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Effect of Inorganic Fertilizers and Organic Manures on Physical Properties of Soil: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Deterioration of physical properties of soil and there after depletion the soil fertility are the main constrains in food and environment security of any country. This review paper summarizes the current knowledge and information on the effect of inorganic fertilizers and organic manures on soil physical properties. The use of inorganic fertilizer or organic fertilizer alone has both positive and negative effects on soil properties, plant growth and nutrient availability. Most of earlier

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investigators confirmed that combined application of inorganic fertilizers and organic manures improved the physical properties and available nutrient status in soils. Organic manures improve physical properties of soil but they are comparatively low in nutrient content, addition of larger quantity of manures is required for successful plant growth. However, inorganic fertilizers is contain all the essential nutrients which are early accessible for plants. Due to continuous use of inorganic fertilizers alone causes soil organic matter degradation, soil acidity or alkalization, soil deterioration and environmental pollution, so integrated or mixed inorganic and organic nutrient management system is an alternative system for the sustainable and cost effective management of soil and the result is improve in soil properties and raising soil fertility without affecting environment. The objective of the review is to assess the effect of inorganic fertilizer and organic manure on physical properties of soil. The study revealed that appropriate application of inorganic fertilizers with organic manures improves soil physical properties and increases the productivity without negative effect on soil health than the values obtained by organic or inorganic fertilizers separately.

Keywords: Inorganic fertilizers; organic manures; physical properties.

1. INTRODUCTION

The long-term field experiments are considered to be the most practical approach for assessing the sustainability of farming practices. In India, long-term fertilizer experiments conducted over several years have provided valuable insights into the effects of continuous cropping and fertilizer usage on soil quality and the overall sustainability of the system [1]. Soil physical characteristics play a vital role in soil productivity and are essential components of soil quality assessment. Parameters such as bulk density, mean weight diameter, aggregate stability, hydraulic conductivity, soil strength, and infiltration rate are crucial in regulating soil functions [2]. However, the rapid increase in the human population and other factors have led to the degradation of natural resources in the country, posing a serious threat to sustainable food production and environmental security [3]. To address this issue and enhance soil fertility in the short term, nutrients need to be added to the soil. This is commonly achieved through the application of chemical fertilizers. However, in order to maintain soil fertility balance and ensure agricultural productivity, the use of organic nutrient sources and the application of suitable inorganic fertilizers are crucial. The continuous use of inorganic fertilizers alone has resulted in an imbalance in soil physical properties and unsustainable crop production [4].

Studies have shown that combining inorganic and organic fertilizers provides greater benefits compared to using either input alone, as they interact positively and improve soil physical properties [5]. The addition of organic amendments has been proven to maintain soil organic matter content, thereby contributing to the improvement of soil physical properties and enhancing fertilizer use efficiency [6]. Organic matter directly supplies nutrients to crops and indirectly modifies soil physical properties, creating an improved root environment that stimulates plant growth [7]. Neither inorganic nor organic amendments alone can adequately maintain soil organic matter levels [8]. Therefore, the balanced and integrated use of organic and inorganic fertilizers enhances the accumulation of soil organic matter and improves soil physical properties [9].

2. INTEGRATED NUTRIENT MANAGEMENT

The integrated nutrient management system provides an alternative approach that involves reducing the input of inorganic fertilizers and incorporating the combined use of inorganic fertilizers with organic materials such as animal manures, crop residues, green manure, and composts [6,10]. The combined application of organic and inorganic fertilizers plays a significant role in sustaining soil fertility [11]. Furthermore, the use of organic fertilizers in conjunction with inorganic fertilizers has a more pronounced positive effect on soil physical properties and enhances soil health. It also improves the utilization efficiency of recommended inorganic fertilizers and reduces associated costs [12].

3. ORGANIC FERTILIZER

Organic fertilizers consist of natural materials derived from plants or animals, such as livestock manure, green manures, crop residues, household waste, compost, etc. These organic fertilizers serve as a direct source of plant nutrients and also indirectly impact the physical, biological, and chemical properties of the soil [13]. When organic fertilizers are added to the soil, microorganisms present in the soil decompose the organic matter, making its nutrients available for plant uptake. This process is characterized by the gradual release of nutrients, providing a sustained supply for plant growth [14].

