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Effect of planting geometry and nitrogen levels on growth parameters, yield attributes and yield of black rice

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Abstract
An experiment was carried out during *kharif*, 2021 with different plant spacings and nitrogen levels to find out the best spacing and optimum dose of nitrogen in black rice at the Agricultural College Farm, Bapatla. The experiment was laid out in a split plot design with three replications. The main plot treatments were; plant spacings (10 cm x 15 cm, 15 cm x 15 cm, 20 cm x 10 cm, 20 cm x 15 cm) and sub-plot treatments were Nitrogen levels (90 kg N ha^{-1}, 120 kg N ha^{-1}, 150 kg N ha^{-1}). The research results indicated that 20 cm x 15 cm recorded significantly the highest growth attributes, yield attributing characters, grain yield (4519 kg ha^{-1}) of black rice. Among different levels of nitrogen 150 kg N ha^{-1} recorded significantly maximum growth, yield attributing characters and grain yield (4298kg ha^{-1}) of black rice. In interaction effect between planting geometry and nitrogen levels, plant spacing of 20 cm X 15 cm coupled with 150 kg N ha^{-1} recorded the highest grain yield (5266 kg ha^{-1}) of black rice.

Keywords: Spacings, nitrogen, black rice, *Oryza sativa* L.

Introduction
Rice (*Oryza sativa* L.) is one of the most important cultivated cereal crops of the world, it is the major food source of nearly half of the world population. Among the rice cultivars, black rice is a variant rice species (*Oryza sativa* L.) gaining demand in today's world. With the increasing health consciousness among the people for nutrient rich grain quality, black rice got evolved as a promising cultivar in the recent year. Black rice has more antioxidants than any other rice variety. It is considered to have multiple benefits in human health due to the presence of different antioxidants (Sutharut and Sudarat 2012) [11]. Crop geometry is an important factor for optimizing the spacing between plants for efficient utilization of the natural resources like light, water, nutrient and space (Haque *et al*., 2015) [4]. The optimum planting geometry under varied fertility regimes needs to be worked out to exploit the genetic potential of a genotype. Nitrogen fertilization is important for modern rice varieties in order to exploit their maximum yield potential (Mrudhula *et al*., 2021) [7]. High yielding modern rice varieties show a greater response in relation to applied nitrogen, while they differ in nitrogen demand depending on their genotype and agronomic traits under different climatic condition. In order to exploit the optimum plant population with respect to optimised doses of N in black rice need to be standardized.

Materials and Methods
A field experiment was conducted on black rice (*Oryza sativa* L.) in *kharif* season of 2021 at the Agricultural College Farm, Bapatla. The soil was sandy clay loam having pH 6.57, EC of 0.16 ds m^{-1}, organic carbon -0.45%, available N -198 kg ha^{-1}, P_2O_5 -36.72 kg ha^{-1} and K_2O -232.8 kg ha^{-1}. The experiment was conducted in split plot design with four main plots consists of different plant spacings; M_1: 10 cm x 15 cm, M_2: 15 cm x 15 cm, M_3: 20 cm x 10 cm and M_4: 20 cm x 15 cm and three subplots consist of nitrogen levels (kg ha^{-1}) *viz*. S_1: 90 kg N ha^{-1}, S_2: 120 kg N ha^{-1}, S_3: 150 kg N ha^{-1}. A popular variety BPT-2841 (Black rice) with 135 days duration was used for this experiment. Twenty-five-day old seedlings were planted at different plant spacings with 2-3 seedlings per hill. Weed control measure were taken up by application of pre-emergence herbicide of pyrazosulfuron ethyl 10% WP @ 200 g ha^{-1} followed by two hand weeding's at 20 and 40 days after transplanting. Water level in the crop was maintained at a depth of 2 cm up to the panicle initiation and 5 cm thereafter up to one week before harvest. The field was drained before application of fertilizers and one week before harvest.

Fertilizers were applied as per the treatments through urea, single super phosphate (SSP) and muriate of potash (MOP). Entire P & K and 1/3 recommended N was applied as basal, remaining N was applied in two equal splits at active tillering and panicle initiation as per the treatments. The experiments received uniform plant protection and cultural management practices throughout crop growth period. Data on growth, yield attributes and yield were collected following standard procedures from 5 randomly marked hills. The surface soil samples were collected up to 15 cm depth before and after the harvest of the crop and analysed by following standard procedures. Data were analysed by using ANOVA and the significance was tested by Fisher's least significance difference (0.05).

