Research Article
Agrobiological Records
ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

MULTIVARIATE ANALYSIS IN THE EVALUATION OF PRUNING TECHNIQUES AND NITROGEN DOSAGE ON EARLY-MATURING RICE CAKRABUANA VARIETIES

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ABSTRACT

Rice productivity in Indonesia is increasingly challenged by climate change, necessitating adaptive strategies through early-maturing varieties and improved crop management. This study evaluated the effects of vegetative-phase pruning and nitrogen (N) fertilization on the growth and yield of the early-maturing Cakrabuana rice variety and identified key agronomic traits associated with yield using multivariate analysis. Field experiments were conducted in Maradekkaya Village, Gowa Regency, South Sulawesi, Indonesia, from August to November 2025 using a split-plot randomized complete block design with three replications. Pruning treatments consisted of no pruning and one-time pruning at 21 days after planting (DAP) at a height of 25 cm above the soil surface, while N was applied at 0, 50, 100, and 150 kg ha^{-1}. Observed parameters were evaluated sequentially using ANOVA, Pearson correlation, path analysis, principal component analysis (PCA), and multiple regression. Nitrogen application significantly influenced most growth and yield-related traits, whereas pruning significantly increased total and productive tillers, flag leaf characteristics, panicle length, yield per clump, and grain yield. Significant pruning × nitrogen interactions were observed for tiller number, panicle length, grain length, 1000-grain weight, and yield. Correlation and path analyses identified productive tillers, panicle length, filled grain percentage, and yield per clump as the primary determinants of grain yield, while maturity duration showed a negative association. PCA explained 87.9% of total variation and clearly separated pruned and non-pruned treatments. Overall, pruning combined with adequate N fertilization, particularly 150 kg ha^{-1}, enhanced productive tillering, grain filling, and yield, demonstrating its potential to support climate-adaptive rice production systems.

Keywords: Climate change, Early-maturing rice, Multivariate analysis, Nitrogen, Pruning.

Article History: ABR-26-263 || Received: 26-Jun-2026 || Revised: 01-Aug-2026 || Accepted: 09-Aug-2026 || Published Online: 05-Sep-2026

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the world's major food crops, widely cultivated especially in tropical regions and serving as a staple food source in Indonesia (Sakir et al., 2024). Rice productivity in Indonesia is heavily influenced by climatic conditions; climate change and agricultural land conversion can reduce rice production (Fan et al., 2021). Climate change negatively affects the rice production system, with the risk of crop failure due to rising temperatures, shifts in rainfall patterns, extreme weather, sea level rise, as well as declining soil fertility—factors that all contribute to a decrease in rice production in Indonesia (Roy et al., 2022; Ansari, 2023). In this context, climate change is seen as one of the main factors that can decrease income and threaten the sustainability of farming as a profession (Priyanto et al., 2021; Kamal & Shabbir, 2025; Gbughemobi et al., 2025; Zafar et al., 2025). These stress factors, together with shifts in planting seasons, pest outbreaks, and soil degradation, further strengthen the urgent need for adaptation strategies, including climate-resilient varieties and sustainable agricultural practices, to protect rice production and Indonesia's food security (Dey et al., 2023; Musa et al., 2024; Kamal et al., 2024; Shoukat, 2025; Zafar et al., 2026).

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Mitigation of climate change has been carried out through the use of short-maturity rice varieties (Dey et al., 2023). Short-maturity rice (<100 days) has the capability to avoid the negative impacts of extreme weather (Anshori et al., 2025a; Nafi'Azizi et al., 2025). The faster life cycle allows the crop to complete its growth (escape) before adverse environmental factors occur (Rezvi et al., 2023). This adaptation functions not only as a short-term response to minimize losses, but also as a long-term effort to maintain productivity. One strategy that can also be adopted by farmers to adapt to climate change is the use of rice plant pruning technology. Proper pruning can help regulate the number of tillers, improve air circulation, and minimize the risk of disease (Yuta et al., 2024). In addition, using short-duration rice varieties can increase planting frequency within a year, and when combined with pruning techniques, production yields can be significantly improved (Musa et al., 2024; Kurniawati et al., 2025).

