International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133; Print ISSN: 2664-7125; Impact Factor: RJIF 5.28
Received: 26-01-2021; Accepted: 27-02-2021; Published: 14-03-2021
Volume 3; Issue 1; 2021; Page No. 418-422

Effect of long term fertilization and manuring on physical properties of *Vertisol* in central India

Himanshu Patel[1*], Alok Tiwari[2], Vinay Bachkaiya[3], Vinay Samadhiya[4]
[1] Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, IGKV, Raipur, Chhattisgarh, India
[2] Principal Scientist, Department of Soil Science and Agricultural Chemistry, IGKV, Raipur, Chhattisgarh, India
[3] Scientist, Department of Soil Science and Agricultural Chemistry, IGKV, Raipur, Chhattisgarh, India
[4] Senior Scientist, Department of Soil Science and Agricultural Chemistry, IGKV, Raipur, Chhattisgarh, India

Abstract
The All India Coordinated Research Project on Long Term Fertilizer Experiment has been continued since 1999 at Research farm, Department of Soil Science and Agricultural Chemistry, IGKV, Raipur. In this experiment various physico-chemical parameters of soil studied results revealed that soil physical properties have significant effect on nutrient accessibility which was significant credits of soil quality. It was observed from experiment that increasing levels of NPK with and without organic manure decreased the bulk density (BD) at both the depths as compared to without inorganic fertilizers. Volumetric moisture content (Ɵv %) of soil at both the depths was significantly affected by different treatments of nutrient application. The pattern of variation in soil reaction and salt concentration of soil between the treatments were almost negligible and non-significant.

Keywords: bulk density, porosity, volumetric moisture content

Introduction

Traditional method of agriculture rehearsed with intensive tillage operations, clean development (uncovered soil with no spread), single harvest developing or determined customary yield revolution, imbalanced manure use and little utilization of organics have brought about a great deal of issues in arable Indian grounds. Major problems in the arable lands of India are: deteriorating soil health (physical, chemical and biological); declining or stagnating yield trends of rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) (Ladha *et al.*, 2003) [15] and farm income reduction (Aggarwal *et al.*, 2004); high surface water run-off and soil erosion (on average, 5-10 Mg/ha/year) (Pimentel, 2006) and declining soil fertility. Conventional agricultural practices in the Indo-Gangetic Plains (IGP) has reduced soil fertility by reducing population of nutrient mineralising microbes, as these soils have low soil organic carbon (SOC) (Loke, 2012). In addition, declining soil aggregation attributed to intensive tillage, application of mineral fertilizers and pesticides in soils causes soil degradation.

The crops are growing for many decades with different nutrient management practices according to the available input resources. Rice–wheat systems, as a result of several decades of continuous cropping and the contrasting edaphic requirements of the two cereals, have shown evidence of soil nutrient depletion and imbalances, low nutrient use efficiency, a general reduction in soil organic matter, and stagnating or declining yields (Dawe *et al.* 2000 and Ladha *et al*. 2003) [8, 16]. There may be various factors behind yield stagnation of both the crops such as edaphic constraints, infestation of insects and diseases, growing of local and susceptible cultivars, adverse and fluctuating climate conditions, conventional methods of sowing, rainfed cultivation of crop and low soil organic carbon coupled with nitrogen status in soil.

Material and Method

Cropping System, Location, Climate and Soil

Raipur is situated at 21^0 4' North Latitude and 76^0 3' East Longitude with an altitude of 293 meter above mean sea level. The Research farm is located at National highway No.53 in eastern part of Raipur city and located between 20^0 4' North Latitude and 81^0 39' East Longitude with an altitude of 293 m above mean sea level. The area goes under sub-humid climate and the overall atmosphere of this locale is dry wet, sub humid and the district gets 1200-1400 mm precipitation every year, About 88 percent precipitation is gotten during stormy season (June to September) and 8 percent during winter season (October to February). May is the hottest and December is the coolest month of the year. The precipitation design has incredible varieties during blustery season from year to year. The temperature throughout the late spring months comes to as high as 47°C and drop to 7°C during December to January. The experimental soil (*Vertisol*) is fine montmorillonitic hyperthermic chromustert locally called as *Kanhar* and is identified as Arang II series. It is usually deep, heavy clayey (50 %), dark brown to black in color and neutral to alkaline in reaction due to presence of lime concentrations.

