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Effect of high temperature and nitrogen stress on growth attributes of rice cultivars

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Abstract

A field experiments were conducted in a Temperature Gradient Tunnel (TGT) at the MB-4C farm of ICAR-Indian Agricultural Research Institute, New Delhi, during 2019 and 2020, focusing on rice crops. This study aimed to evaluate the impact of varying temperature conditions and nutrient treatments on the photosynthetic performance of rice at different growth stages, including tillering, panicle initiation, booting, flowering, and ripening. The results revealed significant variations in photosynthetic rates, with maximum values observed in treatments with higher nutrient levels (N_1V_6 , N_1V_4) and minimum rates in nutrient-deficient conditions (N_0V_2 , N_0V_1). Notably, treatment N_1V_6 consistently exhibited the highest photosynthetic rates across all growth stages. Additionally, the investigation of chlorophyll content (chl a+b) across various treatments N_1V_3 had the highest values at all growth stages, while N_0V_1 recorded the lowest. Overall, the findings underscore the critical role of temperature and nutrient management in optimizing photosynthetic efficiency and enhancing rice productivity in the face of changing climatic conditions.

Keywords: Rice, temperature gradient tunnel, photosynthetic performance, tillering, panicle initiation, booting, ripening, chlorophyll content, nutrient management, climatic conditions, photosynthetic rates

1. Introduction

Rice (*Oryza sativa* L.) is the most important and extensively cultivated food crop that has been referred as “Global Grain” because of its use as prime staple food in about 100 countries of the world. Its cultivation is of immense importance to food security of Asia, where more than 90% of the global rice is produced and consumed. Rice provides 32-59% of the dietary energy and 25-44% of the dietary protein in 39 countries. In India, it accounts for more than 40% of food grain production, providing direct employment to 70% people in rural areas (Anon., 2020) ^[1]. Over 2 billion people in Asia alone derive 80 per cent of their energy needs from rice, which contains 80 percent carbohydrates, 7-8 per cent protein, 3 per cent fat, and 3 per cent fiber, which constitutes the principle food for about 60 per cent of the world’s population.

Globally, rice demand is expected to increase by 25% from the year 2001 to 2025 to meet the requirement of increasing population. Globally, total rice area is about 165.62 M ha, production is 520.90 Mt with productivity of 3.1 t ha⁻¹ (Anonymous, 2023a) ^[2].

In India, increase in minimum support price of rice and its adaptability to various biotic and abiotic factors have made it a preferable crop for farmers especially those who fall under the category of marginal farmers. In India it is cultivated area in nearly 46.51 million ha with production of about 130.29 million tonnes and average productivity of 2809 kg/ha (Anonymous, 2023b) ^[3].

Rice plays a vital role in our food as well as nutritional security for millions of livelihood. Thus, the slogan “Rice is life” by IRRI during 2004 seems to be most appropriate (Chandrasekaran *et al.*, 2007) ^[6]. Rice ranks second to wheat in terms of area harvested but in terms of importance as a food crop, rice provides more calories ha⁻¹ than any cereal crop. Besides its importance as food, rice provides. Nutrients are one of the most important inputs, required by the plants for their growth and yield. The N, P and K are major nutrients and are supplied through fertilizers and manures. At present, increasing cost of fertilizers, growing ecological 2 concern and

conservation of energy have created considerable interest for the use of organics as a source of plant nutrients with blending of chemical fertilizer to reduce losses of nutrients as integrated nutrient management system (Verma *et al.*, 2017)^[18].