3.1 Scope of Organic Fertilizer

Organic fertilizers offer numerous advantages that contribute to improved soil fertility. Firstly, they increase the organic matter content in the soil, which enhances soil structure by creating more air space and improving water retention [15,16,17,18,19]. Additionally, organic fertilizers enhance soil nitrogen content and promote nutrient availability. They release nutrients at a slower and more consistent rate, ensuring a sustained supply for plant growth. Furthermore, they aid in nutrient mobilization and provide protection against erosion caused by rain and wind [15,16,17]. Organic fertilizers also play a significant role in enhancing soil biological activity and fostering the colonization of mycorrhizae, which promotes a beneficial association between fungi and higher plants. This, in turn, contributes to increased root growth due to improved soil structure and the promotion of soil aggregates. Moreover, organic fertilizers enhance the cation exchange capacity of the soil, further benefiting nutrient availability and uptake [16]. Lastly, organic fertilizers act as buffering agents against undesirable fluctuations in soil pH, providing stability and maintaining optimal pH levels for plant growth [13,20].

3.2 Limitations of Organic Fertilizer

Potentially pathogenic organic fertilizers that are improperly processed can pose risks to both humans and plants. This is because organic fertilizers are derived from materials such as animal feces or plant and animal matter, which may be contaminated with pathogens [10,21]. Additionally, organic fertilizers are relatively low in nutrient content, requiring larger quantities to provide sufficient nutrients for optimal plant growth. As a result, it becomes challenging to sustain large-scale agriculture without the use of inorganic fertilizers [11]. Another challenge with organic fertilizers is the difficulty in matching nutrient supply with the specific requirements of crops throughout their life cycle. It can be challenging to provide nutrients in the exact quantities needed for desired crop production. Furthermore, the breakdown and release of nutrients from organic fertilizers rely on microbial activity. This microbial activity is dependent on factors such as warmth and moisture in the soil. Consequently, the effectiveness of organic fertilizers may be limited seasonally [10, 21].

4. WHY INORGANIC FERTILIZER ARE PREFERRED?

Farmers in developing countries, such as India, are increasingly utilizing waste dung from domestic animals and crop residues as a source of fuel rather than using them as compost or manure for soil improvement and nutrient supply. This practice has resulted in soil degradation, thereby creating a need for immediate relief to crop production. Chemical fertilizers are often used in such cases, as they can quickly restore soil fertility, making nutrients readily available to plants upon application [17]. Moreover, inorganic fertilizers can indirectly increase root residues, which in turn contribute to the accumulation of organic matter in the soil [22]. In light of these circumstances, farmers have increasingly emphasized the application of chemical fertilizers to enhance productivity [13].

4.1 Scope of Inorganic Fertilizer

Inorganic fertilizers are an effective source of nutrients for crops, providing immediate effects on their growth. This is because the nutrients in inorganic fertilizers are already in a water-soluble form, allowing for rapid absorption by plants [10]. As a result, the impact of inorganic fertilizers is typically immediate and fast, as they contain all the necessary nutrients in readily available forms. Additionally, inorganic fertilizers have a high nutrient content, requiring only relatively small quantities for productive results [19]. Moreover, the proper and scientific application of inorganic fertilizers can lead to an increase in soil organic matter content through the promotion of higher root mass and the incorporation of crop residues [21,22].

4.2 Limitations of Inorganic Fertilizer

Excessive application of chemical fertilizers can have adverse effects, including leaching, water pollution, soil acidification, and a decrease in the availability of trace elements. This can also lead to soil alkalization [23]. Chemical fertilizers can accelerate the decomposition of soil organic matter, resulting in the degradation of soil structure and a reduction in soil aggregation. As a consequence, nutrients can be lost from the soil through fixation, leaching, and gas emissions, leading to decreased fertilizer use efficiency [10,21,24,25].Furthermore,the excessive use of chemical fertilizers can harm decomposers and other beneficial soil organisms, diminish the colonization of plant roots by mycorrhizae, and inhibit symbiotic nitrogen fixation by rhizobia, particularly with high nitrogen fertilization. Additionally, this practice can have hazardous effects on the soil environment [10,12]. It is evident that the unscientific and excessive use of chemical fertilizers not only impacts soil health but also poses risks to water quality, human health, and the environment as a whole [21, 26].

