Research Article

Optimizing Ultra-Early-Maturing Rice Cultivation: Effects of Pruning and Variety Selection on Agronomic Traits and Yield

Abd Haris Bahrun[1,2*], Andi Amran Sulaiman[2,3], Amir Yassi[1,2], Muh Farid[1,2], Yunus Musa[1,2], Eka Setiawan[4], Ayu Anisa Amir[3], Madonna Casimero[5], Dian Ratnadilah Abdullah[2], Salwa Aulia Haruni[1], Azmi Nur Karimah Amas[2] and Muhammad Fuad Anshori[1,2]

[1]Department of Agronomy, Faculty of Agriculture, Hasanuddin University, Makassar 90245, Indonesia; [2]Rice Research Group, Faculty of Agriculture, Hasanuddin University, Makassar 90245, Indonesia; [3]Department of Agribusiness, Faculty of Agriculture, Hasanuddin University, Makassar 90245, Indonesia; [4]Food Crop Production Technology, Vocational Faculty, Hasanuddin University, Makassar 90245, Indonesia; [5]International Rice Research Institute, University of the Philippines Los Baños, Los Baños, Philippines.

Abstract | The cultivation of ultra-early maturing rice varieties enhances resilience to climate change and increases annual rice planting in Indonesia. One technique for ultra-early rice cultivation is pruning. This study aimed to identify the optimal pruning time for ultra-early maturing rice yields. This study examined the effects of pruning treatments and variety selection on the agronomic traits and yield of three varieties: Cakrabuana, Padjajaran, and M70D. A split-plot, randomized complete block design was used, with pruning treatments as the main plots and varieties as sub-plots. The pruning treatments included no pruning, pruning 5 days before the second fertilization (25 days after planting, DAP), and pruning 5 days after the second fertilization (35 DAP). Agronomic characteristics, including plant height, tiller number, flag leaf length, days to flowering and harvest, panicle traits, and yield components, were observed. Based on the analysis of variance, the variety and pruning treatments significantly influenced most characteristics. In contrast, their interaction only affected plant height and yield. Correlation identified grain density and grain yield per hill as critical criteria for assessing the effectiveness of the pruning treatments. The Padjajaran variety had the highest grain density (5.07 grains cm^{-1}), whereas pruning at 25 DAP resulted in the highest grain yield per hill (23.31). The interaction between pruning at 25 DAP and the Padjajaran variety showed the most promising results for optimizing the yield in ultra-early maturing rice (6.37 ton ha^{-1}). These findings suggest that a combination of appropriate pruning timing and variety selection can enhance ultra-early maturing rice productivity, supporting the optimization of the three planting intensities per year in the Indonesian Agricultural Program.

Received | October 05, 2025; **Accepted** | January 12, 2026; **Published** | June 27, 2026
***Correspondence** | Abd Haris Bahrun, Department of Agronomy, Faculty of Agriculture, Hasanuddin University, Makassar 90245, Indonesia; **Email:** abahrun67@yahoo.com
Citation | Bahrun, A.H., A.A. Sulaiman, A. Yassi, M. Farid, Y. Musa, E. Setiawan, A.A. Amir, M. Casimero, D.R. Abdullah, S.A. Haruni, A.N.K. Amas and M.F. Anshori. 2026. Optimizing ultra-early-maturing rice cultivation: effects of pruning and variety selection on agronomic traits and yield. *Sarhad Journal of Agriculture*, 42(2): 1072-1082.
DOI | https://dx.doi.org/10.17582/journal.sja/2026/42.2.1072.1082
Keywords | Ultra-early-maturing varieties, Climate change resilience, Cultivation optimization, *Oryza sativa*, Padjajaran variety, Pruning techniques

Introduction

Rice is the main food commodity for the Indonesian population (Rozaki, 2020, 2021). Indonesia's domestic demand for rice continues to increase in line with population growth (Schmidt *et al*., 2021; Firmansyah *et al*., 2025). In 2024, total national rice consumption reached 31.21 million tons (Agricultural Ministry, 2024), whereas domestic production was only able to produce 30.62 million tons (Statistics Indonesia, 2025). The disparity between demand and production has resulted in a deficit, prompting an increase in imports to meet national needs (Rozaki, 2020; Yuan *et al*., 2022; Umar, 2025). In addition, climate change has emerged as an issue that can reduce rice production (Ruminta and Nurmala, 2018; Vogel *et al*., 2019; Fan *et al*., 2022). Climate change harms the rice production system, with the risk of crop failure owing to rising temperatures, changing rainfall patterns, and extreme weather events (Caruso *et al*., 2016; Sulaminingsih *et al*., 2024; Rajakaruna *et al*., 2024). Therefore, effective innovation in developing resilient rice varieties to climate change is required to increase rice production in the future.

Resilience to climate change has been pursued through the use of ultra-early maturing rice varieties (Acquaah, 2012; Syukur, 2018). Ultra-early maturing rice varieties with lifespans of less than 100 days can mitigate the negative impacts of extreme climates (Dey *et al*., 2023). Plants with rapid life cycles can complete their growth and development before the onset of adverse weather conditions (Rohaeni and Ishaq, 2015; Wening *et al*., 2018; Subekti and Umar, 2022). This advantage not only keeps production stable but also reduces the risk of crop failure owing to unpredictable seasonal changes (Achyadi *et al*., 2019). Moreover, these varieties open up opportunities to increase planting frequency within a year, thereby significantly improving production yields (Wening and Susanto, 2014; Achyadi *et al*., 2019; Yun, 2023). Several ultra-early maturing varieties have been developed and released by the Ministry of Agriculture, including Cakrabuana and Padjajaran (Barokah *et al*., 2021; Balitbangtan, 2021). Additionally, the private sector has contributed to the development of ultra-early maturing varieties such as M70D (Palobo *et al*., 2019). However, the potential of ultra-early maturing rice varieties still requires cultivation optimization tailored to their growth characteristics (Sutardi *et al*., 2022; Sitaresmi *et al*., 2023 a,b). The main difference lies in the vegetative growth phase, which directly affects generative development; therefore, cultivation strategies must be carefully designed (Musa *et al*., 2023; Anshori *et al*., 2024). The optimization of ultra-early maturing rice cultivation can be achieved through the optimization of cultivation techniques.

