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Maneesh Bhatt
PhD Scholar, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

AP Singh
Associate Professor, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Veer Singh
Associate Professor, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

DC Kala
PhD Scholar, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Vineet Kumar
PhD Scholar, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Correspondence
Maneesh Bhatt
PhD Scholar, Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

Long–term effect of different fertilizer substitution practices on grain yield of rice and wheat and their correlation with soil properties in a Mollisol

Maneesh Bhatt, AP Singh, Veer Singh, DC Kala and Vineet Kumar

Abstract
Rice-wheat cropping system is a central agricultural production system to meet the increasing food demand. Productivity of rice-wheat cropping system cannot be sustained until and unless the nutrient supply at a desired level is not maintained. Generally, yields in the long-term experiments remained stable when recommended doses of N, P and K were applied Though, use of chemical fertilizers is the fastest way of replenishing the nutrient depletion, yet ever increasing energy cost, limited input availability and rising fertilizer prices deter the farmers from using these inputs to required level. In order to study the long-term effect of different treatments on crop yield and their correlation with soil properties in a Mollisol, a field experiment was conducted at Norman E. Borlaug Crop Research Centre of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar during 2014-2015. The partial replacement of N through FYM, wheat straw and mung straw caused significant improvement in soil properties and crop yield. The grain yield of rice and wheat in the year 2014-2015 ranged from 2552.67 to 5700.67, 1850.00 to 4315.67 kgha^{-1}, respectively under different treatments. The grain yield of rice was found maximum T_7 (5700.67 kg ha^{-1}) treatment where the recommended dose of fertilizer was substituted to the extent of 25% by FYM, followed by T_{10} (5625.67 kg ha^{-1}) where 50 percent of N was applied through mung straw along with 50 percent through NPK and T_8 (5621.67 kg ha^{-1}) where substituted to the level of 50% by wheat straw. Whereas, the maximum grain yield of wheat was found in T_7 (4315.67 kg ha^{-1}) treatment where the recommended dose of fertilizer was substituted to the extent of 25% by FYM, followed by T_6 (4292 kg ha^{-1}) treatment where substitution to the level of 50% by FYM and T_{11} (4130.67 kg ha^{-1}) where substituted to the level of 25% by mung straw. There were significantly negative relationship of rice grain yield with soil pH($r = -0.745^{**}$), electrical conductivity ($r = -0.641^{*}$) and significantly positive relationship with phosphorus ($r = 0.903^{**}$), sulphur ($r = 0.906^{**}$) and calcium ($r = 0.856^{**}$). Whereas, the grain yield of wheat showed significantly negative relationship with pH ($r = -0.833^{**}$) and significantly positive relationship with phosphorus ($r = 0.885^{**}$), sulphur ($r = 0.866^{**}$) and calcium ($r = 0.825^{**}$). While, other soil properties showed non-significant correlation with rice and grain yield of crops.

Keywords: Rice-wheat cropping system, grain yield and soil properties

Introduction
Rice and wheat are the most important food-grain crops which account for about 60 percent of world's human food requirement. These crops contribute more than 70 percent of the total cereal production in India and thus form the backbone of food security (Lathwal *et al*., 2010) [20]. Also, rice-wheat is the predominant cropping system in India occupying around 10.5 million hectares area (Sharma *et al*., 2009) [28]. In South Asia, the rice-wheat cropping system is a central agricultural production system to meet the increasing food demand and thus this production system was accepted with a massive expansion of irrigation facilities along with the availability of high yielding, short duration crop cultivars, leading to the first 'Green Revolution' in India (Yadav *et al*., 2000) [35]. Rice followed by wheat is grown in sizable area; both the crops are heavy feeders of nutrients. Under this situation, sustainability is always at stake. This has resulted in nutrient mining in soils causing stagnant or decline in crop yields. An estimate of ministry of agriculture, Government of India indicates that about 10 million tons of plant nutrients are mined over above the supply every year and this in turn ultimately results in consequent decline in productivity (Dakshinamorthy *et al*., 2005) [12]. High productivity of rice-wheat cropping system cannot be sustained until and unless the nutrient

supply at a desired level is not maintained. Generally, rice yield in the long-term experiments remained stable when recommended doses of N, P and K were applied (Dawe *et al*. 2000, Ladha *et al*. 2003, and Bi *et al*. 2009) [11, 13, 18, 6]. Where yield declines occurred, the major causes were attributed to inappropriate fertilizer management (Dobermann *et al*. 2000) [11, 13], delay in sowing (Regmi *et al*. 2002) [25]. Though, use of chemical fertilizers is the fastest way of replenishing the nutrient depletion, yet ever increasing energy cost, limited input availability and rising fertilizer prices deter the farmers from using these inputs to required level.

