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Effect of Organic, Inorganic and Integrated Nutrient Sources on the Yield and Its Attributes of Two Basmati Rice Varieties *viz* Type-3 and Taraori Grown in Tarai Regions of Uttarakhand India

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A B S T R A C T

A field experiment was conducted at the organic block of breeder seed production center, G.B.P.U.A&T, Pantnagar, Uttarakhand, India during the kharif season of 2015 and 2016 to study the effect of different organic, inorganic and integrated nutrient sources on the growth, yield and yield attributes of two basmati rice varieties. The experiments were laid out in Split plot design replicated thrice with eight treatments as main plots viz., T_1: GM+FYM (AWD), T_2: Organic (AWD), T_3: FYM+VC (AWD), T_4: SRI with FYM (AWD), T_5: DSR + Soybean (LSI), T_6: Organic control (CF), T_7: Chemical control (CF), T_8: Integrated (CF) and two varieties Type-3 and Taraori in the sub plots. The plant height at maturity was highest in treatment T_8 which was at par with T_7 in both the years. The organic treatments T_1 and T_3 were at par with T_7 and T_8 in terms of productive tillers/m^{-2}, grain weight/panicle and thousand grain weight. However number of filled grains/panicle was non-significant in both the years. The grain yield ranged from 2.63-3.00 t/ha and the treatments T_1, T_3, T_7 and T_8 were at par in the in both the years 2015 and 2016. Further the results suggest that the organic manures such as vermicompost, FYM and green manures have equal potential in comparison to chemical and integrated fertilizers for rice production.

Introduction

Rice (*Oryza sativa*) is one of the most important cereal grains in the world today and serves as a staple food source for more than half of the world's population (Gross and Zaho, 2014). About 90 % of rice is grown and consumed in south and Southeast Asia (www.ricepedia.org IRRI, 2006). Although rice yields are still growing, the rate of growth has been declining; compound growth rate was 2.5 % per annum (pa) during 1962–1979 and declined to 1.4 % pa during 1980–2011 (Adjao and Staatz, 2015). The cereal production forecast by Food and Agriculture Organization (FAO) in April-2018 indicated that out of the total cereal production, the contribution of rice (milled) is likely to be 503.9 million tonnes MMT. It is expected in future that the additional pressures will be build on the global food system because the demand for agricultural products is estimated to increase by about 50% by 2030 as the global population increases (Wheeler and Braun, 2013). Agricultural scientists are forced to produce more food within limited availability of cultivated land and water resources and particular socio-economic conditions. Over exploitation of vegetation and soil resources and adoption of inappropriate farming systems have resulted in land degradation and reduced crop production (Vaithiyanathan and Sundaramoorthy, 2016). The challenge of feeding a growing population expected to reach 9 to 10 billion people by 2050 while protecting the environment is daunting (Reganold and Wachter, 2016). A promising option is eco-functional intensification through organic farming, an approach where agricultural production aims at closing nutrient cycles, in which plant residues or manure from livestock are returned back to the fields, whereas neither synthetic fertilizers nor synthetic pesticides are applicable which minimizes negative environmental impacts (Lori *et al.,* 2017). In the recent years organic agricultural land has increased almost five-fold as compared with 1999, when only 11 million hectares land area was under organic. In 2015, 6.5 million hectares, or almost 15 percent more were reported compared with 2014 (Willer and Lernoud, 2017). Although crop quality and yield depends on various factors, among which the nutrient sources and establishment methods play a vital role, there is very little information available on how rice yield is affected by different organic manures under different establishment methods and irrigation regimes. Therefore with this concept and the benefits of organic fertilizers in mind the present investigation was carried out to understand the effect of different organic and inorganic nutrient sources and different establishment methods and water management systems on morphological and agronomical parameters such as plant height, productive tillers/m^{-2} grain weight/panicle, thousand grain weight, number of filled grains per panicle, grain yield, straw yield and harvest index of Taraori and Type-3 basmati rice varieties.

Materials and Methods

Experimental Site

Field experiments were carried out at the Organic block of Breeder seed production Centre (BSPC) of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India, during Kharif season 2015-2016. The experimental field was situated at 29° N latitude, 79.3° E longitude and 243.8 m above the mean sea level and lies in a narrow belt to the south of the foothills of Himalaya known as Tarai region.

Weather data

The minimum temperature, maximum temperature, sunshine hrs, rainfall and evaporation (Figure 1) were recorded for all meteorological weeks in 2015 & 2016.

Experimental details and Statistical Design

The experiment was laid out in Split plot design with eight treatments as main plots and two basmati rice varieties *viz* Type-3 and Taraori as the sub plot with three replications of each treatment (Table 1).In GM treatment, *Sesbania aculeata* was incorporated at 50-55 days stage before the transplanting of rice along with 10 t FYM/ha. Manually field was prepared with the help of spade followed by puddling and levelling. Two seedlings were translated in 20 cm × 20 cm spacing. In the SRI treatment the twelve days old seedling were transplanted in a square grid pattern with one seedling per hill quickly and carefully so that roots get minimum trauma. In the DSR treatment direct seeded rice was intercropped with soybean and its yield was calculated as basmati rice grain equivalent yield. During both the years of the crop the weed management was done with the help of conoweeder after 15 days of transplanting (DAT) thereafter followed by two hand weedings at 30 and 45 DAT. Whereas in SRI treatment three weeding were done through conoweeder. Whereas in DSR, three hand weedings were done at 15, 30 and 45 DAT. Irrigations were managed as per the treatment requirements. The nursery preparation was done in the month of June in both the years and FYM 50 kg/10 m^2 was used as nutrient source. The nursery was sprayed with Leachate of vermicompost (10%) + Neem cake (10%) + Cow urine (10%) along with *Trichderma* and *Pseudomonas* (@ each of 5 gm/l) after 15 days.

