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Effect of integrated nutrient management on soil health and yield of crops under rice-wheat cropping system in alluvial soil of Bihar, India

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Abstract
During first green revolution era a static or declining trend of crop productivity has been observed in Indo-Gangetic Plain especially after 1990s due to sole dependence on chemical fertilizers. The integrated use of chemical fertilizers with organics can help in sustainable and environmentally sound nutrient management of soils. A field experiment was conducted in the Krishi Vigyan Kendra, Jamui, Bihar during 2014-15 and 2015-16 with rice (cv. Rajendra mahsoori-1) as *kharif* crop and wheat (cv. PBW-502) as a *rabi* crop to investigate the influence of integrated nutrient management on soil health and yield of crops in rice-wheat cropping system. The experiment comprised of nine treatments, each replicated five times with a plot size of 20 m^2 in randomized block design. Soil samples were collected and analyzed for physical, chemical and biological properties before and after the crop harvest. Based on pooled data, the highest grain yield (44.69 q/ha) in wheat and (49.80 q/ha) in rice were recorded in the T8 treatment. The lowest grain yield was recorded in T9 treatment. The treatments received organic amendments recorded higher microbial biomass carbon, basal soil respiration and fluorescein diacetate hydrolyzing activity over the treatments received chemical fertilizers in both rice and wheat crop. The T_8 treatment recommended for higher productivity and good soil health in rice-wheat cropping system in southern east Bihar.

Keywords: Integrated nutrient management, indo-gangetic plain, microbial biomass, soil respiration, fluorescein diacetate hydrolyzing activity, rice-wheat cropping system

1. Introduction
Over a period of time, for higher production, growers are totally dependent upon the use of chemical fertilizers. As the higher cost of fertilizers and the low purchasing capacity of peasants, restrict the use of costly fertilizers. Along with that intensive use of these chemical fertilizers have resulted into numerous problems like micro-nutrient deficiencies, nutrient imbalance in soil and plant system, increased pest infestation, environmental degradation, deterioration of soil health and stagnation of crop yield. Integrated nutrient supply is the systematic approach to nutrient management as the combined application of organic and in organic sources, improves the soil fertility and crop productivity (Shree *et al.*, 2014) [26]. Organic carbon is the main building block of soil fertility and combined application of mineral with inorganic fertilizers showed higher organic carbon content (Marin *et al.*, 2007) [16]. The rice *(Oryza sativa*) and wheat *(Triticum aestivum*) cropping system occupies about 13.5 million ha in the Indo-Gangetic plains (IGP) of south East Asia and provides food and chief source of calories foe million of people. However, decadal yield-trend analysis revealed that food basket not only suffered for productivity stagnation but also depleted in inherent nutrient status and declines in quantity and quality of soil organic matter (Majumder *et al.*, 2008) [15]. In India too rice-wheat cropping system (RWCS) is most widely adopted system, covering over 10.5 million ha-mostly in the IGP. However, the productivity of both rice and wheat is low i.e. 2,323 and 3056 kg/ha, respectively. Therefore, future demand for food will have to be met mainly through increases in production per unit of harvested area (Ladha *et al.*, 2003) [14]. The combination of poor soil fertility and inadequate, unbalanced, and inefficient use of fertilizers contributes much to this problem.

Sustainability of rice-wheat system has emerged in a big way in Indo-Gangetic plains (Yadav *et al.*, 1998) [34].

Both crops in the rice-wheat system are fertility exhaustive and result in decline of soil organic carbon and deterioration in soil health. Sustainable production of rice-wheat cropping system could be achieved only by maintaining a balance between supply of demand of nutrients by integration of inorganic and organic sources of nutrients. Sustenance of the productivity of rice-based cropping system necessitates the integrated use of organic, bio-organic and inorganic sources of nutrients (Sharma *et al.*, 2001) [24].

