Review Article

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

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 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; soil.

Introduction

The long-term field experiments are cogitate about to provide the best practical approximation to a test of sustainability of farming practices. The long-term fertilizer experiments that have been in operation in India for last many years have distinctly indicated that they could be used to measure and evaluate the effect of continuous cropping and fertilizer used on soil quality and hence the sustenance of the system (Wagnet *et al.,* 1997).Soil physical characteristics have a vital role in soil productivity and are necessary components of soil quality assessment. Physical parameters such as bulk density, mean weight diameter, aggregate stability, hydraulic conductivity, soil strength and infiltration rate regulates the soil functions (Bhatt *et al.,* 2017).However, increased human population and other factors have degraded the natural resources in the country thus seriously threatening sustainable food and environmental security (Zeleke and Hurni, 2001). In order to increase soil fertility in the short run, nutrients have to be added to the soil. This is often done by applying chemical fertilizers. However, to sustain the balance of soil fertility and to ensure agricultural productivity use of organic nutrient source fertilizer and application of amenable inorganic fertilizer are quite essential. Continuous use of inorganic fertilizer resulted in a imbalance in soil physical properties and unsustainable

Comment [R1]: Review all citations in the introduction.

Author Guidelines
All references must be numbered consecutively and citations of references in text should be identified using numbers in square brackets (e.g., “as discussed by Smith [9]”; “as discussed elsewhere [9, 10]”

crop production (Jeyathilake *et al.,* 2006). Combining inorganic and organic fertilizers result in greater benefits than either input alone through positive interactions on soil physical properties (Bekunda *et al.,* 2010). The addition of organic amendments has beenshown to maintain soil organic matter content and thereby contribute to improve soil physical properties and enhanced fertilizer use efficiency (Negassa *et al.,* 2005).Organic matter affect crop growth and yield either directly by supplying nutrients or indirectly by modifying soil physical properties that can improve the root environment and stimulate plant growth (Darwish *et al.,* 1995). Neither inorganic nor organic amendments alone can maintain organic matter status of soil (Prasad, 1996).Therefore, balanced and integrated use of organic and inorganic fertilizers enhance the accumulation of soil organic matter and improves soil physical properties (Brar*et al.,* 2015).

Comment [R2]: Suggestion: As this is a review study, cite more current references
For example:
Alzamel, N.M.; Taha, E.M.M.; Bakr, A.A.A.; Loutfy, N. Effect of Organic and Inorganic Fertilizers on Soil Properties, Growth Yield, and Physiochemical Properties of Sunflower Seeds and Oils. *Sustainability* **2022**, *14*, 12928.
Sigaye MH, Nigussei A, Lulie B, Mekuria R, Kebede K (2020) Effects of Organic and Inorganic Fertilizers on Soil Properties, Yield and Yield Components of Maize (Zea mays L.) Grown on an Andisols at Hawassa Zuria, Ethiopia. Res Vol.11 No.4:9.

Comment [R3]: Suggestion: insert the objective at the end of the introduction:
This review paper summarizes the current knowledge and information on the effect of inorganic fertilizers and organic manures on soil physical properties.

Integrated Nutrient Management-

The integrated nutrient management system is an alternative and is characterized by reduced input of inorganic fertilizers and combined use of inorganic fertilizers with organic materials such as animal manures, crop residues, green manure and composts (Negassa*et al.,* 2007 and Chen, 2008). Combined use of organic and inorganic fertilizers plays a significant role in sustaining soil fertility (Ali *et al.,* 2009; Elkholy *et al.,* 2010 and Vanlauwe*et al.,* 2010) and the use of organic fertilizers together with inorganic fertilizers, has a higher positive effect on physical properties and enhances soil health (Elkholy *et al.,* 2010) and improves the use efficiency of recommended inorganic fertilizer and reduces its cost (Ali *et al.,* 2009 and Abedi*et al.,* 2010).

