to compaction and the results were in conformity with those of Kharche *et al.* (2013) [12] and Thakur *et al.* (2011) [19].

3.2 Particle density (Mg m^{-3})

The data furnished in table 1, indicated that particle density of soil at different soil depths. The particle density was lowest with plots receiving 100% NPK+FYM @ 15 t ha^{-1} (T_3). The values were statistically significant in both the surface and sub surface soil.

Different treatments varied significantly for particle density recorded at surface soil. The value of particle density ranged from 2.50 to 2.67 Mg m^{-3}. The lowest particle density at surface soil was recorded in 100% NPK + FYM @ 15 t ha^{-1} treated plot (T_3), whereas, the highest particle density was observed in the control plot (T_1).

The application of 100% NPK chemical fertilizer with 15 t FYM ha^{-1} significantly reduction of particle density as compared to control plot (T_1). This could be due to increasing organic carbon content which helps to formation more stable aggregate and micro and macro pore. Results of our experiment are in conformity with (Nandapure *et al*., 2014 and Dhaliwal *et al*., 2015) [14, 7]. The lowest particle density was observed under different agro-forestry tree species as compared to the agriculture field primarily due to the higher SOC content under tree species by the incorporation of organic matter through leaf litter, twigs, pruning debris *etc* (Tandel *et al*., 2009). Singh *et al*. (2018) [17] observed that the soil particle density was increased successively with the increasing soil depth from 0-15 cm to 30-45 cm under different agro-forestry systems as well as sole agriculture cropping field.

3.3 Soil mean weight diameter (MWD mm)

Critical examination of the data presented in the table 2 it was noticed that the mean weight diameter of soil aggregates was significantly influenced by the different treatments. The values were statistically significant in both the surface and sub surface soil.

The mean weight diameter recorded at surface soil varied from 0.62 to 0.90 mm. In deeper soil layer (15-30 cm) mean weight diameter varied from 0.52 to 0.78 mm. The highest mean weight diameter of soil aggregates at surface and sub surface soil was observed in FYM along with 100% NPK fertilizer treated plot (T_3). This might be due to the application of FYM and chemical fertilizer significantly enhanced organic carbon status in soil and increases the MWD of soil aggregates.

The mean weight diameter was lower in plots applied chemical fertilizer alone and in control as compared to FYM with fertilizer applied plots (Tripathi *et al*., 2014) [20]. Bhaduri *et al*. (2017) [4] found that the Mean weight diameter of aggregates was significantly less in puddled rice field than in non-puddled field. Gupta *et al*. (2009) [9] also observed that the average mean weight diameters in agro-forestry soils were higher in both surface layers than in the sole cropping systems could be due to more SOC under agro-forestry. The beating action of raindrops on soil particle could be decrease the MWD, whereas, in agro-forestry systems, the soils could have remained protected from raindrops by leaf litter which may act as mulch in addition to increasing the SOC status (Saha *et al*., 2007).

3.4 Saturated hydraulic conductivity (cm hr^{-1})

The data (Table 2) revealed that saturated hydraulic conductivity of surface and sub surface was significantly influenced by different treatments.

With respect to surface soil, saturated hydraulic conductivity varied from 0.168 to 0.344 (cm hr^{-1}). In the sub surface soil layer (15-30 cm) saturated hydraulic conductivity ranged from 0.136 to 0.257. The application of 100% NPK fertilizer with FYM recorded the highest hydraulic conductivity at surface and sub surface soil. This could be due to organic matter reduce the compaction of soil and increase capillary and non capillary pores as well as total pore space of the soil resulting increase hydraulic conductivity of soil. These results were in conformity with the findings of Bhatt *et al*. (2017) [5] and Das (2007) [6].

The hydraulic conductivity was lower in plots applied chemical fertilizer alone and in control as compared to FYM with fertilizer applied plots. Agarwal (2008) [1] also reported that HC varied from 0.67 to 0.85 mm hr^{-1}. The fertilizer treatments showed a significantly effect on hydraulic conductivity. Lowest hydraulic conductivity was recorded in control.

3.5 Soil water holding capacity (%)

Data as regards the effect of various treatments on water holding capacity of soil presented in table 2 indicated that the treatments effect was significant.