2. Materials and Methods

Study Site and Experimental Design

The field experiments were conducted at the MB-4C farm facility at IARI Farm (Latitude: 28°4'N, Longitude: 77°09'E, Altitude: 228.16 m above MSL) on rice crops during the years 2019-20 and 2020-21. The study utilized a randomized block design with six treatments, each having three replications. The treatments included two nitrogen levels (N_1 - recommended nitrogen dose of 120 kg/ha, and N_0 - no nitrogen application) and six rice varieties: Basmati 370 (V_1), Jaldi Dhan-13 (V_2), Jaldi Dhan-6 (V_3), Pusa Basmati-1 (V_4), Annapurna (V_5), and Nagina-22 (V_6). Each experimental plot had a specified area, and standard agronomic practices, including irrigation, pest management, and fertilization, were followed as per local recommendations. Data were collected for photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) at various growth stages: tillering, panicle initiation, booting, flowering, and ripening.

The photosynthetic rate was measured using a portable photosynthesis measurement system at different growth stages during both years. The data were recorded for each treatment at specific intervals during the growing season, with significant maximum and minimum values for photosynthetic rate observed in different treatments. Chlorophyll content (Chl a + b) was also measured at several days after transplanting (DAT) intervals: 10, 17, 24, 31, 38, 45, 52, 59, 66, 73, and 80 DAT. Chlorophyll measurements were taken using a chlorophyll meter, and the results were analyzed for significant differences across treatments. Statistical analysis of the data was performed using analysis of variance (ANOVA) to assess the significant differences between the treatments, and means were compared using the randomized block design at a significance level of $p \leq 0.05$.

3. Result

Photosynthetic Rate ($\text{mmol m}^{-2} \text{s}^{-1}$)

Ambient

Tillering

The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_6 (9.32), which was at par with the treatment, N_1V_5 (9.32) and N_1V_5 (9.08). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2 (6.40) in the year 2019-20. The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_6 (10.27), which was at par with the treatment, N_1V_5 (10.25) and N_1V_5 (10.02). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2 (7.35) in the year 2020-21. The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_6 (9.80), which was at par with the treatment, N_1V_5 (9.78) and N_1V_5 (9.55). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2 (6.88) in the pooled mean.

Panicle initiation

The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_6 (12.17 $\text{mmol m}^{-2} \text{s}^{-1}$), which was at par with the treatment, N_0V_5 (11.26 $\text{mmol m}^{-2} \text{s}^{-1}$) and N_1V_4 (11.77 $\text{mmol m}^{-2} \text{s}^{-1}$). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2

(8.58 $\text{mmol m}^{-2} \text{s}^{-1}$) in the year 2019-20. The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_6 (12.70 $\text{mmol m}^{-2} \text{s}^{-1}$), which was at par with the treatment, N_0V_5 (11.54 $\text{mmol m}^{-2} \text{s}^{-1}$) and N_1V_4 (12.32 $\text{mmol m}^{-2} \text{s}^{-1}$). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2 (9.12 $\text{mmol m}^{-2} \text{s}^{-1}$) in the year 2020-21. The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_6 (12.44 $\text{mmol m}^{-2} \text{s}^{-1}$), which was at par with the treatment, N_0V_5 (11.54 $\text{mmol m}^{-2} \text{s}^{-1}$) and N_1V_4 (12.04 $\text{mmol m}^{-2} \text{s}^{-1}$). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2 (8.85 $\text{mmol m}^{-2} \text{s}^{-1}$) in the pooled mean.

Booting

The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_4 (16.95 $\text{mmol m}^{-2} \text{s}^{-1}$), which was at par with the treatment, N_1V_1 (15.65 $\text{mmol m}^{-2} \text{s}^{-1}$) and N_1V_6 (15.61 $\text{mmol m}^{-2} \text{s}^{-1}$). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2 (11.63 $\text{mmol m}^{-2} \text{s}^{-1}$) in the year 2019-20. The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_4 (17.71 $\text{mmol m}^{-2} \text{s}^{-1}$), which was at par with the treatment, N_1V_1 (16.60 $\text{mmol m}^{-2} \text{s}^{-1}$) and N_1V_6 (16.36 $\text{mmol m}^{-2} \text{s}^{-1}$). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2 (12.00 $\text{mmol m}^{-2} \text{s}^{-1}$) in the year 2020-21. The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_4 (17.33 $\text{mmol m}^{-2} \text{s}^{-1}$), which was at par with the treatment, N_1V_1 (16.13 $\text{mmol m}^{-2} \text{s}^{-1}$) and N_1V_6 (15.99 $\text{mmol m}^{-2} \text{s}^{-1}$). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2 (11.81 $\text{mmol m}^{-2} \text{s}^{-1}$) in the pooled mean.

