

Review Article

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Effect of Continuous Application of Organic and Inorganic Sources of Nutrients on Chemical Properties of Soil

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ABSTRACT

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Continuous applications of organic manures and inorganic fertilizers have been reported to affect soil pH, electrical conductivity, Soil organic carbon, available N, P and K. Electrical conductivity has been used as chemical indicator of soil biological quality in response to crop management practices. Continuous application of organic manure and inorganic fertilizer decreased soil pH but increased total soluble salt concentration. Soil organic carbon, available N, available P; and water soluble, exchangeable and total K were significantly increased with the conjoint application of organic manure and inorganic fertilizer whereas the concentration of non-exchangeable K was significantly decreased with combined application of organic manure and inorganic fertilizer in comparison to application of fertilizer alone. Thus the use of organic and inorganic sources of nutrients improved chemical properties of soil, ultimately soil health and productivity.

Introduction

Indiscriminate use of chemical fertilizers and other agro chemicals in intensive agriculture polluted the soil, water and environment and also affected human beings. Consequently, more attention has been given to clean agriculture and application of eco-friendly practices. Intensive cultivation and growing of exhaustive crops in sequence had resulted in mining of nutrients and deficiency of soil macro and micro nutrients. Over exploitation and unscientific use of soil without regard to long-term sustainability has resulted in deterioration of soil health and jeopardizing the food security (Yadav, 2007). Nitrogen is a

major limiting nutrient for crop production. It can be applied through chemical or biological means. Over application can result in negative effects such as leaching, pollution of water resources, destruction of microorganisms and friendly insects. Due to the prohibitive cost of chemical fertilizers, majority of farmers who are mostly marginal and small, do not apply the recommended dose of fertilizers. There are reports of declining or stagnating crop yields and questions are now being raised about the sustainability of the rice-wheat cropping system. The underlying reasons for decline or stagnation of crop yields are not precisely known, though it has been attributed to changes in quantity and quality of soil

organic matter (SOM) and a gradual decline in the supply of soil nutrients, causing macro and micronutrient imbalances (Ladha *et al.*, 2000). Long-term studies indicated that supplying of plant nutrients only through chemical fertilizers lead to depletion of SOM and declined the soil productivity (Singh *et al.*, 2001). The use of organic manures provides soil with essential nutrients and adsorbs nutrients against leaching. It also improve soil texture, increase ion exchange capacity of soil, increase soil microbial populations and activity, improve moisture-holding capacity of the soil and enhanced soil fertility (Aranconet *et al.*, 2005). Lower availability of plant nutrients in plots applied with organic amendments is expected due to slower release rates of nutrients from organic materials particularly during initial years of conversion to organic production (Gopinath *et al.*, 2009). Farmers are using indigenous organic manures as sources of nutrients. These organics are bulky in nature but, contain reasonable amount of nutrients. The use of organic manures in INM helps in mitigating multiple nutrient deficiencies. Organic fertilizers are gaining importance because of their low cost, no residual toxicity and capacity to enrich soil fertility in addition to high returns under favourable conditions. Therefore, to maintain soil health for long-term sustainability of crop production system and to offset decrease in SOM, application of organic manures, compost and crop residues have commonly been advocated.

Soil pH

Soil pH, a function of parent material, time of weathering, vegetation and climate is considered as one of the dominant chemical indicators of soil characteristics, identifying trends in change for a range of soil biological and chemical functions such as acidification, salinisation, crop performance, nutrient availability and cycling and biological activity

