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RELATIONSHIP BETWEEN SOIL PHYSICO-CHEMICAL PROPERTIES AND NUTRIENT UPTAKE BY RICE IN CALCAREOUS SOIL

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Abstract–The long term impact of integrated nutrient management practices on soil physical, chemical and biological properties of soil as well as crop yield were studied. The experiment is being conducted in a sandy loam (Calciorthents) at Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, since 1988 under rice-wheat cropping system. Integrated effects of chemical fertilizers with compost and crop residue augmented N, P, K, S, Zn and B uptake by crop. There was a build-up of available N, P, K and S and depletion of available Zn and B. Addition of different organic materials increases the organic carbon, porosity, water holding capacity, CEC and decreased the pH and EC irrespective of NPK levels and organic addition. These was also a considerable increase in microbial population was recorded with conjoint use of organics and chemical fertilizer. Correlation study indicated that most of the soil parameters were positively and significantly correlated with uptake of nutrients of rice. It may be concluded that conjoint use of inorganic fertilizers with compost @ 10 t ha^{-1} and crop residue of previous crop improve the productivity and soil health.

INTRODUCTION

Ensuring global food security is the second of 17 sustainable development goal adopted by the UN as part of its 2030 agenda for sustainable development (Griggs *et al.,* 2013) but achieving this while reducing negative environmental impact is one of the greatest challenges facing humanity (Amundson *et al.,* 2015). Intensive rice-wheat cropping system sequence resulted in severe problems *viz*., degradation of soil health, lowering down water table, increase in insects-pests and disease and deficiency of micronutrients (Bhatt, 2017). Under these conditions agriculture become unattractive due to the increased cost of cultivation. For improving the water and nutrient use efficiency, computation of soil water balance component *viz*., irrigation, evaporation, seepage, rainfall is a most (Bhatt *et al.,* 2015). Rice and wheat are the major cereal crop grown in Indo-Gangetic plains, grown in rotation in 13.5 m ha of land provides food for 400 million people. The productivity of this region is appearing to have reached a plateau because of fatigued natural resource base (Mazumdar *et al.,* 2015). Among the factor, continuous use of imbalanced fertilizers and decline in soil physical productivity and organic matter are considered responsible (Yadav *et al.,* 2000). To improve physical condition, and to improve matter status in soil, incorporation of crop residues and organic amendment such as FYM, green manure, compost, vermicompost etc. are recommended (Bandyopadhyay *et al.,* 2010). Nutrient deficiency affect the quantity and quality of produce. Yield of crop is determined through soil fertility and soil fertility is determined by the availability of macro micro nutrient. For sustainability rice production, soil and plant nutrient characterization in relation to fertility status of soil of the reason will be useful (Bhat *et al.,* 2017). Soil organic matter content being an energy source and habitat for biota is an important determination of soil health. Through its impact on soil physical, chemical and biological properties and nutrient dynamics also determine numerous ecosystem services essential for human and nature conservancy (Lal, 2020).

To sustain the crop yield and increase land productivity, combination of organic manure and fertilizers not only increase the crop yield but also improves physical, chemical and biological properties of the soil (Chopra *et al.,* 2020).

MATERIALS AND METHODS

Site description

The long term experiment is being conducted at the Dr. Rajendra Prasad Central Agricultural University, Research Farm, Pusa, Bihar (25°59′N, 85°48′ E and 52-92 m above sea level) since 1988. The experimental area is characterized as sub-tropical with hot and desiccating summer but frost less winter with a mean annual precipitation of 1270 mm. Most of the rain is received in rice growing season. The mean air temperature is recorded at 25.3°C in rice. The soil is calciorthent with sandy loam texture (47,41 and 12% sand, silt and clay, respectively). At the start of experiment, the field soil (0-15 cm) had bulk density 1.44 mg m^{-3}, water holding capacity 31.22%, pH 8.4, EC 0.37 dSm^{-1}, free $CaCO_3$ 34.34% organic carbon 5.0 g kg^{-1}, available N 237 kg ha^{-1}, available P_2O_5 19.9 kg ha^{-1}, available K_2O 100 kg ha^{-1}, available S 10.27 mg kg^{-1}, available B 0.52 mg kg^{-1} and available Zn 0.79 mg kg^{-1}.

