Int.J.Curr.Microbiol.App.Sci (2017) *6*(2): 185-194

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 2 (2017) pp. 185-194**
Journal homepage: http://www.ijcmas.com

Original Research Article http://dx.doi.org/10.20546/ijcmas.2017.602.025

Short-term Effects of Organic and Inorganic Fertilizers on Soil Properties and Enzyme Activities in Rice Production

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Keywords

Soil, Physico-chemical properties, Microbial biomass carbon, Enzyme activity, Rice.

Article Info

Accepted:
12 January 2017
Available Online:
10 February 2017

A B S T R A C T

A field study was carried out on Alluvial soils of Varanasi to analyse the short term impacts of replacing mineral by organic fertilizers on the physico-chemical properties and enzyme activities relevant for soil fertility and crop production. Three types of fertilization regimes were tested *viz.*, no fertilizer, conventional as 100% RDF by inorganic fertilizer and combined integrated fertilizer in which 70% RDF with 30% of the nitrogen were supplied by either FYM or pressmud or vermicompost or combination of these two or all. In the experiment, application of 70% recommended dose of fertilizers (RDF) + 30% N supplied through FYM and pressmud improved soil pH, organic carbon, cation exchange capacity, bulk density and water holding capacity of post harvest soil of rice. However, nutrient integrations with organic and inorganic sources had a non significant effect on electrical conductivity, CEC, BD and WHC of soil. Available N, P and K of soil were significantly affected by integrated nutrient treatments which showed up to 25.52, 54.85 and 29.87% increase of these nutrients over control, respectively. The DTPA extractable cationic micronutrients also increase significantly by combined application of organics and inorganic fertilizers. The highest microbial biomass carbon (218.2 µg g^{-1}), urease activity (221.9 µg urea g^{-1} h^{-1}), alkaline phosphatase (121.5 µg pNP g^{-1} h^{-1}) and dehydrogenase activity (44.5 µg TPF g^{-1} d^{-1}) recorded with treatment 70% RDF with 30% N by FYM and pressmud equally. The study reveals the effects of the organic amendments were observed even when they involved a small portion of the total amount of nutrients supplied; thereby confirming that some of the beneficial effects of integrated fertilizer strategies may occur in the short term in rice production and the promising combination was 70% of recommended NPK combined with FYM and pressmud on basis of 30% N by produced the best response.

Introduction

Fertile soils are a fundamental asset for a sustainable rice–wheat cropping systems followed in 13 Mha in the Indo-Gangetic plains (IGP). Managing practices for the rice–wheat cropping system are changing and in turn influencing soil fertility parameters (Singh and Singh, 2012).

For over a decade, rice–wheat cropping system yields in IGP have either stagnated or declined. The most important reason is a decline in factor productivity resulting from depletion of soil fertility. The system commonly shows signs of fatigue and is no longer exhibiting increased production with higher input use based on the current pattern.

Even with current generalized recommended rates of fertilization for this system, a negative balance of the primary nutrients exists (Shukla *et al.*, 2005). Rice is the staple food crop for more than 70% of Indian people and is the main crop during rainy season in IGP (Mahajan *et al.*, 2012). The practice of adopting a cereal–cereal cropping system on the same piece of land over years has led to soil fertility deterioration and questions are being raised about its sustainability (Singh *et al.*, 2015).

It has been realized from long-term fertilizer experiments that neither inorganic fertilizers nor organic manures alone can achieve sustainability in production, whereas integrated use of organics as well as inorganic fertilizers are essential to improve soil health and enhance productivity and input use efficiency which can sustain a highly intensive cropping system. The positive effect of judicious use of organic manure and inorganic fertilizers on productivity of crops and soil fertility has been reported by many workers (Baishya *et al.*, 2015; Singh *et al.*, 2015 and Kundu *et al.*, 2016)

