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SHADING EFFECT ON VARIOUS TRAITS AND THEIR ASSOCIATION IN RICE (*ORYZA SATIVA* L.)

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SUMMARY

Rice (*Oryza sativa* L.) is one of the most essential food commodities, and to increase rice production, weather is a significant factor affecting productivity, especially the sunlight requirement. Appropriate shading techniques and regulating the sunlight can enhance rice production. The presented study aimed to increase rice production under shaded environments. The latest research began in November 2023 until February 2024 at the Malikussaleh University. The study employed a split-plot design with three replications, and the primary factor was shading and no shade at the main plot. The secondary factor was the six rice genotypes, i.e., US-20 (Unsyiah Simeulue), CBD-08 (Cot Bada), CBD-04 (Cot Bada), Sigupai UA12, Cibatu, and Inpago9, used as subplots. The rice genotypes and shade (G × N) interactions demonstrated significant ($P < 0.01$) differences for the number of tillers, total grains, and filled grains and grain weight per hill. Inpago-9 exhibited the highest grain weight per hill (74.67 g) under the shaded condition. The correlation was significantly positive between grain weight per hill under shaded conditions and the number of productive tillers, total grain number, number of filled grains, and 1000-grain weight. The use of shade represents a potential alternative of increasing rice production; however, the net assimilation rate demonstrated a notable decline.

Keywords: Rice (*Oryza sativa* L.), shading effect, growth and yield traits, traits correlation, net assimilation rate

Key findings: The promising study examined the impact of shading on several traits of rice (*O. sativa* L.) production. The results demonstrated 25% shading could positively affect the rice performance and indicated superior promising lines tolerant to 25% of shade. The insights gained will be highly useful for breeders in tailoring treatments to achieve the desired plant outcomes.

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the vital food commodities globally. With the global expansion in the world's population, rice demand has continuously increased. Rice production incurs influences from several ecological factors, including environmental conditions, drought, shade, soil quality, and the saline level. The use of shading generally inhibits the growth and yield of a crop; therefore, it is necessary to explore alternatives to address this issue by developing rice varieties tolerant to shading.

The prevalence of clouds and precipitation can intensify haze levels, reducing the available sunlight. Furthermore, sunlight use plays a pivotal role in the growth and development of rice plants (Dai *et al*., 2014). Sunlight is a crucial factor for rice plants to grow and develop, particularly in the photosynthesis process, which generates food reserves distributed throughout the crop plants. In addition to photosynthesis, sunlight can influence the relative abundance and quality of various macromolecules in crop plants by regulating the formation and transport of photosynthetic products (Pan *et al.,* 2016).

The shade utilization can regulate the amount of sunlight entering the plants. Additionally, shade intends to prevent the direct entry of rainwater into the plant when there is continuous rainfall because excessive water can accelerate the deterioration of plants, including rice, which can result in lodging. Using an appropriate level of shade is a crucial element for plant growth, particularly in the case of rice, which requires optimal illumination. The use of low shade percentages have shown to increase chlorophyll content in wheat and rice during the winter, while higher shade percentages lead to a decrease in pigment content (Wang *et al.,* 2015).

The interaction between shade and rice genotypes significantly affects rice production. A more effective and well-planned procedure is essential to ascertain the proportion of shade required to achieve the desired rice yield. Currently, environmental constraints represent a crucial challenge that requires consideration to improve the assessment of research activities aimed at increasing rice harvest. Therefore, it is necessary to develop genotypes that are shade-tolerant to maintain high productivity even under overcast weather conditions. Shade-tolerant genotypes hope to provide high production yields, ensuring stable productivity even under unpredictable weather conditions. The presented study aimed to determine the effect of shading on rice plants and identify tolerant promising rice lines under a shading condition.

MATERIALS AND METHODS

Breeding material and procedure

The relevant research commenced at the Malikussaleh University, Aceh, Indonesia in November 2023 until February 2024. The experiment comprised two environments—with 25% shade, and without shade. The rice genotypes used in the study were US-20 (Unsyiah Simeulue), CBD-08 (Cot Bada), CBD-04 (Cot Bada), Sigupai UA-12, Cibatu, and Inpago-9. The selected genotype is a local variety with high productivity. The experimental layout in a split-plot design had two factors and three replications. The first factor was the shade levels, i.e., 25% shade (S) and no shade (NS), designated at the main plots. The second factor were the six genotypes placed in subplots. Twelve-treatment combinations incurred assessment per replication, resulting in 36 experimental units, with 10 plants sown in each experimental unit, thus, totaling 360 plants.