Selection of healthy seeds and control of disease was taken care from the initial stages for it the seeds were treated with salted water followed by the treatment of *Pant bio agent-3 (Mixture of Trichoderma harzianum* and *Pseudomonas fluorescens*) powder @ 10 g/kg seeds and the seeds were kept moist under wet sack for germination. Insects and pests were controlled by spraying of 10% cow urine fortified with neem leaves at every 15 days interval. Whereas stem borers were controlled by the application of Trichocards (1 card for 1 acre area; 5 releases) and pheromone traps (5 mg pheromone per trap; 20 traps/ha; 20 × 25 m distance) within a week of transplanting. The lure was replaced after 30 days and the height of the trap was kept at 30 cm above the crop canopy.

Statistical Analysis

The statistical analysis of data for all the parameters was carried out with analysis of variance for split plot design. Critical difference (CD) was evaluated at 5 % level of significance. The means were tested at P > 0.05 using STPR software designed at Department of Mathematics, Statistics and Computer Science, CBSH, G.B. Pant University of Agriculture & Technology, Pantnagar, India.

Results and Discussion

Morphological and Agronomical parameters

Plant height (cm)

The plant height at maturity for two subsequent years i.e. 2015 and 2016 is summarized in the Table 2. The plant height at maturity stage in 2015 was maximum (167 cm) in T_8 Integrated (CF) and minimum (144 cm) in T_5 DSR + Soybean (LSI). The plant height in the treatments followed the order T_8 Integrated (CF) > T_7 Chemical Control (CF) > T_2 Organic (AWD) = T_4 SRI with FYM (AWD) > T_6 Organic Control (CF) > T_1 GM + FYM (AWD) = T_3 FYM+VC (AWD) > T_5 DSR + Soybean (LSI). The maximum percent increase in plant height (1.27 %) was observed in T_8 Integrated (CF) over T_7 Chemical Control (CF) and maximum percent decrease (-12.50 %) in plant height was found in T_5 DSR + Soybean (LSI) over T_7 Chemical Control (CF). The treatments T_8 and T_7 were statistically at par with each other. However among both the basmati rice varieties significantly higher plant height at maturity stage was found in Type-3 (160 cm) than Taraori basmati rice variety (152 cm). In the year 2016 maximum plant height (164 cm) was observed in T_8 Integrated (CF) and minimum (142 cm) in T_5 DSR + Soybean

(LSI). The plant height in the treatments followed the order T_8 Integrated (CF) > T_7 Chemical Control (CF) > T_2 Organic (AWD) > T_4 SRI with FYM (AWD) = T_6 Organic Control (CF) > T_3 FYM+VC (AWD) = T_1 GM + FYM (AWD) > T_5 DSR + Soybean (LSI). The highest percent increase in plant height (1.05 %) was observed in T_8 Integrated (CF) over T_7 Chemical Control (CF) and maximum percent decrease (-12.36 %) in plant height was found in T_5 DSR + Soybean (LSI) over T_7 Chemical Control (CF). The treatments T_8 and T_7 were at par with each other. However among both the basmati rice varieties significantly higher plant height (157 cm) was found in Type-3 than Taraori (150 cm) basmati rice variety.

This could be due to the reason that the fundamental process of nutrient absorption by plants is well established. Irrespective of whether nutrients originate from organic or inorganic sources, plants are only capable of absorbing nutrients in certain forms. For example, nitrogen is only absorbed as nitrate (NO_3^-) ions or ammonium (NH_4^+) ions and potassium only as K^+ ions. Water soluble inorganic fertilizers readily provide nutrients in these forms which could be easily taken up by the plants and utilized for their growth and development (Das and Mandal, 2015).

In a similar experiment higher plant height (118 cm) at the harvest stage was recorded with the application of 50 % N through RDF + 50% N through vermicompost to rice variety GR 11 (Dekhane *et al.*, 2014). In another study the application of organic and inorganic manures also increased the plant height significantly over control where maximum plant height was observed in treatment where RDF (150-90-60 NPK kg/ha) was applied. However different organic manures with 50% of RDF showed average plant height. Minimum plant height (94.59 cm) was recorded in control (Arif *et al.*, 2015).

Plant height significantly increased due to different treatments compared to control treatment. At harvesting stage the highest plant height was recorded in treatment with farmyard manure @ 12.5 t/ha in combination with 100% RDF (M4S1) followed by fish pond silt from desi poultry dropping @ 5 t/ha + vermicompost @ 5 t/ha combined with 100% RDF (M1S1). This increase in plant height in response to RDF might be primarily due to the improved vegetative growth and supplementary contribution of nitrogen (Kumar and Balusamy, 2017).

Yield components

Productive tillers/m^{-2}

Productive tillers/m^{-2} at maturity (Table 3) of both the basmati rice varieties was significantly influenced by different organic, inorganic and integrated treatments in both the years. In the year 2015 maximum productive tillers/m $^{-2}$ (230) was observed in T_5 DSR + Soybean (LSI) and minimum (190) in T_4 SRI with FYM (AWD). The productive tillers/m $^{-2}$ in the treatments followed the order T_5 DSR + Soybean (LSI) > T_8 Integrated (CF) > T_1 GM + FYM (AWD) = T_3 FYM+VC (AWD) > T_7 Chemical Control (CF) > T_6 Organic Control (CF) > T_2 Organic (AWD) > T_4 SRI with FYM (AWD). The maximum percent increase in productive tillers/m^{-2} (5.76 %) was observed in T_5 DSR + Soybean (LSI) over T_7 Chemical Control (CF) and maximum percent decrease (-12.29 %) in productive tillers/m^{-2} was found in T_4 SRI with FYM (AWD) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher productive tillers/m^{-2} (218) was found in Type-3 than Taraori (212) basmati rice variety.

