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Effect of Planting Geometry and Inorganic Fertilizers with Nano Urea on Growth Indices of Rice Crop (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted at Agronomy Research Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India during Kharif season 2022 and 2023 to find out the effect of planting geometry and inorganic fertilizers with nano urea on

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growth indices of rice crop. All the growth indices parameters viz. Crop growth rate (g m^{-2} day^{-1}) Relative growth rate (g g^{-1} day^{-1}x 10^{-3}), Net Assimilation rate (g m^{-2} day^{-1}) and yield were significantly higher with the treatment P_1 (20 cm × 10 cm) and F_2 [100% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}(Tillering and Panicle initiation stage)] at par with treatment combination P_1 (20 cm × 10 cm) and F_3 [75% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}(Tillering and Panicle initiation stage)] and significantly higher than the other treatments. It can be concluded that treatment C_1 (20 cm × 10 cm) with the application of F_2 [100% RDF + foliar spray of nano urea @ 3000 ml ha^{-1} (Tillering and Panicle initiation stage)] proved better during both the year for all growth indices to achieve higher yield and remuneration of rice crop.

Keywords: CGR; RGR; NAR; nano urea.

1. INTRODUCTION

"Rice (*Oryza sativa* L.) is the prominent staple food for a large part of the world belongs to the family Poaceae, genus *Oryza* originated from South- East Asia and accounts for 20% calories consumed worldwide" [1]. "India is the world's second largest producer of rice accounting for 20% of all world rice production after China. In India, rice is cultivated in 450.57 Lakh ha with an annual production of 122.27 million tons and average productivity of 2713 kg ha^{-1}" [2]. "The productivity level of rice is low compared to the productivity levels of many countries in the world. It is, therefore, there is ample scope to increase the productivity of rice in the country. Planting geometry is the arrangement of the plants in different rows and columns in an area to efficiently utilize the natural resources. So that the optimum planting geometry ensures the proper growth of aerial as well as underground plant parts by efficient utilization of solar radiation, nutrients, and water" [3].

"Rice plants require large amounts of mineral nutrients including nitrogen for their growth, development, and grain production" [4]. "which forces farmers to increase the amount of N fertilizers to accomplish better crop yield. When there is a high N supply in leafy vegetable crops, N mobile form concentrations (i.e., nitrate, ammonium) increase in leaves, thus becoming hazardous to human health. Foliar application can improve nutrient utilization and lowers environment pollution through reducing the amount of fertilizers added to soil. Nano-fertilizers and slowly released fertilizers are appropriate alternatives to conventional fertilizers for gradual and controlled supply of nutrients in the soil [5,6]. Being less expensive than conventional urea, therefore, it is currently the best alternative to urea fertilizer. IFFCO is manufacturer of the world's first revolutionary, innovative Nano-urea fertilizer production in the world, approved by the Government of India and included in the Fertilizer Control Order (FCO) also. Nano nitrogen particles size varies from 20-50 nm with 10,000 times higher surface area to volume size than normal granular urea and it contains 4 % total nitrogen (w/v) evenly dispersed in water. Therefore, Rice production under the current inputs & technology is not sufficient to meet targeted demand and there is an urgent need to increase rice productivity in the world" [7].

2. MATERIALS AND METHODS

The experiment was carried out during *Kharif* 2022 and 2023 at Agronomy Research farm, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). Geographically the experimental site falls under sub- tropical climate of Indo-gangatic plains (IGP) having alluvial calcareous soil and the soil of experimental field was "silty loam" in texture, low in organic carbon and available nitrogen while medium in phosphorous and rich in potassium. The experiment was laid out in Split Plot Design with three (3) replications. The treatment comprised of 3 planting geometry P_1 (20 cm × 10 cm), P_2 (20 cm × 15 cm) and P_3 (20 cm × 20 cm) in main plot and 5 fertilizer levels in sub plot i.e., F_1 [100% RDF (150:60:40)], F_2 [100% RDF + foliar spray of nano urea @ 3000 ml ha^{-1} (Tillering and PI stage)], F_3 [75% RDF + foliar spray of nano urea @ 3000 ml ha^{-1} (Tillering and PI stage)], F_4[50% RDF + foliar spray of nano urea @ 3000 ml ha^{-1} (Tillering and PI stage)] and F_5 [Control (no fertilizers)]. The rice variety Sarju-52 was manually transplanted in kharif season in both year on 2nd June 2022 and 13th June 2023 respectively.

