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Effect of soil-test-based long-term fertilization on soil health and performance of rice crop in Vertisols of central India

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Abstract

The present investigation was carried out to study the effect of soil-test-based long-term fertilization on soil health and performance of rice crop in Vertisols of Central India. The experiment was started in 2007-08 consisting six treatments viz. Control (No fertilizers), General Recommended Dose (GRD) (120-60-40), STCR based for 4 t ha^{-1} target, STCR based for 5.5 t ha^{-1} target, STCR based for 4 t ha^{-1} target + 5 t FYM ha^{-1} and STCR based for 5.5 t ha^{-1} target + 5t FYM ha^{-1} and with four replications. The crop cultivar of rice MR-219 was grown with different treatments and performance in terms of grain yield and straw yield were recorded at harvest of the crop. The soil chemical and biological properties were assessed by analyzing the soil samples after harvest of the crop collected from 0-15 cm depth. Experimental data was statistically analyzed by the standard analysis of variance technique appropriate to randomized block design to test the significance of treatment effects. The results of the study revealed that, balanced fertilization based on soil test recorded higher yield of rice over general recommended dose of fertilizers. Similarly, soil organic carbon, available NPK and microbial activity in terms of FDA, DHA and Phosphates enzyme were also significantly enhanced under the treatments receiving STCR based recommended dose of fertilizers along with FYM. Thus, the application of fertilizers based on soil test improved the performance of rice crop along with enhanced soil organic carbon, available macronutrients and soil microbial enzyme activities as compared to the application of general recommendation of fertilizers.

Highlights

- Application of fertilizers based on soil test value (STCR approach) significantly improved the yield of rice
- Application of fertilizers (STCR approach) along with FYM significantly improved soil organic carbon, soil nutrient availability and soil microbial activities.

Keywords: Rice, soil test based fertilization, soil health, STCR approach, Vertisols

Rice-wheat is one of the most predominant cropping systems of the India and contributes about 74 per cent of the total food grains of the country (Walia *et al.*, 2014). Rice is India's preeminent crop, and is also the hub of food security of the global population (Kumar *et al.*, 2014). After the green revolution the continuous use of dwarf varieties responsive to the fertilizers in intensive agriculture enhance the agriculture production. Intensive agriculture, involving exhaustive high yielding varieties of rice and other crops, has led to heavy withdrawal of nutrients from the soil; imbalanced and discriminate use of chemical fertilizers has resulted in deterioration of soil health (John *et al.*, 2001). The soil test crop response (STCR) approach for targeted yield is unique in indicating both soil test based fertilizer dose and the level of yield that can be achieved with good management practices. In order to sustain the yield and reduce the cost of fertilizers and in turn cost of cultivation, the STCR approach is very important (Saxena *et al.*, 2008; Chatterjee *et al.*, 2010). Long-term fertilizer experiments provide best possible means to study changes in soil properties, dynamics of nutrient processes and future strategies for maintaining soil health (Swarup, 2010). Such experiments in India suggested that under continuous cropping, changes in soil fertility due to imbalanced fertilization may be recognized as one of the important factor that limits crop yields.

It is thus important to measure the changes in soil properties with yield of crop in the fertilization practices where soil test based fertilizer application is done. This research work is therefore planned to examine the changes in soil properties with yield of rice crop as affected by long-term cropping with different rates of balanced (soil test based) and general fertilization.

Materials and Methods

Experimental Details

The experiment was started in 2007-08 at the Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV) research field under the ongoing AICRP on STCR trials, managed by Department of Soil Science and Agricultural Chemistry, Jabalpur. The experimental site is situated in the south-eastern part of Madhya Pradesh at 23^o 13′ N, 79^{o}57′ E with an altitude of 393 meter above mean sea level. Jabalpur lies in the "Kymore Plateau and Satpura hills" agro climatic zone of Madhya Pradesh. It has sub-tropical climate characterized by hot dry summers and cool dry winter. The soil of a experimental site is a Vertisol (fine clay, montmorillonite, hypothermic family of Typic Haplustert, Kheri series) with pH 7.6, CEC 42 Cmol (P^+) kg^{-1} and OC 5 g kg^{-1}. The soil samples (0-15 cm depth) were collected from the experimental site before the initiation (Kharif 2008) of the experiment and its fertility status was assessed.

