Soil organic and enzymatic properties as influenced by green manuring and establishment methods in rice-rice system

Abstract

The field study was conducted during *kharif* and *rabi* seasons of 2016-17, 2017-18 and 2018-19 to evaluate the effect of green manuring and establishment methods on growth parameters of rice-rice system. The experimental site was sandy loam in texture, slightly acidic in reaction, low in available N (198 kg/ha), medium in available P (18 kg/ha), K (193 kg/ha), OC (0.51%) with EC (0.20 dS/m). The rice variety "Swarna sub-I" and "Lalat" were grown in *kharif* and *rabi* seasons, respectively. The experiment was designed with two groups of treatments, one without green manuring and the other with green manuring with *Sesbania* in main plot along with nine establishment methods *i.e*PTR-PTR, PTR-NPTR, PTR-DSR, NPTR-PTR, NPTR-NPTR, NPTR-DSR, DSR-PTR, DSR-NPTR, DSR-DSR as sub plots in *kharif* and *rabi* seasons. From the above experiment, it is observed that the soil organic carbon in green manured plots were superior with respect to soil biological properties as it realized highersoil organic carbon (0.51%), microbial biomass carbon (246.29µg C/g soil), microbial biomass nitrogen (83.5µg N/g soil). The enzymatic activities of the soil were also enhanced with green manuring recording higher dehydrogenase and phosphatase activityof 226.40 mg TPF/g soil/24 hrs and352.81 mg p-nitrophenol/kg soil/1hr respectively, at 0-15 cmafter 3 years of rice-rice system. Among the establishment methods, DSR-DSR method of establishment recorded higher soil organic carbon, microbial biomass carbon and microbial biomass nitrogen of 0.58%, 251.33µg C/g soil and 89.36 µg N/g soil respectively. Similarly, the Dehydrogenase and Alkaline phosphatase activities were also enhanced under DSR-DSR method of establishment recording 242.60 mg TPF/g soil/24 hrs and 381.90 mg p-nitrophenol/kg soil/1hr respectively, after 3 years of rice-rice system.

Introduction

Rice (*Oryza sativa* L.) is one of the major staple foodgrain for more than 50% of the world's population providing major source of the food energy. Rice is the most important food crop of India with a production of 118.4 MT with an acreage of 43.8 million ha (Directorate of Economics & Statistics, GoI, 2019-20). *Kharif* and r*abi* rice accounts for 89% and 11% of total rice area and 85% and 15% of total rice production, respectively. Rainfed lowlands constitutes about 17.4 million ha, of which 14.6 million ha are in eastern India. (Singh*et al.*, 2015). The option of intensifying the area under rice in the near future is limited. Consequently, this extra rice production needed has to come from a productivity gain. The productivity and sustainability of rice-based systems are threatened

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Please mention the place of the experiment.

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....low in available nitrogen (N) (198 kg/ha), medium in available phosphorus (P) (18 kg/ha), potassium (K) (193 kg/ha), organic carbon (OC) (0.51%) with electrical conductivity (EC) (0.20 dS/m).

Comment [E3]: The rice varieties 'Swarna sub-I' and 'Lalat' were...

Comment [E4]: .....with *Sesbania* in main ....
Please specify *Sesbania* sp. or the specie used.

Comment [E5]: PTR-PTR, ...
Please explain the abbreviations.

Comment [E6]: TPF?
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Comment [E7]: Similarly, the dehydrogenase and alkaline phosphatase activities.......

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References must be listed at the end of the manuscript and numbered in the order that they appear in the text. Every reference referred in the text must also present in the reference list and vice versa. In the text, citations should be indicated by the reference number in brackets [1].

Singh et al., 2015......in fact ....[1] will be 1. at the Reference section.

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because of (1) inefficient use of inputs (fertilizer, water, labour); (2) increasing scarcity of resources, especially water and labour; (3) changing climate; (4) the emerging energy crisis and rising fuel prices; (5) rising