Experimental design and treatments

Treatments represented combination of inorganic and organic sources of nutrients. In rice, the full recommended levels of N, P and K were supplemented with N through compost, crop residue (wheat straw) so that the 100% recommended N dose was available to rice crop. The experiment included two crops per year, rice and wheat with 16 treatment combination which were laid out in split plot design and replicated thrice. Four fertility levels consisting of control, low fertility (50% of recommended NPK), medium fertility (100% of recommended NPK) and high fertility (150% of recommended NPK) were used as treatments in main plots. Each main plot was divided into four sub plots in which sub treatments (i) no crop residue or compost (ii) compost @ 10 t ha^{-1}, (iii) 100% crop residue and (iv) compost 10 t ha^{-1} + 100% crop residue were superimposed over NPK levels. Recommended dose of 100% NPK referred to as 120 kg N ha^{-1}, 26.7 kg P ha^{-1} and 32.2 kg K ha^{-1} to each rice and wheat crops under rice-wheat cropping system. Nitrogen, phosphorus and potash were supplied in the form of urea, single super phosphate and muriate of potash. The plot size was 10 m^2. The crops investigated and reported in this paper were 36th crop of rice (*cv*. Rajshree) in *kharif* and 37th crop of wheat (*cv*. HD 2733) in *rabi* season with continuous application of 10 t compost ha^{-1} to each rice and wheat and/or 100%. Crop residue of respective plot alone or in combination with different levels of NPK *viz*., 0, 50, 100 and 150% of recommended dose of fertilizer. The residue of wheat before rice transplanting and the residue of rice before wheat sowing were incorporated to soil. Half dose of nitrogen and entire dose of P and K were applied at the time of transplanting of rice and sowing of wheat and remaining N fertilizers were applied in equal split at tillering and flowering initiation stage.

Soil sampling and analysis

Soil samples were collected from the experimental plot after harvest of wheat. Samples were taken from 0-15 cm depth. Each sample was a composite of four spots in a plot. All the sample were brought to the laboratory and air dried. The air dried soil was passed through a set of 0.5 and 0.2 mm sieve for its further chemical analysis. All the standard procedures were followed for analysis of different soil physical and chemical parameters.

Plant sampling and analysis

The grain and straw samples were taken after harvest of rice. These samples were washed sequentially in detergent solution (0.2% liquid), 0.01 N HCl solution and deionized water and dried in oven of 70 °C. Finally grounded samples weighed 0.2 and 0.5 g respectively were digested in di acid mixture of H_2SO_4 and $HClO_4$ in the ratio 9:1 for nutrients (P, K, S, Zn and B). After the digestion, a known volume was made with distilled water and stored in well washed plastic bottles after filtration through Whatman filter paper 42. P and K was estimated by Vanado-molybdate yellow colour method with the help of colorimeter and flame photometer. S content was analyzed following turbidimetric method as described by Chesnin and Yien (1950) with the help of spectrophotometer. Zn content was determined with the help atomic absorption spectrophotometer and boron content was determined by developing colour with carmine and estimated on spectrophotometer. For the estimation of N content, 0.5 g powdered plant sample and 5.0 g digestion mixture of was taken in 100 ml digestion tube and 10 ml of concentrate sulphuric acid was added in it. The digestion tube were kept on block digester and maintained the block temperature at 410 °C. The sample turned colourless on light green at the end of digestion, cooled and the digestion tube was fitted in the automatic ammonia distillation apparatus. The ammonia liberated after addition of 35 ml 40% NaOH in the tube, was collected in 4% boric acid. The N content was estimated by titration the distillates with 0.01 N H_2SO_4. The uptake of nutrient was calculated on the basis of nutrient content on dry weight basis of grain and straw. Data obtained was statistically analyzed and correlation analysis was performed. The correlation coefficient was fetched between different soil parameters and nutrient uptake by grain and straw.

RESULTS AND DISCUSSION

Relationship of soil physical parameters with nutrient uptake by crop

The correlation coefficient values of physical properties *viz*., bulk density, percent pore space and water holding capacity with uptake of nutrients were worked out and presented in Table 1. The data revealed that percent pore space and water holding capacity were positively and significantly correlated with N, P, K, S, Zn and B uptake by rice, whereas negative and significant correlation were observed with bulk density. The negative correlation between bulk density and nutrient uptake may be due to decrease in bulk density of soil with the incorporation of compost and crop residue which improves the soil structure. Improved soil texture has positive impact of different physico-chemical and microbiological processes, which build-up nutrient availability to plant leading to increased nutrient uptake. Positive and significant correlation of organic carbon with plant available nutrients was also reported by Bhat *et al.* (2017). Soil quality parameters including total C, porosity and aggregate stability were highly correlated with crop productivity (Stine and Weil, 2002).

