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Long term effect on soil fertility by rice crop after 35 years cropping cycle under rice-wheat cropping system

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Abstract
The study was conducted on the AICRP-IFS experiment located at BAU, Sabour having twelve treatments with four replications in randomized block design having 25 to 50% of nitrogen substitution through different organics viz, FYM (Farmyard manure), GM (Green manure) and WS (wheat straw) under long term effect with rice-wheat cropping system affecting physic-chemical properties of soil was studied. After the analysis of soil samples a significant reduction in soil pH was observed from its initial value of 7.40 to 7.25, organic carbon build up from 0.46% to 0.87%, available N from 194.00 to 269.91 kg ha^{-1}, available P_2O_5 from 23.60 to 46.91 kg ha^{-1} and available K_2O from 0.75 to 184.44 kg ha^{-1} respectively due to long term 35 years of INM practices under rice-wheat in alluvial soil. Substitution of 50% and 25% N through organics either by FYM/GM/WS showed a significant increase in the DTPA-extractable Zn, Cu, Fe and Mn of post harvest soil after 35 years of the experiment.

Keywords: Soil fertility, rice crop, cropping cycle, rice-wheat cropping system

Introduction
The rice (*Oryza sativa*) and wheat (*Triticum aestivum*) cropping system is the chief source of calories for million of people occupying 13.5 million hectare in the Indo-Gangetic plain feeding about 1/5 th of world population (Saharawat *et al*., 2010) [21]. Rice – wheat covers 53% of total area of India and is called the "food bowl "or" food basket" (Koshal 2014) [13]. The introduction of high yielding dwarf wheat and rice varieties during Green revolution has spread this cropping system in non traditional areas such as the wheat belt in Northwestern India. The production of rice- wheat cropping system increased rapidly during 1962-90 with the development of highly fertilizer responsive varieties, expansion of irrigated area, improved management and supportive government policies. Moreover integrated approach to the management of soil nutrients along with other complementary measures must be included as the overall strategy for increasing the crop yields and sustaining them at high level.
The imbalanced use of fertilizers is an important issue in an Indian Agriculture so now an alternate option is combined use of organic and inorganic sources of essential nutrients increasing the production and profitability of field crops and thus helps in maintaining the fertility status of soil (Gupta *et al*., 2006) [9]. The Integrated Nutrient Management (INM) concept targets to ensure sustainable farming system by improving crop productivity and soil health (Das *et al*., 2014) [6]. INM refers to conjunctive use of all available nutrient sources (organic, inorganic and biofertilizers) to sustain soil fertility and crop productivity based on economic consideration. INM has the potentiality to ensure the sustained availability of nutrients as well as enhancing Nutrient Use Efficiency (NUE) in the soils of Indo- Gangetic plains of Bihar. Incorporation of wheat straw, FYM and green manuring with *Sesbania aculeata* helps in improving the soil structure thus reducing BD, soluble salt concentration, pH and increased porosity, infiltration rate, SOC of soil. The continuous application of organic manures alone or in combination with fertilizers over a period of 10 years decreased the soil pH as reported by Antil and Mandeep 2007. SOC is the basis of soil fertility as it promotes the structure, biological and physical health of soil and is a buffer against harmful substances. Therefore, SOC act as key indicator of soil quality and productivity (Bauer and Black, 1994)

[2]. Organic sources of plant nutrients offer the dual benefits of increasing organic matter content and improvement in physical and chemical properties of soil besides supplying nutrients to the crops (Chaudhary, Singh and Jha, 2011) [5]. INM is developed with an understanding of the interactions among crops, soils and climate which advocates interaction of inorganic and organic sources of nutrients. Bodruzzaman *et al*., 2002 [4] reported that the combined use of organic manure with inorganic fertilizers performed better than sole inorganic fertilizer to sustain the soil fertility and rice-wheat productivity. It has been reported that in the absence of FYM, the soil productivity declines. The challenge is only to identify organic sources of waste material nature with little value as fodder and fuel and are locally available at low cost. As FYM is limited in supply so green manuring proves to be a more feasible substitute for fertilizer N. Green manuring helps in maintaining and improving soil structure by adding of OM, minimize P, K fixation in all types of soils, produces humus, which in turn enhances the utilization of fertilizer nutrient by plants and thus helps in reducing leaching losses by enhancing water retention ability of soil.