Experimental details

The experiment was carried out in Randomized Block Design, replicated four times with ten permanent treatments *viz.* T_1-Control; T_2 - 50% of the recommended optimum NPK fertilizer dose (50:30:20::N:P_2O_5:K_2O,kg ha^{-1}); T_3 - 100% of the recommended optimum NPK fertilizer dose (100:60:40::N:P_2O_5:K_2O,kg ha^{-1}); T_4 -150% of the recommended optimum NPK fertilizer dose (150:90:60::N:P_2O_5:K_2O,kg ha^{-1}); T_5 - 100% of the recommended optimum NPK fertiliser + $ZnSO_4$

@25kg /ha in *kharif crops* only (100:60:40::N:P_2O_5:K_2O,kg ha^{-1} + $ZnSO_4$); T_6 - 100% N and P of recommended dose of fertilizer (100:60:0::N:P_2O_5:K_2O,kg ha^{-1}); T_7 - 100% N of recommended dose of fertilizer (100:0:0::N: P_2O_5:K_2O,kg ha^{-1}); T_8 - 100%NPK recommended fertilizer dose +FYM (5 t /ha in *kharif crop* only); T_9 -50% NPK recommended fertilizer dose +BGA (10kg/ha dry culture in *kharif* crop only); T_{10} - 50% NPK recommended fertilizer dose +GM (Sown in site, cut and mixed in soil in *kharif* season only)

Results and discussion

Effect of long term fertilization and manuring on soil physical properties

Soil physical properties have significant effect on nutrient accessibility which is significant credits of soil quality. Most physical properties of soil are generally affected by management and the change in physical properties of soil is exhibited distinctly under long-term adoption of management measures. The important physical properties of soil *viz*., bulk density, particle density, porosity, moisture content and mean weight diameter are generally considered as soil quality indicators. The impact of long-term inorganic fertilization and organic manuring on these physical properties in *Vertisol* under rice-wheat cropping system was studied and the results thus obtained are presented under following subheads:

Bulk Density

The data pertaining to the effect of long-term application of integrated nutrients on bulk density (BD) of soil at 0-15 and 15-30 cm depths are given in Table 1. The data clearly indicated that BD of soil at both the depths was significantly affected by different treatments of nutrient application. The data further revealed that highest BD of surface (1.44 and 1.45 Mg m^{-3}) and sub-surface (1.47 and 1.47 Mg m^{-3}) soil was recorded in control and lowest (1.36 and 1.36 Mg m^{-3}) and (1.39 and 1.40 Mg m^{-3}) under 100 % NPK + FYM followed by 50 % NPK +GM in both the year of study. It was also evident from the data that BD of sub-surface soil layer was higher as compared to surface soil layer in all the treatments due to overburden pressure of upper layers. The results clearly indicated that integration of organic source with inorganic nutrients decrease the BD of soil and also the BD increased with soil depth irrespective of the nutrients application treatments (Katkar, 2012) [12].

