

Response of rice (*Oryza sativa*) varieties to graded levels of nitrogen under aerobic culture

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ABSTRACT

A field experiment was conducted during 2006 and 2007 at Agricultural College, Naira on the response of rice (*Oryza sativa* L.) varieties to graded levels of nitrogen. Plant height, leaf area index, root volume and dry matter production were the highest with 'Vasundhara' and 120 kg N/ha at all the stages during both the years of study. Panicles/m², filled grains/panicle, grain yield (4.51 and 4.30 t/ha) and straw yield and nitrogen uptake by grain and straw were also significantly higher in the variety 'Vasundhara'. Increasing levels of nitrogen progressively enhanced panicles/m², filled grains/panicle, grain and straw yield and nitrogen uptake by grain and straw only up to 120 kg N/ha. Varieties and nitrogen levels interacted significantly and the highest grain yield and economics were recorded with 'Vasundhara' at 120 kg N/ha and it was found to be optimum combination for aerobic rice.

Key words : Aerobic rice, Nitrogen levels, Varieties

World rice production has continuously increased in the past three decades beginning with the green revolution, but the productivity has not increased since 1999. Rice demand was projected to increase by 25% from 2001 to 2025 to keep pace with population growth. To fulfill the increased rice demand with shrinking resources, it is necessary to increase yield per unit area with less water. 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. A growing scarcity of fresh water will pose problems for rice production in future years. Rice grown under upland conditions, where the crops are not flooded at any time 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). The new concept of aerobic rice entails the use of nutrient-responsive cultivars that are adapted to aerobic culture aiming at yields of 70-80% of high input flooded rice (Prasad, 2011). The target environments are irrigated lowlands, where water is insufficient to keep lowland (rainfed or irrigated) paddy fields flooded and favorable uplands with access to supplementary irrigation. Specific cultivars were bred in china for aerobic rice. The results of

trials on such cultivars showed that the yields were double that of traditionally grown upland rice, but were 20-30 per cent lower than that of lowland rice cultivars under flooded conditions (Takeshi *et al.*, 2005). University of Agricultural Sciences (UAS), Bangalore has developed six cultivars of aerobic rice by cross-breeding a local variety and IR 64, which require almost half the water needed to grow conventional varieties. The yield is about 5.5 tonnes/ha, on par with the traditional varieties.

Nitrogen is the key nutrient that most frequently limits the rice production. In low land 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%. Field experiments done on wetlands at Agricultural College and Research Institute, Tamilnadu Agricultural University, Coimbatore by Maheswari *et al.* (2007) indicated that application of 150 kg N/ha was found to be optimal dose for the aerobic rice variety 'PMK-3' on wetlands. However, there is a need to quantify the requirement of nitrogen for the aerobic rice with particular reference to the cultivars, location and management conditions. North coastal region of Andhra Pradesh is having substantial area under rainfed/semi-dry rice and has a vast scope of growing rice under aerobic conditions. However, reliable information on the vital agro-techniques for successful aerobic rice culture in this region is absolutely lacking. In this backdrop, the present study was undertaken with the objective

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to identify the suitable cultivar of rice for aerobic culture in North Coastal Zone of Andhra Pradesh and to formulate the optimum nitrogen dose for maximum productivity of rice under aerobic culture.

MATERIALS AND METHODS

The experiment on response of rice varieties to graded levels of nitrogen under aerobic culture was undertaken during *khariif* 2006 and 2007. The field experiments were conducted at upland block of college farm, Agricultural College, Naira campus of Acharya N G Ranga Agricultural University, Andhra Pradesh, which is geographically situated at 18.24° N latitude, 83.84° E longitude and at an altitude of 27 m above mean sea level in the North Coastal Zone of Andhra Pradesh. During the crop period 586.8 mm rainfall was received in 39 rainy days in the first year as against the decennial average of 608 mm received in 40 rainy days. In the second year 488.5 mm rainfall was received in 28 rainy days. Soils were sandy clay loam in texture, low in organic carbon (0.40%) and available nitrogen (175.9 kg/ha) and medium in available phosphorous (55.7 kg/ha) and available potassium (245.3 kg/ha). The experiment was laid out in split plot design with four varieties 'Vasundhara', 'Sambamashuri', 'Sonamashuri' and 'Vijetha' as main plots and graded levels of nitrogen 80, 100, 120 and 140 kg/ha as subplots. Nitrogen was applied in four equal splits at seeding, active tillering, panicle initiation and heading. A uniform dose of 60 kg P₂O₅/ha and 50 kg K₂O/ha was applied to all the plots. The experimental area was ploughed twice with tractor drawn cultivator and levelled with leveling blade to obtain the desired tilth for direct seeding of rice seeds. The seed of rice was directly sown in rows in the non puddled and non flooded soil on 21 July, 2006 and 27 July, 2007 during first and second year respectively. The seed was treated with fungicide Carbendazim @ 1g/kg seed and then dibbled as single seed with a spacing of 20 cm x 10 cm. Thinning and gap filling 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. Irrigations were given to the crop as and when the crop did not receive rainfall for a continuous period of 7-10 days. Blast and brown spot incidence was observed during *khariif*, 2006 and 2007. Two sprays, one with tricyclazole @ 0.6g/l and the second with carbendazim @ 1g/l were given at seven days interval for control of the diseases. The crop was harvested on 4 December 2006 during first year and on 12 December 2007 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 as suggested by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Growth attributes

