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Effect of Organic Nitrogen Management on Yield and Nutrient Uptake of Aromatic Rice (*Oryza sativa* L.) Genotype

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ABSTRACT

The field experiment were conducted to evaluate the response of integrated nitrogen management on productivity, nutrients uptake and nitrogen use efficiency of aromatic rice genotype during *kharif* season of2010 and 2011. The experiment comprised three aromatic rice genotype viz. Pusa Basmati-1, PRH-10 and HUR-105 and seven integrated nitrogen management practices viz 100% RND, 75% RND + 25% RND as FYM, 75% RND + 25% RND as VC, 75% RND + 25% RND as FYM + BGA, 75% RND + 25% RND as VC + BGA, 75% RND +25% RND as FYM + *Azospirillum* and 75% RND + 25% RND as VC + *Azospirillum*. Experiment was laid out in split plot design and replicated thrice. The results indicated that aromatic rice hybrid PRH-10 was recorded significantly highest number of panicle/ m^2, 1000-grain weight, grain and straw yield (t/ha), harvest index (%), nutrient content and their uptake and nitrogen use efficiency over Pusa Basmati-1. However, it is statistically at par with HUR-105. Application of 75% RND + 25% RND as VC +BGA at par with 75% RND + 25% RND as FYM + BGA and recorded significantly highest number of panicle/ m^2, 1000-grain weight, grain and straw yield (t/ha), harvest index (%), nutrient content and their uptake, nitrogen use efficiency and nitrogen uptake efficiency as compared to other treatments during both the years of investigation.

Keywords Integrated nitrogen, Yield, NUE, Aromatic rice.

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INTRODUCTION

Rice (*Oryza sativa* L.) provides more than half the daily food for one of every three persons in the world, especially for South-Eastern Asia, where 90% of the world production of rice are grown and consumed. At global level, it occupies an area of about 163.51 million ha with production and productivity of 498.65 million tonnes and 4.55 tonnes/ha, respectively (USDA 2018). India ranks first in respect of area 44.50 million ha second in production 115.63 million tonnes with average productivity 3.90 tonnes/ha (USDA 2018) . Aromatic rice varieties have occupied a prime position in national and international market because of their excellent quality characters. During 2018-19 basmati rice production in India about 5.5 million tonnes and export 1.5 million tonnes, it bring Rs 32,804.19 crores as foreign exchange to the country (APEDA 2019). In India rice productivity is still very low. During the last few decades, though country has witnessed some increase in productivity but to meet our expected demand of 140 million tonnes by the end of 2020, it can be achieved only by increasing the production by over 2 million tonnes per year in coming decades. Efficient input management is the basic concept that can help in achieving the target.

Rice is a heavy nitrogen feeder, however, fertilizer N efficiency in rice is very low under tropical conditions where it rarely exceeds 50% and usually ranges between 15 to 35% (De Dutta and Buresh 1989). Most of the N taken up by rice plant is supplied through soils own natural resources. In wetland rice cultivation, the significance of native soil N is apparent from the fact that 60–80% of N absorbed by the crop is derived from native pool (Broadbent 1979). A major portion of N in wetland soils occur in organic pool, though this is usually very low. Majority of small and marginal farmers do not have financial resources to purchase sufficient fertilizers to replace soil nutrients removed through crop harvests. As a result, soil fertility has declined and yields of staple food crops are typically low (Sanchez et al. 1997). Continuous use of chemical fertilizers, especially the nitrogenous fertilizers, may cause environmental hazards such as ground and surface water pollution by nitrate leaching that may deteriorate human and animal health (Pimentel 1996). One of the possible options to reduce their use could be recycling of locally available organic wastes, viz. crop residue, green manure, farmyard manure (FYM) and vermicompost, which can be a valuable and inexpensive source of plant nutrients. Positive effects of organic wastes on soil structure, aggregate stability and water-holding capacity have been well documented (Odlare et al. 2008). N-fixing blue-green algae (BGA) or cyanobacteria and *Azospirillum*, have been shown to be the most important in maintaining and improving the productivity of rice fields (Baba et al. 2010). It is well established that the growth, yields and quality parameters of aromatic rice increases with integrated nitrogen management practices through organic, inorganic and bio-fertilizers (Adhikari et al. 2005, Meena et al. 2019). Keeping these facts in consideration, the efforts were made to find out the response of integrated nitrogen management on productivity, nutrients uptake and nitrogen use efficiency of aromatic rice genotype.