It is clear from the data that increasing levels of NPK with and without organic manure decreased the BD at both the depths as compared to without inorganic fertilizers. Mean of BD under 100%NPK+FYM was 1.36 and 1.39 Mg m^{-3} at 0-15 and 15-30 cm depth, respectively which was significantly low as compared to other treatments. Similar trend was reported by Hati (2007) [10] and Bandyopadhyay (2010) for 100% NPK+FYM. The 50% and 100% NP treatment shows similar BD values 1.40 Mg m^{-3} at 0-15 cm depth. As the depth increase to 15-30 cm the BD values increases slightly to 1.44 and 1.43 Mg m^{-3} for 50% and 100% NP. Increase in the BD value from 1.43 to 1.46 Mg m^{-3} was found in 100% N from surface to sub-surface soil. The 100%NPK +Zn had slightly higher BD values than 100%NPK at both the surface. Over all, combination of organic manures with inorganic fertilizer show lower mean BD values as compared to inorganic fertilizer and control plots. In fact field without fertilizer (control) show comparatively higher mean BD values as compared to other treatments.

The extent of reduction of BD was more when organic manures were applied along with inorganic fertilizers. A slight reduction in BD in NPK treated plots could be ascribed to the increased root biomass production that might have increased organic matter content of the soil (Kusro *et al.* 2014) [14]. The BD of soil decreased with the application of FYM, GM and BGA in combination with fertilizers and use of imbalanced fertilizers increased the BD, which might be due to deterioration of soil structure (Kharche *et al.* 2013) [13]. Continuous application of chemical fertilizers along with organics for 20 crop cycles caused significant decrease in the BD of soil may be due to addition of higher organic carbon that resulted in more pore space and good soil aggregation (Selvi *et al.* 2005; Bajpai *et al.* 2006; Yaduvanshi *et al.* 2013) [25, 3, 36].

The decrease in BD with application of FYM is increase in organic carbon content and also possibly due to increase in root biomass production (Walia and Dhaliwal, 2010). The results are also in close conformity with the findings of Tadesse *et al.* (2013) [33]. The BD had not much changed due to NPK treatments at lower depths, however, a marginal reduction was observed than control due to NPK levels which could be attributed to the increased biomass production with consequent increase in the organic matter content of the soil (Nayak *et al.* 2015) [19].

Porosity

The data pertaining to the effect of long-term application of integrated nutrients on porosity of soil at 0-15 and 15-30 cm depths are given in Table 2 Data clearly indicated that porosity of soil at both the depths was significantly affected by different treatments of nutrient application. Data further revealed that highest porosity of surface (49.20 and 49.44 %) and sub-surface soil (47.84 and 47.76%) was in 50 % NPK +GM, followed by 100 % NPK + FYM and lowest (45.95 and 45.37%) and (44.77 and 44.67%) under control in both the year of study. It was also evident from the data that porosity of sub-surface soil layer was lower as compared to surface soil layer in all the treatments. It was negatively correlated with BD values (Tables 1).The results clearly indicated that integration of organic source with inorganic nutrients increase the porosity of soil and also the porosity decreased with soil depth irrespective of the nutrients application treatments (Badanur *et al.* 1990) [2].

Among the different treatments mean porosity of surface and subsurface soil was found in decreasing order of 50%NPK+GM > 100% NPK+FYM > 100% NPK > 100% NPK+ Zn > 50% NPK + BGA > 50% NPK >150% NPK >100% NP > 100% N and control. The enhancement of porosity was more when organic manures were applied along with inorganic fertilizers. A slight reduction in porosity in NPK treated plots could be ascribed to the depleting organic matter content of the soil (Sharma *et al.*, 2000). The porosity of soil increased with continuous application of chemical fertilizers along with FYM, GM and BGA for 20 crop cycles caused significant increase in the porosity of soil may be due to addition of higher organic carbon that resulted in more granulated soil structure and well aggregation leads to higher total pore space (Sur *et al.* 1993; Sharma and Gupta 1998) [32, 27].

