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Productivity and profitability of aerobic rice (*Oryza sativa*) as influenced by varieties and integrated nitrogen management

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ABSTRACT

A field experiment was conducted during the *kharif* seasons of 2009 and 2010 at Indian Agricultural Research Institute, New Delhi to study productivity and profitability of aerobic rice as influenced by varieties and integrated nitrogen management. The experimental treatments included 2 rice varieties, viz. Pusa Basmati 1 and Pusa Basmati 1121 and 8 integrated nitrogen management practices, viz. N control (N_0); 100% RDN (120 kg N/ha through urea); 75% RDN + 25% N through farmyard manure; 75% RDN + 25% N through green manuring; 75% RDN + 25% N through biofertilizers; 75% RDN + 25% N through vermicompost; 100% N through FYM+GM+BF+VC and 100% N through FYM+GM+BF+VC+$ZnSO_4$. The results showed that rice variety Pusa Basmati 1 out performed Pusa Basmati 1121 in yield attributes, grain yield and harvest indices. Application of recommended dose of nitrogen (RDN) through integrated nitrogen management (INM) approach significantly increased the crop growth parameters, yield attributes, grain as well straw yields and net returns over other INM approaches. Treatment with 100% N by FYM+GM+BF+VC+Zn showed highest crop growth and yield attributes, grain and straw yield and net returns as compared to other integrated nitrogen management treatments, but this treatment was closely followed by 100% N by FYM+GM+BF+VC and 75% RDN + 25% VC during both the years.

Key words: Aerobic rice, *Basmati* rice, Integrated nitrogen management, Net return, Vermicompost, Yield attributes

Rice is the most important cereal crop of India. The conventional method of rice culture (puddled and transplanted) consumes a great amount of water. However, the water scarcity is becoming more and more a global concern and in India signs of serious water scarcity are already evident in agricultural areas. It is estimated that by 2025, 2 million ha of Asia's irrigated dry-season rice and 13 million ha of its irrigated wet-season rice may experience 'physical water scarcity', and most of the approximately 22 million ha of irrigated dry-season rice in South and Southeast Asia may suffer 'economic water scarcity' (Tuong and Bouman 2003). The shortage of water available for irrigation may affect the rice production severely, particularly in the light of climatic changes. Various water-saving technologies exist or are being developed to help farmers cope with water scarcity in irrigated environments. These technologies increase the productivity of water inputs (rainfall, irrigation) mainly by reducing unproductive seepage and percolation losses and to a lesser extent by reducing evaporation (GRiSP, 2013). In this direction, the aerobic rice cultivation method (direct seeding) can play an important role to reduce the water use in rice production.The aerobic rice is a new production system in which rice is grown under non puddled, non flooded, and non saturated soil conditions as other upland crops (Prasad 2011). The major gain is water saving, which may be 50–60% less in aerobic rice as compared to puddled and transplanted rice. Thus in aerobic rice, soils are kept aerobic almost throughout the rice growing season (Prasad, 2011), which helps in saving water. The rice production under aerobic system is a new concept in India to grow rice using high yielding varieties under irrigated environment. A few preliminary studies suggest that the nutrient requirements for the same variety under similar environment are different from puddled and transplanted rice. The information on nitrogen management under aerobic rice is not available for *Basmati* varieties. Given the importance of nitrogen fertilization in rice, it is necessary to know the optimum dose for *Basmati* varieties. Further, it is also important to find out the nitrogen sources or their combinations which give better crop performance, yields and improvement in soil fertility. Chemical fertilizers alone may not be a better choice to achieve long-term sustainability of rice production. The high doses of chemical fertilizers create health hazard and reduces microbial population in

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soil besides being quite expensive and increase the cost of crop production (Balasubramanian and Wahab 2012). In such a situation, the integrated nitrogen nutrition through combined dose of chemical fertilizer and organic nutrients/ amendments like FYM, vermicompost, biofertilizers and green manures can play an important role in increasing crop productivity with lesser harm on the environment (Singh *et al.* 2011). Considering these aspects, a field experiment was conducted to find out productivity and profitability of aerobic rice as influenced by varieties and integrated nitrogen management.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* seasons of 2009 and 2010 at the research farm of Indian Agricultural Research Institute, New Delhi situated at latitude of 28°40' N and longitude of 77°12' E, altitude of 228.16 m above the mean sea level. Total rainfall received at the experimental farm during the growing seasons (July to November) was 529.2 mm and 925.2 mm during 2009 and 2010, respectively. In the first year, the rainfall was much less than the normal rainfall, but in the second year, it was much higher than the normal rainfall.