Organic Fertilizer-

Organic fertilizers are natural materials of either plant or animal source, including livestock manure, green manures, crop residues, household waste, compost, and works directly as a source of plant nutrients and indirectly influences the physical, biological and chemical properties of soil (Son *et al*., 2004; Basel and Sami, 2014). Microorganisms from the soil decay the organic fertilizer to make its nutrients available for utilize by plants which added into the soil and have the characteristic nature of slow release of nutrients (Amujoyegbe *et al*., 2007).

1.1 Scope of Organic Fertilizer-

Organic fertilizers have the many advantages like to improve soil fertility, increasing organic matter content in soil that improves the soil structure, creating more air space and water retention within the soil and enhances soil nitrogen content, enhanced nutrient availability, releasing nutrients at a slower and more consistent rate, improves nutrient mobilization and protects the soil against rain and wind erosions. (Akhtar *et al*.,2009; Lal, 2006; Matsumoto and Yamano 2009; Nyalemegbe *et al*., 2009 and Han *et al*., 2016).Organic fertilizer enhances soil biological activity and the colonization of mycorrhizae, that enhances mutuality association between fungi and higher plants. Organic fertilizer increase root growth due to enhanced soil structure, promoting soil aggregates, enhances cation exchange capacity (Lal, 2006). Organic fertilizer also acts as a buffering agent against undesirable soil pH fluctuations (Basel and Sami, 2014; Olaniyi and Ajibola, 2008).

1.2 Limitations of Organic Fertilizer-

Potentially pathogenic improperly-processed organic fertilizers may contain pathogens that are harmful to humans or plants because organic fertilizers are derived from substances like animal feces or plant/animal matter contaminated with pathogens (Chen, 2008 and GTZ, 2009).They are relatively low in nutrient content, so larger quantity is needed to supply enough

nutrients for plant growth. Hence, large-scale agriculture without use inorganic fertilizers is difficult (Vanlauwe, 2010).Supply of nutrients to as per need of crops during their life cycle which difficult to match as source of nutrient for desired crop production. Microorganisms are also required to break down and release nutrients into the soil. The microbial activity need warmth and moisture to do their job. Thus the effectiveness of organic fertilizer is limited seasonally (Chen, 2008 and GTZ, 2009).

Comment [R4]: Suggestion: other items can be inserted because it is a review, for example:
1.Effects of Organic Fertilizers on Soil
2.Effects of inorganic fertilizers on soil
3.Disadvantages of organic fertilizers
4.Disadvantages of inorganic fertilizers

2. Why Inorganic Fertilizer are preferred ?

Mostly farmers from developing countries like India are how using the waste dung of all domestic animals and crop residues for fuel purpose instead of as manures as compost as a source of nutrients and a soil health improvement ammendments.This leads to degradation of soils that much deteriorated the chemical fertilizers are the immediate relief to crop production as they re-establish the soil fertility very quickly and the nutrients are early to available to plants as soon as the fertilizers are applied to crops (Matsumoto and Yamano, 2009). Inorganic fertilizers increase root residues that mean indirectly increases organic matter (Scholl and Nieuwenhuis, 2004). Due to this situation of organic and effect of chemical fertilizers, recently farmers put more emphasis on chemical fertilizer application in order to increase the productivity (Basel and Sami, 2014).

2.1 Scope of Inorganic Fertilizer-

Inorganic fertilizers are good source of nutrient for immediate effects on crop and their growth because the nutrients in inorganic fertilizers are already water soluble (Chen, 2008). Therefore the effect is usually immediately and fast, contains all necessary nutrients that are ready to use. Inorganic fertilizers are quite high in nutrient content and only relatively in small quantity is required for productivity (Han *et al.,* 2016). Scientific applications of inorganic fertilizer can increase soil organic matter content through higher levels of root mass and crop residues (GTZ, 2009; Scholl and Nieuwenhuis, 2004).