The principal aim of Long Term Fertilizer Experiment (LTFE) set up in the country in 1885 has been to evaluate the long term effect of organic and inorganic manuring on crop production and soil health under high input soil management technology. It is well recognized that LTFEs are valuable repositories of information in context to sustainability of intensive agriculture. The purpose of LTFE at fixed sites in different agro- ecological zones (AEZ) and on important cropping system focuses not only to monitor the changes in yield response due to continuous application of plant nutrient inputs from fertilizers and organic sources, but also helps in the development of strategies and policies for rational fertilizer use and management and in turn resulting in improvement of quality of soil and the environment.

DTPA extractable micronutrients status in soil varies to a great extent with changes in basic soil chemical properties viz. pH, CEC and SOC (Moharana, Sharma, Biswas, 2017) [18]. Higher uptakes of Zn, Cu, Fe and Mn were observed with the increased application of nitrogeneous fertilizers in alkaline soils under rice-wheat cropping system. The application of nitrogeneous fertilizers to rice resulted in decreased soil pH of and enhancing the availability of micronutrient cation in soil. Goe *et al*., 2000 [29] reported that manure applications are better source of available Fe, Mn and Znthan synthetic fertilizers but on the sametime results in the accelerated depletion of available Cu on a purple paddy soil in southwestern China after 9 years of fertilization.

Materials and Methods

Experimental site description

The experiment entitled "Long term effect on soil fertility by rice crop after 35 years cropping cycle under rice-wheat cropping system" was based at Bihar Agricultural College, Sabour, Bhagalpur, India. Permanent plot experiment was established in 1984 at the Bihar Agricultural College Research Farm (25°23'N, 87°07'E, 37.19 m.s.l.), Bhagalpur, Bihar, India under the network project research program of the Project Directorate on Farming System Research, Modipuram. The soil is Ustochrept clayey soil with general properties: pH 7.40, organic carbon 0.46%, available N 194 kg ha^{-1}, available P 10.12 kg ha^{-1} and available K 128.65 kg ha^{-1}.

The experiment was laid out in randomized block design with 4 replications consisting of 12 treatment combinations *viz*; control (T_1) (no fertilizer no organic manure); 50% recommended dose of fertilizers (RDF) to both rice and wheat (T_2); 50% RDF to rice and 100% RDF to wheat (T_3); 75% RDF to both rice and wheat (T_4); 100% RDF to both rice and wheat (T_5); 50% RDF + 50% N through farm yard manure (FYM) to rice and 100% RDF to wheat (T_6); 75% RDF + 25% N through FYM to rice and 75% RDF to wheat (T_7); 50% RDF + 50% N through wheat straw to rice and 100% RDF to wheat (T_8); 75% RDF + 25% N through wheat straw to rice and 75% RDF to wheat (T_9); 50% RDF + 50% N through green leaf manure (GLM) (*Sesbania aculeata*) to rice and 100% RDF to wheat (T_{10}); 75% RDF + 25% N through (GLM) to rice and 75% RDF to wheat (T_{11}); farmer's fertilizers practice to rice and wheat (70 kg N + 13.2 kg P + 8.3 kg K/ha)(T_{12}). The recommended dose of fertilizers (N: P: K) for rice (cv. Sita) and wheat (cv. UP-262) is 80:17.6:33.2 kg/ha and 120:26.4:33.2 kg/ha, respectively. The required amount of FY; Farmer's Practice ($N_{70}P_{30}K_{10}$) in rice and ($N_{80}P_{30}K_{15}$) in wheat (T_{12}). The recommended dose of fertilizers (N: P_2O_5: K_2O) for rice (cv. Sita) and wheat (cv. HD-2967) is 80:40:20 kg ha^{-1} and 120:60:40 kg ha^{-1} respectively. The FYM, wheat straw and green manure used in this experiment contain 0.30%, 0.22% and 0.12% P and 0.5%, 0.65% and 0.53% N respectively.

Composite surface (0–15 cm) soil samples were collected from each plot at the harvesting stage of rice crop (on 5rd November 2018). The collected soil samples were air dried, ground, and passed through 2 mm sieve and stored in polyethylene packets for further analysis.