5. PHYSICAL PROPERTIES

The physical characteristics of soil are crucial in assessing the sustainability of soil for crop production. Several physical properties, including bulk density, aggregate stability, hydraulic conductivity, and mean weight diameter, are considered essential indicators of soil quality. These parameters help evaluate the overall health and quality of the soil. The incorporation of fertilizers and organic manures in the soil has been shown to improve these physical properties, such as bulk density, particle density, aggregate stability, hydraulic conductivity, and mean weight diameter [2].

6. THE EFFECT OF ORGANIC AND INORGANIC FERTILIZER ON PHYSICAL PROPERTIES OF SOIL

6.1 Bulk Density

Bulk density refers to the mass per unit volume of dry soil, encompassing the volume of solid particles as well as the pore spaces. [27] conducted a 20-year study and found that the continuous application of FYM (farmyard manure) and NPK fertilizers helped maintain and improve the physical properties and organic carbon content of an acidic red loam soil. However, the application of fertilizer nitrogen alone had a slight detrimental effect on soil physical properties. In some treatments, there was a tendency for bulk density to increase from the initial level, but the lowest bulk density was observed in the FYM+PK plot in Inceptisols. Other studies have also reported a decrease in bulk density with the application of organic matter [28]. The combined application of inorganic and organic materials has been shown to maintain and improve soil physical conditions and productivity in red sandy loam soil [29]. Urea was found to be a better source of organic fertilizer nitrogen for maintaining soil physical conditions and productivity compared to other sources of nitrogen [30]. Additionally, studies have revealed that increased fertilizer levels or FYM application can lead to a reduction in soil bulk density, while unmanured plots generally maintain stable bulk density [30]. Incorporating sun hemp or using organic and inorganic sources of nitrogen has also been associated with decreased bulk density [31,32,33]. The use of organic sources has consistently demonstrated a considerable decrease in bulk density [34]. Various studies have highlighted the positive impact of FYM in conjunction with fertilizers on penetration resistance and bulk density [35,36]. In deep Vertisols, the conjunctive use of recommended doses of fertilizer and farmyard manure has resulted in a significant decrease in bulk density [37]. Furthermore, the application of farmyard manure has shown a significant decrease in bulk density compared to chemical fertilizers in Vertisol of Akola [38]. It has been observed that the bulk density tends to increase with an increase in recommended chemical fertilizers, but the differences are not significant. However, the addition of FYM at a rate of 10 t/ha has led to a significant decrease in bulk density in silty clay loam soil [39]. In conclusion, the combined use of inorganic/chemical fertilizers and organic manures has shown improvement in soil bulk density, irrespective of the type of soil or the crop being cultivated.

6.2 Hydraulic Conductivity

Hydraulic conductivity refers to the soil's ability to transmit water under saturated or nearly saturated conditions and is typically measured in cm/hr. It is influenced by various soil properties such as texture, structure, compaction, and exchangeable cations. In a study by [27]. on acidic red loam soil, the combined use of FYM (farmyard manure) at a rate of 20 t/ha with inorganic fertilizers supplying P and K significantly increased hydraulic conductivity (2.5 cm/hr) compared to the control plot. After 20 years of treatment, the hydraulic conductivity in the control plot remained unchanged at 2.0 cm/hr. [40]. reported that nitrogenous and phosphate fertilizers tended to increase hydraulic conductivity, likely due to the creation of larger pores in the soil. [41]. found that increasing levels of fertilizer doses significantly increased hydraulic conductivity in calcareous silt loam soil. In terms of fertilizer application, the use of 100% NPK solely through chemical fertilizers resulted in reduced hydraulic conductivity (14.7 x 10^{-7} m/sec), whereas the combined application of inorganic fertilizers with FYM increased hydraulic conductivity (23.7 x 10^{-7} m/sec). The combined application of FYM and fertilizers had a favorable effect on the hydraulic conductivity of soil, which corresponded to the treatment effects on soil aggregation and bulk density [42]. Further research by [42]. demonstrated that increasing levels of NPK significantly increased hydraulic conductivity, and the combined application of FYM and NPK resulted in even higher hydraulic conductivity compared to NPK alone. The highest hydraulic conductivity was observed in the plot treated with 100% NPK + $ZnSO_4$ (1.99 cm/hr), while the control plot had the lowest hydraulic conductivity (1.44 cm/hr). [38]. revealed that the direct addition of organic matter through farmyard manure, along with the increased root biomass, positively influenced soil microorganism growth and development, leading to improvements in mean weight diameter, available water holding capacity, and hydraulic conductivity. Similarly, [2]. observed that the highest hydraulic conductivity in both surface and sub-surface soil layers was achieved with the application of N_{180} + P_{80} + K_{40} + Zn(F) + FYM, while the lowest values were observed in the control plots. In conclusion, while the addition of nutrients through chemical fertilizers can increase hydraulic conductivity, the significant and pronounced increase in hydraulic conductivity occurs with the combined application of organic manures and inorganic fertilizers. This demonstrates the importance of utilizing a combination of organic and inorganic sources to maximize the improvement in soil hydraulic conductivity.