Nano Urea: Nano urea taken from Indian Farmers Fertilizer Cooperative Limited i.e., IFFCO were applied 3000 ml ha^{-1}, i.e., 4 ml liter $^{-1}$, in two split doses i.e., Tillering and Panicle Initiation stages.

2.1 Crop Growth Rate

It represents the dry weight gained by a unit area of crop in unit time. The crop growth rate (CGR) was estimated by using the formula suggested by Buttery [8] and expressed in g m^{-2} day^{-1}.

$$CGR = \frac{1}{A} \times \frac{W_2 - W_1}{T_2 - T_1}$$

Where, A is area, W_1 and W_2 Whole plant dry weight at T_1 and T_2 time, respectively.

2.2 Relative Growth Rate

It is an index of the amount of growing material per unit dry weight of plant present per unit time. The relative growth rate (RGR) was estimated by using the formula suggested by Blackman [9] and expressed as g g^{-1} day^{-1}.

$$RGR = \frac{Log_e W_2 - Log_e W_1}{T_2 - T_1}$$

Where, W_1 and W_2Whole plant dry weight at T_1 and T_2 time, respectively. While Log e is the Neparian log value.

2.3 Net Assimilation Rate

It is increase in dry matter per unit of leaf area per unit time. NAR is calculated by using the formula as suggested by Gregory [10] and expressed as mass $unit^{-1}$ leaf area present per unit time (g cm^{-2} day^{-1}).

$$NAR = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{Log_e A_2 - Log_e A_1}{A_2 - A_1}$$

Where, W_2-W_1/T_2-T_1 is the CGR, A_2 & A_1 is the leaf area at times T_2 and T_1 respectively and log e is the Neparian log value.

3. RESULTS AND DISCUSSION

3.1 Effect of Planting Geometry

3.1.1 Crop growth rate (g m^{-2} day^{-1})

The data related to Crop growth rate (g m^{-2} day^{-1}) have been summarized in Table 1 and depicted in Fig. 1a and 1b. The crop growth rate significantly influenced by planting geometry during kharif season 2022 and 2023. Data further revealed that maximum crop growth rate 15.73 g m^{-2} day^{-1} and 16.13 g m^{-2} day^{-1}, 12.24 g m^{-2} day^{-1} and 12.31 g m^{-2} day^{-1}, 6.99 g m^{-2} day^{-1} and 7.40 g m^{-2} day^{-1} during the year 2022 and 2023 respectively which was recorded under planting geometry P_1 (20 cm × 10 cm) which was statistically at par with P_2 (20 cm × 15 cm) while significantly higher than P_3 (20 cm × 20 cm) at 30 to 60, 60 to 90, 90 DAS to at harvest. This might be due to Accumulation of photosynthates per unit area per day which is very important to contribute more towards higher photosynthetic efficiency and higher yield. All the most similar results were reported by Yoshida [11] and [5].

3.1.2 Relative growth rate (g g^{-1} day^{-1}x 10^{-3})

The data related to relative growth rate (g g^{-1} day^{-1}x 10^{-3}) have been summarized in Table: 2 and depicted in Fig. 2a and 2b clearly indicate that planting geometry did not influence significantly relative growth rate at all stages of crop growth except 30 to 60 DAT during both the year of experimentation.

Data further revealed that the maximum relative growth rate 36.57 g g^{-1} day^{-1} x 10^{-3} and 36.65 g g^{-1} day^{-1} x 10^{-3} at 30 to 60 DAT during the year 2022 and 2023 respectively, recorded under planting geometry P_1 (20 cm × 10 cm) which was statistically at par with P_2 (20 cm × 15 cm) while significantly higher than P_3 (20 cm × 20 cm) and non-significantly effect at 60 to 90 DAT, 90 to at harvest. This might be due to Accumulation of photosynthates per unit area per day which is very important to contribute more towards higher photosynthetic efficiency and higher yield. All the most similar results were reported by Yoshida [11] and [6].

3.1.3 Net assimilation rate (g cm^{-2} day^{-1})

The data related to Net Assimilation rate (g cm^{-2} day^{-1}) have been summarized in Table:3 and depicted in Fig. 3a and 3b clearly indicated that planting geometry had significant effect on Net Assimilation rate (NAR) at 30 to 60 and 60 to 90 DAT stages of crop growth during both the year of experimentation.

