International Journal of Bio-resource and Stress Management 2015, 6(3):300-308
DOI:10.5958/0976-4038.2015.00048.2

Full Research Article

Productivity, Economics and Nutrient Use Efficiency of Basmati Rice Varieties and its Impact on Soil Fertility under SRI

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Article History

Manuscript No. AR1375
Received in 19th April, 2015
Received in revised form 9th May, 2015
Accepted in final form 6th June, 2015

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Keywords

SRI, basmati rice, INM, organic manuring, yield, nutrient balance

Abstract

The results of a field experiment conducted at OUAT, Bhubaneswar on basmati rice varieties under system of rice intensification (SRI) showed that the application of organic manure (FYM 15.0 t ha^{-1}) produced high grain yield (4415 kg ha^{-1}), biomass yield (10946 kg ha^{-1}) and NPK removal comparable to those of INM (50% RDF+7.5 ton FYM ha^{-1}), but significantly greater than those of inorganic fertilization (RDF). Organic manuring (OM) and INM recorded higher gross return but RDF paid higher net return. OM also showed greater available NPK contents and NPK balance in soil than those of INM and RDF. The lowest available NPK contents and NPK balance were recorded RDF treated plots. Cultivar Pusa Basmati-1 performed significantly better than Geetanjali variety. Crop planted at close spacing (20×20 cm^2) increased yield and NPK removal over those of wide spacing (25×25 cm^2); but had no effect on available NPK contents and reverse effect on NPK balance in soil. Crop productivity, nutrient removal, nutrient content and nutrient balance in soil did not vary much with 10 and 15-day old seedling. The results suggest growing Pusa Basmati-1 at close spacing (20×20 cm^2) with 10 to 15-day old single seedlings with organic manuring or INM practice for higher yield and better nutrient balance in soil.

1. Introduction

Sustainable development in agriculture intends the food and nutrition security for the increasing population. Rice (*Oryza sativa* L.) being a predominant food crop of the World, only second to wheat, will play a pivotal role towards ensuring both food and nutrition security to the global population in general and the southeast Asia, including India, in particular. Hence, the demand for the crop will continue to grow along with increase in population (Carriger and Vallee, 2007; Borkar et al., 2008). India produces nearly one fourth (22%) of world's rice and occupies second position next to China (GOI, 2009). It is the third largest rice exporter, after Thailand and Vietnam, amounting to 4.4 mt (1.2 mt Basmati and 3.2 mt non-Basmati) annually. India will need about 180 mt rough rice by 2020 with an average productivity of 4.03 t ha^{-1} to maintain its food self sufficiency (Thakur et al., 2010). The projected rice demand can only be met by maintaining steady increase in productivity under depleting natural resources, environmental quality and decreasing total factor productivity (Mishra et al., 2006; Ginigaddara and Ranamukhaarachchi, 2009). Rice production in India increased continuously during the past three decades, but has stagnated since 1999 (GOI, 2009) because of degraded soil quality resulted in yield plateauing or declining total factor productivity. The System of Rice Intensification (SRI) has come up as a ray of hope that emphasizes alternative crop management for quicker, surer and cheaper remedies for the impending hazards (Uphoff et al., 2008; Tsujimoto et al., 2009). The key practices in SRI are transplanting single young seedling of 8-12 days old at 2-3 leaf stage, grown in a non-flooded garden like nursery, wider spacing in a square pattern, avoiding continuous flooding of the field to maintain mostly aerobic soil condition, controlling weeds mechanically and applying compost as much as possible (Makarin et al., 2002; Uphoff et al., 2009; Kassam et al., 2011). This method not only boosts production but also saves water, induces greater resistance to disease and insect pest, reduces vulnerability to drought, lodging, storm damage, improves soil health and reduces environmental threats (Sato and Uphoff, 2007;

Veeramani and Singh, 2011) The proponents of SRI claimed substantial increase in rice yield (2-3 times) with increasing the productivity of land, labour, water and capital (Thakur et al., 2009; Choudhary et al., 2010; Uphoff et al., 2011).