6.3 Infiltration Rate

The infiltration rate refers to the speed at which water enters the soil, usually measured in millimeters per hour. [31]. observed an improvement in the infiltration rate of Vertisol in a sorghum-safflower crop rotation under dry land conditions with the application of 50% RDF (recommended dose of fertilizer) + 50% nitrogen (N) through green manure (GM) or farmyard manure (FYM). [43]. found that the incorporation of Sesbania GM and mungbean residues in a rice-wheat cropping system resulted in reduced bulk density, increased soil aggregation, and subsequently increased infiltration and percolation rates. [44]. noted a significant increase in infiltration rate (3.10 and 3.60 mm/day) with the combined application of FYM + N and GM + N compared to the general recommended dose treatment (2.50 mm/day) in Vertisol. This suggests that the addition of coarse organic matter with inorganic fertilizers enhanced the basic infiltration rate. [45]. reported a substantial increase in infiltration rate from 0.58 mm/hr to 1.97 mm/hr with the incorporation of Sesbania seaban lopping as green manure in a rice-wheat system in sandy loam soil. [46]. found that green manuring with sesbania or green gram residues, in combination with 100% nitrogen application, resulted in increased infiltration rates compared to fallow plots. [34]. observed that integrated nutrient management in a rice-wheat system had a significant influence on infiltration rate, with a higher rate (1.30 cm/hr) observed in the 100% recommended NPK through fertilizer treatment compared to the control plot (0.85 cm/hr) [47]. reported that the application of organic manure with chemical fertilizers had a notable impact on infiltration rate, with higher rates observed in the 100% NPK + FYM and 50% NPK + GM treatments compared to others. [48]. found that the infiltration rate was highest in the 100% NPK + FYM treatment and lowest in the non-treated control, which may be attributed to increased soil organic carbon concentration, rooting density, improved aggregation, and soil structure. [49]. observed that the application of 100% recommended dose of fertilizers alone increased infiltration rate by 24% compared to the treatment with 50% recommended dose of fertilizers. Although the infiltration rate slightly decreased in the sub-surface soil layer, the overall trend was similar to that observed in the surface soil layer. In conclusion, while the application of recommended chemical fertilizers (NPK) alone can improve soil infiltration rate, combining chemical fertilizers with GM or FYM has a significant effect on enhancing infiltration rates compared to control or other chemical fertilizer treatments.