One of the early-maturing varieties that has been developed and released by the Ministry of Agriculture is the cakrabuana variety. Besides having early maturity, the cakrabuana variety is also distinguished by its yield potential, reaching up to 10.2 tons/ha, with an average yield of 7.5 tons/ha (Waluyo & Suparwoto, 2023; Barokah et al., 2021). The success of cultivating early-maturing varieties depends not only on their genetic characteristics, but also on the appropriate cultivation strategy (Sitaresmi et al., 2023a). Early-maturing rice varieties have great potential, but their cultivation practices need to be tailored to their growth characteristics to achieve optimal yields (Sutardi et al., 2022; Sitaresmi et al., 2023b). In addition to the use of superior varieties, rice production improvement is also highly influenced by nutrient availability for the crop. Fertilization technology for early-maturing rice can be optimized through several approaches, including adjusting nitrogen fertilization rates (Musa et al., 2025). Complex optimization regarding nitrogen management is critically needed, including for early-maturing rice (Sakinah et al., 2024). Nitrogen fertilization is crucial because rice plants have relatively high nitrogen requirements and it directly affects growth and productivity. Superior varieties require more nitrogen fertilizer because they possess traits that demand more intensive management. Early-maturing rice varieties have different growth patterns and a shorter developmental phase, which can alter the dynamics of nutrient uptake compared to longer-lived varieties. As a result, standard nitrogen recommendations may not be appropriate, so specific optimization strategies are needed to suit the accelerated life cycle (Musa et al., 2023; Anshori et al., 2024).

If nitrogen content in plants falls below the threshold, plant growth slows, reducing productivity. Conversely, excessive nitrogen content can increase the susceptibility of rice plants to disease and cracking risk (Zhang et al., 2020; Zhang et al., 2024). Excessive nitrogen content can divert assimilates from productive growth, which negatively impacts productivity, so nitrogen application must be efficient for optimal yield (Patti et al., 2013). Nitrogen content in rice is believed to indicate growth status such as the number of tillers and yield predictions (Yang et al., 2014). In addition to fertilization, efforts to optimize rice cultivation potential include technical cultivation measures such as pruning during the vegetative phase (Jamilah et al., 2023). Pruning in rice is intended to improve quality and stimulate an increase in tiller numbers (Islam et al., 2006; Suyanto et al., 2023a). Pruning can stimulate plants to absorb nutrients from the soil more quickly, making fertilizer use more efficient and minimizing residue. With appropriate fertilizer dosing, the macro- and micronutrients in fertilizer can be absorbed by the plant and then the plant's shoots can be pruned, so that the resulting assimilates will be more directed toward panicle formation (Suyanto et al., 2023b). The increase in tiller numbers correlates with the number of panicles produced and increases rice productivity (Musa et al., 2023). Thus, this potential can serve as an adaptive measure to climate change in optimizing the cultivation of early-maturing rice. Especially the Cakrabuana variety, which has a high genetic potential for absorbing and utilizing nutrients, especially nitrogen, to support the development of productive tillers and grain filling (Waluyo & Suparwoto, 2023).

Although nitrogen fertilization strategies and pruning technology have long been practiced in rice cultivation, there remains a research gap in understanding the synergistic interaction between these two factors in optimizing plant growth to achieve maximum productivity. Many previous studies have tended to evaluate these treatments partially, so the mechanisms by which pruning affects nitrogen use efficiency in relation to yield components are still not comprehensively mapped. In this context, the integration mechanism of nitrogen management and pruning on rice crop productivity becomes the main focus of this study, making an in-depth assessment of agronomic traits essential in evaluating these outcomes. Such in-depth analysis can be conducted through multivariate analysis (Anshori et al., 2025b). Multivariate analysis is used to simplify and process data with many variables, making interpretation easier. This type of analysis is commonly applied in agriculture, particularly for grouping and determining evaluation or selection criteria (Farid et al., 2024). In general, multivariate analysis uses two approaches: (1) dividing the distribution of data variability into simpler dimensions or eigenvalues, and (2) reducing data variability to identify unique characteristics of complex data. These approaches simplify evaluation concepts while maintaining analytical depth, resulting in a more detailed and accurate evaluation process.

Therefore, this study aims to identify agronomic variables determining yield through a multivariate analysis approach, while also analyzing the interaction between pruning application and various nitrogen fertilizer doses on growth characteristics and productivity of Cakrabuana rice variety.

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2. MATERIALS AND METHODS

2.1. Experimental Design

This research was conducted in Maradekkaya Village, Bajeng Subdistrict, Gowa Regency, South Sulawesi, Indonesia, at the coordinates 5°16’54.47”S and 119°26’40.03”E, as shown in Fig. 1. The research activities took place from August to November 2025. The plant material used was rice (*Oryza sativa* L.) seeds of the Cakrabuana variety obtained from a certified seed source. The Cakrabuana variety is one of the new high-yielding varieties (VUB) with an early maturity period, high yield potential, good adaptability to various environmental conditions, and productive tillering characteristics that support increased harvest yields. The seeds used were selected based on high purity and germination rates to ensure uniform plant growth throughout the study. The selection of the Cakrabuana variety is based on the increasing adoption of this variety in rice cultivation in Indonesia, particularly as an alternative early-maturing variety that supports adaptation to climate change and planting index efficiency. Nevertheless, studies on efforts to optimize tiller formation in this variety remain relatively limited. In fact, one of the main advantages of Cakrabuana lies in its ability to produce productive tillers that directly contribute to increasing panicle number and grain yield.

Fig. 1: Location Map of Study Area.