Volumetric moisture content

The data pertaining to the effect of long-term application of integrated nutrients on volumetric moisture content (ϴv %) of soil at 0-15 and 15-30 cm depths are given in Table 3. The data clearly indicated that ϴv of soil at both the depths was significantly affected by different treatments of nutrient application. The data further revealed that highest ϴv of surface (35.62 and 35.76 %) and sub-surface soil (41.37 and 41.56 %) was in 100 % NPK + FYM, followed by 50 % NPK +GM and lowest (29.43 and 30.17 %) and (33.98 and 34.19 %) under in 100 % N in both the year of study. It was also evident from the data that ϴv of sub-surface layer was higher as compared to surface soil layer in all the treatments.

Further results showed that ϴv does not affected by optimal or suboptimal doses of inorganic fertilization rather by inorganic fertilization with organic manure. Mean of ϴv under 100%NPK+FYM was 35.69 and 41.47 % at 0-15 and 15-30 cm depth, respectively which was significantly higher as compared to other treatments. Similar trend was reported by Hati (2008) [11] and Chakraborty *et al.* (2010) Among the different treatments mean ϴv of surface as well as subsurface soil was found in decreasing order of 100% NPK+FYM >50%NPK+GM> 100% NPK+ Zn > control > 150% NPK > 100% NPK >100% NP > 50%NPK + BGA > 50% NPK and 100% N.

The extent of increasing of ϴv was more when organic manures were applied along with inorganic fertilizers. A slight reduction in ϴv in NPK treated plots could be ascribed to the decreased root biomass production that might have decreased organic matter content of the soil (Chesti *et al.* 2013) [6]. The ϴv of soil increased with the application of FYM, GM and BGA in combination with fertilizers, while use of imbalanced inorganic fertilizers decreased the volumetric moisture content, which might be due to deterioration of soil structure (Kharche *et al.* 2013) [13]. Continuous application of chemical fertilizers along with organics for 20 crop cycles caused significant increase in the ϴv of soil may be due to the addition of higher organic carbon that resulted in more pore space and good soil aggregation (Selvakumari *et al.* 2000; Pattanayak *et al.*, 2001; Singh *et al.*, 2001; Smiciklas *et al.*, 2002 and Sarwar *et al.*, 2003) [24, 20, 31, 23].

Table 1: Effect of long term application of inorganic fertilization and organic manuring on bulk density

Treatments	Bulk density (Mgm^{-3})					
	0-15 cm			15-30 cm		
	2017-18	2018-19	Mean	2017-18	2018-19	Mean
Control	1.44	1.45	1.45	1.47	1.47	1.47
50% NPK	1.40	1.41	1.40	1.43	1.44	1.44
100% NPK	1.40	1.41	1.39	1.41	1.42	1.41
150% NPK	1.40	1.40	1.40	1.43	1.43	1.43
100% NPK + Zn	1.41	1.40	1.40	1.42	1.43	1.43
100% NP	1.40	1.41	1.40	1.43	1.44	1.43
100% N	1.43	1.44	1.43	1.46	1.46	1.46
100%NPK+ FYM	1.36	1.36	1.36	1.39	1.40	1.39
50% NPK + BGA	1.40	1.40	1.40	1.42	1.43	1.42
50% NPK + GM	1.36	1.36	1.36	1.39	1.40	1.40
Mean	1.40	1.40	1.40	1.42	1.43	1.43
SEm (±)	0.02	0.01	0.01	0.02	0.01	0.01
CD at 5%	0.04	0.04	0.03	0.04	0.04	0.03

Table 2: Effect of continuous application of inorganic fertilizers and manures on porosity of soil