In the year 2016 maximum productive tillers/m^{-2} (231) was observed in T_8 Integrated (CF) and T_5 DSR + Soybean (LSI) and minimum (192) in T_4 SRI with FYM (AWD). The productive tillers/m^{-2} in the treatments followed the order T_5 DSR + Soybean (LSI) = T_8 Integrated (CF) >T_1 GM + FYM (AWD) > T_7 Chemical Control (CF) > T_3 FYM+VC (AWD) > T_2 Organic (AWD) > T_6 Organic Control (CF) > T_4 SRI with FYM (AWD). However among both the basmati rice varieties higher productive tillers/m^{-2} (222) was found in Type-3 than Taraori (217) basmati rice variety.

The use of organic manures and green manure would have resulted in improved soil quality it has also been previously reported that the fertile tillering also depends primarily upon soil physical conditions that were superior due to addition of poultry manure (Usman, 2003). Application of 50 % N through RDF + 50% N through vermicompost recorded higher number of tillers per plant which were 8.7 and 12.1 at 45 DAT and at harvest time respectively, of rice variety GR 11 (Dekhane *et al.,* 2014). Similarly the highest number of productive tillers/m^2 (409 and 422) was obtained in the treatment M4S1 (farm yard manure @ 12.5 t/ha in combination with 100% RDF) during both years respectively, which was followed by M1S1 (fish pond silt from desi poultry dropping @ 5 t/ha + vermicompost @ 5 t/ha with 100% RDF) (Kumar and Balusamy, 2017).

Grain weight/panicle (g)

Grain weight/panicle at harvest of both the basmati rice varieties under different organic, inorganic and integrated treatments in 2015 and 2016 are summarized in Table 3. In 2015 maximum grain weight/panicle was observed in T_4 system of rice intensification (SRI) (1.61) and minimum (1.43 g) in T_2 Organic (AWD). The grain weight/panicle in the treatments followed the order T_4 SRI with FYM (AWD) > T_8 Integrated (CF) > T_3 FYM+VC (AWD) > T_1 GM + FYM (AWD) > T_7 Chemical Control (CF) > T_5 DSR + Soybean (LSI) > T_6 Organic Control (CF) > T_2 Organic (AWD). The maximum percent increase in grain weight/panicle (5.76 %) was observed in T_4 SRI with FYM (AWD) over T_7 Chemical Control (CF) and maximum percent decrease (-6.86 %) in grain weight/panicle was found in T_2 Organic (AWD) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher grain weight/panicle (1.53 g) was found in Taraori than Type-3 (1.51 g) basmati rice variety.

In 2016 maximum grain weight/panicle (1.67 g) was observed in T_4 SRI with FYM (AWD) and minimum (1.42 g) in T_2 Organic (AWD).

The grain weight/panicle in the treatments followed the order T_4 SRI with FYM (AWD) > T_8 Integrated (CF) > T_3 FYM+VC (AWD) > T_1 GM + FYM (AWD) = T_7 Chemical Control (CF) > T_5 DSR + Soybean (LSI) > T_6 Organic Control (CF) > T_2 Organic (AWD). The maximum percent increase in grain weight/panicle (8.37 %) was observed in T_4 SRI with FYM (AWD) over T_7 Chemical Control (CF) and maximum percent decrease (-7.67 %) in grain weight/panicle was found in T_2 Organic (AWD) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher grain weight/panicle (1.55 g) was found in Taraori than Type-3 (1.52 g) basmati rice variety.

This could be due to the reason that SRI has wider spacing between the plants due to which there is less below and above ground competitions for better grain filling, higher grain weight and more number of filled grains per panicle. Optimum supply of irrigation water with mechanical weeding resulted in higher nutrient availability subsequently resulting in better source to sink conversion and in turn enhanced the production of more total number of seeds and filled seeds per panicle (Lu *et al.,* 2005). SRI method not only had the benefit of reducing the water requirement for rice cultivation but also increased the productivity. (Thiyagarajan *et al.,* 2005). In similar study it was also recorded that significantly higher grain weight/panicle (5.26g) was recorded in treatment with 45 kg N/ha through VC among all other organic sources (Srivastava *et al.,* 2016).

In another study maximum grain weight per panicle (1.44 g) was recorded in SRI treatment followed by chemical control (1.38 g) which was significantly higher with other treatments except GM + VC and DSR (Singh *et al.,* 2017).

Thousand grain weight (g)

Thousand grain weight of both the basmati rice varieties under different organic, inorganic and integrated treatments in 2015 and 2016 are summarized in Table 4. In 2015 maximum thousand grain weight was observed in T_3 FYM+VC (AWD) (21.37 g) and T_8 Integrated (CF) (21.37 g) and minimum (20.83 g) in T_4 SRI with FYM (AWD). The thousand grain weight in the treatments followed the order T_8 Integrated (CF) = T_3 FYM+VC (AWD) > T_2 Organic (AWD) > T_7 Chemical Control (CF) > T_1 GM + FYM (AWD) > T_6 Organic Control (CF) > T_5 DSR + Soybean (LSI) > T_4 SRI with FYM (AWD). The maximum percent increase in thousand grain weight (1.81 %) was observed in T_3 FYM+VC (AWD) over T_7 Chemical Control (CF) and maximum percent decrease (-0.75%) in thousand grain weight was found in T_4 SRI with FYM (AWD) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher thousand grain weight (21.72 g) was found in Taraori than Type-3 (20.41 g) basmati rice variety.