The Net Assimilation rate was improved with crop up to 30-60 DAT, but there after slightly declined at stage 60-90 DAT, during both year of the experimentation. Data further revealed that maximum Net Assimilation rate 3.61 g m^{-2} day^{-1} and 3.65 g m^{-2} day^{-1}, 2.5 g m^{-2} day^{-1} and 2.56 g m^{-2} day^{-1} during both the year 2022 and 2023 respectively, which was recorded under planting geometry P_1 (20 cm × 10 cm) and were

statistically at par with P_2 (20 cm × 15 cm) while significantly higher than P_3 (20 cm × 20 cm) at 30 to 60, 60 to 90, 90 DAS to at harvest. This might be due to Accumulation of photosynthates per unit area per day which is very important to contribute more towards higher photosynthetic efficiency and higher yield. All the most similar results were reported by Davis and Mc Cree [12].

Table 1. Effect of different planting geometry and inorganic fertilizers with nano urea on Crop growth rate (g m^{-2} day^{-1}) at different growth stages of rice

Treatments	Crop growth rate (g m^{-2} day^{-1})					
	30-60		60 -90		90 - At harvest	
	2022	2023	2022	2023	2022	2023
(A) Planting geometry						
P_1: 20 cm×10 cm	15.73	16.13	12.24	12.31	6.99	7.40
P_2: 20 cm×15 cm	14.60	15.28	11.83	11.93	6.60	6.88
P_3: 20 cm×20 cm	13.48	14.01	11.13	11.15	5.54	6.29
SE(m)±	0.28	0.29	0.22	0.22	0.12	0.13
C.D. (P=0.05)	1.15	1.18	0.87	0.89	0.50	0.52
(B) Fertilizers levels						
F_1: 100% RDF	15.30	15.85	13.04	13.29	8.29	8.69
F_2: 100% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}	16.14	16.61	13.73	13.87	8.64	9.09
F_3:75% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}	15.37	16.03	13.29	13.33	8.40	8.77
F_4:50% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}	14.31	14.42	10.22	10.57	4.58	5.13
F_5:Control (no fertilizers)	11.97	12.53	9.33	9.72	2.87	3.33
SE(m)±	0.30	0.31	0.24	0.24	0.13	0.14
C.D. (P=0.05)	0.87	0.90	0.70	0.59	0.38	0.41

Table 2. Effect of different planting geometry and inorganic fertilizers with nano urea on Relative growth rate (g g^{-1} day^{-1} x 10^{-3}) at different growth stages of rice

Treatments	Relative growth rate (g g^{-1} day^{-1} x 10^{-3})					
	30-60		60 -90		90 - At harvest	
	2022	2023	2022	2023	2022	2023
(A) Planting geometry						
P_1: 20 cm×10 cm	36.57	36.65	14.22	13.69	5.74	5.97
P_2: 20 cm×15 cm	35.13	35.55	14.03	13.65	5.64	6.03
P_3: 20 cm×20 cm	33.93	34.30	13.85	13.30	5.16	5.67
SE(m)±	0.68	0.29	0.25	0.25	0.12	0.11
C.D. (P=0.05)	2.50	1.17	NS	NS	NS	NS
(B) Fertilizers levels						
F_1: 100% RDF	35.78	36.37	15.21	14.39	6.65	6.80
F_2: 100% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}	37.21	37.10	15.08	14.74	6.89	7.10
F_3:75% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}	36.23	36.54	15.12	14.64	6.86	6.90
F_4:50% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}	35.18	34.71	11.76	12.03	4.58	5.01
F_5:Control (no fertilizers)	31.64	32.13	12.99	11.92	3.15	3.63
SE(m)±	0.73	0.65	0.30	0.29	0.12	0.13
C.D. (P=0.05)	2.01	1.89	0.86	0.83	0.34	0.36

Table 3. Effect of different planting geometry and inorganic fertilizers with nano urea on Net Assimilation Rate (g m^{-2} day^{-1}) at different growth stages of rice

