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Effect of Spatial Distribution and Nitrogen Level on Growth Attributes of Hybrid Rice (*Oryza sativa* L.)

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A field trial was conducted to investigate the effect of spatial distribution and different levels of nitrogen on growth of hybrid rice variety PA 6201, comprising of 16 different treatments using randomized complete block design with three replications at agronomy research farm of Narendra Deva University of Agriculture and Technology, Faizabad (U.P.), India during the season of *Kharif* in the year 2012. It was found that the spacing of 20×15 cm was found significantly superior over other geometric configurations and at par with closer spacing 20×10 cm for the entire growth characteristics. Application of 187.5 kg N ha^{-1} proved to be better over other in respect to all growth attributes. There has been an increase in plant height, number of tillers, leaf area index as well as in dry matter of the plant.

Introduction

Rice, one of the most important food crops in the world, forms the staple diet of 2.7 billion people (FAOSTAT, 2007). In India, the cultivation of rice is done in an area of 44 million hectare with an average production of 90 million tonnes thereby making a productivity of 2.0 tonnes per hectare (Thiyagarajan, 2007). It is cultivated on an area of 44.1 million ha having annual production of about 131.3 million tonnes with productivity of 3.0 tonnes ha^{-1} (Ferrer, 2011). It accounts for about 42% of total food grain production and 55% of cereal production in the country. In Uttar Pradesh (U.P.) state, rice is grown on an area of about 5.69 million ha with a production of 11.7 million tonnes and productivity of about 2.06 tonnes ha^{-1}. Consumption of rice is continuously growing every year and it is anticipated that in 2025, the requirement would be 140 million tonnes (Thiyagarajan, 2007). Its cultivation is of immense importance for providing food security in Asian countries, where more than 90% of the global rice is produced and consumed (Ferrer, 2011). To meet the demand of increasing population and maintain the self sufficiency, the present production level needs to be increased by over 2 million tonnes year^{-1} in coming decade (Subbaiah, 2006). To sustain present food self-sufficiency and to meet future food requirements, scientists have started to look forward for highly productive varieties. Hybrid rice yields about 15-20% more than the promising high-yielding commercial varieties (Chaturvedi, 2005). The hybrid rice has a yield advantage of at least 1 tonnes ha^{-1} more than the highest yielding inbred cultivars with similar maturity duration. In India, it is estimated that area under hybrid rice has increased from 10000 to 1 million hectare from year 1995 to 2006 (Viraktamath *et al*., 2006).

Earlier studies have revealed that the judicious and proper use of agronomic practices, especially planting geometry and use of fertilizers can markedly increase and improve the growth of rice plants. Plant space determines solar radiation interception, crop canopy coverage and total dry matter accumulation (Anwar *et al*., 2011). Also, several studies had shown that the closer planting may cause mutual shading which may direct to intra-specific competition that increases the problems of lodging (Bond *et al*., 2005), insect pest infestation (Tan *et al*., 2000) and even rat injuries (Castin and Moody, 1989). Therefore, plant spacing should be optimized by keeping in mind different aspects of cropping management techniques. Optimized plant spacing ensures proper growth of plants both above and under the ground by utilizing equal amount of solar radiation, enhancing soil respiration and providing better weed control thereby, higher crop yields (Gautam *et al*., 2008) and other nutrients from soil (Ashraf *et al*., 2014). The plant spacing can further influence variations through alteration in the attainment of phenophases and eventually the development of plant canopy (Faisul-ur-Rasool *et al*., 2013). In a study, wider spacing of 20×15 cm gave higher yield as compared to crop planted with closer spacing of 20×10 and 15×15 cm (Rajesh and Thanunathan, 2003).

Nitrogen is a key player in increasing any type of agriculture production and is one of the most yield-limiting nutrients for annual crops (Roy and Mishra 1999). Inadequate nitrogen in soils show reduced leaf area limiting light interception thereby causing reduced photosynthesis which finally has an effect on biomass growth and grain yield (Sinclair, 1990). Bacon (1980) and Inthavongra *et al*., (1985) showed the most appropriate time of nitrogen application to rice is panicle initiation, which produced maximum plant height, grains/panicle and grain yield. Keeping in view the importance of spatial distribution of crop plants and nitrogen levels in soil, the present study was therefore, designed to find out the response of different levels of nitrogen with respect to plant spacing on growth attributes of a hybrid rice variety PA 6201 which may play an important role in minimizing the present gap between potential and achievable growth of hybrid rice.