Results and Discussion

Results of the data indicated that the planting geometry and nitrogen levels significantly influenced the crop growth of black rice. At harvest, the crop geometry of 20 cm x 15 cm recorded significantly the highest plant height (160.8 cm) and it was on par with 15 cm x 15 cm. Among the nitrogen levels significantly the highest plant height (157.3 cm) was recorded with 150 kg N ha^{-1} at harvest but it was statistically at par with 120 kg N ha^{-1}. This was mainly because of availability of sufficient space for the plant above and below the ground to grow as well as the increased light transmission into the canopy, leading to greater plant height reported by Dass and Chandra (2012) [2]

In different crop geometries; 20 cm x 15 cm crop geometry recorded significantly the highest number of tillers m^{-2} (304) at 60 DAT. The number of tillers increased up to 60 DAT and significantly higher number of tillers m^{-2} (277) was obtained with 150 kg N ha^{-1} and it was on par with 120 kg N ha^{-1} at 60 DAT. This might be due to increased levels of nitrogen favours greater absorption of nutrients resulting in rapid expansion of foliage, better accumulation of photosynthates and eventually resulting in increased plant height as stated by Dakshina Murthy *et al.* (2015) [1]. Crop geometry and nitrogen levels showed a significant interaction effect on number of tillers m^{-2} at 60 DAT and the maximum number of tillers (335 m^{-2}) at 60 DAT was recorded with crop geometry of 20 cm × 15 cm and nitrogen rate of 150 kg N ha^{-1}. This was due to higher uptake of applied nitrogen and greater availability of soil nutrients by Ram *et al.* (2014) [8].

Data reveals that significantly the higher number of effective tillers m^{-2} (240), maximum panicle length (21.2 cm), total number of grains per panicle (158) and filled grains per panicle (147) was recorded with the crop geometry of 20 cm x 15 cm in comparison to other spacings. This might be the reason that the plant could exploit more sunlight for photosynthesis resulting in the accumulation of more carbohydrates, thereby increasing the number of yield attributing characters stated by Jahan *et al.* (2017) [5]. Test weight and panicle length was recorded nonsignificant with all crop geometries. The rate of nitrogen application recorded significant effect on yield attributes of transplanted black rice. Significantly the highest number of effective tillers m^{-2} (223 m^{-2}), panicle length (21.7 cm), total number of grain $panicle^{-1}$ (152), filled grains $panicle^{-1}$ (140) and test weight (14.3 g) was recorded with 150 kg N ha^{-1} in comparison to rest of the other nitrogen levels but panicle length (cm) and test weight (g) was statistically at par with 120 kg N ha^{-1}. Adequate supply of nitrogen probably favoured the proper cellular activities during panicle formation and development, which led to increase in development of yield attributing characters reported by Sorour *et al.* (2016) [10]. The interaction effect of crop geometry and nitrogen levels shows significant effect on yield attributes and the highest number of effective tillers m^{-2} (257), number of total grains per panicle (174) and filled grains per panicle (163) was recorded with the crop geometry of 20 cm x 15 cm and nitrogen level150 kg N ha^{-1} treatment.

The grain yield and straw yield were significantly affected by crop geometry and significantly the highest grain yield (4519 kg ha^{-1}) and straw yield (5653 kg ha^{-1}) was recorded with the spacing of 20 cm x 15 cm and it was superior over 10 cm x 15 cm, 15 cm × 15 cm and 20 cm × 10 cm spacing. It is well known fact that grain is the function of a greater number of effective tillers per unit area, number of grains per panicle and test weight (Gupta *et al*., 2011) [3]. Significantly the highest grain yield (4298 kg ha^{-1}) and straw yield (5361 kg ha^{-1}) was obtained with 150 kg N ha^{-1} and it was superior over the rest of other nitrogen level treatments and the lowest grain yield (3629 kg ha^{-1}) was observed with 90 kg N ha^{-1}. Increased yield associated with added fertilizer levels might be due to the cumulative effect of increased translocation of photosynthates to sink resulting in enhanced level of yield components stated by Rao *et al.* (2014) [9]. The interaction effect of plant spacings and nitrogen levels showed significant effect on improving grain yield of black rice and the highest grain yield (5266 kg ha^{-1}) was obtained with the plant spacing of 20 cm x 15 cm coupled with 150 kg N ha^{-1}.