Flowering

The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_4 (23.20 $\text{mmol m}^{-2} \text{s}^{-1}$), which was at par with the treatment, N_1V_1 (23.19 $\text{mmol m}^{-2} \text{s}^{-1}$) and N_1V_6 (21.59 $\text{mmol m}^{-2} \text{s}^{-1}$). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2 (14.90 $\text{mmol m}^{-2} \text{s}^{-1}$) in the year 2019-20. The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_4 (24.00 $\text{mmol m}^{-2} \text{s}^{-1}$), which was at par with the treatment, N_1V_1 (23.99 $\text{mmol m}^{-2} \text{s}^{-1}$) and N_1V_6 (22.39 $\text{mmol m}^{-2} \text{s}^{-1}$). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2 (15.70 $\text{mmol m}^{-2} \text{s}^{-1}$) in the year 2020-21. The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_4 (23.60 $\text{mmol m}^{-2} \text{s}^{-1}$), which was at par with the treatment, N_1V_1 (23.59 $\text{mmol m}^{-2} \text{s}^{-1}$) and N_1V_6 (21.99 $\text{mmol m}^{-2} \text{s}^{-1}$). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_2 (15.30 $\text{mmol m}^{-2} \text{s}^{-1}$) in the pooled mean.

Ripening

The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_2 (4.12 $\text{mmol m}^{-2} \text{s}^{-1}$), which was at par with the treatment, N_1V_4 (4.10 $\text{mmol m}^{-2} \text{s}^{-1}$) and N_1V_6 (4.04 $\text{mmol m}^{-2} \text{s}^{-1}$). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_1 (2.38 $\text{mmol m}^{-2} \text{s}^{-1}$) in the year 2019-20. The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was significantly maximum in treatment N_1V_2 (4.16 $\text{mmol m}^{-2} \text{s}^{-1}$), which was at par with the treatment, N_1V_4 (4.15 $\text{mmol m}^{-2} \text{s}^{-1}$) and N_1V_6 (4.09 $\text{mmol m}^{-2} \text{s}^{-1}$). The significantly minimum photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) was seen in treatment N_0V_1 (2.42 $\text{mmol m}^{-2} \text{s}^{-1}$) in the year 2020-21. The observations about photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$)

~ 621 ~

chlrophyll content (chl a+b) was seen in the treatment N₀V₃ (1.65) in the pooled mean.

The data regarding on chlrophyll content (chl a+b) at 73 DAT significantly maximum in the treatment N₁V₁ with value (3.08), which was followed by the treatment N₀V₄ and N₁V₄ with measuring (1.93) and (2.25). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂ (0.00) in the year 2019-20. The data regarding on chlrophyll content (chl a+b) at 73 DAT significantly maximum in the treatment N₁V₁ with value (3.12), which was followed by the treatment N₀V₄ and N₁V₄ with measuring (1.98) and (2.21). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂ (0.00) in the year 2020-21. The data regarding on chlrophyll content (chl a+b) at 73 DAT significantly maximum in the treatment N₁V₁ with value (3.10), which was followed by the treatment N₀V₄ and N₁V₄ with measuring (1.96) and (2.23). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂ (0.00) in the pooled mean.

The data regarding on chlrophyll content (chl a+b) at 80 DAT significantly maximum in the treatment N₁V₁ with value (3.63), which was followed by the treatment N₀V₁ and N₁V₄ with measuring (2.20) and (1.87). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂ (0.00) in the year 2019-20. The data regarding on chlrophyll content (chl a+b) at 80 DAT significantly maximum in the treatment N₁V₁ with value (2.68), which was followed by the treatment N₀V₁ and N₁V₄ with measuring (2.25) and (1.91). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂ (0.00) in the year 2020-21. The data regarding on chlrophyll content (chl a+b) at 80 DAT significantly maximum in the treatment N₁V₁ with value (2.66), which was followed by the treatment N₀V₁ and N₁V₄ with measuring (2.23) and (1.89). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂

(0.00) in the pooled mean.