2.2. Procedural Design

This study was designed using a split-plot design and a completely randomized block design (CRBD) as the environmental design. The main plot is the pruning factor (P) consisting of two levels, namely no pruning (p0) and pruned (p1). The subplots are nitrogen dosage (N), consisting of four dosage levels (n0: 0 kg ha^{-1}, n1: 50 kg ha^{-1}, n2: 100 kg ha^{-1}, n3: 150 kg ha^{-1}). Based on these two factors, there are 8 treatment combinations, with each treatment repeated three times, resulting in a total of 24 experimental plot units.

Before planting, a soil test was first conducted at a depth of 0–20 cm to analyze the initial physical and chemical properties of the soil. The analysis results showed that the soil at the research site had a clay texture with a pH of 6.35 and a cation exchange capacity of 20.25. Land preparation began with thorough tillage using a tractor, and a basal fertilizer in the form of organic compost was applied. After the land was prepared, the next step was to create 24 experimental plots. Each plot measured 3.5 m x 5 m, with a square planting system (25 x 25 cm), resulting in 280 plants per plot. Fertilization was conducted twice at 7 days after planting (DAP) and 28 DAP using urea fertilizer at doses according to the treatment. Supporting fertilizers were also used such as TSP 46, and KCL. Pruning was done once, at 21 DAP, using a grass cutter at a height of 25 cm measured from the soil surface as shown in Fig. 2. In addition, maintenance includes pest and disease control, irrigation management, and mechanical weeding. The crop is harvested when the grains have reached the physiological maturity stage, indicated by 80% of the plants turning yellow and the rice grains at the base of the panicle having hardened.

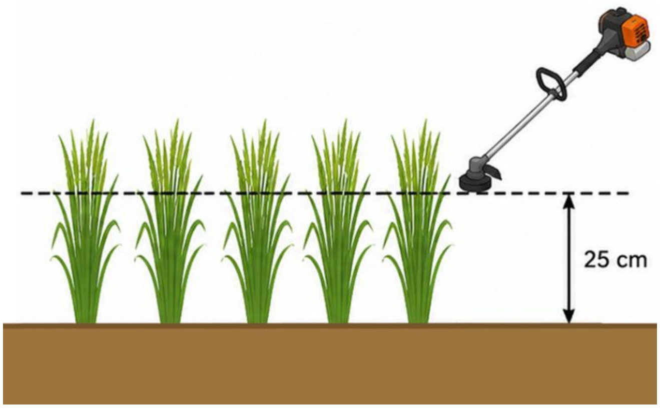

Fig. 2: Experimental Illustration of Rice Pruning.

2.3. Observation Data

The parameters observed in this study include growth characteristics, yield components, and rice crop yield. Growth characteristics consist of plant height (PH), number of total tillers (NTT), number of productive tillers (NPT), days to flowering (DoF), days to maturity (DoM), flag leaf length (FLL), and flag leaf width (FLW). Growth parameters were observed from the vegetative to the generative phase at observation times adjusted to plant development and expressed in days after planting (DAP). Yield component parameters were observed after harvest and include panicle length (PL), percentage of filled grains (PFG), panicle density (PD), length of grain (LoG), and weight of 1000 grains (W1000G). In addition, yield per clump (YPC) and grain yield (Y) were also measured to evaluate crop yield performance. All post-harvest parameters were observed after harvest at the physiological maturity stage.

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2.4. Data Analysis

The data obtained were analyzed using a multivariate approach with Microsoft Excel and RStudio version 4.5.0. Analysis of variance (ANOVA) was performed in accordance with the experimental design used to evaluate the effect of treatments on all observed variables, using Microsoft Excel at a significance level of $\alpha = 0.05$. The relationships among variables were analyzed using Pearson's correlation between each agronomic trait and yield, where $r \geq 0.5494$ (either positive or negative) indicates a highly significant correlation. Variables showing a significant association with yield were subsequently analyzed using path analysis to identify the magnitude of direct and indirect effects on yield. Traits with a positive direct effect on yield were then used in Principal Component Analysis (PCA) to reduce data dimensionality, identify relationship patterns among traits, and determine the variables contributing most to data variability. In addition, multiple linear regression was performed with yield as the response variable to evaluate the simultaneous contributions of the selected traits in explaining the variation in crop yield.

