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Dry Matter Partitioning and Growth Dynamics of Two Short Duration Rice Varieties at Variable Doses of Nitrogen

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A R T I C L E I N F O

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A B S T R A C T

Nitrogen availability is a major factor influencing rice growth and developmental processes. The present research was conducted at the West Byde Research Field of the Bangladesh Rice Research Institute (BRRI), Gazipur to evaluate the effects of different nitrogen levels on growth dynamics and dry matter partitioning in short duration Boro rice varieties. The experiment was laid out in a randomized complete block design (RCBD) with two factors: six nitrogen levels N_0, N_{30}, N_{60}, N_{90}, N_{120}, N_{150} and two short duration rice varieties, BRRI dhan81 and BRRI dhan88 comprising twelve treatment combinations. Forty days old seedlings were transplanted with the planting geometry of 20 cm × 20 cm. Nine plants were randomly sampled from each plot at 15-day intervals to record dry matter production, growth parameters and grain yield. Dry matter partitioning and different growth parameters showed insignificant interaction for variety × nitrogen levels. However, nitrogen levels significantly influenced all evaluated parameters. Higher dry matter partitioning in leaves, culms and panicles was recorded under N_{150} and N_{120} followed by N_{60} and N_{90} across all growth stages. Growth parameters such as Leaf Area Index (LAI), Crop Growth Rate (CGR) and Net Assimilation Rate (NAR) were lowest at initial stage and reached to peak during 60-75 days after transplanting (DAT). The result indicated that nitrogen level N_{150} and N_{120} were most effective in enhancing growth and yield of rice followed by N_{60} and N_{90}. Therefore, optimum nitrogen management specially N_{120} – N_{150} produced the highest dry matter at all growth stages resulting higher grain yield followed by N_{60} and N_{90}. Growth parameters (LAI, CGR, and NAR) were lowest at the initial stage and peaked at 60–75 DAT. Overall, optimum nitrogen levels (N_{120}–N_{150}) enhanced growth dynamics more effectively and dry matter accumulation, resulting in higher grain yield in short duration rice varieties.

1. Introduction

Rice (*Oryza sativa* L.) is the staple food for about 156 million people of the country (Shelley et al., 2026) It is also the primary dietary food for nearly 50% of the world's population and supplies about 35%–60% of the dietary calories for more than three billion people, highlighting its global importance for food security (Amanullah et al., 2016). Bangladesh has a long-standing tradition of rice cultivation. The country's favorable agro-climatic conditions support rice cultivation throughout the year. The national

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average rice yield is much lower (around 3.2–3.4 t/ha) than that of other rice-growing countries (BBS, 2025). Additionally, with increasing pressure on land and natural resources, improving rice productivity through efficient crop and nutrient management remains a critical challenge. So, it is important to cultivate our arable land with very intensified way maintaining proper input. Short-duration rice varieties have gained importance due to their adaptability to intensified cropping systems and climate-resilient agriculture. Rice growth and yield determination not only influenced by genetic factors but also by efficiency of dry matter partitioning across different phenophases which is basically influences by source sink relationship (Li et al., 2023). Among the macro nutrient elements, Nitrogen requirement is higher in rice than that of other nutrients and nitrogen is one of the important limiting factors playing significant role by regulating vegetative growth, tillering ability, improving leaf area biomass accumulation and finally yield and production. On the other hand, excessive nitrogen application may lead to inefficient dry matter partitioning, prolonged vegetative growth and reduced nitrogen use efficiency, ultimately affecting yield and environmental sustainability (Saudy et al., 2023). Although atmospheric nitrogen constitutes nearly 79% of the air, it is not directly available to rice plants (Vijayakumar et al., 2022). Low efficacy of nitrogenous fertilizer is attributed mainly to ammonia volatilization, denitrification, leaching and runoff losses (Cho, 2003). Nitrogen is involved in all the metabolic processes in plants and about 75% of leaf N is associated with chloroplast, which are essential for dry matter production during photosynthesis (Mae, 1997). High nitrogen availability to the plant has been associated with increase in plant height, high chlorophyll content and leads to increase productivity (Garnier et al., 1995). Short duration rice varieties exhibit noticeable growth patterns; unique nitrogen requirements compared to long duration cultivars (Chen et al., 2022). Understanding their growth behavior and dry matter accumulation under different levels of nitrogen is essential for optimizing nutrient management practices and maximizing productivity within limited growing periods. Dry matter accumulation and its partitioning among plant organs are dynamic processes that vary with phenological stages of rice growth stages. Efficient partitioning of assimilates from source organs to sink tissues is essential for yield formation. Moreover, nitrogen is the important source to increase the dry matter production which ultimately partitioned into the grain yield. Therefore, the present study was undertaken to quantify growth rates at different phenophases of two short-duration rice varieties under varying nitrogen levels. The outcomes of this research are expected to provide physiological insights to support improved nitrogen management strategies for short-duration rice cultivation.

