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Effect of long term continuous application of STCR based fertilizer in calcareous soil on soil properties under rice based cropping system

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Abstract
A field experiment was carried out during *kharif* 2019-20 under a long-term experiment of Soil Test Crop Response (STCR) started during rabi-2012 at experimental farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, (Bihar) on the "Effect of long term continuous application of STCR based fertilizer in calcareous soil on soil properties" to evaluate the effect of STCR based fertilizer on soil properties (pH, EC, OC, Dehydrogenase activity and soil microbial biomass carbon). Therefore, a long-term experiment design was randomized block design with three cropping system (rice-wheat, rice-mustard and rice-maize) and nine treatments [T_1- control, T_2-FP, T_3-GRD, T_4-YT 35q/ha, T_5-YT 40 q/ha, T_6-YT 45 q/ha, T_7-STCR (YT 35 q/ha) + IPNS, T_8-STCR (YT 40q/ha) + IPNS, T_9-STCR (YT 45 q/ha) +IPNS. Continuous addition of STCR based fertilizer along with 5 tons ha^{-1} compost decline the soil pH, improved soil organic carbon and microbial properties whereas control unfertilized decreased the most, results unsustainable yields and soil fertility. Treatment T_9 for rice based cropping system was superior over all the other treatments in chemical and biological properties of soil. Among different treatment for three cropping system, treatment T_8 was at par with T_7 for soil microbial biomass carbon and dehydrogenase in soil. Most detrimental effect of omission of nutrient was observed in treatment T_1 control unfertilized. Thus, it can be resulted that continuous supply of STCR based fertilizer with IPNS improved the organic carbon content and microbial properties over FP and GRD in surface soil (0-15 cm).

Keywords: Dehydrogenase, microbial biomass carbon, crop rotation, calcareous

Introduction
Rice (*Oryza sativa* L.) is the major crop of India and occupies largest cropped area of 43.7 million hectares with an annual production of 106.29 million tones and the productivity is 2432 kg ha^{-1} (GOI, 2018). The Soil test based fertilizer recommendation harmonizes the much debated approaches namely, "Fertilizing the soil" versus "Fertilizing the crop" ensuring for real balance (not apparent balance) between the applied fertilizer nutrients among themselves and with the soil available nutrients. Based on this concept, soil test crop response studies have been undertaken in different parts of India in various crops like wheat, rice, pearl millet (Subba Rao and Srivastava, 2000) [17]. Truog (1960) [19] illustrated the possibility of "Prescription method" of fertilizer use for obtaining high yields of corn using empirical values of nutrient availability from soil and fertilizer. Higher microbial activities indicate presence of dehydrogenase enzyme more in soil. Dehydrogenase is essential for intact cells and reflects the all oxidative activities of soil micro-flora, essential for oxidation of soil organic matter (Itziar *et al*. 2003) [8]. The dehydrogenase activity (DHA) in normal soil, saline soil and in alkali soil (under different cropping system under Haryana, India. Dehydrogenase activity in normal soil was 103 per cent greater under tree canopies over rice-wheat cropping system, where as in saline soil it was 100% greater under pearl millet-wheat cropping sequence than under tree canopies. In alkali soil, higher (58%) de-hydrogenase activity was recorded in rice-wheat (with 50% G.R.) and under karnal grass (37%) (*Leptochloa fusca* [*Diplachne fusca*], without gypsum) as comparison to tree canopies. Sodic soil have minimum DHA, while, it was at par of saline and normal soils (Sriramachandrasekharan, 2002) [16]. The microbiological properties were undertaken from organic sources and inorganic fertilizers treatment at the end of fourth year of experiment in Ludhiana, Punjab, India. The collected soil samples from surface (0-15) and sub-surface (15-30 cm) layers after the harvesting of wheat crop in rice-wheat cropping pattern (Cheema *et al*. 2008) [6].

