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Agronomic Characteristics of Three Superior Varieties of Rice Plants (*Oryza sativa* L.) At Different Planting Distances in the System of Rice Intensification (SRI) Pattern System

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Abstract

The increasing population necessitates a corresponding rise in rice production each year, a condition significantly influenced by cultivation practices and the application of technology. This study aims to evaluate the agronomic characteristics of three superior rice varieties at different planting distances within the System of Rice Intensification (SRI) framework. The research will be conducted in Geulumpang Payong Village, Jeumpa District, Bireuen Regency, at an altitude of approximately 0 to 969 meters above sea level (masl) from August to November 2024. This study employed a split-plot design (RPT) experimental method within a randomized block design (RAK). Two factors were tested: varieties (Ciherang, Inpari 49, and Mustajab) and planting distances (25 cm x 25 cm as the control, 25 cm x 30 cm, 30 cm x 30 cm, and 35 cm x 35 cm). Consequently, 12 treatment combinations were established, with each treatment replicated three times, resulting in a total of 36 experimental units. Each plot contained four research plants, leading to a total of 144 plants. The data obtained from the research were statistically analyzed using the F-test with SAS V9.12 software. If the results of the analysis of variance indicated significant differences at the 5% level, the Duncan Multiple Range Test (DMRT) was conducted. The results suggested that the variety had a considerable influence on the parameters of plant height and the number of leaves. In contrast, leaf area, root length, and the number of tillers did not show significant effects. In terms of planting distance, the number of leaves and tillers was significantly affected, while plant height, leaf area, and root length did not exhibit significant changes. The interaction between the two factors had a substantial impact on the number of leaves, while plant height, leaf area, root length, and the number of tillers showed no significant effects. The Ciherang variety, combined with a planting distance of 30 cm x 30 cm, emerged as the most effective treatment, indicating it was the optimal condition in this study.

Keywords: Ciherang, Cultivation, Effective, Inpari 49, Technology

1. Introduction

Rice plants (Oryza sativa L.) serve as the primary food source for the Indonesian population, with the majority cultivated in paddy fields. Given its significance as a staple food, national rice production in 2024 is projected to reach 53.14 million tons of dry-milled grain (GKG). This point represents a decrease of 838.27 thousand tons, or 1.55%, compared to the rice production in 2023, which totaled 53.98 million tons of GKG. Rice must remain consistently available in Indonesia (Harjadi, 2019). The growing population necessitates an annual increase in rice production. Agricultural practices and the application of technology have a significant influence on this demand. The use of high-quality rice varieties is a fundamental component of Integrated Crop Management (ICM) in paddy fields, serving as a key strategy to enhance the productivity of rice farming operations. Superior rice varieties exhibit high yield potential and resistance to pests and diseases. Additionally, the adoption of these varieties can improve harvest quality and enhance the welfare of farmers ., 2018).

In 2018, the area of rice fields was 21,595 ha;

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however, by 2022, the area had decreased to 15,006 ha (BPN, 2022). To achieve the target of the National Rice Production Increase Program (P2BN), the government, specifically the Ministry of Agriculture through the Research and Development Agency, has issued numerous recommendations for farmers to apply. This study utilized three superior rice varieties: Ciherang, Inpari 49, and Mustajab. The Ciherang variety is a non-local rice variety released in 2000 with the pedigree number S3383-IdPn-41-3-1. Farmers argue that the use of the Ciherang variety is based on the fact that the weight of the grain is heavier, the rice is softer, and the rice seeds are easier to obtain on the market when the planting season arrives, although they are less resistant to pests and diseases. (Marlina et al ., 2017) . The Inpari 49 rice variety is a hybrid of Ciherang, known for its high yield, and IRBB50, which is resistant to bacterial leaf blight (BBL). Farmers have used Inpari 49 in several areas, including Pringsewu, and have shown an increase in its use every year. (Sari and Rahayu 2023). The Mustajab variety is the result of mutation breeding conducted on a local rice variety known as Jembar. It has a less-than-ideal plant structure, including overly spreading growth, which makes it easy to fall over, and curved leaves. To improve these characteristics, the National Nuclear Energy Agency (BATAN) conducted research using radiation mutation techniques with Cobalt-60 gamma rays at a dose of 0.2 kGy. The Mustajab variety was chosen for comparison because it has an optimal productivity level, with an average yield of 7.9 tons ha-1 and a potential yield of 10 tons ha-1 (Ramadhan et al., 2023).