MATERIALS AND METHODS

Experimental site

The field experiment were conducted during *kharif* season of 2010 and 2011 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India located at 25^o 18´ N latitude, 83^o 03´ E longitude and at altitude of 75.7 MSL of Indo-Gangetic region of Eastern UP (India). The soil of experimental site was sandy clay loam, 7.32 soil pH (pH meter) , 0.40% organic carbon (Walkley and Black 1934), 180.50 kg/ha available nitrogen (Subbiah and Asija 1973), 18.34 kg/ha available phosphorus (Olsen et al. 1954) and 208.42 kg/ha available potassium (Jackson 1973).

Experimental design and treatments

The experiment was laid out in split plot design consisting 21treatment combinations and were replicated thrice. The experiment comprised three aromatic rice genotype viz Pusa Basmati-1 (V_1) , PRH-10 (V_2) and HUR-105 (V_3) assigning main plot and seven integrated nitrogen management viz. 100% RND (F_1), 75% RND + 25% RND as FYM (F_2),75% RND + 25% RND as VC (F_3), 75% RND + 25% RND as FYM + BGA (F_4) 75% RND + 25% RND as VC + BGA (F_5), 75% RND+25% RND as FYM + *Azospirillum* (F_6) and 75% RND +25% RND as VC + *Azospirillum* (F_7) were allocated in sub-plot. Recommended doses of nitrogen, phosphorus and potassium (N, P_2O_5 and K_2O) i.e. @ 90, 40 and 30 kg ha^{-1}, respectively were applied to aromatic rice. The N, P and K were supplied through urea (46% N), DAP (46% P_2O_5 and 18% N) and muriate of potash (60% K_2O) respectively. Uniform basal application of phosphorus and potassium was made to all the plots. Half dose of nitrogen was applied as basal and remaining half dose applied in two equal splits at

Table 1. Effect of organic, inorganic and biofertilizers on growth and yield attributes of aromatic rice genotype. RND = Recommended nitrogen dose, FYM = Farmyard manure, VC= Vermicompost, BGA = Blue green algae.

Treatments	Number of panicles/m^2 2010	Number of panicles/m^2 2011	1000-grain weight (g) 2010	1000-grain weight (g) 2011	Grain yield (t/ha) 2010	Grain yield (t/ha) 2011	Straw yield (t/ha) 2010	Straw yield (t/ha) 2011	Harvest index (%) 2010	Harvest index (%) 2011
Genotype										
Pusa Basmati-1	239.48	258.79	19.27	19.83	4.21	4.36	7.04	7.13	37.43	37.96
PRH-10	294.00	320.79	22.21	22.61	5.11	5.25	7.48	7.62	40.57	40.81
HUR-105	282.45	295.59	21.90	21.93	4.89	5.05	7.38	7.54	39.83	40.08
LSD at 5%	29.98	31.62	1.10	1.27	0.20	0.21	0.33	0.35	1.40	1.49
Integrated nitrogen management										
100% RND	230.71	250.31	19.69	19.93	4.24	4.34	6.81	6.83	38.38	38.87
75% RND + 25% RND as FYM	260.44	261.91	20.53	21.06	4.60	4.70	7.14	7.25	39.19	39.28
75% RND + 25% RND as VC	266.24	276.89	20.79	20.79	4.69	4.84	7.25	7.35	39.24	39.64
75% RND + 25% RND as FYM + BGA	296.93	322.60	22.21	22.50	4.96	5.15	7.56	7.72	39.57	39.93
75% RND + 25% RND as VC + BGA	303.39	340.96	22.58	22.73	5.06	5.25	7.70	7.83	39.62	40.09
75% RND +25% RND as FYM + *Azospirillum*	269.24	286.67	20.88	21.27	4.77	4.94	7.30	7.47	39.43	39.74
75% RND + 25% RND as VC + *Azospirillum*	276.88	302.71	21.39	21.83	4.82	5.01	7.35	7.55	39.52	39.77
LSD at 5%	21.73	21.77	0.74	0.77	0.14	0.15	0.23	0.25	NS	NS
Interaction										
V × F	NS	NS	NS	NS	S	S	NS	NS	NS	NS

tillering and panicle initiation stages as per treatment requirement. Quantity of FYM and vermicompost to be applied were calculated as per their treatment requirement and thoroughly spread and mixed into respective plots. *Azospirillum* was applied mixed with FYM and vemicompost as per treatment requirement before transplanting and BGA was applied in standing water after 10 days of transplanting of rice during both the years of investigation. Seedlings of 25 days old were transplanted at 20 × 15 cm spacing under puddle conditions. The crop was harvested at the physiological maturity of rice during both the years. Irrigation applied depending upon requirements. The other crop management practices were followed as per standard recommendations.