Technical cultivation engineering can be performed through pruning, including in rice. Previous studies have emphasized the role of pruning in improving plant quality and stimulating tiller production (Islam *et al*., 2006; Suyanto *et al*., 2023; Chachar *et al*., 2025). An increase in tiller number is positively correlated with panicle formation and indirectly enhances rice productivity (Musa *et al*., 2023). In addition, pruning during the vegetative phase has been reported to trigger elicitors that strengthen resistance to pests and diseases (Jamilah *et al*., 2018). However, most of these studies were conducted on conventional or medium-duration rice varieties, with limited attention paid to ultra-early maturing rice. The timing of pruning, which is critical for synchronizing vegetative growth and reproductive transition, has not been systematically investigated in ultra-early varieties of grapevines. This represents a significant gap, particularly in the context of climate change adaptation, where ultra-early maturing rice is increasingly prioritized to cope with shortened growing seasons and unpredictable rainfall. Therefore, our research highlights the novelty of evaluating pruning time, specifically in ultra-early rice varieties. By integrating agronomic performance with statistical analyses, this study provides new evidence on how pruning can be optimized to maximize the yield potential while enhancing resilience. The objective of this study was to identify the optimal pruning time for ultra-early maturing rice yields as a resilience effort under climate change.

Materials and Methods

Research design

This phase of the research involved two treatments: pruning techniques and ultra-early maturing rice varieties. The combinations were arranged using a split-plot design with a randomized complete block design (RCBD). The main plots in this study were pruning treatments involving three pruning times: no pruning, pruning 5 days before the second fertilization (25 days after planting (DAP)), and pruning 5 days after the second fertilization (35 DAP). The subplots consisted of three ultra-early maturing

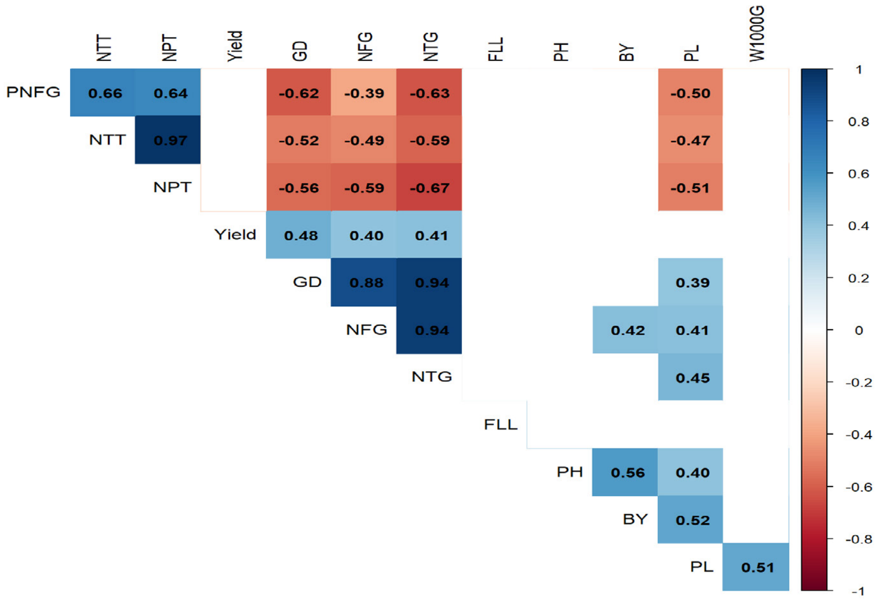

Figure 1: *Pearson Correlation Analysis of growth characteristics in the combination of treatment and ultra-early rice varieties. (PH: plant height, NTT: Number of total tillers, NPT: Number of productive tillers, FLL: flag leaf length, PL: panicle length (cm), NFG: number of filled grains, NTG: Number of total grains, PFG: Percentage of filled grains, GD: grain density, W1000G: weight of 1000-grains)*

varieties: Cakrabuana, Padjajaran, and M70D. All combinations were repeated thrice, resulting in 27 experimental units. Each unit had a plot size of 3 × 3 m. The procedure for this study followed Musa *et al*. (2023); Anshori *et al*. (2024). These procedures include land preparation, mapping, seedling planting, maintenance and harvesting. Modifications to these procedures were tailored to the treatments used in this study.

Observation parameters

The observations thoroughly covered the agronomic, economic, and social aspects. Other agronomic characteristics observed, consisting of: plant height (cm), total tillers and productive tillers (stems), flag leaf length (cm), days to harvest (DAP), panicle length (cm), grain density (grains cm^{-1}), 1000-grain weight (g), grain yield per hill at 14% moisture content (g), and the yield per ha at 14% moisture content (tons ha^{-1}).

Data analysis

The observational data obtained were analyzed using analysis of variance (ANOVA) followed by the least significant difference (LSD) test at a 0.05 significance level using Statistical Tool for Agricultural Research (STAR) 2.0.1 software and parametric multivariate analysis by RStudio with the ggplot2 package, especially for correlation and bar chart analysis.

Results

The analysis of variance focused on three sources of variation: pruning treatment, varietal differences, and the interaction between pruning and variety (Table 1). Pruning treatments significantly affected plant height, productive tiller number, flag leaf length, total grain number, and grain yield per hill. Variety treatment was the dominant factor significantly influencing almost all characteristics, except for flag leaf length, grain density, and 1000-grain weight. The interaction between the two varieties had a significant effect only on plant height and yield characteristics.