Plant height and leaf area index (LAI) tended to increase with advance in the age of crop up to flowering (Table 1). The tallest plants were observed with 'Vasundhara' which were comparable with that of 'Sonamashuri' and both of them were significantly superior to 'Vijetha' and 'Sambamashuri', which produced plants of shortest stature. The highest LAI was recorded with 'Vasundhara' which was comparable with that of 'Sonamashuri'. The lowest LAI was associated with 'Sambamashuri'. The highest root volume and total tillers/m² was observed with 'Vasundhara' which was significantly higher than all the other varieties. The root volume and total tillers/m² of 'Sonamashuri' was comparable with that of 'Vijetha'. Significantly highest dry matter production (DMP) was noticed with 'Vasundhara' followed by 'Sonamashuri'. The lowest dry matter was produced by 'Sambamashuri'.

Plant height increased up to 120 kg N/ha, which was however, comparable with 140 kg N/ha. The shortest plant stature was recorded with 80 kg N/ha. The LAI tended to increase progressively up to 120 kg N/ha and was significantly superior to all the other nitrogen levels. The LAI with the highest nitrogen level was comparable with 100 kg N/ha while the lowest LAI was recorded with 80 kg N/ha. The dry matter production and root volume increased progressively up to 120 kg N/ha, which was significantly superior to all the other nitrogen levels tried. The DMP with the highest nitrogen level was comparable with 100 kg N/ha, while the lowest DMP was recorded with 80 kg N/ha.

The highest stature of the growth parameters *viz.*, plant height, LAI, root volume and dry matter production was noticed with the variety 'Vasundhara' at all the stages during both the years of study, while the lowest stature of all the above mentioned growth attributes was noticed with the variety 'Sambamashuri'. Production of the highest growth stature with 'Vasundhara' might be due to its potential for profuse rooting and tillering ability under aerobic culture in the domain of investigation. The lowest stature of all the growth parameters of rice under aerobic culture was with the variety 'Sambamashuri', which might be due to poor rooting and tillering ability, since the varieties susceptible to withstand moisture stress, would lead to poor growth especially under aerobic culture. It can also be attributed to the enhanced leaf senescence, leading to reduced canopy photosynthesis and thereby the lower stature of growth parameters. The highest stature of all the growth parameters *viz.*, plant height, LAI and dry matter production was noticed with the 120 kg N/ha, while the lowest stature of all the above mentioned growth attributes

was noticed with the 80 kg N/ha.

Growth of rice under aerobic culture was found the highest with 120 kg N/ha and it was the lowest with 80 kg N/ha, during both the years of study. The higher nitrogen requirement for aerobic rice may be due to the fact that more leaching of nitrate is expected with increased soil aeration (either with growing rice under non flooded conditions, or with the shift to upland conditions) than under flooded conditions. As a general rule, the response of the crop in terms of growth during vegetative and reproductive phases to the application of nitrogen will be limited up to a particular dose of application of nitrogen even though higher rates of nitrogen applications are being tried. In the present investigation the highest dry weight and root volume were also observed with 120 kg N/ha and the lowest with 80 kg N/ha. The increased rate of nitrogen application at the highest level failed to produce higher dry matter and root volume. The present findings are in accordance with those of Kumar *et al.* (1996); Mhaskar *et al.* (2005) and Guang Hui Xie *et al.* (2005). Favourable growing environment under 120 kg N/ha during the vegetative stage produced larger proportion of effective tillers and thereby increased the grain yield of rice.

Yield attributes

The highest number of panicles/m² and filled grains/panicle was produced with the variety 'Vasundhara' which were significantly higher than all the other varieties (Table 1). Among the varieties, production of panicles with 'Sonamashuri' was on par with 'Vijetha'. 'Sambamashuri' produced the lowest number of panicles/m² and filled grains/panicle. The lowest spikelet sterility was observed

in the variety 'Sambamashuri' which was, however, comparable with 'Vijetha' during both the years. 'Vasundhara' recorded the highest spikelet sterility during both the years of study. The highest thousand grain weight (Table 1) was recorded with 'Vasundhara' followed by 'Vijetha', 'Sonamashuri' and 'Sambamashuri' with significant disparity between any of them during both the instances of study. Effective translocation of assimilates to the sink might have resulted in sound filling of grains as revealed by highest number of filled grains/panicle. Variation in growth stature with different varieties in a given environment under aerobic culture has been amply documented by Bouman *et al.* (2006) and Atlin and Lafitte (2002).