The experiment was conducted in a sandy clay loam soil. The initial soil sample of experimental field had 160.0 kg/ha alkaline permanganate oxidizable N, 15.0 kg/ha available P, 262.0 kg 1 N ammonium acetate exchangeable K, 0.40% organic carbon and 8.2 pH. Before sowing, the field was pre-irrigated, ploughed, harrowed and leveled for the experimentation. *Sesbania* seeds were sown in adjacent field in summer for green manuring. The experiment was laid out in split plot design. There were 16 treatment combinations including 2 rice varieties (Pusa Basmati 1 and Pusa Basmati 1121) and 8 nitrogen management practices, viz. N control (N_0); 100% recommended dose of nitrogen (RDN), i.e. 120 kg N/ha through urea); 75% RDN + 25% N through farmyard manure (FYM); 75% RDN + 25% N through green manuring (GM); 75% RDN + 25% N through *Azotobacter* biofertilizers (BF); 75% RDN + 25% N through vermicompost (VC); 100% N through FYM+GM+BF+VC and 100% N through FYM+GM+BF+VC+$ZnSO_4$. Seed of both varieties were treated with bactericide (Streptocycline) and fungicide (Bavistin) and manually drilled in plots with a row spacing of 20 cm. The seed rate for both varieties was 30 kg/ha. A common dose of P (60 kg P_2O_5/ha) and K (40 kg K_2O/ha) was applied in all the plots as basal through single super phosphate (SSP) and muriate of potash (MOP), respectively. Nitrogen was applied through urea, FYM, green manuring, bio-fertilizers (*Azotobacter)* and vermicompost, as per treatment. Quantity of FYM, *Sesbania* green manure, biofertilizers and vermicompost was computed on the basis of their N concentration/contribution and these were applied as basal. Detailed analysis of applied organic sources is given in Table 1.

The field was kept under non-saturated aerobic condition throughout the whole growing seasons. Supplemental surface irrigations were applied on a few occasions when crop leaves started to roll (in the afternoon) due to drought/stress and drainage was conducted whenever heavy rains resulted in ponding of water. For weed-management, pre-emergence Pendimethalin (Stomp) @ 3.3 liter/ha was sprayed two days after seeding. For management of post-emergence weeds, herbicide Cyhalofop butyl (Cleancher) was sprayed @ 800 ml/ha at 15 days after sowing and it was followed by hand weeding twice at 25 and 40 days after sowing. Observations on seed germination were taken and gap filling was done to maintain the uniform plant population in all the plots. At maturity, border area on all sides was removed and remaining hills were harvested as net plot. Observations were recorded on plant growth parameters, yield attributes and yield of rice during both the years, but mean data is reported in this paper. Economics of different nutrient sources for aerobic rice was also worked out. Statistical analysis of mean data was done as per the procedure of analysis of variance and significance of a split plot design was tested by "F" test. Standard error of means (SEm+) and least significant difference (LSD) at 5% level of significance were worked out for mean values of each parameter.

Table 1 Detailed analysis of nutrients in FYM, vermicompost and *Sesbania* (dry weight basis)

Nutrient	Vermicompost		FYM		*Sesbania aculeata*	
	2009	2010	2009	2010	2009	2010
N (%)	1.65	1.71	0.45	0.47	2.74	2.65
P_2O_5 (%)	0.54	O.57	0.17	0.18	0.14	0.15
K_2O (%)	1.34	1.40	0.55	0.56	1.54	1.48
Ca (%)	0.44	0.47	0.91	0.88	0.96	0.98
Mg (%)	0.15	0.14	0.19	0.21	0.32	0.34
Fe (ppm)	175.2	163.62	146.50	132.35	124.34	123.21
Mn (ppm)	96.51	95.34	69.00	71.33	65.32	62.22
Zn (ppm)	24.43	21.51	14.50	14.37	13.17	14.21
Cu (ppm)	4.89	4.32	2.80	2.78	4.47	4.76
C:N ratio	15.50	14.22	25.22	26.19	22.54	23.67

