<u>Original Research Article</u>

Assessment of soil properties under long term integrated nutrient management 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, Organic carbon, Electrical conductivity, $CaCO_3$, cation exchange capacity

1. Introduction

The rice (*Oryza sativa* L.) -wheat (*Triticum aestivum* L.) cropping system, as a source of the world's basic food, is essential for maintaining global food security (Timsina and Connor, 2001; Lalik *et al.,* 2014; Banjara *et al*., 2021a). The RWCS is technologically most advanced system in existence that has experienced extensive evolution. For more than 85 percent of the overall RWCS in South Asia, this system is among the most substantial cereal crops utilized in the Indo-Gangetic Plains (IGP; Banjara *et al*., 2021b). This system depletes the soil nutrients heavily (Bhatt et al., 2016). With emerging environmental footprints, there are stoking fears about yield stagnation or contraction in the R-W system (Gupta et al., 2007; Sharma et al., 2019). In order to safeguard agricultural productivity and nutrition security in India, the quality of the soil must be restored and strengthened (Basak *et al*., 2021).

Through agricultural intensification, India became able to produce enough food, feed, bioenergy, and fibre to satisfy the requirements of its 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 real hurdle for the nation in the upcoming years will be how to produce enough food and fibre in along with high-quality produce, which can only be accomplished by boosting the productivity of various crops through a collaborative approach of adopting organic and chemical fertilizers. INM improves soil quality and sustainability while increasing crop yields by 8–150% when compared to conventional farming methods (Jat et al., 2015). It also boosts farmers' economic returns (Ramalingam et al., 2020) and the efficiency with which they use water and nutrients (Rathore et al., 2006). The primary factor contributing to the ongoing loss of soil fertility is changes in fundamental soil properties such as pH, cation exchange capacity (CEC), and soil organic carbon (SOC) concentration under various fertiliser management schemes. To address these challenges, the recommendation of fertiliser based on soil test results and crop response offers a hint for prudent and balanced nutrient application to maintain production. Due to their complementary effects, combining organic and inorganic nutrient aids in reaching the intended result and improving soil health (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) with 0.5N H_2SO_4 in the presence of bromothymol blue and bromocresol green. The organic carbon in soil samples were determined using $K_2Cr_2O_7$ as oxidizing agent (1N) and back titrating with 0.5 N FAS method as suggested by 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.

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.

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)

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 release of carbon dioxide (CO2) and organic acids into the soil during the breakdown of the manure may have contributed to the reduction in soil pH in the FYM treatments. As a result of FYM's breakdown, aliphatic and aromatic hydroxyl acids may also be produced, which may complicate free and exchangeable aluminium ions and lower pH levels (Swarup and Wanjari, 2000; Hati et al., 2008;Yadav et al., 2017).

3.2. Electrical Conductivity

In different nutrient management systems, the electric conductivity as a measure of soluble salts or salinity changed 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 management 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 ±	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 ±	0.028	0.010	0.119
CD (*p=0.05*)	NS	NS	0.347
M x S			
SEm ±	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; Alaamer et al., 2020; Shtewy et al., 2020). 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), Sarkar et al. (2007) and Brar et al., (2015) 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; Ingole et al., 2018). Dubey *et al*. (2015) reported that application 100% NPK with FYM significantly increased the calcium carbonate content in sub-surface soil.

4. Conclusion

The current study showed that a targeted yield approach based on STCR boosted the utilization of integrated FYM and NPK fertiliser. 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. The addition of FYM along with NPK fertiliser elevated soil organic carbon levels compared to NPK alone treated plots, which may have contributed to the better soil properties in FYM treated plots against 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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