Aromatic rice is cultivated mainly on the foot hills of the Himalayas along with some distant pockets of few states in India. The cultivation of newly released and prevailing Basmati varieties in non-traditional areas with intensive management is a strategy to increase the productivity and annual production of aromatic rice to meet the export as well as domestic demand (Kumari et al., 2010; Panigrahi et al., 2014). The Basmati varieties are expected to respond to the new SRI technique, which needs appropriate management of plant, soil, water and nutrients. Very little work has so far been done in Basmati varieties under SRI. Keeping this idea in view and considering the importance of the problem an investigation was undertaken to study the productivity, nutrient removal, nutrient use efficiency of Basmati rice varieties and its impact on soil fertility under System of Rice Intensification.

2. Materials and Methods

A field experiment was conducted at the Central Farm of OUAT, Bhubaneswar (20°15´ N Latitude, 85°52´ E Longitude and an altitude of 25.9 m MSL) during the *kharif* season of 2007 and 2008 in split-plot design with three nutrient management practices [F_1=60-30-30 kg N-P_2O_5-K_2O ha^{-1} (RDF), F_2=50% RDF+7.5 t FYM ha^{-1} and F_3=15 t FYM ha^{-1}] and two spacing (S_1=20×20 cm^2 and S_2=25×25 cm^2) in the main-plots and two Basmati rice varieties (V_1=Geetanjali and V_2=Pusa Basmati-1) with two seedling age (A_1=10 day-old and A_2=15 day-old seedlings) in the sub-plots in three replications. The soil was sandy loam with pH 5.7, organic carbon 3.5 g kg^{-1} soil, available N 153 kg ha^{-1}, available P 11.6 kg ha^{-1} and available K 136 kg ha^{-1}. The crop received 1373 and 1521 mm rainfall during 2007 and 2008, respectively. Seedlings were raised in wet garden-like nursery in which seeds of each variety were sown twice at a gap of 5 days to obtain 10 and 15 day-old seedlings to be planted in the main field on the same date. One seedling along with the soil and seed (embryo) attached to the seedling was placed on the grids marked by the marker at the specific spacing as per the treatments. The same layout plan was used for conducting the experiment during both the years. The manures and fertilizers were applied through FYM, urea, single super phosphate and muriate of potash. Full dose of FYM, phosphorus and potassium and one-third of nitrogen were applied as basal. Top dressing of one-third N was done at 10 days after transplanting and remaining one-third at panicle initiation stage. The nutrient contents of the FYM used were 0.53% N, 0.28% P and 0.56% K (determined by methods mentioned in the next Para). Weeding was done thrice at 10 days interval starting from 10 days after transplanting (DAT) using a cono-weeder. Experimental plots were kept moist up to panicle initiation stage by suitably maintaining the water level in the side channels of each bed. Thereafter a thin film of water was allowed to stand over the bed from panicle initiation stage to 10 days before the harvest of the crop. Excess rain water was drained out as and when required. Gall midge was observed during the *kharif* season of 2007, which was controlled successfully by spraying triazophos @ 2 ml l^{-1} of water.