Measurements and methods

Crop response to the treatments was measured in terms of yield, nutrients uptake and nitrogen use efficiency. Five hills in the net plot area were randomly selected and tagged for recording the yield attributes.

Nutrient uptake in grain and straw of the crops were calculated in kg/ha in relation to yield kg/ha by using the following formula :

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%)} \times \text{Yield (kg/ha)}}{100}$$

Nitrogen use efficiency as grain production per unit nitrogen available in the soil and nitrogen uptake efficiency is the efficiency of soil nitrogen can be taken up by the plant. It is calculated by formula given by Moll et al. (1982).

$$\text{Nitrogen use efficiency (kg/ha)} = \frac{\text{Grain yield (kg/ha)}}{\text{Nitrogen supply (kg/ha)}}$$

Table 2. Interaction effect of genotype and integrated nitrogen management on grain yield.

Treatments	Genotype 2010 Pusa Basmati-1	PRH-10	HUR-105	2011 Pusa Basmati-1	PRH-10	HUR-105
Integrated nitrogen management						
100% RND	3.91	4.51	4.31	4.01	4.59	4.33
75% RND + 25% RND as FYM	4.17	4.93	4.72	4.17	5.14	4.80
75% RND + 25% RND as VC	4.18	5.01	4.81	4.26	5.22	5.05
75% RND + 25% RND as FYM + BGA	4.32	5.37	5.19	4.51	5.55	5.38
75% RND + 25% RND as VC + BGA	4.44	5.52	5.24	4.69	5.62	5.45
75% RND + 25% RND as FYM + *Azospirillum*	4.21	5.22	4.90	4.40	5.32	5.09
75% RND + 25% RND as VC + *Azospirillum*	4.25	5.31	4.95	4.41	5.48	5.12
		LSD at 5%			LSD at 5%	
F at same levels of V		0.24			0.25	
V at same/ different levels of F		0.29			0.31	

$$\text{Nitrogen uptake efficiency (\%)} = \frac{\text{Total nitrogen uptake (kg/ha)}}{\text{Nitrogen supply (kg/ha)}} \times 100$$

Data analysis

The data recorded were analyzed by using the standard procedures of statistical analysis for Split Plot Design (Gomez and Gomez 1984). Analysis of variance (ANOVA) was used to determine the effect of each treatment. When F ratio was significant, a multiple mean comparison was performed using least significance difference test (0.05 probability level).

RESULTS

Number of panicles/m^2

Aromatic rice hybrid PRH-10 was produced significantly higher number of panicles/m^2 but remained at par with PRH-10. The lower number of panicles/m was observed with Pusa Basmati-1 during both the years of experimentation. The perusal of the result obtained after the statistical analysis of data, it became clear that integrated nitrogen management caused significant variation in number of panicles m^2 during 2010 and 2011 (Table 1). However, integrated nitrogen management treatment was significantly superior over 100% RND. The highest number of panicles/m^2 was observed with to application of 75% RND + 25% RND as VC + BGA and it showed significant superiority over rest of the treatments except treatment 75% RND + 25% RND as FYM + BGA which were at par with each others during both the years of investigation.

1000-grain weight

Varieties showed significant variation on 1000-grain weight (Table 2). Aromatic rice genotype PRH-10 and HUR-105 though proved equally effective in increasing 1000-grain weight but established their marked superiority over Pusa Basmati-1. The highest 1000-grain weight was obtained with aromatic rice hybrid PRH-10 and at par with HUR-105 during 2010 and 2011. However, lowest 1000-grain weight was obtained in Pusa Basmati-1 during both the years of investigation. Marked effect of integrated nitrogen management was noticed on 1000-grain weight during both the years of study. Application of 75% RND + 25% RND as VC + BGA proved significant superiority over other treatments in respect of 1000-grain weight . However, it is statistically at par with 75% RND + 25% RND as FYM + BGA during both the years of investigation. Minimum 1000-grain weight was recorded with treatment 100% RND.