Significantly the highest harvest index (44.8%) was recorded with the spacing of 20 cm x 15 cm and was on par with 15 cm x 15 cm. In case of nitrogen levels, significantly the highest harvest index (44.2%) was recorded with 150 kg N ha^{-1} and was on par with 120 kg N ha^{-1}. Harvest index is dependent on the ability of variety or a treatment to produce more grain yield than the straw accumulation. As such, higher grain yields than the straw would account for higher harvest index stated by Yumnam *et al.* (2021) [12]. The interaction effect between plant spacings and nitrogen levels showed non-significant effect on harvest index.

Table 1: Effect of planting geometry and nitrogen rates on plant height (cm) at harvest of black rice

Nitrogen levels (kg ha^{-1})				
Spacings	**S_1: 90**	**S_2: 120**	**S_3: 150**	**Mean**
M_1: 10 cm x 15 cm	139.7	144.4	150.5	144.9
M_2: 15 cm x 15 cm	144.6	154.0	166.0	154.9
M_3: 20 cm x 10 cm	135.4	141.0	143.5	140.0
M_4: 20 cm x 15 cm	150.9	162.3	169.3	160.8
Mean	142.6	150.4	157.3	
	SEm±	CD	CV	
Main plot	2.56	8.9	5.1	
Sub plot	2.70	8.1	6.2	
Interaction				
S at same level of M (S X M)	5.39	NS		
M at same or different level of S (M X S)	5.09	NS		

Table 2: Number of tillers m^{-2} of black rice at 60 DAT as influenced by planting geometry and nitrogen levels

Nitrogen levels (kg ha^{-1})				
Spacings	**S_1: 90**	**S_2: 120**	**S_3: 150**	**Mean**
M_1: 10 cm x 15 cm	218	228	223	223
M_2: 15 cm x 15 cm	246	275	290	270
M_3: 20 cm x 10 cm	207	247	259	238
M_4: 20 cm x 15 cm	263	314	335	304
Mean	233	266	277	
	SEm$\pm$	CD	CV	
Main plot	7.6	26	8.8	
Sub plot	3.8	12	5.2	
Interaction				
S at same level of M (S X M)	7.7	23		
M at same or different level of S (M X S)	9.9	32		

Table 3: No. of productive tillers m^{-2} of Black rice as influenced by planting geometry and nitrogen levels

Nitrogen levels (kg ha^{-1})				
Spacings	**S_1: 90**	**S_2: 120**	**S_3: 150**	**Mean**
M_1: 10 cm x 15 cm	177	179	180	179
M_2: 15 cm x 15 cm	205	219	229	218
M_3: 20 cm x 10 cm	180	192	224	199
M_4: 20 cm x 15 cm	218	245	257	240
Mean	195	209	223	
	SEm$\pm$	CD	**CV**	
Main plot	5.5	19	8.0	
Sub plot	3.1	9	5.4	
Interaction				
S at same level of M (S X M)	6.1	18		
M at same or different level of S (M X S)	7.5	24		

Table 4: Panicle length (cm) of black rice as influenced by planting geometry and nitrogen levels

Nitrogen levels (kg ha^{-1})				
Spacings	**S_1: 90**	**S_2: 120**	**S_3: 150**	**Mean**
M_1: 10 cm x 15 cm	19.1	19.3	20.7	19.7
M_2: 15 cm x 15 cm	19.2	20.5	21.8	20.5
M_3: 20 cm x 10 cm	19.0	20.2	21.5	20.3
M_4: 20 cm x 15 cm	20.0	20.9	22.7	21.2
Mean	19.1	20.2	21.7	
	SEm$\pm$	CD	CV	
Main plot	0.46	NS	6.8	
Sub plot	0.38	1.1	6.4	
Interaction				
S at same level of M (S X M)	0.75	NS		
M at same or different level of S (M X S)	0.77	NS		

Table 5: Total no. of grains panicle^{-1} of black rice as influenced by planting geometry and nitrogen levels

Nitrogen levels (kg ha^{-1})				
Spacings	**S_1: 90**	**S_2: 120**	**S_3: 150**	**Mean**
M_1: 10 cm x 15 cm	119	126	131	125
M_2: 15 cm x 15 cm	138	140	157	145
M_3: 20 cm x 10 cm	127	133	147	136
M_4: 20 cm x 15 cm	141	160	174	158
Mean	131	140	152	
	SEm$\pm$	CD	CV	
Main plot	2.4	8	5.1	
Sub plot	3.6	11	8.8	
Interaction				
S at same level of M (S X M)	7.2	21		
M at same or different level of S (M X S)	6.3	19		