cost of cultivation; and (6) emerging socioeconomic changes such as urbanization, labour migration, preference to non-agricultural work and concerns about farm-related pollution (Ladha *et al.*, 2009). Resource-conservation technologies (RCTs) such as DSR and non-puddled transplanting (NPTR) have been shown to be beneficial in terms of improving soil health, water use, crop productivity and farmers' income (Gupta and Sayre, 2007; Singh *et al.*, 2009). Direct Seeded Rice (DSR) is the long-standing common technique practiced in many parts of the world, by broadcasting seeds directly on dry or puddled soils, dropping seeds in moist soil behind country plough or manual seeding. DSR helps farmers to earn more carbon credits than transplanted rice (TPR) by mitigating methane emission and has higher economic returns, saves water and reduces labour requirement. Continuous cultivation of rice is lowering soil fertility and organic matter, depleting ground water resources and exacerbating weed, diseases and pest problems. Introduction of a legume green manure crop in cropping system has the obvious advantages well beyond the N addition through BNF including nutrient recycling from deeper soil layers, minimizing soil compaction, increase in soil organic matter, breaking of weed and pest cycles and minimizing harmful allelopathic effects. *Sesbania* is a legume used as a green manure crop in rice cultivation either as pre- rice or inter- or mixed crop with rice (Singh *et al.*,2009b). It also facilitates atmospheric nitrogen fixation and facilitation of crop emergence in areas where soil crust formation is a problem (Singh *et al.*, 2009b). The interest in the use of green manures in the rice-based cropping system has developed a solution for sound ecosystem and sustainable rice production. Soils in the rice tract are found slightly alkaline in nature. Green manuring reduces soil pH, improves soil fertility, soil structure, porosity, water holding capacity and partially reduces the need of nitrogen fertilizer for rice crop. Considering the above benefits pertaining to green manuring and appropriate crop establishment methods which may play a vital role in improving growth and productivity of rice-rice system.

Materials and methods

The fieldstudy was conducted during *kharif*and *rabi* seasons of 2016-17, 2017-18 and 2018-19 to evaluate the effect of green manuring and establishment methods on growth parameters of rice-rice system. The experimental site was sandy loam in texture, slightly acidic in reaction, low in available N (198 kg/ha), medium in available P (18 kg/ha), K (193 kg/ha), OC (0.51%) with EC (0.20 dS/m). The rice variety "Swarna sub-I" and "Lalat" were grown in *kharif* and *rabi* seasons, respectively. The experiment was designed with two groups of treatments, one without green manuring and the other with green manuring with *Sesbania*in main plot along with nine establishment methods *i.e* PTR-PTR, PTR-NPTR, PTR-DSR, NPTR-PTR, NPTR-NPTR, NPTR-DSR, DSR-PTR, DSR-NPTR, DSR-DSR as sub plots in *kharif* and *rabi*seasons.

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DSR is the long-standing common ....

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Comment [E15]: ....beyond the nitrogen (N) addition.......
Please also explain .....BNF abbreviation.

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2.1. Experimental site
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2.5. Statistical analysis
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Comment [E18]: MATERIALS AND METHODS

Comment [E19]: ....low in available nitrogen (N) (198 kg/ha), medium in available phosphorus (P) (18 kg/ha), potassium (K) (193 kg/ha), organic carbon (OC) (0.51%) with electrical conductivity (EC) (0.20 dS/m).

Comment [E20]: The rice varieties 'Swarna sub-I' and 'Lalat' ....

Comment [E21]: ...with *Sesbania* ...??
Sesbania sp.? or which *Sesbania* specie?

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Statistical analysis is also recommended.

Results and discussions

A critical study of the data revealed that, the mean soil organic carbon in upper layer of soil (0-15 cm) was 0.50 %. Further, plots with green manuring recorded significantly higher soil organic carbon after 3 years of rice-rice system (0.51%) as compared to the plots without green manuring (0.48%).With green manuring the rise in organic carbon was 6.3% at 0-15 cmas compared to without green manuring. The increase in soil organic carbon might be due to the continuous addition and incorporation of green manure into the soil which upon decomposition increased the soil organic carbon at different depths(Udgata*et al.*, 2020). Combination of green manure along with chemical fertilizer recorded an increase in microbial population over the plots without green manuring respectively. The increasemay be because of higher soil microbial activity by application of green manure as source of carbon and energy in soil for microbes(Gadad*et al.*, 2018). Further, the microbial biomass carbon content increased significantly with green manuring which recorded higher microbial biomass carbon (246.29 µg C/g soil) as compared to the plots without green manuring (243.83 µg C/g soil). The microbial biomass nitrogen increased significantly with green manuring which recorded higher microbial biomass nitrogen (83.50 µg N/g soil) as compared to the plots without green manuring (74.10 µg N/g soil). The green manured plots registered 1.1 and 12.6 % increase in MBC and MBN content, respectively as compared to the plots without green manuring. This increasemight be due to the application of more hydrolysable carbon which accelerated microbial activity, dehydrogenase activity and more humic acid formation in these conditions(Roy *et al.*, 2017). Again, dehydrogenase activity increased significantly with green manuring which recorded higher dehydrogenase activity in soil (226.40 mg TPF/g soil/24 hrs) as compared to the plots without green manuring (210.90 mg TPF/g soil/24 hrs). Phosphatase activity in soil increased significantly with green manuring which recorded higher phosphatase activity of 352.81 mg p-nitrophenol/kg soil/1hr as compared to the plots without green manuring (329.60 mg p-nitrophenol/kg soil/1hr). Higher dehydrogenase and phosphatase activity was found under green manuring. The green manured plots registered 7.3 and 7.0 % increase in dehydrogenase and phosphatase activity respectively, as compared to the plots without green manuring. This might be due to higher P content of soil in organic (green manure) treated plot. Organic source of nutrient along with inorganic fertilizer stimulated the activity of microorganisms to utilize the native pool of organic carbon, which acts as substrate for microbial activity thus their activity improved (Bedi *et al.*, 2009).