Analytical procedure

Analysis of soil were done for pH (Jackson 1973) [11], organic carbon (Walkley and Black 1934) [27], available N (Subbiah and Asija 1956) [24], available P (Olsen *et al*. 1954) [19], and available K (Hanway and Heidel 1952). Available soil micronutrients were determined following a method (Lindsay and Norvell (1978) [14] using DTPA extractant).

Statistical analysis

Data generated from the field experiment was analyzed using Analysis of Variance (ANOVA) in RBD as suggested by Gomez and Gomez (1984) [8].

Results and Discussion

Soil pH

The combined application of organics and mineral fertilizers continuously over a period of 35 years resulted in tremendous and significant ($p<0.01$) reduction of soil pH which varied from 7.25 to 7.54 with an increase of 0.14 and a decrease of 0.15 units across various treatments when compared with the initial status of 7.4 revealing a remarkable decrease in soil pH as observed in T_8 (50% RDF + 50% N through wheat straw to rice and 100% RDF to wheat) as compared to T_5 (100% RDF to both rice and wheat). The reason behind this might be due to the decomposition of organic matter resulting in release of various organic acids. Moreover the decrease in soil pH in organic treatment might also be due to the release of carbon dioxide into the soil during manure decomposition (Moharana *et al*., 2017) [18]. Mairan *et al*. (2005) [15] worked under LTFE on fixed plot with sorghum-sunflower cropping system at Parbhani reported that there is a significant decrease in pH values in those treatments where 50 percent N was applied through organic source viz., green manure, FYM, press mud compost, wheat straw and at 100 percent N through organic sources. The continuous application of varying quantities of inorganic fertilizers and their combinations with FYM over a period of 22 years altered the soil pH appreciably as reported by Sheeba and Chellamuthu, 2000 [23].

Soil Organic carbon (SOC)

The organic carbon which is considered as one of the crucial factors for sustaining agricultural production also improved to a promising extent under integrated nutrient management system. The SOC content across different treatments varied from 0.37% under T_1 control to 0.87% in the treatment T_8 receiving (50% RDF + 50% N through wheat straw to rice and 100% RDF to wheat) followed by T_{10} receiving (50% RDF + 50% N through green leaf manure (GLM) (*Sesbania aculeata*) to rice and 100% RDF to wheat) and then with T_6 receiving (50% RDF + 50% N through farm yard manure (FYM) to rice and 100% RDF to wheat) respectively. This beneficial effect of integrated use of inorganic fertilizer with organic manures resulted incorporation of organic material in the soil and also increase in number and activity of microorganism in the soil which ultimately leads to better regulation of organic carbon dynamics in soils. Additionally this effect was further more enhanced by addition of fertilizers that improved the root and shoot growth leading to build up of Soil organic matter thus helps in improvement of the nutrient status of the soil. The organically treated plots showed a significant higher OC content in comparision to T_5 which received only recommended dose of inorganic fertilizer as reported by Saha *et al*., 2018 [20]. The higher SOC under FYM addition as compared with wheat straw and green manure owed to the slower rate of decomposition of FYM (as reported by Moharana *et al*., 2017) [18] due to having higher lignin and polyphenyl content in it as reported by Majumder *et al*., 2008) [16].

Available NPK

The available N ranged from 137.31 to 269.91 kg ha^{-1}, available P from 19.81 to 46.91 kg ha^{-1} and available K ranged from 117.72 to 184.44 kg ha^{-1} respectively in the continuous manuring and cropping for 35 years under rice – wheat cropping system over the initial value of 194.0 kg ha^{-1} N, 23.6 kg ha^{-1} P and 155 kg ha^{-1} K_2O. The increase of all available N was highest in T_6 (50% RDF + 50% N through farm yard manure (FYM) to rice and 100% RDF to wheat) followed by T_8 (50% RDF + 50% N through wheat straw to rice and 100% RDF to wheat) and for P highest in T_6 followed by T_{10} (50% RDF + 50% N through green leaf manure (GLM) (*Sesbania aculeata*) while for K highest recorded in T_6 followed by T_8 respectively. The available N showed an increase in the treatments with combined application of organic manures and inorganic fertilizers which may be due to the mineralization of N from its native sources during the process of decomposition as reported by Walia, Walia and Dhaliwal 2010 [26]. Bhandari *et al*., 2002 [3] observed that the increase in available P content in FYM treated plot might be due to the result of high organic P content of FYM. Moreover the addition of FYM, wheat straw and green manure in the soil increases available P either by mineralization or by solubilizing the native P reserves as reported by Walia, Walia, and Dhaliwal 2010 [26], Shambhavi *et al*. 2018 [22]; Saha *et al*., 2018 [20].

