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Review/Overview

Response of rice (*Oryza sativa*) varieties to different levels of nitrogen under rainfed aerobic ecosystem

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ABSTRACT

A field experiment was conducted during 2011 and 2012 at Jagdalpur on the response of rice (*Oryza sativa* L) varieties to different levels of nitrogen. Plant height, leaf area-index, root volume and dry matter production were the highest with 'Tulsi' at 90 kg N/ha. Panicles/m^2, filled grains/panicle, grain (4.50 tonnes/ha) and straw yield and nitrogen uptake by grain and straw were also significantly higher with 'Tulsi', Increasing levels of nitrogen enhanced panicles/m^2, filled grains/panicle, grain and straw yield and nitrogen uptake by grain and straw only up to 90 kg N/ha. Varieties and nitrogen levels interacted significantly and the highest grain yield and economics were recorded with 'Tulsi' at 90 kg N/ha and it was found to be optimum combination for aerobic rice.

Key words : Aerobic rice, Crop production, Nitrogen levels, varieties

Rice demand was projected to increase by 25% from 2001 to 2025 to keep pace with population growth (FAO, 2001). Upland rice area is being shrinking due to lack of appropriate technologies on nitrogen levels and suitable varieties for rainfed ecosystems. It is necessary to increase yield per unit area with less water to fulfill the increasing rice demand with shrinking resources. Water is a looming crisis due to competition among agricultural, industrial and domestic users. In Asia, more than 50% of irrigation water is used to irrigate rice. Under upland conditions, where the crops are not flooded at all during the growth period is an effective way to save water and to reduce the methane emissions produced by flooded rice (Tuong *et al*., 2005). This concept of aerobic rice entails the use of nutrient responsive cultivars that are adapted to aerobic culture aiming at 70–80% yields of high input flooded rice (Prasad, 2011).

Nitrogen is the key nutrient that limits the rice production. In lowland rice ecosystems, the nitrogen-use efficiency is approximately 30%, whereas in upland rice, whether irrigated or rainfed, nitrogen-use efficiency would be in the range of 40 to 60% (Dubey *et al*., 1983). However, there is a need to quantify the requirement of nitrogen for the aerobic rice with particular condition to the cultivars, location and management conditions. The reliable information on the vital agro-techniques for successful aerobic rice in this region is absolutely lacking. The present study was undertaken to identify the suitable cultivar and estimate the optimum nitrogen dose for maximum productivity of rice under aerobic culture.

MATERIALS AND METHODS

The field experiment was conducted during the rainy (*kharif*) season 2011 and 2012 at upland of instructional farm, S.G. College of Agriculture and Research Station, IGKV, Jagdalpur (19.05^0 N, 81.57^0 E at 774 m above mean sea level) in the Plateau of Chhattisgarh. Soil was light in texture, low in organic carbon (0.40%) and available nitrogen (155 kg/ha) and medium in available phosphorus (22 kg/ha) and available potassium (240 kg/ha). The experiment was laid out in split plot design with 4 varieties 'Tuls'i, 'Swarna', 'Poornima' and 'Annada' and for nitrogen levels, viz. 40, 60, 90 and 110 kg/ha, as subplots. Nitrogen was applied in 4 equal splits at seeding, active tillering, panicle initiation and grain filling. A uniform dose of 60 kg P_2O_5/ha and 50 kg K_2O/ha was applied to all the plots as basal. The experimental area was ploughed twice with tractor drawn cultivator to obtain the desired tilth. The seed of rice was directly sown in rows on 8 June 2011 and 9 June 2012. The seed was treated with fungicide Carbendazim @ 1 g/kg seed and then dibbled as single seed with a spacing of 20 cm. Thinning and gap fill-

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ing were done at 10 DAS to maintain the uniform plant stand in all the plots. Hand weeding was done twice at 20 and 40 DAS for control of weeds. The crop was harvested on 11 December 2011 during first year and on 11 December 2012 during the second year. The data recorded on various growth and yield parameters of rice crop were analyzed following standard statistical analysis of variance procedure.

RESULTS AND DISCUSSION

Growth parameters

Rice varieties 'Tulsi' and 'Poornima' had significantly higher plant height and leaf-area index (LAI) than 'Annada' and Swarna' (Table 1). The lowest LAI was associated with 'Swarna'. The significantly higher root volume and total tillers/m^2 were observed in 'Tulsi' than the other varieties. The root volume of 'Tulsi' was not found comparable with rest of varieties. Significantly higher dry matter was noticed with 'Tulsi', followed by 'Poornima'. The lowest dry matter was produced by 'Swarna'. Plant growth parameters like plant height, LAI, dry matter and root volume increased up to 90 kg N/ha only and at 110 kg N/ha there was significantly increased in these parameters.