The rice genotypes' planting continued in polybags (40 cm × 60 cm) with the composition of planting media soil and manure in a ratio of 2:1. Soaking the rice genotype seeds for 24 hours twice occurred before planting, and then, drained for 48 hours until the seed roots sprouted. Subsequently, planting the seeds in each polybag contained four seeds per bag. The fertilizer doses utilized were 300 kg ha^{-1} urea (46% N), 100 kg ha^{-1} TSP (36% P_2O_5), and 100 kg ha^{-1} KCl (60% K_2O), each applied three times. Retransplanting after seven days of sowing replaced dead seedlings. The irrigation's adjustment to twice daily depended on the crops' condition. The control of pests and weeds were optimal. The deployment of pesticides serves to modulate the symptoms and intensity of pest attacks in the field. The harvesting process started at 90% of maturity.

Observations and statistical analysis

A random sample of five plants selected received recording of data on the agronomic and yield-related traits. The data recorded comprised the traits plant height, leaf area, number of productive tillers, panicle length, total grain number, number of filled grains, percentage unfilled grain (%), 1000-grain weight, flowering maturity, and grain weight per hill. All the recorded data underwent analysis of variance (ANOVA), with the Least Significant Different ($LSD_{0.05}$) test used for comparison and separation of the means for significantly different characters. Moreover, the correlation analysis helped to ascertain the relationship between the observed characters. The calculation of the net assimilation rate employed the following formula (Vernon and Allison, 1963). The observation of the net assimilation rate, conducted three times, was specifically at 10 days after planting (DAP), 30, and 50 DAP.

$$\text{NAR} = \frac{(W_2 - W_1)(log_e L_2 - log_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

Where, W_1 and W_2 are initial and final total dry-weight biomass, respectively, of sample, L_1 and L_2, the initial and final leaf-area indices, and $t_2 - t_1$ as the length of the interval in weeks.

RESULTS AND DISCUSSION

Combined analysis of variance

The results of variance analysis revealed the shade treatments had a significant ($P < 0.05$) effect on the traits, plant height, leaf area, percent of unfilled grain, and grain weight per hill (Table 1). Similarly, the rice genotypes had a noteworthy ($P < 0.05$) impact on the leaf area and total grain number. This result aligns with Deng *et al*. (2022), indicating shading conditions lead to increased photosynthesis, which then affects leaf area. Therefore, shading significantly enhances leaf chlorophyll content, non-photochemical quenching, and the efficiency of primary light energy conversion, while simultaneously reducing actual photochemical efficiency and the leaf's net photosynthetic rate. These results were in an insufficient supply of photo assimilates for rice growth and development, such as, for genotype of CBD-08 and Sigupai. This study clearly declare the non-realization of potential grain growth when available assimilate failed to meet the assimilate requirement. A study

Table 1. Analysis of variance for growth and yield traits in rice under optimum and minimum fertilizer environments.

Traits	C	S	G	G × S	CV
Plant height	7.90^{ns}	405.35*	33.15^{ns}	23.51^{ns}	7.54
Leaf area	112.65^{ns}	860.25*	95.11*	46.23^{ns}	11.56
Number of productive tillers	0.567^{ns}	1.04ns	65.15**	3.46**	4.00
Panicle length	1.08^{ns}	107.12^{ns}	17.09^{ns}	8.65^{ns}	13.71
Total number of grains	347.58^{ns}	386.78*	5089.40^{ns}	8025.44**	18.99
Number of filled grains	142.41^{ns}	1305.02*	2479.18^{ns}	5545.19**	21.84
Unfilled grains (%)	4.31^{ns}	736.31*	35.95^{ns}	25.24^{ns}	31.96
1000 grain weight	0.26^{ns}	247.28*	14.29^{ns}	2.89^{ns}	13.88
Flowering age	0.53^{ns}	30.25^{ns}	89.49**	8.38^{ns}	2.79
Grain weight per hill	35.99^{ns}	2409.17*	3161.04**	449.83**	21.91

C= block, S= shade, G= genotype, CV= coefficient variation, LSD= least significant difference, ****:** significant at 1% level, ***:** significant at 5% level, and ^{ns}: not significant at 5% level.

has shown that shortage of available assimilate caused by shading during the early grain-filling period (approximately the first 10 days after heading) restricts final grain weight at the fully ripe stage (Kobata *et al.*, 2000).

Additionally, significant ($P < 0.01$) differences were evident for the number of tillers, flowering age, and grain weight per hill. The interactions between the rice genotypes and shade (G × S) revealed considerable variances for the number of tillers, total grains, and filled grains, and grain weight per hill. Hidayah *et al.* (2022) reported the number of tillers and grains bore notable influences from the genotype by environment interactions in lowland rice, and this study examined how the environment, specifically the use of shade, affected these factors. In the presented study, the coefficients of variations attained levels of classification, as low to high, ranging from 2.79% to 31.96%.

The remarkable effects of shade indicated the traits would vary with the prevailing shade conditions and the rice genotypes, which produced a marked outcome. The significant effect of the genotype by shade interaction (G × S) authenticated that a rice genotype may not necessarily exhibit superiority in an environment without shade (Jayaningsih *et al.,* 2019). The interaction consequences of the studied factors exerted a dominant influence on the plant characters under consideration. In the latest study, the low coefficient of variation indicated a high degree of accuracy in the experimental results. Conversely, a high coefficient of diversity always indicates a low degree of accuracy. The elevated coefficient of variation may refer to several factors, including environmental influences exerting a considerable impact on the accumulation of diversity coefficient for a given character (Delgado *et al.,* 2019).

Agronomic and yield traits

Under the shaded environment, the average plant height (82.51 cm) was significantly higher than in the non-shaded environment (75.80 cm) (Table 2). The standard for rice plant height divides into three criteria, i.e., low (<110 cm), medium (110–130 cm), and high (>130 cm) (IRRI, 2013). Based on this standard, the plant height received a low classification, which provided the plants with more stability and resilience during the rainy season and more water. In plant height, the discrepancy resulting from shading proved more pronounced due to the reduction in light availability, which prompted the accumulation of the auxin hormone in the shoots, thereby, accelerating the elongation rate. Furthermore, the application of shade can impede the expansion of stem diameter, directing growth toward stem elongation and, consequently, lead to an increased plant height compared with the treatment with no shade (Fan *et al.,* 2018).

Table 2. Mean values for plant height, leaf area, panicle length, unfilled grains (%), 1000-grain weight, and flowering age in rice.

Traits	PH (cm)	LA (cm^2)	PL (cm)	PUG (%)	TGW (g)	FA
Environment						
25% Shade	82.51^a	55.93^a	26.31^a	9.44^b	23.36^a	64.22^b
No shade	75.80^b	46.15^b	22.86^a	18.48^a	18.12^b	69.05^a
Genotype						
US-20	79.40^a	48.00^{bc}	24.34^a	15.54^a	20.26^a	70.17^b
CBD-08	77.20^a	46.55^c	23.08^a	10.93^a	20.32^a	67.67^{bc}
CBD-04	78.06^a	55.00^{ab}	22.64^a	12.74^a	20.22^a	74.67^a
Sigupai	77.06^a	49.28^{bc}	24.84^a	15.67^a	18.71^a	64.00^d
Cibatu-08	79.83^a	50.78^{abc}	25.24^a	11.84^a	21.67^a	67.33^{bcd}
Inpago-9	83.36^a	56.61^a	27.35^a	17.02^a	23.26^a	65.00^{cd}
Interaction	Ns	ns	Ns	ns	ns	ns

PH= plant height, LA= leaf area, PL= panicle length, PUG= percentage of unfilled grains, TGW= 1000 grain weight, FA= flowering age.

In rice, the leaf area gained influences from shading treatments and genotypes (Table 2). The shade treatments resulted in a considerably higher leaf area (55.93) than rice plants without shade (46.15). Genotype Inpago-9 demonstrated the enhanced leaf area (56.61), and it may be due to its genetic potential. This genotype could be particularly appropriate to environments with reduced light availability. In general, due to shading the increased leaf area will reduce the leaf thickness, with the leaf growth primarily expanding the leaf area (Díaz-Pérez, 2013). Plants growing in shaded conditions tend to exhibit a larger leaf area, as significant number of cells receive light with low-intensity and then, utilized in photosynthesis (Ilić *et al.,* 2015; Wang *et al.,* 2015). The shade treatments did not affect the rice panicle length, and were 26.31 cm under shade and 22.86 cm without the shade. Furthermore, the rice genotypes revealed nonsignificant effect on the panicle length, ranging from 22.64 to 27.35 cm. Mumtaz's *et al*. (2018) findings enunciated rice panicle length received more control from the genetic make-up of genotypes than the environmental conditions. Consequently, the length of panicles did not appear to have alterations by the types of treatments applied in this study

The percentage of unfilled grain (%) obtained under the shaded treatment was significantly lower (9.44%) than the acquired value without shade (18.84%) (Table 2). These findings suggested the shade proved effective in reducing hollow grains. For the 1000-grain weight, the shade treatment resulted in a greater weight (23.36 g), while the no-shade treatment produced a reduced weight (18.12 g). The use of shading during the early growth stage can suppress weed growth hindering rice development, thus, alleviating nutrient competition between rice and weeds, and allowing rice growth to proceed uninterrupted. Shading at 25% can yield results similar to full sunlight, but if shading exceeds 25%, it will lead to a decrease in rice productivity (Chauhan, 2013).

In the flowering characters, the shade treatment had a notable effect, and a shaded environment resulted in a faster flowering age (64.22 days) and the absence of shade led to a slower flowering age (69.05 days) (Table 2). Additionally, the rice genotypes had a dominant impact on flowering age, ranging from 64.00 to 74.67 days. The flowering age of rice substantially affected the time required for seed filling and the harvest period. A reduction in the flowering age results in a corresponding reduction in the time required for rice harvesting (Song *et al*., 2022). In plant breeding programs, the plant's flowering age plays a primary role in the development of early maturing rice cultivars. The shading has demonstrated to accelerate the flowering process, thereby, offering an alternative means of developing rice cultivars with an early maturation cycle. In addition to the shade treatment, it is essential to consider the genetic traits of each genotype under examination. The genotype Sigupai-UA12 exhibited the shortest flowering period, making it a promising candidate for developing early maturing cultivars. The crossing of the genotype Sigupai-UA12 with other cultivars that flower rapidly could be a viable approach in the hybridization program.

The average number of tillers incurred nonsignificant effect from the shading treatments (Table 3). However, the rice genotypes revealed sizable differences in the number of tillers. The maximum number of tillers resulted from genotype Inpago-9 (22.36), while the lowest number came from the genotype Sigupai-UA12 (12.69). The results indicated significant interaction effects between the shading treatments and the genotypes, whereby the genotype Inpago-9, grown under shade conditions, exhibited the most tillers (23.03). In addition to environmental influences, the number of tillers sustained effects from the rice genotypes due to their varied genetic make-up. Each rice genotype possesses distinctive characteristics contributing to variations in the number of tillers produced in rice crops (Mumtaz *et al*., 2018; Nuraida *et al.,* 2020). In rice plant leaves, applying shade can diminish leaf temperature and transpiration rates while maintaining their photosynthetic yield, thereby, directing the obtained food reserves throughout the plant, resulting in a more

Table 3. Mean values for number of productive tillers, total number of grains, number of filled grains, and grain weight per hill in rice.

Traits	Environment	Genotypes						Average
		US-20	CBD-08	CBD-04	Sigupai	Cibatu-08	Inpago-9	
NPT	25% Shade	15.79^{c}	15.05^{c}	16.08^{bc}	13.03^{d}	20.05^{b}	23.03^{a}	17.18^{a}
	No shade	16.64^{c}	15.43^{d}	15.87^{cd}	12.36^{e}	17.03^{b}	21.70^{ab}	16.50^{a}
	Average	16.21^{bc}	15.24^{bc}	15.97^{bc}	12.69^{c}	18.54^{b}	22.36^{a}	
TGN	25% Shade	186.33^{abc}	126.00^{c}	239.33^{a}	171.33^{bc}	199.00^{ab}	296.67^{a}	203.11^{a}
	No shade	161.33^{b}	189.00^{b}	140.33^{b}	198.67^{b}	167.67^{b}	191.33^{ab}	174.72^{b}
	Average	173.83^{a}	175.50^{a}	189.83^{a}	185.00^{a}	183.33^{a}	243.5^{a}	
FGN	25% Shade	165.67^{abc}	118.39^{c}	223.10^{a}	147.11^{bc}	180.04^{ab}	223.53^{a}	176.31^{a}
	No shade	128.83^{b}	160.09^{b}	114.16^{b}	164.29^{ab}	143.49^{b}	172.46^{abc}	147.22^{b}
	Average	147.25^{a}	139.24^{a}	168.84^{a}	155.70^{a}	161.76^{a}	197.28^{a}	
GWH (g)	25% Shade	71.00^{ab}	67.33^{b}	67.67^{b}	64.33^{c}	69.33^{ab}	74.67^{a}	69.05^{a}
	No shade	69.33^{ab}	68.00^{b}	62.33^{c}	63.67^{c}	65.33^{bc}	74.67^{a}	67.22^{b}
	Average	70.17^{b}	67.67^{bc}	65.00^{cd}	64.00^{d}	$67.33b^{bcd}$	74.67^{a}	

NPT= number of productive tillers, TGN= total number of grains, FGN= number of filled grains, GWH= grain weight per hill.

significant number of tillers formed (Chen *et al*., 2019).

The average number of rice total grains and hulled grains appear in Table 3. The higher the total grain number, the higher the number of filled grains. A significant interaction existed between both factors in the latest study. Genotype G6 in the shaded condition produced the highest total grain number (296.67) and number of filled grains (223.53). In response to the observed growth differences resulting from the application of shade treatments, it was evident that notable variations occurred among the rice genotypes. These differences for various traits could refer to genetic variations among the genotypes. Genotypes that are physiologically more adaptive to the shading effect will produce superior grain numbers in rice (Sharif *et al.,* 2010). On another hand, several genotypes, US-20, CBD-04, Cibatu-08 and Inpago-9, have an increasing total grain number, with such condition affected by the genetics vital to the environment (Lu *et al.,* 2022). Moreover, the reason is due to the pleiotropism, a phenomenon where a single gene influences multiple traits or characteristics in an organism (Zhao *et al*., 2022). In the context of agriculture and genetics, this means changes in one gene can alter various aspects of a plant, such as, yield and total number of grains or grain quality. Pleiotropism can influence plant-breeding strategies, as improvements in one trait may also unexpectedly influence other traits. However, there is a need for molecular confirmation, which will progress through further research.

Grain weight per hill is an important yield-contributing trait, and the average values of grain weight per hill are available in Table 3. The results demonstrated an interaction between the rice genotypes and shading environments. Genotype Inpago-9 in shading and no shaded conditions produced the highest and at par grain weight per clump (74.67 g). The utilization of diverse genotypes can exert a pronounced influence on the grain weight per hill, given that each genotype possesses a distinctive genetic composition, thereby, giving rise to variations in traits manifested within the rice genotype (Panja *et al*., 2017). Furthermore, the rice genotypes interaction with shaded environment and their effect on various traits has elucidated that genotypes in diverse environmental conditions would result into varied grain weights per hill (Wang *et al*., 2013).

Correlation analysis

The correlation analysis outcomes among the various traits under shaded and non-shaded conditions occur in Figure 1. In shaded conditions, the grain weight per hill appeared

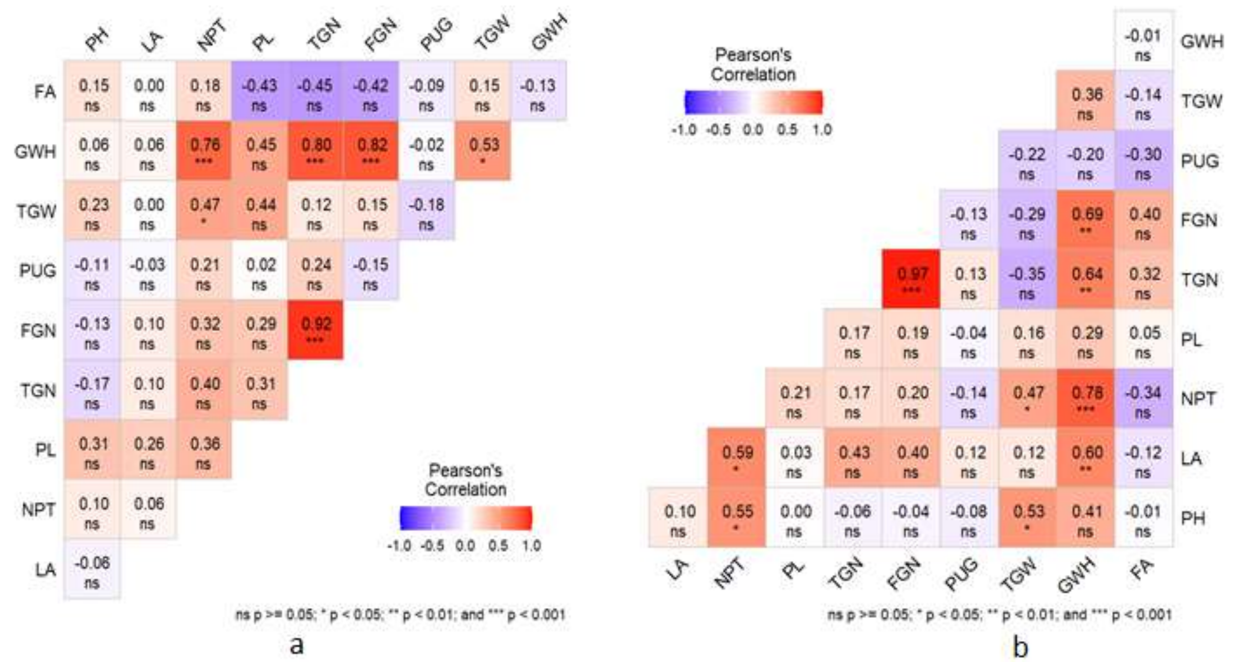

Figure 1. Pearson correlation between various traits: a) 25% shade, b) No shade.

positively correlated with the number of productive tillers, total grain number, number of filled grains, and 1000-grain weight. In non-shaded conditions, grain weight per hill provided a positive association with leaf area, number of productive tillers, 1000-grain weight, and total grain number. Correlation indicates the direction and strength of the relationship between two or more interdependent characters and expressed in positive and negative forms in rice and other crops (Rini *et al*., 2018).

Based on the existing correlation, an increase in grain weight per hill would follow an increase in number of productive tillers, total grain number, number of filled grains, and 1000-grain weight under shaded conditions. In non-shading conditions, the increase in grain weight per hill had complementing expansion in leaf area, the number of productive tillers, 1000-grain weight, and total grain number. In the presented study, the panicle length showed no correlation with the number of grain traits. Hussain *et al*. (2014) also reported panicle length did not always correlate with the number of grains, as multiple factors, including the number of branches and grain density also affect the grain traits in rice.

Net assimilation rate

The net assimilation rate (NAR) implies the ability of plants to produce dry matter from assimilation per unit leaf area and per unit time (Sudhakar *et al.,* 2016). In the presented study, the first observation of NAR appeared at 10 HSS (high source-to-sink ratio) in the shading condition (0.79) and with non-shading (1.26) (Table 4). The second observation emerged at 30 HSS in the shade (0.97) and non-shading (1.51) conditions. The third observation occurred at 50 HSS in the shading (0.16) and non-shading (0.19) conditions. In the first observation of genotype differences, the CBD-04 genotype had the highest net assimilation rate of 1.29, while in the second and third observations, the net assimilation rates among the different genotypes did not differ significantly. The net assimilation rate would increase with an enhanced leaf area to a certain extent and then decrease. This is because in a crown with a high value of leaf area ratio, young leaves are capable of absorbing the most significant quantity of light. Consequently, it exhibits a high photosynthetic rate and translocation of most photosynthates to other parts of the plant, including the lower leaves (Buntoro *et al.,* 2014).

The NAR displayed a positive correlation with the photosynthetic parameters (Priyadarsini *et al*., 2024). NAR is a measure of the efficiency with which a plant converts light energy into biomass over a specific period. It quantifies the amount of carbon assimilated (or photosynthesized) per unit leaf area per unit time, typically expressed in grams of dry weight per square meter per day (g/m²/day). Various factors influence NAR, including light intensity, temperature, CO_2 concentration, and the plant's physiological status. It is an important parameter in plant growth studies, as it helps assess a plant's overall productivity and ability to capture and utilize resources efficiently (Priyadarsini *et al.,* 2024). The net assimilation rate decreases over time; and in contrast to this study, the net assimilation rate increases in the second observation. At 30 HSS, the net assimilation rate of the rice plant reached its peak. Subsequently, at 50 HSS, the net assimilation rate decreased, as the rice plants entered the maximum vegetative phase. This resulted in the growth and development of the plants toward the formation of panicles by the nature of determinate rice plants. According to the hypothesis proposed by Gardner *et al*. (2017), the net assimilation rate of the plants is not a constant value over time and exhibits a decline with the onset of a new growth phase.

The provision of shade results in a reduction in the net assimilation rate because the assimilation rate revealed close correlation to the photosynthesis process. In this case, the shade results in a decrease in the sunlight reaching the plant, leading to a corresponding decrease in photosynthesis (Díaz-López *et al*., 2020). The shading effect on photosynthesis proved relatively minor, with the 25% shade used in the experiment having a limited effect on the photosynthesis process. Plants could generally tolerate and adapt to shaded conditions, and the reduction in sunlight did not drastically impair their ability to perform photosynthesis.

Cluster analysis

The diversity of genotypes is often in association with traits appearing in crop plants. The heatmap visualization in Figure 2 showed the grouping of rice genotypes based on these traits. Genotype Inpago-9 exhibited superior performance for traits, such as, number of productive tillers, plant height, leaf area, panicle length, grain weight per hill, and 1000-grain weight. Meanwhile, the genotypes' grouping based on their performance in shaded and non-shaded conditions revealed the rice genotype G6 stands out for its ability to produce better performance in both environments. Additionally, the cultivar Inpago-9 was superior for its resistance to low water availability and can be successful for planting on dry land, making it more resistant to drought stress (Jati *et al.,* 2021; El-Malky, 2024; Rauf *et al*., 2024). Based on these results, the rice genotype Inpago-9 demonstrated sustainable and highest production in both shaded and non-shaded conditions. The diversity of a genotype often links with cluster analysis, which is an alternative method for determining the kinship of a genotype and genotypes' grouping based on their traits (Yang *et al*., 2014; Tuhuteru *et al.,* 2021).

CONCLUSIONS

Significant genotype by shade (G × N) interaction was evident for the traits—the number of tillers, total grains, and filled grains and grain weight per hill—in rice (*Oryza sativa* L.) genotypes. The six genotypes showed considerable variations and better response under shading treatment for growth and yield traits, except for the NAR. The application of shade results in a reduction in the net assimilation rate compared with the non-shading condition in rice genotypes. Cultivar Inpago-9 can yield the best results both under shaded and non-shaded environmental conditions.

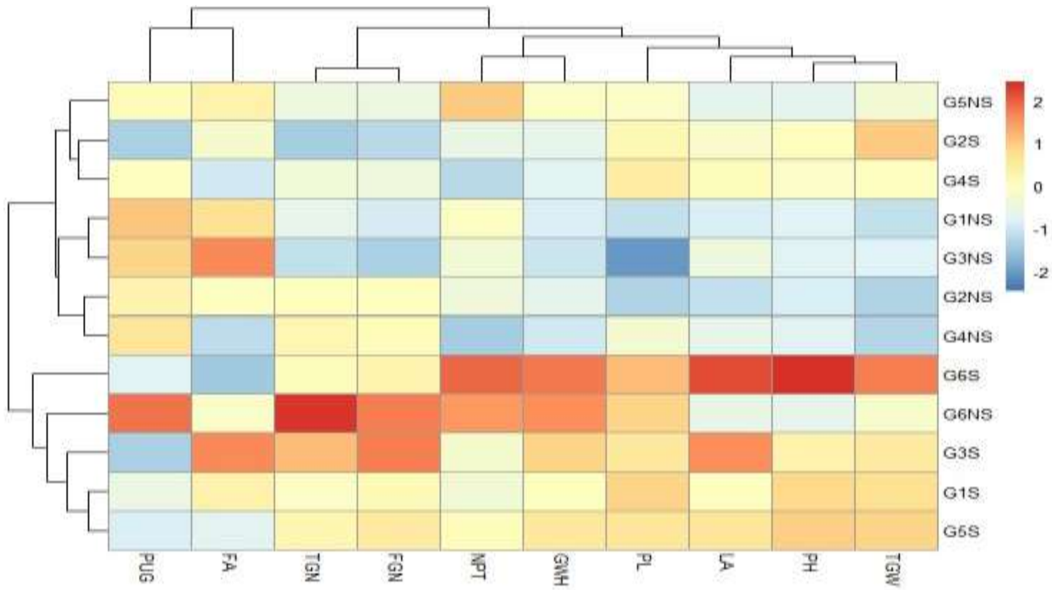

Figure 2. Heatmap showing the relationship between rice traits and genotypes under shaded and non-shaded conditions.

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