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Productivity and resource use efficiency as influenced by green manuring and establishment methods in rice-rice system

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Abstract
The field study was conducted during the *kharif* and *rabi* seasons of 2016-17, 2017-18 and 2018-19 to evaluate the effect of green manuring and establishment methods on the growth parameters of the 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 the 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 subplots in *kharif* and *rabi* seasons. From the above experiment, it is observed that green manuring recorded higher grain yield of 9211 kg/ha, recovering higher N from the soil (163.9 kg/ha) while, registering higher internal nitrogen use efficiency of 56.0 kg/kg and irrigation water productivity of 0.52 kg/m^3. Among the different establishment systems, NPTR-PTR method was found to be superior with a yield of 11337 kg/ha, nitrogen uptake of 186.8 kg/ha, internal nitrogen uses efficiency of 60.7 kg/kg and irrigation water productivity of 0.67 kg/m^3.

Keywords: Green manuring, establishment methods, 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 constitute about 17.4 million ha, of which 14.6 million ha are in eastern India. (Singh *et al.*, 2015) [9]. 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 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) [6]. 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) [5, 10]. 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) [11]. It also facilitates atmospheric nitrogen fixation and facilitation of crop emergence in areas where soil crust formation is a problem (Singh *et al*., 2009b) [11]. 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.

Results and Discussions

The grain yield of rice-rice system increased significantly with green manuring (9211 kg/ha), which was 4.7% higher than the crop without green manuring (8798 kg/ha). Again, the same trend was evident in case of the straw yield with an advantage of 5.2%. This might be due to increased availability of plant nutrients from soil due to combined application of organic green manure with inorganic fertilizers which maintained favourable physical, chemical and biological environment that was ultimately reflected in increasing the growth thereby enhancing the accumulation and translocation of photosynthates to the sink to boost the yield parameters and yield. (Udgata *et al*., 2020) [13]. Similarly, among the establishment methods, the straw yield ranged from 8615 kg/ha to 13961 kg/ha. The maximum straw yield was recorded under NPTR-PTR method (13961 kg/ha) which was significantly higher than other establishment methods. The straw yield recorded under PTR-DSR and DSR-NPTR methods were comparable. The DSR-DSR method (8615 kg/ha) recorded the lowest straw yield. This could be possibly due to better growth and higher photosynthates which produced higher number of effective tillers, total grains, filled grains per panicle and test weight. Heavy infestation of weeds in DSR method of establishment might have competed with crop for nutrients and water and declined the yield of rice (Fukai, 2002) [4]. Less weed infestation and leaching loss of nutrients and water due to puddled soil under NPTR-PTR method (Chander and Pandey, 1997) [2], increases their availability to crops improving the yield (Choudhary *et al*., 2016) [3]. The nutrient uptake by the system was markedly increased by green manuring recording 3.5% higher uptake of N than the crop without green manuring, respectively. It might be due to addition of organic matter which resulted in the enhanced availability of nutrients and higher dry matter production as well as nutrient concentration that improved uptake (Udgata *et al.*, 2020) [13]. Higher N uptake with integrated use of green manure with chemical fertilizers might be due to balanced and longer release of N as a result of decomposition of succulent legume crop. Addition of organic matter resulted in the enhanced availability of nutrients and higher drymatter production as well as nutrient concentration that improved its uptake (Prasad, 2004) [8]. On the other hand, the crop under NPTR-PTR method removed the maximum quantity of N in both grain and straw and the lowest nutrient uptake was with DSR-DSR method. This might be due to higher biomass accumulation as compared to other establishment methods which leads to higher nutrient uptake under NPTR-PTR method even if the content was low (Anbumani *et al*., 2004) [1]. The NPTR-PTR system recorded the highest nutrient uptake of 186.8 kg N /ha, respectively which was 45.1% higher than that under DSR-DSR method. It might be because of higher grain and straw yields under NPTR-PTR method of establishment (Chander and Pandey 1997) [2]. Higher system internal nitrogen use efficiency of 56.0 kg/kg was recorded by crop with pre-*kharif* green manuring as compared to the crop without green manuring (55.3 kg/kg). Similarly, among the establishment methods, the NPTR-PTR method recorded significantly higher system internal nitrogen use efficiency of 60.7 kg/kg which was at par with PTR-PTR (59.5 kg/kg) but significantly higher than other establishment methods. It might be due to addition of organic matter which resulted in the enhanced availability of nutrients and higher dry matter production as well as nutrient concentration that improved uptake (Udgata *et al.*, 2020) [13]. Higher N uptake with integrated use of green manure with chemical fertilizers might be due to balanced and longer release of N as a result of decomposition of succulent legume crop. Addition of organic matter resulted in the enhanced availability of nutrients and higher dry matter production as well as nutrient concentration that improved its uptake (Prasad, 2005) [8]. The water use was higher in green manured plots (17961 m^3) as compared to the plots without green manuring. Again, the irrigation water productivity improved by 4.1% to 0.51 kg/m^3 with green manuring due to the incremental yield of the green manured crop. Water productivity is the amount of economic yield produced per unit quantity of water used. The highest water productivity was obtained under NPTR-PTR method (0.67 kg/m^3) as compared to 0.32 kg/m^3 in DSR-DSR method. The land preparation was reduced in direct seeded rice as compared to transplanted rice which led to a significant reduction in irrigation and total water input. However, during the crop growth period in the main field, PTR had a shorter crop growth duration and total water input than DSR. Although the quantity of water used in NPTR-PTR method was higher than the PTR-NPTR, NPTR-NPTR, DSR-NPTR and PTR-PTR methods, the relative increase in yield in NPTR-PTR method compensated for the higher water used resulting in the highest water productivity (Mahajan *et al*., 2011) [7].

Table 1: Yield and resource use efficiency of rice-rice system as influenced by different establishment methods and green manuring (Pooled data of three years)

Treatment	Grain Yield (kg/ha)	Straw Yield (kg/ha)	N Uptake (kg/ha)	Internal Nitrogen Use Efficiency (kg/kg)	Irrigation Water Productivity (kg/m^3)
Green Manuring					
Without GM	8798	11019	158.4	55.3	0.50
With GM	9211	11595	163.9	56.0	0.52
S.Em±	88	119	1.51	0.159	0.006
CD (0.05)	304	411	5.20	0.55	0.02
Establishment Methods					
PTR-PTR	10549	13062	177.3	59.5	0.63
PTR-NPTR	9323	11649	165.5	56.3	0.58
PTR-DSR	8626	10658	159.1	54.2	0.44
NPTR-PTR	11337	13961	186.8	60.7	0.67
NPTR-NPTR	9863	12264	171.6	57.5	0.59
NPTR-DSR	8942	11650	163.9	54.6	0.44
DSR-PTR	7620	9571	144.7	52.7	0.44
DSR-NPTR	8162	10332	152.4	53.6	0.49
DSR-DSR	6622	8615	128.7	51.5	0.32
S.Em±	155	258	3.06	0.518	0.020
CD (0.05)	466	775	9.24	1.56	0.06

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