The observations on biomass and grain yield were recorded at harvest of each plot. Soil samples were collected (0-20 cm depth) from all plots after harvesting of the crop and analyzed for pH, organic carbon and available nutrients (NPK). The pH was determined in a 1:2.5 soil: water suspension (Jackson, 1973), organic carbon (OC%) determined following Walkey and Black (1934) methods, available N by alkaline potassium permanganate method (Subbiah and Asajia, 1956), available P by Bray's method (Bray and Kurtz, 1945) and available K by ammonium acetate extraction method (Jackson, 1973). The nutrient (N, P and K) contents in rice grain and straw at harvest were estimated in the laboratory following micro-kjeldahl, spectrophotometer and flame photometer methods, respectively as described by Jackson (1973). N, P and K removal by the crop was then estimated by multiplying biomass and grain yield of rice with their respective N, P and K contents. Partial factor productivity of applied nutrient (PFPN) was calculated as the grain yield per unit of applied nutrient (Huang et al., 2008), nutrient use efficiency for grain production (NUE) was estimated as the ratio of grain yield to total nutrient uptake (Swain et al., 2006), physiological nutrient use efficiency (PNUE) was calculated as the ratio of biomass yield to total nutrient uptake (Singh et al., 1998) and nutrient harvest index (NHI) was the ratio of nutrient uptake in grain to the total nutrient uptake by the crop (N, P and K). Data were analyzed following analysis of variance as suggested by Gomez and Gomez (1984) and means of treatments were compared based on the least significant difference (LSD) at the 0.05 probability level. The economics of Basmati rice under SRI was calculated on the basis of prevailing market price of various inputs and the outputs.

3. Results and Discussion

3.1. Crop productivity

Nutrient management practices significantly influenced the grain and biomass yields, but it did not affect the harvest index of Basmati rice. Application of organic manure (15 t FYM ha^{-1}) produced the highest grain (4117 kg ha^{-1} in 2007 and 4712 kg ha^{-1} in 2008) and biomass (10615 kg ha^{-1} in 2007 and 11277 kg ha^{-1} in 2008) yields, but was comparable to those of INM (50% RDF+7.5 t FYM ha^{-1}) during both the years. Use of RDF (60-

30-30 kg ha^{-1} N-P_2O_5-K_2O, respectively) resulted in the lowest grain and biomass yields, which were significantly lower than those of organic manuring (OM) and INM during both the years except in 2007 when the grain yield of Basmati rice did not vary markedly between RDF and INM (Table 1). Pooled analysis of two years data also showed that OM and INM were much superior to RDF in respect of grain and biomass yields of Basmati rice. Organic manure alone or in combination with inorganic fertilizers might have minimized the N loss because of its slow release and have supplied nutrients in optimal congruence with crop demand resulting in improvement of its yield attributes and yield (Borkar et al., 2008; Kumari et al., 2010; Bera and Pramanik, 2012). Organics were beneficial in reducing the fixation or precipitation of added or mineralized nutrients and played complementary role to boost the crop yield (Shafi et al., 2012; Baishya et al., 2013).

Both grain (4205 kg ha^{-1} in 2007 and 4739 kg ha^{-1} in 2008) and biomass (10703 kg ha^{-1} in 2007 and 11328 kg ha^{-1} in 2008) yields increased significantly at close (20×20 cm^2) spacing over those of wide (25×25 cm^2) spacing (Table 1). Close spacing with high plant density registered higher grain and straw yields than those of wide spacing with low plant density (Bommayasamy et al., 2010; Mondal et al., 2013). This might be due to less number of plants (hills) $unit^{-1}$ area, which could not be compensated by greater tillering at wide spacing (25×25 cm^2) in comparison to close spacing (Thakur et al., 2009; Surya Prabha et al., 2011). The harvest index, however, did not vary much between the close and wide spacing during both the years. Pusa Basmati-1 produced higher grain (4410 kg ha^{-1}) and biomass (10857 kg ha^{-1}) yields than those of Geetanjali (4410 and 10448 kg ha^{-1} grain and biomass, respectively). The varietal difference in rice yield might be due to the differences in genetic makeup of the varieties (Bera and Pramanik, 2013; Mondal et al., 2013). Age of seedling at transplanting did not cause much variation in the grain and biomass yields and harvest index of Basmati rice varieties under the study.

