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Brajesh Kumar
Department of Agricultural Chemistry and Soil Science, Institute of Agricultural Science, University of Calcutta, Hazra Road, Kolkata, West Bengal, India

Sudipta Tripathi
Department of Agricultural Chemistry and Soil Science, Institute of Agricultural Science, University of Calcutta, Hazra Road, Kolkata, West Bengal, India

Abhijeet Sharma
SMS Agrometeorology, Krishi Vigyan Kendra, Jamui, Bihar, India

Correspondence
Abhijeet Sharma
SMS Agrometeorology, Krishi Vigyan Kendra, Jamui, Bihar, India

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Effect of integrated nutrient management on soil health and crop yield under rice–maize cropping system in alluvial soil of Bihar, India

Brajesh Kumar, Sudipta Tripathi and Abhijeet Sharma

Abstract
Integrated nutrient supply of inorganic and organic sources is of great importance for maintenance of soil health and crop productivity in intensive rice - maize cropping systems. 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 maize (Shakatiman-4 hybrid) as a *rabi* crop to investigate the influence of integrated nutrient management on soil health and yield of crops in rice-maize 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 two years pooled data, the highest grain yield (49.2 q/ha) in rice and (53.9 q/ha) in maize. The lowest grain yield was recorded in T_9 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 maize crop. The T_8 treatment comprising 100 % NPK+ Vermicompost @ 2 t/ha+ PSB @ 8 kg/ha (Soil application), both in rice and maize recommended for higher productivity and good soil health in rice – maize cropping system in Bihar.

Keywords: Integrated nutrient management, Microbial biomass, Soil respiration, Fluorescein diacetate hydrolyzing activity, Rice-maize cropping system.

Introduction
Rice-maize is most important cropping system after rice-wheat in Bihar (Anon. 2010) [1]. The Planning Commission of India has delineated country in 15 broad agro-climatic regions based on physiography and climate, and rice maize systems are prevalent in all agro-climatic regions, especially in the Indo-Gangetic Plain (Pandey *et al*. 2008) [12]. As maize cropping becomes more widespread and intensive, an emerging issue of great importance is how to sustain the productivity of rice-maize cropping systems through integrated soil fertility management strategies. Rice-maize systems extract large amounts of mineral nutrients from the soil due to large grain and stover yields. Proper nutrient management of exhaustive systems like rice-maize should aim to supply fertilizers adequate for the demand of the component crops and apply in ways that minimize loss and maximize the efficiency of use (Cassman *et al*. 1998) [4].
Recent reports on land use and soil of Indo-Gangetic Plains, indicate a general decline in soil fertility. Soil that previously had a high nutrient status is now found to be deficient in organic matter. In general cereal based cropping system, imbalance use of fertilizers and over-tilling that contribute a gradual reduction in organic matter (Gupta *et al*. 2003) [7]. Chemical fertilizers cannot be avoided completely since they are the potential source of high amount of nutrients in easily available forms. Most of the crops respond quickly to chemical fertilizers and give higher yield and maize is more responsive. But, continuous application of chemical fertilizers alone is not desirable as it has been reported to deteriorate soil health. At the same time, application of organic manures alone do not produce required yield due to their low nutrient status (Ravi *et al*. 2012) [16]. Efficacy of organic sources to meet the nutrient requirement of crop is not as assured as mineral fertilizers, but the joint use of chemical fertilizers along with various organic sources is capable of improving soil quality and higher

crop productivity on long-term basis. Highest productivity of crops in sustainable manner without deteriorating the soil and other natural resources could be achieved only by applying appropriate combination of different organic manures and inorganic fertilizers (Chandrashekara *et al*. 2000) [5].

Studies in rice-maize systems have indicated that combined inorganic and organic sources of nutrients are generally superior to the use of each component separately. With these considerations in mind, a field experiment was conducted in alluvial soil of southern east Bihar, India with objective to study the effect of integrated use of chemical fertilizers and organic sources on crop productivity and soil health in an irrigated rice-maize system.