Table 1: Treatment details

Treatment	Description
T1	Control (No fertilizer)
T2	General Recommended Dose (GRD)
T3	STCR Recommended dose (Targeted Yield 4 t ha^{-1})
T4	STCR Recommended dose (Targeted Yield 5.5 t ha^{-1})
T5	STCR Recommended dose (Targeted Yield 4 t ha^{-1}) + 5 t FYM ha^{-1}
T6	STCR Recommended dose (Targeted Yield 5.5 t ha^{-1}) + 5 t FYM ha^{-1}

The field experiment was laid out using a randomized complete block design and replicates four times during rice-wheat cropping. The treatment consist of Control (No fertilizers), General Recommended Dose (GRD) (120-60-40), STCR based for 4 t ha^{-1} targeted yield, STCR based for 5.5 t ha^{-1} targeted yield, STCR based for 4 t ha^{-1} targeted yield + 5 t FYM ha^{-1}, STCR based for 5.5 t ha^{-1} targeted yield+ 5t FYM ha^{-1}. The soil test values of NPK were 216, 16.1 and 270 kg ha^{-1}, respectively (Table 1). The STCR based fertilizer recommended doses for 4 and 5.5 t ha^{-1} target yield of rice were calculated by using the following calibration equations developed by JNKVV, Jabalpur under STCR project (AICRP-JNKVV, 2013). The FYM has been applied as additional dose in treatments 5 and 6.

STCR Fertilizer calibration equations for Rice:

$$FN = 4.25\ T - 0.45\ SN$$

$$FP_2O_5 = 3.55\ T - 4.89\ SP$$

$$FK_2O = 2.10\ T - 0.18\ SK$$

Where, FN, FP and FK are the doses of Fertilizer nitrogen, phosphorous and potassium, respectively to be applied (kg ha^{-1}),

T- Targeted yield of rice (q ha^{-1}) and SN, SP and SK are the available soil nitrogen, phosphorous and potassium (kg ha^{-1}), respectively (soil test values).

The N, P and K were applied using Urea (46% N), SSP (16% P_2O_5) and MOP (60% K_2O), respectively. The FYM used in experiment was contained 0.92, 0.72 and 0.90 per cent N, P_2O_5 and K_2O, respectively.

Soil analysis

Soil samples were collected from soil 0-15 cm from each plot after harvesting of the crop. Soil was composited for each replicate, air dried, and ground to pass through a 2mm sieve prior to analysis. Soil organic carbon was determined by following the Walkley and Black (1934) wet oxidation method. Available nitrogen in soil samples were determined by adapting the alkaline permanganate method of Subbiah and Asija (1956). Available P was determined colorimetrically after the extraction of 1 g soil with 20 ml 0.5 M sodium bicarbonate ($NaHCO_3$) for a half hour (Olsen *et al.*, 1954). Exchangeable potassium was determined using a flame photometer following soil extraction with 1N ammonium acetate ($COO-CH_3-NH_4$) (Hanway and Heidel, 1952). Soil microbial activity was determined by the assay of dehydrogenase activity (Casida, 1977), fluorescein diacetate activity (Adam and Duncan, 2001) and alkaline phosphatase activity (Tabatabai and Bremner, 1969). The data was analyzed statistically and treatment means were compared using LSD techniques at 5% probability appropriate for RBD (Gomez and Gomez, 1984).

Results and Discussion

Effect of different treatments on grain and straw yield of rice

The effect of different treatments on grain and straw yield of rice has been shown in Table 2. The grain and straw yield of rice significantly influenced by long term fertilization and followed the trend: T6 (5.9 and 9.1 t ha^{-1}) >T4 (5.0 and 9.1 t ha^{-1})> T5 (4.9 and 8.1 t ha^{-1})> T2 (4.5 and 6.4 t ha^{-1})>T3 (4.3 and 6.3 t ha^{-1}) >T1 (2.0 and 4.6 t ha-1) respectively. It is indicated that targeted yields under different treatments were achieved with 8-20 per cent variations. The data presented in Table 2 showed that the highest grain and straw yield were obtained in treatment T6 (Targeted Yield 5.5 t ha^{-1} + 5 t FYM ha^{-1}), which was significantly higher among the treatments. The lowest yield was recorded in T1 (control) treatment. Rahman et al. (2009) reported that the application of organic manure and chemical fertilizers increased the grain and straw yields of rice. It is clear that organic manure in combination with inorganic fertilizers increased the vegetative growth of plants and thereby increased straw yield of rice. Islam *et al.* (2013).