Treatments	Net Assimilation Rate (g m^{-2} day^{-1})			
	30-60 DAS		60-90 DAS	
	2022	2023	2022	2023
(A) Planting geometry				
P_1: 20 cm×10 cm	3.61	3.65	2.5	2.56
P_2: 20 cm×15 cm	3.5	3.54	2.36	2.43
P_3: 20 cm×20 cm	3.09	3.14	1.91	2.00
SE(m)±	0.09	0.07	0.08	0.04
C.D. (P=0.05)	0.36	0.28	0.31	0.15
(B) Fertilizers levels				
F_1: 100% RDF	3.73	3.88	2.72	2.86
F_2: 100% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}	4.07	4.13	2.93	3.01
F_3:75% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}	3.93	3.97	2.78	2.98
F_4:50% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}	2.79	2.83	1.65	1.72
F_5:Control (no fertilizers)	2.70	2.73	1.56	1.62
SE(m)±	0.12	0.09	0.08	0.06
C.D. (P=0.05)	0.35	0.27	0.24	0.15

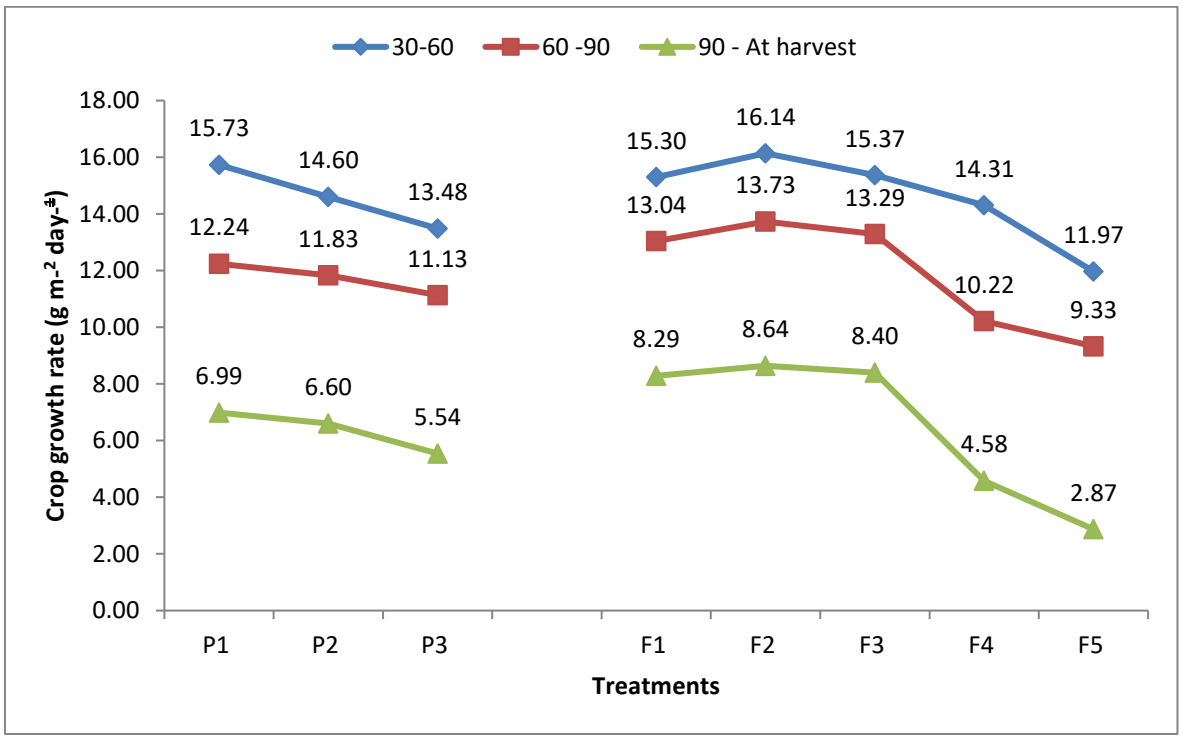

Fig. 1a. Effect of different planting geometry and fertilizers levels on crop growth rate (g $m^{-2}$$day^{-1}$) of rice during 2022