(Dalal and Moloney, 2000). Continuous applications of inorganic fertilizers and organic manures have been reported to affect soil pH. The magnitude of effects depends on soil type, cropping systems, nutrient management practices and nature of fertilizer materials used. In a Mollisol, continuous cropping of rice-wheat and cowpea for 31 years had no significant effect on soil pH in NPK treated plots (Sharma *et al.*, 2007). On the contrary, application of inorganic fertilizer in an Alfisols decreased soil pH from its initial value of 5.5 to 4.1 in NPK treated plots (Mishra *et al.*, 2008). Continuous application of organic and inorganic sources of nutrients for 20 years lowered the soil pH by 0.3-0.9 units compared to unfertilized soil (Tirol-Padre *et al.*, 2007). According to Sharma *et al.*, (1998) soil pH was maintained or declined with integrated nutrient management (INM) treatments after 31 years compared to initial value. There was no significant effect of various treatments (FYM, NPK, crop residues) observed on soil pH at 0-15 and 15-30 cm soil depth after 35 years of continuous cropping and fertilization (Agarwal *et al.*, 2010). Application of FYM, rice straw and green manure along with inorganic fertilizer decreased soil pH as compared to the fertilizers alone in rice-wheat cropping system (Kumar *et al.*, 2012). Selvi *et al.*, (2005) reported that application of chemical fertilizer for 32 years significantly reduced soil pH while application of organic manure improved soil pH. The increase in soil pH might be due to moderating effect of organic manure as it decreases the activity of exchangeable Al^{+3} ions in solution due to chelation effect of organic molecules (Sharma and Subehia, 2003). Parvathi *et al.*, (2013) studied the long-term effect of manure and fertilizer on physical and chemical properties of Alfisols and observed that soil pH was the highest in FYM amended plots (5.51) and the lowest in NPK + lime plots (5.21). The soil pH in the treatment receiving recommended dose of

inorganic fertilizer was 7.24 which decreased to 7.08 and 7.04 with the addition of FYM and vermicompost, respectively (Srikanth *et al.*, 2000). This was ascribed to the acidifying effect of organic acids produced during the course of decomposition of organic amendments.

Electrical conductivity

Soil electrical conductivity, a measure of salt concentration is considered as an easily measured and reliable indicator of soil quality (Arnold *et al.*, 2005). It can indicate trends in salinity, crop performance, nutrient cycling and biological activity and along with pH. It can act as a surrogate measure of soil structural decline, especially in sodic soil. Electrical conductivity has been used as chemical indicator of soil biological quality in response to crop management practices (Gil *et al.*, 2009). Long-term application of fertilizer and manure significantly affected EC of the soil (Hati *et al.*, 2007). Plots treated with NPK either alone or in combination with FYM showed significantly higher EC compared to unfertilized plots and fertilizer N alone treated plots. This increase in EC might be due to increase in base saturation of the soil where optimum rate of fertilizer and manure was applied compared to control plots. Kumar *et al.*, (2012) reported that application of FYM, rice straw and green manure along with inorganic fertilizer decreased soluble salt concentration compared to the fertilizers alone in rice-wheat cropping system. Several long-term studies showed non-significant effect of treatments on EC of soil (Parvathi *et al.*, 2013; Agarwal *et al.*, 2010; Hemalatha and Chellamuthu, 2013).

Soil organic carbon

The level of soil organic carbon (SOC) at a point of time reflects the long-term balance between addition and losses of SOC under

continuous cultivation. Changes in agricultural practices often influence both quantity and quality of SOC and its turnover rates. Dynamics of organic carbon storage in agricultural soils influence global climatic change and crop productivity (Li *et al.*, 2007). The common management practices leading to improved SOC status include integrated nutrient management involving the use of chemical fertilizers along with organic sources such as manure, compost, crop residues and bio-solids, mulch farming, conservation tillage, agro-forestry, diverse cropping system and cover crops (Lal, 2004).