Comment [E23]: RESULTS AND DISCUSSIONS

Comment [E24]: The obtained results are shown in Table 1.

Comment [E25]: .....the microbial biomass carbon (MBC) content ...

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The establishment methods had a distinct effect on the soil organic carbon and biological indices of the soil. A higher soil organic carbon was recorded under DSR-DSR method (0.58%) after 3 years of rice-rice system which was comparable with DSR-NPTR (0.57%) and NPTR-DSR methods (0.56%). The rise in soil organic carbon was 38.0%compared to the PTR-PTR. This might be due to the higher plant root biomass decomposition which increased the soil organic carbon at different depths. Moreover, the soil compaction in DSR-DSR system was less leading to better microbial environment and decomposition which in turn increased the soil organic carbon at different depths of the soil(Mahajan *et al.*, 2013).A soil higher microbial biomass carbon was recorded under DSR-DSR method (251.33 µg C/g soil) which remained at par with DSR-NPTR (250.00 µg C/g soil) but was significantly higher than other establishment methods. Similarly, higher microbial biomass nitrogen was also recorded under DSR-DSR method (89.36 µg N/g soil). The DSR-DSR method registered 5.5 and 44.0% increase in MBC and MBN content as compared to the PTR-PTR method. This might be due to the higher organic carbon concentration and hydrolysable carbon which accelerated microbial activity, dehydrogenase activity and more humic acid formation in these conditions (Ladha *et al.*, 2009).Higher dehydrogenase activity in soil was recorded under DSR-DSR (242.60 mg TPF/g soil/24 hrs) which was comparable with DSR-NPTR method (239.64 mg TPF/g soil/24 hrs). Similarly, higher phosphatase activity was recorded under DSR-DSR method (381.90 mg p-nitrophenol/kg soil/1hr) which was at par with DSR-NPTR (380.60 mg p-nitrophenol/kg soil/1hr) and NPTR-DSR methods (378.80 mg p-nitrophenol/kg soil/1hr). The DSR-DSR method of establishment registered 30.0 and 33.5% increase in dehydrogenase and phosphatase activities respectively, as compared to the PTR-PTR method. This might be due to better soil physical conditions available under DSR which stimulated the activity of microorganisms to utilize the native pool of organic carbon, which acts as substrate for microbial activity thus their activity improved (Mahajan *et al.*, 2013).

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Table 1.Soil organic carbon and microbial properties of rice-rice system as influenced by different establishment methods and green manuring after three years of rice-rice system (Pooled data of three years)

Treatment	**Soil Organic Carbon (%)**	**MBC (µg C/g soil)**	**MBN (µg N/g soil)**	**DHA (mg TPF/g soil/24 hrs)**	**APA (mg p-nitrophenol/kg soil/1hr)**
Green manuring					
Without G M	0.48	243.83	74.10	210.90	329.60
With GM	0.51	246.29	83.50	226.40	352.81
SE±(m)	0.008	0.272	0.699	0.786	0.951
CD (0.05)	0.03	0.94	2.41	2.71	3.28
Establishment methods					
PTR-PTR	0.42	238.29	62.05	186.63	286.15
PTR-NPTR	0.42	239.82	64.33	195.35	293.42
PTR-DSR	0.43	242.05	75.72	195.36	306.45
NPTR-PTR	0.46	244.06	78.65	220.18	324.38
NPTR-NPTR	0.51	245.71	85.20	230.86	375.24
NPTR-DSR	0.56	249.92	85.94	231.63	378.80
DSR-PTR	0.50	244.35	81.74	225.60	345.25
DSR-NPTR	0.57	250.00	86.21	239.64	380.60
DSR-DSR	0.58	251.33	89.36	242.60	381.90
SE±(m)	0.024	0.455	0.924	1.532	1.349
CD(0.05)	0.07	1.37	2.78	4.61	4.06
Initial	**0.38**	**243.25**	**65.71**	**184.36**	**282.95**

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