Micronutrient

The available micronutrient Zn, Fe, Cu and Mn content in the 35th cycle of rice-wheat cropping system as influenced under different treatments varied from 0.68 to 1.49, 27.00 to 38.11, 2.01 to 3.67 and 34.19 to 48.06 mg kg $^{-1}$ soil respectively. The significant (p<0.01) and highest DTPA-Zn (1.49 mg kg^{-1}), Fe (38.11 mg kg^{-1}), Cu (3.67 mg kg^{-1} and Mn (48.06 mg kg^{-1}) were recorded in T_6 receiving 50% mineral NPK fertilizer supplemented with 50% N through FYM to rice and 100% RDF to wheat as compared to recommended dose of NPK fertilizer in T_5. However treatments T_1, T_2, T_3, T_4 and T_{12} were at par with T_5 receiving 100% RDF in context with DTPA-Zn and Cu while treatments T_1, T_2, T_3, T_4, T_9, T_{11} and T_{12} were found statistically similar to T_5 for DTPA- Fe and Mn. Moreover there has not a significant but considerable depletion in the available micronutrient status under only mineral nutrient applied treatments as seen with treatments T_2, T_3, T_4 and T_5 when compared to treatment T_1 (control) where no any nutrient applied for both the cereal crops viz. rice and wheat both. This might be due to the continuous use of only NPK chemical fertilizers and long term intensive cultivation of cereal-cereal cropping sequence in the absence of addition of any organic manure or crop residues leading to the mining of these micronutrients which further suggest the need of regular use of organics for maintaining micronutrient status of soils as well as INM playing a significant role in maintaining available micronutrient status of soil over a long term cropping period. Additionally, with the addition of organic materials enhances the microbial activity in the soil and consequently releases complex organic substances like chelating agents which could have prevented micronutrients from precipitation, fixation, oxidation and leaching and also addition of these nutrients through organic sources. The amount of available Fe, Mn, Cu and Zn (61.80, 41.18, 2.62 and 0.98 mg kg^{-1} respectively) was maximum where 50% NPK + 50% N through FYM in Kharif and 100% NPK in Rabi had been applied as reported by Subehia and Sepehya (2012) followed by 75% NPK +25% N through FYM in Kharif and 75% NPK in Rabi which were significantly higher over control. The considerable depletion in available Fe, Mn, Cu and Zn status of soil as compared to their initial status before 22 years under only chemical fertilizers found by Kharche *et al*. (2013) [12]. However, integration of organics helps to maintain the level of micronutrient cations above the critical level in soil.

