Original Research Article

Assessment of soil properties under long term organic and chemical fertilizer applications using STCR-based targeted yield equations under Rice-wheat cropping system

ABSTRACT: Present experiment was carried out to assess the effect of organic and chemical fertilizers on soil chemical properties under a nine year long experiment of AICRP on STCR initiated in *Kharif* 2008. The field experiment was laid out at research farm of JNKVV, Jabalpur after *Rabi* season of 2018-19. The study was framed in split plot design with four main treatments of nutrient management viz., T_1-control; T_2-GRD; T_3- Soil test based NPK application for yield of 6.0 t ha^{-1} for each crop, and T_4- Soil test based NPK application for yield of 6.0 t ha^{-1} for each crop + 10 t ha^{-1} yr^{-1} FYM and four soil depths as sub treatment from D_1- 0-15 cm; D_2- 15-30 cm; D_3- 30-45 cm and D_4 – 45-60 cm replicated three times. The results shows significant influence of INM on soil organic carbon (SOC), cation exchange capacity (CEC) and $CaCO_3$ content of soil. After nine years of chemical fertilizer applications on general recommended dose bases and soil test bases in combination with FYM reported no profound impact on soil pH, electrical conductivity.

Keywords: Chemical properties, SOC, $CaCO_3$, CEC

1. Introduction

The rice (*Oryza sativa L*.) – wheat (*Triticum aestivum L*.) cropping system plays a vital role in global food security as it provides staple food to the globe (Lalik *et al.,* 2014; Banjara *et al*., 2021a). The RWCS is extensively cultivated and the most technologically advanced system in the world. This system is one of the most exhaustive cereal crops being practiced in the Indo-Gangetic Plains for more than 85% of the RWCS in South Asia (IGP; Banjara *et al*., 2021b). The RWCS deplete the soils nutrients heavily. There are increasing concerns of yield stagnation or decline in the R–W system, with increasing environmental footprints. However, restoration and improvement of soil quality is the prerequisite for ensuring agricultural productivity and food security in India (Basak *et al*., 2021).

India achieved food security through intensification of its agriculture for production of enough food, feed, bioenergy and fiber to meet the demand of burgeoning population. The augment of synthetic agrochemicals and nutrient responsive high yielding crop varieties made us self-sufficient in the sector of food production. But the boost in agricultural production system has slowed down or even declines over last few years due to heavy removal of native nutrients which lead to diminish the soil health.

The major confrontation behind the country during the upcoming years is to produce enough food and fiber besides being quality produce which can be achieved only by escalating the productivity of different crops using organic and integrated approach in agriculture. Changes in basic soil characteristics such as pH, cation exchange capacity (CEC) and soil organic carbon (SOC) content under different nutrient management systems is the main cause of continuously depleting soil fertility. To address these challenges, fertilizer prescription based on soil test values and crop response is a clue to judicious and balanced nutrient application for sustaining the productivity. Integration of organic and inorganic nutrients helps in achieving the desired goal and enhancing soil health due to its complementary effect (Antil *et al*., 2011).

2. Materials and Methods

2.1 Site and Soil

The present field experiment on rice-wheat cropping system was initiated in monsoon 2008 at research farm of JNKVV, Jabalpur under the network of All India Coordinated Research Project (AICRP) on Soil Test Crop Response (STCR). The experimental field was located at $23^{0}10'$ N latitude and $79^{0}57'$ E longitude and at an elevation of about 393.0 meter above mean sea level. The climate of the experimental site is sub-tropical with hot dry summers and cool winters with an average annual rainfall, average humidity and average evaporation are 1274 mm, 73 percent and 3.93 mm/day, respectively. The experimental area represents to *Kymore* Plateau and Satpura hills agro-climatic zone of Madhya Pradesh belongs to *Kheri* series. The soil is vertisol characterized as medium deep black soil. Based on the analytical report the soils are neutral in reaction, medium salt concentration, organic carbon, available phosphorus and potassium and low in available nitrogen. Clay mineralogy is dominated by fine montmorillonitic minerals. Taxonomically it belongs to of hyperthermic family of T*ypic Haplustert*. The initial soil samples from surface (0-15 cm) and sub- surface (15-

30 cm) were analysed for mechanical composition, pH, electrical conductivity (EC), cation exchange capacity (CEC), bulk density (BD), organic carbon (OC) and available nitrogen, phosphorous and potassium following standard procedure. The physio-chemical properties of the initial soil under study are presented in Table 1.

2.2 Experimental design and treatments

The field experiment on rice-wheat cropping system was designed under AICRP on STCR with three nutrient management practices along with a control in a split plot design with three replications. The treatments selected for this study consisted of (i) unfertilized control (control); (ii) General Recommended Dose (GRD) of NPK (120 N_2O: 60 P_2O_5: 40 K_2O ha^{-1}); (iii) Soil Test Based (STB) NPK + Targeted Yield (TY) of 6.0 t ha^{-1}; (iv) STB NPK + TY of 6.0 t ha^{-1} + FYM @10.0 t ha^{-1} yr^{-1} (NPK+ FYM).