Material and Methods

A field experiment was conducted during 2014-15 and 2015-16 at the Experimental Farm of the Krishi Vigyan Kendra, Khadigram, Jamui, Bihar ($24^0$97' N and $88^0$30' E). The soil was sandy loam in texture, bulk density (1.38 g/cc), low water holding capacity (28.4 %) with slightly acidic in soil reaction (pH 6.84) with non saline conductivity (0.18 dSm^{-1}). The organic carbon content was 0.488 % and the available nitrogen (N), available phosphorus (P), available potassium (K), microbial biomass carbon (MBC), basal soil respiration (BSR) and fluorescein diacetate hydrolizing activity (FDHA) status in initial soils were 251.6 kg ha^{-1}, 10.6 kg ha^{-1},133.6 kg ha^{-1}, 181 µg g^{-1}, 0.94 µg CO_2–C g^{-1}soil h^{-1} at 25 °C soil and 29.0 µg fluorescein g^{-1} soil h^{-1} at 24 °C respectively.

Soil samples from top 15 cm depth were collected from the experimental site before sowing of maize 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) [20] and water holding capacity was determined according to Piper (1950) [14]. 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) [9] and Vance *et al*. (1987) [21]. 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) [19].

Treatment detail

The experiment was conducted during *rabi* of 2014-15 and 2015-16 with maize as *rabi* crop and rice as a *kharif*, 2015 and 2016. The experiment plots of *rabi and kharif* season, comprised 9 treatments, each replicated five times with a plot size of 5.0 × 4.0 m^2 in randomized block design. The treatment details were as under:

Table 1: Treatment details of the experiment

Treatments	Maize	Rice
T_1:	Farmers' practice (100:80:0 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 @ kg ha^{-1} (Soil application)	T_1 + PSB @ kg ha^{-1} (Soil application)
T_4:	T_2 + PSB @ 8 kg/ha (Soil application)	T_2 + PSB @ kg ha^{-1} (Soil application)
T_5:	100 % NPK (120:75:50 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 @ kg ha^{-1} (Soil application)
T_9:	Control	Control

After the field preparation, Shakatiman-4 hybrid of maize, was sown at a spacing of 60x 25 cm between rows and plant respectively, using seed rate of 20 kg/ha, on 27 November, 2014 and 29 November, 2015 respectively. After the harvest of maize, plots were prepared for rice transplanting. 25 days old seedling of rice (cv. Rajendra mahsoori-1) was transplanted on 27 July, 2015 and 30 July, 2016 respectively in the plots with a spacing of 20 X 15 cm between rows and plants respectively.

Recommended package of practice was followed for crop cultivation during both the years. Yield and yield attribute data, namely cob length, grain weight cob^{-1}, tiller $hill^{-1}$, panicle m^{-2}, 1000 grain weight and grain yield were recorded.

The experimental data pertaining to each character were subjected to statistical analysis 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.

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.

Yield and yield parameters of maize and rice

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

Treatment	Cob length (cm)	Grain weight cob^{-1} (g)	100 grain weight (g)	Grain yield (q ha^{-1})
T_1	9.15^{f*}	41.55^{h}	19.15^{f}	36.00^{f}
T_2	9.45^{ef}	48.60^{f}	21.80^{d}	40.25^{e}
T_3	9.30^{ef}	45.30^{g}	20.25^{e}	39.05^{e}
T_4	9.55^{e}	54.50^{e}	22.10^{cd}	42.40^{d}
T_5	9.85^{d}	58.45^{d}	22.45^{bc}	44.40^{c}
T_6	10.15^{c}	62.70^{c}	23.00^{b}	46.05^{c}
T_7	10.70^{b}	65.50^{b}	23.50^{a}	50.80^{b}
T_8	11.25^{a}	68.30^{a}	23.95^{a}	53.90^{a}
T_9	7.35^{g}	30.65^{i}	17.25^{g}	22.20^{g}

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

The perusal of the data (Table 2) revealed that Application of vermicompost, phosphorus solubilizing bacteria in conjugation with chemical fertilizers resulted in higher cob length, Grain weight cob^{-1} and 100 grain weight were recorded in T_8 treatment and lowest in T_9 treatment. The highest yield (53.9 q/ha) was recorded with the T8 treatment and differ significantly with rest of treatments. The lowest grain yield (22.2 q/ha) was recorded in T_9 treatment. Panwar (2008) [13] reported positive effect of organic matter on intercropping with maize in mid hills of Meghalya.