The water holding capacity recorded at surface soil varied from 51.23 to 71.85. The water holding capacity in surface soil recorded in 100% NPK +15 t FYM ha^{-1} treated plot (T_3) was found 40.24. In deeper soil layer (15-30 cm) water holding capacity varied from 48.82 to 64.19. In sub surface soil 100% RD NPK + FYM @ 15 t ha^{-1} treated plot (T_3) was found 31.48 and 31.54 per cent higher water holding capacity. The maximum water holding capacity in surface and sub surface soil was recorded in 100% NPK + FYM @ 15 t ha^{-1} treated plot (T_3). This might be due to organic matter is highly porous in nature and it increases water holding capacity of the soil. Presence of good amount of soil organic matter causes formation of granular and crumby structure and the soil become well aggregated. So, water holding capacity increases with increases organic matter content of the soil. The minimum value was observed in the control plot (T_1) could be due to less amount of organic content in the control plot. The water holding capacity was decreased significantly with increase soil depth. The results were in conformity with those of Babhulkar *et al.* (2000) [3] and Katkar *et al.* (2012) [11]. The increase in WHC of soil after harvest of crop in treatment that received organic manure was evidently due to effect of organic sources (Talathi *et al.,* 2010) [18].

Table 1: Effect of long term use of organic manure manures and inorganic fertilizers on bulk Density (Mg m^{-3}) and Particle density (Mg m^{-3}) under different cropping systems

S. No.	Treatments	Bulk Density (Mg m^{-3})		Particle Density (Mg m^{-3})	
		Depth (0-15 cm)	Depth (0-15 cm)	Depth (0-15 cm)	Depth (0-15 cm)
T1	Control	1.51^{a}	1.60^{a}	2.67^{a}	2.76^{a}
T2	100% NPK (LTFE)	1.32^{b}	1.39^{b}	2.60^{ab}	2.70^{ab}
T3	100% NPK+FYM (LTFE)	1.26^{b}	1.35^{b}	2.50^{c}	2.61^{b}
T4	Fallow (LTFE)	1.28^{b}	1.36^{b}	2.58^{abc}	2.65^{b}
T5	Poplar (Agroforestry)	1.28^{b}	1.35^{b}	2.56^{bc}	2.62^{b}
T6	Eucalyptus (Agroforestry)	1.30^{b}	1.36^{b}	2.59^{abc}	2.68^{ab}
	S.Em±	0.02	0.02	0.03	0.03
	CD at 5%	0.06	0.07	0.10	0.08
	CV%	3.18	3.08	2.52	2.01

Table 2: Effect of long term use of organic manure manures and inorganic fertilizers on Soil mean weight diameter (mm) and Soil hydraulic conductivity (cm hr^{-1}) under different cropping systems

S. No.	Treatments	Soil mean weight diameter (mm)		Soil hydraulic conductivity (cm hr^{-1})	
		Depth (0-15 cm)	Depth (0-15 cm)	Depth (0-15 cm)	Depth (0-15 cm)
T1	Control	0.62^{e}	0.52^{d}	0.168^{d}	0.136^{e}
T2	100% NPK (LTFE)	0.68^{d}	0.54^{d}	0.278^{c}	0.196^{d}
T3	100% NPK+FYM (LTFE)	0.90^{a}	0.78^{a}	0.344^{a}	0.257^{a}
T4	Fallow (LTFE)	0.74^{bc}	0.62^{c}	0.290^{c}	0.215^{bc}
T5	Poplar (Agroforestry)	0.78^{b}	0.66^{b}	0.312^{b}	0.224^{b}
T6	Eucalyptus (Agroforestry)	0.71^{cd}	0.58^{c}	0.282^{c}	0.204^{cd}
	S.Em±	0.01	0.01	0.007	0.005
	CD at 5%	0.05	0.04	0.020	0.014
	CV%	4.05	3.77	4.728	4.394

4. Conclusion

All physical properties of the soil are the key factor of soil fertility. Different physical properties in soil *viz.*, bulk density, particle density, hydraulic conductivity of soil and mean weight diameter were affected by the application of different organic manures and chemical fertilizers. However the magnitudes of the impact at 0-15 and 15-30 cm soil depth are varies. The particle density was lowest with plots receiving 100% NPK+FYM @ 15 t ha^{-1} (T_3) and highest PD was observed in the control plot (T_1). The values were statistically significant in both the surface and sub surface soil. The highest mean weight diameter of soil aggregates at surface and sub surface soil was observed in FYM along with 100% NPK fertilizer treated plot (T_3). This might be due to the application of FYM and chemical fertilizer significantly enhanced organic carbon status in soil and increases the MWD of soil aggregates.