2.2 Limitations of Inorganic Fertilizer-

Over-application can result in negative effects such as leaching, pollution of water, acidification and reduces the availability of the trace element or alkalization of the soil (Alimi *et al.,* 2007). Chemical fertilizer enhances the decomposition of soil organic matter, which leads to degradation of soil structure and decrease in soil aggregation results in nutrients lost from soils through fixation, leaching, gas emission and thus can lead to diminish fertilizer use efficiency (Chen, 2008; GTZ, 2009; Savci, 2012 and Adediran *et al.,* 2004). Over use of chemical fertilizers can destroy decomposers and other beneficial soil organisms, reduce the colonization of plant roots with mycorrhizae and inhibit symbiotic N-fixation by rhizobia due to high N-fertilization and also hazardous to the soil environment (Chen, 2008 and Abedi *et al.,* 2010). This cleared that over unscientific use of chemical fertilizer causes problems not only to the soil health but also to the water quality, human health and environment (GTZ, 2009 and Gruhn *et al.,* 2000).

3. Physical Properties-

The physical indicators of soil play an important role in determining sustainability of soil for crop production. Among the physical properties of soil, some of the physical properties of soil such as bulk density, aggregate stability, hydraulic conductivity and mean weight diameter serves as the most important parameters for assessing quality of soil. Incorporation of fertilizers and organic manures in soil improves bulk density, particle density, aggregate

stability, hydraulic conductivity and mean weight diameter (Bhatt *et al.,* 2017).

4. The effect of organic and inorganic fertilizer on physical properties of soil-

4.1 Bulk density

Bulk density is the mass per unit volume of dry soil (volume of solid and pore spaces) and expressed as Mg/m^3. The total volume in soil includes particle volume, inter-particle void volume, and internal pore volume. Prasad and Singh (1980) reported that continuous use of FYM and NPK fertilizers over a period of 20 years helped in maintaining and improving the physical properties and organic carbon content of an acidic red loam soil, while the application of fertilizer nitrogen alone slightly deteriorated soil physical properties. The effect of bulk density of soil was not significant, although in some of the treatments there was a tendency for the bulk density to increase from the initial level. However, the lowest bulk density was found in FYM+ PK (1.29 Mg/m^3) plot in Inceptisols. A decline in bulk density due to the application of organic matter also has been reported by Pandey *et al*., (1985). Rabindra *et al*., (1985) found that the combined application of in-organics and organic material maintained and improved the physical conditions of the soil and the productivity in red sandy loam soil. Urea as the organic sources of fertilizer N was found to be better than other sources of N tried in maintaining the soil physical conditions and productivity of soil. The lowest bulk density was found under normal dose of NPK+ 25t FYM ha^{-1} and the highest bulk density was found in soil with addition of no manure (control). Studies conducted by Sharma and Sharma (1994) also revealed that there was a reduction in soil bulk density from the initial value due to the increased fertilizer levels or FYM application, but in un manure plots bulk density remained stable around initial value in Vertisol. Bellakki and Badanur (1997) reported that in black vertisol soils the in situ incorporation of sun hemp for ten years from 1984-94 reduced the bulk density as compared with fertilizer application. Premi (2003)and Mandal *et al.,* (2003) reported that in silty clay loam soil combined use of organic and inorganic sources of N decreased the bulk density of soil. Bajpai *et al.,* (2006) also found that incorporation of organic sources considerably decreased the bulk density of the soil. The lowest bulk density was observed in the 50 per cent NPK through fertilizer + 50 percent N through green manure treatment (1.43 Mg m^{-3}), while the highest was noted in control plot (1.56 Mg m^{-3}) in Inceptisols of Chattisgarh. Chaudhary and Thakur (2007) revealed that FYM along with fertilizers had a positive response on penetration resistance and bulk density of soil. Hati *et al.,* (2007) suggested that the bulk density was reduced significantly with the 100% NPK + FYM treatment over all other treatments in Vertisol of central India. Bandyopadhyay *et al.,* (2010) reported that in deep Vertisols the conjunctive use of recommended dose of fertilizer and farmyard manure (NPK + FYM) resulted in significant ($P < 0.05$) decrease of bulk density. Katkar *et al.,* (2012) noticed that in Vertisol of Akola the application of farm yard manure @ 10 tonnes/ha to recorded significant decrease in bulk density as compared to 100% NPK and 150% NPK through chemical fertilizer without organics. Aziz *et al.,* (2019) revealed that the bulk density increased with increase in recommended chemical fertilizers but does not vary significantly. Addition of FYM @ 10 t ha^{-1} significantly decreased the bulk density (1.22 Mg m^{-3}) than that of other treatment application in silty clay loam soil. Thus, it is concluded that the use of inorganic/chemical fertilizers along with organic manures improved lower Bulk Density of soil instead of an addition of organic or inorganic fertilizers as a source of nutrient to any crop in any soil type.