The results of the correlation analysis between the growth characteristics are shown in Figure 1. The correlation was first focused on the yield as the main criterion for evaluation. Based on the figure, yield had a significant positive correlation only with the number of filled grains (NFG) (0.45), number of total grains (NTG) (0.43), grain density (GD) (0.49), and grain yield per hill (GYC) (0.48). The NFG trait was significantly positively correlated with NTG (0.95), PD (0.92), GYC (0.46), plant height (PH) (0.40), and panicle length (PL) (0.48). The NTG trait also showed a significant positive correlation with PD (0.97), BY (0.41), and PL (0.56). PD traits were also significantly positively correlated with GYC (0.39) and PL (0.46). GYC was also positively correlated with PH (0.48), PL (0.47), and W1000G (0.43) measurements.

Table 1: *Analysis of variance of rice growth character in response to the combination of pruning treatment and ultra-early maturing rice varieties*

Character	P values			CVa	CVb
	Pruning (P)	Variety (V)	PxV		
PH	0.0213^{**}	0.0171^{*}	0.0395^{*}	3.85	2.71
NTT	0.0585	0.0222^{*}	0.4005	12.23	17.97
NPT	0.0138^{*}	0.0032^{**}	0.5741	8.44	17.88
FLL	0.0083^{**}	0.4168	0.3292	8.99	19.29
PL	0.0532	0.0025^{**}	0.0488	5.75	4.48
NFG	0.0655	0.0010^{**}	0.9337	13.12	14.73
NTG	0.0302^{*}	0.0000^{**}	0.7198	9.48	13.28
PFG	0.6121	0.0012^{**}	0.2233	8.04	5.39
GD	0.0571	0.0001^{**}	0.9559	8.38	12.15
W1000g	0.4225	0.1976	0.3319	11.11	8.68
Grain yield per hill	0.0278^{*}	0.2665	0.6247	16.92	28.18
The Yield	0.0686	0.0469^{*}	0.0230^{*}	15.55	12.97

Note: PH: plant height, NTT: Number of total tillers, NPT: Number of productive tillers, FLL: flag leaf length, PL: panicle length (cm), NFG: number of filled grains, NTG: Number of total grains, PFG: Percentage of filled grains, GD: grain density, W1000G: weight of 1000-grains, CVa = coefficient of variance a error, CVb: coefficient of variance b error

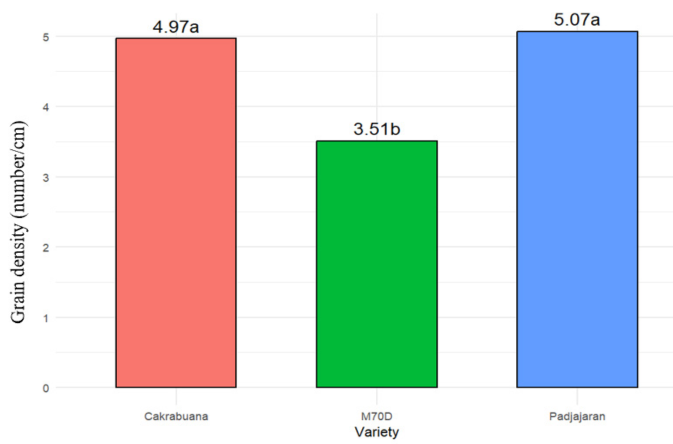

Figure 2: *Post-hoc least significant difference between ultra-early rice varieties on grain density (LSD test statistic = 0.56)*

Further independent analyses were performed on grain density (Figure 2) and grain yield per hill (Figure 3). Based on the grain density, the analysis focused on the effect of variety. Padjajaran had the highest grain density (5.07). However, this potential was not significantly different from that of Cakrabuana (4.97). Conversely, the M70D variety had the lowest potential grain density (3.51). Based on the grain yield per hill, the analysis focused on the pruning treatment. Pruning at 25 DAP was considered the best treatment, inducing a grain yield of 23.31 g per hill. However, this potential was not significantly different from the yield without the pruning treatment (21.94 g). Conversely, pruning at 35 DAP resulted in the lowest grain yield per hill, with a potential yield of 16.39 g.

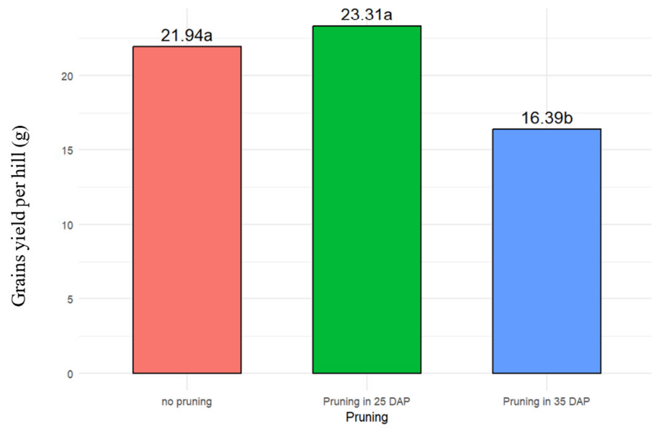

Figure 3: *Post-hoc Least Significant Difference (LSD) test between pruning treatments on grain yield per hill (LSD test statistic = 4.55)*

Table 2: *Interaction analysis of ultra-early rice varieties and pruning treatments on yield*

Varieties	no pruning	Pruning in 25 DAP	Pruning in 35 DAP	LSD
Cakrabuana	4.49^{p}_{ab}	5.06^{p}_{b}	4.91^{p}_{a}	1.16
Padjajaran	5.37^{p}_{a}	6.37^{p}_{a}	3.70^{q}_{b}	
M70D	3.93^{p}_{b}	4.82^{p}_{b}	4.23^{p}_{ab}	
LSD	1.10			

Note: LSD = Least square distance

The interaction analysis in this study focused on the yield (Table 2). Based on the effect of pruning on each variety, Cakrabuana, Padjajaran, and M70D showed an increase in yield with pruning at 25 DAP, with values of 5.06, 6.37, and 4.82 t/ha, respectively. However, these values were not significantly different from those of other pruning treatments. Based on the pruning treatment, the Padjajaran variety showed significant interaction dynamics between the different pruning treatment patterns. In contrast, Cakrabuana and M70D tended to respond positively to pruning, particularly at 25 DAP.