In IGP only few studies have been addressed on the input of sole inorganic fertilizers or its integrated use with organic manure on soil biological and metabolic activities. As a consequence, impact of repeated use of management practices based on organic and mineral input on soil biological and metabolic activities need to be investigated. Hence, the present investigation was conducted to find out suitable nutrient management strategies for rice-wheat cropping system for higher productivity and soil health in alluvial soil of southern east Bihar, India.

2. Material and Methods

Description of field experiment

The present investigation was carried out during 2014-15 and 2015-16 at the Experimental Farm of the Krishi Vigyan Kendra, Khadi Gram, Jamui, Bihar ($24^0$97' N and $88^0$30' E). The climate of the study area was hot humid to sub humid climate with annual rainfall of 1100 mm as received during the wet season (June-September). The mean maximum temperature remains about 35 ºC during the hottest months of May to June. December to February is the coldest months with minimum temperature of about 6 ºC. At the initiation of the experiment, soil of the experimental field was sandy loam in texture, bulk density (1.39 g/cc), low water holding capacity (27.9%) with slightly acidic in soil reaction (pH 6.82) with non-saline conductivity (0.18 dSm^{-1}). The organic carbon content was 0.482% and the available nitrogen, available phosphorus, available potassium, microbial biomass carbon (MBC), basal soil respiration (BSR) and fluorescein diacetate hydrolyzing activity (FDHA) status in initial soils were 248.8 kg ha^{-1}, 10.4 kg ha^{-1},132.1 kg ha^{-1}, 172μg g^{-1}, 0.87μg CO_2-C g^{-1}soil h^{-1} at 25 °C soil and 27.0μg fluorescein g^{-1} soil h^{-1} at 24 °C respectively.

The experiment was conducted during *Rabi* of 2014-15 and 2015-16 with wheat as *Rabi* crop and rice as a *kharif* crop 2015 and 2016. The 9 treatments (Table 1) with five replications in a randomized block design with 20 m^2 plot for each treatment. After the field preparation, wheat seeds (cv. PBW-502) were sown in row with spacing of 20 cm, using seed rate of 125 kg/ha, on 27 and 29 November of 2015 and 2016, respectively. After the harvest of wheat, the plots were prepared for rice transplanting. 25 days old seedling of rice (cv. Rajendra mahsoori-1) was transplanted on July 27, 2015, and July 30, 2016, respectively in the plots with spacing of 20X15 cm. Nitrogen, phosphorous and potash were applied in the form of urea, diammonium phosphate and muriate of potash. All other operations were performed as per recommendations of the crop. The data on various growth and yield attributes, grain and straw yields were recorded under various treatments.

Table 1: Treatment details of the experiment

Treatments	Wheat	Rice
T_1:	Farmers' practice (100:74:0 kg ha^{-1}N:P:K*)	Farmers' practice (100:55:0 kg ha^{-1}N:P:K)
T_2:	T_1 + Vermicompost @ 2 t ha^{-1}	T_1 + Vermicompost @ 2 t ha^{-1}
T_3:	T_1 + PSB @ 8 kg ha^{-1} (Soil application)	T_1 + PSB @ 8 kg ha^{-1} (Soil application)
T_4:	T_2 + PSB @ 8 kg ha^{-1} (Soil application)	T_2 + PSB @ 8 kg ha^{-1} (Soil application)
T_5:	100% NPK (150:60:40 kg ha^{-1})	100% NPK (100:40:20 kg ha^{-1})
T_6:	75% NPK + Vermicompost @ 2 t ha^{-1}	50% NPK + Vermicompost @ 2 t ha^{-1}
T_7:	T_5 + Vermicompost @ 2 t ha^{-1}	T_5 + Vermicompost @ 2 t ha^{-1}
T_8:	T_7+ PSB @ 8 kg ha^{-1}soil application	T_7 + PSB @ 8 kg ha^{-1} (Soil application)
T_9:	Control	Control