Comment [R5]: Paragraph has very old citation add more current references, for example:
Ma, G.; Cheng, S.; He, W.; Dong, Y.; Qi, S.; Tu, N.; Tao, W. Effects of Organic and Inorganic Fertilizers on Soil Nutrient Conditions in Rice Fields with Varying Soil Fertility. *Land* **2023**, *12*, 1026.

Akash S, Pradip Narayan Dalavi, Humnabad Srikanth and Umesh Bonthagorla . Effects of organic manure and fertilizers on physicochemical properties of the soil: A review . The Pharma Innovation Journal 2022; 11(9) 1856-1860.

Teresa Hernandez, José Guillermo Berlanga, Isabel Tormos, Carlos Garcia. Organic versus inorganic fertilizers: Response of soil properties and crop yield[J]. *AIMS Geosciences*, 2021, 7(3): 415-439.

Ding J, Ma M, Jiang X, et al. Effects of applying inorganic fertilizer and organic manure for 35 years on the structure and diversity of ammonia- oxidizing archaea communities in a Chinese Mollisols field. MicrobiologyOpen. 2020;9:e942. https ://doi.org/10.1002/mbo3.942

4.2 Hydraulic conductivity-

Hydraulic conductivity is the ability of soil to transmit water under saturated or nearly saturated conditions which is expressed as cm hr^{-1}.Hydraulic conductivity of soil is largely determined by soil properties such as texture, structure, compaction and exchangeable cations.Prasad and Singh (1980) found that in acidic red loam soil, the use of FYM @ 20 t/ha with inorganic fertilizer providing P and K had significantly higher hydraulic conductivity (2.5 cm hr^{-1}) over the control and hence even after 20 years of treatment there was not any change in hydraulic conductivity (2.0 cm hr^{-1}) in control plot. Bhatia and Shukla (1982) reported that nitrogenous and phosphate fertilizers have showed a tendency to increase hydraulic conductivity and that probably due to increased large pores in soil. Mishra and Sharma (1997) reported that in calcareous silt loam soil, increasing level of fertilizer doses significantly increase the hydraulic conductivity. Among the various fertilizer application, treatments 100% NPK alone only through chemical fertilizers for reported is reduced (14.7 x 10^{-7} m sec^{-1}) Hydraulic Conductivity over the combined application of inorganic fertilizers with FYM increases the hydraulic conductivity (23.7 x 10^{-7} m sec^{-1}). The combined application of FYM and fertilizers has favourable effect on the hydraulic conductivity of soil. The favourable treatment effects on aggregation and Bulk Density were well reflected in their effects on hydraulic conductivity. Selvi *et al.,* (2005) observed that different treatment effects on aggregation and bulk density were well reflected on hydraulic conductivity. Increasing levels of NPK significantly increased hydraulic conductivity, however combined application of FYM and NPK also resulted in significantly the highest show in hydraulic conductivity than that of NPK application. The Highest hydraulic conductivity was noted in 100 percent NPK + $ZnSO_4$ treated plot (1.99 cm hr^{-1}) and lowest was found in control (1.44 cm hr^{-1}) plot. Katkar *et al.,* (2012) revealed that the direct addition of organic matter through farm yard manure and increase in root biomass which helped in growth and development of soil micro-organisms cause beneficial effect on improvement in mean weight diameter, available water holding capacity and hydraulic conductivity.Bhatt *et al.,* (2017) observed that the highest hydraulic Conductivity in surface and sub-surface soil layers was recorded with application of N_{180}+ P_{80}+ K_{40}+ Zn(F)+ FYM, whereas, the lowest was observed under control.It is concluded that the only increasing addition or application amount of nutrients to crops by chemical fertilizers increases the Hydraulic Conductivity of soils, however significance the highest increase in Hydraulic Conductivity of soil was more pronounced by addition of nutrients through combined application of organic manures and inorganic fertilizers to crops.