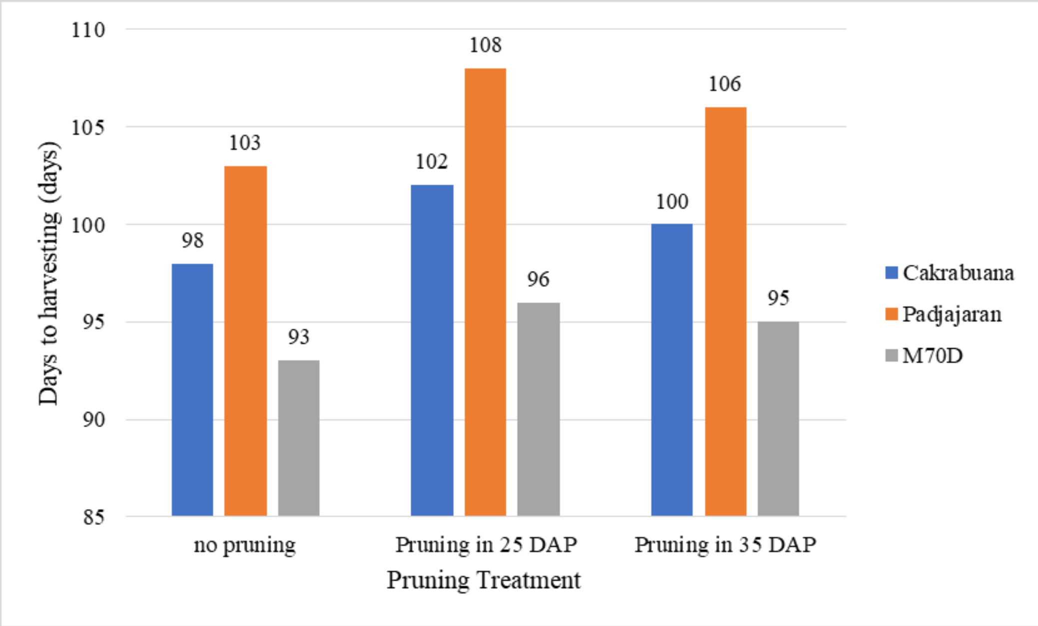

Figure 4: *Days to harvesting of each combination of pruning and ultra-early maturing rice varieties.*

The results of the harvest age observations are shown in Figure 4. Based on the figure, the treatment without pruning was relatively faster than the other treatments. Conversely, treatment with pruning at 25 DAP showed a longer duration than the other treatments, by approximately 3-5 days. All ultra-early rice varieties showed the same trend regarding differences in pruning treatments.

Discussion

The analysis of variance in this study showed that the source of variation from the varieties dominated more than other sources of variation. Conversely, variations due to pruning treatments and their interaction with the varieties only affected a few growth traits. This suggests that each of the ultra-early maturing varieties included in this study exhibited different growth patterns, and the effects of pruning and its interactions were not clearly illustrated. Musa *et al.* (2023, 2025), Anshori *et al.* (2024), and Bahrun *et al.* (2025) reported markedly different growth patterns among these three ultra-early maturing varieties in response to cultivation practices, indicating that varietal diversity strongly dominates the differences in growth traits observed in their research. Nevertheless, certain specific growth characteristics were independently influenced by the supporting treatments and their interactions with the three varieties. This was also observed in the present study, where several significant growth characteristics served as indicators of the response to pruning treatments and their interaction with ultra-early maturing rice varieties. Therefore, evaluations must be conducted in a focused and systematic manner using evaluation criteria.

Determining evaluation criteria has become an important part of the effective assessment of cultivation technologies or varieties. This concept has also been reported by Herzberg *et al.* (2019), Brown *et al.* (2020); Saini *et al.* (2022); Sakinah *et al.* (2022); Han *et al.* (2024), including in ultra-early maturing rice (Musa *et al.*, 2023, 2025; Bahrun *et al.*, 2025). The evaluation criteria for rice can be determined through correlation. This effectiveness has also been reported by Saleh *et al.* (2020); Arifuddin *et al.* (2021); Thuy *et al.* (2023); Bahrun *et al.* (2025). Based on a correlation analysis focusing on yield as the main indicator, the number of filled grains, number of total grains, grain density, and grain yield per hill showed significant positive correlations. This indicates that the increase in yield is likely to be directly influenced by these production components. However, based on the correlation among NFT, NTG, and PD, all variables exhibited a significant correlation exceeding 0.95, indicating the presence of multicollinearity among these variables (Olivoto *et al.*, 2017; Anshori *et al.*, 2021). Consequently, one of these variables, grain density (which has the highest correlation with yield), can be used as a representative criterion for evaluating grain yield per hill. Therefore, both grain density and yield can serve as evaluation criteria, alongside yield, as indicators of the effectiveness of pruning treatment in ultra-early maturing rice varieties.

Grain density is an indicator of productivity related to the number of grains per unit length of a panicle. It reflects the pattern of grain distribution within a panicle, which correlates with the pattern of crop yield increase. A high grain density indicates efficient and effective production per panicle. This characteristic is also associated with genetics, nutrient availability, population density, and environmental conditions (Das *et al*., 2018; Li *et al*., 2022). Based on this study, grain density was independently influenced by varietal diversity. The Padjajaran variety had the highest potential for grain density, followed by Cakrabuana. This is important because ultra-early maturity potential requires effective panicle production. Therefore, both varieties are considered to have good potential as superior ultra-early maturing rice varieties.

Grain yield per hill is a supplementary component of the evaluation criteria that is closely related to the productivity. This potential reflects the independent productive capacity without describing the dynamics of competition between individuals in a population. Nevertheless, grain yield per hill still provides a simple overview of the overall potential for accumulation of yield components in a planting (Li *et al*., 2019; Isnawan *et al*., 2020; Limbongan *et al*., 2022; Khamid *et al*., 2023). According to the results of this study, the grain yield per hill was heavily influenced by the pruning treatment. Pruning at 25 days after planting (DAP) showed a significantly different approach compared to other treatments, particularly compared to pruning at 35 DAP. These findings indicate that the timing of pruning plays an important role in determining vegetative growth efficiency. Cumulatively, pruning at 25 DAP supported an increase in production per hill. In addition, the grain yield per hill complements the yield variation alongside grain density, which synergistically reflects the potential for harvest variation owing to the interaction between these two treatments.