The targeted yield achieved in all the treatments with slight deviations except in treatment T5 where actual yield was 23.3 per cent higher than targeted yield. Desmuka *et al.* (2012) achieved the targeted yield of rice (40 q ha^{-1}) by using the nutrients based on STCR approach for targeting yield of rice. The result further showed that the application of fertilizer based on soil test value for higher yield target along with 5t FYM ha^{-1} treatment (T6) recorded significantly higher grain and straw yield over the T1 (control) by 185.4 and 97.6 per cent respectively.

Table 2: Effect of different treatment on grain and straw yields of rice

Treatment	Rice yield (t ha^{-1})	
	Grain	Straw
T1	2.05	4.62
T2	4.48	6.4
T3	4.33	6.28
T4	5.05	9.05
T5	4.93	8.1
T6	5.83	9.13
SEm ±	0.16	0.36
CD(P=0.05)	0.5	1.08

Effect of different treatments on soil organic carbon content and available macronutrients

Effect of long term fertilization based on soil test and targeted yield on soil properties were assessed by determination of SOC and available NPK (Table 3). The highest soil organic carbon was found in treatment T6 (Targeted Yield 5.5 t ha^{-1} + 5 t FYM ha^{-1}) which was receiving nutrient in integration of fertilizer and manure (FYM). Minimum value of organic carbon (%) was noted under treatment T1, T2 and T3 having 0.4, 0.5 and 0.5 respectively (Table 3). The SOC increased with continuous application of FYM and inorganic fertilizers. Brar *et al.* (2015) also recorded 69% higher SOC under 100% NPK + FYM treatment compared to untreated control. Rasool *et al.* (2007) also reported similar results for rice–wheat system in Punjab, India.

Table 3: Effect of different treatments on the available nutrient status (kg ha^{-1}) in soil

Treatment	SOC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T1	0.4	209	11.9	260
T2	0.5	239	16.5	274
T3	0.5	228	15.7	270
T4	0.6	272	17.4	283
T5	0.6	268	19.6	284
T6	0.7	277	21.0	297
SEm ±	0.02	8.68	0.83	10.63
CD(P=0.05)	0.07	26.97	2.49	32.04

Available N content in soil ranged between 209 and 277 kg ha^{-1}. The application of fertilizer doses based on soil test for higher yield target along with

5 t ha^{-1} FYM recorded significantly higher nitrogen (277 kg ha^{-1}). The reduction in initial available N content was noted for control treatment. The treatments T6, T4 and T5 were found significantly superior over other treatments though these were statistically at par with each other. The increase in available nitrogen status under integrated treatment might also be attributed to a greater multiplication of soil microbes as a result of which organically bound nitrogen was converted to inorganic form of nitrogen Bharadwaj and Omanwar, (1994).

The application of fertilizer doses based on soil test for higher yield target along with 5 t FYM ha^{-1} was found significantly higher available P(21.0 kg ha^{-1}) than other treatments (Table 3). Available P content in soil ranged between 11.9 and 21.0 kg ha^{-1} and followed the trend: T1 (11.9 kg ha^{-1}) <T3 (15.7 kg ha^{-1}) <T2 (16.5 kg ha^{-1}) < T5 (19.6 kg ha^{-1}) <T4 (17.4 kg ha^{-1}) <T6 (21.0 kg ha^{-1}). Swarup and Yaduvanshi (2000) have reported that rice and wheat grown in sequence continuously for three years in Acquic Natrustalfs of Karnal had decreased the available-P content from an initial value of (11.8 to 9.7 kg ha^{-1}) in control plots. While increasing level of P application continuously through fertilizer or along with FYM resulted in an increase in the available P content of soil.

The available K was significantly influenced by different treatment combinations. Significantly higher available K content in soil wasrecorded in treatments T6 (Targeted Yield 5.5 t ha^{-1} + 5 t FYM ha^{-1}) with integration of inorganic fertilizer and FYM. It may be due to the beneficial effects of organic manures affectingclay-oregano interaction and direct K_2O additions widening available K pool of soil. Similar beneficial effect of organic manures on the available K_2O content of the soil was reported earlier Konthoujam *et al.* (2013) and Pawar (1996) in case of vermicompost.