Further, to maximize crop yield, farmers often apply a higher amount of fertilizers than the minimum required for crop growth (Peng *et al*. 2002) [23]. Therefore, nutrient use efficiency is relatively low in rice systems because of the rapid losses of nutrients, especially N, through leaching, surface runoff and gaseous volatilization (Vlek and Byrnes 1986, Zhu and Chen 2002) [31, 36].

The application of organic materials is fundamentally important in that they supply various kinds of plant nutrients including micronutrients, improve soil physical and chemical properties and hence maintain nutrient holding and buffering capacity, and consequently enhance microbial activities (Suzuki, 1997). In addition, organic matter continuously releases N as plant need it. Nitrogen is the most limiting nutrient in irrigated rice systems, but P and K deficiencies are also the constraints in increasing the yield for consecutive planting of rice. Therefore, use of livestock wastes in agricultural soils has been an increasing interest due to the possibility of recycling valuable components such as organic matter, N, P and K. An advantage of farm application of organic wastes is that they usually provide a number of nutritive elements to crops with little added cost.

Therefore, Long-term studies have been conducted to work out the optimal proportions of organic and mineral fertilizers. Continuous integrated use of organic manures and fertilizers would be quite promising in assessing the sustainability of a cropping system *vis-a-vis* monitoring the soil properties. The present investigation was, therefore, undertaken to study the Long–term effect of different fertilizer substitution practices on grain yield of rice and wheat and their correlation with soil properties.

Materials and methods

The soil samples from 0-15 cm and 15-30 cm depths were collected after the harvest of wheat crop from the long-term experiment going on since *Kharif* season of 1983 under AICRP-IFS at Norman E. Borlaugh Crop Research Centre, Pantnagar, laid in Randomized block design with twelve treatments and three replications under rice-wheat cropping system viz. T_1- control in rice and wheat, T_2- 50% RDF in rice and wheat, T_3- 50% RDF through inorganic source in rice and 100 RDF in wheat, T_4- 75% RDF through inorganic source in rice and wheat, T_5-100% RDF through inorganic source in rice and wheat, T_6- 50% RDF through inorganic source with 50% N through FYM in rice and 100% RDF through inorganic source in wheat, T_7-75% RDF through inorganic source with 25% N through FYM in rice and 75% RDF through inorganic source in wheat, T_8-50% RDF through inorganic source with 50% N through wheat straw in rice and 100% RDF through inorganic source in wheat, T_9-75% RDF through inorganic source with 25% N through wheat straw in rice and 75% RDF through inorganic source in wheat, T_{10}-50% RDF through inorganic source with 50% N through mung straw in rice and 100% RDF through inorganic source in wheat, T_{11}-75% RDF through inorganic source with 25% N through mung straw in rice and 75% RDF through inorganic source in wheat, T_{12}- Farmers' practice.

Note: Recommended dose: N=120kg/ha, P_2O_5=60Kg/ha, K_2O=40Kg/ha
Farmers' practice dose: N=120kg/ha, P_2O5=48Kg/ha, K_2O=24Kg/ha

Soil Analysis

The processed soil samples were subjected to following analyses by the methods indicated below:

Bulk density

The core samples drawn from field were used for determining bulk density. The samples were oven dried and weighed and bulk density (Mg m^{-3}) was calculated from the known weight and volume of the soil mass (Wells, 1959) [33].

Soil pH

The pH of the soil was determined in 1:2 (soil: water) ratio after half an hour of equilibrium using glass electrode on a digital pH meter (Jackson, 1967) [17].

Electrical conductivity

Electrical conductivity of the soil sample was measured in 1:2 (soil: water suspension) at 25 ^{0}C using conductivity meter (Bower and Wilcox, 1965) [8].