Based on the interaction between pruning treatment and variety, all three varieties (Padjajaran, Cakrabuana, and M70D) experienced an increase in yield with pruning at 25 DAP, especially the Padjajaran variety. In general, ultra-early maturing rice optimizes the potential biomass of tillers, which correlates with the potential of production components. Pruning at a relatively young age induces an increase in the number of tillers and improves the strength of the rice clump base. This is because the phenology of ultra-early maturing rice at 25 days is entering the elongation stage or the quadratic growth phase on the sigmoid curve (Baharuddin *et al*., 2025). Additionally, pruning stabilizes nutrient content, particularly nitrogen and non-structural carbohydrates, and alters the direction of apical dominance in favor of cytokinin (Yuan *et al*., 2024). This encourages rice plants to focus on the development of tillering and biomass, which are associated with the yield components. Both of these factors are why rice plants are more responsive to the induction of tiller formation and biomass accumulation, particularly when pruning is applied. Moreover, this process is conducted before the second fertilization at 30 DAP, so biomass accumulation and tiller induction will be even more effective with the pruning treatment at 25 DAP. This was also reported by Suyanto *et al*. (2023) for the Agro Pawan rice variety (125 days to harvest), where the effectiveness of pruning occurred at 44 days old, when entering the panicle initiation phase and before the third fertilization. This phenomenon is further supported by the genetic potential of the crop, which is related to grain density. The Padjajaran variety, which has a high grain density, was further induced by this pruning treatment, which directly increased production per hill and production per unit area of the population. Furthermore, based on maturation potential, pruning at 25 DAP did not significantly alter the harvest time. This further strengthens the effectiveness of pruning at 25 DAP in ultra-early maturing rice. Therefore, the concept of combining pruning at 25 DAP with the Padjajaran variety is highly recommended in this study to support <the yield> of ultra-early maturing rice varieties.

Conclusions and Recommendations

The application of pruning and ultra-early rice varieties significantly affected plant growth and yields. Specifically, pruning conducted 25 days after planting, in conjunction with the Padjajaran variety, resulted in an optimal yield by enhancing the grain yield per hill and grain density. The treatment factors directly contributed to the increased yield. Grain density emerged as the most critical trait for yield, whereas grain yield per hill played a supportive role. Although a higher grain count is generally associated with an increased yield, it has a negative direct effect, suggesting a complex relationship. The Padjajaran variety demonstrated the most favorable response to pruning, whereas Cakrabuana and M70D exhibited stable positive responses. Selecting the appropriate variety and timing of pruning can enhance ultra-early rice productivity. Therefore, pruning at 25 DAP and using the Padjajaran variety are highly recommended to optimize the IP 300 program.

Acknowledgements

This work was also supported by the Directorate of Research, Technology, and Community Service of the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia under the Penelitian Fundamental Reguler BIMA scheme (069/C3/DT.05.00/PL/2025).

Novelty Statement

This study offers the inaugural comprehensive assessment of the timing of pruning and varietal selection to enhance the productivity of ultra-early maturing rice in Indonesia. By identifying the synergistic interaction between pruning at 25 days after planting (DAP) and the Padjajaran variety, this study introduces an innovative agronomic strategy that significantly enhances grain yield per hill and grain density. These findings provide a practical innovation to support the intensification of rice cropping cycles under the IP 300 program, thereby contributing to sustainable increases in the national rice production.

Author Contributions

Abd Haris Bahrun: Conceptualisation, Methodology, Original draft, Funding acquisition, reviewed the draft
Andi Amran Sulaiman: Conceptualisation, Validation, reviewed the draft, Funding acquisition
Amir Yassi: Validation, reviewed the draft
Muh Farid: Validation, reviewed the draft
Yunus Musa: Validation, reviewed the draft
Eka Setiawan: Methodology, Formal analysis, reviewed the draft
Ayu Anisa Amir: Data Curation, Conceptualisation, reviewed the draft
Madonna Casimero: Validation, reviewed the draft
Dian Ratnadilah Abdullah: Formal analysis, Investigation, reviewed the draft
Azmi Nur Karimah Amas: Data Curation, reviewed the draft
Salwa Aulia Haruni: reviewed the draft
Muhammad Fuad Anshori: Conceptualisation, Methodology, Formal analysis, Visualisation
All co-authors reviewed the final version and approved the manuscript before submission.

Generative AI and AI-assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript

Conflict of interest
The authors have declared no conflict of interest.

References

Achyadi, M.A., K. Ohgushi and T. Morita. 2019. Impacts of climate change on agriculture for local paddy water requirement irrigation Barito Kuala, South Kalimantan, Indonesia. J. Wetl. Environ. Manag., 7(2): 140–50. https://doi.org/10.20527/JWEM.V7I2.210

Acquaah, G. 2012. Principles of plant genetics and breeding: Second edition. Wiley-Blackwell, Oxford, United Kingdom. https://doi.org/10.1002/9781118313718

Agricultural Ministry. 2024. Pusat Data dan Sistem Informasi Pertanian Sekretariat Jenderal. Buletin konsumsi pangan., 15(1). https://satudata.pertanian.go.id /assets/docs/publikasi/Buletin_Konsumsi_Pangan_Semester_I_2024.pdf

Anshori, M.F., Y. Musa, N.E. Dungga, N. Widiayani, A.S. Arifin, A. Masniawati, F. Firmansyah, M. Farid, A. Dirpan and A.N.K. Amas. 2024. A new approach for selection of transgressive segregants in F3 populations based on selection index and anthocyanin content in cayenne pepper. Front. Sustain. Food. Syst., 8: 1288579. https://doi.org/10.3389/fsufs.2024.1288579