3.2. Economics

Nutrient management practices exerted significant effect on gross return, net return and return per rupee invested (Table 2). OM of Basmati rice through 15 t FYM ha^{-1} fetched the highest gross returns (₹ 44,310 ha^{-1}) followed by INM (₹ 42,958 ha^{-1}). Both of the above nutrient management practices paid markedly higher gross return than that of RDF (₹ 41,281 ha^{-1}). However, application of RDF to the crop registered the higher net returns (₹ 23,520 ha^{-1}) and returns per rupee invested (1.33), which were significantly greater than those of INM and OM. OM recorded the lowest net returns (₹ 20,501 ha^{-1}) and returns per rupee invested (0.86) among the nutrient management practices because of highest cost of organic manures. Crop at close spacing (20×20 cm^2) paid greater gross and net returns and thus earned higher return per rupee invested than those obtained from the crop planted at wide spacing (Table 3). Similarly, Pusa Basmati-1 registered its superiority with respect to economics (gross return, net return and return per rupee invested) of rice production over Geetanjali. The results are in conformity with the findings of Kumari et al. (2010). Transplanting of seedlings of different ages did not cause much variation in the economics of rice production under the study.

Table 1: Effect of nutrient management practices, spacing and age of seedling on productivity of basmati rice varieties under SRI

Treatments	Grain yield (kg ha^{-1})			Biomass yield (kg ha^{-1})		Harvest Index (%)	
	2007	2008	Pooled	2007	2008	2007	2008
Nutrient management							
RDF*	3853	4353	4103	10020	10603	38.4	41.1
INM	3979	4570	4275	10386	11012	38.4	41.4
OM	4117	4712	4415	10615	11277	38.8	41.8
SEm±	62	70	55	112	123	0.78	0.67
CD (p=0.05)	191	214	170	342	381	NS	NS
Spacing							
20×20 cm^2	4205	4739	4472	10703	11328	39.3	41.8
25×25 cm^2	3761	4351	4056	9977	10601	37.7	41.0
SEm±	56	67	50	103	115	0.72	0.58
CD (p=0.05)	166	200	145	313	351	NS	NS
Variety							
Geetanjali	3870	4365	4118	10209	10686	37.9	40.8
Pusa Basmati-1	4095	4725	4410	10471	11242	39.1	42.0
SEm±	50	61	43	88	101	0.57	0.52
CD (p=0.05)	145	180	122	260	298	NS	NS
Age of seedling							
10 days	4035	4554	4295	10452	11026	38.6	41.3
15 days	3930	4536	4233	10228	10902	38.4	41.6
SEm±	50	61	43	88	101	0.57	0.52
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

*RDF (Recommended dose of fertilizer): 60 kg N, 30 kg P_2O_5 30 kg K_2O ha^{-1}; INM (Integrated nutrient management): 50% RDF +7.5 t FYM ha^{-1}; OM (Organic manuring):15 t FYM ha^{-1}

3.3. Nutrient removal

Nutrient management practices exerted significant effect on N, P and K uptake by grain and total biomass. The crop grown with OM (15.0 t FYM ha^{-1}) recorded the highest uptake of N, P and K which were significantly greater than those of RDF, but were comparable to those obtained with INM. INM also registered significantly higher N, P and K uptake than those of RDF under the study (Table 3). It increased 4.3, 8.3 and 6.5% N, P and K uptake respectively by grain and 4.1, 4.7 and 4.0% N, P and K uptake respectively by total biomass over those of RDF. But OM increased 7.8, 12.5 and 9.3% N, P and K uptake respectively by grain and 7.4, 8.4 and 6.7% N, P and K uptake respectively by total biomass over those of RDF under the study. Crop spacing showed significant effect on N, P and K uptake in grain and total biomass of Basmati rice. Crop planted at 20×20 cm^2 spacing recorded greater uptake of N (51.7 and 89.0 kg N ha^{-1} by grain and total biomass respectively), P (11.0 and 20.8 kg P ha^{-1} by grain and total biomass respectively) and K (12.1 and 99.8 kg K ha^{-1} by grain and total biomass respectively) than those at 25×25 cm^2 spacing. Crop at close spacing recorded 16.2, 15.8 and 16.3% higher uptake of N, P and K respectively by grain and 11.5, 10.6 and 6.3% higher N, P and K uptake respectively by total biomass over 25×25 cm^2 spacing.