The nutrient requirements of wheat were met through FYM, FYM+ rice husk ash, rice straw compost, brewery sludge and recommended inorganic fertilizers. Potentially mineralizable nitrogen and labile carbon content were highest were highest in treatment receiving FYM and their values were lower in sub-surface soil. Soil biological properties are one of the best indicators for soil fertility thus plays important role in sustainability of cropping system. The microbial biomass and activities of soil enzymes an important role on nutrient cycling and to reserve the soil fertility. The soils were collected from the fields of wheat-mungbean and wheat-maize cropping systems. The variations in soil microbial biomass carbon and dehydrogenase activity were observed during all seasons. The summer season showed more SMBC and dehydrogenase activities compared to other seasons. The soil MBC values was maximum in wheat-maize cropping pattern in Kahuta areas, while, dehydrogenase activities were more pronounced in wheat-mungbean cropping system (Liu *et al.* 2013; Ullah *et al.* 2013) [11]. The microbial and enzyme activities of the soil are closely associated to the organic matter content and influenced by hydrothermal regime of the soil. The dehydrogenase activity and microbial population (bacteria, fungi and actinomycetes) was evaluated from more than 20 years' old cultivation under different cropping systems i.e., mango, cashew, vegetable, rose and medicinal and aromatic crops at different soil depth (0-15, 15-30, 30-50 and 50-100 cm). They recorded significantly higher enzymes activity and microbial population in surface soil (0-15 cm) under mango and cashew over annual crops (Bhavya *et al.* 2018; Katkar *et al.* 2011) [3, 10].

Material and Method

The long-term experiment of Soil Test Crop Response (STCR) started during rabi-2012 at experimental farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. The surface soil sample (0-15 cm) was collected from the experimental field with the help of screw auger prior to research as per standard procedure during the month of May-2019. The climate of experimental location is sub-tropical having three distinct seasons *i.e.* rainy (mid June to September), winter (October-February) and summer (March to mid June) with hot and humid summer and cold winter. During the study period, the monthly mean maximum temperature varied between 29.3 to 37.5 ^{0}C, with an average of 33.1 ^{0}C. The mean minimum temperature ranged between 22.1 ^{0}C to 26.8 ^{0}C, with an average of 25.3 ^{0}C. Overall, the highest temperature showing month was June. It receives a mean rainfall of 193.1 mm and it was maximum during the month of September-2019. The fertilizer K dose for rice crop was calculated as per STCR equation and accordingly applied during kharif-2019 is depicted in table 1. The pH of 1:2 soil: water suspension was determined with the help of glass electrode pH meter (Systronics pH system 361) as described by Jackson, 1967 [9]. The EC in the clear extract of soil with soil: water ratio of 1:2 was analysed by Electrical Conductivity Bridge (Systronics conductivity TDS meter 308) by the method of Bower and Wilcox, 1965 [4]. Organic carbon was analyzed by rapid titration method (Walkley and Black, 1934) [21]. Dehydrogenase activity measure with the help of Colorimetric determination (Casida *et al.* 1964) [5]. The rice nursery (Rajendra Bhagwati and Prabhat) were sown on 14 June, 2019 and transplanted on 7 July, 2019 and all the better agronomical operation were followed during the rice growing season. Rajendra Bhagwati was harvested on 20 Oct., 2019 while Prabhat on 28 September 2019.

Statistical analysis

The research data were analyzed with the help of analysis of variance with OPSTAT (Sheoron *et al.* 1998). OPSTAT is a free online agricultural data analysis tool developed by O.P. Sheoran, Computer Programmer at CCS HAU, Hisar, India (http://14.139.232.166/opstat/). The mean values of treatment were separated by Fischer's protected least significant difference (LSD) test at $P \leq 0.05$.