Grain yield

Perusal of data on grain yield (t/ha) of rice revealed that aromatic rice hybrid PRH-10 produce significantly higher grain yield over HUR-105 and Pusa Basmati-1 (Table 1). The per cent increment by PRH-10 was 4.54 and 21.42% over HUR-105 and Pusa Basmati -1, respectively during 2010 of experiment. During 2011 of field trial the aromatic rice hybrid PRH-10 registered significantly higher grain yield but remained at par with HUR-105 and both genotype significantly superior over variety Pusa Basmati-1. The aromatic rice genotype PRH-10 and HUR-105 recorded 20.48 and 13.51% more yield than Pusa Basmati-1, respectively. The grain yield markedly increased significantly by integrated nitrogen management practices over fertilizer alone during both the years of study. Application of 75% RND + 25% RND as VC + BGA produced maximum grain yield over other treatments and it was 19.38 and 20.88% more than 100% RND during 2010 and 2011, respectively but remained at par with 75% RND + 25% RND as FYM + BGA. However, it was recorded 16.86 and 18.54 more yield than 100% RND during both the years, respectively. Interactions between genotype×organic, inorganic nitrogen sources along with biofertilizers were significant with respect to grain yield of aromatic rice during both years of study. Aromatic rice hybrid PRH-10 with 75% RND + 25% RND as VC + BGA recorded higher grain yield.

Straw yield

Aromatic rice hybrid PRH-10 was produced significantly higher straw yield (t/ha) but remained at par with HUR-105 and both varieties significantly superior over Pusa Basmati-1 during both the years of study. The perusal of the result obtained after the statistical analysis of data, it is clear that integrated nitrogen management caused significant variation in straw yield during 2010 and 2011. However, integrated nitrogen management treatment was significantly superior over 100% RND. The highest straw yield was observed due to application of 75% RND + 25% RND as VC + BGA and it showed significant superiority over rest of the treatments during both the years except treatment 75% RND + 25% RND as FYM + BGA which were at par with each others during both the years of experimentation.

Harvest index

Data of harvest index (%) differed significantly by aromatic rice genotype during both the years of study. PRH-10 registered significantly higher harvest as compared to Pusa Basmati-1. Genotype HUR-105 was at par with PRH-10 during both the year of study. Integrated nitrogen management practices failed to influence the harvest index during 2010 and 2011.

Nutrients content in grain and straw

Among the different aromatic rice genotype, PRH-10 recorded the highest N, P and K content in grain and straw which was significantly superior over Pusa Basmati-1(Table 3). The aromatic rice genotype HUR-105 was at par with PRH-10 during both the years of study. A close scanning of data clearly manifested marked effect of integrated nitrogen on nitrogen content in straw and highest N, P and content in grain and straw was recorded with application of 75% RND + 25% RND as VC + BGA which was significantly superior over other treatment and at par with 75% RND + 25% RND as FYM + BGA during both the years. The treatment 75% RND + 25% RND as FYM, 75% RND + 25% RND as VC and 75% RND + 25% RND as FYM + *Azospirillum* at par with each other and 75% RND + 25% RND as VC + *Azospirillum* at par with 75% RND + 25% RND as FYM + *Azospirillum* and significantly superior than 100% RND during both the years experimentation.

Nutrients uptake by grain and straw

Genotype showed significant variation on N, P and K uptake by grain and straw (Table 4). Rice hybrid PRH-10 recorded significantly higher N, P and K uptake by grain and straw over Pusa Basmati-1. Whereas HUR-10 at par with PRH-10 during both the years of experimentation. Incorporation of integrated nitrogen management brought about significant improvement in N, P and K uptake. Application of 75% RND + 25% RND as VC + BGA significant superior over rest of the treatment and being at par with 75% RND + 25% RND as FYM + BGA in respect of N, P, K uptake by grain and straw. The lowest N, P and K uptake by grain and straw was observed in application of 100%

Table 3. Effect of organic, inorganic and biofertilizers on nutrients content of aromatic rice genotype. RND = Recommended nitrogen dose, FYM = Farmyard manure, VC = Vermicompost, BGA = Blue green algae.