There are several technologies in paddy cultivation, one of which is known as SRI (System of Rice Intensification) rice technology. The SRI cultivation technique in Indonesia was first used in the dry season of 1999, yielding 6.2 tons/ha-1, and in the rainy season of 1999/2000, it produced an average of 8.2 tons of rice.ha-1 (Uphoff, 2002). One of the characteristics of SRI rice planting is its vast planting distance. In the SRI method, the required planting distances are 30 cm x 30 cm and 50 cm x 50 cm. In contrast, the conventional method recommends a planting distance of 20 cm x 20 cm to 25 cm x 25 cm. In practice, some farmers plant rice at a planting distance of 15 cm x 15 cm (2011). The vast planting distance in the SRI method allows plants to produce a large number of tillers. At a planting distance of 50 cm x 50 cm, rice plants can produce 50-80 tillers per clump (Tani, 2011). On the other hand, narrow planting distances force plants to produce only a few shoots. At very narrow planting distances, even a single plant produces only 4 to 5 shoots. At a planting distance of 25 cm x 25 cm, one clump only produces 4-5 plants. According to Salahuddin et al. (2009), planting distance also affects panicle length, the number of grains per panicle, and yield per hectare of rice plants.

Although wider spacing can increase the number of rice tillers, spacing that is too wide also has the potential to be wasteful. Many parts of the land become unused by plants, especially when they lack sufficient tillers, resulting in a lot of space. This large amount of unused space ultimately results in a decrease in rice yield per unit area of land. In other words, land productivity becomes low. (Hikmawati, 2019) .

Planting distance is also influenced by varieties that differ in their ability to produce tillers. Certain varieties have a high number of tillers, while others have very few. Some varieties that farmers widely plant are classified as having many tillers, such as the Pandan Wangi variety. On the other hand, several varieties in circulation are classified as having few or moderate tillers, such as the Ciherang variety. Therefore, there is no ideal planting distance for all varieties. However, each variety has its ideal planting distance (Hatta, 2011). The proper planting distance not only produces maximum growth and a higher number of shoots but also yields the best results. According to Alim et al. (2017), an optimum planting distance will provide good growth of the upper part of the plant, allowing it to utilize more sunlight, and good growth of the lower part of the plant, enabling it to utilize more nutrients. On the other hand, planting distances that are too close will result in very intense competition between plants for sunlight, water, and nutrients. As a result, plant growth is hampered and crop yields are low. Optimization of the use of land area units can also be obtained by adjusting the type of planting distance. Asri (2016) in his research showed that the Ciherang variety and a planting distance of 30 x 30 cm showed quite good results for rice growth and production.

The advantage of the SRI system is its higher productivity compared to rice cultivation using conventional systems. Based on the experiment's results, it was demonstrated that SRI rice productivity ranged from 10.5 to 16.0 tons ha-1 in China, Madagascar, and the Philippines. (Hui and Jun, 2003) . These results are certainly auspicious compared to conventional systems, which typically yield an average of only 4.5 tons per hectare. Rahimi et al. (2012) in their research demonstrated that the SRI method can increase the number of panicles per clump, accelerate harvesting, and enhance milled grain production per square meter. This study aims to determine the agronomic characteristics of three superior rice varieties at varying planting distances in the SRI pattern system.

2. Material and Methods

This research will be conducted in the village of Geulumpang Payong, Jeumpa District, Bireuen Regency, located at an altitude of approximately 969 meters above sea level (masl). Physiological analysis was conducted at the Laboratory of the Faculty of Agriculture, Malikussaleh University, located at coordinates 4°55′00″N 97°00′00″E/4.9167 °N 97°. This research was conducted from August to November 2024. The plant materials used in this study were rice seeds of the Ciherang, Mustajab, and

Inpari 49 varieties, manure, Phonska + Urea compound fertilizer (300 kg/ha + Urea 20 kg/ha), Dithan M 45, Curater 2G and antracol fungicide. The tools used include meters, watering cans, digital scales, chlorophyll speedometers, labels, nameplates, ovens, and all other tools necessary for the research.