	Porosity (%)					
	0-15 cm			15-30 cm		
Treatments	2017-18	2018-19	Mean	2017-18	2018-19	Mean
Control	45.95	45.37	45.66	44.77	44.67	44.72
50% NPK	47.16	46.84	47.00	45.94	46.47	46.21
100% NPK	47.24	48.45	47.84	47.38	46.99	47.19
150% NPK	47.21	47.06	47.14	45.88	46.33	46.11
100% NPK + Zn	46.98	47.17	47.08	46.32	47.04	46.68
100% NP	47.21	46.64	46.93	46.33	46.02	46.17
100% N	46.23	45.85	46.04	44.91	44.96	44.93
100%NPK+ FYM	48.87	49.16	49.02	47.80	47.66	47.73
50% NPK + BGA	47.75	47.81	47.78	46.91	46.33	46.62
50% NPK + GM	49.20	49.44	49.32	47.84	47.76	47.80
Mean	47.38	47.38	47.38	46.41	46.42	46.42
SEm(±)	0.61	0.51	0.37	0.56	0.61	0.39
CD at 5%	1.78	1.49	1.07	1.64	1.77	1.12

Table 3: Effect of inorganic fertilization and manuring on volumetric moisture content

	Volumetric moisture content (ϴv%)					
	0-15 cm			15-30 cm		
Treatments	2017-18	2018-19	Mean	2017-18	2018-19	Mean
Control	30.84	31.33	31.08	36.53	36.09	36.31
50% NPK	29.86	29.75	29.80	35.38	34.47	34.43
100% NPK	30.94	30.76	30.85	37.70	34.81	36.26
150% NPK	30.26	31.80	31.03	36.22	36.55	36.38
100% NPK + Zn	31.91	31.90	31.91	37.59	38.14	37.87
100% NP	30.71	30.81	30.76	35.74	36.19	35.96
100% N	29.43	30.17	29.80	33.98	34.19	34.09
100%NPK+ FYM	35.62	35.76	35.69	41.37	41.56	41.47
50% NPK + BGA	29.50	30.30	29.90	34.96	35.33	35.15
50% NPK + GM	33.52	34.64	34.08	40.21	40.30	40.26
Mean	31.26	31.72	31.49	36.76	36.86	36.81
SEm(±)	0.74	0.61	0.47	0.87	0.70	0.53
CD at 5%	2.14	1.77	1.49	2.55	2.03	1.54

Conclusion

From the above results obtained following conclusions can be drawn

1. The physical properties (bulk density, porosity, volumetric moisture content) were improved by amalgamation of organic sources as well as balanced fertilizer use. The physical properties were affected most by FYM followed by GM and inorganic fertilizers. The hydraulic conductivity was influenced by GM followed by FYM and inorganic fertilizers alone application.
2. Long term application of inorganic fertilizers alone or integration with any of the organics did not influence soil pH and electrical conductivity.

References

1. Aggarwal PK, Joshi PK, Ingram JSI, Gupta RK. Adapting food systems of the Indo-Gangetic plains to global environmental change: key information needs to improve policy formulation. Environmental Science and Policy. 2004; 7:487-498.
2. Badanur VP, Poleshi CM, Naik BK. Effect of organic matter on crop yield and physical and chemical properties of Vertisol. J Indian Society of Soil Science. 1990; 38:426-429.

