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Effect of crop geometry and nitrogen rates on growth and yield of transplanted rice (*Oryza sativa* L.)

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Abstract
The experiment was conducted during the *kharif* season of 2018 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (Uttar Pradesh). The experiment was carried out with factorial RBD design with three replication, three crop geometry levels (15 × 15, 20 × 11.25, 25 ×9 cm) and four nitrogen rates (0, 75, 150, 225 kg ha^{-1}). In the experiment rice variety SWARNA SUB-1 was used. The crop geometry (20 × 11.25 cm^{-2}) and nitrogen rates 150 kg N ha represents significantly higher crop growth (plant height, number of tillers, dry matter accumulation), yield and yield attributes (panicle weight (g), panicle length (cm), grain panicle^{-1} and test weight (g) grain yield.

Keywords: Crop, geometry, nitrogen, transplanted, *Oryza sativa* L.

Introduction
Rice (*Oryza sativa* L.) is a semi-aquatic annual plant. Rice is widely grown major cereal crop of the world. Rice forms the staple diet for 70 percent of the world population. Rice is globally grown on 161.1 million hectares and annual production of 751.9 million tonnes (FAO 2017) [2]. India is the world's second largest rice producer and consumer next to China. Rice is grown in highly diverse conditions in India and major share is cultivated during *kharif* season. In India, rice is cultivated in an area about 43.2 million hectares with the total production of 112.91 million tones and productivity of 2.78 tonnes ha^{-1} (GoI, 2018-19). Rice is grown in India more than 70% under rainfed condition, 9% under upland and 21% under partially or fully irrigated conditions. In India Uttar Pradesh state is second largest producer of rice after West Bengal. In Uttar Pradesh rice is grown about 5.9 million hectares with total production of 12.95 million tonnes and productivity of 2.194 tonnes ha^{-1} (GoI, 2018-19). Crop geometry plays a significant role for optimization of rice yield due to efficient utilization of solar radiation as well as nutrients in rice (Siddiqui *et al.*, 1999) [11]. Closer crop geometry hampers intercultural operations and as such more competition arises among the plants for nutrients, air and light as a result, plant becomes weaker and thinner producing lower yield. The crop geometry and spatial configuration exploit the initial vigor of the genotypes with enhanced soil aeration creating favorable condition for better establishment (Shukla *et al.*, 2014) [10]. A planting density that can bring down the seed requirement without sacrificing productivity would go a long way in popularizing the direct seeded rice cultivation. Crop geometry of a crop affects the interception of solar radiation, crop canopy coverage, dry matter accumulation and crop growth rate (Anwar *et al.*, 2017) [1]. Optimum planting geometry ensures the proper growth of aerial as well as underground plant parts by efficient utilization of solar radiation, nutrients and water (Miah *et al.*, 1997). Plant density is one of the main factors that influence yield in rice, together with N availability (Zhu *et al.*, 2017). Nitrogen is the major element in the production of rice and gives higher response in production process. It is an essential plant nutrient that plays a significant role in growth, yield and metabolic processes of rice. Nitrogen is an integral part of protoplasm, protein and chlorophyll and plays a remarkable role in increasing cell size which in turn increases yield. To optimize nitrogen application, a quantitative understanding of nitrogen uptake and distribution within the plant and the impact of plant nitrogen content on crop growth and grain yield is essential.

Materials and Methods
The experiment was conducted during the *kharif* season of 2018 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