2. Materials and methods

2.1. Experimentation

The experiment was conducted at Bangladesh Rice Research Institute (BRRI) research farm, Gazipur (23°85.9′ N and 90°82.4′ E), Bangladesh, during Boro rice season, 2022-23. Two short-duration rice varieties, BRRI dhan81 and BRRI dhan88 were evaluated under six nitrogen levels: N0, N30, N60, N90, N120, N150. The experiment was designed with Randomized Complete Block Design (RCBD) and total replications was three. The recommended doses of other fertilizers (P–K–S–Zn) were applied at rates of 60–120–56–5 kg ha^{-1}, respectively. All fertilizers were applied as a basal dose, except nitrogen, which was top-dressed in three equal splits. Forty-day-old seedlings were transplanted in January 2022 with a spacing of 20 cm × 20 cm in plot measuring 2.5 m × 6 m.

2.2. Site description

The soil of the experimental site was clay loam in texture, slightly alkaline in reaction (pH, 6.7), non-saline (ECe, 1.02 dS/m), medium fertile soil containing organic carbon (1.18%), total N (0.15%), exchangeable K 0.13 meq/100 g soil, available S 14 mg/kg and available Zn 1.5 mg/kg.

2.3. Data recording and handling

Nine plants were taken randomly from each plot as representative sample for dry matter production and other growth parameter data mostly at 15 days' interval after transplanting. The samples were cleaned, separated into leaves, culm and panicle and then oven-dried at 70 º C until a constant weight is obtained and dry weight of leaves, culm and panicle were recorded separately in gm^{-2}. Total dry weight was calculated as the sum of dry weights of the plant components. At harvest yield data were recorded from an area of 5 square meter. Leaf area(LA) and leaf area index (LAI) were measured according to Gomez et al. (1972). Physiological growth parameters were calculated using successive sampling data following the methods described by Watson (1952).

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf Area (A)}}{\text{Ground Agea (P)}}$$

$$\text{Grop growth rate (CGR)} = \frac{W2 - W1}{P\ (T2 - T1)}\ g\ m^{-2}\ day^{-1}$$

Where,

W_1 = Dry weight of plant m^{-2} at time T_1

W_2 = Dry weight of plant m^{-2} at time T_2

P = Ground area (m_2)

T_1 and T_2 are the two consecutive time period

$$\text{Relative growth rate (RGR)} = \frac{LnW2 - LnW1}{T2 - T1}\ g\ g^{1}\ day^{-1}$$

Where,
W_1 = Dry weight of plant m^{-2} at time T_1
W_2 = Dry weight of plant m^{-2} at time T_2
Ln = Natural log
T_1 and T_2 are the two consecutive time period

$$Net\ assimilation\ rate\ (NAR) = \frac{W2 - W1}{T2 - T1} \times \frac{1}{LA}$$

Where,
W_1 = Dry weight of plant m^{-2} at time T_1
W_2 = Dry weight of plant m^{-2} at time T_2
T_1 and T_2 are the two consecutive time period
LA = Leaf area

2.4. Statistical analysis

Data were analyzed using RStudio version 4.0. Factorial ANOVA was performed to evaluate the effects of rice varieties, nitrogen levels and their interaction on growth parameters at different growth stages of short duration rice varieties. Treatment means were compared using the Critical Difference (CD) test at a 5% level of significance. Graphical representations of the results were prepared using Microsoft Excel 2010.