3. RESULTS

The results of the analysis of variance are presented in Table 1. Based on the table, the coefficient of variation (CV) values for all traits ranged from 1.06% – 6.83%. This relatively low CV indicates a high level of experimental precision and good environmental control during the execution of the research. The effect of nitrogen (N) dosage had a highly significant impact on nearly all observed parameters, including total tiller number (NTT), productive tiller number (NPT), day of maturing (DoM), flag leaf length (FLL), flag leaf width (FLW), panicle length (PL), percentage of filled grains (PFG), panicle density (PD), length of grain (LoG), weight of 1000 grains (W1000G), weight per clump (YPC), and yield. This indicates that nitrogen availability is the main factor significantly determining the growth and productivity of the crop. Meanwhile, pruning treatment (P) had a significant to highly significant effect on the traits NTT (211.6**), NPT (74.67**), FLL (110.07*), FLW (0.04*), PL (7.97*), YPC (93.62**), and Yield (2.26**). The highly significant influence of pruning on tiller number (NTT and NPT) shows that the pruning technique applied was effective in manipulating the distribution of assimilates, thereby triggering a growth response that impacts productivity increase. However, pruning did not have a significant effect on plant height (PH), day of flowering (DoF), or day of maturing (DoM), indicating that pruning treatment mainly affects vegetative efficiency rather than phenological aspects of plant development. The interaction between pruning and nitrogen application (P x N) showed significant effects on key variables such as productive tiller number (NPT), panicle length (PL), weight of 1000 grains (W1000G), weight per clump (YPC), and final yield (Yield). This significant interaction demonstrates that the effectiveness of nitrogen application in increasing crop yield is strongly determined by the pruning technique implemented. Pruning is presumed to help optimize light availability and regulate nutrient distribution, enabling plants to respond to nitrogen fertilizer application more efficiently.

Table 1: Analysis of variance of the growth of Cakrabuana rice variety with pruning and nitrogen fertilizer dosage.

Characters	Mean Square			CV (a)	CV (b)
	P	N	P x N		
PH (cm)	166.73	292.66 **	6.78	3.30	1.81
NTT (stems)	211.60**	208.45**	8.56**	6.83	6.00
NPT (stems)	74.67**	81.83**	0.98*	2.86	2.71
DoF (DAP)	8.17	3.78	0.17	1.68	2.32
DoM (DAP)	8.17	38.67**	0.17	1.06	2.20
FLL (cm)	110.07*	275.87**	3.73*	4.19	3.13
FLW (cm)	0.04*	0.13**	0.01	3.19	3.86
PL (cm)	7.97*	8.55**	3.90**	1.51	1.77
PFG (%)	34.81	88.94**	29.75	2.79	4.60
PD (grain/cm)	0.50	0.18**	0.05	4.41	3.01
LoG (mm)	0.34	0.20*	0.20*	3.72	2.35
W1000G (g)	13.81	6.79**	3.53*	3.72	3.07
YPC (g)	93.62**	179.04**	4.85*	3.09	4.11
Y (tons.ha^{-1})	2.26**	5.56**	0.43*	2.42	6.26

Note: *Significant effect at the 5% error level; **significant effect at the 1% error level; CV, coefficient of variation. PH, plant height; NTT, number of total tillers; NPT, number of productive tillers; DOF, day of flowering; Dom, day of maturing; FLL, flag leaf length; FLW, flag leaf width; PL, panicle length; PFG, percentage of filled grains; PD, panicle density; LoG, Length of Grain; W1000G, weight of 1000 grains; YPC, yield per clump; Y, yield; CV (a), pruning; CV (b), nitrogen dosage.

The results of the Pearson correlation analysis are shown in Fig. 3. Fig. 3 illustrates diverse patterns of relationships among agronomic traits. In general, traits associated with vegetative and generative growth components exhibit a strong positive correlation with Yield, while phenological traits show a negative correlation. The traits showing the strongest positive correlation with Yield are YPC (0.96), NPT (0.92), NTT (0.89), FLL (0.70), and FLW (0.70). This indicates that increases in the number of productive tillers (NPT) and cluster weight (YPC) are the main determinants in yield improvement. These traits can serve as primary selection targets due to their very strong and linear association with productivity. Days to flowering (DoM) shows a negative correlation with several growth parameters such as PL (-0.64), FLL (-0.77), FLW (-0.60), PD (-0.56), and YPC (-0.56), as well as with Yield at -0.54.