*NPK stands for fertilizer doses

Soil sampling and analysis

Soil samples from top 15cm depth were collected from the experimental site before sowing of wheat crop (November, 2014) and also collected from each replication after harvest of crop. The soil samples were air dried, processed and passed through 2 mm sieve and properly stored in polythene bags for physico-chemical analysis. The field moist soil sample were collected in polythene bag, and kept in refrigerator for microbiological analysis. The physical property like bulk density was determined according to Singh (1980) [28] and water holding capacity was determined according to Piper (1950) [18]. The chemical properties like pH, organic carbon, available N, available P and available K were determined using standard methods of analysis. The biological properties like microbial biomass carbon (MBC) was determined according to Joergensen (1995) [11] and Vance *et al*. (1987) [32]. The basal soil respiration (BSR) was determined according to Alef (1995) [2] and fluorescein diacetate hydrolyzing activity (FDHA) was determined according to Schnurer and Rosswall (1982) [23]. Grain and straw yields were recorded after harvest. The results of both the years were statistically analysed by using the technique of analysis of variance (ANOVA) and the ANOVA was carried out by RBD using SPSS 16.0 statistical package. The mean values of the treatments were compared by DMRT at 5% probability level.

3. Results and Discussion

The experimental finding indicated that the compared to control, application of nutrients through INM treatments progressively improved all yield and yield attributes of both crops and soil health parameters viz.: OC, MBC, FDHA and BSR.

3.1 Yield and yield parameters of wheat and rice

Data on yield and yield attributes of both wheat and rice revealed that as compared to control and application of nutrients through inorganic fertilizers the INM treatments progressively improved all the yield and yield parameters. In wheat the perusal of the data (Table 2) revealed that the number of tiller/m^2 (286.1) was significantly highest with the T8 treatment and lowest (211.5) in T9 treatment. The number of grain/spike (38.7) was highest with the T8 treatment and it is at par with T7, T6, T5, T4, T3 and T2 and lowest (32.9) was recorded in T9 treatment. The maximum 1000-grain weight (40.0 g) was recorded with the T8 treatment and it was significantly superior to rest of treatments and lowest (36.58 g) was recorded in T9 treatment. The highest grain yield (44.69 q/ha) was recorded with the T8 treatment, it was closely followed by T7 (43.35 q/ha) and differ significantly with rest of treatments. The lowest grain yield (20.79 q/ha) was recorded in T9 treatment.

Table 2: Effect of different treatments on yield and yield parameters of wheat (Pooled data of two years i.e., 2014-15 and 2015-16)

Treatment	Number of tiller m^{-2}	Number of grain $spike^{-1}$	1000 grain weight (g)	Grain yield (q ha^{-1})
T_1	245.2g*	36.0b	37.80f	28.80e
T_2	260.8e	37.1ab	39.12cd	34.07cd
T_3	257.1f	37.3ab	38.63e	32.79d
T_4	265.2d	37.6ab	38.82de	35.47c
T_5	267.6d	38.0ab	39.03cd	38.69b
T_6	271.4c	38.0ab	39.26bc	39.52b
T_7	277.6b	38.2ab	39.57b	43.35a
T_8	286.1a	38.7a	40.00a	44.69a
T_9	211.5h	32.9c	36.58g	20.79f

*Figures denoted by same alphabets are statically similar at 5% probability level by DMRT

In rice the perusal of the data (Table 3) revealed that T8 gave the highest number of tillers $hill^{-1}$ (26.55), which differed significantly from all other treatments except T4, T6 and T2. The lowest number of tiller $hill^{-1}$ (21.9) was recorded for T9 that differed significantly from all other treatments. The highest number of panicles m^{-2} (388.5) was recorded for T8, which differed from all other treatments. The lowest number of panicle m^{-2} (355.5) was recorded for control T9. The maximum weight (23.55 g) was obtained by the treatment T8, which was closely followed with other treatments except T3, T1 and T9. The highest grain yield (49.80 q/ha) was recorded with the T8 treatment and differ significantly with rest of treatments. The lowest grain yield (30.01 q/ha) was recorded in T9 treatment.