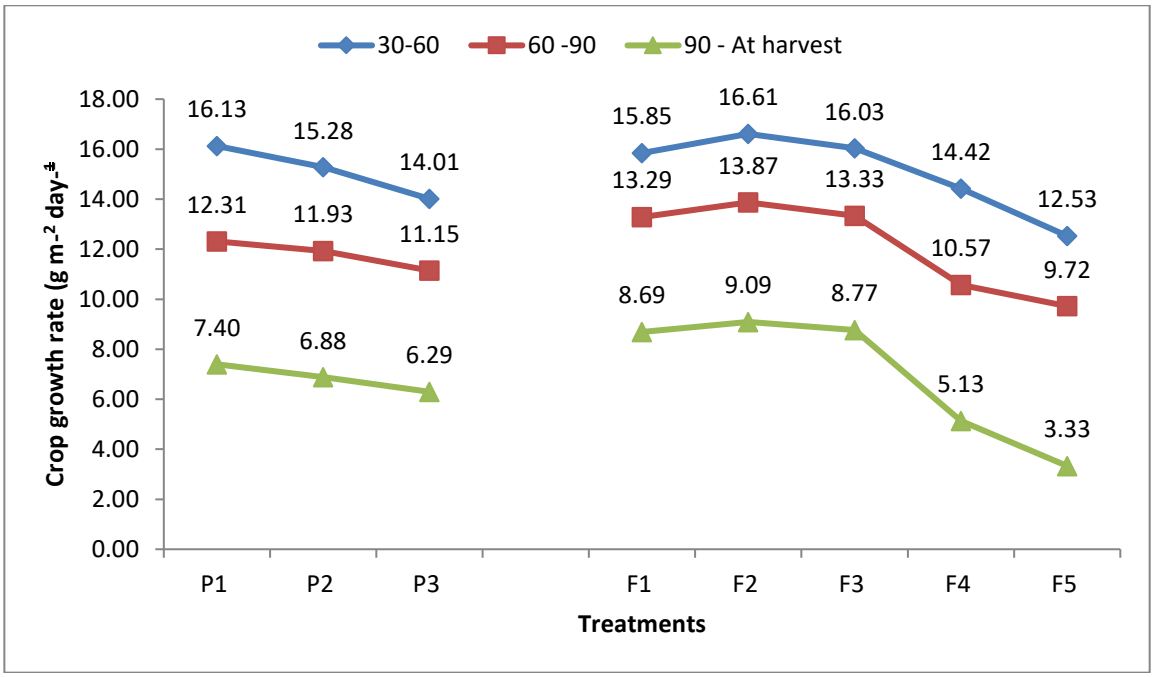

Fig. 1b. Effect of different planting geometry and fertilizers levels on crop growth rate (g m^{-2}day^{-1}) of rice during 2023

