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Growth Responses of Superior Varieties of Rice in South Coast of Kebumen Regency

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ABSTRACT

The rice plant (*Oryza sativa* L.) is a staple food source for most people in Indonesia, including those in Kebumen Regency; hence, any decline in rice productivity will impact national food security. A research was carried out to evaluate the growth responses of nine rice varieties under marginal coastal lands in Kebumen Regency. The varieties tested were Inpari 34 Salin Agritan, Inpari 35 Salin Agritan, Inpari Unsoed 79 Agritan, Inpari 47 WBC, IPB 12S, IPB13S, TP-Padi 1, TP-Padi 2, Ciherang, Cilamaya Muncul. Each variety was planted using a square planting system at a distance of 25cm × 25cm, with a plot size of 4m × 5m. Plant growth variables were plant height, number of tillers, root length, root dry weight, shoot dry weight, root/shoot ratio, 50% flowering age and plant lifespan. Paddy varieties grown in South Kebumen coastal area significantly showed different response in plant height, number of tillers, shoot dry weight, 50% flowering age, and plant lifespan. The varieties of IPB 12S, Inpari 47 WBC, and Inpari 34 Salin Agritan have higher growth and flowering performance in coastal area that might be have potential to the tolerance to salinity and drought stresses.

INTRODUCTION

The rice plant (*Oryza sativa* L.) serves as a staple food for the majority of Indonesia people who depend heavily on rice as their staple food. This will be a problem if the supply of rice cannot meet the basic needs of the community. Kebumen Regency in Central Java Province is one of the primary agricultural regions where rice is cultivated. However, rice production in Kebumen Regency has experienced seasonal declines, particularly during prolonged dry seasons when agricultural land faces drought stress. Additionally, much of the agricultural land in Kebumen Regency is located along the Southern Coast of Java, which further exacerbates productivity challenges.

Surorejan Village is a coastal village in Kebumen Regency where rice cultivation frequently encounters abiotic and biotic stresses, particularly salinity and drought stress. These stresses disrupt plant morphology and physiology, reducing rice growth and yield. The combination of salinity and drought stress leads to reduced seed production and impaired plant development.

The population of Kebumen Regency increased from 1,362,757 (2021) to 1,397,555 (2023) (BPS, 2024a). The harvested area also

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increased from 74,646 ha (2021) to 75,547 ha (2023). However, rice production decreased from 425,285 tons (2022) to 404,318 tons (2023). Rice productivity also decreased from 5.64 tons.ha^{-1} (2022) to 5.35 tons.ha^{-1} (2023). This decline is inversely proportional to the rising population and expanded harvested area, highlighting significant challenges in meeting the community's rice needs (BPS. 2024b).

The decline in rice production and productivity in Kebumen Regency is caused by various factors, such as the reduction of agricultural land and environmental stress. The reduction of agricultural land results from its conversion into buildings, such as houses, educational institutions, and industries. The increasing population each year (BPS, 2023a) exacerbates this trend, as more agricultural land is converted into housing for the community. Land conversion impacts food production by decreasing it, thereby increasing reliance on food imports. The conversion of agricultural land to non-agricultural use poses a significant threat to food security, directly affecting the broader community (Prabowo et al., 2020).

For this reason, agricultural extensification or the expansion of agricultural land in Kebumen Regency is necessary to support increased rice production. Extensification efforts for rice cultivation can focus on sub-optimal lands, such as saline land, forest land, grassland, peatland, or other marginalized areas (Barus and Rauf, 2020). