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Impact of low light stress on physiological contributing traits and biochemical parameter on early, medium and late rice genotypes (*Oryza sativa* L.)

Amrit Kumar Nirala, VB Kuruwanshi and Snehal Gupta

Abstract
The physiological and biochemical parameters like specific leaf area, specific leaf weight, total dry matter, apparent translocation rate, net assimilation rate, total dry matter at flowering and harvesting and protein content were significantly reduced under low light conditions. Conversely, the leaf area index (LAI) and total chlorophyll SPAD values showed an increase in response to low light condition. Notably, the early, medium and late genotype LL-604, LL-613 and LL-602 exhibited the maximum LAI among the tested genotypes under low light stress conditions. The leaf chlorophyll content was lower in full sun light conditions than in low irradiance environments. The exposure of low light among early, medium and late rice genotypes, the total chlorophyll SPAD values of LL-604, LL-613 and LL-603 recorded higher at panicle initiation and flowering stage.

Keywords: Normal light (NL), Low light (LL)

Introduction
Rice (*Oryza sativa* L.) is the staple food of more than half of the world population. It is cultivated over an area of 165.25 m ha with a production of 514.9 mt. (International Grains Council (IGC)), 2021-22. Solar radiation has a profound impact on crop growth and productivity. The main rice growing *Kharif* (monsoon) season (June to December) in the Eastern region of India comprising the state of West Bengal, Assam, Bihar, M.P, C.G. which is characterized by low light intensity of 250-300 cal cm^{-2} day^{-1}. Solar radiation is limited during the monsoon season and in July and August, the average daily duration of bright sunshine is only 2-3 hours per day. Lower incidence of solar radiation coupled with fluctuating light intensity due to overcast sky sun during the wet season (Feb. to Nov.) is one of the major constraints for rice production in eastern India.
Light and shade are essential important environmental factors for plants growth in the biological system as well as these environmental factors also affects growth, morphology, physiology and biochemistry of plant.

Methods and Materials
Field research trial was conducted at the Research cum Instructional Farm during the *Kharif* season of 2022-2023. The laboratory analysis was performed in the Department of Plant Physiology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur (C.G.). The experimental material was collected from DRR, Hyderabad (14 genotypes), while one check variety from IGKV, Raipur during *kharif* 2022-23. The genotypes were categories in early, medium and late genotypes.

Treatments Details
T_1: Control (Normal light).
T_2: Low light (Net shade 70:30).

Results and Discussion
Effect of Light Intervention on Physiological Traits of Rice Genotypes
Leaf Area Index (LAI) at Flowering Stage
The leaf area index data is presented in Table 1, which showing significant variations among the treatments. In normal light condition, the tested rice genotypes showed varying leaf area indices.

LL-604 emerged as the early genotype with the highest leaf area index (5.86), followed by LL-609 (4.41), whereas poornima recorded the lowest leaf area index (3.72). Among the medium duration genotypes, LL-613 had found maximum leaf area index (5.62), followed by LL-614 (5.10), whereas LL-612 exhibited the lowest leaf area index (3.74). In terms of late duration genotypes, LL-608 showed the highest leaf area index (6.71) followed by LL-607 (5.09), while LL-611 had observed the lowest leaf area index (3.17) at flowering stage.

In condition of low light, the LL-604 early genotype exhibited the maximum leaf area index (6.25) with closely behind LL-609 (5.94), whereas poornima had the lowest leaf area index (5.00). Among the medium duration genotypes, LL-612 had found maximum (6.73) followed by LL-613 (6.68) while, LL-614 had the lowest (6.32) leaf area index. In the case of late duration genotypes, LL-602 had the highest (8.38) with LL-601 following (7.31), while LL-606 had the lowest (4.40) leaf area index at flowering stage. The relationship between solar radiation and LAI can be explained as a plant adaptation to develop larger, thinner leaves under low light conditions. However, it is worth noting that the increase in LAI is constrained by low levels of solar radiation as noted by Tanaka *et al.* (1964) [7].

Specific Leaf Area (SLA) at Flowering Stage

The findings regarding specific leaf area are presented in Table 2, the significant variations were observed among the treatments with respect to specific leaf area. In normal light condition, the specific leaf area was varied of different rice genotypes. Among the early genotypes, LL-609 recorded the highest specific leaf area of (324.36), followed by LL-604 (265.12), whereas poornima had the lowest specific leaf area of (190.02). In terms of medium duration genotypes, LL-612 had the highest (250.33), followed by LL-613 with (223.60), whereas LL-614 had the lowest specific leaf area of (202.48). Lastly, among the late duration genotypes, LL-606 showed the maximum (389.63) followed by LL-605 with (301.04), while LL-607 had the lowest specific leaf area (207.61) at flowering stage.

In condition of low light, genotype LL-604 early genotype exhibited the greatest (358.82) followed by LL-609 (328.09), whereas poornima displayed the lowest specific leaf area (264.30). Genotype LL-613 had the highest specific leaf area (515.06) trailed by LL-614 (460.82), while LL-612 showed the lowest specific leaf area (310.38) among medium duration genotypes. As far as late duration genotypes concerned, LL-610 had recorded maximum specific leaf area (485.71) followed by LL-605 (428.72), whereas LL-607 had the lowest specific leaf area (209.33) at flowering stage. The shaded rice genotype, the increase in SLA and the development of a darker green leaf color were primarily attributed to higher nitrogen content in the leaves. These adaptations, including increased SLA and darker leaf color, likely contributed to the higher rate of photosynthesis observed in the shaded rice genotype. Similar results were also observed by Robakowski *et al*. (2003) [6].

Specific Leaf Weight (SLW) at Flowering Stage

Specific leaf weight result shown in Table 3, the treatments revealed significant variations in specific leaf weight at flowering stage. The specific leaf weight of different rice genotypes varied and the early genotypes, LL-604 found the highest specific leaf weight of 0.0038, followed by poornima with 265.12, whereas LL-609 had the lowest specific leaf weight 0.0031. The medium duration genotypes, LL-614 had the maximum specific leaf weight of 0.0049 followed by LL-613 with 0.0045, while LL-612 had the lowest specific leaf weight of 0.0040. Among the late duration genotypes, LL-607 showed the highest 0.0048 followed by LL-601 with 0.0045, whereas LL-606 had the lowest specific leaf weight of 0.0026 under normal light condition.

In low light condition, the early genotypes LL-604 and LL-609 had higher (0.0028 and 0.0025, respectively), while poornima had the lower specific leaf weight (0.0023). Among medium duration genotypes, LL-612 had maximum (0.0032), followed by LL-614 (0.0022), while LL-613 showed minimum specific leaf weight (0.0020). The late duration genotype, LL-601 and LL-607 had found maximum (0.0038), followed by LL-603 (0.0030), whereas LL-610 and LL-606 had recorded minimum specific leaf weight (0.0020 and 0.0023, respectively) at flowering stage. In the presence of low light conditions, there was a notable decrease in specific leaf weight (SLW) as compared to normal light conditions Koumotoa *et al.* (2016) [3].

Net Assimilation Rate (NAR) (gm cm^{-2} Day^{-1}) at Flowering Stage

The net assimilation rate data is displayed in Table 4, the significant difference was observed among treatments. Under normal light condition, the net assimilation rate varied among different rice genotypes. The early genotypes, LL-609 found maximum 0.0130, while poornima had a rate of 0.0067 and LL-604 was observed minimum 0.0064 net assimilation rate. Among the medium duration genotypes, LL-612 had found 0.0147, LL-614 had 0.0064 and LL-613 showed 0.0058 minimum net assimilation rate. However, the late duration genotypes, LL-601 had higher 0.0111 followed by LL-608 0.0104, while LL-606 had lower 0.0054 net assimilation rate at flowering stage.

Under low light condition, LL-609 early genotype noticed maximum (0.0043) with closely behind LL-604 (0.0042), while poornima had the lowest net assimilation rate (0.0024). Among medium duration genotypes, LL-612 observed higher (0.0048), followed by LL-613 (0.0044), whereas LL-614 had lower net assimilation rate (0.0039). Genotype LL-611 showed maximum (0.0045) followed by LL-610 (0.0042), while LL-605 and LL-603 exhibited minimum net assimilation rate (0.0024) in late duration genotypes. Ahmad *et al.*, (2009) [1] reported that the low light condition can have an impact on various aspects of rice crops, including their morphological, physiological and yield parameters.

Total Dry Matter (TDM) (gm/m^{-2}) at Flowering Stage

The total dry matter has been shown in Table 5 and it was found significant differences among the treatments at flowering stage. Under normal light condition, the total production of dry matter varied among different rice genotypes. In the early genotypes, LL-604 exhibited maximum (1548.04), followed by poornima (1461.28), whereas LL-609 recorded minimum dry matter production (919.11). Among the medium duration genotypes, LL-614 displayed higher (1694.25), followed by LL-612 (1645.77), while LL-613 had lower total dry matter production (1522.41). Lastly, within the late duration genotypes, LL-607 possessed maximum (2525.37) followed by LL-608

(1918.48), whereas LL-602 had minimum total dry matter production (1304.99) at flowering stage.
In conditions of limited light, early-generation genotypes LL-604 found maximum (942.82) followed by poorniuma (895.50), whereas LL-609 exhibited the lowest total dry matter production (581.72). Among medium-duration genotypes, LL-613 recorded higher (862.74) followed by LL-614 (854.32), while LL-612 exhibited the lowest total dry matter production (806.90). Among the late-duration genotypes, LL-601 showed the maximum (953.80), followed by LL-605 (906.12), whereas LL-608 had minimum total dry matter production (495.41) at flowering stage. Palit *et al.* (1976) observed that the allocation of total dry matter is poor in low light conditions due to a limited supply of carbohydrates.

Total Dry Matter (TDM) (g m^{-2}) at Maturity Stage
The impact of normal and low light conditions on the total dry matter of various rice genotypes at the maturity stage is illustrated in Table 6. Under normal light condition, the dry matter production of various rice genotypes exhibited variation at maturity. Among the early genotypes, poornima displayed the highest (2686.06), trailed by LL-604 (2647.35), whereas LL-609 exhibited the lowest total dry matter production (2534.12). The medium duration genotypes, LL-613 recorded higher (2799.05), followed by LL-614 (2626.42), whereas LL-612 exhibited lower total dry matter production (2579.10). Lastly, among the late duration genotypes, LL-605 noted maximum (2781.32) followed by LL-601 (2767.54), whereas LL-602 exhibited minimum total dry matter production (2183.43) at maturity stage.
Under low light conditions LL-609 early genotype found maximum (1092.27), with poorniuma (1006.54) ranking second, while LL-604 exhibited the lowest total dry matter production (953.21). Among medium duration genotypes, LL-614 had the higher (1217.61), followed by LL-613 (1134.39), whereas LL-612 observed lower total dry matter production (1125.99). Regarding the late duration genotypes, LL-605 demonstrated the maximum (1292.04) followed by LL-602 (1273.84), whereas LL-611 had minimum total dry matter production (1015.25) at maturity stage. Murty *et al.* (1976) [4] demonstrated that under lower light intensity, the movement of photosynthetic products to the aerial parts of the plant is enhanced. However, the actual availability of photo assimilates is limited due to impaired photosynthesis under reduced light conditions.

Apparent Translocation Rate (ATR)
The apparent translocation rate data displayed in Table 7 revealed noticeable variations among the treatments. The significant differences were observed in relation to the apparent translocation rate. Under normal lighting condition, the apparent translocation rate of different rice genotypes varied and among the early genotypes, poornima exhibited higher (0.567), followed by LL-604 (0.483), whereas LL-609 had the lowest rate of movement (0.383). In terms of medium duration genotypes, LL-613 had the maximum (0.617), followed by LL-614 (0.537), whereas LL-612 had the lowest rate of movement (0.413). Lastly, among the late duration genotypes, LL-611 observed higher (0.657), followed by LL-602 (0.653), while LL-605 had the lowest rate of movement (0.347). In conditions of low light, the early genotype LL-604 recorded maximum apparent translocation rate (0.357), with closely behind poornima (0.347), while LL-609 observed lower apparent translocation rate (0.213). Among medium duration genotypes, LL-614 found higher (0.357) followed by LL-612 (0.270) and LL-613 had the lowest apparent translocation rate (0.257). Concerning with late duration genotypes, LL-608 showed the highest (0.407), followed by LL-611 (0.387), while LL-606 had found the lowest (0.257) apparent translocation rate.

Total Chlorophyll (SPAD Value) at Panicle Initiation (PI) Stage
The data on chlorophyll content are presented in table 8. The significant differences were noticed among the treatments in relation to chlorophyll content. The total chlorophyll SPAD values of different rice genotypes varied under normal light condition. In the case of early genotypes, LL-604 recorded maximum (38.99), followed by LL-609 (35.74) and poornima recorded minimum total chlorophyll SPAD value (35.34). The medium duration genotypes, LL-613 found maximum (40.69), followed by LL-612 (39.13), while LL-614 observed minimum SPAD value (33.93). Genotype LL-611 exhibited the higher (42.79), followed by LL-608 (41.12), whereas LL-606 had lower total chlorophyll SPAD value (32.30) among the late duration genotypes.
In condition of low light, LL-604 early genotype measured higher (39.34), with following closely behind poornima (38.14) and LL-609 measured lower (36.84) total chlorophyll SPAD values. Among medium-duration types, LL-613 had the highest (42.87), followed by LL-612 (40.06), while LL-614 observed the lowest total chlorophyll SPAD value (36.08). Among the late-duration genotypes, LL-603 showed the highest (45.34) trailed by LL-605 (43.85), while LL-608 had the lowest total chlorophyll SPAD value (36.02) at panicle initiation (PI) stage.

Total Chlorophyll (SPAD Value) at Flowering Stage
The data on total chlorophyll content (SPAD Value) at flowering stage is presented on table 8. The results revealed significant difference in the treatments at flowering stage. The total chlorophyll SPAD values of different rice genotypes varied under normal light condition. Among the early genotypes, LL-604 possessed higher total chlorophyll 40.32, followed by LL-609 with a value of 38.26, whereas poornima observed lower 37.40. The medium duration genotypes, LL-613 exhibited maximum 43.03, followed by LL-612 with a value of 41.11, while LL-614 had minimum total chlorophyll SPAD value of 35.21. However, among the late duration genotypes, LL-611 showed higher 45.37, followed by LL-602 with a value of 43.40, while LL-606 had lower 34.37 total chlorophyll SPAD values.
Under the low light, LL-604 early genotypes exhibited higher (41.27), followed by poornima (39.95), while LL-609 displayed the lower total chlorophyll SPAD values (39.16). Within the medium duration genotypes, LL-613 recorded maximum (45.00), followed by LL-612 (42.07), whereas LL-614 recorded minimum (38.03) total chlorophyll SPAD values. Genotype LL-611 observed higher (46.75), closely behind LL-603 (46.62) while LL-608 had found lower total chlorophyll SPAD value (38.81) at flowering stage. Hidema *et al*. (1991) [2] showed that the leaf chlorophyll content was lower in full sun light conditions than in low irradiance environments.

Biological Parameter

Protein Content (%) on Rice

The grain protein content (%) data are provided in Table 4.18 and Figure 4.18 and revealed significant variations among the treatment groups. In the early genotypes, poornima recorded maximum 9.46, followed by LL-609 at 8.94, whereas LL-604 exhibited minimum protein content 8.36. Among the medium duration genotypes, LL-614 showed higher 9.46, followed by LL-613 at 9.39, while LL-612 had the lower 8.88 protein content. Lastly, within the late duration genotypes, LL-601 noted the maximum 9.33, followed by LL-603 at 9.07, whereas LL-608 observed minimum protein content at 7.84 under normal light condition.

Among the early genotypes, LL-609 exhibited the highest (8.36) followed by poorniuma (8.23), whereas LL-604 had the lowest (7.71) protein content. Within the medium duration genotypes, LL-613 had the maximum (8.68), followed by LL-612 (8.42), while LL-614 showed minimum (8.10) protein content. Regarding the late duration genotypes, LL-601 had higher (8.42), followed by LL-603 (8.23), whereas LL-610 had lower protein content (6.94) under low light condition. Murty *et al.* (1976) [4] demonstrated that under lower light intensity, the movement of photosynthetic products to the aerial parts of the plant is enhanced. However, the actual availability of photo assimilates is limited due to impaired photosynthesis under reduced light conditions.

Table 1: Effects of normal light and low light on leaf area index (LAI) at flowering stage of rice genotypes

	Genotype	Control (NL)	Treated (LL)	Varietal Mean
Early	LL-604	5.86	6.25	6.06
	LL-609	4.41	5.94	5.17
	Poornima	3.72	5.00	4.36
Medium	LL-612	3.74	6.73	5.23
	LL-613	5.62	6.68	6.15
	LL-614	5.10	6.32	5.71
Late	LL-601	4.40	7.31	5.85
	LL-602	4.65	8.38	6.52
	LL-603	4.37	6.32	5.34
	LL-605	4.70	5.34	5.02
	LL-606	3.72	4.40	4.06
	LL-607	5.09	4.84	4.96
	LL-608	6.71	7.30	7.00
	LL-610	4.80	6.77	5.79
	LL-611	3.17	4.78	3.98
	Treatment Mean	4.67	6.16	

ANOVA Table

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.127	0.063	0.045
Factor(B)	0.349	0.174	0.123
Factor(A X B)	0.493	0.246	0.174

Table 2: Effect of normal light (NL) and low light (LL) on specific leaf area (SLA) (cm^2g^{-1}) at flowering stage of rice (*Oryza sativa* L.) genotypes

	Genotype	Control (NL)	Treated (LL)	Varietal Mean
Early	LL-604	22.01	15.61	18.81
	LL-609	17.51	15.90	16.71
	Poornima	16.22	9.62	12.92
Medium	LL-612	14.60	13.34	13.97
	LL-613	18.51	14.37	16.44
	LL-614	20.54	17.29	18.92
Late	LL-601	14.97	13.81	14.39
	LL-602	20.45	16.23	18.34
	LL-603	14.51	10.91	12.71
	LL-605	14.43	12.03	13.23
	LL-606	19.82	18.76	19.29
	LL-607	19.48	18.48	18.98
	LL-608	18.59	18.34	18.47
	LL-610	15.05	12.07	13.56
	LL-611	12.60	10.58	11.59
	Treatment Mean	17.29	14.49	

Anova Table

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.272	0.135	0.096
Factor(B)	0.744	0.371	0.262
Factor(A X B)	1.053	0.525	0.371

Table 3: Effect of normal light (NL) and low light (LL) on specific leaf weight (SLW) (cm^2g^{-1}) at flowering stage of rice (*Oryza sativa* L.) genotypes

	Genotype	Control (NL)	Treated (LL)	Varietal Mean
Early	LL-604	0.0038	0.0028	0.0033
	LL-609	0.0031	0.0025	0.0028
	Poornima	0.0038	0.0023	0.0030
Medium	LL-612	0.0040	0.0032	0.0036
	LL-613	0.0045	0.0020	0.0032
	LL-614	0.0049	0.0022	0.0036
Late	LL-601	0.0045	0.0038	0.0042

	LL-602	0.0040	0.0027	0.0033
	LL-603	0.0044	0.0030	0.0037
	LL-605	0.0033	0.0024	0.0029
	LL-606	0.0026	0.0023	0.0024
	LL-607	0.0048	0.0038	0.0043
	LL-608	0.0034	0.0023	0.0029
	LL-610	0.0034	0.0020	0.0027
	LL-611	0.0039	0.0026	0.0033
	Treatment Mean	0.0039	0.0027	

Table 4: Effect of normal light (NL) and low light (LL) on net assimilation rate (NAR) (gm $cm^{-2}day^{-1}$) at flowering stage of rice (*Oryza sativa* L.) genotypes

	Genotype	Control (NL)	Treated (LL)	Varietal Mean
Early	LL-604	0.0064	0.0042	0.0053
	LL-609	0.0130	0.0043	0.0087
	Poornima	0.0067	0.0024	0.0045
Medium	LL-612	0.0147	0.0048	0.0098
	LL-613	0.0058	0.0044	0.0051
	LL-614	0.0064	0.0039	0.0052
Late	LL-601	0.0111	0.0027	0.0069
	LL-602	0.0077	0.0032	0.0055
	LL-603	0.0100	0.0024	0.0062
	LL-605	0.0169	0.0024	0.0097
	LL-606	0.0054	0.0040	0.0047
	LL-607	0.0063	0.0033	0.0048
	LL-608	0.0104	0.0040	0.0072
	LL-610	0.0081	0.0042	0.0062
	LL-611	0.0088	0.0045	0.0066
	Treatment Mean	0.0092	0.0037	