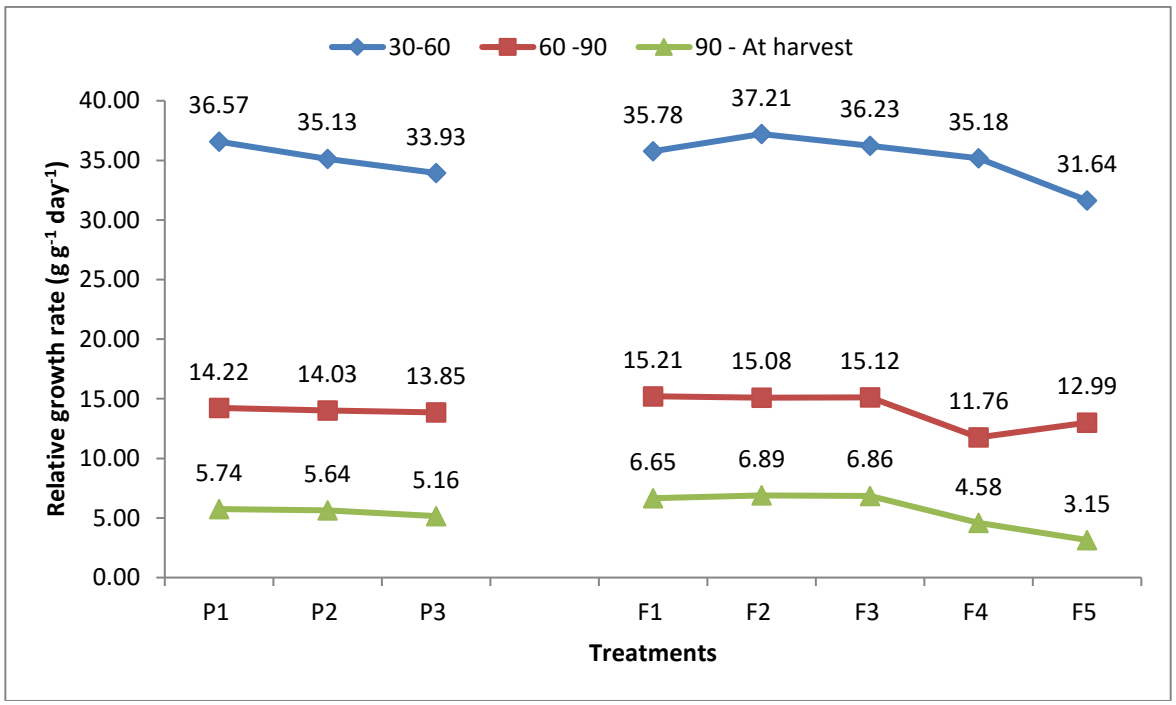

Fig. 2a. Effect of different planting geometry and fertilizers levels on relative growth rate (g g^{-1} day^{-1}) of rice during 2022

3.2 Effect of Fertilizer Levels

3.2.1 Crop growth rate (g m^{-2} day^{-1})

The data related to crop growth rate (g m^{-2} day^{-1}) have been summarized in Table :1 and depicted in Fig. 1a and 1b clearly indicated that planting geometry had significant effect on crop growth rate (CGR) at all stages of crop growth during both the year of experimentation. Application of F_2 [100% RDF + foliar spray of nano urea @ 3000 ml ha^{-1} (Tillering and PI stage)]recorded

significantly maximum crop growth rate 16.14 g m^{-2} day^{-1} and 16.61 g m^{-2} day^{-1}, 13.73 g m^{-2} day^{-1} and 13.87 g m^{-2} day^{-1}, 8.64 g m^{-2} day^{-1} and 9.09 g m^{-2} day^{-1} during year 2022 and 2023 respectively which was statistically at par with application which was at par with application of F_3 (75% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}) and F_1 (100% RDF). While significantly higher than the rest of the fertilizer levels during both years. This might be due to treatment F_2 which supplies adequate amount of nitrogen both in root zone and plant system The findings are consistent with those of [13].

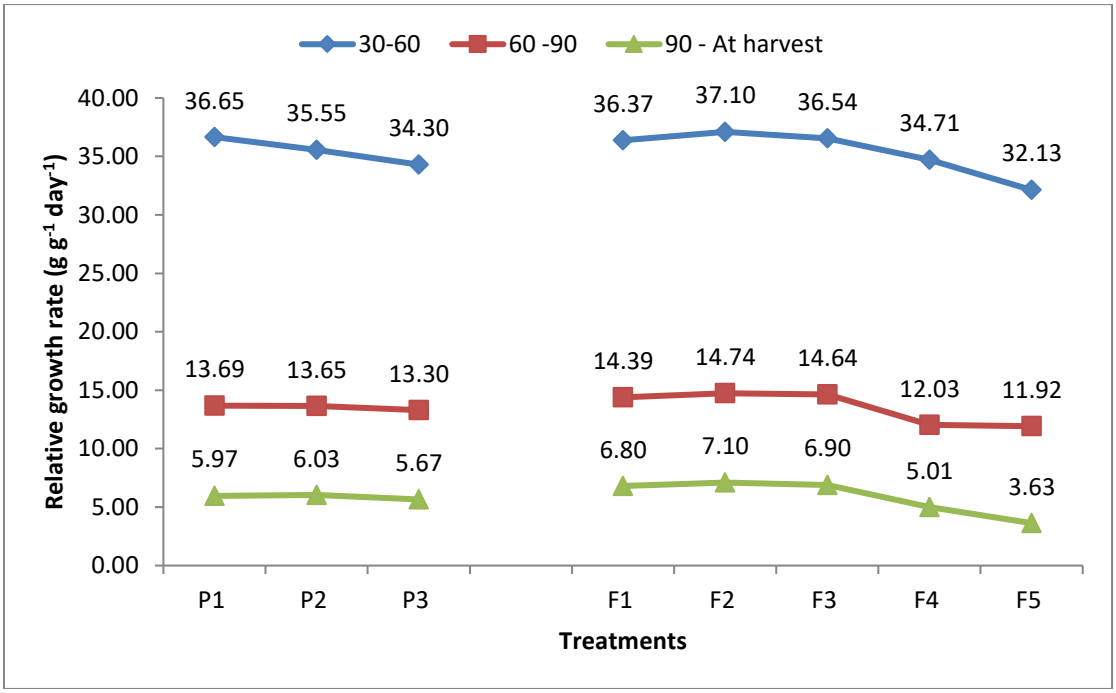

Fig. 2b. Effect of different planting geometry and fertilizers levels on relative growth rate (g g^{-1} day^{-1}) of rice during 2023