Results and Discussion

Effect on soil Chemical properties

Addition of compost reduction in pH, EC and enhance organic matter content in soil may be due to produce organic acid, during decomposition of organic manures which neutralize the sodium salts present in the soil and increase the hydrogen ions concentration. The pH of surface soil varied from 8.03 to 8.34, 8.04 to 8.30, 8.06 to 8.30 in rice –wheat, rice-mustard and rice-maize cropping system, respectively (table 2.). In general, the pH declined significantly under the treatment T_8 (STCR, YT40 q/ha+IPNS) and T_9 (STCR, YT40 q/ha+IPNS) over Control and FP under all the three cropping systems. Long-term application of organics and also addition of more root biomass under STCR+IPNS treated plots released organic acids during its decay and caused decline in pH (Malarkodi *et al.* 2019) [12]. Bharadwaj *et al.* (1994) [2] and Santhy *et al.* (1999) [14] also reported decline in pH due to long-term application of fertilizers along with manure over control and without application of manure. The EC of soil affected by different treatments in surface soil was non-significant (table 2.). The EC in upper layers (0-15 cm) varied from 0.180 to 0.223, 0.181 to 0.220 and 0.193 to 0.216 in rice-wheat, rice-mustard and rice-maize cropping system, respectively. The OC of surface soil varied from 0.33 to 0.53, 0.24 to 0.44, 0.34 to 0.51 per cent in rice-wheat, rice-mustard and rice-maize cropping system, respectively (table1.). In general, higher organic carbon content was recorded in the plot receiving treatment STCR (YT 45q/ha) along with IPNS (T_9) (0.53) over unfertilized (T_1) (0.33) and FP (T_2) (0.39) whereas the lowest content was recorded in unfertilized control plot (T_1) (0.33).

Effect on microbial properties

The significantly higher dehydrogenase enzyme in treatment receiving STCR based fertilizer along with compost 5 tons ha^{-1} (T_9) (12.3) in rice –maize cropping system comparison to rice-wheat and rice-mustard cropping system. The content of dehydrogenase enzyme varied from 8.4 to12.3, 7.5 to 13.1 and 9.8 to 13.2 µg TPF g^{-1} hr^{-1} in upper layer of soil under rice-wheat, rice-mustard and rice-maize cropping system, respectively. Addition of manure improved the status of dehydrogenase enzyme as well as soil biological properties (Table 3.). The results of different nutrient management practices on dehydrogenase activity in continuous application of organic along with inorganic. The organic manure applied treatment showed significantly higher dehydrogenase activity (0.85 µg TPFg^{-1} hr^{-1}) than INM (0.80 µg TPF g^{-1} hr^{-1}) and control showed lower value 0.75 reported by Tamilseive *et al*. (2015) [18].

The microbial biomass carbon increased significantly in treatment receiving STCR based fertilizer along with compost. Microbial biomass carbon ranged from 122.3 to 206.2, 103.3 to 197.6 and 139.4 to 232.1 in surface soil in rice-wheat, rice-mustard and rice-maize cropping system, respectively. STCR (YT45q/ha) along with IPNS significantly correlate with all treatment except STCR (YT40q/ha) along with IPNS and at par with STCR (YT40q/ha) along with IPNS related results were described by Ramachandran (2013) [13]. The addition of organics and NPK enhance MBC, might be due to priming effect. However during the incubation period the microbial biomass carbon increased in treatment receiving STCR based fertilizer with IPNS.

Table 1: Treatment details

Treatment	K- fertilizer (kg K_2O/ha)		
	Rice (Rice-wheat cropping system)	Rice (Rice-mustard cropping system)	Rice (Rice-maize cropping system)
T_1: Control	0	0	0
T_2: Farmers practice	33	33	33
T_3: GRD	40	40	40
T_4: STCR (YT35 q/ha)	37.4	50.0	23.8
T_5: STCR (YT40 q/ha)	47.2	58.9	28.5
T_6: STCR (YT45 q/ha)	55.8	67.6	36.1
T_7: STCR (YT35q/ha)+IPNS	28.3	45.2	11.0
T_8: STCR (YT40q/ha)+IPNS	36.7	53.6	17.1
T_9: STCR (YT45q/ha)+IPNS	44.8	62.0	24.2

Notes: GRD= General Recommended Dose; YT = Yield Target; IPNS = Integrated Plant Nutrient System (in IPNS, 5 tonnes compost/ha was supplied); STCR= Soil Test Crop Response