Production of the highest growth stature with ' Tulsi' might be due to its potential for profuse rooting and tillering ability under aerobic culture in the domain of investigation over 'Swarna', which might be due to reverse response, since the varieties susceptible to withstand moisture stress, would lead to poor growth especially under aerobic culture. It also reduced canopy photosynthesis and thereby the lower growth parameters. The highest stature of all the growth parameters, viz. plant height, LAI and dry matter production, was noticed with 90 kg N/ha, while the lowest was noticed with the 40 kg N/ha (Kumar *et al.*, 1996). The increased rate of nitrogen application at the highest level failed to produce higher dry matter and root volume.

Yield attributes

'Tulshi' produced significantly higher number of panicles/m^2 and filled grains/panicle than all the other varieties (Table 1). However, number of panicle with 'Poornima' was at par with 'Annada' and Swarna. Swarna produced the lowest number of panicles/m^2 and filled grains/panicle. The lowest spikelet sterility was observed in the variety 'Swarna' which was comparable with 'Annada' during both the years. 'Tulsi' recorded the higher sterility during both the years because of effective translocation of assimilates to the sink, which might have resulted in sound filling of grains as revealed by highest number of filled grains/panicle. This has been documented by Bouman *et al.* (2006) in their findings.

Increasing levels of nitrogen up to 90 kg N/ha significantly enhanced the number of panicles/m^2 and filled grains/panicle, over other nitrogen levels. The lowest was recorded with 40 kg N/ha. Spikelet sterility progressively enhanced with the increase in N level up to 90 kg N/ha. The lowest spikelet sterility was recorded with 40 kg N/ha because of total nitrogen content in the leaves increased with the increase of nitrogen supply and was forced to be associated with the spikelet sterility induced by low temperature (Haque, 1988). Spikelet sterility at 60 kg N/ha was comparable with 90 kg N/ha, which recorded the highest sterility during both the years. Effective transloca-

Table 1. Growth and yield attributes of rice varieties as influenced by different levels of nitrogen (pooled data of 2 years)

Treatment	Plant height at harvesting (cm)	Leaf-area index at 60 DAS	Root volume/hill at 60 (cc)	Dry matter production at harvest (t/ha)	Panicles/m^2	Filled grains/ panicle	Spikelet sterility (%)
Variety							
'Tulsi'	90.4	4.2	24.3	12.6	178.5	135.6	10.8
'Swarna'	76.1	3.3	18.4	9.5	164.2	113.2	5.8
'Poornima'	87.4	4.0	21.4	11.4	170.3	123.4	9.0
'Annada'	80.3	3.6	21.0	10.7	167.2	119.3	7.0
SEm±	1.1	0.1	0.8	0.2	1.4	2.0	0.7
CD (P=0.05)	3.6	0.4	2.8	0.8	5.1	7.1	2.3
Nitrogen (kg/ha)							
40	80.1	3.2	17.7	10.1	160.1	107.1	6.2
60	83.3	3.8	21.3	11.1	170.3	123.4	8.8
90	86.5	4.2	24.3	12.0	176.4	133.6	9.7
110	85.1	3.9	21.7	11.3	171.3	127.5	7.7
SEm±	0.9	0.1	0.7	0.1	1.4	1.7	0.5
CD (P=0.05)	2.8	0.2	2.1	0.5	4.0	5.0	1.4

DAS, days after sowing

tion of assimilates to the sink might have resulted in sound filling of grains as revealed by the highest number of filled grains/panicle. The poorest condition of all the yield attributes resulted with 40 kg N/ha. Better performance under 90 kg N/ha in respect of yield attributes of rice under aerobic culture confirms the findings of Maheswari *et al.* (2007) and Dubey *et al.* (1983).

Grain and straw yields

The significantly higher grain yield was produced by the variety 'Tulsi' than that of all the other varieties (Table 2). The grain yield of 'Poornima' and 'Annada' were at par and the lowest grain yield was produced with 'Swarna'. Increasing levels of nitrogen progressively enhanced the grain yield up to 90 kg N/ha and thereafter the yield declined. Significantly higher grain yield was recorded with 90 kg N/ha over other doses. Regardless of the varieties, the highest grain yield was recorded with 90 kg N/ha over other doses.

The interaction effect of varieties and nitrogen levels revealed that the highest grain yield was recorded with 'Tulsi' at 90 kg N/ha, which was comparable with 'Tulsi' with 60 kg N/ha and 'Poornima' with 90 kg N/ha, whereas the lowest was recorded with 'Swarna' at 40 kg N/ha. The trend with varieties and levels of nitrogen on the biological yield of rice was similar to that of grain yield.