	Nutrients content (%)											
	Nitrogen				Phosphorus				Potassium			
	Grain		Straw		Grain		Straw		Grain		Straw	
Treatments	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Genotype												
Pusa Basmati-1	1.205	1.222	0.440	0.437	0.193	0.203	0.129	0.128	0.292	0.300	1.698	1.705
PRH-10	1.276	1.281	0.477	0.492	0.232	0.253	0.161	0.166	0.329	0.336	1.742	1.753
HUR-105	1.274	1.277	0.474	0.490	0.230	0.250	0.159	0.165	0.319	0.333	1.737	1.734
LSD at 5%	0.041	0.043	0.023	0.030	0.019	0.026	0.017	0.020	0.026	0.031	0.034	0.035
Integrated nitrogen management												
100% RND	1.215	1.221	0.432	0.427	0.183	0.190	0.119	0.118	0.286	0.277	1.682	1.677
75% RND + 25% RND as FYM	1.236	1.228	0.448	0.458	0.203	0.217	0.142	0.141	0.305	0.306	1.715	1.708
75% RND + 25% RND as VC	1.247	1.249	0.457	0.459	0.214	0.234	0.148	0.148	0.308	0.314	1.723	1.741
75% RND + 25% RND as FYM + BGA	1.271	1.290	0.482	0.490	0.238	0.264	0.163	0.173	0.328	0.351	1.744	1.761
75% RND + 25% RND as VC + BGA	1.282	1.308	0.487	0.502	0.245	0.272	0.170	0.179	0.338	0.371	1.753	1.771
75% RND + 25% RND as FYM + *Azospirillum*	1.248	1.255	0.461	0.458	0.219	0.229	0.150	0.150	0.314	0.321	1.730	1.724
75% RND + 25% RND as VC + *Azospirillum*	1.253	1.271	0.467	0.477	0.225	0.242	0.157	0.160	0.319	0.336	1.736	1.733
LSD at 5%	0.027	0.031	0.014	0.021	0.013	0.015	0.012	0.013	0.018	0.022	0.022	0.022

RND during both the years. Genotype × integrated nitrogen management produced marked variation on N removal by grain during both the years (Table 5). Application of 75% RND + 25% RND as VC +

Table 4. Effect of organic, inorganic and biofertilizers on nutrients uptake of aromatic rice genotype. RND = Recommended nitrogen dose, FYM= Farmyard manure, VC= Vermicompost, BGA =Blue green algae.

	Nutrients uptake (kg/ha)											
	Nitrogen				Phosphorus				Potassium			
	Grain		Straw		Grain		Straw		Grain		Straw	
Treatments	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Genotype												
Pusa Basmati-1	50.77	53.41	30.98	31.21	8.15	8.90	9.10	9.15	12.34	13.16	119.65	121.67
PRH-10	65.34	67.25	35.77	37.61	11.95	13.41	12.12	12.66	16.83	18.03	130.39	133.67
HUR-105	62.34	64.93	35.05	36.94	11.29	12.60	11.80	12.49	15.62	17.39	128.38	130.91
LSD at 5%	3.62	3.82	2.41	2.43	1.22	1.24	1.49	1.62	1.77	1.81	6.16	6.46
Integrated nitrogen management												
100% RND	51.64	53.05	29.54	29.57	7.84	8.29	8.10	8.10	12.18	12.29	114.55	114.56
75% RND + 25% RND as FYM	57.07	57.86	32.11	33.70	9.39	10.27	10.13	10.27	13.86	14.49	122.47	123.93
75% RND + 25% RND as VC	58.63	60.63	33.27	34.13	10.12	11.44	10.78	10.91	14.48	15.48	124.99	128.02
75% RND + 25% RND as FYM + BGA	63.21	66.89	36.66	38.37	11.90	13.74	12.36	13.39	16.34	18.34	132.00	136.05
75% RND + 25% RND as VC +BGA	65.11	68.82	37.66	39.77	12.53	14.36	13.14	14.04	17.17	19.70	135.02	138.84
75% RND + 25% RND as FYM + *Azospirillum*	59.90	62.06	33.82	34.62	10.54	11.39	10.96	11.21	15.04	16.09	126.32	128.83
75% RND + 25% RND as VC + *Azospirillum*	60.85	63.75	34.46	36.51	10.94	12.18	11.56	12.12	15.41	17.04	127.64	131.01
LSD at 5%	2.19	2.20	1.49	1.70	0.81	0.87	0.89	1.00	1.20	1.22	4.22	4.27
Interaction												
V × F	S	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5. Interaction effect of genotype and organic, inorganic and biofertilizers on nitrogen uptake.