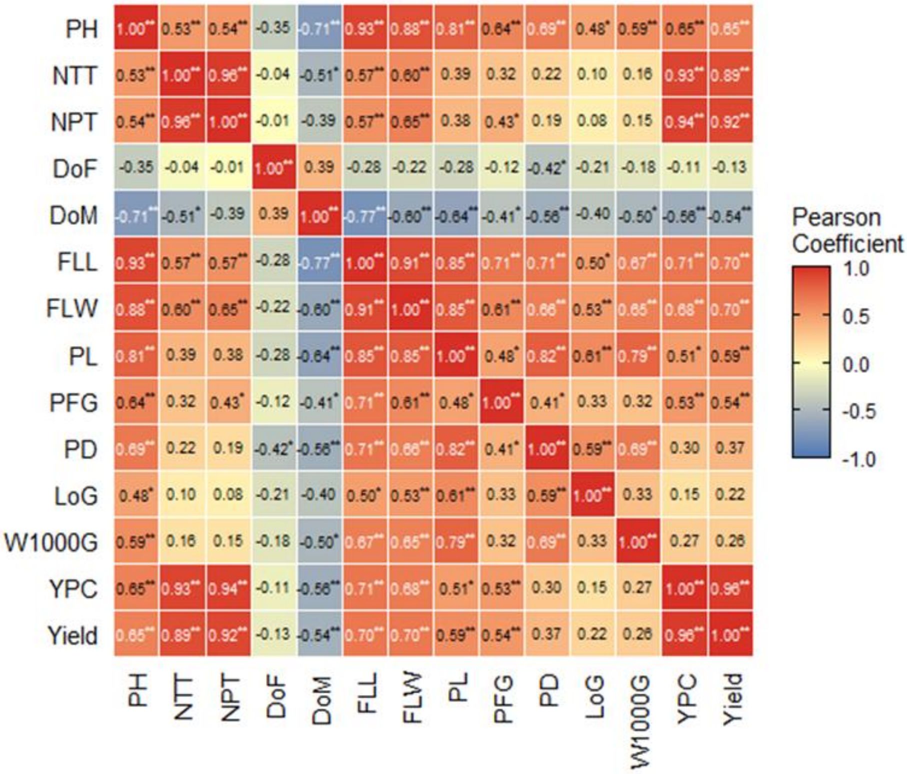

Fig. 3: Correlation analysis of the growth characteristics of Cakrabuana rice variety with pruning and nitrogen fertilizer dosage.
Note: NTT, number of total tillers; NPT, number of productive tillers; DOF, day of flowering; Dom, day of maturing; FLL, flag leaf length; FLW, flag leaf width; PL, panicle length; PFG, percentage of filled grains; PD, panicle density; LoG, Length of Grain; W1000G, weight of 1000 grains; YPC, yield per clump; Y, yield.

This negative correlation indicates that plants reaching the flowering stage earlier tend to have smaller leaves and lower yields under the experimental conditions. This phenomenon often occurs when a vegetative phase that is too short limits biomass accumulation before the plants enter the reproductive stage. Panicle length (PL) has a strong positive correlation with FLL (0.85) and FLW (0.85), indicating that plants with a broader canopy tend to support the growth of longer panicles. The weight of 1000 grains (W1000G) has a positive correlation with PL (0.79) and FLL (0.67), demonstrating the contribution of panicle size and leaf area to grain filling.

The results of the path coefficient analysis are shown in Table 2. Path coefficient analysis was used to determine the direct and indirect contributions of various agronomic traits to yield. In this study, yield was set as the dependent variable, while NPT, DoM, FLL, FLW, PL, PFG, and YPC were considered independent variables. The division of direct and indirect effects is explained in detail in Table 2. NPT showed the highest direct effect on yield, at 0.59. This indicates that NPT is the main determinant of crop yield. In addition to its direct effect, NPT also makes a positive indirect contribution through YPC (0.38). PL showed a direct effect of 0.50. This suggests that the longer the panicle, the higher the yield obtained directly, although there is a slight negative indirect effect through the FLL (-0.16) and FLW (-0.28) traits. YPC had a direct effect of 0.41. YPC plays a very important role because it has a significant indirect effect through NPT (0.55), making it a trait with an extremely significant total contribution to yield.

Table 2: Path coefficient analysis of the direct, indirect, and residual effects of agronomic traits on the yield of the Cakrabuana variety with pruning and nitrogen fertilizer dosage.

Characters	Direct effect	Individual effect							Indirect Effect	Residual
		NPT	DoM	FLL	FLW	PL	PFG	YPC		
NPT	0.59		0.02	-0.11	-0.21	0.19	0.06	0.38	0.92	0.03
DoM	-0.05	-0.23		0.15	0.20	-0.32	-0.06	-0.23	-0.54	
FLL	-0.19	0.34	0.04		-0.30	0.42	0.11	0.29	0.70	
FLW	-0.33	0.38	0.03	-0.17		0.42	0.09	0.28	0.70	
PL	0.50	0.22	0.03	-0.16	-0.28		0.07	0.21	0.59	
PFG	0.15	0.25	0.02	-0.14	-0.20	0.24		0.21	0.54	
YPC	0.41	0.55	0.03	-0.14	-0.22	0.25	0.08		0.96	

Note: NPT, number of productive tillers; DoM, day of maturing; FLL, flag leaf length; FLW, flag leaf weigth; PL, panicle length; PFG, percentage of filled grains; YPC, yield per clump..

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
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The results of the principal component analysis are presented in Table 3. Based on the table, there are two principal components (PC) that can explain most of the total variation in the five criteria. PC1 explains 71.8% of the total data, and PC2 explains 16.1%. These two components account for 87.9% of the total variation, so PC1 and PC2 are sufficiently representative in describing the relationships among the characters and treatments.