In 2016 maximum thousand grain weight (21.10 g) was observed in T_1 GM + FYM (AWD) and minimum (20.87 g) in T_5 DSR + Soybean (LSI). The thousand grain weight in the treatments followed the order T_1 GM + FYM (AWD) > T_4 SRI with FYM (AWD) > T_8 Integrated (CF) > T_7 Chemical Control (CF) > T_6 Organic Control (CF) > T_3 FYM+VC (AWD) > T_2 Organic (AWD) > T_5 DSR + Soybean (LSI). The maximum percent increase in thousand grain weight (0.19 %) was observed in T_4 SRI with FYM (AWD) over T_7 Chemical Control (CF) and maximum percent decrease (-0.91 %) in thousand grain weight was found in T_5 DSR + Soybean (LSI) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher thousand grain weight (21.46 g) was found in Taraori than Type-3 (20.59 g) basmati rice variety.

It could be due to the reason that vermicompost is usually superior to ordinary aerobic compost in terms of nutritional status and microbial and enzymatic properties (Singh and Ganguly, 2005). Whereas green manure is a cheaper alternative to mounting price of fertilizer nitrogen and has become an effective technology in economizing the agriculture production system (Bana and Pant, 2000). In a similar experiment it was reported that there was a increase in 1000 grain weight from the plot receiving poultry manure and compost in combination with 50% RDF and 100% recommended dose of fertilizer, which might be due to optimum accessibility of required plant nutrients as compared to other treatments (Arif *et al.,* 2014).

Similarly thousand grain weight was recorded higher in SRI-organic + inorganic (21.8g, 18.7g, 14.9g and 14.8g) in Kharif season 2008 & 2009 and Rabi season 2008 & 2009 respectively (Gopalakrishnan *et al.,* 2014). It was also reported that increase (23.20 % over control) in 1000 grain weight which was 21.12g reported in Poultry manure+50%RDF treatments (Arif *et al.,* 2014).

Fig.1 Weekly weather data of Pantnagar during the crop season (2015 & 2016)

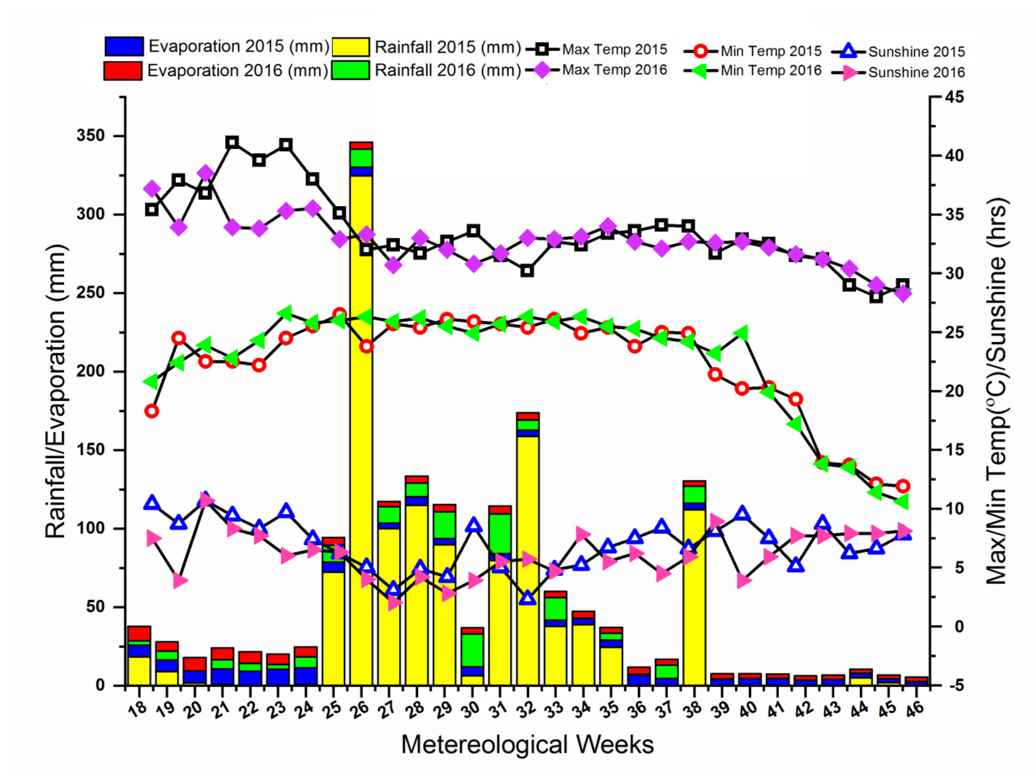

Fig.2 Effect of different treatments and varieties on rice grain yield (t/ha), straw yield (t/ha) and harvest index (%) in 2015 & 2016