3. Results and discussion

3.1. Dynamics of dry matter accumulations

Dry matter accumulation is a crucial determinant of grain yield in rice. The enhancement of rice yield potentiality might come from the increased dry matter production. Total dry matter production varied significantly due to the effect of N-levels at different growth stages. Total dry matter production (TDM) increased progressively with the increase of growth stages and N-levels. The application of N fertilizer alone and in combination with P effectively promote dry matter accumulation, translocation across growth stages and increase yield (Qin et al., 2025).

The interaction effect between variety and nitrogen level was insignificant for culm, leaf and panicle dry matter production at different growth stages. However, nitrogen levels exerted a significant effect on dry matter accumulation. At 30 DAT the highest culm and leaf dry matter was obtained with N150. Culm dry matter at N_{30}, N_{60} N_{90} and N_{120} level was similar. Lowest culm and leaf dry matter was produced by N0. At 60 DAT, culm and leaf dry matter production was higher in N_{150} followed by N_{120} than other treatment. However, culm and leaf dry matter was the lowest at N0 followed by N_{30} level. At 75 DAT the highest culm dry matter was obtained with N_{150} and N_{120}. Culm dry matter was statistically similar at nitrogen level N60 and N_{90}. However, lowest culm dry matter was found in N_{30} and N_0. Leaf dry matter was highest under the treatment N_{150} followed by N_{120} and N_{90}. Lowest leaf dry matter was observed in nitrogen level N_0 followed by N_{30} and N_{60}. At this stage panicle weight was higher in the treatments with N_{150} nitrogen level. However, lowest panicle weight was obtained with nitrogen level N_0. At 90 DAT, culm dry matter production was higher in nitrogen level N_{150} which was statistically similar with N_{120} and N_{90}. Leaf and panicle dry matter production was observed highest in N_{150} followed by N_{120}. The rapid growth of dry matter at the higher nitrogen level may be due to the robust growth of plants (Fig. 1).

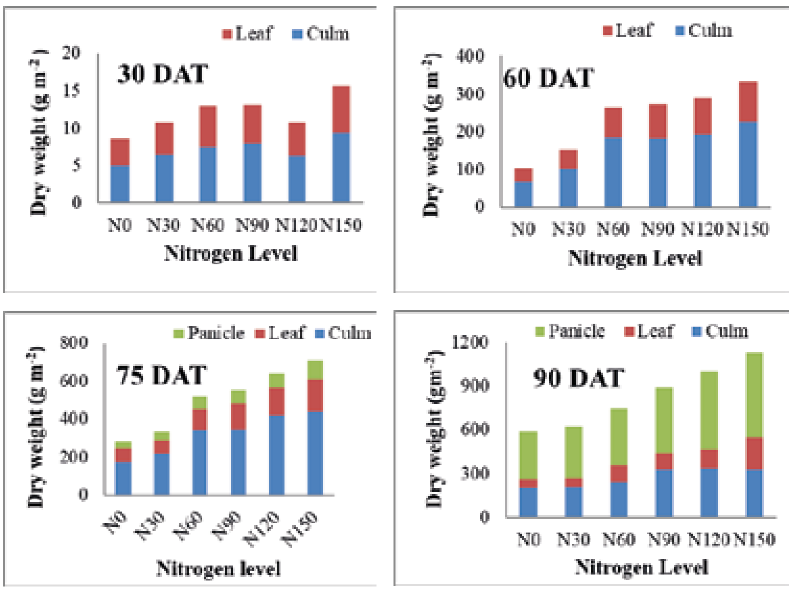

Fig.1. Dry matter partitioning (g m^{-2}) in rice at different days after transplanting.

3.2. Correlation studies of TDM with grain yield

The results demonstrated a positive correlation between total dry matter production at 30, 60, 75 and 90 DAT grain yield of the tested rice varieties which indicates that grain yield was greatly influenced by total dry matter production (Fig. 2). At 30 DAT (early vegetative stage), plants have low total biomass, but this period is crucial for setting up the "framework" of the plant, including root system development, leaf area expansion, and tiller number. Small, early increases in dry matter directly contribute to increased photosynthetic capacity (higher Leaf Area Index) and enhanced ability to acquire nutrients and water. This directly influences final yield potential, leading to a high "slope" in the relationship between biomass increase and yield, as shown in studies where early growth parameters were the best estimators of yield. By 60 DAT, plants have already accumulated significant biomass, and the structure of the plant is largely established. At this stage, each additional unit of biomass typically represents "filler" material or stems rather than productive, high-efficiency photosynthetic machinery, resulting in a lower marginal yield increase (lower slope). This dynamic reflects the logistic nature of plant growth, where the rate of biomass accumulation is highest in the middle, but the impact of that accumulation on final yield is highest during early development (Castaño et al., 2026).