Materials and Methods

The field experiment was conducted during Kharif season of 2012, at Agronomy Research farm, N.D. University of Agriculture and Technology, Faizabad, U.P., India. The study area is geographically situated between 26.47° N latitude to 82.12° E longitude and at an altitude of 113 m above mean sea level on Faizabad-Raebareli road about 42 km away from Faizabad city. The climate of Faizabad district is semi-arid with hot summer and cold winter. Experimental site falls under sub-tropical climate in Indo-gangetic plains having alluvial calcareous soil. The experimental field was well leveled having good irrigation and drainage facilities. The rice variety used in the experiment was PA 6201. The experiment was laid out in a randomized complete block design with a factorial arrangement of 16 treatments replicated thrice with a net plot size of 2.20 x 4.80 m. The treatments consisted of 4 levels of planting spacing *viz*. S_1 (20×10 cm), S_2 (20×15 cm), S_3 (20×20 cm) and S_4 (20×25 cm). A recommended dose of entire phosphorus, potassium and zinc was applied uniformly at 60 kg ha^{-1} through single super phosphate, 60 kg K_2O ha^{-1} of potash and 30 kg $ZnSO_4$ ha^{-1}, respectively. The effect of nitrogen level was determined by reducing 25% (N_1) or supplementing the recommended dose (150 kg ha^{-1}; N_2) with additional 25% (N_3) and 50% (N_4) nitrogen. Nitrogen was applied as per treatment through urea in three equal split doses, half as basal, one fourth as dressed at early tillering stage and the remaining a week before panicle initiation stage. The treatment details were provided in Table 1.

All the recommended agronomic practices were followed to raise a good crop. Data were recorded on a five randomly selected hills from each plot for growth characters *viz*., Plant height (cm), number of tillers (m^{-2}), leaf area index (LAI) and dry matter accumulation (g m^{-2}). The recorded data were further subjected to one way analysis of variance (ANOVA) techniques as suggested by Gomez and Gomes (1984). Critical difference at 0.05 probability level was worked out to compare the treatments.

Results and Discussion

Effect of geometric distribution of plants and nitrogen levels on plant height and number of tillers

Height is an index of plant growth and is known to be influenced by environmental and crop management practices. With a plant spacing of 20×15 cm, significantly taller plants with more number of tillers were recorded than wider plant spacing 20×20 cm, 20×25 cm and with closer spacing 20×10 cm at all the growth stages (Table 2). Nayak *et al*., (2003) with same hybrid rice recorded the maximum plant height and number of tiller at the similar spatial distribution of plants than spacing of 20×10 and 15×15 cm. As far as the tillers production $plant^{-1}$ is concerned, data clearly indicates that the total tillers production per plant increased with increase in row spacing, but the increase in tillers production failed to meet out beyond 20×15 cm of spacing and showed a reduction in the number of tillers (Table 3). Verma *et al*., (2002) studied the effect of spacing on hybrid rice PA 6201 and found that crop planted with 20×20 and 20×15 cm produced significantly more number of productive tillers per m^2 than the crop planted with 20 × 10 cm. These observations suggest that this rice variety needs an optimum plant spacing of 20×15 cm for attaining utmost plant height and number of tillers.

An examination of data presented on plant stature with nitrogen fertilizers revealed that significant improvement in plant height and tiller production at all the growth stages *viz*, 30, 60, 90 DAT and at harvest. Application of 187.5 kg N ha^{-1} registered significantly tallest plant and maximum number of tillers followed by 225 kg N ha^{-1} and lower doses (112.5 and 150 kg N ha^{-1}) with at all the growth stages (Table 2,3).

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Effect of plant spacing and nitrogen levels on leaf area index and dry matter accumulation

Different spatial distribution of plants also influenced the leaf area and dry matter significantly at various growth stages. It is imperative to note that plant spacing of 20×15 cm produced significantly higher LAI (7.3) over the wider plant spacing of 20×20 cm and 20×25 cm and at par with closer spacing 20×10 cm. Highest spacing produced lowest LAI at all the growth stages (Table 4). It is obvious from the data that LAI increased with increase in age of crop up to 90 DAT. The rate of increase LAI was very fast between 30 to 60 DAT. The data given in Table 5 clearly indicate that dry matter accumulation (g m^{-2}) increased significantly with 20×15 cm spacing than wider spacing 20×20 cm and 20×25 cm and at par with closer spacing 20×10 cm at all the stages of crop growth.