This study employed a split-plot design (RPT) experimental method within a randomized block design (RAK). There were two factors tested, namely varieties (Ciherang, Inpari 49, and Mustajab) and planting distance (25 cm x 25 cm (control), 25 cm x 30 cm, 30 cm x 30 cm, and 35 cm x 35 cm). Thus, 12 treatment combinations were obtained, and each treatment was repeated 3 times, resulting in 36 experimental units. Then, each plot consisted of four research plants, resulting in a total of 144 plants. The data obtained from the research results were analyzed statistically using the F-test in SAS V9.12 and Excel software. If the results obtained in the analysis of variance were significantly different at the 5% level, a further Duncan Multiple Range Test (DMRT) was carried out. The research flow diagram is presented in Figure 1 below.

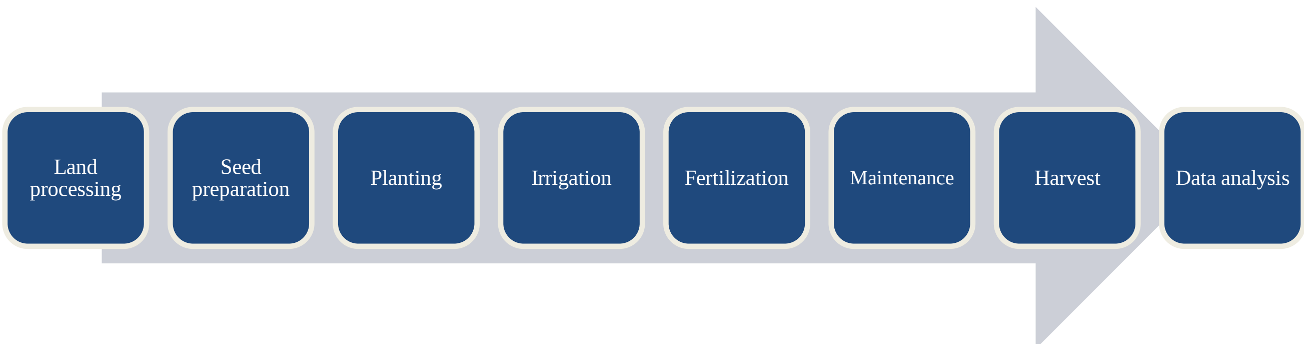

Figure 1. Research flow diagram

3. Results and Discussion

3.1. Plant Height (cm)

The results of the analysis of variance showed that the variety of treatments had a significant effect. In contrast, the planting distance and its interaction with the other factors had no significant impact on the height of the rice plant. The average plant height (cm) of three superior rice varieties at different planting distances in the SRI pattern system is presented in Table 1.

Table 1. Average Plant Height (cm) of Three Superior Varieties of Rice Plants (Oryza sativa L.) At Different Planting Distances in the SRI Pattern System

Varieties	Planting Distance				Average
	25 cm x 25 cm	25 cm x 30 cm	30cm x 30cm	35cm x 35cm	
Ciherang	125.00 ± 1.73	124.67 ± 10.73	120.67 ± 3.38	120.00 ± 4.04	122.58 ± 1.31 b
Inpari 49	115.33 ± 2.73	126.00 ± 8.72	127.67 ± 1.20	120.67 ± 3.48	122.42 ± 2.79 b
Efficacious	136.00 ± 3.00	139.67 ± 0.33	147.33 ± 5.24	140.00 ± 0.58	140.75 ± 2.37 a
Average	125.44 ± 5.97 a	130.11 ± 4.79 a	131.89 ± 7.98 a	126.89 ± 6.56 a	

Description: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test. The study was repeated 3 times.

Based on Table 1, it is evident that the highest rice plant height is achieved by the Mustajab Variety at 140.75 cm, followed by the Ciherang Variety at 122.58 cm, and the lowest is recorded in the Inpari 49 Variety at 122.42 cm. This result is due to the Mustajab Variety having the genetic potential for increased plant height growth, as evident from the study results. The Mustajab Variety has a better plant height compared to other varieties. Based on the study's results, Rahayu (2017) stated that the plant height of the Inpari 49 Variety is lower than that of varieties such as Ciherang, Cibogo, and Inpari 33.