Anshori, M.F., Y. Musa, M. Farid, M. Jayadi, A.H. Bahrun, A. Yassi, A.A. Sulaiman, Y.C. Huang, M. Casimero, L. Llorca, W.B. Suwarno, M.M. Putra, H. Sembiring, B.S. Purwoko, D.O. Wasonga and M.F. Seleiman. 2024. A new concept in assessing adaptability index for superior potential cropping intensity in ultra-early-maturing rice. Front. Sustain. Food Syst., 8: 1407880. https://doi.org/10.3389/

fsufs.2024.1407880

Anshori, M.F., B.S. Purwoko, I.S. Dewi, S.W. Ardie and W.B. Suwarno. 2021. A new approach to select doubled haploid rice lines under salinity stress using indirect selection index. Rice Sci., 28(4): 368-378. https://doi.org/10.1016/j.rsci.2021.05.007

Arifuddin, M., Y. Musa, M. Farid, M.F. Anshori, N. Nasaruddin, A. Nur and A.I. Sakinah. 2021. Rice screening with hydroponic deep-flow technique under salinity stress. SABRAO J. Breed. Genet., 53(3): 435-446. https://sabraojournal.org/wp-content/uploads/2021/09/SABRAO-J-Breed-Genet-533-435-446-ARIFUDDIN.pdf

Balitbangtan. 2021. Laporan Tahunan 2021. [online]. https://bbpadi-litbangppid.pertanian.go.id

Statistics Indonesia. 2025. Luas panen dan produksi padi di Indonesia 2024. [online]. https://www.bps.go.id/id/pressrelease/ 2025/02/03/2414/pada-2024--luas-panen-padi-mencapai-sekitar-10-05-juta-hektare-dengan-produksi-padi-sebanyak-53-14-juta-ton-gabah-kering-giling--gkg--.html.

Baharuddin, A.K., R. Padjung, K. Kaimuddin, Y. Musa, A.H. Bahrun, A. Yassi, M. Casimero, L. LIorca. I. Bugayong. B. Jardinero, H. Sembiring, A. Nur, D.O. Wasonga, M.F. Seleiman, and M.F. Anshori. 2025. Validation assessment of nitrogen and irrigation effects on ultra-early maturing rice varieties Cakrabuana and Inpari 13 through ORYZA (v3) modelling. Front. Sustain. Food Syst., 9: 15411691. https://doi.org/10.3389/fsufs.2025.1541691

Bahrun, A.H., M.F. Anshori, M. Riadi, Y. Musa, M. Farid, N. Widiayani, N. Nurlela, A.I. Sakinah, A.K. Baharuddin, Y.C. Huang and M. Casimero. 2025. A novel approach to evaluate the interaction effects of nano silica bokashi fertilizer on several rice varieties using multivariate analysis. Int. J. Agric. Biosci., 14(1): 136-144. https://doi.org/10.47278/journal.ijab/2024.197

Barokah, U., R.J. Nugroho and M. Huda. 2021. Uji adaptasi varietas unggul baru padi sawah berbasis penerapan teknologi terpadu di Kecamatan Karangsambung Kabupaten Kebumen. Cermin: J. Penelit., 5(1): 36–50. https://repository.pertanian.go.id/handle/123456789/7203

Brown, D., I.V.D. Bergh, S.D. Bruin, L. Machida and J.V. Etten. 2020. Data synthesis for crop variety evaluation. A review. Agron. Sustain. Dev., 40(25): 1-20. https://doi.org/10.1007/s13593-020-00630-7

Caruso, R., I. Petrarca and R. Ricciuti. 2016. Climate change, rice crops, and violence: evidence from Indonesia. J. Peace. Res., 53(1): 66–83. https://www.jstor.org/stable/43920583

Chachar, Z., X. Xue, J. Fang, M. Chen, W. Chen, X. Li, N. Ahmed, S. Chachar, A. Ali, Z.L. Chen, L. Fan, R. Lai and Y. Qi. 2025. Genetic and molecular insights into tiller development and approaches for crop yield improvement. Front. Plant Sci., 16: 1532180. https://doi.org/10.3389/fpls.2025.1532180

Das, K., B.B. Panda, B.P. Shaw, S.R. Das, S.K. Dash, E. Kariali and P.K. Mohapatra. 2018. Grain density and its impact on grain filling characteristics of rice: mechanistic testing of the concept in genetically related cultivars. Sci. Rep., 8: 4149. https://doi.org/10.1038/s41598-018-22256-2

Dey, S., P.K. Singh, K. Abbhishek, A. Singh and G. Chander. 2023. Climate-resilient agricultural ploys can improve livelihood and food security in Eastern India. Environ. Dev. Sustain., 1–24. https://doi.org/10.1007/s10668-023-03176-2

Fan, X., D. Zhu, X. Sun, J. Wang, M. Wang, S. Wang and A.E. Watson. 2022. Impacts of extreme temperature and precipitation on crops during the growing season in South Asia. Remote Sens., 14(23): 1-20. https://doi.org/10.3390/rs14236093

Firmansyah, A.M., T.R. Humaidi, A.D. Nugrahaini and C. Syahnaz. 2025. Price sensitivity analysis of medium quality rice: insights from low to middle income households in Gresik Regency, Indonesia. Cendekia: J. Penelit. Pengkaj. Ilmiah., 2(1): 81–95. https://doi.org/10.62335/220j1554

Han, Y., K. Wang, Q. Zhang, F. Yang, S. Pan, Z. Liu and Q. Zhang. 2024. Developing a comprehensive evaluation model of variety adaptability based on machine learning method. Field Crop Res., 306: 109203. https://doi.org/10.1016/j.fcr.2023.109203

Hastini, T., Y. Haryati, I. Noviana, B. Nurbaeti, F. Perdhana, Kurnia, R. Sari, W.R. Rohaeni and U. Susanto. 2022. Short communication: Variation of panicle branching structure of new high yielding and local rice varieties from farmer's field. Biodiversitas., 23(3): 1336-1343. https://doi.org/10.13057/biodiv/d230318