Table 3: Effect of different treatments on yield and yield parameters of rice (Pooled data of two years i.e., 2015 and 2016)

Treatment	Number of tiller $hill^{-1}$	Number of panicle m^{-2}	1000 grain weight (g)	Grain yield (q ha^{-1})
T_1	24.5c*	359.2f	22.08b	36.86f
T_2	25.6ab	373.9d	23.30a	42.59d
T_3	24.8bc	365.6e	22.38b	40.92e
T_4	26.0ab	382.5b	23.35a	45.55c
T_5	25.4bc	366.8e	23.14a	41.18e
T_6	25.7abc	373.7d	23.22a	44.93c
T_7	26.1ab	379.1c	23.37a	47.05d
T_8	26.6ab	388.5a	23.55a	49.80a
T_9	21.9d	355.5g	22.04b	30.01g

*Figures denoted by same alphabets are statically similar at 5% probability level by DMRT.

The wheat and rice yield was increased significantly due to combined application of inorganic fertilizer and organic manure might be attributed to control release of nutrients in the soil through mineralization of organic manure which might have facilitated better crop growth (Katkar *et al.*, 2011) [12]. The increased availability of N, P and K in addition to other plant nutrients released by the vermicompost might have contributed in enhancing the crop yield and yield-attributes. The positive impact of availability of individual plant nutrients and humic substances from vermicompost and balanced supplement of nutrient through inorganic fertilizers might have induced cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells, resulting in the enhancement of yield parameters. Similar trend have also been reported by Ranwa and Singh (1999) [20] in wheat. The higher rice yield due to integrated nutrient management might be due to the combined effect of many yield components, like number of tillers, number of panicles and 1000 grain weight. Kausar *et al.* (2001) [13] and Rahman *et al.* (2001) [19] also reported similar results. The weight of individual grains and the number of filled grains are governed by the grain growth supported by concurrent CO_2 assimilation during the grain filling phase rather than by the stored reservoir of carbohydrates during the vegetative phase. Thus, better nutrition of plants associated with increased fertilization helped in maintaining significantly better vegetative growth leading to greater interception of solar radiation by the crops and ultimately contributed towards the significant increase in number of filled grains. These results corroborate the findings of Patidar and Mali (2002) [17] and Sharma (2004) [25]. Individual grain weight (expressed as 1000-grain weight) was also significantly improved with the application of vermicompost, PSB and 100% NPK fertilizers. Vigorous growth of crops with increase in fertility levels is closely associated with higher sink capacity which ultimately resulted in higher values of 1000-grain weight. This in turn, increases the number of panicles m^{-2} because more biomass and nutrient addition was there. The other reason could be the organic manure, which help to increase the soil fertility through improvement in soil physical, chemical and biological characteristics. Similar trend was found in the findings of Umar *et al.* (2004) [31]. The higher grain yields of rice with integrated use of vermicompost, PSB and chemical fertilizers might be attributed to higher availability of macro and micro nutrients and facilitating uptake by plants resulting in better growth and dry matter production (Barik *et al*., 2008) [4]. Improvement in yield due to combined application of inorganic fertilizer and vermicompost be attributed to control release of nutrients in the soil through mineralization of organic manure which might have facilitated better crop growth. Similar type of trends indicating beneficial effects of combination of vermicompost and inorganic fertilizers have also been reported by Jadhav *et al*. (1997) [10]; Rani and Shrivastava (1997) [21] in rice.