RESULTS AND DISCUSSION

Crop growth

Rice variety Pusa Basmati 1121 had much better growth in terms of plant height, number of tillers and dry matter accumulation than Pusa Basmati 1 (Table 2).Varietal differences in plant growth of different rice varieties has been reported by several researchers and this difference is mainly due to their genetic constitution (Adhikari 2004). Among the treatments of integrated nitrogen management (INM), plant growth parameters like plant height, number of tillers and dry matter accumulation at control treatment were significantly lower than all the other treatments having application of organic or inorganic fertilizers alone or in combination. Treatment with 100% N by FYM + GM + BF + VC + Zn showed highest plant growth as compared to other integrated nitrogen management treatments but, this treatment was very close with the treatm=ents having 100%

Table 2 Effect of rice varieties and integrated nitrogen management on plant growth parameters at different growth stages

Treatment	Plant height (cm.)				No. of tillers/meter row length (nos.)				Dry matter accumulation (g/plant)			Days to 50% flowering
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	
Variety												
Pusa Basmati 1	33.4	65.2	96.1	94.6	96.3	150.6	118.6	106.7	5.7	17.8	21.2	78.4
Pusa Basmati 1121	36.4	72.7	98.0	96.9	120.1	173.2	138.2	129.4	6.5	18.8	21.8	83.0
S Em ±	0.23	0.65	0.69	0.67	0.85	1.13	1.62	1.33	0.06	0.13	0.12	0.28
LSD (P=0.05)	0.67	1.89	2.01	1.95	2.48	3.27	4.70	3.86	0.18	0.40	0.37	0.81
Integrated nitrogen management (INM)												
N control (N_0)	30.4	62.8	84.7	87.0	87.0	125.7	102.1	95.3	5.0	14.5	17.7	78.8
100% RDN (120 kg N/ha)	35.0	68.5	95.6	95.5	108.5	162.4	130.2	118.2	5.9	17.6	21.0	80.5
75% RDN+25% FYM	36.0	70.9	98.7	96.3	110.6	168.9	132.7	120.4	6.2	18.1	21.7	81.0
75% RDN+25% GM	34.3	65.7	94.6	93.4	101.4	148.9	121.7	114.1	5.9	17.3	20.7	80.0
75% RDN+25% BF	33.6	64.8	92.7	91.8	98.0	142.8	115.5	109.9	5.6	17.1	20.3	78.8
75% RDN+25% VC	36.0	72.4	101.2	98.5	111.5	172.4	136.6	125.4	6.6	19.6	22.8	81.5
100% N by FYM+ GM+BF+VC	36.8	74.1	102.9	101.0	116.1	175.0	141.2	128.5	6.7	20.6	23.5	82.0
100% N by FYM+ GM+BF+VC+$ZnSO_4$	37.3	74.8	106.1	102.9	132.7	197.4	147.3	132.7	6.8	21.2	24.3	82.5
SE m ±	0.46	1.30	1.38	1.35	1.71	2.26	3.24	2.66	0.12	0.26	0.25	0.59
LSD (P=0.05)	1.35	3.77	4.01	3.91	4.96	6.55	9.39	7.73	0.36	0.80	0.74	1.71

RDN, Recommended dose of nitrogen; FYM; farmyard manure; GM; greeen manuring; BF; biofertilizers; VC; vermicompost; NS; non significant; DAS; days after sowing.

N by FYM+GM+BF+VC and 75% RDN + 25% VC at all the growth stages. Best response due to the treatment having 100% N by FYM+GM+BF+VC+Zn might be due to the balanced and integrated supply of N and other nutrients, vitamins, hormones etc. by this treatment. Application of N with 75% RDN + 25% FYM also recorded higher plant growth than 100% RDN but differences were not significant. Application of N with 100% RDN exhibited higher plant height and dry matter accumulation than treatment with 75% RDN + 25% GM and 75% RDN + 25% BF in all the observations but the differences between these treatments were non-significant. Increase in growth parameters like plant height, tillers and dry matter production of aerobic rice by different nitrogen management practices has also been reported by many researchers (Sathiya and Ramesh 2009, Balasubramanian and Wahab 2012). They argued that increase in plant growth might be due to the presence of more available nutrients, vitamins and phyto-regulators. Kadiyala *et al.* (2012) reported increased plant growth parameters due to nitrogen application over control in aerobic rice. They explained that better plant growth due to INM might be attributed to more availability of nitrogen that play important role in cell division. Besides this, plant growth also depends largely upon soil physical conditions that were improved due to the addition of organic matter.