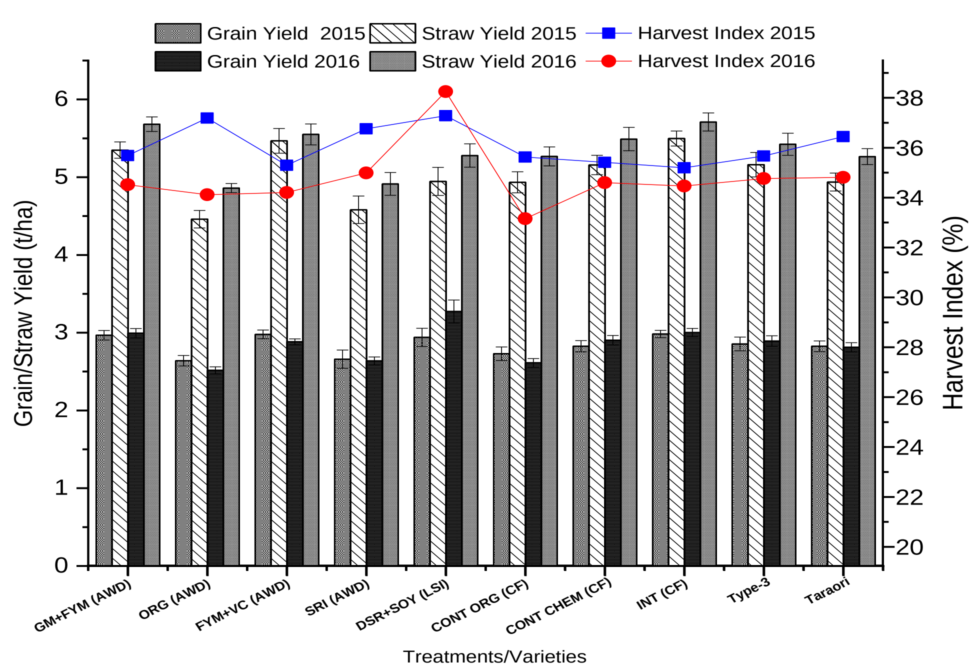

Table.1 Details of treatments

Treat. No.	Abbreviation	Water management practice	Details
T_1	Green manuring + FYM (AWD)	Alternate wetting and drying	Transplaned rice using *Sesbania aculeata* as GM 55 days old crop @ 16 t ha^{-1} (fresh biomass) and FYM @ 5 t ha^{-1} as nutrient source.
T_2	Organic (AWD)	Alternate wetting and drying	Transplanted rice using FYM @ 10 t ha^{-1} as nutrient source.
T_3	FYM+VC (AWD)	Alternate wetting and drying	Transplanted rice using FYM @ 10 t ha^{-1} and VC @ 5 t ha^{-1} as nutrient source.
T_4	SRI with FYM (AWD)	Alternate wetting and drying	System of Rice Intensification (SRI) using FYM @ 10 t ha^{-1} as nutrient source.
T_5	DSR+Soybean (LSI)	Life saving irrigation	Direct seeded rice crop + soybean using FYM @ 10 t ha^{-1} as nutrient source.
T_6	Organic Control (CF)	Continuous flooding	Organic control using FYM @ 10 t ha^{-1} as nutrient source.
T_7	Chemical Control (CF)	Continuous flooding	Chemical control using 70 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1} as nutrient source.
T_8	Integrated (CF)	Continuous flooding	Integrated using 35 kg N ha^{-1}, 20 kg P_2O_5 ha^{-1} and 15 kg K_2O ha^{-1} along with farm yard manure @ 5t/ha as nutrient source.

Table.2 Effect of different organic, inorganic and integrated nutrient sources on plant height of two basmati rice varieties at maturity stage in 2015 and 2016

Treatments	Plant height (cm) 2015	PCOC	Plant height (cm) 2016	PCOC
T_1: GM + FYM (AWD)	153	-7.01	151	-6.98
T_2: Organic (AWD)	155	-5.93	153	-5.44
T_3: FYM+VC (AWD)	153	-7.11	151	-6.52
T_4: SRI with FYM (AWD)	155	-6.10	152	-6.25
T_5: DSR + Soybean (LSI)	144	-12.50	142	-12.36
T_6: Organic Control (CF)	154	-6.80	152	-6.44
T_7: Chemical Control (CF)	165	-	162	-
T_8: Integrated (CF)	167	1.27	164	1.05
CD(p=0.05)	3.77		3.25	
SEm ±	1.24		1.07	
Variety				
Type-3 Basmati	160		157	
Taraori Basmati	152		150	
CD(p=0.05)	1.51		0.93	
SEm ±	0.50		0.31	

PCOC: Percent change over chemical control

Table.3 Effect of different organic, inorganic and integrated nutrient sources on productive tillers/m^2 at maturity stage and grain wt/panicle (g) of two basmati rice varieties in 2015 & 2016

Treatments	Productive tillers/m^2 2015	PCOC	Productive tillers/m^2 2016	PCOC	Grain wt/panicle (g) 2015	PCOC	Grain wt/panicle (g) 2016	PCOC
T_1: GM + FYM (AWD)	219	0.69	228	1.56	1.54	0.40	1.54	-0.22
T_2: Organic (AWD)	212	-2.46	216	-3.79	1.43	-6.86	1.42	-7.67
T_3: FYM+VC (AWD)	219	0.92	222	-0.97	1.56	2.03	1.55	0.34
T_4: SRI with FYM (AWD)	190	-12.29	192	-14.14	1.61	5.04	1.67	8.37
T_5: DSR + Soybean (LSI)	230	5.76	231	3.13	1.50	-1.70	1.52	-1.12
T_6: Organic Control (CF)	214	-1.38	214	-4.54	1.44	-5.58	1.48	-4.20
T_7: Chemical Control (CF)	217	-	224	-	1.53	-	1.54	-
T_8: Integrated (CF)	220	1.38	231	3.13	1.58	3.49	1.57	1.62
CD(p=0.05)	8.58		11.95		NS		0.11	
SEm ±	2.83		3.94		0.03		0.04	
Variety								
Type-3 Basmati	218		222		1.51		1.52	
Taraori Basmati	212		217		1.53		1.55	
CD(p=0.05)	3.12		4.15		NS		NS	
SEm ±	1.04		1.38		0.01		0.01	

PCOC: Percent change over chemical control

Table.4 Effect of different organic, inorganic and integrated nutrient sources on thousand grain weight (g) and Number of filled grains/panicle in 2015 and 2016