3. Bajpai RK, Chitale S, Upadhyay SK, Urkurkar JS. Long-term studies on soil physico-chemical properties and productivity of rice - wheat system as influenced by integrated nutrient management in Inceptisol of Chhattisgarh. Journal of the Indian Society of Soil Science. 2006; 54(1):24-29.
4. Bandyopadhyay KK, Mishra AK, Ghosh PK, Hati KM. Effect of Integrated Use of Farmyard Manure and Chemical Fertilizers on Soil Physical Properties and Productivity of Soybean. Soil & Tillage Research. 2010; 110(1):115-125.
5. Chakraborty D, Garg RN, Tomar RK, Dwivedi BS, Aggarwal P, Singh R *et al*. soil physical quality as influenced by long-term application of fertilizers and manure under maize-wheat system. Journal of the Indian society Soil Science. 2010; 175:128-136.
6. Chesti MH, Kohli Anshuman, Sharma AK. Effect of Integrated Nutrient Management on Yield of and Nutrient Uptake by Wheat (*Triticum aestivum*) and Soil Properties under Intermediate Zone of Jammu and Kashmir. Journal of the Indian Society of Soil Science. 2013; 61(1):1-6.
7. Das B, Chakraborty D, Singh VK, Aggarwal P, Singh R, Dwivedi BS *et al*. Effect of integrated nutrient management practice on soil aggregate properties, its stability and aggregate-associated carbon content in an intensive rice–wheat system. Soil and Tillage Research. 2014; 136:9-18.
8. Dawe D, Dobermann A, Moya P, Abdulracman S, Singh B, Lal P, Li SY *et al.* How widespread are yield declines in long term rice experimental in Asia. Field Crop Research. 2000; 66:175-193.
9. Gupta Vikas, Sharma RS, Vishwakarma SK. Long-term effect of integrated nutrient management on yield sustainability and soil fertility of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system. Indian Journal of Agronomy. 2006; 51(3):160-164.
10. Hati KM, Swarup A, Dwivedi AK, Mishra AK, Bandopadhyay KK. Changes in soil physical properties and organic carbon status at the top soil horizon of a Vertisol of Central India after 28 years of continuous cropping, fertilization and manuring. Agriculture, Ecosystem and Environment. 2007; 119(2):127-134.
11. Hati KM, Swarup N, Mishra B, Manna MC, Wanjari RH, Mandal KG, *et al*. Impact of long-term application of fertilizer, manure and lime under intensive cropping on physical properties and organic carbon content of an Alfisol. Indian Agricultural Research Institute. Journal of Agricultural Research. 2008; 148:173–179.
12. Katkar RN, Sonune BA, Rewatkar SS, Karche VK. Effect of long tern nutrient management on sustainability crop productivity and soil quality under sorghum-wheat crop sequence on *Vertisol*. Proceeding of national seminar on soil security for sustainable agriculture. 28-29 February, 2010, College of Agriculture, Nagpur, 2010.
13. Kharche, Vilas & Patil, Shivaji & Kulkarni, A & Patil, V & Katkar, Rajendra. Long-term Integrated Nutrient Management for Enhancing Soil Quality and Crop Productivity under Intensive Cropping System on Vertisols. Journal of the Indian Society of Soil Science. 2013; 61:323-332.
14. Kusro PS, Singh DP, Paikra MS, Kumar D. Effect of organic and inorganic additions on physico-chemical properties in vertisol American International Journal of Research in Formal. Applied & Natural Sciences. 2014; 5(1):51-53.
15. Ladha JK, Pathak H, Tirol-Padre A, Dawe D, Gupta RK. Productivity trends in intensive rice–wheat cropping systems in Asia. Improving the Productivity and Sustainability of Rice–Wheat Systems: Issues and Impacts, (improvingthepro), 2003, 45-76.
16. Ladha JK, Dawe D, Pathak H, Padre AT, Yadav RL, Singh B, *et al*. How extensive are yield declines in long-term rice-wheat experiments in Asia. Field Crop Research. 2003; 81:159-280.
17. Loke PF. Long-term effects of residue management on soil fertility indicators, nutrient uptake and wheat grain yield (Doctoral dissertation, University of the Free State Bloemfontein), 2012.
18. Moharana PC, Sharma BM, Biswas DR, Dwivedi BS, Singh RV. Long-term effect of nutrient management on soil fertility and soil organic carbon pools under a 6-year-old pearl millet–wheat cropping system in an Inceptisol of subtropical India. Field crop research. 2012; 136:32-41.
19. Nayak T, Patel T, Bajpai RK. Influence of organic and inorganic fertilization on soil physical properties in a vertisol under rice. All International Quality of Environmental Science the Ecoscan. 2015; 9(1&2):71-74.
20. Pattanayak SK, Mishra KN, Jena MK, Nyack RK. Evaluation of green manure crops fertilized with various phosphorus sources and their effect on subsequent rice crop. Journal of the Indian Society Soil Science. 2001; 49(2):285-291.
21. Pimentel D. Soil erosion: a food and environmental threat. Environment, development and sustainability. 2006; 8:119-137.
22. Prasad B, Sinha SK. Long-term effects of fertilizers and organic manures on crop yields, nutrient balance and soil properties in rice – wheat cropping, 2000.
23. Sarwar G, Hussain N, Mujeeb F, Schmeisky H, Hassan G. Biocompost application for the improvement of soil characteristics and dry matter yield of *Lolium perenne* (Grass). Asian Journal of the Plant Science. 2003; 2(2):237-241.
24. Selvakumari GM, Baskar, D Jayanthi, KK Mathan. Effect of integration of flyash with fertilizers and organic manures on nutrient availability, yield and nutrient uptake of rice in alfisols. Journal of the Indian Society of Soil Science. 2000; 48(2):268-278.
25. Selvi D, Santhy P, Dhakshina Moorthy M. Effect of inorganic alone and in combination with farmyard manure on physical properties and productivity of vertic haplustepts under long-term fertilization. Journal of the Indian Society of Soil Science. 2005; 53(3):302-307.
26. Sequence as Affected by Long-Term Fertilization. National Academy of Agricultural Science. 33(4):3157-3162.
27. Sharma MP, Gupta JP. Effect of rainfed soybean (Glycine max)-safflower (Carthamum tictorious) sequence to nitrogen and sulphur fertilization in vertisols. Indian Journal of Agricultural Science. 1998; 68(11):715-717.
28. Sharma SK, Sharma SN. Integrated nutrient management for sustainability of rice (*Oryza sativa*) - Wheat (*Triticum aestivum*) cropping system on soil fertility. Indian Journal of Agricultural Sciences. 2002; 70(6):357-359.