6.4 Soil Aggregates

Soil aggregation and its stability are critical physical properties that significantly impact soil quality and productivity. Soil aggregates are formed when primary soil particles adhere to each other more strongly than to surrounding particles. [41]. observed that the combined application of fertilizer and organic manure increased the percentage of fine (11.4%) and coarse (4.2%) aggregates in calcareous silt loam soil compared to the control plot. The application of farmyard manure (FYM) enhanced the formation of water-stable aggregates larger than 0.25 mm (80.7%) and increased the mean weight diameter (MWD) to 0.81 mm, while the control plot had values of 69.7% and 0.61 mm, respectively [50]. The addition of manures affected the distribution of soil aggregate sizes, reducing the proportion of aggregates smaller than 0.1 mm at a depth of 0.15 to 0.30 m (from 34% to 31%), and increasing the proportion of aggregates larger than 1 mm at depths of 0.0-0.15 m (from 30.2% to 40%) and 0.15 to 0.30 m (from 25% to 33.6%) [51]. [52]. reported that the application of recommended doses of fertilizer in Vertisol soil increased the percentage of water-stable aggregates (WSA) larger than 0.25 and 0.10 mm, as well as the MWD, to 40.4%, 74.0%, and 0.286 mm, respectively, compared to the control with values of 34.1%, 64.1%, and 0.233 mm. [42]. observed a significant increase in MWD and WSA values in plots treated with continuous fertilizer application (100% NPK) compared to the control. The increase in aggregate stability may be attributed to the role of phosphate ions in binding soil particles or the substantial residue production in fertilized plots, which promotes aggregate formation. [36]. found that the MWD and % WSMA (water-stable macro-aggregates) were significantly higher in plots treated with 100% NPK + FYM compared to other treatments. The application of fertilizer combined with manure increased MWD by 35.3%, while the recommended rate of fertilizer application (100% NPK) increased it by 17.6% compared to the control. In terms of MWD, 100% NPK was significantly higher than the control and 100% N alone, likely due to the higher organic matter content in plots treated with NPK alone or in conjunction with FYM. [53]. observed that the best aggregation was found in plots treated with 100% NPK + farmyard manure, where macro-aggregates accounted for more than 50% of the total soil mass. [2]. found that the mean weight diameter ranged from 0.63 to 1.04 mm, with the highest values observed in the surface and subsurface soil layers treated with N_{180} + P_{80} + K_{40} + Zn(F) + FYM, and the lowest values in the control plot. In conclusion, the phenomenon of soil aggregation and stability is influenced by both chemical fertilizers and the combined use of chemical fertilizers with organic manures, similar to other physical properties of soils.

7. CONCLUSION

This review emphasizes the crucial role of physical conditions and properties in regulating soil quality and sustainable productivity. Key physical properties, including bulk density, hydraulic conductivity, infiltration rate, and soil aggregation, can be influenced by the application of chemical fertilizers and organic manures. The application of recommended doses of NPK through chemical fertilizers contributes to the improvement of soil physical properties. Moreover, integrated nutrient management practices, such as combining 50% of the nutrients from chemical fertilizers and 50% from organic sources like farmyard manure, green manuring, and sesbania green manure, have shown significant effects in enhancing soil physical properties and promoting sustainable crop productivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Wagenet RJ, Hutson JL. Soil quality and its dependence on soil physical processes. J Environ Qual. 1997;26(1):41-8.
2. Bhatt MKB, Navneet Pareek RC, Chandra R, Pareek N, Singh DK. Use of inorganic fertilizers and FYM for twenty-nine years in rice-wheat cropping system improves physical soil quality indices after rice. Int J Curr Microbiol Appl Sci. 2017;6(9):3431-8.
3. Zeleke G, Hurni H. Implications of land use and land cover dynamics for mountain resource degradation in the Northwestern Ethiopian Highlands. Mt Res Dev. 2001;21(2):184-91.
4. Jayathilake PKS, Reddy IP, Srihari D, Reddy KR. Productivity and soil fertility status as influenced by integrated use of N-fixing biofertilizers, organic manures and inorganic fertilizers in onion. J Agric Sciences. 2006;2(1):46-58.
5. Bekunda B, Sanginga N, Woomer PL. Restoring soil fertility in sub-Sahara Africa. Adv Agron. 2010;108:184-236.
6. Negassa W, Gebrekidan H, Friesen DK. Integrated use of farmyard manure and NP fertilizers for maize on farmers Fields. J Agric Rural Dev Tropics Subtrop. 2005; 106(2):131-41.