Table 2: Effect of nutrient management, spacing and age of seedling on economics of basmati rice varieties under SRI

Treatments	Gross return (₹ ha^{-1})		Net return (₹ ha^{-1})		Return ₹$^{-1}$ invested	
Nutrient manage-ment	2007	2008	2007	2008	2007	2008
RDF*	38,848	43713	21200	25839	1.20	1.45
INM	40,281	45634	19620	24706	0.95	1.18
OM	41,532	47087	17856	23145	0.75	0.97
SEm±	789	854	391	441	0.012	0.016
CD (*p*=0.05)	2328	2519	1154	1302	0.037	0.047
Spacing						
20×20 cm^2	44,475	47367	23237	25985	1.09	1.22
25×25 cm^2	35,966	43589	15880	23140	0.79	1.13
SEm±	644	697	319	360	0.010	0.013
CD (*p*=0.05)	1901	2057	942	1062	0.030	0.04
Variety						
Geetanjali	40,091	42825	19436	22035	0.94	1.06
Pusa Basmati-1	40,342	48131	19674	27091	0.95	1.29
SEm±	500	668	246	341	0.008	0.011
CD (*p*=0.05)	NS	1972	NS	1006	NS	0.031
Age of seedling						
10 days	40464	45563	19778	24651	0.96	1.18
15 days	39968	45393	19331	24475	0.94	1.17
SEm±	500	668	246	341	0.008	0.011
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS

1 US \$=₹ 39.47 and ₹ 48.57 in Oct 2007 and 2008, respectively

Basmati rice varieties exerted significant effect on N, P and K uptake by both grain and total biomass. Pusa Basmati-1 recorded significantly higher uptake of N, P and K by grain and total biomass than those of Geetanjali over the years (Table 3). Pusa Basmati-1 increased 10.0, 11.3 and 10.3% N, P and K uptake by grain and 7.6, 9.5 and 4.1% N, P and K uptake by total biomass respectively over those of Geetanjali. Higher uptake of nutrients under organic and INM practice than RDF, in closer than wider spacing and in Pusa Basmati-1 than Geetanjali was mainly due to high quantum of harvest and their content because of better crop nutrition under such situation (Bommayasamy et al., 2010; Shekara et al., 2010). Age of seedlings at transplanting did not play effective role on influencing N, P and K uptake by the crop under the study.

3.4. Nutrient use efficiency

The nutrient management registered significant effect on partial factor productivity of applied nutrient (PFPN) but nutrient use efficiency for grain production (NUE), physiological nutrient use efficiency (PNUE) and nutrient harvest index (NHI) did not vary significantly due to different nutrient management treatments. The crop with RDF recorded high value of PFPN (30.8 kg grain kg^{-1} fertilizer applied) which was significantly higher than INM and OM. INM gave higher value of PFPN as compared to that of OM (15.0 t FYM ha^{-1}) which recorded the lowest value of PFPN (Table 3). PFPN is the grain yield per unit of applied nutrient (NPK). The lowest PFPN recorded in OM was mainly because of higher rate of nutrient application (190.5 kg NPK ha^{-1}) than INM (144.5 kg NPK ha^{-1}) and RDF (98.3 kg NPK ha^{-1}) in spite of producing high grain yield. Similarly, low values of PFPN were also noticed by Peng et al. (2006) due to higher rate of nutrient application through OM. INM increased PFPN over OM due to better nutrition of the crop through balancing nutrient supply by both organic and inorganic sources (Chen et al., 2014; Wu and Ma, 2015). Crop spacing exerted marked effect on PFPN and NHI, but it had very little effect on NUE and PNUE. Crop planted at close spacing recorded greater PFPN (25.9 kg grain kg^{-1} NPK applied) and NHI (35.7%) than that of wide spacing (PFPN 24.3 kg grain kg^{-1} NPK applied and NHI 33.5%). This