Treatments	1000 grain weight (g) 2015	PCOC	1000 grain weight (g) 2016	PCOC	No of filled grains/panicle 2015	PCOC	No of filled grains/panicle 2016	PCOC
T_1: GM + FYM (AWD)	20.98	-0.06	21.10	0.19	121	22.29	109	9.72
T_2: Organic (AWD)	21.06	0.33	20.96	-0.47	108	8.95	99	-0.17
T_3: FYM+VC (AWD)	21.37	1.81	20.97	-0.41	114	15.71	111	11.89
T_4: SRI with FYM (AWD)	20.83	-0.75	21.08	0.09	127	28.37	123	23.45
T_5: DSR + Soybean (LSI)	20.96	-0.17	20.87	-0.91	117	18.75	92	-7.20
T_6: Organic Control (CF)	20.97	-0.08	21.05	-0.04	103	3.88	106	6.20
T_7: Chemical Control (CF)	20.99	-	21.06	-	99	-	100	-
T_8: Integrated (CF)	21.37	1.81	21.07	0.06	118	19.73	114	14.57
CD(p=0.05)	0.44		NS		NS		NS	
SEm ±	0.15		0.16		13.57		6.64	
Variety								
Type-3 Basmati	20.41		20.59		128		120	
Taraori Basmati	21.72		21.46		98		94	
CD(p=0.05)	0.34		0.172		17		10.35	
SEm ±	0.11		0.58		5.55		3.45	

PCOC: Percent change over chemical control

Table.5 Effect of different organic, inorganic and integrated nutrient sources on grain yield (t/ha), straw yield (t/ha) and harvest index (%) of two basmati rice varieties in 2015

Treatments	Grain yield (t/ha)	PCOC	Straw yield (t/ha)	PCOC	Harvest index (%)	PCOC
T_1: GM + FYM (AWD)	2.97	4.85	5.35	3.65	35.68	0.74
T_2: Organic (AWD)	2.64	-6.73	4.46	-13.57	37.19	4.99
T_3: FYM+VC (AWD)	2.98	5.24	5.47	5.95	35.29	-0.35
T_4: SRI with FYM (AWD)	2.66	-6.02	4.58	-11.24	36.76	3.77
T_5: DSR + Soybean (LSI)	2.94	3.90	4.95	-4.15	37.28	5.25
T_6: Organic Control (CF)	2.73	-3.53	4.93	-4.37	35.63	0.58
T_7: Chemical Control (CF)	2.83	-	5.16	-	35.42	-
T_8: Integrated (CF)	2.98	5.41	5.50	6.53	35.19	-0.64
CD(p=0.05)	0.21		0.33		0.67	
SEm ±	0.06		0.11		0.22	
Variety						
Type-3 Basmati	2.86		5.16		35.66	
Taraori Basmati	2.83		4.94		36.44	
CD(p=0.05)	NS		0.14		0.71	
SEm ±	0.02		0.05		0.24	

PCOC: Percent change over chemical control

Table.6 Effect of different organic, inorganic and integrated nutrient sources on grain yield (t/ha), straw yield (t/ha) and harvest index (%) of two basmati rice varieties in 2016.

Treatments	Grain yield (t/ha)	PCOC	Straw yield (t/ha)	PCOC	Harvest index (%)	PCOC
T_1: GM + FYM (AWD)	2.99	3.24	5.68	3.49	34.52	-0.24
T_2: Organic (AWD)	2.52	-13.24	4.86	-11.48	34.11	-1.40
T_3: FYM+VC (AWD)	2.88	-0.58	5.55	1.10	34.20	-1.14
T_4: SRI with FYM (AWD)	2.64	-9.09	4.91	-10.51	34.99	1.13
T_5: DSR + Soybean (LSI)	3.27	12.85	5.28	-3.85	38.25	10.54
T_6: Organic Control (CF)	2.61	-9.93	5.27	-4.06	33.16	-4.17
T_7: Chemical Control (CF)	2.90	-	5.49	-	34.60	-
T_8: Integrated (CF)	3.00	3.52	5.71	4.01	34.46	-0.40
CD(p=0.05)	0.18		0.29		1.31	
SEm ±	0.06		0.10		0.43	
Variety						
Type-3 Basmati	2.89		5.42		34.76	
Taraori Basmati	2.81		5.26		34.81	
CD(p=0.05)	0.06		0.15		NS	
SEm ±	0.02		0.05		0.24	

PCOC: Percent change over chemical control

Similarly application of 50 % N through RDF + 50% N through vermicompost recorded higher 1000-grain weight (19.7 g) (Dekhane *et al.*, 2014). In another study highest test weight (22.32 g) was recorded in SRI treatment followed by DSR (21.84 g) which was significantly higher with organic control (19.88 g) and chemical control (20.00 g) treatment during 2012. While, in 2013, highest test weight was recorded in GM + VC treatment (23.33 g) which was significantly higher with DSR (19.70 g) and organic control (19.73 g) treatment. However, there was no significant difference in all treatments during 2014 (Singh *et al.*, 2017).

Number of filled grains/panicle

Number of filled grains/panicle of both the basmati rice varieties under different organic, inorganic and integrated treatments in 2015 and 2016 are summarized in Table 4. In 2015 maximum number of filled grains/panicle (127) were observed in T_4 SRI with FYM (AWD) and minimum (99) in T_7 Chemical Control (CF). The number of filled grains/panicle in the treatments followed the order T_4 SRI with FYM (AWD) > T_1 GM + FYM (AWD) > T_8 Integrated (CF) > T_5 DSR + Soybean (LSI) > T_3 FYM+VC (AWD) > T_2 Organic (AWD) > T_6 Organic Control (CF) > T_7 Chemical Control (CF). The maximum percent increase in number of filled grains/panicle (28.37 %) was observed in T4 SRI with FYM (AWD) over T_7 Chemical Control (CF) and minimum percent increase (3.88 %) in number of filled grains/panicle was found in T_6 Organic Control (CF) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher number of filled grains/panicle (128) was found in Type-3 than Taraori (98) basmati rice variety.