2.3 Soil sampling and analysis

After completion of nine cropping cycles of rice- wheat, soil samples from 0-15, 15-30, 30-45 and 45-60 cm soil depth were collected. In each plot, soil was collected from three points randomly and mixed into one sample. The samples were air-dried in shade, ground to pass through a 2 mm sieve and used for the estimation of soil chemical properties. The pH was measured in 1:2.5 soil: water suspension with a glass electrode. The electrical conductivity was measured in supernatant liquid of soil: water (1:2.5) suspension with the help of conductivity meter as described by Jackson (1973). The $CaCO_3$ content was determined following the rapid titration method (Puri, 1930). The organic carbon in soil was determined by rapid titration method (Walkley and Black, 1934). The available major nutrients viz., nitrogen, phosphorous and potassium were estimated using the methods suggested by Subbiah and Asija (1954); Watanabe and Olsen's (1965) and Jackson (1973) respectively.

Table 1. Physicochemical properties of the experimental soil before commencing the study.

Soil characteristics	Soil depth		Method followed
	0-15 cm	15-30 cm	
Soil pH (1:2.5 at 25°C)	7.48	7.45	Glass electrode pH meter (Jackson, 1973)
Electrical Conductivity (EC) (dSm^{-1} at 25°C)	0.285	0.267	Electrical conductivity meter (Jackson, 1973)
Organic Carbon (g kg^{-1})	5.37	5.28	Potassium dichromate rapid titration method (Walkly and Black, 1934)
Available Nitrogen (Kg ha^{-1})	211.66	164.69	Alkaline potassium permanganate method (Subbiah and Asija, 1954)
Available Phosphorous (Kg ha^{-1})	22.95	14.97	Soil extracted with 0.5 M NaHCO3 and colour development by ascorbic acid (Watanabe and Olsen's, 1965)
Available Potassium (Kg ha^{-1})	307.53	282.76	Neutral normal ammonium acetate method by using flame photometer (Jackson, 1973)

2.4 Statistical analysis

For statistical analysis of data, ANOVA for split plot design on Microsoft Excel were prepared. Analysis of variance (ANOVA) was drawn as described by Gomez and Gomez (1984). The differences of treatment means were tested by 'F' test of significance on the bases of null hypothesis at 5% level of significance.

3. Results and Discussion

3.1 Soil pH

Integrated nutrient management practices and soil depth had no significant effect on soil pH (Table 2). The pH of soil under different management practices ranged from 7.47 to 7.57. Lower value of soil pH was recorded under treatments of soil test based NPK for targeted yield of 6 t ha^{-1} and soil test based NPK+FYM@10.0 t ha^{-1} yr^{-1} for targeted yield of 6 t ha^{-1} as compared to treatments with general recommended dose of NPK and control. Lower pH value of 7.53 at 0-15 cm was recorded. Soil pH followed the increasing trend with increasing depth. The decrease in soil pH in the FYM treatments might have resulted from the release of organic acids and carbon dioxide (CO_2) into the soil during the decomposition of the manure. The production of aliphatic and aromatic hydroxyl acids as a result of decomposition of FYM could also result in complexing of free and exchangeable aluminium ions and thus decrease the pH (Swarup and Wanjari, 2000; Hati et al., 2008).

3.2. Electrical Conductivity

The electric conductivity as a measure of soluble salts or salinity varied in different nutrient management from 0.25 to 0.28 dS m^{-1} with highest value in general recommended dose of NPK and lowest under soil test based NPK+FYM@10.0 t ha^{-1} yr^{-1} for targeted yield of 6 t ha^{-1} (Table 2). However, no significant differences in EC were observed among the treatments and soil depths. At depth level EC ranged between 0.26 to 0.28 dS m^{-1}. The interaction effect of both nutrient mangemnet and soil depth were also found not significant. The results under long-term fertilizer experiments also showed no appreciable change in salinity. The conductivity also followed the same trend as soil pH. The integration of FYM with inorganic fertilizers was found more effective to decrease the EC of soil (Lal Bahadur *et al*., 2012; Parvathi et al., 2013; Gudadhe *et al*., 2015; Tiwari *et al*., 2017).