5. References

1. Agarwal M. Monitoring soil physical, chemical and microbiological properties and nutrients uptake after 35 years of continuous fertilizer use in rice-wheat system. Ph. D. Thesis submitted to G.B.P.U.A. & T., Pantnagar, India, 2008, 153.
2. Arevalo CBM, Bhatti JS, Chang SX, Sidders D. Land use change effects on ecosystem carbon balance: from agricultural to hybrid poplar plantation. Agricultural, Ecosystem and Environment, 2011;141:342-49.
3. Babhulkar PS, Wandile RM, Badole WP, Balapande SS. Residual effect of long-term application of FYM and fertilizers on soil properties (Vertisols) and yield of soybean. Journal of the Indian Society of Soil Science, 2000;48:89-92.
4. Bhaduri D, Purakayasth TJ, Chakraborty D, Chakraborty K, Singh M. Integrated tillage-water-nutrient management effects on selected soil physical properties in a rice-wheat system in the Indian subcontinent. Archives of Agronomy and Soil Science. 2017;64(1):132-145.
5. Bhatt MK, Raverkar KP, Chandra R, Pareek N, Singh DK, Yaseen M. Use of inorganic fertilizers and FYM for twenty-nine years in Rice-Wheat cropping system improves physical soil quality indices after rice. International Journal of Current Microbiology and Applied Sciences. 2017;6(9):3431-3438
6. Das T. Studies on long-term impact of NPK fertilizers and manure on yield, grain quality and nutrient uptake by wheat and relationship with physical and chemical properties of Mollisol. Thesis, Master of Science in agriculture (Soil Science), G.B.P.U.A.&T., Pantnagar. 2007.
7. Dhaliwal MK, Dhaliwal SS, Thind HS, Gupta RK. Effect of integrated nutrient management on physico-chemical parameter of soil in rice-wheat system. Journal of Agricultural Research. 2015;52(2):130-137.
8. FAO, 2015. http://www.fao.org/forestry/agroforestry/80338/en/
9. Gupta N, Kukal SS, Bawa SS, Dhaliwal GS. Soil organic carbon and aggregation under poplar based agroforestry system in relation to tree age and soil type. Agroforestry System. 2009;76:27-35.
10. Jat RK, Sapkota TB, Singh RG, Jat ML, Kumar M, Gupta RK. Seven years of conservation agriculture in a rice-wheat rotation of Eastern Gangetic Plains of South Asia: yield trends and economic profitability. Field Crops Research. 2014;164:199-210.
11. Katkar RN, Kharche VK, Sonune BA, Wanjari RH, Singh M. Long term effect of nutrient management on soil quality and sustainable productivity under sorghum-wheat crop sequence in Vertisol of Akola, Maharashtra. Agropedology. 2012;22(2):103-114.
12. Kharche VK, Kulkarni AA, Patil SR, Katkar RN. In

proceeding of Vasantrao Naik agriculture seminar on soil security for sustainable agriculture, 28-29 February, 2010, College of Agriculture, Nagpur. 2013.

13. Kumar BM, Nair PK. The enigma of tropical home gardens. Agroforestry Systems. 2004;61:135-152.
14. Nandapure SP, Sonune BA, Patil RT. Long-term effects on integrated nutrient management on soil physical properties and crop productivity in sorghum-wheat cropping sequence in a Vertisol. Indian Journal of Agricultural Research. 2014;45(4):336-340.
15. Sapkota TB, Jat RK, Singh RG, Jat ML, Stirling MG, Jat MK *et al*. Soil organic carbon changes after seven years of conservation agriculture in a rice–wheat system of the eastern Indo-Gangetic Plains. Soil Use and Management. 2017;33:81-89
16. Singh G, Kumar R, Kumar S. Effect of tillage and nitrogen levels on growth and yield of maize (*Zea mays*). Annals of Agricultural Research. 2006;27:198-199
17. Singh I, Rawat P, Kumar A, Bhatt P. Soil Physico-bio-chemical properties under different agroforestry systems in Terai region of the Garhwal Hiamalayas. Journal of Pharmacognosy and Phytochemistry. 2018;7(5):2813-2821.
18. Talathi MS, Pinjari SS, Bhondave TS. Judicious use of organic manures and inorganic fertilizers for sustaining productivity and fertility dynamics under rice-maize and rice-groundnut cropping systems. Journal of Maharashtra Agricultural University. 2010;5:23-28.
19. Thakur R, Sawarkar SD, Kauraw DL, Singh M. Effect of inorganic and organic sources on nutrients availability in a Vertisols. Agropedology. 2011;20(1):53-59.
20. Tripathi R, Nayaka AK, Bhattacharya P, Shukla AK, Shahid M, Raja R *et al*. Soil aggregation and distribution of carbon and nitrogen in different fractions after 41 years long-term fertilizer experiment in tropical rice-rice system. Geoderma. 2014;213:280-286.