Organic amendments such as recycling of agricultural wastes and application of organic manures have sustained crop production for several years before the introduction of inorganic fertilizers along with the entry of high yielding and fertilizer responsive cultivars that have largely replaced the traditional practices (Ramachandran and Biswas, 2016). However, there are many reports that the yield of crops are either stagnate or declined in recent years due to continuous application of mineral fertilizers alone (Sekhon *et al.*, 2009; Scotti *et al.*, 2015). The major reason behind this is the decline in soil organic carbon (SOC) which is considered as the most important factor in maintaining soil fertility and sustaining the productivity of agroecosystems (Su *et al.*, 2006). Sharma and Subehiya (2014) viewed that integrated use of organic manure and chemical fertilizers would be quite promising not only in providing greater stability in production, but also in maintaining better soil fertility. It is generally believed that combining organics with inorganic fertilizer will increase synchrony and reduce losses by converting inorganic N into organic forms. The application of organic manures influences the physical and chemical properties of soil and enhances the biological activities (Kharche *et al.*, 2013; Jat *et al.*, 2015). It is also positively correlated with soil porosity and enzymatic activity (Srinivas *et al.*, 2015).

Application of different organic manure in combination with chemical inorganic fertilizer to agricultural lands is a popular practice in crop production. However, little information is available on suitable combination of different organics with chemical fertilizer on the soil properties. Keeping in view above facts, the present investigation studies an integration of chemical fertilizer, organics *i.e.* FYM, pressmud, vermicompost and its influence on physico-chemical properties and enzyme activity in rhizospheric soil of rice in rice-wheat cropping system.

Materials and Methods

Study area

The present investigation conducted at Agricultural Research Farm, Banaras Hindu University, Varanasi during *kharif* season of 2013 using paddy as test crop. The experimental site was located between 25.14^0 to 25.33^0 N latitude and 82.56^0 to 83.03^0 E longitudes and falls in a semi arid to sub humid climate. The mean ambient temperature and relative humidity during the experiment ranged from 17.3 ^{0}C to 34.8 ^{0}C and 75% to 86%, respectively.

Characteristics of organic inputs

Three organic inputs used under study *viz.*, FYM, pressmud and vermicompost. The FYM had pH 7.42, EC 1.44 dS m^{-1}, organic carbon 22.8%, total N,P,K and S contents were 0.78, 0.36, 0.50 and 0.18%, respectively with C:N ratio 29.2:1. Vermicompost having pH 7.42, EC 1.26 dS m^{-1}, organic carbon 31.3%, total N, P, K and S contents were 1.41, 0.43, 0.63 and 0.42%, respectively with C:N ratio 22.2:1. Similarly pressmud had pH 7.56, EC 1.58 dS m^{-1}, organic carbon 35.0%, total N, P, K and S contents were 2.0, 1.78, 0.42 and 2.28%, respectively with C:N ratio 17.5:1.

Experimental design and treatment combination

The experiment was conducted in randomized block design in three replications with 9 treatments. The treatments consisted of different organics which applied on nitrogen basis and inorganic fertilizer *viz.*,T_1- Control (no fertilizer), T_2- 100% RDF (120:60:60), T_3- 70% RDF + 30% N by FYM, T_4- 70% RDF + 30% N by vermicompost (VC), T_5- 70% RDF + 30% N by pressmud (PM), T_6- 70% RDF + 15% N by FYM+15% VC, T_7 - 70% RDF + 15% N by VC+15% PM, T_8 - 70% RDF + 15% N by FYM+15% PM, T_9 - 70% RDF + 10% N by FYM+10%PM+10% VC. Organic manures were applied before 15 days of transplanting.