The doses of nitrogen produced significant increase in LAI and dry matter. Application of nitrogen at 187.5 kg N ha^{-1} resulted significant increase in LAI at all the growth stages. Maximum LAI is recorded with application of 187.5 kg N ha^{-1} which is found at par with 225 kg N ha^{-1} at all the growth stages.

Plant growth is substantially ruled by planting density of the crop under different agro-climatic and edaphic conditions. Appropriate spatial distribution is one of the important factors to acquire higher yield in rice. In case of rice hybrids, the developmental habits of hybrid plant are distinct from conventional varieties (Siddiq, 1993). A planting density can minimize the seed necessity without reducing the overall productivity that can be managed by abundant tillering which will balance the yield. An increase in plant height might be due to the exposure of large number of plants and leaf area to sunlight during the growth period resulting in better photosynthesis and consequently increasing the plant height. Similar results have also been reported by Das *et al*., (1988) and Srinivasulu (1997). The increased plant height may further have been resulted due to availability of more time for growth period with optimum photoperiod and temperature for the growth of the crop plants which may effect in more nitrogen absorption for the synthesis of protoplasm responsible for rapid cell division which may increase the plant in shape and size. This is in line with the results of Sahu (1994), Parihar *et al.*, (1995) and Paliwal *et al.*, (1996).

Table.1 Details of the treatment used in the current study

Treatment combination	Nitrogen levels (kg ha^{-1}) + Spacing (cm)
T_1 N_1S_1	25% lower than recommended dose + 20 x 10
T_2 N_1S_2	25% lower than recommended dose + 20 x 15
T_3 N_1S_3	25% lower than recommended dose + 20 x 20
T_4 N_1S_4	25% lower than recommended dose + 20 x 25
T_5 N_2S_1	*Recommended dose + 20 x 10
T_6 N_2S_2	*Recommended dose + 20 x 15
T_7 N_2S_3	*Recommended dose + 20 x 20
T_8 N_2S_4	*Recommended dose + 20 x 25
T_9 N_3S_1	25% higher than recommended dose + 20 x 10
T_{10} N_3S_2	25% higher than recommended dose + 20 x 15
T_{11} N_3S_3	25% higher than recommended dose + 20 x 20
T_{12} N_3S_4	25% higher than recommended dose + 20 x 25
T_{13} N_4S_1	50% higher than recommended dose + 20 x 10
T_{14} N_4S_2	50% higher than recommended dose + 20 x 15
T_{15} N_4S_3	50% higher than recommended dose + 20 x 20
T_{16} N_4S_4	50% higher than recommended dose + 20 x 25

Table.2 Plant height of hybrid rice as influenced by plant spacing and nitrogen levels

Treatment type	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	At harvest
Plant geometry (cm)				
20 x 10	64.48	98.80	124.80	126.88
20 x 15	66.34	101.65	128.40	130.54
20 x 20	59.52	91.20	115.20	117.12
20 x 25	57.66	88.35	111.60	113.46
SEm±	1.29	1.90	2.07	2.54
CD (p=0.05)	3.76	5.45	5.91	7.40
Nitrogen level (kg ha^{-1})				
112.5	56.42	86.45	109.20	111.02
150	60.76	93.10	117.60	119.65
187.5	65.72	100.70	127.20	129.32
225	65.10	99.75	126.00	128.10
SEm±	1.29	1.90	2.07	2.54
CD (p=0.05)	3.76	5.45	5.91	7.40

Table.3 Number of tillers m-2 of hybrid rice as influenced by plant spacing and nitrogen levels at various growth stages

Treatments	**30 DAT**	**60 DAT**	**90 DAT**	**At harvest**
Plant geometry (cm)				
20 x 10	322.40	377.00	405.60	358.80
20 x 15	331.70	387.88	417.30	369.15
20 x 20	297.60	348.00	374.40	331.20
20 x 25	288.30	337.13	362.70	320.58
SEm±	6.20	7.60	8.16	6.90
CD (p=0.05)	17.92	21.97	23.57	19.94
Nitrogen level (kg ha^{-1})				
112.5	282.10	329.88	354.90	313.95
150	303.80	355.25	382.20	338.10
187.5	328.60	384.25	413.40	365.70
225	325.50	380.63	409.50	362.25
SEm±	6.20	7.60	8.16	6.90
CD (p=0.05)	17.92	21.97	23.57	19.94