Table 3: Effect of nutrient management practice, spacing and age of seedling on nutrient removal and nutrient use efficiency by basmati rice varieties under System of Rice Intensification (Pooled over 2 years)

Treatments	N removal ($kg\ ha^{-1}$)		P removal ($kg\ ha^{-1}$)		K removal ($kg\ ha^{-1}$)		Nutrient use efficiency			
	Grain	Total biomass	Grain	Total biomass	Grain	Total biomass	PFPN ($kg\ kg^{-1}$)	NUE ($kg\ kg^{-1}$)	PNUE ($kg\ kg^{-1}$)	NHI (%)
RDF*	46.2	81.3	9.6	19.0	10.7	93.5	30.8	21.2	53.2	34.3
INM	48.2	84.6	10.4	19.9	11.4	97.2	25.1	21.2	53.0	34.7
OM	49.8	87.3	10.8	20.6	11.7	99.8	22.1	21.3	52.7	34.8
SEm±	0.59	0.93	0.22	0.25	0.18	1.01	0.59	0.37	0.82	0.29
CD (*p*=0.05)	1.8	2.8	0.7	0.8	0.6	3.0	1.83	NS	NS	NS
Spacing										
20×20 cm^2	51.7	89.0	11.0	20.8	12.1	99.8	25.9	21.3	52.6	35.7
25×25 cm^2	44.5	79.8	9.5	18.8	10.4	93.9	24.3	21.1	53.4	33.5
SEm±	0.52	0.75	0.16	0.18	0.13	0.84	0.48	0.30	0.67	0.24
CD (*p*=0.05)	1.6	2.3	0.5	0.6	0.4	2.5	1.44	NS	NS	0.71
Variety										
Geetanjali	45.8	81.3	9.7	18.9	10.7	94.9	24.6	21.1	53.5	33.9
Pusa Basmati-1	50.4	87.5	10.8	20.7	11.8	98.8	25.6	21.3	52.4	35.3
SEm±	0.45	0.66	0.15	0.16	0.12	0.67	0.33	0.25	0.59	0.18
CD (*p*=0.05)	1.3	1.9	0.4	0.5	0.3	1.9	0.98	NS	NS	0.53
Age of seedling										
10 days	48.5	85.2	10.4	20.0	11.4	97.8	25.2	21.2	52.9	34.6
15 days	47.8	83.6	10.1	19.6	11.1	96.0	25.0	21.3	53.0	34.6
SEm±	0.45	0.66	0.15	0.16	0.12	0.67	0.33	0.25	0.59	0.18
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*RDF (Recommended dose of fertilizer): 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}; INM (Integrated nutrient management): 50% RDF+7.5 t FYM ha^{-1}; OM (Organic manuring): 15 t FYM ha^{-1}

was mainly due to higher grain productivity at close spacing (Panigrahi et al., 2014). Basmati rice varieties also showed significant effect on PFPN and NHI but NUE and PNUE did not vary much between the varieties. Pusa Basmati-1 recorded significantly higher PFPN (25.6 kg grain kg^{-1} NPK applied) and NHI (35.3%) than that of Geetanjali because of superiority of Pusa Basmati-1 over Geetanjali in grain productivity (Table 3). Age of seedlings at transplanting did not affect the any of nutrient use efficiency of the crop under the study.