Table 3: Principal component analysis of the growth of Cakrabuana rice variety with pruning and nitrogen fertilizer dosage

Variable	PC1	PC2	PC3	PC4	PC5
NPT	0.477	-0.436	-0.041	0.720	-0.248
PL	0.354	0.628	0.664	0.194	0.029
PFG	0.356	0.567	-0.740	0.052	-0.039
YPC	0.508	-0.251	-0.006	-0.215	0.796
Y	0.512	-0.173	0.099	-0.629	-0.550
Eigenvalue	3.5882	0.8055	0.5225	0.0498	0.0339
Proportion	0.718	0.161	0.105	0.01	0.007
Cumulative	0.718	0.879	0.983	0.993	1

Note: NPT, number of productive tillers; PL, panicle length; PFG, percentage of filled grains; YPC, yield per clump; Y, yield.

The visualization results of the biplot graph from the PCA analysis are presented in Fig. 4. Fig. 4 presents a PCA biplot showing a clear separation between the non-pruned group and the pruned group. The pruning groups tend to cluster in the lower part of the biplot, while the unpruned groups are mostly located in the positive PC2 region, and the pruned groups tend to be located in the negative PC2 region. The non-pruned group displays a wide distribution and overlaps with the pruned group, reaching into the negative side of PC2. The non-pruned group has the largest ellipse, reflecting the highest phenotypic diversity, while the pruned group exhibits the smallest and most centered ellipse. The overlap between ellipses indicates that some nitrogen dose treatments still produced the same characteristics. Conversely, the broad spread in the non-pruned group demonstrates a greater degree of variation further from the initial distribution center. Variables such as panicle length and filled grain percentage are oriented toward the upper right quadrant, indicating a group of variables that remain positively correlated with PC1. On the other hand, variables such as NPT, YPC, and other yield components show relatively long vectors pointing toward the lower right quadrant (positive PC1, negative PC2), indicating a significant contribution to variation in PC1 and a strong relationship among these variables. This indicates that pruning tends to be associated with increases in components that directly contribute to PC1 (Yield, YPC and NPT), which have previously been identified as components of crop productivity.

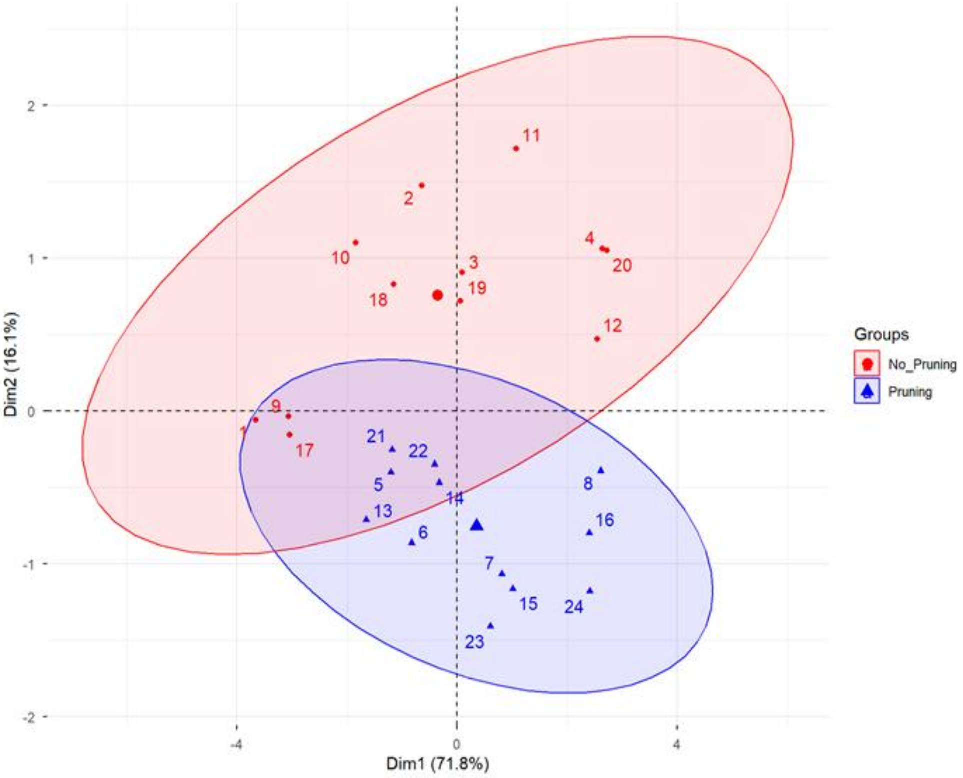

Fig. 4: PCA Biplot of growth of Cakrabuana rice variety with pruning and nitrogen fertilizer dosage.