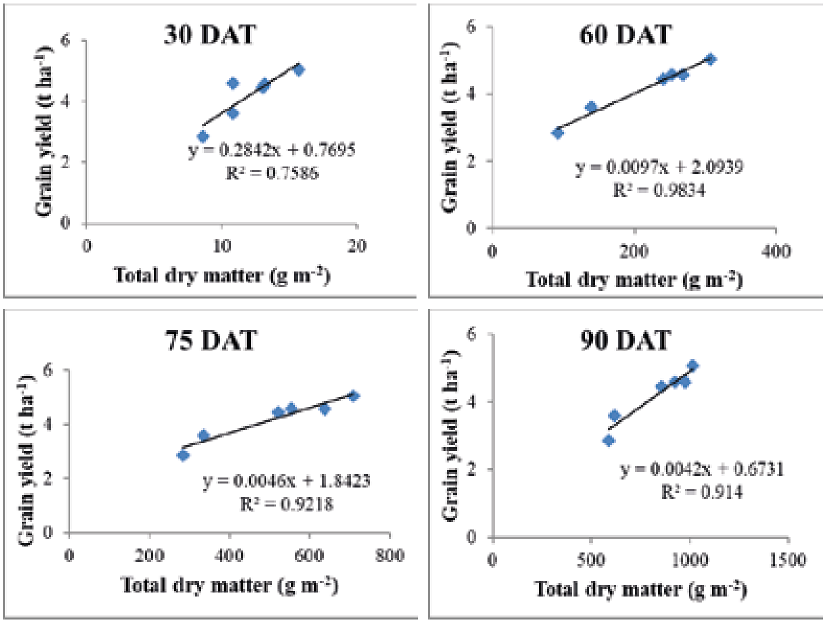

Fig. 2. Relationship between total dry matter production and grain yield in rice at different days after transplanting.

3.3. Leaf area index

Leaf area index is important physiological parameters which accounts for the production of photosynthate and finally determines crop yield because it influences the light interception by the crop canopy (Fageria et al., 2006). Interaction effect of variety and nitrogen level for leaf area index was insignificant for all growth stage except 90 DAT. The average leaf area index (LAI) of the rice increased gradually up to 60 DAT and thereafter it increased sharply reaching a peak value at 90 DAT that is heading or flowering, but there after it decreased gradually towards maturity due to senescence of leaves. The LAI of rice increases as crop growth advances and reaches a maximum at about heading or flowering (Yoshida, 1981). The LAI reached the maximum in the heading stage and then declined until the maturity stage (Qi et al., 2024). Significant effect of nitrogen level was found for all growth stages except 30 DAT. Leaf area index was higher in nitrogen level N_{150}, N_{120} and N_{90} and N_{60} at 60 DAT, 75 DAT and 90 DAT irrespective of varieties. At maturity stage N_{120} and N_{150} produced the highest leaf area index. Higher leaf area index may be due to the higher number of leaves and increased leaf area. Navinkumar et al. (2018) also reported that the higher LAI was associated with the increased tiller production and size of the leaves. However, for all the treatment combination LAI was lower than the average. This may be due to low nitrogen supply. LAI at maximum tillering in rice typically ranges around 3–5 under optimal conditions, but can fall below 3 when nitrogen is limited or under suboptimal management (Yoshida., 1981) (Table 1).

Table 1

Leaf area index of rice as influenced by varieties and nitrogen levels at different DAT.