In rice-wheat system, incorporation of rice straw improved SOC concentration by 19% and total N by 37% over unfertilized control. FYM application improved SOC concentration by 11% and total N concentration by 77%. Addition of both rice straw and FYM together resulted in greatest improvement in SOC (34%) and total N (90%) concentration (Benbi and Senapati, 2010). Several studies have reported that integrated use of organic sources and mineral fertilizers results in improved SOC under different soil, crop and climatic conditions (Yang *et al.*, 2004; Moharana *et al.*, 2012; Benbi *et al.*, 2012). Yang *et al.*, (2004) reported that SOC content in paddy soil was 40-60% higher under combined application of organic sources and chemical fertilizers compared to application of chemical fertilizers. In rice-wheat cropping system continuous application of FYM either alone or in combination with NPK resulted in considerable accumulation of SOC in surface soil layer than unfertilized control (Moharana *et al.*, 2012). Kumar *et al.*, (2012) studied the long-term effect of organic materials along with fertilizers and found that SOC was significantly increased in soil treated with organic materials and fertilizers in comparison to the soil treated with fertilizers alone. The application of FYM increased

SOC by 48 and 17% compared to control and fertilizer treatments, respectively. However, fertilizers alone also increased SOC by 26% as compared to unfertilized control. The increase in SOC with application of inorganic fertilization is attributed to higher above ground and root biomass than in control plots. Further, higher build-up of SOC with the long-term application of organic manures along with the fertilizers may be attributed to additional C inputs resulting from return of crop residues into soils.

Soil nutrient status

Available N

In rainfed lowland rice ecosystem, increase in rate of FYM application from nil to 7.5 and 15 t ha^{-1} significantly improved the total N content of the soil by 17 and 30% respectively, reported by Tadesse *et al.*, (2013). Dhaliwal *et al.*, (2013) studied buildup of macro, micro and secondary nutrient under rice-wheat cropping system. They observed that N status varied from 141-155 kg ha^{-1} compared to initial value of 134 kg ha^{-1} and recorded maximum value in treatment $\text{N}_{150}\text{P}_{60}\text{K}_{150}\text{Cu}_{10}\text{Mn}_{20}\text{Zn}_{25}$ (154.6 kg ha^{-1}). Katkar *et al.*, (2012) studied long-term impact of nutrient management on soil quality and sustainable productivity under sorghum-wheat crop sequence in Vertisols. They observed that the availability of N was increased by 2.6 % in the integrated nutrient management (INM) treated plots compared to the plots receiving only inorganic fertilizer. The increase in available N with the application of NPK and FYM may be due to mineralization of organic N from FYM and enhanced microbial activity which might have enhanced the conversion of organically bound soil N to mineral form (Tolanur and Bandanur, 2003). Continuous rice-wheat cropping system for five years involving use of fertilizer N in combination with P and K

fertilizers slightly increased the available N (Yaduvanshi, 2001). However, available N content of the soil was significantly increased with green manuring and FYM treatments. This increase might be due to the mineralization of N from green manuring and FYM in soil.

Availability of N was increased with the addition of nitrogenous fertilizer in the FYM amended plots suggesting that appropriate combination of inorganic fertilizer plus organic manure is required for proper management of nitrogen (Gupta and Laik, 2002). It was found that 30 t ha^{-1} FYM applied during summer was most suitable dose when combined with urea at 120 kg N ha^{-1} in releasing plant available N. However, if chemical fertilizer is avoided then 30 t ha^{-1} FYM will have to be applied during both seasons for higher release of nitrogen. Nath *et al.*, (2011) reported that the application of compost and biofertilizers improved soil N content under integrated nutrient management (INM) treatments. They reported that soils receiving treatment 25% NP + 100% NPK + biofertilizers + compost at 2 t ha^{-1} showed highest available N (234 kg/ha) followed by treatment 25% NP + 100% NPK + compost at 2 t ha^{-1} (231 kg/ha). The occurrence of highest available N content was attributed to the continuous application of N-fixing biofertilizers coupled with compost. Addition of organic manure and inorganic fertilizer (60 kg N ha^{-1} from urea+ *Azolla*) increased available N content in soil due to higher supply of N through urea and atmospheric nitrogen fixation by *Azolla*(Singh *et al.*, 2005). Changes in soil biological and biochemical characteristics in a long-term field experiment on a sub-tropical Inceptisol was studied by Masto *et al.*, (2006). They reported that total N was lower in the reference soil (1023 kg/ha) than in the control (1041 kg/ha) and increased significantly in plots receiving 50% NPK (1429 kg/ha), 100%