Table 6: Total no. of filled grains panicle^{-1} of black rice as influenced by planting geometry and nitrogen levels

Nitrogen levels (kg ha^{-1})				
Spacings	**S_1: 90**	**S_2: 120**	**S_3: 150**	**Mean**
M_1: 10 cm x 15 cm	103	111	116	110
M_2: 15 cm x 15 cm	122	127	147	132
M_3: 20 cm x 10 cm	112	118	133	121
M_4: 20 cm x 15 cm	129	148	163	147
Mean	117	126	140	
	SEm$\pm$	CD	CV	
Main plot	2.27	8	5.3	
Sub plot	3.63	11	9.9	
Interaction				
S at same level of M (S X M)	7.26	22		
M at same or different level of S (M X S)	6.34	19		

Table 7: Test weight (g) of black rice as influenced by planting geometry and nitrogen Levels

Nitrogen levels (kg ha^{-1})				
Spacings	**S_1: 90**	**S_2: 120**	**S_3: 150**	**Mean**
M_1: 10 cm x 15 cm	12.8	13.2	13.5	13.2
M_2: 15 cm x 15 cm	13.5	14.1	13.9	13.9
M_3: 20 cm x 10 cm	13.3	13.5	13.8	13.6
M_4: 20 cm x 15 cm	13.6	14.2	15.8	14.6
Mean	13.3	13.8	14.3	
	SEm$\pm$	CD	CV	
Main plot	0.64	NS	13.9	
Sub plot	0.30	0.9	7.4	
Interaction				
S at same level of M (S X M)	0.59	NS		
M at same or different level of S (M X S)	0.80	NS		

Table 8: Grain yield (kg ha^{-1}) of black rice as influenced by planting geometry and nitrogen levels

Nitrogen levels (kg ha^{-1})				
Spacings	**S_1: 90**	**S_2: 120**	**S_3: 150**	**Mean**
M_1: 10 cm x 15 cm	3385	3569	3727	3560
M_2: 15 cm x 15 cm	3683	4057	4400	4047
M_3: 20 cm x 10 cm	3639	3776	3800	3738
M_4: 20 cm x 15 cm	3809	4481	5266	4519
Mean	3629	3971	4298	
	SEm$\pm$	CD	CV	
Main plot	79.9	276	6.0	
Sub plot	76.3	229	6.7	
Interaction				
S at same level of M (S X M)	152.6	458		
M at same or different level of S (M X S)	148.0	464		

Table 9: Straw yield (kg ha^{-1}) of black rice as influenced by planting geometry and nitrogen levels

Nitrogen levels (kg ha^{-1})				
Spacings	**S_1: 90**	**S_2: 120**	**S_3: 150**	**Mean**
M_1: 10 cm x 15 cm	4259	4424	4626	4436
M_2: 15 cm x 15 cm	4546	5008	5587	5047
M_3: 20 cm x 10 cm	4517	4750	4780	4682
M_4: 20 cm x 15 cm	4806	5703	6451	5653
Mean	4532	4971	5361	
	SEm$\pm$	CD	CV	
Main plot	161.9	560	9.8	
Sub plot	124.4	373	8.7	
Interaction				
S at same level of M (S X M)	248.9	NS		
M at same or different level of S (M X S)	259.8	NS		

Table 10: Harvest index of black rice as influenced by planting geometry and nitrogen levels

Nitrogen levels (kg ha^{-1})				
Spacings	**S_1: 90**	**S_2: 120**	**S_3: 150**	**Mean**
M_1: 10 cm x 15 cm	40.7	41.7	42.0	41.5
M_2: 15 cm x 15 cm	42.2	43.4	45.1	43.5
M_3: 20 cm x 10 cm	41.7	42.4	43.3	42.5
M_4: 20 cm x 15 cm	43.3	45.0	46.3	44.8
Mean	42.0	43.1	44.2	
	SEm±	CD	CV	
Main plot	0.9	3.1	6.3	
Sub plot	0.6	1.9	5.1	
Interaction				
S at same level of M (S X M)	1.3	NS		
M at same or different level of S (M X S)	1.4	NS		

Conclusion

Crop geometry and nitrogen levels clearly effect the crop growth, yield attributes and yield of black rice. In different crop geometries; crop geometry of 20 cm × 15 cm recorded significantly the highest crop growth, yield attributing characters and yield of black rice and in nitrogen levels 150 kg N ha^{-1} observed significantly the highest crop growth characters, yield attributes and yield of black rice.

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