Enhanced yield under aerobic culture with a suitable variety was owing to the fact that production of significantly more productive tillers lead to accrual of more photosynthates, resulting in higher grain yield of rice under aerobic culture. Performance of different varieties under aerobic culture with variation in the yield was reported by Bouman *et al.* (2005) using different N levels, which was due to enhanced stature of yield attributes, forming larger sink size coupled with efficient translocation of photosynthates to the sink. These results corroborate with those reported by Belder *et al.* (2005) and Sathiya and Ramesh (2009). The higher yields can also be attributed to the availability of nitrogen both as ammonium and nitrate forms due to alternate wetting and drying conditions, which might be beneficial to crop growth than provision of single form by itself.

Nitrogen uptake

The highest uptake of nitrogen by grain and straw was recorded with 'Tulsi', which was significantly higher than all other varieties (Table 2). Among the varieties, the highest uptake of nitrogen was recorded in 'Tulsi', followed by Poornima. The lowest uptake of nitrogen by grain and straw was noticed on 'Swarna'. Increasing levels of nitrogen progressively enhanced the uptake of nitrogen up to 90 kg N/ha and thereafter the uptake of nitrogen declined. The highest uptake of nitrogen by grain and straw was recorded with 90 kg N/ha, which was significantly higher than rest of the nitrogen levels. The response at the highest levels of nitrogen was lesser as the levels were above the optimal dose required for the potential crop performance. The uptake of nitrogen was lower with 40 kg N/ha due to its poor LAI and dry-matter production leading to lesser uptake.

Economics

Gross, net returns and benefit: cost ratio of rice under aerobic culture differed significantly with varieties and

Table 2. Yield, economics and nitrogen uptake of rice varieties as influenced by different level of nitrogen (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Biological yield (t/ha)	Nitrogen uptake (kg/ha)		Gross returns/ha (×10³ ₹/ha)	Net returns/ha (×10³ ₹/ha)	Benefit: cost ratio
			Grain	Straw			
Variety							
'Tulsi'	4.50	11.42	27.5	45.5	49.06	36.62	4.01
'Swarna'	3.56	8.87	20.8	36.0	38.76	26.32	3.16
'Poornima'	3.96	10.00	23.5	39.9	43.25	30.80	3.53
'Annada'	3.78	9.49	22.3	38.3	41.21	28.87	3.38
SEm±	0.10	0.21	0.7	0.7	0.86	0.82	0.06
CD (P=0.05)	0.37	0.71	2.4	2.5	2.96	2.86	0.21
Nitrogen(kg/ha)							
40	3.33	8.36	19.8	34.5	36.21	24.07	3.05
60	4.00	10.10	23.8	40.2	43.66	31.31	3.60
90	4.40	11.02	26.1	43.7	48.04	35.39	3.89
110	4.08	10.30	24.4	41.3	44.57	31.72	3.53
SEm±	0.09	0.21	0.5	0.6	0.92	0.92	0.07
CD (P=0.05)	0.27	0.61	1.5	1.7	2.65	2.65	0.19

Table 3. Effect of varieties and N-levels on grain yield (t/ha) of rice

Treatment	2011				2012			
	'Tulsi'	'Swarna'	'Poornima'	'Annada'	'Tulsi'	'Swarna'	'Poornima'	'Annada'
Nitrogen (kg/ha)								
40	3.98	2.96	3.42	3.22	3.79	2.82	3.25	3.10
60	4.51	3.68	3.92	4.29	4.32	3.48	3.73	4.04
90	4.80	3.80	4.29	4.18	4.82	3.94	4.38	3.97
110	5.09	4.16	4.63	3.84	4.61	3.61	4.06	3.64
	SEm±	CD (P=0.05)			SEm±	CD (P=0.05)		
V × N	0.15	0.46			0.14	0.44		
N × V	0.16	0.47			0.15	0.45		

levels of nitrogen (Table 2). The significantly higher gross and net returns and benefit: ratio was realized with the variety 'Tulsi', higher than all other varieties. However, gross and net returns and benefit: cost ratio of 'Poornima', were at par with 'Annada'. Remunerative economic returns play a key role for adoption of any refined version of agro-techniques. In the present study, gross and net returns as well as benefit: cost ratio were found highest with 'Tulsi' and at a nitrogen level highest 90 kg/ha. It is obvious that realization of higher gross returns was the result of higher grain and straw yield with the best treatment.

Hence for rice grown under aerobic culture, variety 'Tulsi' with application of 90 kg N/ha was found optimum as it has resulted in the highest growth of aerobic rice and higher productivity besides enhancing profitability.

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