Table 1 shows that the highest rice plant height in the treatment of 30 cm x 30 cm planting distance is 131.89 cm, followed by 25 cm x 30 cm planting distance is 130.11 cm, then 35 cm x 35 cm planting distance is 126.89 cm, and the lowest is 25 cm x 25 cm planting distance is 125.44 cm. This result is due to the wider planting distance providing more growing space for plants, which in turn results in lower competition between plants for light, water, and nutrients. With the availability of more optimal resources, plants can grow taller when planted at closer distances. In line with Christanto et al. (2014), vast or loose planting distances in rice plants provide greater space and availability of growth factors above and below the ground, as competition for these factors becomes smaller, even though land use efficiency is also reduced. At the appropriate planting distance, rice plants can experience increased growth and productivity, which can further minimize seed use (Muyassir, 2012).

3.2. Number of Leaves (Shells)

The results of the analysis of variance showed that varieties, planting distance, and the interaction between the two significantly affected the number of leaves on rice plants. The average number of leaves (strands) of three superior rice varieties at different planting distances in the SRI pattern system is presented in Table 2.

Table 2. Average Number of Leaves (Sheets) of Three Superior Varieties of Rice Plants (Oryza sativa L.) At Different Planting Distances in the SRI Pattern System

Varieties	Planting Distance				Average
	25 cm x 25 cm	25 cm x 30 cm	30cm x 30cm	35cm x 35cm	
Ciherang	128.00 ± 2.31	125.00 ± 2.08	120.00 ± 1.15	126.33 ± 1.20	124.83 ± 1.72 a
Inpari 49	124.00 ± 1.53	106.33 ± 2.40	123.00 ± 2.08	104.00 ± 2.08	114.33 ± 5.32 b
Efficacious	123.00 ± 2.08	104.00 ± 1.15	112.67 ± 1.86	104.00 ± 1.15	113.50 ± 5.48 c
Average	125.00 ± 1.53 a	111.78 ± 6.65 c	118.56 ± 3.07 b	111.44 ± 7.44 c	

Description: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test. The study was repeated 3 times.

Based on Table 2, it is evident that the highest number of rice plant leaves is found in the Ciherang Variety, at 124.83 strands, followed by the Inpari 49 Variety, at 114.33 strands, and the lowest is in the Mustajab Variety, at 113.50 strands. It is suspected that the difference in the number of leaves between varieties is influenced by genetic factors that control plant growth and development. The Ciherang variety, which exhibits the highest number of leaves, has more active gene expression in stimulating leaf formation compared to the Mustajab variety. The number of leaves on each plant depends on the array, and leaf characteristics are one of the morphological characteristics closely related to plant productivity (Donggulo et al., 2017).

Table 2 shows that the highest number of leaves of rice plants at a planting distance of 25 cm x 25 cm is 125.00 strands, followed by a planting distance of 30 cm x 30 cm of 118.56 strands, then a planting distance of 25 cm x 30 cm of 111.78 strands and the lowest at a planting distance of 35 cm x 35 cm of 111.44 strands. This result is due to a more optimal growing space, allowing plants to have sufficient access to resources such as light, water, and nutrients. Light is a significant factor in the process of photosynthesis, where increasing light intensity can increase photosynthetic activity and plant biomass production (Taiz & Zeiger, 2015). At a denser planting distance, the plant canopy closes more quickly, resulting in higher light competition between plants. This condition can inhibit leaf growth because plants that lack light will experience etiolation or stem elongation to find light, which ultimately reduces the energy allocated to the formation of new leaves (Salisbury & Ross, 1992).

3.3. Leaf Area (cm)

The results of the analysis of variance showed that varieties, planting distances and the interaction of both did not significantly affect the leaf area of rice plants. The average leaf area (cm) of three superior rice plant varieties at different planting distances in the SRI pattern system is presented in Table 3.

Table 3. Average Leaf Area (cm) of Three Superior Rice Plant Varieties (Oryza sativa L.) At Different Planting Distances in the SRI Pattern System

Varieties	Planting Distance				Average
	25 cm x 25 cm	25 cm x 30 cm	30cm x 30cm	35cm x 35cm	
Ciherang	27.00 ± 1.15	28.67 ± 2.85	28.00 ± 1.00	26.67 ± 0.88	27.58 ± 0.46 a
Inpari 49	29.67 ± 1.20	24.67 ± 2.73	29.33 ± 2.73	18.33 ± 4.26	25.50 ± 2.65 a
Efficacious	25.67 ± 1.45	27.33 ± 2.03	26.33 ± 1.45	29.33 ± 0.67	27.17 ± 0.80 a
Average	27.45 ± 1.18 a	26.89 ± 1.18 a	27.89 ± 0.87 a	24.78 ± 3.31 a	

Description: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test. The study was repeated 3 times.