Treatments	**Leaf area index (LAI)**			
Varieties	**30 DAT**	**60 DAT**	**75 DAT**	**90 DAT**
BRRI dhan81	0.05	1.05	2.09	1.36
BRRI dhan88	0.06	1.18	2.19	0.67
SED ±	0.01	0.089	0.253	0.147
CD at 5%	NS	NS	NS	0.303
Nitrogen (N) (kg ha^{-1})				
N_0	0.05	0.43	1.03	0.50
N_{30}	0.07	0.79	1.23	0.44
N_{60}	0.07	1.09	2.01	0.62
N_{90}	0.05	1.39	2.59	1.23
N_{120}	0.05	1.29	2.83	1.79
N_{150}	0.07	1.69	3.17	1.52
SED ±	0.018	0.154	0.439	0.255
CD at 5%	NS	2.06	0.90	0.526
Interaction (V × N)				
SED ±	0.025	0.218	0.62	0.36
CD at 5%	NS	NS	NS	0.743

3.4. Crop growth rate

Insignificant interaction was present between variety and nitrogen level for this trait. No significant interaction was observed among treatments combination for CGR. Both varieties showed almost similar growth patterns across the nitrogen levels from N_0 to N_{150}. Nitrogen mainly affected the magnitude of growth, but it did not change the growth pattern over time. Since the treatments were applied at 30 DAT and data were collected at 15-day intervals, the growth pattern remained nearly similar across treatments, resulting in an insignificant interaction (Ronanki et al., 2017; Sridhar et al., 2019). Crop growth rate was very minimum at the initial stage as 0-30 DAT which increased gradually towards the growth stages. It reached to peak at flowering stage and then decreased gradually to 75-90 DAT as harvest. With the increase of leaf area over time, CGR also increased until 60 DAT and then declined at 80 DAT in all cultivars (Kaysar et al., 2022). Higher crop growth rate was obtained with nitrogen level N_{120} and N_{150} at 0-30 DAT. Significant effect of nitrogen level was found for 30-60 DAT and 60-75 DAT. At 30-60 DAT and 60-75 DAT highest crop growth rate was observed in N_{120} and N_{150} nitrogen level. However, at 75-90 DAT CGR decreased drastically. Higher CGR may be due to the higher LAI produced by this nitrogen level. Lower CGR in the initial growth stage appears to be mainly due to low leaf area, while higher CGR at flowering and grain development stages may be due to higher LAI and decrease in CGR towards maturity may be attributed to decrease in leaf area as a result of senescence of leaves (Sridhar et al., 2019) (Fig. 3 and Table 2).

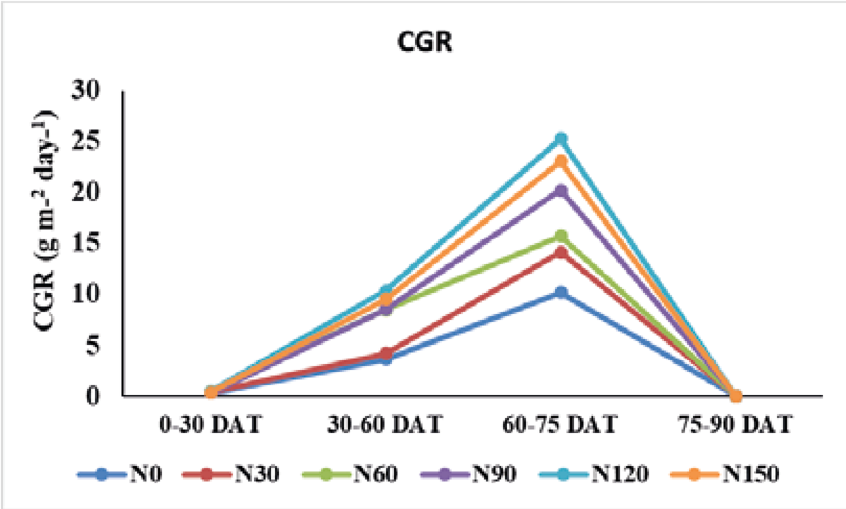

Fig. 3. Effect of various nitrogen treatments on crop growth rate (g m^{-2} day^{-1}) at different intervals.

Table 2
Crop growth rate of rice as influenced by varieties and nitrogen levels at different DAT.