Table 2 Effect of INM and soil depth on pH, EC and organic carbon

Treatment / Nutrient management	pH	EC (dS m^{-1})	SOC (g kg^{-1})
T_1	7.57	0.27	4.83
T_2	7.54	0.28	5.92
T_3	7.53	0.26	6.10
T_4	7.47	0.25	6.62
SEm $\pm$	0.049	0.014	0.053
CD (*p=0.05*)	NS	NS	0.155
Soil depth			
D_1	7.53	0.26	6.74
D_2	7.55	0.27	6.07
D_3	7.54	0.27	5.54
D_4	7.56	0.28	5.11
SEm $\pm$	0.028	0.010	0.119
CD (*p=0.05*)	NS	NS	0.347
M x S			
SEm $\pm$	0.063	0.013	0.308
CD (*p=0.05*)	NS	NS	NS

3.3 Soil organic carbon

It is evident that continuous application of FYM in combination with NPK resulted in considerable changes of SOC than that of unfertilized control as well as NPK treated plots on the bases of general recommended dose and soil test base (Table 2). In the present study, the plots that received FYM+NPK (6.62 g kg^{-1}) and soil test based NPK (6.10g kg^{-1}) had significantly higher build-up in SOC over general recommended dose of NPK (5.92g kg^{-1}) and unfertilized control (4.83g kg^{-1}). At depth level 0-15 cm soil depth reported maximum retention of SOC (6.74 g kg^{-1}) followed by 15-30 cm (6.07 g kg^{-1}), 30-45 (5.54 g kg^{-1}) cm and 45-60 cm (5.11 g kg^{-1}). Integrated nutrient management practice either maintains or enhances the organic carbon content in soil (Singh et al., 2007; Manna et al., 2004). Application of 100% NPK + FYM @ 10t ha^{-1} increased the organic carbon content (Swarup and Yaduvanshi, 2000; Santhy et al., 2001; Mandal, 2011; Verma et al., 2012; Kumari et al., 2013; Khan et al., 2017).

3.4 Cation Exchange Capacity

The cation exchange capacity of the soil in different treatments ranged from 34.3 C mol (P^+) kg^{-1} to 40.0 C mol (P^+) kg^{-1}. Treatment received FYM+NPK reported maximum 40.0 C mol (P^+) kg^{-1} cation exchange capacity followed by 38.9 C mol (P^+) kg^{-1} in soil test based NPK, 37.4 C mol (P^+) kg^{-1} in general recommended dose of NPK and 34.3 C mol (P^+) kg^{-1} unfertilized control. Data also indicated that CEC of soil significantly decreased with increasing soil depth and ranged from 40.7 to 34.5 C mol (P^+) kg^{-1} with highest value at 0-15 cm depth which was statistically at par with that found at 15-30 cm but significantly higher than those obtained at 30-45 cm and 45-60 cm soil depths. Cation exchange capacity of the soil increased significantly with the application of organic manures along with recommended dose of fertilizers (Prakash et al., 2002; Laxminarayana, 2001; Singh, 2007; Rathore et al., 2011). However, Hati et al. (2006) and Sarkar et al. (2007) reported higher CEC of soil in 150% NPK treatment over 100% NPK+FYM treatment.

3.5 Calcium carbonate content

Nutrient management practices and soil depths significantly affected the $CaCO_3$ content of the soil (Table 3). $CaCO_3$ content in soil under control (56.3 g kg^{-1}) was significantly lower than those obtained in other treatments. The $CaCO_3$ content under general recommended dose of NPK (62.5 g kg^{-1}), soil test based NPK (60.6 g kg^{-1}) and treatment received NPK+FYM (62.4 g kg^{-1}) reported statistically on par. Data further revealed that $CaCO_3$ content in soil significantly increased from 53.5 to 65.3 g kg^{-1} with increasing soil depth from 0-60 cm with highest (65.3 g kg^{-1}) value at 45-60 cm and lowest (53.5 g kg^{-1}) at 0-15 cm depth. The downward movement of Ca and its subsequent precipitation as carbonate or decomposition of $CaCO_3$ increases its content in the pedons with soil depth (Sharma *et al*., 2004; Sarkar *et al*., 2006). Dubey *et al*. (2015) reported that application 100% NPK with FYM significantly increased the calcium carbonate content in sub-surface soil.

4. Conclusion

The present study demonstrated that integrated use of FYM and NPK fertilizer using STCR based targeted yield approach increased soil organic carbon content. After 9-year of application of various fertilizer treatments, it was observed that SOC, cation exchange capacity and $CaCO_3$ content of soil showed significant differences among the treatments, while soil pH and electrical conductivity were not found significantly different. Addition of FYM in combination with NPK fertilizer increased soil organic carbon over NPK alone treated plots which, in turn, may have been the cause of better soil conditions in FYM treated plots compared with NPK treated plots.

Table 3 Effect of INM and soil depth on CEC and $CaCO_3$ of soil

Treatment	**CEC**	**$CaCO_3$**
Nutrient management	**[C mol (P^+) kg^{-1}]**	**(g kg^{-1})**
T_1	34.3	56.3
T_2	37.4	62.5
T_3	38.9	60.6
T_4	40.0	62.4
SEm ±	**0.61**	**0.71**
CD (*p=0.05*)	**1.79**	**2.09**
Soil depth, cm		
D_1	40.7	53.5
D_2	38.7	59.1
D_3	36.6	63.8
D_4	34.5	65.3
SEm ±	**0.76**	0.43
CD (*p=0.05*)	**2.13**	**1.25**
M x S		
SEm ±	1.17	0.79
CD (*p=0.05*)	**NS**	**NS**

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