Table 3 shows that the highest leaf area of rice plants is found in the Ciherang variety, at 27.58 cm, followed by the Mustajab variety, at 27.17 cm, and the lowest in the Inpari 49 variety, at 25.50 cm. This result is due to environmental conditions, such as the availability of water and nutrients in the soil, which may also affect leaf development. Optimal ecological conditions greatly support the growth of rice plants, including the availability of water and light. The availability of water for rice plants, such as during drought stress, can affect the leaf area of the plants. However, the response to this stress is also influenced by genetic factors of the variety. Hendrati (2016) notes that plants experiencing water shortages tend to have smaller sizes compared to plants that grow normally. In addition to water environmental conditions, light can also affect the area of plant leaves. According to Buntoro (2014), high light intensity can cause smaller thylakoids to aggregate in leaf cells, resulting in reduced chlorophyll and smaller leaf sizes.

Table 3 shows that the highest leaf area of rice plants is at a planting distance of 30 cm x 30 cm of 27.89 cm, followed by a planting distance of 25 cm x 25 cm of 27.45 cm, then a planting distance of 25 cm x 30 cm of 26.89 cm and the lowest at a planting distance of 35 cm x 35 cm of

24.78 cm. It is suspected that the narrower the planting distance, the more it will inhibit the development of leaf area. This result is because the wide distance between plants provides enough space for the plants to grow, and the leaves between plants do not overlap, allowing for the capture of sunlight by the leaves. The results are also supported by Yulisma's (2011) statement that increasing the planting distance can increase the total leaf area, which is in line with the increasing age of the plant, as the leaf area also increases. Research by Kurniasih et al. (2008) indicates that planting rice at a distance of 30 cm x 30 cm can produce the highest leaf area, namely 3309.30 cm², which is significantly different from the leaf area produced by planting at a distance of 20 cm x 20 cm, which is 2230.10 cm².

3.4. Root Length (cm)

Based on the results of the analysis of variance, it is shown that the variety, planting distance, and the interaction of both do not have a significant effect on the root length (cm) of rice plants. The average root length (cm) of three superior rice plant varieties at different planting distances in the SRI pattern system is presented in Table 4.

Table 4. Average Root Length (cm) of Three Superior Rice Plant Varieties (Oryza sativa L.) At Different Planting Distances in the SRI Pattern System

Varieties	Planting Distance				Average
	25 cm x 25 cm	25 cm x 30 cm	30cm x 30cm	35cm x 35cm	
Ciherang	27.00 ± 1.15	28.67 ± 2.85	28.00 ± 1.00	26.67 ± 0.88	27.58 ± 0.46 a
Inpari 49	29.67 ± 1.20	24.67 ± 2.73	29.33 ± 2.73	18.33 ± 4.26	25.50 ± 2.65 a
Efficacious	25.67 ± 1.45	27.33 ± 2.03	26.33 ± 1.45	29.33 ± 0.67	27.17 ± 0.80 a
Average	27.45 ± 1.18 a	26.89 ± 1.18 a	27.89 ± 0.87 a	24.78 ± 3.31 a	

Description: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test. The study was repeated 3 times.

Table 4 shows that the highest root length of rice plants is found in the Ciherang variety at 27.58 cm, followed by the Mustajab variety at 27.17 cm, and the lowest in the Inpari 49 variety at 25.50 cm. The difference in root length is most likely influenced by the genetic factors of each array that control the development of the root system. According to Uga et al . (2013), the characteristics of the plant root system are greatly influenced by the expression of genes that regulate root growth, such as the DEEPER ROOTING 1 (DRO1) gene, which plays a role in increasing root penetration into the soil to increase the efficiency of water and nutrient absorption.

Table 4 shows that the highest root length of rice plants is at a planting distance of 30 cm x 30 cm of 27.89 cm, followed by a planting distance of 25 cm x 25 cm of 27.45 cm, then a planting distance of 25 cm x 30 cm of 26.89 cm and the lowest at a planting distance of 35 cm x 35 cm of 24.78 cm. This result shows that although variations in planting distance do not provide significant differences, the availability of optimal space can support better root growth. According to Wissuwa et al. (2020), an optimal planting distance allows plant roots to develop more efficiently because competition between plants for water and nutrients becomes more balanced. Plants with greater space availability may experience decreased stimulation in root exploration due to the absence of competition from other plants (Gowda et al., 2019). Conversely, planting distances that are too close can also limit root development due to high competition between plants for nutrients and water. Therefore, balancing planting distances is crucial in supporting an optimal root system.