In 2016 maximum number of filled grains/panicle (123) was observed in T_4 SRI with FYM (AWD) and minimum (92) in T_5 DSR + Soybean (LSI). The number of filled grains/panicle in the treatments followed the order T_4 SRI with FYM (AWD) > T_8 Integrated (CF) > T_3FYM+VC (AWD) > T_1 GM + FYM (AWD) > T_6 Organic Control (CF) > T_7 Chemical Control (CF) > T_2 Organic (AWD) > T_5 DSR + Soybean (LSI). The maximum percent increase in number of filled grains/panicle (23.45 %) was observed in T_4 SRI with FYM (AWD) over T_7 Chemical Control (CF) and maximum percent decrease (-7.20 %) in number of filled grains/panicle was found in T_5 DSR + Soybean (LSI) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher number of filled grains/panicle (120) was found in Type-3 than Taraori (94) basmati rice variety. The number of grains per panicle contributes materially towards the final grain yield. It was reported that maximum filled grains per panicle (138.64) was observed in T_2 (100 % RDF) which was statistically at par with poultry manure + 50% of RDF (138.06) and compost + 50% of RDF (137.55) (Arif *et al.*, 2014). It may be due to the reason that SRI has wider spacing between the plants due to which there is less below and above ground competitions for better grain filling and more number of filled grains per panicle. Subsequently resulting in better source to sink conversion and in turn enhanced the production of more total number of seeds and filled seeds per panicle (Lu *et al.*, 2005).

In a similar experiment application of 50 % N through RDF + 50% N through vermicompost also recorded higher number of grains per panicle (128.0) (Dekhane *et al.*, 2014). The significantly higher number of filled grains per panicle (220.2) was recorded in SRI method as compared to conventional method (138.0) in Dehradun rice variety (Mandal *et al.*, 2015). The O_p treatment produced the highest filled grain percentage in both the dry (88.18%) and wet (80.67%) seasons but these values did not differ significantly from those recorded for the O_c and O_v treatments. The O_0 treatment produced the lowest percentages in both season (Moe *et al.,* 2017).

Grain yield, straw yield and harvest index

Grain yield, straw yield and harvest index of both the basmati rice varieties under different organic, inorganic and integrated treatments in both the years are summarized in Figure 2 and Table 5 & 6.

Grain yield (t/ha)

The grain yield in 2015 was maximum (2.98 t/ha) in T_8 Integrated (CF) and T_3 FYM+VC (AWD) (2.98 t/ha) and minimum (2.64 t/ha) in T_2 Organic (AWD). The grain yield in the treatments followed the order T_8 Integrated (CF) = T_3 FYM+VC (AWD) > T_1 GM + FYM (AWD) > T_5 DSR + Soybean (LSI) > T_7 Chemical Control (CF) > T_6 Organic Control (CF) > T_4 SRI with FYM (AWD) > T_2 Organic (AWD). The maximum percent increase in grain yield (5.41 %) was observed in T_8 Integrated (CF) over T_7 Chemical Control (CF) and maximum percent decrease (-6.73 %) in grain yield was found in T_2 Organic (AWD) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher grain yield (2.86 t/ha) was found in Type-3 than Taraori (2.83 t/ha) basmati rice variety.

In the year 2016 maximum grain yield (3.00 t/ha) was observed in T_8 Integrated (CF) and minimum (2.52 t/ha) in T_2 Organic (AWD). The grain yield in the treatments followed the order T_5 DSR + Soybean (LSI) > T_8 Integrated (CF) > T_1 GM + FYM (AWD) > T_7 Chemical Control (CF) > T_3 FYM+VC (AWD) > T_4 SRI with FYM (AWD) > T_6 Organic Control (CF) > T_2 Organic (AWD).The highest percent increase in grain yield (12.85 %) was observed in T_5 DSR + Soybean (LSI) over T_7 Chemical Control (CF) and maximum percent decrease (-13.24%) in grain yield was found in T_2 Organic (AWD) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher grain yield (2.89 t/ha) was found in Type-3 than Taraori (2.81 t/ha) basmati rice variety.

Straw yield (t/ha)

The straw yield in 2015 was maximum (5.50 t/ha) in T_8 Integrated (CF) and minimum (4.46 t/ha) in T_2 Organic (AWD). The straw yield in the treatments followed the order T_5 DSR + Soybean (LSI) > T_4 SRI with FYM (AWD) > T_7 Chemical Control (CF) > T_1 GM+FYM (AWD) > T_8 Integrated (CF) > T_3 FYM+VC (AWD) > T_2 Organic (AWD) > T_6 Organic Control (CF). The maximum percent increase in straw yield (6.53 %) was observed in T_8 Integrated (CF) over T_7 Chemical Control (CF) and maximum percent decrease (-13.57 %) in straw yield was found in T_2 Organic (AWD) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher straw yield (5.16 t/ha) was found in Type-3 than Taraori (4.94 t/ha) basmati rice variety.

In the year 2016 maximum straw yield (5.71 t/ha) was observed in T_8 Integrated (CF) and minimum (4.86 t/ha) in T_2 Organic (AWD).The straw yield in the treatments followed the order T_8 Integrated (CF) > T_1 GM + FYM (AWD) > T_3 FYM+VC (AWD) > T_7 Chemical Control (CF) > T_5 DSR + Soybean (LSI) > T_6 Organic Control (CF) > T_4 SRI with FYM (AWD) > T_2 Organic (AWD). The highest percent increase in straw yield (4.01%) was observed in T_8 Integrated (CF) over T_7 Chemical Control (CF) and maximum percent decrease (-11.48%) in straw yield was found in T_2 Organic (AWD) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher straw yield (5.42 t/ha) was found in Type-3 than Taraori (5.26 t/ha) basmati rice variety.