7. Darwish OH, Persaud N, Martens DC. Effect of long-term application of animal manure on physical properties of three soils. Plant Soil. 1995;176(2):289-95.
8. Prasad R. Cropping systems and sustainability of agriculture. Indian Farm. 1996;46:39-45.
9. Singh Brar BS, Singh J, Singh G, Kaur G. Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. Agronomy. 2015;5(2):220-38.
10. Chen JH. The Combined Use of Chemical and Organic Fertilizers and/or Biofertilizer for Crop Growth and Soil Fertility. Taichung, Taiwan; 2008.
11. Vanlauwe B, Bationo A, Chianu J, Giller KE, Merckx R, Mokwunye U et al. Integrated soil fertility management: operational definition and consequences for implementation and dissemination. Outlook Agric. 2010;39(1):17-24.
12. Abedi T, Alemzadeh A, Kazemeini S. Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of Wheat. Aust J Crop Sci. 2010;4:384-9.
13. Basel N, Sami M. Effect of organic and inorganic fertilizers application on soil and cucumber (*Cucumis sativa L.*) plant productivity. Int J Agric For. 2014;4:166-70.
14. Amujoyegbe BJ, Opabode JT, Olayinka A. Effect of organic and inorganic fertilizer on yield and chlorophyll content of Maize (*Zea mays L.*) and Sorghum (*Sorghum bicolor L.*) Moench. Afr J Biotechnol. 2007;6:1869-73.
15. Akhtar MJ, Asghar HN, Shahzad K, Arshad M. Role of plant growth promoting rhizobacteria applied in combination with compost and mineral fertilizers to improve growth and yield of Wheat (*Triticum aestivum*.). Pak J Bot. 2009;41:381-90.
16. Lal R. Enhancing crop yields in the developing countries through restoration of the soil organic carbon pool in agricultural lands. Land Degrad Dev. 2006;17(2):197-209.
17. Matsumoto T, Yamano T. Soil fertility, fertilizer and the maize green revolution in East Africa. Policy Working Paper, WPS5158, Japan's National Graduate Institute for Policy Studies and the World Bank Development Research Group Agriculture and Rural Development; 2009.
18. Nyalemegbe KK, Oteng JW, Brempong SA. Integrated organic-inorganic fertilizer management for rice production on the vertisols of the Accra Plains of Ghana. West Afr J Appl Ecol. 2009;16:23-33.
19. Han SH, An JY, Hwang J, Kim SB, Park BB. The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of Yellow Poplar (*Liriodendron tulipifera Lin*.) in a Nursery System. Forest Sci Technol. 2016;12(3):137-43.
20. Olaniyi JO, Ajibola A. Effects of inorganic and organic fertilizers application on the growth, fruit yield and quality of Tomato (*Lycopersicon lycopersicum*). J Appl Biol Sci. 2008;8:236-42.
21. GTZ. Food Crisis and Land: The World Food Crisis, Land Degradation and Sustainable Land Management: Linkages, Opportunities and Constraints; 2009.
22. Scholl L, Nieuwenhuis R. Soil fertility management. Wageningen: Agromisa Foundation, Netherland; 2004.
23. Alimi T, Ajewole OC, Awosola O, Idowu EO. Organic and inorganic fertilizer for vegetable production under Tropical conditions. J Agric Rural Dev. 2007;1:120-36.
24. Savci S. Investigation of effect of chemical fertilizers on environment. APCBEE Procedia. 2012;1:287-92.
25. Adediran JA, Taiwo LB, Akande MO, Sobulo RA, Idowu OJ. Application of organic and inorganic fertilizer for sustainable maize and cowpea yield in Nigeria. J Plant Nutr. 2005;27(7):1163-81.
26. Gruhn P, Goletti F, Yudelman M. Integrated nutrient management, soil fertility and sustainable agriculture: current issues and future challenges. Washington, DC: International Food Policy Research Institute; 2000.
27. Prasad B, Singh AP. Changes in soil properties with long term use of fertilizer, lime and FYM. J Indian Soc Soil Sci. 1980;28(4):465-8.
28. Pandey SP, Sankar H, Sharma VK. Efficiency of some organic and inorganic residues in relation to crop yield and soil characteristics. J Indian Soc Soil Sci. 1985;33(1):179-81.
29. Rabindra B, Narayanswamy GV, Janardhan NA, Vanagappa S. Long range effect of manures and fertilizer on soil physical properties and yield sugarcane. J Indian Soc Soil Sci. 1985;33(1):704-6.
30. Sharma GD, Sharma HL. Utilization of weed plants as organic manure under

different methods of rice establishment. Indian J Agric Sci. 1994;64(3):184-6.