3.5. *Soil fertility status*

The pH and organic carbon content in soil showed an increasing trend with two years of rice cropping in *kharif* season. The pH increased from 5.7 (Initial) to 6.0 after first year's cropping and 6.4 after second year's cropping due to organic manuring. Similarly, organic carbon content in soil increased from 0.35% (initial) to 0.45% after the first year's cropping and to 0.54% after the second year's cropping in organic manured plots (Table 4). The integrated nutrient management also helped in increasing soil pH over its initial value to some extent and it increased organic carbon content in soil markedly over its initial value and RDF applied plots. Use of only chemical fertilizers (RDF) though tended to decrease the soil pH, yet it tended to increase the organic carbon content in soil over its initial value. Positive and significant effect of N nutrition on soil organic carbon was also noticed by Kaur et al. (2008) and Njoku and Mbah (2012). The crop variety, spacing and age of seedlings for transplanting did not cause significant variation in pH and organic carbon content in soil under the study.

The nutrient management practices caused marked variation in available N, P and K content in soil during both the years and the increase was more after the second year's cropping. Organic manuring recorded the highest increase in available N (194 and 223 kg ha^{-1}), P (15.5 and 16.8 kg ha^{-1}) and K (153 and 165 kg ha^{-1}) content in soil in 2007 and 2008 respectively and was significantly greater than those of INM and RDF plots (Table 4). The INM practices also significantly increased

Table 4: Effect of nutrient management practices, spacing and age of seedling on soil properties after the crop harvest under System of Rice Intensification

Treatments	pH		OC (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Initial status	5.7		0.35		153		11.6		136	
Nutrient management										
RDF*	5.4	5.3	0.36	0.38	158	187	12.2	13.5	137	148
INM	5.7	5.9	0.41	0.47	173	210	13.7	15.0	145	157
OM	6.0	6.4	0.45	0.54	194	233	15.6	16.8	153	165
SEm±	0.10	0.11	0.008	0.009	3.0	3.3	0.25	0.23	2.5	2.7
CD (p=0.05)	0.31	0.33	0.025	0.030	9.3	10.5	0.77	0.73	7.3	8.0
Spacing										
20×20 cm^2	5.6	5.8	0.40	0.46	172	206	13.6	14.9	144	156
25×25 cm^2	5.8	5.9	0.41	0.47	178	214	14.0	15.3	146	158
SEm±	0.08	0.09	0.007	0.008	2.4	2.7	0.20	0.19	1.9	2.2
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Variety										
Geetanjali	5.8	5.9	0.41	0.47	177	213	13.9	15.0	146	158
Pusa Basmati-1	5.6	5.8	0.40	0.46	173	207	13.7	15.2	144	156
SEm±	0.07	0.08	0.006	0.007	2.2	2.4	0.17	0.16	1.8	2.0
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Age seedling										
10 days	5.7	5.9	0.40	0.46	174	209	13.7	15.0	146	157
15 days	5.7	5.8	0.41	0.47	176	211	13.9	15.2	144	157
SEm±	0.07	0.08	0.006	0.007	2.2	2.4	0.17	0.16	1.8	2.0
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

the available N, P and K contents in soil over those of RDF during both the years. Use of only chemical fertilizers (RDF) also helped in increasing the available N, P and K contents in soil over its initial value, but the increase was higher only in the second year. Organic manuring increases the nutrient holding capacity of the soil by improving its organic matter content and thus increases the available N, P and K contents in soil (Babou et al., 2009; Wang et al., 2013). Maximum N, P and K balances were noticed by organic manuring, which were significantly greater than those of INM. INM, on the other hand, registered markedly higher N, P and K balances over those of the RDF plots in which only chemical fertilizers were added (Table 5). Mineralization of organic matter and the residual effect of plant nutrient from organic sources probably enhanced the nutrient levels of the soil (Kaur et al., 2008; Shafi et al., 2012). Organic sources release nutrients slowly as they mineralize comparatively slowly and contribute to the residual pool of organic N, P and K in the soil and reduce nutrient loss from the soil by improving soil organic matter (Rafique et al., 2012a, b and c). Organic sources of plant nutrients, thus, exerted long lasting residual effects on crop yield and soil properties by improving soil nutrients and soil organic matter (Njoku and Mbah, 2012; Wang et al., 2013). Our study also showed that nutrient supply through organic manuring and chemical fertilizers was most conducive for improving soil organic matter and maintaining long term soil productivity. Nutrient supply through chemical fertilizers only was not helpful in improving the N, P and K balance in soil.