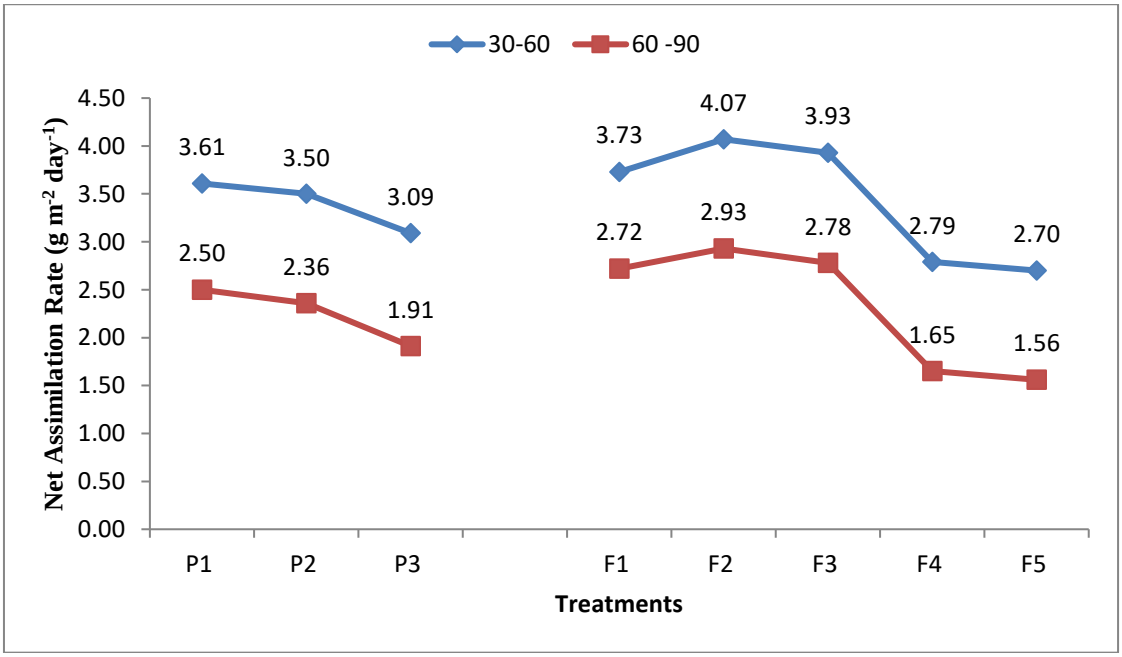

Fig. 3a. Effect of different planting geometry and fertilizers levels on net assimilation rate (g m^{-2} day^{-1}) of rice during 2022