Herzberg, R., C.T.M. Tran, T.G. Pham, M. Kappas and D. Wyss. 2019. Multi-criteria decision analysis for the land evaluation of potential agricultural land use types in a hilly area of Central Vietnam. Land., 8(6): 90. https://doi.org/10.3390/land8060090

Islam, K.K., A.T.M.R. Hoque and M.F. Mamun. 2006. Effect of Level of Pruning on the Performance of Rice-Sissoo Based Agroforestry System. Am. J. Plant Physiol., 1: 13–20. https://doi.org/10.3923/ajpp.2006.13.20

Isnawan, B.H., Samanhudi, Supriyono and Supriyadi. 2020. Growth and yield of various local rice varieties with system of rice intensification irrigation system. IOP Conf. Ser.: Earth Environ. Sci., 458(012021): 1-8. https://doi.org/10.1088/1755-1315/458/1/012021

Jamilah, J. 2018. Budidaya padi yang dipangkas secara periodik dan diberi pupuk kompos Chromolaena odorata dan analisis usahataninya. J. Ilmiah Pertanian., 14(2): 35-45. https://doi.org/10.31849/jip.v14i2.260

Khamid, M.B.R., A. Junaedi, H. Purnamawati, H. Aswidinnoor and L.B. Prasetyo. 2023. Genotypes assessment for developing varieties on multi-canopy rice cultivation system. Biodiversitas., 24(2): 1175-1185. https://doi.org/10.13057/biodiv/d240258

Li, J., Y. Feng, X. Wang, G. Xu, Z. Luo, J. Peng, Q. Luo, W. Lu and Z. Han. 2022. High nitrogen input increases the total spikelets but decreases the high-density grain content in hybrid indica rice. Field Crop Res., 288: 108679. https://doi.org/10.1016/j.fcr.2022.108679

Li, R., M. Li, U. Ashraf, S. Liu and J. Zhang. 2019. Exploring the relationships between yield and yield-related traits for rice varieties released in China from 1978 to 2017. Front. Plant Sci., 10(543): 1-12. https://doi.org/10.3389/fpls.2019.00543

Limbongan, Y.L., T.Y. Parari, A.A. Limbongan and M.M. Palese. 2022. Agronomic performance and correlation of growth components, yield components and production on 30 F3 lines of new plant type of black rice specific to highland ecosystems. IOP Conf. Ser.: Earth Environ. Sci., 1200(012031): 1-9. https://doi.org/10.1088/1755-1315/1200/1/012031

Musa, Y., M. Farid, N. Nasaruddin, M.F. Anshori, A.F. Adzima, M.F. Maricar, A. Sulaiman, Y.C. Huang, H. Iswoyo, A.H. Bahrun and A. Adnan. 2023. Sustainability approach in cropping intensity (CI) 400 through optimizing the dosage of compost and chemical fertilizers to ultra-early-maturing rice varieties based on multivariate analysis. J. Agric. Food Res., 14: 100907. https://doi.org/10.1016/j.jafr.2023.100907

Musa, Y., R. Padjung, N. Nasaruddin, M. Farid, A.S. Soma, A.K. Baharuddin, M.F.A. Qautzar, R.M. Fakhri, M. Casimero, A. Nur, M.F. Seleiman, M. Alotaibi, N. Ali and M.F. Anshori. 2025. Comprehensive evaluation of nitrogen fertilization impact on ultra-early maturing rice varieties using multivariate analysis and vegetation indices. Front. Sustain. Food Syst., 9: 1615799. https://doi.org/10.3389/fsufs.2025.1615799

Olivoto, T., V.Q. de Souza, M. Nardino, I.R. Carvalho, M. Ferrari, A.J. de Pelegrin, V.J. Szareski and D. Schmidt. 2017. Multicollinearity in Path Analysis: A Simple Method to Reduce Its Effects. Agron. J., 109 (1): 131-142.

Palobo, F., S. Tirajoh and M. Thamrin. 2019. Pengembangan padi sawah melalui pendekatan pengelolaan ramah lingkungan di Kabupaten Merauke. J. Budidaya Pertanian.. 15(1): 44-50. https://doi.org/10.30598/jbdp.2019.15.1.44

Rajakaruna, R.M.A.S.D., B.G.N. Sewwandi and M.M.M. Najim. 2024. Effects of climate change and adaptation strategies on food security in Sri Lanka. YSF Thematic Publ. 3–17. https://www.researchgate.net / publication/377952520_Effects_of_Climate_Change _and_Adaptation_ Strategies_on_Food_Security_in_ Sri_Lanka

Rohaeni, W.R. and M.I. Ishaq 2015. Evaluasi varietas padi sawah pada display varietas unggul baru (VUB) di Kabupaten Karawang, Jawa Barat. Agric., 27(1): 1-7. https://doi.org/10.24246/agric.2015.v27.i1.p1-7

Rozaki, Z. 2020. COVID-19, agriculture, and food security in Indonesia. Rev. Agric. Sci., 8: 243-60. https://doi.org/10.7831/ras.8.0_243

Rozaki, Z. 2021. Food security challenges and opportunities in Indonesia post COVID-19. Adv. Food Secur. Sustain., 6: 119–68. https://doi.org/10.1016/bs.af2s.2021.07.002

Ruminta, H. and T. Nurmala. 2018. Indikasi perubahan iklim dan dampaknya terhadap produksi padi di Indonesia (Studi kasus: Sumatera Selatan dan Malang Raya). J. Agro., 5(1): 48-60. https://doi.org/10.15575/1607

Saini, A., B. Ali, S. Manuja, A. Hafeez, P. Poczai and S. Kumar. 2022. Impact of cultivation practices and varieties on productivity, profitability, and nutrient uptake of rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) cropping system in India. Agric., 12(10): 1678. https://doi.org/10.3390/agriculture12101678

Sakinah, A.I., Y. Musa, M. Farid, A. Hairmansis, M.F. Anshori and N. Nasaruddin. 2022. Rice selection criteria based on morphological and image-based phenotyping under drought- and salinity-stress conditions. SABRAO J. Breed. Genet., 54 (4): 686-699. http://doi.org/10.54910/sabrao2022.54.4.1