	Genotype					
	2010			2011		
Treatments	Pusa Basmati-1	PRH-10	HUR-105	Pusa Basmati-1	PRH-10	HUR-105
Integrated nitrogen management						
100% RND	46.24	54.44	54.23	49.05	55.85	54.24
75% RND + 25% RND as FYM	49.77	61.99	59.44	49.81	63.89	59.86
75% RND + 25% RND as VC	50.41	63.77	61.05	51.56	65.98	64.35
75% RND + 25% RND as FYM + BGA	52.58	69.97	67.08	56.28	72.46	71.91
75% RND + 25% RND as VC + BGA	54.45	72.19	68.70	59.37	74.52	72.58
75% RND + 25% RND as FYM + *Azospirillum*	50.89	66.84	62.45	53.53	67.53	65.11
75% RND + 25% RND as VC + *Azospirillum*	51.05	68.20	63.46	54.26	70.52	66.46
		LSD at 5%			LSD at 5%	
F at same levels of V		3.79			3.80	
V at same/different levels of F		4.98			5.13	

BGA with PRH-10 recorded maximum N removal by grain.

Nitrogen use efficiency and nitrogen uptake efficiency

Rice hybrid PRH-10 registered higher nitrogen use efficiency and nitrogen uptake efficiency and at par with HUR-105 both genotype significantly superior over Pusa Basmati-1 during 2010 and 2011 (Table 6). The perusal of the result obtained after the statistical analysis of data, it is clear that organic, inorganic nitrogen sources along with biofertilizers were significantly superior over alone application of recommended nitrogen dose during both the years. Application of 75% RND + 25% RND as VC + BGA recorded significantly higher nitrogen use efficiency and nitrogen uptake efficiency but remained at par with 75% RND + 25% RND as FYM + BGA during both the years. The lower nitrogen use efficiency and

Table 6. Effect of genotype and integrated nitrogen management on nitrogen efficiency and nitrogen uptake efficiency of aromatic rice. RND = Recommended nitrogen dose, FYM=Farmyard manure, VC = Vermicompost, BGA + Blue green algae.

	Nitrogen use efficiency (kg kg^{-1})		Nitrogen uptake efficiency (%)	
Treatments	2010	2011	2010	2011
Genotype				
Pusa Basmati-1	46.79	48.51	90.83	94.02
PRH-10	56.82	58.43	112.33	116.51
HUR-105	54.35	56.08	108.22	113.19
SEm ±	0.61	0.62	1.47	1.49
CD (p=0.05)	2.39	2.44	5.77	5.87
Integrated nitrogen management				
100% RND	47.17	48.26	90.20	91.80
75% RND + 25% RND as FYM	51.21	52.28	99.09	101.73
75% RND + 25% RND as VC	52.14	53.84	102.10	105.40
75% RND + 25% RND as FYM + BGA	55.13	57.20	110.97	116.95
75% RND + 25% RND as VC + BGA	56.32	58.34	114.15	120.65
75% RND + 25% RND as FYM + *Azospirillum*	53.00	54.85	104.14	107.42
75% RND + 25% RND as VC + *Azospirillum*	53.59	55.61	105.90	111.40
SEm ±	0.56	0.58	1.39	1.45
CD (p=0.05)	1.60	1.66	3.99	4.16

nitrogen uptake efficiency was under the treatment 100% RND during 2010 and 2011.

DISCUSSION

In physiological term, yield of most cereals is largely governed by source (photosynthesis) and sink (grain growth) relationship (Evans and Wardlaw 1976). However, capacity of system transporting the photosynthesis and partitioning of assimilates between their sites of utilization i.e. sink, are the major determinants of crop yield (Gifford and Evans 1981, Meena et al. 2019). Thus crop yield and quality are net result of interactions between the genetic structure of genotypes and the external environment. The highest panicles/m^2, 1000-grain weight, grain and straw yield and harvest index were registered significantly in aromatic rice hybrid PRH-10. This might be due to more number of tillers per unit area, better growth and development of panicles, higher photosynthetic efficiency due to LAI and finally better genetic makeup of genotypes. Alim (2012) also reported that most of the yield components i.e. bearing tillers hill^{-1}, panicle length number of grains panicle^{-1}, 1000-grain weight, grain yield, straw yield and biological yield were significantly influenced due to genotype. Similar results on variation in the yield attributes by rice genotype have been reported by Manzoor et al. (2006), Hossain et al. (2008), Islam et al. (2012), Sharma et al. (2012).