The crop variety, spacing and age of seedlings at planting did not affect much on available N, P and K contents of the experimental soil but crop variety and spacing markedly influenced the N, P and K balance in soil. Crop planted at 25×25 cm^2, spacing recorded greater N, P and K balances in the soil than those of the 20×20 cm^2 planted crop. Similarly, plots of Geetanjali had significantly higher N, P and K balances than those of the plots of Pusa Basmati-1. This might be due to less crop productivity of Geetanjali and widely planted crop leaving more nutrients in the soil.

Table 5: Effect of nutrient management practices, spacing and age of seedling on nutrient balance in soil after 2 crop cycle under System of Rice Intensification

Treatments	Nutrient added in			Nutrient removed by			Soil available nutrient after			Nutrient balance (gain/loss) over initial status (kg ha^{-1})**		
Nutrient management	2 crop cycle (kg ha^{-1})	P	K	2 crop cycle (kg ha^{-1})	P	K	2 crop cycle (kg ha^{-1})	P	K	N	P	K
RDF*	120	27	50	163	38	187	187	13.5	148	34.0	1.9	12.0
INM	140	55	109	169	40	194	210	15.0	157	57.0	3.9	21.0
OM	159	82	168	175	41	200	233	16.8	165	80.0	5.7	29.0
SEm±				2.9	0.71	3.8	3.3	0.23	2.7	1.55	0.09	0.52
CD (p=0.05)				9.0	2.21	11.8	10.5	0.73	8.5	4.80	0.29	1.62
Spacing												
20×20 cm^2	140	55	109	178	42	200	206	14.9	156	53.0	3.8	20.0
25×25 cm^2	140	55	109	160	38	188	214	15.3	158	61.0	4.2	22.0
SEm±				2.4	0.58	3.1	2.7	0.19	2.2	1.26	0.08	0.43
CD (p=0.05)				7.1	1.73	9.2	NS	NS	NS	3.77	0.23	1.27
Variety												
Geetanjali	140	55	109	163	38	190	213	15.0	158	60.0	3.8	22.0
Pusa Basmati-1	140	55	109	175	41	198	207	15.2	156	54.0	4.2	20.0
SEm±				2.0	0.53	2.7	2.4	0.16	2.0	1.12	0.07	0.36
CD (p=0.05)				6.0	1.57	7.9	NS	NS	NS	3.31	0.20	1.07
Age seedling												
10 days	140	55	109	170	40	196	209	15.0	157	56.0	3.9	21.0
15 days	140	55	109	167	39	192	211	15.2	157	58.0	4.1	21.0
SEm±				2.0	0.53	2.7	2.4	0.16	2.0	1.12	0.07	0.36
CD (p=0.05)				NS	NS	NS	NS	NS	NS	NS	NS	NS

*RDF (Recommended dose of fertilizer): 60 kg N, 13.3 kg P and 25 kg K ha^{-1}; INM (Integrated nutrient management): 50% RDF+7.5 t FYM ha^{-1}; OM (Organic manuring): 15 t FYM ha^{-1}; **Initial status: 0.35% OC; 153, 11.6 and 136 kg available N, P and K ha^{-1} respectively

4. Conclusion

Organic manuring @ FYM 15.0 t ha^{-1} or integrated nutrient management (50% RDF+7.5 ton FYM ha^{-1}) may be recommended for increasing productivity of Basmati rice, improving nutrient balance and soil fertility status in spite of greater nutrient removal under SRI. Pusa Basmati-1 planting at close spacing (20×20 cm^2) with 10 to 15-day old single seedlings seems to be better than Geetanjali.

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