Saleh, M.M., K.F.M. Salem and A.B. Elabd. 2020. Definition of selection criterion using correlation and path coefficient analysis in rice (*Oryza sativa* L.) genotypes. Bull. Natl. Res. Cent., 44 (143): 1-6. https://doi.org/10.1186/s42269-020-00403-y

Schmidt, E., P. Dorosh and R. Gilbert. 2021. Impacts of COVID-19 induced income and rice price shocks on household welfare in Papua New Guinea: household model estimates. Agric. Econ., 52(3): 391-406. https://doi.org/10.1111/agec.12625

Sitaresmi, T., H. Safitri, U. Susanto, A. Hairmansis, C. Gunarsih, C. Roza and Y. Nugraha. 2023a. Selection of rice promising lines having Ciherang's idiotype for improved resistance of main pest and diseases. IOP Conf. Ser.: Earth Environ. Sci., 1172(1): 012022. https://doi.org/10.1088/1755-1315/1172/1/012022

Sitaresmi, T., N. Nafisah, U. Susanto, R. Rahmini, Y. Widyastuti, B. Kusbiantoro, M.I. Wahab, A. Hairmansis and Y. Nugraha. 2023b. Deciphering genetic-by-environment interaction, pests and disease's reaction, grain quality, and response to fertilizer for targeting high-yielding rice varieties. Ecol. Genet. Genomics., 28: 100189. https://www.sciencedirect.com/science/article/pii/S2405985423000307

Subekti, A. and A. Umar. 2022. Keragaan dua belas varietas unggul baru padi pada agroekosistem lahan pasang surut di Kalimantan Barat. Agrica. Ekstensia., 16(1): 8-13. https://doi.org/10.55127/ae.v16i1.112

Sulaminingsih, S., E. Silamat, A. Ruruh, M. Syaiful, A. Ninasari and A.R. Muchdir. 2024. Dampak perubahan iklim terhadap peningkatan dan penurunan produktivitas tanaman pangan. J. Rev. Pendidik Pengajaran., 7(3): 10189–95. http://journal.universitaspahlawan.ac.id/index.php/jrpp

Sutardi, Y. Apriyana, P. Rejekiningrum, A.D. Alifia, F. Ramadhani, V. Darwis, N. Setyowati, D.E.D. Setyono, Gunawan, A. Malik, S. Abdullah, Muslimin, W. Wibawa, J. Triastono, Yusuf, F.D. Arianti and A.Y. Fadwiwati. 2022. The transformation of rice crop technology in Indonesia: Innovation and sustainable food security. Agron., 13(1): 1-14. https://doi.org/10.3390/agronomy13010001

Suyanto, A., A. Masulili, Setiawan and I. Astar. 2023. Use of balanced fertilizer doses and pruning methods to increase growth and yield of rice plants in acidic sulphate lands in West Borneo. J. Tek. Pertanian Lampung., 12(3): 765-776. https://doi.org/10.23960/jtep-l.v12i3.765-776

Syukur, M. 2018. *Teknik pemuliaan tanaman*. Penebar Swadaya, Jakarta. https://kikp-pertanian.id/pepi/uploaded_files/temporary/DigitalCollection/MWJkYjc1YzE4Yzc4NmI5MDMyM2M3O DBjN2I5ZmNjNDk0YWU5M2 YwMg==.pdf

Thuy, N.P., N.N. Trai, B.D. Khoa, N.H.X. Thao, V.T. Phong and Q.V.C. Thi. 2023. Correlation and path analysis of association among yield, micronutrients, and protein contentin rice accessions grown under aerobic condition from Karnataka, India. Plant Breed. Biotech., 11(2): 117-129. https://doi.org/10.9787/PBB.2023.11.2.117

Umar, M.K. 2025. Dampak impor beras terhadap harga eceran tertinggi beras lokal Indonesia. J. Ilmiah Ekon. Manaj., 3(2): 146–53. https://doi.org/10.61722/jiem.v3i2.3809

Vogel, E., M.G. Donat, L.V. Alexander, M. Meinshausen, D.K. Ray, D. Karoly, N. Meinshausen, and K. Frieler. 2019. The effects of climate extremes on global agricultural yields. Environ. Res. Lett., 14(5): 054010. https://doi.org/10.1088/1748-9326/ab154b

Wening, R.H. and U. Susanto. 2014. Skrining plasma nutfah padi terhadap cekaman kekeringan. Widyariset., 17(2): 193-203. https://doi.

org/10.14203/widyariset.17.2.2014.193-203

Wening, R.H., I.A. Rumanti and Y. Samaullah. 2018. Indeks seleksi galur padi rawa dengan pembobot daya hasil tinggi dan tahan penyakit hawar daun bakteri. Penelit. Pertan. Tanam. Pangan., 2(2): 67-75. https://doi.org/10.21082/jpptp.v2n2.2018.p67-75

Yuan, R., Y. Mao, D. Zhang, S. Wang, H. Zhang, M. Wu, M. Ye and Z. Zhang. 2024. The formation of rice tillers and factors influencing it. Agron., 14(2904): 1-15. https://doi.org/10.3390/agronomy14122904

Yuan, S., A.M. Stuart, A.G. Laborte, J.I.R. Edreira, A. Dobermann, L.V.N. Kien, L.T. Thuy, K. Paothong, P. Traesang, K.M. Tint, S.S. San, M.Q. Villafuerte, E.D. Quicho, A.R.P. Pame, R. Then, R.J. Flor, N. Thon, F. Agus, N. Agustiani, N. Deng, T. Li and P. Grassini. 2022. Southeast Asia must narrow down the yield gap to continue to be a major rice bowl. Nat. Food., 3(3): 217-226. https://doi.org/10.1186/s12870-025-07105-5

Yun, Y. 2023. Changes in the growth and yield of an extremely ultra-early-maturing rice variety according to transplanting density. Agric., 13(3): 717. https://doi.org/10.3390/agriculture13030717