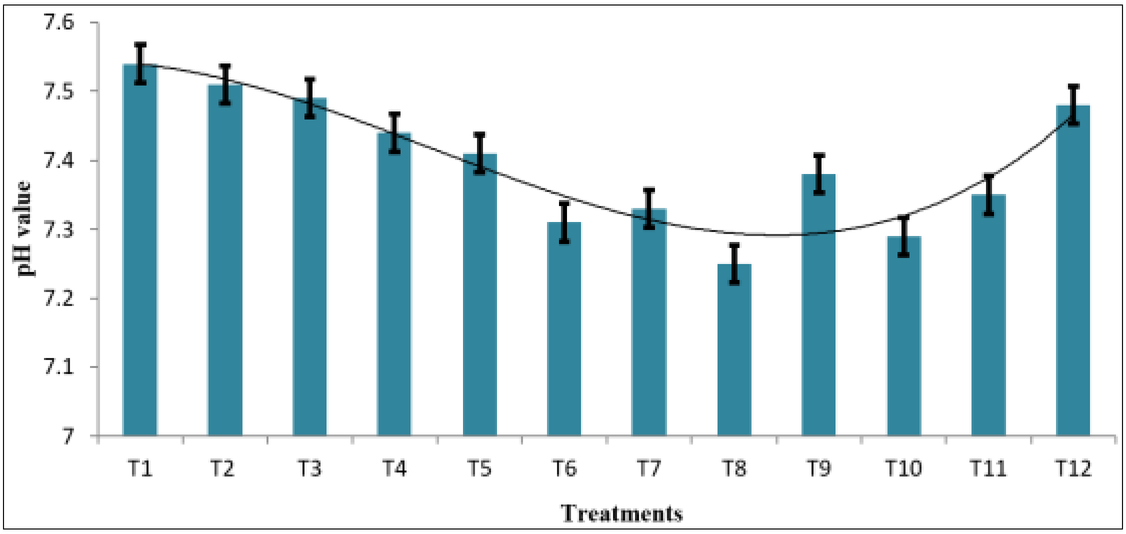

Fig 1: Long term effect on pH by rice crop after 35 years cropping cycle under rice-wheat cropping system

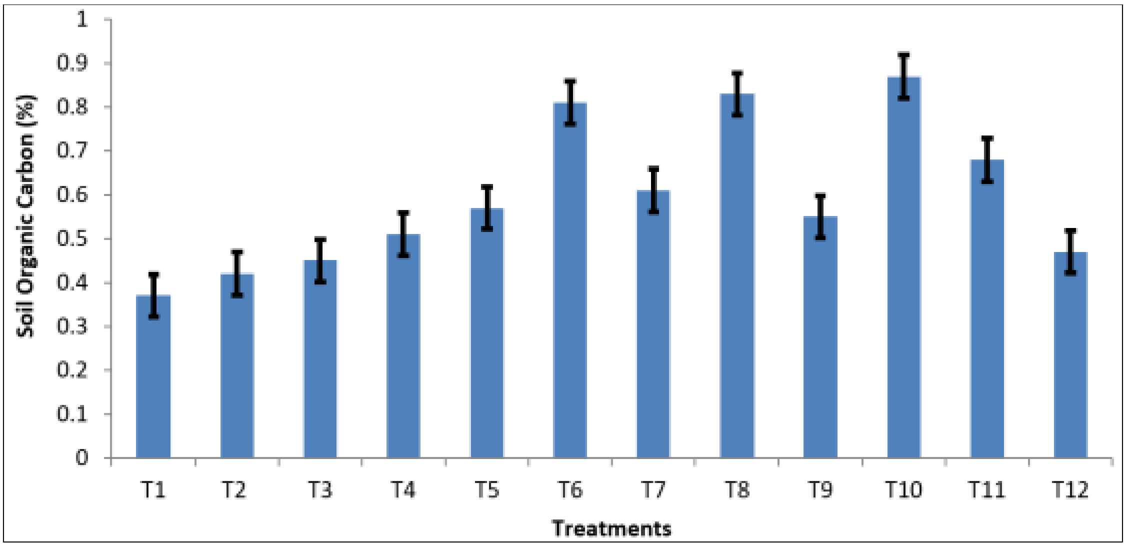

Fig 2: Long term effect on SOC by rice crop after 35 years cropping cycle under rice-wheat cropping system