Increase in available P with the addition of organics is might be due to enhanced activity of phosphorus solubilizing bacteria (PSB) in soil with appreciable quantity of organic matter in soil (Negassa *et al.* 2007) [11]. Karforma *et al.* (2012) [10] found the same result for maize in rain fed upland of tarai region of West Bengal. Sarwar *et al.* (2012) [18] reported that effect of organic matter on maize yield along with nutrition uptake of plants. From the results of the present study, it may be inferred that maize crop for higher yield needs to be inoculated with vermicompost, phosphorus solubilizing bacteria in conjunction with fertilizer nitrogen (recommended dose) for higher yield and soil quality.

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	24.8^{d*}	358.0^{f}	22.18^{g}	37.00^{g}
T_2	25.6^{cd}	371.5^{c}	23.04^{cd}	43.90^{b}
T_3	25.1^{cd}	362.0^{e}	22.41^{fg}	38.70^{f}
T_4	26.0^{bc}	379.0^{b}	23.27^{bc}	46.05^{c}
T_5	25.2^{cd}	364.8^{b}	22.73^{ef}	42.17^{d}
T_6	25.1^{cd}	370.0^{c}	22.84^{de}	43.75^{d}
T_7	26.7^{ab}	378.4^{b}	23.55^{ab}	47.68^{b}
T_8	27.0^{a}	389.0^{a}	23.89^{a}	49.21^{a}
T_9	21.8^{e}	353.0^{g}	21.52^{h}	29.19^{h}

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

A perusal of the data (Table 3) revealed that the integrated application of both organic and inorganic source of nutrient resulted in higher number of tiller $hill^{-1}$, Number of panicle m^{-2} and 1000 grain weight with the T_8 treatment and lowest in T_9 treatment. The highest grain yield (49.21 q/ha) was recorded with the T_8 treatment and differ significantly with rest of treatments. The lowest grain yield (29.19 q/ha) was recorded in T_9 treatment. 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) [3]. 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) [8] and Rani and Shrivastava (1997) [15] in rice.

Table 4: Organic carbon, MBC, BSR and FDHA in soil after harvest of maize 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	0.477^{g*}	182.0^{h}	1.00^{h}	30.5^{g}
T_2	0.626^{d}	226.0^{e}	1.40^{e}	41.5^{e}
T_3	0.490^{e}	195.0^{f}	1.11^{f}	33.0^{f}
T_4	0.636^{c}	237.5^{d}	1.48^{d}	45.0^{d}
T_5	0.482^{ef}	190.5^{g}	1.06^{g}	32.5^{fg}
T_6	0.638^{c}	253.0^{c}	1.53^{c}	47.0^{c}
T_7	0.678^{b}	257.0^{b}	1.60^{b}	53.0^{b}
T_8	0.714^{a}	265.5^{a}	1.67^{a}	60.5^{a}
T_9	0.472^{g}	175.5^{i}	0.89^{i}	25.5^{h}

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

3.2 Soil parameters after harvest of maize

The data (Table 5) showed that the highest organic carbon (0.714 %), MBC (265.5 µg g^{-1} soil), BSR (1.67 µg CO_2–C g^{-1}soil h^{-1} at 25 °C) and FDHA (60.5 µg fluorescein g^{-1} soil h^{-1} at 24 °C) were recorded in T_8 and all these differs significantly with rest of treatments. The lowest organic carbon (0.472 %), MBC (175.5 µg g^{-1} soil), BSR (0.89 µg CO_2–C g^{-1}soil h^{-1} at 25 °C) and FDHA (25.5 µg fluorescein g^{-1} soil h^{-1} at 24 °C) were recorded in T_9 treatment. Rao *et al.* (2010) [17] found the positive result to increase the soil productivity with the help of integrated nutrient management.

Conclusion

From the tow years experimentation it can be concluded that, application of 100 % NPK+ Vermicompost @ 2 t/ha+ PSB @ 8 kg/ha (Soil application) is the best combination of organic and inorganic fertilizers for increasing for increasing productivity of hybrid maize and rice with sustainability. This treatment is also responsible for improving soil health. So, we recommend it for higher productivity and maintenance of good soil health in rice-maize cropping system in alluvial soil of Bihar.

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