The data regarding on chlrophyll content (chl a+b) at 87 DAT significantly maximum in the treatment N₁V₄ with value (2.30), which was followed by the treatment N₀V₁ and N₁V₁ with measuring (1.85) and (2.07). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂ (0.00) in the year 2019-20. The data regarding on chlrophyll content (chl a+b) at 87 DAT significantly maximum in the treatment N₁V₄ with value (2.34), which was followed by the treatment N₀V₁ and N₁V₁ with measuring (1.89) and (2.11). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂ (0.00) in the year 2020-21. The data regarding on chlrophyll content (chl a+b) at 87 DAT significantly maximum in the treatment N₁V₄ with value (2.32), which was followed by the treatment N₀V₁ and N₁V₁ with measuring (1.87) and (2.09). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂ (0.00) in the pooled mean.

The data regarding on chlrophyll content (chl a+b) at 94 DAT significantly maximum in the treatment N₁V₁ with value (1.81), which was followed by the treatment N₀V₁ and N₁V₁ with measuring (1.54) and (0.00). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂ (0.00) in the year 2019-20. The data regarding on chlrophyll content (chl a+b) at 94 DAT significantly maximum in the treatment N₁V₁ with value (1.85), which was followed by the treatment N₀V₁ and N₁V₁ with measuring (1.61) and (0.00). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂ (0.00) in the year 2020-21. The data regarding on chlrophyll content (chl a+b) at 94 DAT significantly maximum in the treatment N₁V₁ with value (1.83), which was followed by the treatment N₀V₁ and N₁V₁ with measuring (1.57) and (0.00). While the significantly minimum chlrophyll content (chl a+b) was seen in the treatment N₀V₂ (0.00) in the pooled mean

Table 1: Effect of high temperature and nitrogen stress of photosynthetic rate (mmol m⁻² s⁻¹) on tillering and panicle initiation

Tr. No.	Photosynthetic Rate (mmol m ⁻² s ⁻¹)											
	Tillering						Panicle initiation					
	AMBIENT			TGT			AMBIENT			TGT		
	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean
N0V1	8.47	9.71	9.09	7.63	8.97	8.30	8.58	9.69	9.14	9.00	10.34	9.67
N0V2	6.40	7.64	7.02	5.68	7.02	6.35	9.12	10.23	9.68	6.89	8.23	7.56
N0V3	7.61	8.85	8.23	6.69	8.03	7.36	10.27	11.38	10.83	7.27	8.61	7.94
N0V4	8.84	10.08	9.46	7.88	9.22	8.55	9.12	10.23	9.68	9.51	10.85	10.18
N0V5	8.10	9.34	8.72	8.18	9.52	8.85	11.26	12.37	11.82	9.55	10.89	10.22
N0V6	8.89	10.13	9.51	8.89	10.23	9.56	11.12	12.23	11.67	10.80	12.14	11.47
N1V1	8.71	9.95	9.33	8.00	9.34	8.67	9.50	10.61	10.06	10.09	11.43	10.76
N1V2	6.57	7.81	7.19	5.98	7.32	6.65	10.15	11.26	10.70	7.96	9.30	8.63
N1V3	7.73	8.97	8.35	7.07	8.41	7.74	11.05	12.16	11.61	8.85	10.19	9.52
N1V4	9.08	10.32	9.70	8.08	9.42	8.75	11.77	12.88	12.32	10.60	11.94	11.27
N1V5	9.31	10.55	9.93	8.65	9.99	9.32	10.40	11.51	10.96	11.30	12.64	11.97
N1V6	9.32	10.56	9.94	9.10	10.44	9.77	12.17	13.28	12.73	11.57	12.91	12.24
S.Em(±)	0.39	0.65	0.32	0.52	0.30	0.28	0.77	0.38	0.45	0.59	0.36	0.31
CD (5%)	1.13	1.90	0.93	1.52	0.88	0.82	2.26	1.11	1.33	1.73	1.04	0.90
CV (%)	8.10	11.82	6.17	11.69	5.80	5.79	12.86	5.70	7.20	10.78	5.72	5.26

Table 2: Effect of high temperature and nitrogen stress of photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) on booting and flowering.