4.3 Infiltration rate-

The infiltration rate is the rate or speed at which water enters into the soil. It is usually measured by the depth (in mm) of the water layer that can enter the soil in one hour. Bellaki and Badanur (1997) found that the improvement in infiltration rate of Vertisol in 50% RDF + 50% N applied either through green manure or FYM in Sorghum-Safflower crop rotation over 10 year under dry land condition. *Sesbania* GM and Mungbeen residue incorporation resulted in reduction of bulk density and increase in soil aggregation which in turn increased the infiltration rate and percolation rate in rice-wheat cropping system (Mandal *et al.,* 1999). Harne (2001) observed that the combined application of FYM @ 3.37 t ha^{-1} + 55 Kg N and GM @ 1.9 t ha^{-1} + 40 Kg N showed significantly increased infiltration rate i.e. 3.10 and 3.60 mm day^{-1} respectively, over general recommended dose treated plot (2.50 mm day^{-1}). This indicates that in Vertisol, addition of coarse organic matter with inorganic fertilizers increased the basic

infiltration rate. This higher infiltration rate could be associated with decreased bulk density and increased porosity of Vertisol. Gangwar *et al.,* (2002) reported that in rice-wheat system, there was tremendous increase in infiltration rate from 0.58 mm hr^{-1} of initial value to 1.97 mm hr^{-1} with the addition of *Sesbania seaban* lopping @ 5 t ha^{-1} year as green manure incorporation in sandy loam soil. This higher infiltration rate could be associated with decreased bulk density and increased porosity of Vertisol. Sharma (2005) reported that green manuring with *sesbania* or green gram residues incorporation in combination with 100 per cent N (120 kg ha^{-1}) treated plot recorded increased infiltration rate i.e. 2.21 and 2.19 cm hr^{-1} respectively, over the fallow plots (2.13 cm hr^{-1}). Residue incorporation resulted in reduction in bulk density and increase in soil aggregation, which in turn increased infiltration, percolation rate and hydraulic conductivity of soil. Bajpai *et al.,* (2006) observed that integrated nutrient management in rice wheat system had marked influence on infiltration rate. However the infiltration rate was significantly higher (1.30 cm hr^{-1}) in 100 per cent recommended NPK through fertilizer in rice and wheat, over the control plot (0.85 cm hr^{-1}). Tadesse *et al.,*(2013) revealed that the application of organic manure along with chemical fertilizers had marked influence on infiltration rate. The higher infiltration rate in treatment 100% NPK + FYM and 50% NPK + GM as compared to other treatments. This indicates that the higher infiltration rate could be associated with decreased bulk density and increased porosity of the soil. Brar *et al.* (2015) reported that the infiltration rate was the highest in 100% NPK + FYM treatment and lowest in non-treated control. Increase in infiltration rate in 100% NPK + FYM treatment may be due to increase in SOC concentration, rooting density and the attendant improvement in aggregation and soil structure resulting in higher porosity and pore continuity.Binjola *et al.* (2018) observed that the application of 100% recommended dose of fertilizers alone also increased infiltration rate by 24% over the treatment where 50% recommended dose of fertilizers was applied. Although the infiltration rate slightly decreased in sub-surface soil layer but the trend followed was similar to that observed in surface soil layer. It is conclude that the application of recommended dose (NPK) of crops through chemical fertilizers improve the infiltration rate of soil, but chemical fertilizers along with GM or FYM had significant effect in improve Infiltration rate of soil over the control or any chemical fertilizer treatment.