Rice variety Pusa Basmati 1121 took significantly more number of days to 50% flowering as compared to Pusa Basmati 1. Pusa Basmati 1121 took 83 days while PB 1 took 78.4 days for 50% flowering. This might be mainly due to their genetic constitution and varietal characteristics. Application of RDN and INM significantly increased the number of days to 50% flowering over the control treatments. Application of RDN and INM also delayed the flowering over control treatment. Krishna *et al.* (2008) also reported significant increase in number of days to 50% flowering due to the application of FYM and recommended dose of fertilizers (RDF) over the control. It confirms the beneficial role of organic amendments on growth attributes, particularly in aerobic rice.

Yield attributes

Rice variety Pusa Basmati 1 showed significantly higher values of yield attributes viz. panicle length, no. of filled grains, total grains/panicle and spikelet fertility as compared to Pusa Basmati 1121 (Table 3). However, yield attributes like effective tillers and 1000-grain weights were significantly higher in Pusa Basmati 1121 than Pusa Basmati 1. Difference in yield attributes of both the rice varieties might be due to their genetic makeup and their response to nitrogen nutrition. Singh *et al.* (2010) reported difference in yield attributes of rice varieties. Application of RDN and INM significantly influenced the yield attributes over the control. Application of 100% N by FYM+GM+BF+VC+Zn showed significantly higher values of yield attributes as compared to all the other treatments and it was followed by 100% N by FYM+GM+BF+VC. Many researchers have reported the increased number of effective tillers, panicle length and number of grains/panicle due to the integrated application of fertilizers and organic sources (Mahajan *et al.* 2011, Balasubramanian and Wahab 2012, Kadiyala *et al.* 2012).

Table 3 Effect of rice varieties and integrated nitrogen management on yield attributes

Treatment	Yield attributes						
	Effective tillers/m	Panicle length (cm)	1000 Grain weight (g)	Filled grains/ panicle	Unfilled spikelets/ panicle	Total grains/ panicle	Spikelet fertility (%)
Variety							
Pusa Basmati 1	97.3	27.7	20.4	124.1	32.0	156.1	78.8
Pusa Basmati 1121	120.0	25.0	28.1	79.5	28.3	107.7	73.2
SEm ±	1.16	0.25	0.03	1.44	0.69	1.49	0.43
LSD (P=0.05)	3.36	0.71	0.09	4.18	1.99	4.31	1.25
Integrated nitrogen management (INM)							
N control (N_0)	87.5	25.1	23.3	69.3	43.1	112.3	60.3
100% RDN (120 kg N/ha)	109.4	26.3	24.2	98.7	31.2	129.8	75.7
75% RDN+25% FYM	111.3	26.4	24.4	102.5	28.2	130.7	77.9
75% RDN+25% GM	107.0	26.0	24.0	95.5	31.6	127.1	74.8
75% RDN+25% BF	101.6	25.5	23.6	90.3	35.5	125.8	71.4
75% RDN+25% VC	113.1	26.7	24.6	109.9	25.8	135.7	80.6
100% N by FYM+GM+BF+VC	118.1	27.0	24.8	119.5	24.3	143.7	82.5
100% N by FYM+GM+BF+VC+$ZnSO_4$	121.1	28.0	25.0	128.7	21.4	150.1	85.0
SEm ±	2.32	0.49	0.06	2.88	1.37	2.97	0.86
LSD (P=0.05)	6.73	1.43	0.19	8.36	3.99	8.62	2.50