It is located in the south eastern part of Varanasi at 25^{0}18' N latitude and 83^{0}03' E longitude and has an altitude of 75.7 meter above the MSL. The experiment was conducted in field number A/9 of Research Farm. Normally the rainfall received in *kharif* season Varanasi 800-1000 mm. The average rainfall received during crop season 777.7 mm, average temperature 20.9^{0}C to 31.78^{0}C, mean evaporation 3.16 mm day^{-1}, mean relative humidity 73.68%. The soil characteristic of experimental site was alluvial soil, texture (sand 56.26%, silt 24.30%, clay 19.44%) low in available nitrogen (188.1 kg ha^{-1}), medium in available phosphorus (22.6 kg ha^{-1}), potassium (218.2 kg ha^{-1}) and basic pH value 7.2. The experiment was carried out with factorial RBD design with three replication, three crop geometry levels (15 × 15, 20 × 11.25, 25 ×9 cm) and four nitrogen rates (0, 75, 150, 225 kg ha^{-1}). In the experiment rice variety SWARNA SUB-1 was used. It is most suitable variety grown in north eastern state and submerge condition. It takes 140-150 days to mature in *kharif* season. The application of 50% nitrogen as basal, 25% nitrogen at tillering stage and 25% nitrogen at flag leaf unfolded stage. Application 60 kg P_2O_5 and 60 kg K_2O per hectare were applied in all plots in the form of Single super phosphate (SSP) and Muriate of potash (MOP). The crop was grown in irrigated condition and all the recommended practices were adopted as per need of the crop. The observation was recorded at regular interval from the net plot area randomly selected tagged plants.

Results and Discussion

The crop geometry and nitrogen rates significantly influenced the growth and yield attributes of rice crop due to inter and intra competition for light, space and nutrients (Gautam *et al.*, 2008) [3]. The all crop geometry level (15 x 15, 20 x 11.25, 25 x 9 cm^{-2}) revealed that crop geometry 20 x 11.25 cm^{-2} maintained its superiority in plant height at 90 DAT. The variations in plant height at 30 to 60 DAT due to different crop geometry were non-significant. The maintenance of crop geometry in rice crop was recorded that significantly higher number of tillers with the crop geometry 20 x 11.25 cm^{-2} at 30, 60 and 90 DAT and it was statistically at par with 15 cm x 15 cm crop geometry at 30, 60 and 90 DAT. The maximum dry matter accumulation was recorded with 20 cm x 11.25 cm crop geometry at all stage of the observation and it was statistically at par with 25 cm x 9 cm crop geometry at 60 and 90 DAT. The significantly higher number of effective tillers, maximum panicle length and panicle weight was recorded with the crop geometry 20 x 11.25 cm^{-2} in comparison to others. Test weight and grain per panicle was recorded non-significant with all level of crop geometry (15 x 15, 20 x 11.25, 25 x 9 cm^{-2}).

The rate of nitrogen application provided a significant effect on the growth and yield attributes of transplanted rice. The significantly higher plant height (93.45 cm) was recorded with 150 kg N ha^{-1} at 90 DAT rest of the other treatments but it was statistically at par with 225 kg N ha^{-1}. The number of tillers increased up to 60 DAT and significantly higher number of tillers was obtained with 150 kg N ha^{-1} at all intervals of the observation. Crop geometry and nitrogen rates showed a significant combination effect at 90 DAT and maximum number of tillers (411.33) was recorded with crop geometry 20 cm × 11.25 cm and nitrogen rates 150 kg N ha^{-1}. The maximum dry matter accumulation (52.93 and 227.74g) was recorded with 225 kg N ha^{-1} at 30 and 60 DAT but 90 DAT maximum dry matter accumulation (435.11g) with 150 kg N ha^{-1} 60 DAT. Significantly higher effective tiller (314), panicle weight (g), panicle length (cm), grain panicle^{-1}, test weight (g) was produced with 150 kg N ha^{-1} in comparison to rest of the other treatments but panicle weight (g), panicle length (cm), grain panicle^{-1} and test weight (g) statistically at par with 225 kg N ha^{-1}. The rice grain yield, (Singh *et a.*, 2008) [12] and harvest index (Rajput *et al.*, 2016) [9] significantly affected by crop geometry depend on different management factors and crop geometry also, the significantly higher grain yield (3949.15 kg ha^{-1}), and harvest index (44.14) was recorded with 20 cm x 11.25 cm crop geometry at harvesting and it was superior over 15 cm × 15 cm, and 25 cm × 9 cm. It is well known fact that grain is the function of more number of effective tillers per unit area, number of grain per panicle and test weight (Gupta *et al.,* 2014). Significantly higher grain yield (4219.22 kg ha^{-1}) and harvest index (47.56) was produced with 150 kg N ha^{-1} and it was superior over the rest of the other treatments. Lowest grain yield (3180.54 kg ha^{-1}) was obtained with control. The interaction effect of crop geometry and nitrogen rates shows significant effect on number of tillers m^{-2}. At 90 DAT significantly higher number of tillers (411 m^{-2}) was recorded with the crop geometry 20 cm x 11.25 cm and nitrogen rates 150 kg N ha^{-1}.