Tr. No.	Photosynthetic Rate ($\text{mmol m}^{-2} \text{s}^{-1}$)											
	Booting						Flowering					
	AMBIENT			TGT			AMBIENT			TGT		
	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean
N0V1	13.49	15.00	14.24	10.16	11.70	10.93	18.06	19.48	18.77	11.09	12.77	11.93
N0V2	11.63	13.13	12.38	9.11	10.65	9.88	14.90	16.32	15.61	9.96	11.64	10.80
N0V3	12.24	13.74	12.99	9.06	10.60	9.83	15.37	16.79	16.08	9.57	11.25	10.41
N0V4	14.67	16.17	15.42	11.08	12.62	11.85	17.42	18.84	18.13	12.20	13.88	13.04
N0V5	12.76	14.26	13.51	10.06	11.60	10.83	15.80	17.22	16.51	11.63	13.31	12.47
N0V6	13.64	15.14	14.39	12.29	13.83	13.06	16.95	18.37	17.66	14.99	16.66	15.82
N1V1	15.65	17.15	16.40	13.57	15.11	14.34	23.19	24.61	23.90	17.09	18.77	17.93
N1V2	14.45	15.95	15.20	11.98	13.52	12.75	17.91	19.33	18.62	14.08	15.76	14.92
N1V3	15.06	16.57	15.81	12.13	13.67	12.90	18.66	20.08	19.37	14.48	16.16	15.32
N1V4	16.95	18.45	17.70	14.63	16.17	15.40	23.20	24.62	23.91	17.50	19.18	18.34
N1V5	13.42	14.92	14.17	11.99	13.53	12.76	18.12	19.54	18.83	15.19	16.87	16.03
N1V6	15.61	17.12	16.36	14.69	16.23	15.46	21.59	23.01	22.30	19.79	21.46	20.62
S.Em($\pm$)	0.80	0.66	0.53	0.68	0.94	0.65	0.77	1.24	0.72	0.95	0.82	0.61
CD (5%)	2.33	1.94	1.56	1.99	2.77	1.91	2.27	3.63	2.10	2.79	2.40	1.80
CV (%)	9.76	7.32	6.18	10.04	12.31	9.03	7.28	10.80	6.48	11.81	9.05	7.17

Table 3: Effect of high temperature and nitrogen stress of photosynthetic rate ($\text{mmol m}^{-2} \text{s}^{-1}$) on ripening

Tr. No.	Photosynthetic Rate ($\text{mmol m}^{-2} \text{s}^{-1}$)					
	Ripening					
	AMBIENT			TGT		
	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean
N0V1	2.38	3.62	3.00	1.20	2.54	1.87
N0V2	3.21	4.45	3.83	2.02	3.36	2.69
N0V3	3.36	4.60	3.98	1.64	2.98	2.31
N0V4	2.77	4.01	3.39	1.77	3.11	2.44
N0V5	3.20	4.44	3.82	1.86	3.20	2.53
N0V6	2.95	4.19	3.57	2.53	3.20	2.87
N1V1	3.66	4.90	4.28	2.77	4.11	3.44
N1V2	4.12	5.36	4.74	3.28	4.62	3.95
N1V3	3.54	4.78	4.16	2.96	4.30	3.63
N1V4	4.10	5.34	4.72	3.18	4.52	3.85
N1V5	3.76	5.00	4.38	2.98	4.32	3.65
N1V6	4.04	5.28	4.66	3.69	5.03	4.36
S.Em($\pm$)	0.27	0.41	0.23	0.17	0.28	0.13
CD (5%)	0.79	1.21	0.68	0.49	0.81	0.38
CV (%)	13.56	15.28	9.87	11.68	12.68	7.23