Table.4 Leaf area index of hybrid rice as subjective to the plant spacing and nitrogen levels at various growth stages

Treatments	**30 DAT**	**60 DAT**	**90 DAT**
Plant geometry (cm)			
20 x 10	3.64	6.92	7.09
20 x 15	3.75	7.12	7.30
20 x 20	3.36	6.38	6.55
20 x 25	3.26	6.18	6.34
SEm±	0.07	0.13	0.13
CD (p=0.05)	0.12	0.40	0.39
Nitrogen level (kg ha-1)			
112.5	3.19	6.05	6.21
150	3.43	6.52	6.68
187.5	3.71	7.05	7.23
225	3.68	6.98	7.16
SEm±	0.07	0.13	0.13
CD (p=0.05)	0.12	0.40	0.39

Table.5 Dry matter accumulation (g m-2) of hybrid rice as influenced by plant spacing and nitrogen levels

Treatments	30 DAT	60 DAT	90 DAT	At harvest
Plant geometry (cm)				
20 x 10	209.56	447.20	738.40	769.60
20 x 15	215.61	460.10	759.70	791.80
20 x 20	193.44	412.80	681.60	710.40
20 x 25	187.40	399.90	660.30	688.20
SEm±	4.22	9.00	14.21	15.52
CD (p=0.05)	12.21	25.99	41.04	44.85
Nitrogen level (kg ha^{-1})				
112.5	183.37	391.30	646.40	673.40
150	197.47	421.40	695.80	725.20
187.5	213.59	455.80	752.50	777.00
225	211.58	451.50	745.60	740.40
SEm±	4.22	9.00	14.21	15.52
CD (p=0.05)	12.21	25.99	41.04	44.85

Hybrid rice variety growing in a close spacing may gets over-crowded due to which the plants had to compete for soil, space, nutrients, water, air and light while wider produced higher tillers per hill may resulted in weak plants. The findings are in conformity with Nayak *et al*., (2003), Gobi *et al*., (2006) and Awan *et al*., (2011). The total tillers per m^2 in planted crop might be owing to the higher number of ear bearing shoots which might be due to better development of early form tillers up to the stage of earing because of better photosynthesis activities of the plant in the optimum photoperiod at optimum temperature to supply energy in term of photosynthate for their proper development. The productive tillers significantly may be higher in early planting due to the fact that better development of early form tillers up to reproductive phase of the crop while in case of late planting the production of tillers may take place but due to unavailability of sufficient amount of photosynthates as source of energy may result in the mortality of tillers and number of productive tillers may reduced.

Patra and Nayak (2001) found that rice crop planted with 20×10 cm spacing produced significantly more effective tillers than the crop planted with 15×10 cm and 10×10 cm spacing. Rice is the major consumer of fertilizer nitrogen and gives high response to the applied nitrogenous fertilizers. One major consequence of inadequate nitrogen is reduced leaf area, thereby, limiting light interception, photosynthesis and finally biomass growth (Sinclair, 1990). The major effect of nitrogen fertilizer is to speed-up of leaf expansion rate leading to increased interception of daily solar radiation by the canopy (Squire *et al*., 1987). Our results had also shown higher LAI as well as dry weight matter by increasing nitrogen levels. LAI was higher because of exposer of large number of plants and leaf area to sunlight in a wider space during the growth period resulting better photosynthesis and consequently showing good growth characteristics. The higher LAI recorded might also be due to more leaves number and size.

Dry matter accumulation increased significantly with nitrogen fertilizer application at all the growth stages of the crop. It was as expected since availability of higher vegetative growth period for development of more tillers as well as number of leaves per hill and more plant height which ultimately may have been increased by protein content thereby contributing to the dry matter of plant (Reddy, 2000). In general, dry matter accumulation increased at higher rate up to 90 days after transplanting and thereafter no significant increase was documented. Our results are in complete agreement with Mandal *et al*., (1992), Reddy and Reddy (1994), and Dhiman *et al*., (1995). The higher dry mass of nitrogen treated plants could be connected with the positive effect of nitrogen in some important physiological processes. These differences were statistically significant. However, Zhang *et al*., (2009) showed either more or less nitrogen before or after anthesis, respectively may increase dry matter accumulation and grain filling.

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