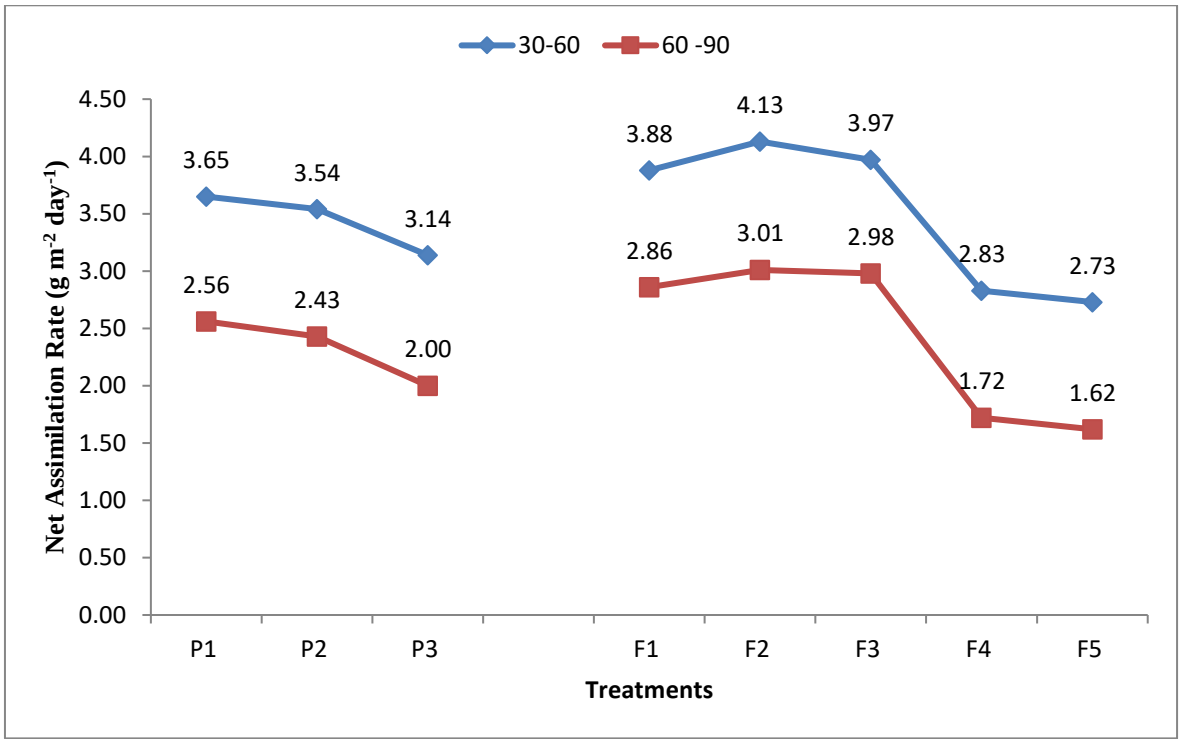

Fig. 3b. Effect of different planting geometry and fertilizers levels on net assimilation rate (g m^{-2} day^{-1}) of rice during 2023

3.2.2 Relative growth rate (g g^{-1} day^{-1}x 10^{-3})

The data related to relative growth rate (g g^{-1} day^{-1}x 10^{-3}) have been summarized in Table:2 and depicted in Fig. 2a and 2b clearly indicate that planting geometry did not influence significantly relative growth rate at all stages of crop growth except 30 to 60 DAT during both the year of experimentation.

Application of F_2 [100% RDF + foliar spray of nano urea @ 3000 ml ha^{-1} (Tillering and PI stage)]recorded significantly maximum relative growth rate 37.21 and 37.10, 15.08 and 14.74, 6.89 and 7.10 at 30 to 60, 60 to 90, 90 DAT and at harvest during the year 2022 and 2023 respectively, which was statistically at par with application which was at par with application of F_3 (75% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}) and F_1 (100% RDF). While significantly higher than the rest of the fertilizer levels during both years. This might be due to treatment F_2 which supplies adequate amount of nitrogen both in root zone and plant system The findings are consistent with those of [13].

3.2.3 Net assimilation rate (g cm^{-2} day^{-1})

The data related to Net Assimilation rate (g cm^{-2} day^{-1}) have been summarized in Table 3 and depicted in Fig. 3a and 3b clearly indicated that planting geometry and inorganic fertilizers with nano urea had significant effect on Net Assimilation rate (NAR) at 30 to 60 and 60 to 90 DAT stages of crop growth during both the year of experimentation.

Application of F_2 [100% RDF + foliar spray of nano urea @ 3000 ml ha^{-1} (Tillering and PI stage)]recorded significantly maximum Net Assimilation rate 4.07 g m^{-2} day^{-1} and 4.13 g m^{-2} day^{-1} , 2.93 g m^{-2} day^{-1} and 3.01 g m^{-2} day^{-1} during both the year 2022 and 2023 respectively, which was statistically at par with application which was at par with application of F_3 (75% RDF + foliar spray of nano urea @ 3000 ml ha^{-1}) and F_1 (100% RDF). While significantly higher than the rest of the fertilizer levels during both years. This might be due to treatment F_2 which supplies adequate amount of nitrogen both in root zone and plant system The findings are consistent with those of [13,14,15,16,17].

4. CONCLUSION

From the above overall studies, it can be concluded that the treatment C_1 (20 cm × 10 cm) with the application of the F_2 [100% RDF + foliar spray of nano urea @ 3000 ml ha^{-1} (Tillering and

PI stage)] found better growth indices i.e., Crop growth rate (CGR), Relative growth rate (RGR) and Net Assimilation rate (NAR).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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