Table 4: Effect of high temperature and nitrogen stress chlorophyll content (chl a+b)

Tr. No.	Chlorophyll content (chl a+b)											
	10 DAT			17 DAT			24 DAT			31 DAT		
	AMBIENT			AMBIENT			AMBIENT			AMBIENT		
	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean
N0V1	0.92	0.98	0.95	1.02	1.07	1.05	1.08	1.11	1.09	1.35	1.37	1.36
N0V2	0.98	1.03	1.00	1.22	1.28	1.25	1.28	1.31	1.30	1.96	2.01	1.99
N0V3	0.99	1.04	1.01	1.22	1.29	1.25	1.29	1.33	1.31	1.96	1.00	1.48
N0V4	1.01	1.08	1.05	1.15	1.20	1.18	1.23	1.27	1.25	1.90	1.93	1.91
N0V5	1.01	1.07	1.04	1.20	1.25	1.23	1.27	1.32	1.29	1.90	1.94	1.92
N0V6	1.02	1.08	1.05	1.24	1.29	1.26	1.33	1.37	1.35	2.18	2.22	2.20
N1V1	0.93	0.97	0.95	1.13	1.19	1.16	1.17	1.22	1.20	1.50	1.54	1.52
N1V2	1.11	1.16	1.14	1.30	1.35	1.32	1.42	1.46	1.44	2.38	2.41	2.39
N1V3	1.12	1.18	1.15	1.31	1.37	1.34	1.44	1.49	1.47	2.43	2.47	2.45
N1V4	1.01	1.07	1.04	1.20	1.27	1.23	1.31	1.38	1.34	2.04	2.09	2.06
N1V5	1.04	1.09	1.06	1.29	1.35	1.32	1.40	1.44	1.42	2.15	2.19	2.17
N1V6	1.11	1.17	1.14	1.29	1.34	1.32	1.44	1.51	1.48	2.45	2.51	2.48
S.Em($\pm$)	0.06	0.08	0.05	0.05	0.09	0.06	0.06	0.07	0.05	0.14	0.08	0.08
CD (5%)	0.19	0.22	0.14	0.16	0.27	0.16	0.16	0.20	0.14	0.41	0.24	0.23
CV (%)	10.95	12.07	7.67	7.75	12.59	7.70	7.42	8.88	6.11	11.89	7.09	6.71

Tr. No.	Chlorophyll content (chl a+b)								
	38 DAT			45 DAT			52 DAT		
	AMBIENT			AMBIENT			AMBIENT		
	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean
N0V1	1.47	1.51	1.49	1.62	1.65	1.63	1.99	2.03	2.01
N0V2	2.16	2.19	2.17	2.40	2.45	2.42	2.24	2.27	2.26
N0V3	2.11	2.16	2.14	2.44	2.49	2.46	2.26	2.29	2.28
N0V4	1.96	2.00	1.98	2.33	2.37	2.35	2.49	2.52	2.50
N0V5	2.21	2.25	2.23	2.36	2.39	2.37	2.27	2.32	2.29
N0V6	2.31	2.36	2.33	2.47	2.52	2.50	2.34	2.37	2.36
N1V1	1.62	1.68	1.65	1.85	1.92	1.88	2.30	2.35	2.32
N1V2	2.67	2.73	2.70	3.18	3.23	3.20	2.36	3.39	2.88
N1V3	2.70	2.76	2.73	2.99	3.04	3.01	2.55	2.59	2.57
N1V4	2.38	2.42	2.40	2.61	2.65	2.63	2.79	2.82	2.80
N1V5	2.52	2.58	2.55	3.22	3.28	3.25	2.93	2.96	2.95
N1V6	2.74	2.79	2.76	3.30	3.36	3.33	2.79	2.83	2.81
S.Em(±)	0.10	0.13	0.09	0.17	0.12	0.09	0.13	0.13	0.10
CD (5%)	0.31	0.37	0.27	0.49	0.36	0.26	0.39	0.39	0.29
CV (%)	8.08	9.50	7.07	11.23	8.04	6.01	9.43	8.98	6.82