4.4 Soil Aggregates-

Soil aggregate and its stability is the most important physical property of soil which regulate the quality and productivity of soil. A soil aggregate is a group of primary soil particles that cohere to each other more strongly than to other surrounding particles. Soil aggregates form through the combined action of cohesion and fragmentation processes. Mishra andSharma (1997) revealed that the interaction effect of fertilizer and organic manures was not significant but its values indicated that combined application of fertilizer with FYM increased per cent fine (11.4%) and coarse aggregate (4.2%) size, in calcareous silt loam soil over control plot *i.e.* 10% fine and 3.9% coarse aggregates. An application of FYM enhanced water stable aggregates > 0.25 mm (80.7%) and MWD (0.81 mm) than control (69.7% and 0.61 mm), respectively (Bhagat *et al.,* 2002).Manures application affected the distribution of soil aggregate sizes by reducing the amount of < 0.1 mm size in the 0.15 to 0.30 m depth (34% to 31%) and increased the amount of > 1 mm size in the 0.0-0.15 m (30.2 to 40%) and 0.15 to 0.30 m (25 to 33.6%) depths. The water stable aggregates > 0.24 mm were significantly higher (58.2%) in fallow than in cultivated plots (Kurnal *et al.,* 2004). Marathe and Bharambe (2005) reported that application of recommended dose of fertilizer in Vertisol soil of

Nagpur have per cent water stable aggregates (WSA) more than 0.25, 0.10 mm and mean weight diameter (MWD) recorded 40.4, 74.0 and 0.286 mm as compared to control *i.e*., 34.1, 64.1 and 0.233 mm, respectively. Selvi *et al.,* (2005) revealed that the continuous application of fertilizer (100% NPK) showed significant increase in MWD and per cent WSA values from 0.703 mm and 82.3% as compared to 0.696 mm and 72.6% in control. They further reported that increase in aggregate stability as compared to control due to balanced dose of fertilizer on soil structure may be because of the role played by phosphate ions in binding of soil particles or due to large amount of residues produced in the fertilized plots resulting in aggregate formation. Hati *et al.,* (2007) studied that the MWD and % WSMA in 100% NPK + FYM were significantly higher than in the other treatments. Fertilizer plus manure application (100% NPK + FYM) increased by 35.3%, while recommended rate of fertilizer application (100% NPK) increased it by 17.6% compared to the control. The MWD in 100% NPK was significantly more than in control and 100% N. This might be ascribed to higher organic matter content in the plots where NPK was applied alone or in conjunction with FYM. Chakraborthy *et al.,* (2010) observed that better aggregation was found with 100% NPK + farmyard manure, where macro aggregates were greater than 50% of total soil mass.Bhatt *et al.* (2017) found that the mean weight diameter varied from 0.63 to 1.04 mm. Highest mean weight diameter in surface and subsurface soil layers was recorded with application of N_{180}+ P_{80}+ K_{40}+ Zn(F)+ FYM, whereas, the lowest was observed under control.It is concluded that the phenomenon of soil aggregation and their stability is also under influence of chemical fertilizers and combined use of chemical fertilizers with organic manures as like other physical properties of soils.

5 Conclusion

This review clarified that the physical condition and physical properties are most important in regulation of soil quality and its productivity on sustainable basis. The physical properties namely bulk density, hydraulic conductivity, infiltration rate and soil aggregate their changes (improvement or degradation) are under influence of application of chemical fertilizers and organic manures. Application of Recommended dose of NPK through chemical fertilizers helps to improve physical properties of soil. Application of NPK and micronutrients through Integrated Nutrient Management practices particularly 50% nutrients through chemical fertilizers and 50% nutrients organic sources like FYM, green manuring, *sesbania* GM had significant effect in improvement of physical properties of soil and sustainable crop productivity.

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