Nutrients content their uptake by grain and straw, nitrogen use efficiency and nitrogen uptake efficiency were significantly higher with aromatic rice hybrid PRH-10 during 2010 and 2011. The significant variation in NPK content, their uptake by grain and straw, nitrogen use efficiency and nitrogen uptake efficiency among the genotypes might be due to their genetic characteristic and differential performance in growth and development. Mannan (2005) observed that the significant variation of N uptake among the genotype. These results are agreement with the findings of Adhikari et al. (2005), Sikdar et al. (2008), Hassan et al. (2009), Narayanrao (2010), Sharma et al. (2012).

Nutrient balance with proper integration of fertilizer/manure/biofertilizers is a critical factor for maximizing the growth and yield of a rice. The application of 75% RND + 25% RND as VC + BGA recorded higher plant height, dry matter accumulation, crop growth rate and relative growth rate. This is probably because 25% N substituted by VC or FYM and BGA when combined with fertilizer released the nitrogen probably at faster rate and longer time that providing sufficient amount of nitrogen for required various metabolic processes and perform better in mobilization of synthesized carbohydrates into amino acids and proteins, which is turn stimulated rapid cell division and cell elongation and facilitated faster vegetative growth and leads to higher internodal elongation and finally enhanced the growth characters (Xiuming et al. 2004, Garai et al. 2013). The additional nitrogen fixed by BGA increased the availability of major nutrients into the soil that results greater supply of nitrogen and plant growth regulating substances such as IAA, hormone with efficient utilization for cell multiplication and enlargement. It is also for the formation of nucleic acids and other virtually important organic compounds in cell sap (Khadayate et al. 2005). Natarajan et al. (2008) also reported that the application of 50% N was inorganic with 50% N through *Sesbania aculeate* was found to be the best in enhancing the plant height and number of tillers in both the seasons at various stages.

Yield is a function of complex inter-relationships of its components, which are determined from the growth rhythms in vegetative phase and its subsequent reflection in reproduction phase of the plant. Vigorously growing plants are able to absorb larger quantity of mineral nutrients through well- developed root system. Significant increase in the number of panicles/m^2, 1000-grain weight, grain and straw yield were recorded due to application of 75% RND + 25% RND as VC + BGA. Higher nitrogen absorption by the plants from tillering to panicle initiation stage helped to produce more number of panicles, panicle length and panicle weight. Thakur et al. (2011) also showed that higher number of spikelet's due to integrated fertilizer management as compared to chemical fertilizer alone. Vermicompost also contains solubilizing bacteria which might have solubilized the native nitrogen, phosphorus and other micronutrients in the soil/root zone of the crop thereby increasing their availability toplants. Therefore, yield attributes and yield increased (Kumar et al. 2007). BGA also excrete Vitamin B_{12}, ascorbic acid and auxins which may improve the growth, yield attributes and finally yield of rice crop. These results are in close conformity with the findings of Patro et al. (2011).

Integrated approaches of organic inorganic and biofertilizers nutrient management have increased the N, P, K content, their uptake by grain and straw, nitrogen use efficiency and nitrogen uptake efficiency. This is because of minimal loss of nitrogen in case of organic sources and nitrogen was available to the crop for longer period. Due to application of vermicompost in lowland rice, the activity of beneficial microbes and colonization of micorhizal fungi increased, which play an important role in mobilization of nutrients and thereby leading to better availability of nutrients facilitating uptake by plants resulting in high nitrogen use efficiency (Chakravorti and Samantaray 2006). Sahrawat (1979) reported that mineral nitrogen through inorganic fertilizer was more susceptible to different type of nitrogen losses and hence it had low nitrogen use efficiency as compared to organic materials. There is continuous supply of nitrogen by organic manures and tying up of inorganic soil nitrogen prevents its loss through denitrification, volatilization or leaching. Similar results have also been reported by Khan et al. (2010), Baba et al. (2010).

CONCLUSION

The results indicate that application of 75% RND + 25% RND as VC + BGA with aromatic rice hybrid PRH-10 were significantly increased the panicles/m^2, 1000-grain weight, yield, nutrients content and their uptake and nitrogen use efficiency of aromatic rice during both the years of experimentation.

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