29. Singh DK, Pandey PC, Gupta Shilpi. Long term addition of organics to sustain the system productivity of Rice (*Oryza sativa* L.) –Wheat (*Triticum aestivum* L.) under Indo-Gangetic Plains of India. International Journal of Scientific Research and Innovative Technology, 2014, 1(1).
30. Singh RP, Das SK, Bhaskara Rao UM, Narayana Reddy M. Towards Sustainable Dryland Agriculture Practices, Technical Bulletins, Central Research Institute for Dryland Agriculture, Hyderabad, India, 1990, 1-106.
31. Smiciklas KD, Walker PM, Kelley TR. Utilization of Compost (Food, Paper, Landscape and Manure) in Row Crop Production. Department of Agriculture and Health Sciences, Illinois State University, USA, 2002.
32. Sur HS, Sidhu Rachhpal Singh AS, Aggrawal GC, Sandhu KS. Long term effect of green manuring on soil physical properties and production potential in green manure- maize-wheat sequence. Annuals of Agricultural Research. 1993; 14(2):125-131.
33. Tadesse T, Dechassa N, Bayu W, Gebeyehu S. Effects of Farmyard Manure and Inorganic Fertilizer Application on Soil Physico-Chemical Properties and Nutrient Balance in Rain-Fed Lowland Rice Ecosystem. American Journal of Plant Sciences. 2013; (4):309-316.
34. Walia MK, Dhaliwal SS. Effect of inorganic fertilizers and manures application on physical property and nutrient uptake of soil under long- term rice-wheat system. Journal of Soil and Crops. 2010; 17(2):191-197.
35. Wanjari RH, Singh MV, Ghosh PK. Sustainable yield index: An approach to evaluate the sustainablility of long-term intensive cropping system in India. Journal of Sustainable Agriculture, USA. 2004; 24(4):39-58.
36. Yaduvanshi NPS, Sharma DR, Swarup A. Impact of Integrated Nutrient Management on Soil Properties and Yield of Rice and Wheat in a Long-Term Experiment on a Reclaimed Sodic Soil. Journal of the Indian Society of Soil Science. 2013; 61(3):188-194.