Organic carbon

Organic carbon content in the soil was determined by modified Walkely and Black method (1934) [32] as described by Jackson (1967) [17].

Available nitrogen

Available nitrogen was estimated by alkaline $KMnO_4$ method (Subbiah and Asija, 1956).

Available phosphorus

Available phosphorus was extracted by Olsen's method (Olsen *et al*., 1954) [22]

Available potassium

Available potassium in soil was determined by extraction with 1 N ammonium acetate (pH 7) and K concentration was determined by flame photometer (Perur *et al*., 1973) [24].

Available sulphur

The 0.15% calcium chloride extractable sulphur was determined by the method suggested by Williams and Steinbergs (1959) [34].

Available calcium

Soil samples were analyzed for exchangeable Ca in 1N neutral ammonium acetate extract of soils by titration it with EDTA using versanate method following the method outlined by Cheng and Bray (1951) [10].

Results and Discussion

Grain yield of rice: Effect of different levels of nitrogen and its substitution by organic sources at two levels on yield of rice is presented in (Table 1). The grain yield of rice ranged from 2552.67 kg ha^{-1} to 5700.67 kg ha^{-1}. The grain yield of rice was found maximum T_7 (5700.67 kg ha^{-1}) treatment where the recommended dose of fertilizer was substituted to the extent of 25% by FYM, followed by T_{10} (5625.67 kg ha^{-1}) where 50 percent of N was applied through mung straw along with 50 percent through NPK and T_8 (5621.67 kg ha^{-1}) where substituted to the level of 50% by wheat straw. The minimum grain yield of rice was found under control T_1 (2552.67 kg ha^{-1}) treatment, while in T_{12} treatment where farmers' practice was applied showed 4502.67 kg ha^{-1}. The T_7 treatment showed 123% more yield of rice grain over control followed by T_8 treatment showed 120% more yield of rice over control. On comparing T_{12} plot with T_1, plot under (T_{12}) farmers' practices showed 76% yield of rice over (T_1) control.

The grain yield of rice was found maximum in T_7 treatment where recommended dose of fertilizer was substituted to the extent of 25% by FYM, followed by T_{10} and T_8 where 50 percent of N was substituted through mung straw and 50 percent through wheat straw respectively, over control. This might be due to the improvement in physicochemical properties of soil that resulted in increased productivity by increasing availability of plant nutrients. Chaudhary and Thakur (2007) [9] reported similar result. Further, the addition of organic matter also maintains regular supply of macro and micronutrients in soil resulting in higher yields. Gupta *et al.* (2006) [16] found si1milar result.

Mohapatra *et al*. (2008) [21] also reported that improvement in yield due to combined application of inorganic fertilizer and organic manure might be attributed to controlled release of nutrients in the soil through mineralization of organic manure which might have facilitated better crop growth.

Grain yield of wheat: The grain yield of wheat ranged from 1850 kg ha^{-1} to 4315.67 kg ha^{-1} (Table 1). The maximum grain yield of wheat was found in T_7 (4315.67 kg ha^{-1}) treatment where the recommended dose of fertilizer was substituted to the extent of 25% by FYM, followed by T_6 (4292 kg ha^{-1}) treatment where substitution to the level of 50% by FYM. The grain yield of wheat was lowest under control (1850 kg ha^{-1}) receiving no fertilizer or organic manure, while in T_{12} treatment where farmers' practice was applied show 3836 kg ha^{-1}. The T_7 treatment showed 133% greater yield of wheat grain over control followed by T_6 treatment showed 132% greater yield of wheat over control. On comparing T_{12} plot with T_1, plot under (T_{12}) farmers' practices showed 107% yield of rice over (T_1) control.

The grain yield of wheat increased with the long-term application of organic materials along with inorganic fertilizers as compared to inorganic fertilizer alone may be due to increased in soil organic carbon and nutrient availability. Babhulkar *et al*. (2000) [5] and Lado *et al*. (2004) [19] also reported similar result under long-term experiment. The application of T7 (where 25% N dose applied through FYM + 75% through NPK) resulted into highest grain yield (4315.67 kg ha^{-1}) followed by T6 (4292 kg ha^{-1}) where 50% N dose applied through FYM + 50% through NPK. Grain yield of wheat was lowest under control (1850 kg ha^{-1}) receiving no fertilizer or organic manure. This indicates the potential use of farmyard manure for sustaining the soil productivity. Similar effect of long-term application of FYM on yield of wheat in pearl millet-wheat cropping system was reported by (Antil *et al*., 2011) [1].