ANOVA Table

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.0003	0.0002	0.0001
Factor(B)	0.0009	0.0004	0.0003
Factor(A X B)	0.0013	0.0006	0.0004

Table 5: Effect of normal light (NL) and low light (LL) on total dry matter (TDM) (g m^{-2}) at flowering stage of rice (*Oryza sativa* L.) genotypes

	Genotype	Control (NL)	Treated (LL)	Varietal Mean
Early	LL-604	1,548.04	942.82	1,245.43
	LL-609	919.11	581.72	750.41
	Poornima	1,461.28	895.50	1,178.39
Medium	LL-612	1,645.77	806.90	1,226.34
	LL-613	1,522.41	862.74	1,192.58
	LL-614	1,694.25	854.32	1,274.29
Late	LL-601	1,795.32	953.80	1,374.56
	LL-602	1,304.99	506.13	905.56
	LL-603	1,561.34	701.78	1,131.56
	LL-605	1,960.11	906.12	1,433.12
	LL-606	1,963.25	805.57	1,384.41
	LL-607	2,525.37	603.80	1,564.59
	LL-608	1,918.48	495.41	1,206.94
	LL-610	1,719.70	840.48	1,280.09
	LL-611	1,618.44	821.73	1,220.08
	Treatment Mean	1,677.19	771.92	

ANOVA Table

Factors	C.D.	SE(d)	SE(m)
Factor(A)	6.352	3.165	2.238
Factor(B)	17.396	8.668	6.129
Factor(A X B)	24.601	12.258	8.668

Table 6: Effects of normal light (NL) and low light (LL) on total dry matter (TDM) (gm m^{-2}) at maturity stage of rice (*Oryza sativa* L.) genotypes

	Genotype	Control (NL)	Treated (LL)	Varietal Mean
Early	LL-604	2,647.35	953.21	1,800.28
	LL-609	2,534.12	1,092.27	1,813.20
	Poornima	2,686.06	1,006.54	1,846.30
Medium	LL -612	2,579.10	1,125.99	1,852.55
	LL-613	2,799.05	1,134.39	1,966.72
	LL-614	2,626.42	1,217.61	1,922.02
Late	LL-601	2,767.54	1,227.06	1,997.30
	LL-602	2,183.43	1,273.84	1,728.63
	LL-603	2,502.23	1,264.24	1,883.24
	LL-605	2,781.32	1,292.04	2,036.68
	LL-606	2,505.35	1,230.11	1,867.73
	LL-607	2,447.16	1,233.56	1,840.36
	LL-608	2,269.95	1,224.32	1,747.14
	LL-610	2,671.97	1,146.71	1,909.34
	LL-611	2,129.80	1,015.25	1,572.52
	Treatment Mean	2,542.06	1,162.48	

ANOVA Table

Factors	C.D.	SE(d)	SE(m)
Factor(A)	6.352	3.165	2.238
Factor(B)	17.396	8.668	6.129
Factor(A X B)	24.601	12.258	8.668

Table 7: Effect of normal light (NL) and low light (LL) on apparent translocation rate (ATR) of rice (*Oryza sativa* L.) genotypes

	Genotype	Control (NL)	Treated (LL)	Varietal Mean
Early	LL-604	0.483	0.357	0.420
	LL-609	0.383	0.213	0.298
	Poornima	0.567	0.347	0.457
Medium	LL-612	0.413	0.270	0.342
	LL-613	0.617	0.257	0.437
	LL-614	0.537	0.357	0.447
Late	LL-601	0.583	0.343	0.463
	LL-602	0.653	0.363	0.508
	LL-603	0.403	0.377	0.390
	LL-605	0.347	0.383	0.365
	LL-606	0.490	0.257	0.373
	LL-607	0.437	0.323	0.380
	LL-608	0.477	0.407	0.442
	LL-610	0.603	0.370	0.487
	LL-611	0.657	0.387	0.522
	Treatment Mean	0.51	0.334	