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The results of the multiple linear regression analysis are presented in Fig. 5. The regression analysis shows that increasing the nitrogen dose linearly raises crop yield, both under Pruning and No Pruning conditions. Both treatments display a very strong linear regression model, as evidenced by the very high coefficients of determination (R2), namely 0.9683 for No Pruning and 0.9633 for Pruning. This indicates that more than 96% of the variation in crop yield can be explained by the applied nitrogen dose. At every level of nitrogen dose, the pruning treatment consistently produces a higher Yield compared to no pruning. This suggests that pruning provides a positive contribution to crop productivity beyond the effect of nitrogen fertilization. The two lines tend to converge as the nitrogen dose increases. This indicates that at low nitrogen doses, the role of pruning is crucial in boosting yield, whereas at high nitrogen doses, the effect of pruning may become less dominant since the plants have already reached their optimal growth limits.

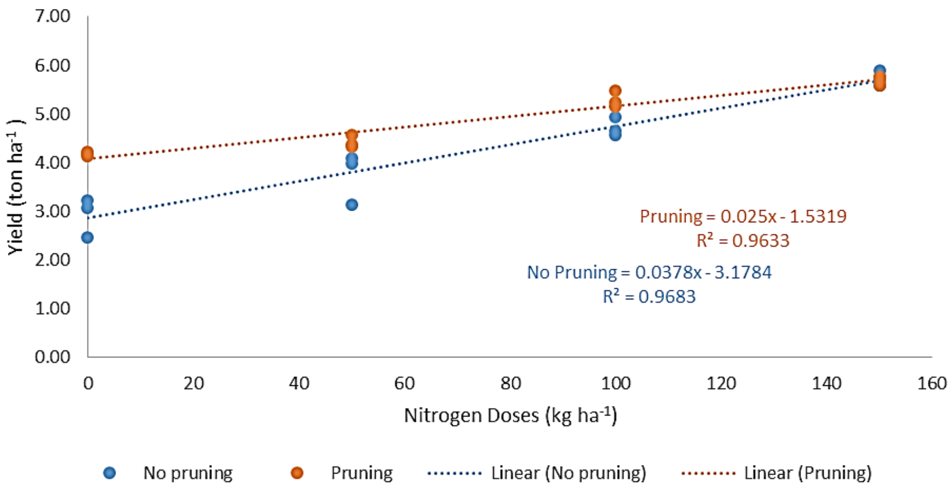

Fig. 5: Results of the interaction analysis regarding the effect of pruning from various nitrogen fertilization doses on productivity.

4. DISCUSSION

Analysis of variance (ANOVA) identified a single source of environmental variation, and the effects of pruning and nitrogen fertilization dosage had a significant impact on almost all agronomic characteristics. According to Nazirah & Simahate (2022), nitrogen fertilization affects all stages of growth and yield in rice plants. The effect of pruning was more frequently observed to be significant on traits influencing yield components, presumably because pruned plants are closer to the root zone, which serves as a source of nutrient supply to all parts of the plant, thereby promoting regrowth after pruning (Siregar et al., 2018). The combination of these two factors creates a specific growing environment for the Cakrabuana variety, thus generating specific interactions in the evaluated rice growth characteristics (Garbanzo et al., 2024).

The multivariate approach in this study integrates correlation analysis, path analysis, PCA and regression analysis to reveal the relationships among the effects of pruning from various nitrogen fertilization doses on the Cakrabuana variety. Various studies have reported that these analyses are effective in identifying evaluation criteria (Zafar et al., 2024). For example, Anshori et al. (2018), Anshori et al. (2021) and Anshori et al. (2022) demonstrated the effectiveness of correlation analysis in determining secondary traits in rice. In addition, Semeskandi et al. (2024) showed the effectiveness of path analysis in establishing selection criteria for rice.

Pearson correlation analysis and path analysis consistently identified NPT, PL, PFG and YPC as determinants of yield, with PFG serving as the main intermediary linking NPT and YPC. In general, short-lived rice varieties rely on productive tiller potential as a key component in increasing rice yield (Anshori et al., 2024). However, the productive tiller potential also depends on the total number of tillers in short-lived varieties (Takai, 2024). This relationship can be seen in the positive correlation between total number of tillers and number of productive tillers, so that the more total tillers, the greater the likelihood of productive tillers. This is further reinforced by research conducted by Suyanto et al. (2023). Pruning can stimulate bud growth, and nutrient needs can be balanced by providing the appropriate dose of nitrogen according to the plant's requirements. Sufficient nitrogen availability in the soil will encourage the plant to produce tillers optimally (Iswahyudi et al., 2018). Pruning also does not affect the loss of carbohydrate content during the tillering growth phase in rice plants as long as they remain in the vegetative stage (Harahap et al., 2017). Physiologically, pruning treatment has a significant impact on the dynamics of plant relationships in regulating the products of photosynthesis. In plants without pruning, most assimilates are often distributed evenly to the plant's vegetative parts and non-productive tillers. Through pruning, these non-productive competing organs can be removed. As a result, the plant redirects the phloem translocation pathway to channel assimilates toward developing reproductive organs such as the number of productive tillers. This is reinforced by the statement of Jatav et al. (2025), who reported that pruning increases rice yield by 12–13% at a 50% canopy reduction level and also enhances tiller formation and biomass accumulation in food crops.