Treatments	**Crop growth rate (g m^{-2} day^{-1})**			
Varieties	**0-30 DAT**	**30-60 DAT**	**60-75 DAT**	**75-90 DAT**
BRRI dhan81	0.36	6.91	17.50	0.03
BRRI dhan88	0.44	7.98	18.64	0.03
SED ±	0.047	0.481	2.812	0.006
CD at 5%	NS	0.992	NS	NS
Nitrogen (N) (kg ha^{-1})				
N_0	0.34	3.62	14.15	0.03
N_{30}	0.38	4.22	10.02	0.04
N_{60}	0.48	8.51	15.71	0.02
N_{90}	0.30	8.46	20.20	0.03
N_{120}	0.49	10.35	25.28	0.03
N_{150}	0.40	9.50	23.06	0.03
SED ±	0.082	0.833	4.871	0.01
CD at 5%	NS	1.719	10.05	NS
Interaction (V × N)				
SED ±	0.12	1.17	6.88	0.014
CD at 5%	NS	NS	NS	NS

3.5. Net assimilation rate (NAR)

NAR is the increase in plant dry mass per unit leaf area per unit time. It is the physiological potential for converting the total dry matter into grain yield. The interaction effect between variety and nitrogen level was not significant. Both varieties followed similar growth patterns for NAR across nitrogen levels (N_0–N_{150}), where nitrogen influenced growth magnitude but not its trend over time, leading to an insignificant interaction (Sridhar et al., 2019). Significant influence of nitrogen level was only observed for net assimilation rate at 75-90 DAT. At 75-90 DAT highest NAR was observed in N60 nitrogen level followed by N_{120} and N_{150}. NAR was low at initial growth stage that is 0-30 DAT and 30-60 DAT. Then it increased linearly upto 60-75 DAT. Finally, it dropped to maturity that is 75-90 DAT for all treatments. The increase NAR during the active growth stages may be attributed to higher LAI and dry matter production with those stages (Table 3). The Higher net assimilation rate with the growth stages was due to higher LAI and dry matter production with those stages (Willians et al., 1946). Sharma et al. (2022) also stated that the maximum NAR was attributable to higher LAI and dry matter production as compared to other varieties.

Table 3

Net assimilation rate of rice as influenced by varieties and nitrogen levels at different DAT.

Treatments	**Net assimilation rate (mg m^{-2} day^{-1})**			
Varieties	**0-30 DAT**	**30-60 DAT**	**60-75 DAT**	**75-90 DAT**
BRRI dhan81	0.67	0.78	0.97	3.1
BRRI dhan88	0.76	0.62	0.88	3.5
SED ±	0.00	0.00	0.00	1.0
CD at 5%	NS	0.00	NS	NS
Nitrogen (N) (kg ha^{-1})				
N_0	0.66	0.70	1.35	2.0
N_{30}	0.73	0.68	0.90	3.0
N_{60}	0.83	0.80	0.93	7.3
N_{90}	0.76	0.66	0.98	4.0
N_{120}	0.66	0.78	0.71	5.0
N_{150}	0.65	0.58	0.70	5.0
SED ±	0.00	0.00	0.00	1.0
CD at 5%	NS	NS	NS	2.0
Interaction (V × N)				
SED ±	0.00	0.00	0.00	2.0
CD at 5%	NS	NS	NS	NS

3.6. Relative growth rate

The rate at which a plant incorporates new material of dry matter accumulation into its sink is measured by RGR and is expressed in g g^{-1} day^{-1}. Insignificant interaction effect of variety and nitrogen level was observed for this trait. Both varieties exhibited similar relative growth rate across nitrogen levels (N_0–N_{150}), where nitrogen affected the magnitude of RGR but did not change its growth trend, resulting in an insignificant interaction. Respiration depends on total biomass, but photosynthesis depends only on photosynthetic biomass, so biomass builds up more slowly as total biomass increases. (Wopereis et al., 1996). RGR was maximum at 30-60 DAT and then it was decreased gradually towards 60-75 DAT. Verma et al. (2023) also found similar observations. After that it become very low to maturity stage that is 75-90 DAT. Kaysar et al. (2022) reported that RGR was higher in the early stages and began to decline as the plants got older. Maximum RGR was obtained with nitrogen level N_{150}, N_{120}, N_{60} and N_{30}. Maximum RGR at 30-60 DAT was mainly due to the higher accumulation of photosynthetic biomass started and then it tends to decrease towards growth stages due to the incretion of non-photosynthetic biomass (Table 4).