ANOVA Table

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.007	0.003	0.002
Factor(B)	0.018	0.009	0.006
Factor(A X B)	0.026	0.013	0.009

Table 8: Effects of normal light (NL) and low light (LL) on total chlorophyll (SPAD value) at panicle initiation (PI) stage of rice (*Oryza sativa* L.) genotypes

	Genotype	Control (NL)	Treated (LL)	Varietal Mean
Early	LL-604	38.99	39.34	39.17
	LL-609	35.74	36.84	36.29
	Poornima	35.34	38.14	36.74
Medium	LL-612	39.13	40.06	39.59
	LL-613	40.69	42.87	41.78
	LL-614	33.93	36.08	35.01
Late	LL-601	37.00	39.62	38.31
	LL-602	40.26	39.80	40.03
	LL-603	39.44	45.34	42.39
	LL-605	41.12	43.85	42.48
	LL-606	32.30	41.38	36.84
	LL-607	38.89	40.03	39.46
	LL-608	34.18	36.02	35.10
	LL-610	34.95	37.39	36.17
	LL-611	42.79	43.39	43.09
	Treatment Mean	37.65	40.01	

ANOVA Table

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.122	0.061	0.043
Factor(B)	0.333	0.166	0.117
Factor(A X B)	0.471	0.235	0.166

Table 8: Effects of normal light (NL) and low light (LL) on total chlorophyll (SPAD value) at flowering stage of rice (*Oryza sativa* L.) genotypes

	Genotype	Control (NL)	Treated (LL)	Varietal Mean
Early	LL-604	40.32	41.27	40.80
	LL-609	38.26	39.16	38.71
	Poornima	37.40	39.95	38.67
Medium	LL-612	41.11	42.07	41.59
	LL-613	43.03	45.00	44.02
	LL-614	35.21	38.03	36.62
Late	LL-601	39.49	41.58	40.53
	LL-602	43.40	44.25	43.82
	LL-603	41.59	46.62	44.11
	LL-605	43.01	44.59	43.80
	LL-606	34.71	44.20	39.46
	LL-607	41.49	42.93	42.21
	LL-608	35.88	38.81	37.34
	LL-610	38.03	39.11	38.57
	LL-611	45.37	46.75	46.06
	Treatment Mean	39.89	42.29	

ANOVA Table

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.106	0.053	0.037
Factor(B)	0.290	0.144	0.102
Factor(A X B)	0.410	0.204	0.144

Table 9: Effect of normal light (NL) and low light (LL) on protein content (%) on rice (*Oryza sativa* L.) genotypes

	Genotype	Control (NL)	Treated (LL)	Varietal Mean
Early	LL-604	8.36	7.71	8.04
	LL-609	8.94	8.36	8.65
	Poornima	9.46	8.23	8.84
Medium	LL-612	8.88	8.42	8.65
	LL-613	9.39	8.68	9.04
	LL-614	9.46	8.10	8.78
Late	LL-601	9.33	8.42	8.88
	LL-602	8.36	8.04	8.20
	LL-603	9.07	8.23	8.65
	LL-605	7.91	7.52	7.71
	LL-606	8.42	7.59	8.01
	LL-607	8.88	7.00	7.94
	LL-608	7.84	7.07	7.46
	LL-610	8.49	6.94	7.72
	LL-611	8.88	8.17	8.52
	Treatment Mean	8.78	7.90	

ANOVA Table

Factors	C.D.	SE(d)	SE(m)
Factor(A)	0.155	0.077	0.054
Factor(B)	0.423	0.211	0.149
Factor(A X B)	0.599	0.298	0.211

Conclusion

The study highlights the significant influence of light conditions on the physiological traits of rice genotypes. The results indicate that low light conditions, typical during the monsoon season in Eastern India, lead to a variety of adaptive responses in rice plants, such as an increase in leaf area index (LAI), specific leaf area (SLA), and chlorophyll content. However, these adaptations were often constrained by the limited solar radiation, affecting key parameters like net assimilation rate and total dry matter production. The genotypes responded differently to low light, with early, medium, and late-duration genotypes displaying distinct patterns. These findings underscore the importance of optimizing light conditions to enhance rice productivity, particularly in regions with reduced sunlight during the growing season.

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