Correlation between crop grain yield and soil properties

The data given in table Showed negative and significant relationship of rice grain yield with soil pH(r = -0.745**) and electrical conductivity (r =-0.641*) (Table 2). Similar result was reported by Ayoubi *et al*. (2009) [4] in barley crop. Fageria (2000) [14] also found negative and significant correlation of rice grain yield with soil pH. The grain yield of rice with EC showed negative and significant correlation. Falaky (1993) [15] also found same result. The grain yield of rice showed positive and significant relationship with sulphur (r = 0.906**). Sharma *et al.* (2013) [29] also found similar result. The grain yield of rice showed positively significant correlation with phosphorus (r = 0.903**). Rokima and Prasad (1991) [26] also found that all the forms of P were significantly correlated with grain yields of rice and wheat. The significant positive correlation (r = 0.856**) between calcium content in grain yield of rice (Table 2). This might be due to significantly higher calcium contents in grain receiving organic residue incorporation combine with NPK dose help plants to attain more calcium and K to avoid sodium uptake which has been an added advantage to improve salinity or sodicity using crop residue incorporation apart from enhancing soil fertility and physical properties. Similar result was reported by (Arshadullah *et al*., 2012) [2]. The grain yield of rice showed negatively non-significant correlation with bulk density (r= -0.003) and positively non-significant correlation with organic carbon (r= 0.190), nitrogen (r= 0.102) and potassium (r= 0.051).

Whereas, the grain yield of wheat with soil pH showed negative and significant (r =-0.833**) relationship. Bijanzadeh and Mokarram (2016) [7] also found negative correlation of soil pH with grain yield of wheat. The grain yield of wheat with sulphur (r = 0.866**) calcium and (r = 0.825**) showed positive and significant correlation. This might be due to increase in conc. of Ca and S in grain reduced the conc. of Na in grain. Similar result was reported by (Arshadullah *et al*., 2013) [3]. The grain yield of wheat with phosphorus (r = 0.885**) showed positive and significant correlation (Table 2). Similar result was reported by (Saha *et al*., 2014) [27]. The grain yield of wheat showed negative and non-significant correlation with electrical conductivity (r=-0.476), bulk density (r=-0.071) and potassium (r=-0.131), while it showed positive and non-significant correlation with organic carbon (r= 0.053) and nitrogen (r= 0.299).

Table 1: Long-term effect of different treatments on rice and wheat grain yield

Treatments	Rice yield (kg ha^{-1})	Wheat yield (kg ha^{-1})
T_1	2552.67	1850.00
T_2	3096.67	2594.33
T_3	3987.67	2718.67
T_4	4157.33	2830.67
T_5	4521.00	3944.00
T_6	5217.00	4292.00
T_7	5700.67	4315.67
T_8	5621.67	3502.00
T_9	5414.67	3503.33
T_{10}	5625.67	4103.33
T_{11}	5519.67	4130.67
T_{12}	4502.67	3836.00
SEm±	20.64	09.28
CD at 5%	60.54	27.54

Table 2: The correlation between rice and wheat grain yields with soil properties

Soil properties	Rice grain yield	Wheat grain yield
pH	-0.745**	-0.778**
Electrical conductivity	-0.641*	-0.476
Bulk density	-0.003	-0.071
Organic carbon	0.190	0.053
Nitrogen	0.102	0.299
Phosphorus	0.903**	0.885**
Potassium	0.051	-0.131
Sulphur	0.906**	0.866**
Calcium	0.856**	0.825**

Conclusion

Thus, it can be concluded that treatment where 25% N was substituted through FYM were found best among all the treatments and showed significantly highest grain yield in both the crops and improve soil properties. Keeping in view their positive effects on soil and their role in decreasing dependence on chemical fertilizers, the organic sources should be applied in maximum possible quantity to sustain soil fertility and ensure food security.

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