Relationship of chemical parameters of soil with nutrient uptake by rice

The data in the Table 2 depicted that organic carbon and CEC were positively and significantly correlated with nutrient uptake by crops and maximum correlation coefficient (r = 0.977**) was recorded between organic carbon and Zn uptake. The strong correlation between organic carbon and nutrient uptake might be attributed to addition of organic matter through compost and crop residue which facilitate better root growth, mineralization and solubilization of nutrient and enhanced multiplication of microbes for the conserve of organically bound nutrient to ionic forms. Vanilarasuand Balakrishnamurthy, 2014 also reported similar finding. Free $CaCO_3$ of the soil exhibited positive correlation with the nutrient uptake. The data revealed that pH and EC showed significant negative correlation with nutrient uptake. Organic material released organic acid during their decomposition which decreased the pH of soil. Similarly, the reason of negative correlation between nutrient uptake and EC may be due to decrease in electrical conductivity due to release of

Table 1. Correlation coefficient (r) of different physical properties of soil with nutrient uptake by rice

Parameters	Bulk Density	Percent pore space	Water Holding Capacity
N uptake	-0.848**	0.848**	0.868**
P uptake	-0.813**	0.814**	0.857**
K uptake	-0.817**	0.818**	0.857**
S uptake	-0.929**	0.929**	0.884**
Zn uptake	-0.872**	0.872**	0.883**
B uptake	-0.855**	0.855**	0.869**

Table 2. Correlation coefficient (r) of different chemical properties of soil with nutrient uptake by rice

Parameters	Organic Carbon	pH	EC	CEC	Free $CaCO_3$
N uptake	0.900**	-0.771**	-0.912**	0.870**	0.015
P uptake	0.868**	-0.731**	-0.905**	0.837**	0.032
K uptake	0.868**	-0.742**	-0.903**	0.833**	0.042
S uptake	0.977**	-0.840**	-0.825**	0.937**	0.116
Zn uptake	0.943**	-0.793**	-0.899**	0.911**	0.028
B uptake	0.885**	-0.780**	-0.911**	0.843**	0.025

Table 3. Correlation coefficient (r) of available nutrients with nutrient uptake by rice

Parameters	Available N	AvailableP_2O_5	Available K_2O	AvailableS	AvailableZn	AvailableB
N uptake	0.895**	0.969**	0.829**	0.956**	-0.032	-0.174
P uptake	0.867**	0.968**	0.818**	0.938**	-0.087	-0.229
K uptake	0.868**	0.966**	0.821**	0.938**	-0.084	-0.**229**
S uptake	0.944**	0.906**	0.798**	0.938**	0.259	0.126
Zn uptake	0.904**	0.951**	0.841**	0.973**	0.023	-0.105
B uptake	0.876**	0.961**	0.848**	0.925**	-0.043	-0.185

organic acid during decomposition of organic materials, which solubilized the salt which may leached down through irrigation water. Patil *et al.*, 2015 also observed such as type of correlations.

Relationship of available nutrients with nutrient uptake by rice

The perusal of the data in table-3 revealed that available N, P_2O_5, K_2O and S were highly significantly and positively correlated with nutrient uptake. On the other hand, available Zn and B was negatively correlated with uptake of nutrients by rice. The positive and significant correlation between available N and nutrient uptake could be because of release of mineralizable nitrogen from soil with integrated use of organic manures and adsorption of NH_4-N by humus complex in soil (Kumar *et al.*, 2014). Similarly acidulating effect of organic manure added, formation of easily accessible organophosphate complex and reduction of phosphorus fixation by humus are the possible reason of the positive correlation of available P with nutrient uptake. This finding is in harmony with the finding of Singh *et al.* (2014). The strong positive and significant correlation between soil available S and uptake of rice might be due to increase in availability of sulphur from organic complex and acidulating action of various organic acid released during the decomposition of organic manures enhanced the weathering of minerals containing sulphur. Similar results were also reported by Pareek, 2007. Available Zn and B exhibited negative correlation with uptake. It is believed that increased in CO_3^{2-}content in soil raises the possibility of soluble Zn to precipitate as $ZnCO_3$ and decrease the availability (Hazra *et al.*, 1987) and formation of Ca borate and B-.silicate which reduce the availability of hot water soluble B (Halder and Mandal, 1987).

CONCLUSION

Correlation of physical and chemical parameters with rice yield are strong, which indicate that they are able to properly explain variation in it. The most important attributes which positively influence rice yield is organic carbon and the others the negatively is a pH. The conjoint use of organic and inorganic sources of nutrients have increased the availability of nutrients, increased the yield of rice, hence increased nutrient uptake.

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