NPK (1733 kg/ha), 150% NPK (1812 kg/ha) and 100% NPK + FYM (1846 kg/ha). The highest available N content was in plots receiving 100% NPK + FYM (285 kg/ha). Impact of long-term fertilization on soil nutrient content in Vertisols under finger millet- maize cropping sequence was studied by Hemalatha and Chellamuthu (2013) and found that available N was highest in plots receiving balanced application of fertilizers and was the lowest in the unfertilized control. The lowering of available N in unfertilized control plot was due to the continuous removal of native soil N in the absence of external supply of N through fertilizers and manures.

Available P

Compost enriched with rock phosphate could improve available P status in soil (Singh *et al.*, 2009). In rice-wheat cropping sequence Nathet *et al.*, (2011) reported that available P was significantly improved with the combined use of compost, biofertilizers or enriched compost only. The highest available P content (28 kg/ha) was observed under 25% NP + 100% K + enriched compost at 2 t ha⁻¹. Hemalatha and Chellamuthu, (2013) reported that P availability was highest under INM. It was attributed to solubilization of P by organic acids released from organic manures coupled with reduction of P fixation in soil due to chelation of P fixing cations like Ca, Mg, Fe, Al, Zn, Mn and Cu and enhanced microbial activities. Available soil P after rice harvest in rain-fed lowland rice ecosystem was highest in soil treated with 15 t FYM and 100 kg P₂O₅ ha⁻¹ (Tadesse *et al.*, 2013). Fertilizer N treated plots fixed the highest amount of P (13.7%) followed by the control (11.4%) and 50% NPK (8.42%) treated plots (Masto *et al.*, 2006). Least P was fixed in soils having 100% NPK + FYM (4.1%) treatment. This lowering of P fixation may be due to the complexing of P by Ca, Mg, Fe and

Al ions and blocking of the fixation sites by molecules released from the decomposition of manure (Subramanian and Kumarswamy, 1989). The organic manures decreased P adsorption or fixation and enhance P availability in P fixing soils (Reddy *et al.*, 1980; Sharpley *et al.*, 1984). In Vertisols, Singh *et al.*, (2007) reported that available P was improved in plots receiving organic manure and P treatment because organic manure has been responsible for maintaining the greater concentration of Olsen P. Tolanur and Bandanur (2003) reported maximum build-up of soil P under NPK + FYM treated plot that was due to build-up of P in soil through release and solubilisation of native P in soil due to release of organic acids from FYM. Reddy *et al.*, (2000) also reported that combined use of manure and fertilizer P proved better than their solitary application in a Vertisols.

K content in soil

Verma and Sharma, (2000) studied the effect of rice straw and FYM application on different K fractions in a long-term experiment on rice-wheat system and reported that rice straw treated soil was higher in available and water soluble K than FYM treated soil. This was attributed to higher percentage of K (2.5%) in rice straw compared to FYM (1.96%). Yadav *et al.*, (2009) reported that in surface soils of eastern plain of Rajasthan water soluble, exchangeable, available, non-exchangeable, HNO₃ soluble and fixed K were 10.3, 242, 254, 1464, 1707, 1927 and 3634 mg kg⁻¹, respectively. While the water soluble K decreased and the non exchangeable, fixed and total K were increased with soil depth because non exchangeable K, fixed K and total K were mainly contributed by clay fraction in soil. Several studies have reported that water soluble K, exchangeable K and non-exchangeable K were significantly