3.5. Number of Offspring (Children)

Analysis of variance revealed that planting distance had a significant effect on the number of tillers. In contrast, the variety and interaction between the two did not have a significant impact on the number of tillers of rice plants. The average number of tillers (children) of three superior rice varieties at different planting distances in the SRI pattern system is presented in Table 5.

Table 5. Average Number of Tillers (Sub-Tillers) of Three Superior Varieties of Rice Plants (Oryza sativa L.) At Different Planting Distances in the SRI Pattern System

Varieties	Planting Distance				Average
	25 cm x 25 cm	25 cm x 30 cm	30cm x 30cm	35cm x 35cm	
Ciherang	32.33 ± 6.44	18.00 ± 2.08	25.00 ± 2.00	31.00 ± 6.35	26.58 ± 3.28 a
Inpari 49	30.00 ± 4.58	14.00 ± 2.65	29.33 ± 8.09	27.00 ± 5.86	25.08 ± 3.75 a
Efficacious	17.67 ± 3.48	13.67 ± 2.40	22.67 ± 6.17	32.33 ± 3.76	21.58 ± 4.03 a
Average	26.67 ± 4.55 a	15.22 ± 1.39 b	25.67 ± 1.95 a	30.11 ± 1.60 a	

Description: Numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test. The study was repeated 3 times.

Table 5 shows that the highest number of tillers in rice plants is found in the Ciherang variety, with 26.58 tillers, followed by the Inpari 49 variety with 25.08 tillers, and the lowest in the Mustajab variety with 21.58 tillers. This result suggests that the Ciherang variety has a higher ability to form tillers compared to the Mustajab variety, especially during the early growth phase until the approach to the generative phase. This result is most likely influenced by the genetic factors of the Ciherang variety, which is known to have high tiller potential. This finding aligns with Misran (2014), who stated that the response of plants, particularly the maximum number of tillers and productive tillers, to the lowland rice planting system, is influenced by the genetic characteristics of the plant. Husana (2010) suggests that the number of tillers will be maximized if the plant has good genetic characteristics coupled with favorable environmental conditions that support plant growth and development. According to Cepy and Wayan (2011), the high and low growth and yield of plants are influenced by two factors: internal factors, including genetic or hereditary traits of plants, and external factors such as environmental factors, soil climate, and biotic factors. The difference in the number of tillers between cultivars is thought to be due to the influence of these factors. This result aligns with the findings of Aryana's (2009) research, which suggests that the number of tillers and plant heights differ because each variety possesses distinct genetic traits. Research by Ramli et al. (2012) indicates that the number of tillers decreased in each clump of the Ciherang Variety due to physiological death.

As illustrated in Table 5, the maximum number of rice plants was observed at a planting distance of 35 cm x 35 cm, yielding 30.11 tillers. This point was followed by a planting distance of 25 cm x 25 cm, which yielded 26.67 tillers, and then a planting distance of 30 cm x 30 cm, yielding 25.67 tillers. The lowest number of tillers was recorded at a planting distance of 25 cm x 30 cm, yielding 15.22 tillers. It is hypothesized that a planting distance of 35 centimeters by 35 centimeters will provide sufficient space for each plant to produce tillers, thereby mitigating competition among clumps. This finding aligns with the observations reported by Hartanti & Jayantika (2017), who found that a planting distance of 35 centimeters by 35 centimeters yielded optimal results in terms of the number of productive tillers exhibited by rice plants of the IR64 variety. The quantity of tillers is contingent upon the planting distance, as this parameter dictates the solar radiation, mineral nutrients, and the cultivation of the plant itself. This finding aligns with the conclusions of Hasrizal (2010), who determined that the planting distance significantly influences the number of productive tillers.

4. Conclusion

The study's findings indicated that the optimal treatment for the parameters of leaf area (27.58 cm), root length (27.58 cm), and number of tillers (26.58 tillers) was observed in the Ciherang variety. Conversely, at a planting distance of 30 cm x 30 cm, the most effective treatment was observed for the parameters of plant height (131.89 cm), leaf area (27.89), and root length (27.89 cm).

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