Table 2: Status of pH (1:2, soil: water), EC (dSm^{-1}) and organic carbon (%) in soil after seven year continuous fertilization under rice based cropping system

Treatments	Rice-wheat			Rice-mustard			Rice-maize		
	pH	EC	OC	pH	EC	OC	pH	EC	OC
Control	8.34	0.194	0.33	8.30	0.202	0.24	8.30	0.210	0.34
FP	8.25	0.214	0.39	8.24	0.203	0.28	8.26	0.211	0.38
GRD	8.28	0.208	0.41	8.17	0.220	0.33	8.27	0.216	0.41
STCR(YT35 q/ha)	8.19	0.201	0.43	8.17	0.212	0.35	8.24	0.211	0.43
STCR(YT 40q /ha)	8.15	0.191	0.44	8.15	0.198	0.35	8.23	0.230	0.43
STCR (YT 45 q/ha)	8.12	0.191	0.46	8.15	0.199	0.34	8.24	0.203	0.45
STCR (YT 35 q/ha)+IPNS	8.06	0.180	0.50	8.05	0.190	0.37	8.11	0.200	0.46
STCR (YT40 q/ha)+IPNS	8.04	0.200	0.52	8.04	0.181	0.43	8.07	0.193	0.48
STCR (YT 45 q/ha)+IPNS	8.03	0.223	0.53	8.05	0.185	0.44	8.06	0.212	0.51
SEm±	0.07	0.011	0.02	0.05	0.009	0.03	0.06	0.011	0.02
CD(p=0.05)	0.20	NS	0.07	0.16	NS	0.08	0.17	NS	0.07

Table 3: Status of dehydrogenase enzyme (μg TPF g^{-1} hr^{-1}) in surface soil after seven year continuous fertilization under rice based cropping system

Treatments	Rice-wheat cropping system	Rice-mustard cropping system	Rice-maize cropping system
T_1: Control	8.4	7.5	9.8
T_2: FP	9.8	8.4	11.3
T_3: GRD	10.2	9.1	11.8
T_4: STCR(YT35 q/ha)	10.8	9.3	12.2
T_5: STCR(YT 40q /ha)	11.2	9.4	12.2
T_6: STCR (YT 45 q/ha)	11.3	9.6	12.5
T_7: STCR (YT 35 q/ha)+IPNS	11.5	11.1	12.6
T_8: STCR (YT40 q/ha)+IPNS	11.9	12.7	13.0
T_9: STCR (YT 45 q/ha)+IPNS	12.3	13.1	13.2
SEm±	0.2	0.2	0.3
CD(p=0.05)	0.7	0.7	1.0

Table 4: Status of SMBC (μg g^{-1}) in surface soil after seven year continuous fertilization under rice based cropping system

Treatments	Rice-wheat cropping system	Rice-mustard cropping system	Rice-maize cropping system
T_1: Control	122.3	103.3	139.4
T_2: FP	128.1	121.5	152.7
T_3: GRD	142.7	130.3	163.0
T_4: STCR(YT35 q/ha)	150.6	131.7	174.2
T_5: STCR(YT 40q /ha)	158.6	135.9	180.0
T_6: STCR (45 q/ha)	173.5	135.4	199.9
T_7: STCR (YT 35 q/ha)+IPNS	175.6	157.6	202.8
T_8: STCR (YT40 q/ha)+IPNS	204.0	194.6	221.5
T_9: STCR (YT 45 q/ha)+IPNS	206.2	197.6	232.1
SEm±	7.3	4.9	11.7
CD(p=0.05)	21.8	14.8	35.2

Conclusion

In this study reported that integrated use of compost and NPK fertilizer using STCR based targeted yield approach increased availability of nutrients and soil properties. After a seven year of application of various fertilizer treatments, it was observed that organic carbon content, microbial activity and soil microbial biomass carbon found significant difference in among treatments, while EC was not found significantly different. These results conclude that for sustainable crop production and maintaining soil quality, addition of organic manure like compost is of more important and should be beneficial in nutrient management under intensive cropping system for maintaining soil health.

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