Soil analysis

Soil was sampled manually from all the plots at 0–15 cm using a tube auger. Five sub-samples per plot were taken and carefully mixed. Soil biological analyses were carried out on moist samples in triplicate and the results were expressed on a dry weight basis. The soil samples were collected after the harvest of rice crop. The soil samples were analyzed for pH in 1:2.5 soil: water suspension; bulk density and water holding capacity (Black, 1965), organic carbon by methods of Walkley and Black (1934); available N by alkaline potassium permanganate (Subbiah and Asija, 1956); $NaHCO_3$ extractable-P (Olsen *et al.*, 1954) by spectrophotometer, ammonium acetate extractable K (Hanway and Heidel, 1952) by flame photometer and 0.15% $CaCl_2$ extractable S by developing turbidity using $BaSO_4$ (Chesnin and Yien, 1950) and DTPA extractable Fe, Cu, Mn and Zn (Lindsay and Norwell, 1978) by atomic absorption spectrophotometer following the procedure outlined in Sparks (1996). The microbial biomass carbon of the soil was determined using the fumigation–extraction method of Vance *et al.,* (1987). The levels of three enzymatic activities in soil were measured, urease activity by KCl-PMA solution (Douglas and Bremner, 1971), alkaline phosphatese activity by p-nitrophenyl phosphate (Tabatabai and Bremner, 1969) and dehydrogenase enzyme activity of soil by triphenyl tetrazolium chloride reduction method as described by Casida *et al.,* (1964). The soil fertility dynamics of experimental field was estimated by soil analysis of composite soil sample from each plot before transplanting and after harvesting of crop. The soil of the experimental site was moderately alkaline in reaction with pH 8.4, electrical conductivity (0.23 dSm^{-1}) medium in organic carbon 0.39%, deficient in available nitrogen (205.7 kg ha^{-1}) medium in available P (29.36 kg ha^{-1}) and medium in K (184.65 kg ha^{-1}), medium in available S (11.45 mg kg^{-1}), and DTPA- extractable Fe, Cu, Mn and Zn was 35.53, 2.31, 9.42 and 1.41 mg kg^{-1}, respectively.

Statistical analysis

The data were subjected to one-way analysis of variance (ANOVA) using SPSS version 16 software. Duncan's multiple range test (DMRT) was performed to test the significance of difference between the treatments.

Results and Discussion

Physico-chemical properties of soil

Both soil pH and EC values varied significantly among various treatments (Table 1). There was decrease in soil pH in all the treatments when compared to the initial values (8.40), where as EC values have increased from 0.23 (initial value) to 0.31 dSm^{-1} with treatment T_8, however there was no significant difference among treatments. The values were fluctuating among the treatments which might be because of the dissolved salts contribution from soil, water and release of ionic species due to reduction process as reported by Sur *et al.,* (2010). It was observed that the application of pressmud were found more effective than application of FYM in reducing soil pH and contributed more salts to increase EC in the soil after the harvest of rice and wheat (Singh *et al.*, 2015). More availability of soluble forms of K, Ca, Mg and Na those lead to formation of some salts due to addition of organics, which might be responsible for the higher EC of the soil after harvest of the rice crop (Gogoi *et al.,* 2015).

Organic carbon content has increased from 0.39 to 0.48 % over initial level and from 0.36 per cent to 0.48 % over control over the years in the treatments with organic sources of nutrients in addition to inorganic fertilizers (Table 1). The increase in organic carbon content in treatments with combination of both organic and inorganic sources may be attributed to higher biomass addition to soil through crop residues as per the observation of Sur *et al.,* (2010). Lowering of organic carbon content of soil was common in control and in treatments with only inorganic fertilizers (Katkar *et al.,* 2012). This type of lowering of organic carbon content of soil may be due to its rapid mineralization resulting from intensive cropping and also as a result of attaining stable equilibrium with the changing soil crop environment (Singh *et al.,* 2008).

The results of the investigation showed that the cation exchange capacity (CEC) of the soil increased significantly over the control due to the application of organic manures in combination with chemical fertilizers. The higher value (10.17 Cmol (p^+) kg^{-1}) of CEC observed in with treatment T_8. Soil organic matter and clay particles have large surface areas and have a large number of exchange sites. As a consequence of the application of organic amendments, which increase organic C stock and result is soil cation exchange capacity (CEC) increases (Scotti *et al.,* 2015).