Table 1: Effect of crop geometry and nitrogen rates on plant height (cm), tillers m^{-2}, dry matter accumulation in transplanted rice

Treatments	Plant height (cm)			Tillers/m^2			Dry matter accumulation		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
Crop geometry (cm^{-2})									
15 × 15	45.96	60.80	88.76	316.42	354.83	283.42	40.33	167.10	328.17
20 × 11.25	47.17	65.99	92.07	322.67	370.83	322.00	45.55	211.42	374.25
25 × 9	44.92	59.19	85.40	272.67	326.00	273.50	50.02	224.70	403.75
SEm±	1.60	2.85	1.81	11.77	11.94	9.25	2.46	8.41	15.71
CD (P=0.05)	NS	NS	5.32	34.52	35.04	27.15	7.23	24.69	46.08
Nitrogen rates (Kg/ha)									
0	41.32	50.12	84.68	249.44	289.44	267.22	34.72	156.39	284.22
75	42.84	58.34	85.57	273.89	344.33	288.78	49.00	205.46	372.44
150	49.46	68.13	93.45	369.00	411.44	324.89	44.52	214.70	435.11
225	50.45	71.39	91.27	323.33	357.00	291.00	52.93	227.74	383.11
SEm±	1.85	3.298	2.09	13.59	13.79	10.69	2.84	9.72	18.14
CD (P=0.05)	5.42	9.66	6.14	39.86	40.46	31.35	8.35	28.51	53.21
S*N	NS	NS	NS	NS	NS	S	NS	NS	NS

Table 2: Interaction effect of crop geometry and nitrogen rates on tillers m^{-2} in transplanted rice

Treatments	Crop geometry (cm^{-2})			
Nitrogen rates (kg N ha^{-1})	**15 × 15**	**20 × 11.25**	**25 × 9**	**Mean**
0	279.00	260.33	262.33	267.33
75	282.00	313.00	271.33	288.78
150	290.00	411.33	273.33	324.89
225	282.67	303.33	287.00	291.00
MEAN	283.42	322.00	273.50	292.90
SEm±	18.51	CD (P=0.05)	54.30	

Table 3: Effect of crop geometry and nitrogen rates on yield attributes and yield

Treatments	Effective tillers (m^2)	Panicle weight (g)	Panicle length (cm)	Panicle grain	Test weight	Grain yield (Kg ha^{-1})	Harvest index (%)
Crop geometry (cm^{-2})							
15 × 15	281.33	2.54	17.61	173.14	17.73	3668.33	42.61
20 × 11.25	309.33	2.88	22.69	161.05	17.60	3949.15	44.14
25 × 9	267.33	2.61	19.24	150.50	15.44	3279.01	40.21
SEm±	7.54	0.19	0.99	7.20	0.97	162.94	1.84
CD (P=0.05)	22.12	0.563	2.90	21.12	2.86	477.89	5.40
Nitrogen rates(Kg/ha)							
0	262.67	1.98	16.31	142.48	13.12	3180.54	34.75
75	282.78	2.49	18.76	158.60	14.59	3512.51	45.99
150	314.00	3.34	23.16	176.80	20.22	4219.22	47.56
225	284.56	2.90	21.16	168.38	19.76	3616.40	40.98
SEm±	8.71	0.22	1.14	8.31	1.12	188.15	2.12
CD (P=0.05)	25.55	0.65	3.35	24.39	3.30	551.82	6.24
G*N	NS	NS	NS	NS	NS	NS	NS

Conclusion

Effect of crop geometry and nitrogen rates clearly showed that the change crop growth in (plant height, number of tillers, dry matter accumulation) yield attributes (panicle weight (g), panicle length (cm), grain $panicle^{-1}$ and test weight (g). The crop geometry (20 × 11.25 cm^{-2}) and nitrogen rates 150 kg N ha represents significantly higher crop growth, yield and yield attributes.

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