Yield and harvest index

Pusa Basmati 1 *variety* of rice produced significantly higher grain yield as compared to Pusa Basmati 1121 under aerobic management. But rice variety Pusa Basmati 1121 gave higher straw yield as compared to Pusa Basmati 1 (Table 4). This may be due to higher tillering and vegetative growth in Pusa Basmati1121. Harvest index of rice variety Pusa Basmati 1 was significantly higher than Pusa Basmati 1121 which might be due to higher grain yield in Pusa Basmati 1. Application of RDN and INM significantly increased the grain and straw yield of rice as compared to control treatment. Highest grain yield was produced by application of 100% N by FYM+GM+BF+VC+Zn followed by 100% N by FYM+GM+BF+VC and 75% RDN + 25%VC. Highest yield with 100% N through FYM+GM+BF+VC+Zn might be due to higher and balanced supply of macro and micronutrients, hormones and vitamin etc from organic sources (Singh *et al.* 2011). In chemical fertilization, these things are not supplied to soil. N application through 75% RDN + 25% FYM also gave higher yield than 100% RDN but the difference was non-significant. Highest straw yield was recorded due to the application of 100% N by FYM+GM+BF+VC+Zn followed by 100% N by FYM+GM+BF+VC and 75% RDN + 25% VC. Many researchers across the world have reported increased grain and straw yields of rice with increased nutrient supply, especially of nitrogen (Singh *et al*. 2006, Pandey *et al*. 2007, Avasthe 2009). Polthanee *et al.* (2008) also reported enhanced grain and straw yields of aerobic rice due to the application of different types of organic fertilizers. Enhanced grain yield of rice due to the application of different organic amendments either applied alone or in combinations has been reported by some other researchers as well (Singh and Dhar 2011, Barik *et al.* 2011, Singh *et al.* 2011, Balasubramanian and Wahab 2012). Kadiyala *et al.* (2012) reported the increased grain yield of aerobic rice with increased N rates up to 120 kg/ha. Organic manures increased the fertilizer use efficiency and physical and chemical properties of soil, hence, making better utilization of nutrients which eventually may have increased the grain and straw yields.

Table 4 Effect of rice varieties and integrated nitrogen management on yield and harvest index

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Variety			
Pusa Basmati 1	3.92	7.00	35.95
Pusa Basmati 1121	3.74	7.50	33.50
SEm ±	0.05	0.11	0.53
LSD (P=0.05)	0.14	0.31	1.54
Integrated nitrogen management (INM)			
N control (N_0)	2.66	5.62	32.50
100% RDN (120 kg N/ha)	3.84	7.24	34.95
75% RDN+25% FYM	4.07	7.53	35.20
75% RDN+25% GM	3.67	7.03	34.50
75% RDN+25% BF	3.39	6.73	33.80
75% RDN+25% VC	4.24	7.70	35.80
100% N by FYM+GM+BF+VC	4.31	7.87	35.70
100% N by FYM+GM+BF+ VC+$ZnSO_4$	4.45	8.29	35.25
SEm ±	0.10	0.22	1.06
LSD (P=0.05)	0.29	0.63	N S

Economics

Gross return and net return of rice variety Pusa Basmati 1121 were higher as compared to Pusa Basmati 1 (Table 5). Highest gross and net returns were recorded with 100% N

Table 5 Effect of rice varieties and integrated nitrogen management on economics of rice cultivation

Treatment	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
Variety				
Pusa Basmati 1	37203	81360	44158	1.19
Pusa Basmati 1121	37658	85905	48248	1.28
Integrated nitrogen management (INM)				
N control (N_0)	33403	58675	25272	0.76
100% RDN (120 kg N/ha)	34885	83765	48881	1.41
75% RDN+25% FYM	38224	88780	50557	1.33
75% RDN+25% GM	35444	80305	44862	1.27
75% RDN+25% BF	34528	74205	39677	1.16
75% RDN+25% VC	37739	92390	54651	1.46
100% N by FYM+GM+ BF+VC	41281	94095	52814	1.28
100% N by FYM+GM+ BF+VC+$ZnSO_4$	42115	97350	55236	1.32

through FYM+GM+BF+VC+Zn and it was followed by 100% N by FYM+GM+BF+VC and 75% RDN + 25% VC. N application with 75% RDN + 25% FYM gave higher gross and net returns than N application by 100% RDN. N application by 100% RDN also gave higher gross and net returns than 75% RDN + 25% GM and 75% RDN + 25% BF. Lowest gross and net returns were recorded in control treatment. B: C ratio of Basmati rice was highest with 75% RDN + 25% VC (1.46) followed by 100% RDN (₹1.41). Singh (2006) observed that application of different organic manures (FYM and GM) with 50% or 100% recommended dose of NPK gave the higher net return and B: C ratio over the control. Singh *et al*. (2006) noticed that the net income and benefit : cost ratio increased when the nutrient was applied in combination with organic and inorganic fertilizers. Yadav *et al*. (2009) reported increased net return and B: C ratio due to the cultivation of rice through INM practices. Sharma *et al*. (2007) also reported that integration of FYM and *Azotobacter* with N increased monetary returns. Singh (2011) showed that the application of N through organic sources gave higher net returns and benefit : cost (B : C) ratio than control. Barik *et al*. (2011) observed increased net return and B : C ratio when 50% FYM + 25% vermicompost (basal) + 25% vermicompost (as top dressing) were applied in organic rice farming.

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