The bulk density (BD) and water holding capacity (WHC) not significantly affected by application of NPK + organics, however lowest value of BD (1.35 Mg m^{-3}) and higher WHC (42.80%) was recorded with treatment T_3 in which 70% NPK + 30% N through FYM were applied and lowest recorded with untreated control (1.35 Mg m^{-3} and 40.10%, respectively). This can be ascribed to addition of higher organic matter through farmyard manure as compared to pressmud and vermicompost and increase in root biomass which helped in growth and development of soil microorganisms causing beneficial effect on improvement in mean weight diameter, available water capacity and hydraulic conductivity (Katkar *et al.,* 2012).

The amount of available N content in soil gradually increased over the initial amount (205.7 kg ha^{-1}) at the harvest of crop irrespective of treatments (Table 2). The highest amount (251.9 kg ha^{-1}) of available N was recorded in the treatment where 70% recommended levels of NPK along with 15% N by FYM and rest 15% by pressmud (T_8) was applied which might be partly due to application of organic matter and fertilizer releasing nitrogen from mineralization (Gogoi *et al.,* 2015) and partly due to releasing of native soil nitrogen. It might be due to the direct addition of N from the decomposition of organic matter leads to mineralization of organically bound nitrogen. The result was in agreement with the findings of many researchers (Chesti *et al.,* 2013; Baishya *et al.,* 2015).

The amount of available P and K in soil was varied between 24.14 to 37.38 and 143.2 to 186.0 kg ha^{-1}, respectively. The amount of both P and K were the highest in the treatment getting 70% RDF with 30% N by FYM and press mud equally (T_8). Such increase in P and K in soil might be explained by the release of P from the applied organic matter after mineralization and K due to releasing from organics and K bearing minerals that already present in alluvial soil. The higher value of available phosphorus was recorded in pressmud treated plots, which might be because pressmud is a rich source of phosphorus. Increasing soil available P with pressmud application in sugarcane was reported by Lakshmi *et al.,* (2011). Singh *et al.,* (2015) reported that organics were superior in improving available P. It might be due solubilizing effect of organic acids on organic phosphorus and organic anions retard the fixation of P in by complexing with organic ligands and chelation of P fixing cations like Ca, Mg, Fe, Al, Zn, Mn and Cu. Phosphorus complex with humic and fulvic acids increase the availability of phosphorus to the plants. However, in the present investigation there was a decline in available K content of soil from the initial value in all treatments except T_6 and T_8. This might be due to a gap between the removal and supplementation of K into the soil. Insufficient addition of K through fertilizers, pressmud and vermicompost, and consequently higher removal by crops might be the possible reason of decrease in K availability in soil (Gogoi *et al.,* 2015). The treatment T_6 and T_8 showed higher in available potassium than initial value. Such favourable effect of integrated nutrient management on increasing the available potassium content in soil were noticed by Baishya *et al.,* 2015; Mondal *et al.,* 2016. Similarly, available S in post harvest soil of rice also improved significantly from their initial value (11.45 mg kg^{-1}) with integration of nutrient through organics and chemical fertilizer. The highest value (16.0 mg kg^{-1}) of sulphur was recorded in T_8. Build up of available S could be justified as a result of mineralization of organic source that contributed to accumulation of more amount of S in soil and also through microbiological oxidation (Gogoi *et al.,* 2015).