The higher yields in the integrated treatment could be due to the reason that there might be continuous supply of nutrients throughout the crop growth period (Aulakh *et al.,* 2016). In a similar experiment rice grown through conventional tansplanting (CT) gave significantly higher grain and straw yields as compared to that grown through SRI. Grain yield of rice was significantly influenced by INM as well as application of inorganic fertilizer over the control. The grain yields (4.44 to 4.23 t/ha) were recorded with the recommended doses of chemical fertilizers which were statistically at par in the INM treatments. However, grain yield and straw yield were higher in INM as compared to the recommended doses of chemical fertilizers (Singh *et al.,* 2013).

In another experiment also the application of 50 % N through RDF + 50% N through vermicompost recorded higher grain yield (4.97 t/ha) and straw yield (5.77 t/ha) of rice variety GR 11. Minimum grain yield (2.76 t/ha) and straw yield (3.53 t/ha) was in control with rice variety GR 11 (Dekhane *et al.,* 2014). Significantly higher grain yield (54 q/ha), straw yield (70 q/ha) were recorded under 100% RDF + vermicompost @ 5 mt/ha + *Trichoderma* compost @ 7.5 kg/ha (Shukla *et al.,* 2016).

Rice produced higher grain yield with different N source ratios. Among the three ratios of urea and organic sources, 50% urea and 50% organic sources resulted in the highest grain yield (9 417 kg/hm^2), followed by 75% urea and 25% organic sources (9 096 kg/hm^2), and 25% urea and 75% organic sources (9014 kg/hm^2). On average, application of N mixtures produced higher grain yield (9176 kg/hm^2) than applying pure organic source. There was no significant difference in grain yield with the application of animal manure and crop residue (Amanullah, 2016).

In an another study where integrated use of manure with fertilizers gave on an average 8.3-33.8% and 2.9-18.3% higher grain yield in Boro and T. Aman rice, respectively over sole fertilizers treatments (Bilkis *et al.,* 2017).

In a similar study all the treatments exerted significant influence on the yield of rice. Among the treatments, application of vermicompost @ 5t ha^{-1} with Azospirillum and phosphobacteria was superior and recorded the highest yield of rice. Treatment S_3 (Press mud @ 10t ha^{-1} with Azospirillum and phospho bacteria) was next in order of ranking. The least yield of rice was recorded in the treatment with no organic manure and biofertilizers (S_5) (Raman and Prakash, 2017).

Harvest index (%)

The harvest index in 2015 was maximum (37.28 %) in T_5 DSR + Soybean (LSI) and minimum (35.29 %) in T_3 FYM+VC (AWD). The harvest index in the treatments followed the order T_5 DSR + Soybean (LSI) > T_2 Organic (AWD) > T_4 SRI with FYM (AWD) T_1 GM + FYM (AWD) > T_6 Organic Control (CF) > T_7 Chemical Control (CF) > T_3 FYM+VC (AWD) > T_8 Integrated (CF). The maximum percent increase in harvest index (5.25 %) was observed in T_5 DSR + Soybean (LSI) over T_7 Chemical Control (CF) and maximum percent decrease (-0.64 %) in harvest index was found in T_8 Integrated (CF) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher harvest index was found in Taraori (36.44 %) than Type-3 (35.66 %) basmati rice variety.

In the year 2016 maximum harvest index (38.25 %) was observed in T_5 DSR + Soybean (LSI) and minimum (33.16 %) in T_6 Organic Control (CF). The harvest index in the treatments followed the order T_5 DSR + Soybean (LSI) > T_4 SRI with FYM (AWD) > T_7 Chemical Control (CF) > T_1 GM+FYM

(AWD) > T_8 Integrated (CF) > T_3 FYM+VC (AWD) > T_2 Organic (AWD) > T_6 Organic Control (CF). The highest percent increase in harvest index (10.54 %) was observed in T_5 DSR + Soybean (LSI) over T_7 Chemical Control (CF) and maximum percent decrease (-4.17 %) in harvest index was found in T_6 Organic Control (CF) over T_7 Chemical Control (CF). However among both the basmati rice varieties higher harvest index (34.81 %) was found in Taraori than Type-3 (34.76 %) basmati rice variety.

In a similar experiment harvest index of Pusa 44 was significantly higher as compared to that of PB1, but it was not significantly influenced due to difference in crop nutrition (Singh *et al.,* 2013)**.** Harvest index shows that there were significant differences among different manures. Poultry manure @ 10t/ha + 50% of RDF had highest HI (43.76%) while control had lowest harvest index. Higher yield and harvest index of poultry manure +50% of RDF indicates better partitioning of photosynthetic substance to economic yield (Arif *et al.,* 2014).

The harvest index (HI) ranged from 0.42 to 0.56 for both inorganic fertilizer and organic manure treatments and there were significant differences among them. However, similar HI values were measured among I_{50}, I_{75}, and I_{100} treatments throughout both seasons. For the organic manures, the O_p treatment produced the highest HI values. These were 0.54 and 0.51 in the dry and wet seasons, respectively. The lowest HI values were recorded for the I_0O_0 treatment (Moe *et al.*, 2017).

In conclusion the application of organic manures such as FYM and VC as well as green manure *Sesbania aculeata* were effective in enhancing growth, yield, and the yield components of the two basmati rice varieties (Type-3 and Taraori).

These results have immense potential for reducing the use of chemical fertilizers without decreasing the yield of the basmati rice varieties.

Since the introduction of high yielding varieties and increased use of chemical fertilizers and pesticides have lead to several harmful effects on the soil environment ultimately reducing the productivity of the soil by affecting the soil health.

It is felt that organic farming may solve all these problems by protecting/sustaining soil health. A major advantage of using organic wastes is that they not only act as the source of nutrients, but also provide micronutrients and enhance the microbial population of soils which help in mobilizing native nutrients in soil-plant system and also improve the efficiency of applied nutrients at very low cost.

Further studies on how various other different organic fertilizers such as poultry manure, fish manure etc and their combination might enhance the growth and yield of recently introduced basmati rice varieties might be performed in the future.

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