Increasing levels of nitrogen progressively enhanced the number of panicles/m² and filled grains/panicle up to 120 kg N/ha, which was significantly higher than with rest of nitrogen levels tried. The lowest was recorded with 80 kg N/ha. With the increase in the levels of nitrogen spikelet sterility progressively enhanced up to 120 kg N/ha. The lowest spikelet sterility was recorded with 80 kg N/ha. Spikelet sterility at 100 kg N/ha was comparable with 120 kg N/ha, which recorded the highest sterility during both the instances of study. Thousand grain weight of rice under aerobic culture with the nitrogen levels tried was not significantly influenced, during both the years of study. Effective translocation 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 stature of all the yield attributes resulted with 80 kg N/ha. Better performance under 120 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).

Table 1. Growth and yield parameters of rice varieties as influenced by graded levels of nitrogen under aerobic culture (data pooled over two years)

Treatment	Plant height at flowering (cm)	LAI at flowering	Root volume/hill at flowering (cc)	Dry matter production at harvest (t/ha)	Panicles/m ²	No. of filled grains/panicle	Spikelet sterility (%)
<i>Varieties</i>							
'Vasundhara'	88.7	4.12	23.9	12.36	175	133	10.6
'Sambamashuri'	75.4	3.31	18.1	9.73	161	111	5.7
'Sonamashuri'	85.7	3.94	21.0	11.20	167	121	8.9
'Vijetha'	78.8	3.60	20.6	10.54	164	117	6.9
SEm±	1.03	0.11	0.81	0.23	1.44	2.02	0.7
CD (P=0.05)	3.6	0.39	2.8	0.79	5.0	7.0	2.3
<i>Nitrogen level (kg/ha)</i>							
80	78.6	3.20	17.4	9.98	157	105	6.1
100	81.7	3.78	20.9	10.94	167	121	8.7
120	84.8	4.13	23.9	11.76	173	131	9.6
140	83.5	3.86	21.3	11.17	168	125	7.6
SEm±	0.97	0.08	0.74	0.18	1.39	1.74	0.5
CD (P=0.05)	2.8	0.24	2.1	0.53	4.0	5.0	1.4

Grain yield

The highest grain yield was produced by the variety 'Vasundhara' which was significantly higher than that of all the other varieties taken for study (Table 2). The grain yield of 'Sonamashuri' and 'Vijetha' were comparable and the lowest grain yield was produced with 'Sambamashuri'. Increasing levels of nitrogen progressively enhanced the grain yield up to 120 kg N/ha and thereafter the yield declined. Significantly the highest grain yield was recorded with 120 kg N/ha. Grain yield with the highest nitrogen level of 140 kg N/ha was comparable with 100 kg N/ha, while the lowest grain yield was recorded with 80 kg N/ha.

Irrespective of the nitrogen levels tried, the highest grain yield was recorded with the variety 'Vasundhara' which was significantly higher than with all the other varieties studied (Table 2). At 100 kg N/ha it was in parity with the variety 'Vijetha' during both the years. Grain yield of 'Sonamashuri' was on par with 'Vijetha' at all the levels of nitrogen. The lowest grain yield was recorded with 'Sambamashuri'. Regardless of the varieties studied, the highest grain yield was recorded with 120 kg N/ha, which was comparable with 140 kg N/ha. The lowest grain yield was produced with 80 kg N/ha in all the varieties studied during both the years.

The interaction effect of varieties and nitrogen levels revealed that the highest grain yield was recorded with 'Vasundhara' at 120 kg N/ha (V_1N_3), which was comparable with 'Vasundhara' at 140 kg N/ha and 'Sonamashuri' at 120 kg N/ha, while the lowest grain yield was recorded with 'Sambamashuri' at 80 kg N/ha (V_2N_1). The trend with varieties and graded levels of nitrogen on the biological yield of rice was exactly similar to that of grain yield.

Enhanced yield under aerobic culture with a suitable variety was due 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 Yang Xiaoguang *et al.* (2002); Bouman *et al.* (2005). With different N levels, it was due to enhanced stature of yield attributes, forming larger sink size coupled with efficient translocation of photosynthates to the sink when the crop was raised under 120 kg N/ha. These results corroborate with those reported by Belder *et al.* (2005) and Sathiyaa 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. Harvest index was not affected by nitrogen levels as it is mostly a genetic character which does not alter with the crop management. The trend with varieties and graded levels of nitrogen on the straw yield of rice was exactly similar to that of grain yield.