3.2 Soil parameters after wheat harvest

The soil organic carbon content was significantly different with different treatments. Highest organic carbon (0.71%) recorded in T8 treatment followed by 0.675% in T7 treatment and 0.635% in T6 treatment. Similar results were reported by Sodhi *et al*. (2009) [29] in rice-wheat. Increased organic carbon in the organic with inorganic applied treatments is in consistent with the increased yield and the external organic carbon inputs through organic manures (Bandyopadhyay, 2010) [3]. The maximum increase of MBC (262.5μg g^{-1} soil) was quantified in T8 treatment, which might be due to the presence of decomposition resistant fiber fractions (Majumder *et al*., 2008) [15]. The MBC is regarded as one of the most sensitive indicators of the sustainability of a management system (Gregorich *et al*. 1997) [9]. It is apparent from Table 5 that MBC is highly correlated with the soil organic matter the MBC increased with the increase in soil organic carbon. Integrated use of inorganic fertilizers and organic manure brings in more MBC in soil compared to exclusive inorganic fertilizer applications (Goyal *et al*. 1999) [7]. Both FDHA (58.5 µg fluorescein g^{-1} soil h^{-1} at 24 °C) and BSR (1.67 µg CO_2–C g^{-1}soil h^{-1} at 25 °C) were significantly higher in T8 treatment. Higher microbial activity, as determined by BSR and FDHA, in the T8 treatment shows that the soil microorganisms were rendered more active. Inorganic supplements exclusively may fulfill the demand for mineral nutrition but not the carbon for cell proliferation by the microorganisms. Similar improvement in microbial properties of soil with organic nutrition has been reported by Saini *et al.* (2005) [22] also. 100% NPK+ Vermicompost @ 2 t ha^{-1}+ PSB @ 8 kg ha^{-1} increased MBC as vermicompost supplied readily available organic matter in addition to increasing root biomass and root exudates due to greater crop growth (Goyal *et al*. 1993) [8]. A strong correlation existed between enzyme activity and bioavailability of soil carbon and nutrients (German *et al*., 2011) [6]. The potential metabolic activities of soil can go through the assay values of FDHA and BSR reflects the metabolic activity of soil. FDHA is a sensitive indicator of ecosystem activities; its disturbance reflects enzyme activities of soil (Tripathi *et al*., 2006) [30].

Table 4: Different soil parameters after harvest of wheat as influenced by different treatments (Pooled data of two years i.e., 2014-15 and 2015-16)

Treatment	O.C. (%)	MBC (µg g^{-1} soil)	BSR (µg CO_2–C g^{-1} soil h^{-1} at 25 °C)	FDHA(µg fluorescein g^{-1} soil h^{-1} at 24 °C)
T_1	0.474^{g*}	180.0^{h}	0.92^{h}	28.5^{g}
T_2	0.623^{d}	224.5^{e}	1.37^{e}	39.5^{e}
T_3	0.486^{e}	193.0^{f}	1.04^{f}	31.0^{f}
T_4	0.633^{c}	235.5^{d}	1.44^{d}	42.5^{d}
T_5	0.479^{ef}	188.0^{g}	0.97^{g}	30.0^{ef}
T_6	0.635^{c}	250.0^{c}	1.47^{c}	44.5^{c}
T_7	0.675^{b}	254.5^{b}	1.59^{b}	50.5^{b}
T_8	0.710^{a}	262.5^{a}	1.67^{a}	58.5^{a}
T_9	0.470^{g}	171.0^{i}	0.83^{i}	23.5^{b}

*Figures denoted by same alphabets are statically similar at 5% probability level by DMRT.

4. Conclusion

It is clearly concluded that there is a good scope of increasing crop yields through the use of integrated nutrient management. It is extremely important for sustaining rice-wheat system and improving the soil health. From the result, it is expected that rice and wheat yields can be maintained on recommended doses of NPK when used in conjunction with vermicompost and PSB. Treatment T8, [100% NPK+ Vermicompost @ 2 t/ha+ PSB @ 8 kg/ha (Soil application)], both in rice and wheat is the best one. So, we recommend it for higher productivity and maintenance of good soil health in rice-wheat cropping system in alluvial soil of Indo-Gangetic plains of India.

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