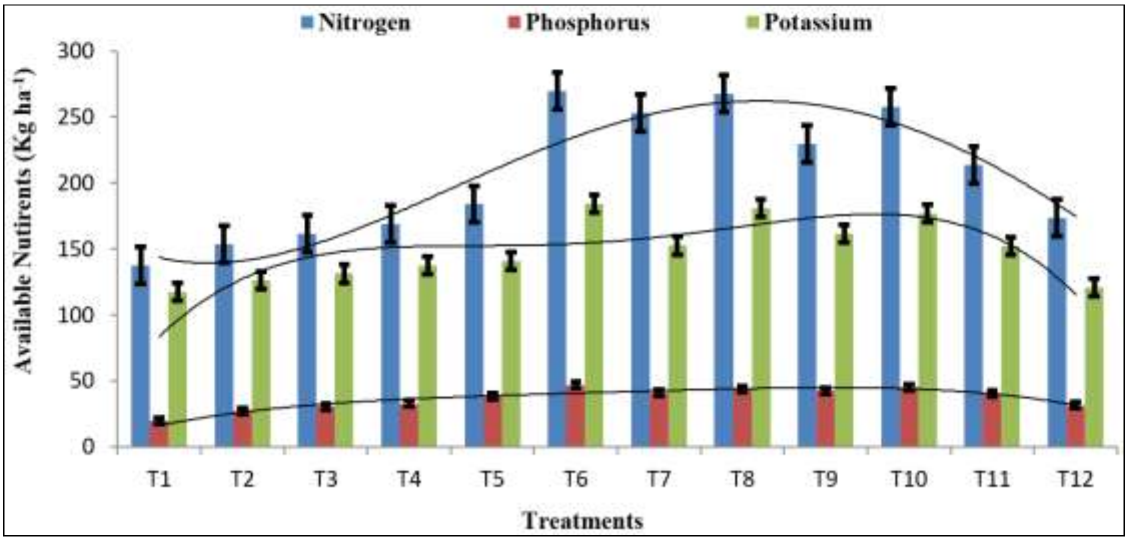

Fig 3: Long term effect on available primary nutrients (N, P & K) by rice crop after 35 years cropping cycle under rice-wheat cropping system

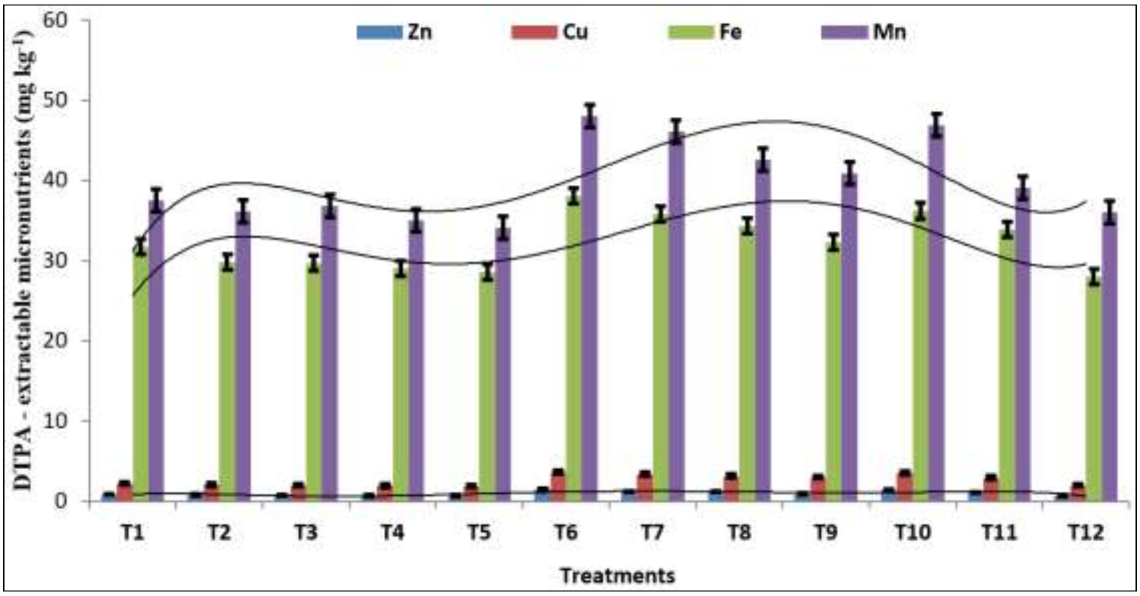

Fig 4: Long term effect on DTPA – extractable micronutrients (Zn, Cu, Fe & Mn) by rice crop after 35 years cropping cycle under rice-wheat cropping system

Conclusion

From the present study under 35 th cycle of LTFE results, the most remarkable conclusion is that the substitution of 50% N through FYM or Wheat straw or Green manure in rice followed by 100% RDF in wheat proved to be an efficient nutrient management options for crop production and nutrition. Additionally increase in SOC, available N, P, K and micronutrient over all the mineral fertilizer treatments as well as control after 35th cropping cycle was recorded. Followed to the above results, higher or almost similar yields were observed with the partial substitution of 25% N through FYM or Green manure or Wheat straw in rice and 75% RDF (NPK 120:26.4:33.2 Kg ha^{-1}). Thus we can save upto 25% inorganic fertilizer by adopting INM concept.

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