The amount of DTPA- extractable Fe, Mn, Cu and Zn content (Table 3) in soil did not followed similar trend changes to that of available N and P content in soil. The highest Fe content (42.90 mg kg^{-1}) was recorded in T_3. The Fe content was found to be higher in the treatments receiving fertilizers with FYM. It may be due to FYM has a good source of Fe as compared to other studied organics. Similar result was also reported by Hemalatha and Chellamuthu (2013). The higher Cu content (2.49 mg kg^{-1}) recorded with T_2 and in most of integrated treatments it was reduced from initial value (2.31 mg kg^{-1}). The reduction was comparatively higher under FYM treatments. This might be due to the inverse relation of organic matter and Cu in soil (Singh *et al.,* 2015). The highest Mn (12.06 mg kg^{-1}) with treatment T_8. It may be due to the chelation of native Mn by organic matter (Hemalatha and Chellamuthu, 2013). The Zn content (2.19 mg kg^{-1}) highest in treatment T_5. Pressmud application increased the Zn availability after harvest of rice. The pressmud contains good amount of Zn and the effect of organic acids might help in increasing available Zn status (Singh *et al.*, 2015).

Microbial biomass carbon and enzyme activities

Microbial biomass carbon (MBC) varied from ~ 149 to 218 µg g^{-1}, with the highest value recorded under the 70% NPK + 15% N by FYM and rest 15% by pressmud (T_8) treatment and the least in the control plots (Table 4). The treatment in which 100% NPK (T_2) were applied which recorded significantly lower (154 µg g^{-1}) MBC as compared to T_8 treatment.

Table.1 Effect of combined application of organics and chemical fertilizer on physico-chemical properties of soil

Treatments	pH	EC (dS m^{-1})	OC (%)	CEC [Cmol (p^+) kg^{-1}]	BD (Mg m^{-3})	WHC (%)
T_1	8.32a	0.19b	0.36b	7.09c	1.39a	40.10a
T_2	8.26ab	0.21ab	0.39b	8.14abc	1.38a	40.88a
T_3	8.15abc	0.24ab	0.46ab	8.60abc	1.35a	42.80a
T_4	8.20ab	0.20ab	0.41ab	7.44bc	1.38a	42.48a
T_5	7.93c	0.26ab	0.43ab	9.29abc	1.38a	42.62a
T_6	8.12abc	0.25ab	0.44ab	9.05abc	1.36a	41.64a
T_7	8.03bc	0.31ab	0.45ab	9.91ab	1.37a	42.15a
T_8	8.01bc	0.32a	0.48a	10.17a	1.36a	42.30a
T_9	8.05bc	0.29ab	0.46ab	9.72ab	1.37a	42.23a

Means followed by same letter in each column are not significantly different by the Tukey HSD test ($P<0.05$).

Table.2 Effect of combined application of organics and chemical fertilizer on available macro nutrient status of soil

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (mg kg^{-1})
T_1	200.7d	24.14d	143.2d	10.59e
T_2	219.1c	30.26c	164.3c	11.36e
T_3	210.1c	29.46c	159.8c	12.76d
T_4	216.4c	29.63c	165.0c	13.23cd
T_5	231.0b	35.07ab	161.1c	16.58a
T_6	230.0b	31.95bc	189.9a	14.40bc
T_7	245.7a	35.68a	176.8b	16.00a
T_8	251.9a	37.38a	186.0ab	15.42ab
T_9	244.6a	34.75ab	181.7ab	14.63b

Means followed by same letter in each column are not significantly different by the Tukey HSD test ($P<0.05$).

Table.3 Effect of combined application of organics and chemical fertilizer on DTPA- extractable micronutrient status of soil

Treatments	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})
T_1	22.97f	1.65de	7.12d	1.01c
T_2	33.53e	2.49a	8.41cd	1.41bc
T_3	42.90a	1.33e	9.74bc	2.06ab
T_4	36.11de	1.60e	8.52cd	2.04ab
T_5	36.44de	1.98cd	10.21b	2.19a
T_6	38.41bcd	2.09bc	9.88bc	1.92ab
T_7	36.85cde	2.47a	10.57ab	1.82ab
T_8	41.12ab	2.35ab	12.06a	1.84ab
T_9	40.39abc	1.41e	10.59ab	1.40bc

Means followed by same letter in each column are not significantly different by the Tukey HSD test ($P<0.05$).