The number of productive tillers plays a direct role in increasing productivity. This relationship aligns with the PCA results, which distinguish between the productivity dimension (PC1) and the yield component dimension (PC2), providing a more comprehensive description of the variable distribution differences under the effects of nitrogen dosage and pruning treatments. The pruning treatment showed the highest yield (ton ha-1) compared to the treatment without pruning. This is because pruning can enhance nutrient absorption by the roots, which in turn supports the growth of new shoots and increases photosynthetic efficiency (Yuta et al., 2024). Photosynthesis and respiration processes are influenced by nutrient availability, thereby determining the direction of plant growth. In rice plants, nitrogen plays an important role in processes such as protein and enzyme formation, cell division, chloroplast development, as well as various metabolic activities, making nitrogen an essential component for supporting rice growth (Shrestha et al., 2020; Jiang et al., 2024).

Differences in response can be observed through multiple regression analysis, which demonstrates the interaction between the two treatments. There is a positive relationship between the pruning treatment and nitrogen dosage on the tested varieties. An increase in yield (ton ha-1) was observed in the pruning treatment, which corresponded to the rise in nitrogen dosage used. Pruning plays a role in enhancing the ability of rice plants to absorb nutrients from fertilizer effectively, so after fertilization, the assimilates produced by the rice will be optimally stored in the grains (Jamilah et al., 2018). In addition, short-maturity varieties such as Cakrabuana rely heavily on the potential of productive tillers as a key component in increasing rice yields (Anshori et al., 2024). In addition, the Cakrabuana variety has high genetic potential for absorbing and utilizing nutrients, especially nitrogen, to support the formation of productive tillers and grain filling (Waluyo & Supartowo, 2023). The Cakrabuana variety not only excels in production characteristics but also demonstrates adaptive advantages in response to increased nitrogen availability, making it a promising variety for intensive cultivation systems with appropriate fertilizer inputs. However, in short-season varieties with a relatively brief vegetative phase, nitrogen utilization often leads to competition in vegetative growth. In this context, pruning plays a crucial role in altering the pathways of assimilate allocation and partitioning by removing less effective vegetative organs. This technology has been shown to optimize the formation of productive tillers; as indicated by the pathway analysis (Table 2), pruning was found to have the highest direct positive effect on final yield. Thus, the results of the regression analysis confirm that the use of pruning technology combined with appropriate nitrogen fertilizer inputs yields higher final yields at every nitrogen dose level compared to treatments without pruning. Therefore, the combination of the Cakrabuana variety's genetic response to nitrogen doses and pruning technology constitutes a highly effective cultivation strategy for consistently boosting productivity.

5. CONCLUSION

Pruning and nitrogen fertilization significantly affect the growth and yield of the Cakrabuana rice variety, with the interaction between the two—particularly at a nitrogen rate of 150 kg ha^{-1}—proven to increase the number of productive tillers and result in the highest yield compared to plants that were not pruned. These findings suggest that combining pruning with optimized nitrogen management can be recommended as a cultivation strategy. Moving forward, research should be expanded to various agroecosystems to test climate stability and supplemented with analyses of the economic viability of farming operations and evaluations of other early-maturing varieties to support climate-adaptive rice production systems.

Declarations

Funding: This research was supported by the Directorate of Research, Technology, and Community Service under the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia through the "Penelitian Fundamental Reguler (PFR) BIMA" scheme (grant number = 121/KPA/C3/KPT/2026; 076/C3/DT.05.00/PL-MULTITAHUN LANJUTAN/2026).

Acknowledgement: We are grateful to the Directorate of Research, Technology, and Community Service from the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia, which supported this study with the scheme of "Penelitian Fundamental Reguler (PFR) BIMA.

Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this manuscript.

Data Availability: The data generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Statement: This study involved rice plants and did not involve human participants, animals, or endangered/protected species. Therefore, formal ethical approval and informed consent were not required.

Author's Contributions: Muhammad Adil Maulana: Investigation, methodology, data collection, formal analysis, visualization, and writing—original draft. Abd. Haris Bahrun: Conceptualization, methodology, supervision, validation, and writing—review and editing. Muhammad Fuad Anshori: Conceptualization, methodology, statistical and multivariate analysis, validation, and writing—review and editing. Andi Amran Sulaiman: Supervision, resources, and writing—review and editing. Fadjry Djufry: Supervision, validation, and writing—review and editing. Hasil Sembiring: Methodology, validation, and writing—review and editing. Amin Nur: Supervision, validation, and writing—review and editing. All authors read and approved the final version of the manuscript.

Generative AI Statements: The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

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