Ayoola and Makinde (2009) found that application of chemical fertilizer with organic manure increased N, P and K content in post harvest soil. The integrated use of fertilizer with FYM increased the nutrient availability. This might be due to the enhanced microbial activity, conversion of unavailable nutrients into available forms and also due to improved physical, chemical and biological properties of soil (Katkar *et al.*, 2011).

Effect of different treatments on soil microbial activities:

The higher microbial activity in terms of fluorescien diacetate (FDA), dehydrogenase (DHA) and alkaline phosphatase was recorded with STCR based fertilizer application for targeted yield (T6,T5,T4,T3) when compared it to general recommended dose (T2) and control (T1) (Fig. 1, 2 and 3).

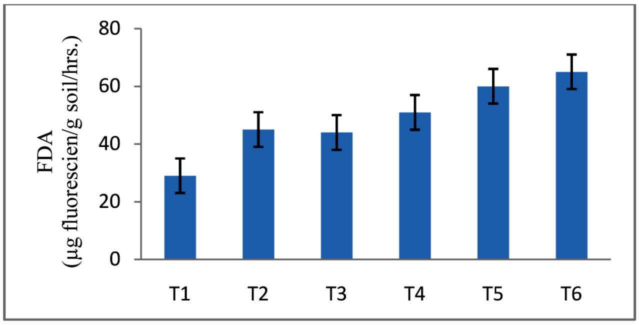

Fig. 1: FDA enzyme activity under different treatments (Error bars indicates CD (P<0.05) value)

The application of organic manure significantly influenced the activity of fluorescien diacetate (FDA), dehydrogenase (DHA) and alkaline phosphatase enzyme activities in the rhizosphere soil. FYM increases the activity because of its high biodegradability and micro-organisms addition. High dehydrogenase and FDA with application of organic manure is attributed to higher content of organic matter. Dehydrogenase is present in viable cells, and it is thought to reflect the total range of oxidative activity of soil microflora (Mandal *et al.*, 2007).

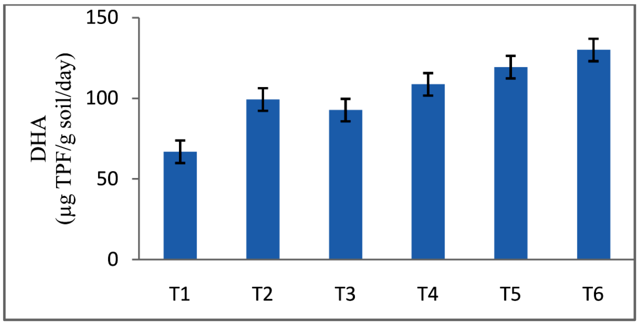

Fig. 2: Dehydrogenase enzyme activity under different treatments (Error bars indicates CD *(P<0.05)* value).

Srilatha *et al.* (2013) was recorded the highest alkaline phosphatase activity in150% NPK treatment followed by the application of 100% NPK +FYM.

The increase in activity with integrated application of organic manures along with chemical fertilizer may be attributed to the increasing population of microorganisms like bacteria, etc., due to increased availability of substrate through organic manure there by resulting in high microbial activity and release of these enzymes in to the soil.

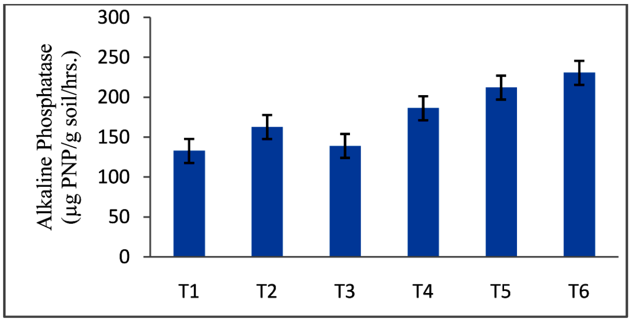

Fig. 3: Alkaline phosphatase enzyme activity under different treatments (Error bars indicates CD *(P<0.05)* value)

Conclusion

The results of study demonstrated that the application of fertilizers based on soil test value (STCR approach) significantly improved the yield of rice along with enhanced soil organic carbon, available macronutrients and soil microbial activities.

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