Uptake of nitrogen

The highest uptake of nitrogen by grain and straw was recorded with variety 'Vasundhara', which was significantly higher than all other varieties taken for study (Table 2). Among the varieties, the nitrogen uptake of 'Sonamashuri' was in parity with 'Vijetha', which in turn was comparable with 'Sambamashuri', which recorded the lowest uptake of nitrogen by grain and straw. Increasing levels of nitrogen progressively enhanced the uptake of nitrogen by up to 120 kg N/ha and thereafter the uptake of

Table 2. Yield, economics and nitrogen uptake of rice varieties as influenced by graded levels of nitrogen under aerobic culture (data pooled over two years)

Treatment	Grain yield (t/ha)	Biological yield (t/ha)	Nitrogen uptake by grain (kg/ha)	Nitrogen uptake by straw (kg/ha)	Gross returns/ha ($\times 10^3$ ₹/ha)	Net returns/ha ($\times 10^3$ ₹/ha)	Benefit: cost ratio
<i>Varieties</i>							
'Vasundhara'	4.41	11.2	27.0	44.6	48.1	35.9	3.93
'Sambamashuri'	3.49	8.7	20.4	35.3	38.0	25.8	3.10
'Sonamashuri'	3.88	9.8	23.0	39.1	42.4	30.2	3.46
'Vijetha'	3.71	9.3	21.9	37.5	40.4	28.3	3.31
SEm \pm	0.10	0.21	0.68	0.69	0.84	0.80	0.06
CD (P=0.05)	0.36	0.7	2.4	2.4	2.9	2.8	0.21
<i>Nitrogen level (kg/ha)</i>							
80	3.26	8.2	19.4	33.8	35.5	23.6	2.99
100	3.92	9.9	23.3	39.4	42.8	30.7	3.53
120	4.31	10.8	25.6	42.8	47.1	34.7	3.81
140	4.00	10.1	23.9	40.5	43.7	31.1	3.46
SEm \pm	0.09	0.21	0.53	0.59	0.90	0.90	0.07
CD (P=0.05)	0.26	0.6	1.5	1.7	2.6	2.6	0.19

Table 3. Grain yield (t/ha) of rice varieties as influenced by graded levels of nitrogen under aerobic culture

Treatment	2006				2007			
	V ₁	V ₂	V ₃	V ₄	V ₁	V ₂	V ₃	V ₄
<i>Nitrogen levels (kg/ha)</i>								
80	3.90	2.90	3.35	3.16	3.72	2.76	3.19	3.04
100	4.42	3.61	3.84	4.21	4.24	3.41	3.66	3.96
120	4.99	4.08	4.54	4.10	4.73	3.86	4.29	3.89
140	4.71	3.73	4.21	3.76	4.52	3.54	3.98	3.57
	SEm ±		CD (P=0.05)		SEm ±		CD (P=0.05)	
V	0.07	0.24			0.07	0.23		
N	0.08	0.22			0.07	0.22		
V at N	0.15	0.45			0.14	0.43		
N at V	0.16	0.46			0.15	0.44		

V₁-Vasundhara, V₂-Sambamashuri, V₃-Sonamashuri, V₄-Vijetha

nitrogen declined. The highest uptake of nitrogen by grain and straw was recorded with 120 kg N/ha, which was significantly higher than rest of the nitrogen levels. The lowest uptake of nitrogen was recorded with 80 kg N/ha. Irrespective of the stage of observation, uptake of nitrogen by rice crop was the highest with the 120 kg N/ha, which is due to higher LAI coupled with higher dry matter production. 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 80 kg N/ha due to its poor LAI and dry matter production leading to lesser uptake.

Economics

Gross and net returns and benefit: cost ratio of rice under aerobic culture differed significantly with varieties and graded levels of nitrogen (Table 2). The highest gross and net returns and benefit:cost ratio was realized with the variety 'Vasundhara', which were significantly higher than with all other varieties taken for study. Among these varieties, gross and net returns and benefit:cost ratio of 'Sonamashuri' were on par with 'Vijetha', which in turn were comparable with 'Sambamashuri', which resulted in the lowest gross and net returns and benefit:cost ratio.

Increasing levels of nitrogen progressively enhanced the gross and net returns and benefit: cost ratio up to 120 kg N/ha and was significantly higher than with rest of nitrogen levels tried. Gross, net returns and benefit cost ratio with the highest nitrogen level of 140 kg N/ha were comparable with 100 kg N/ha, while the lowest gross returns were recorded with 80 kg N/ha.

Remunerative economic returns play a key role, to convince the farmers 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 to be the highest with the variety Vasundhara and at a nitrogen level of 120 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 'Vasundhara' with application of 120 kg N/ha was found optimum as it has resulted in highest growth of aerobic rice and realizing higher productivity besides enhancing profitability in North Coastal Zone of Andhra Pradesh.

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