increased with increasing dose of K and addition of FYM (Majumdar *et al.*, 2002; Nalatwadmath *et al.*, 2003). Verma and Sharma (2000) observed that among different fraction of K, water soluble fraction of K increased up to 45 % and non exchangeable increased up to 73 % by addition of lantana (*Lantana camera* L.) over six years as source of K in acid soils of Palampur. Increasing dose of liquid manure and NPK resulted in a significant increase in the content of available K (Bednarek *et al.*, 2012). Contrarily, Borowiec (1986) reported that the content of available K in soil of the control plot and in the plot that had been steadily fertilized with liquid manure for 20 years did not differ significantly. In rice- wheat cropping system, Tripathi *et al.*, (2013) studied the effect of phosphorus and potash levels alone and in combination with FYM on available K in soil. Increasing levels of K and P increased available K significantly as compared to control treatment. The build-up of available K in soil due to FYM addition may be due to the additional amount of K applied through it. In pearl millet-wheat cropping system, Kumar *et al.*, (2012) reported that long-term integrated nutrient management through FYM in rice-wheat cropping system had resulted in highest available K (318 kg/ha).

The long-term effect of nutrient management on soil fertility and SOC pools under a 6-year-old pearl millet-wheat cropping system in an Inceptisol of subtropical India was studied by Moharana *et al.*, (2012). Plots receiving FYM maintained highest amount of available K (245 kg ha⁻¹) in surface soil followed by integrated use of FYM + NPK (214 kg ha⁻¹), NPK alone (184 kg ha⁻¹) and control (169 kg ha⁻¹). Farmyard manure application resulted in an increase in available K due to greater release of non- exchangeable K from soil as FYM increased soil CEC, which might have resulted in increased NH₄OAc-K and its utilization by crops (Blake

et al., 1999) besides FYM's own K supply. The plots under FYM treatment either alone or in combination with NPK fertilizer showed the maximum accumulation of exchangeable K, possibly because of the increased sorption of K following continuous application of FYM (Poonia *et al.*, 1986). Long-term effect of nutrient management in sorghum-wheat cropping system in Vertisol of Akola was studied by Katkar *et al.*, (2012). They showed that plots treated with both NPK and FYM together showed highest available K and the unfertilized plots showed the lowest. The available K in NPK plus FYM treated plots was higher by 18.6% than NPK treated plots. Increase in available K was probably due to the direct addition to the available K pool of the soil besides reduced K fixation and release of K due to the interaction of organic matter with clay (Sharma *et al.*, 2001). Continuous cropping without addition of K and imbalanced fertilization (N and NP) reduced the availability of K as compared to initial soil K status. In a semi-arid Inceptisol, Masto *et al.*, (2006) reported that available K content increased with increasing rates of K fertilizer, the maximum being with 100% NPK + FYM and 150% NPK. Other studies in India also showed that where K inputs were inadequate, the K needs of the crop were mostly met from the non-exchangeable K fractions of the soil (Rao and Siddaramappa, 2000).

In an Alfisol Parvathi *et al.*, (2013) observed that the available K content in soil decreased irrespective of the organic and inorganic fertilizer treatment. This decrement in available K was attributed to more uptake of K from the soil. Available K content declined significantly after the harvest of 10 crops of rice-wheat treated with chemical fertilizer, whereas it increased with continuous application of K fertilizer and organic manures (Yaduvanshi, 2001). The build-up of available K in soil due to application of green manure or FYM may be due to its self

contributing potential. Application of K fertilizer significantly increased K content of soil by 3 to 4 kg ha⁻¹ in the first year and 17 to 19 kg ha⁻¹ in the second year (Sharma and Sharma, 2002). The available K content of soil was further increased significantly with the application FYM along with NPK over NPK alone. This may be possible due to additional supply of K by FYM. The partial K balance was positive with crop residues application and negative (-107 kg/ha) when straw was removed (Surekha *et al.*, 2004). Available K increased significantly (440-519 kg/ha) with incorporation of rice straw alone or in combination with green manure compared to chemical fertilizers (Kharub *et al.*, 2004).

In conclusion, the combined use of organic and inorganic sources of nutrients improved soil chemical properties such as Soil organic carbon, available N, available P; and water soluble, exchangeable and total K whereas soil pH and non-exchangeable K was significantly decreased with combined application of organic manure and inorganic fertilizer in comparison to application of inorganic fertilizer alone. Thus the combined use of organic and inorganic sources of nutrients improved soil health.

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