31. Bellaki MA, Badanur VP. Long-term effect of integrated nutrient management on properties of vertisols under dry land condition. J Indian Soc Soil Sci. 1997;45:438-42.
32. Premi OP. Integrated nutrient supply for sustainable rice production in acid alfisol. Indian J Agric Res. 2003;37(2):132-5.
33. Mandal UK, Singh G, Victor US, Sharma KL. Green manuring: its effect on soil properties and crop growth under ricewheat cropping system. Eur J Agron. 2003;19(2):225-37.
34. 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. J Indian Soc Soil Sci. 2006;54(1):24-9.
35. Chaudhary SK, Thakur RB. Efficient farm yard management for sustained productivity of rice (*Oryza sativa*) – wheat (*Triticum aestivum*) cropping system. Indian J Agric Sci. 2007;77(7):443-4.
36. Hati KM, Swarup A, Dwivedi AK, Misra AK, Bandyopadhyay KK. Change in soil physical properties and organic carbon status at the topsoil horizon of a vertisol of central India after 28 years of continuous cropping, fertilization and manuring. Agric Ecosyst Environ. 2007;119(1-2):127-34.
37. Bandyopadhyay KK, Misra AK, Ghosh PK, Hati KM. Effect of integrated use of farmyard manure and chemical fertilizers on soil physical properties and productivity of soybean. Soil Till Res. 2010;110(1):115-25.
38. 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 cropping system in vertisol of Akola, Maharashtra. Agropedology. 2012;22:103-14.
39. Aziz MA, Mushtaq T, Ahmad M, Dar EA, Mahdi SS, Qureshi AM et al. Effect of integrated nutrient management on soil physical properties using Soybean (*Glycine max* (*L.*) *Merill*) as indicator crop under temperate conditions. Chem Sci Rev Lett. 2019;8(29):123-8.
40. Bhatia KS, Shukla KK. Effect of continuous application of fertilizer and manure on some physical properties of eroded Alluvial Soil. J Indian Soc Soil Sci. 1982;30(1):33-6.
41. Mishra VK, Sharma RB. Effect of fertilizer alone and in combination with manure on physical properties and productivity of entisol under rice-based cropping system. J Indian Soc Soil Sci. 1997;45(1): 84-8.
42. Selvi D, Santhy P, moorthy D, M. Effect of inorganics alone and in combination with farmyard manure on physical properties and productivity of Vertic Haplustepts under long-term fertilization. J Indian Soc Soil Sci. 2005;53(3):302-7.
43. Mandal UK, Sharma SN, Singh G, Das DK. Effect of Sesbania green manuring and green gram (*Phasiolus radiatus*) residue incorporation on physical properties of soil under rice (*Oryza sativa*)-Wheat (*Triticum aestivum*) cropping system. Indian J Agric Sci. 1999;69:615-20.
44. Harne RB. Influence of integrated use of organics to sustain productivity of rice. M.Sc. (ag.) [thesis], Dept. of Soil Science. Raipur: IGAU; 2001.
45. Gangwar KS, Sharma SK, Sharma GC, Tomar RK. Integrated nutrient management in alley cropping in sustainable upland rice-wheat system. J Farming Syst Res Dev. 2002;8(2):15-8.
46. Sharma SN. Integrated nutrient management in rice – wheat cropping system. Fert News. 2005;50(2):53-64.
47. Tadesse T, Dechassa N, Bayu W, Gebeyehu S. Effects of farmyard manure and inorganic fertilizer application on soil physicochemical properties and nutrient balance in rain fed lowland rice ecosystem. Am J Plant Sci. 2013; 04(2):309-16.
48. Singh Brar BS, Singh J, Singh G, Kaur G. Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. Agronomy. 2015;5(2):220-38.
49. Binjola S, Grewal KS, Antil RS. Long term effect of integrated nutrient management on soil physical indices under pearlmillet-wheat cropping system. Plant Arch. 2018;18:153-6.
50. Bhagat RM, Verma TS. Soil physical and chemical environment as influenced by duration of rice-wheat cropping system. J Indian Soc Soil Sci. 2002;48:75-8.

51. Kurnal A, Tripathi RP. Effect of continuous use of manure and fertilizers of physical properties of soil under paddy-wheat-cowpea cropping system. Crop Res. 2004;3(1):7-12.
52. Marathe RA, Bharambe RR. Physical characteristics of vertisol as influenced by integrated nutrient management system under sweet orange. PKV Res J. 2005; 29(2):179-82.
53. 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. Soil Sci. 2010;175(3):128-36.

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