Tr. No.	Chlorophyll content (chl a+b)								
	59 DAT			66 DAT			73 DAT		
	AMBIENT			AMBIENT			AMBIENT		
	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean
N0V1	2.74	2.79	2.76	2.71	2.78	2.74	1.84	1.89	1.87
N0V2	1.81	1.85	1.83	1.67	1.72	1.69	0.00	0.00	0.00
N0V3	1.87	1.80	1.83	1.62	1.67	1.65	0.00	0.00	0.00
N0V4	2.76	2.79	2.77	2.48	2.52	2.50	1.93	1.98	1.96
N0V5	1.90	1.95	1.93	1.61	1.66	1.63	1.49	1.54	1.52
N0V6	1.93	1.98	1.95	1.66	1.69	1.68	0.00	0.00	0.00
N1V1	2.83	2.89	2.86	3.75	3.82	3.79	3.08	3.12	3.10
N1V2	2.18	2.23	2.21	1.79	1.83	1.81	0.00	0.00	0.00
N1V3	2.15	2.19	2.17	1.71	1.76	1.73	0.00	0.00	0.00
N1V4	3.15	3.21	3.18	2.75	2.79	2.77	2.25	2.21	2.23
N1V5	2.19	2.24	2.21	1.82	1.88	1.85	1.70	1.74	1.72
N1V6	2.23	2.28	2.26	1.83	1.87	1.85	0.00	0.00	0.00
S.Em(±)	0.14	0.15	0.08	0.14	0.16	0.11	0.06	0.07	0.05
CD (5%)	0.41	0.44	0.25	0.41	0.46	0.31	0.16	0.21	0.14
CV (%)	10.43	11.06	6.30	11.39	12.47	8.58	9.36	11.95	7.79

Tr. No.	Chlorophyll content (chl a+b)								
	80 DAT			87 DAT			94 DAT		
	AMBIENT			AMBIENT			AMBIENT		
	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean	Year 2019-20	Year 2020-21	Pooled mean
N0V1	2.20	2.25	2.23	1.85	1.89	1.87	1.54	1.61	1.57
N0V2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N0V3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N0V4	1.81	1.85	1.83	1.70	1.75	1.73	0.00	0.00	0.00
N0V5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N0V6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N1V1	2.63	2.68	2.66	2.07	2.11	2.09	1.81	1.85	1.83
N1V2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N1V3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N1V4	1.87	1.91	1.89	2.30	2.34	2.32	0.00	0.00	0.00
N1V5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N1V6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S.Em(±)	0.05	0.02	0.03	0.04	0.04	0.03	0.01	0.01	0.01
CD (5%)	0.15	0.07	0.08	0.13	0.11	0.08	0.04	0.03	0.02
CV (%)	12.17	5.77	6.38	11.38	9.74	6.96	9.16	6.10	3.87

4. Conclusion

In conclusion, the study demonstrated that nitrogen-rich treatments (N₁) consistently resulted in higher photosynthetic rates and chlorophyll content across various growth stages in both ambient and TGT conditions. Specifically, treatment N₁V₆ performed the best, showing significant improvements in photosynthetic efficiency, biomass accumulation, and overall

growth, compared to other treatments. The results highlight the critical role of nitrogen application in enhancing rice productivity, particularly in optimizing photosynthetic activity and chlorophyll synthesis. These findings emphasize the importance of effective nutrient management, particularly nitrogen, in maximizing rice yield and suggest that further research should focus on refining nutrient strategies to improve

crop performance under varied environmental conditions.

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