Table 4
Relative growth rate of rice as influenced by varieties and nitrogen levels at different DAT.

Treatments	Relative growth rate (g g^{-2} day^{-1})		
Varieties	**30-60 DAT**	**60-75 DAT**	**75-90 DAT**
BRRI dhan81	0.09	0.05	0.03
BRRI dhan88	0.09	0.04	0.03
SED ±	0.004	0.006	0.006
CD at 5%	NS	NS	NS
Nitrogen (N) (kg ha^{-1})			
N_0	0.08	0.06	0.03
N_{30}	0.10	0.05	0.04
N_{60}	0.10	0.05	0.02
N_{90}	0.08	0.04	0.02
N_{120}	0.10	0.04	0.03
N_{150}	0.10	0.05	0.03
SED ±	0.008	0.001	0.01
CD at 5%	0.01	NS	NS
Interaction (V × N)			
SED ±	0.011	0.015	0.015
CD at 5%	NS	NS	NS

Grain yield (t ha^{-1}): Grain yield had significant effect for nitrogen level. Zhou et al. (2023) stated that yield has significant and positive correlation with dry matter accumulation (DMA) and and N accumulation from heading stage to maturity stage. However, interaction effect was observed insignificant for this trait. The insignificant interaction effect on grain yield suggests that the response of both varieties to nitrogen levels (N_0–N_{150}) was similar across treatments. Nitrogen application influenced yield to a certain extent, but it did not differentially affect the varieties, resulting in an insignificant interaction. The highest grain yield was produced at nitrogen level N150 followed by N_{120}, N_{90} and N_{60} where as the lowest yield production was obtained with nitrogen level N0 (Fig. 4). Bhowmick et al. (2000) reported that increase in grain weight at higher nitrogen rates might be primarily due to increase in chlorophyll content of leaves which led to higher photosynthetic rate and ultimately plenty of photosynthates available during grain development.

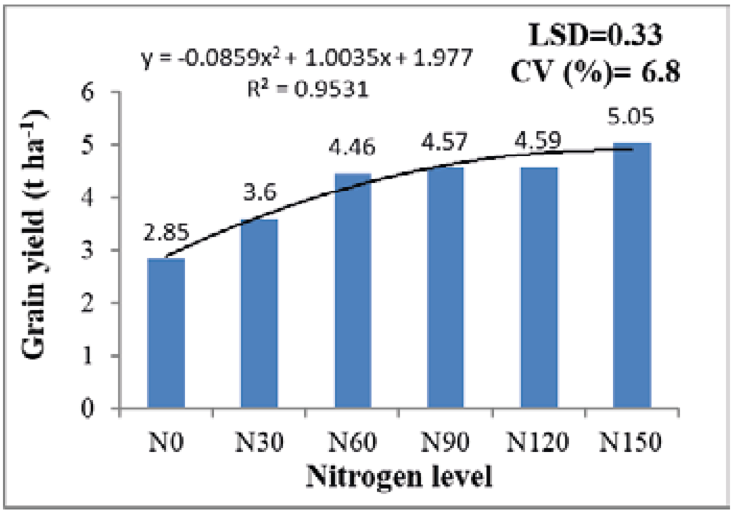

Fig. 4. Grain yield production at variable nitrogen level.

4. Conclusion

The interaction effect between variety and nitrogen level on dry matter partitioning and several growth factors was insignificant. However, nitrogen application significantly influenced growth dynamics, dry matter partitioning, and grain-yield of short duration rice varieties. Higher nitrogen levels, especially N120 and N150, promoted greater dry matter accumulationin leaves, culms and panicles throughout all growth stages. Total dry matter production was strongly correlated with grain yield indicating the importance of biomass accumulationin yield formation. Growth parameters, such as LAI, CGR, and NAR were lowest during the initial growth stages and reached their peaked between 60 and 75 DAT. Overall, nitrogen levels N150 and N120 proved most effective in maximizing physiological growth and grain yield, followed by N90 and N60, representing the crucial role of optimum nitrogen management for maximizing rice productivity of short-duration Boro rice varieties.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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