Table.4 Effect of combined application of organics and chemical fertilizer on microbial biomass carbon and selected enzyme activities of soil

Treatments	MBC (µg g^{-1})	Urease (µg urea g^{-1} h^{-1})	Phosphatase (µg pNP g^{-1} h^{-1})	Dehydrogenase (µg TPF g^{-1} d^{-1})
T_1	149.3e	169.8d	81.83b	27.07b
T_2	154.0de	179.4cd	102.3ab	28.60b
T_3	167.8cde	189.8bcd	105.0a	38.07a
T_4	159.5de	182.9cd	105.0a	28.79b
T_5	177.3cd	200.0abc	116.2a	38.82a
T_6	188.9bc	196.5bc	108.5a	38.31a
T_7	209.6ab	214.0ab	116.5a	44.51a
T_8	218.2a	221.9a	121.5a	43.31a
T_9	200.8ab	210.1ab	112.8a	42.83a

Means followed by same letter in each column are not significantly different by the Tukey HSD test ($P<0.05$).

Increased microbial biomass carbon content recorded in the organically treated plots might be due to suitable conditions for microbial growth where, development had acted as a good substratum for microbial activity. An increase in microbial population by integrated use of FYM and inorganic fertilizer in a rice-wheat system as compared to inorganic fertilizer alone was reported by Biswas *et al.*, 2007 and Kundu *et al.*, 2016 and in soybean by Heidari *et al.*, 2016. All soil enzymatic activities responded to the organic matter applied, but the response differed with dehydrogenase (Table 4). Compared with the 100% NPK (T_2) and untreated control (T_1) treatments, the organics treated soils showed higher activities of urease, alkaline phosphatase and dehydrogenase. The significantly highest activity of urease (221.9 μg urea g^{-1} h^{-1}) reported with treatment T_8, it was 23.7 higher over sole application of 100% NPK (T_2). Significantly lowest value (169.8 μg urea g^{-1} h^{-1}) of urease enzyme activity noticed with unfertilized control. Urease activity of soil was found higher when recommended dose of NPK fertilizers were applied as compared to unfertilized control. It may be due to increase in activity of urease with addition of urea-N (Mishra *et al.*, 2008). Urease activity was found to be increased with application of organic manures in combination with chemical fertilizers over application of chemical fertilizers alone as reported in several studies (Meena *et al.*, 2014 and Lakshmi *et al.*, 2014). Furthermore, the results of present study is consistent with the findings of Heidari *et al.*, (2016) who indicated that organic manure had a positive effect on urease activity.

The highest activity of alkaline phosphatase (121.5 μg pNP g^{-1} h^{-1}) reported with treatment T_8, it was reported 18.8% higher over sole application of 100% NPK (T_2). In alkaline phosphatase activity all integrated treatment reported statistically similar to each other. Chemical fertilizers suppressed the acid and alkaline phosphatase activity which can be explained through considering the fact that phosphatase synthesis is inhibited by available phosphorus (Wang *et al.*, 2008). This increase in activity may be due to the release of more organically bound P due to faster decomposition of organic matter in presence of mineral N and P which stimulate the synthesis of the enzyme (Mohammadi *et al.*, 2012). Dehydrogenase activity recorded higher (44.51 μg TPF g^{-1} d^{-1}) with treatment T_7, closely followed by T_8 and T_9. However, in dehydrogenase activity the difference between integrated treatments was found nonsignificant. This might be due to the reason that sources of potential beneficial microbes in organic manures may possibly provide microbial diversity and activity of microorganisms accompanied by better dehydrogenase activity (Simon and Czako, 2014).

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How to cite this article:

Jat, L.K., and Singh, Y.V. 2017. Short-term Effects of Organic and Inorganic Fertilizers on Soil Properties and Enzyme Activities in Rice Production. *Int.J.Curr.Microbiol.App.Sci.* 6(2): 185-194. doi: http://dx.doi.org/10.20546/ijcmas.2017.602.025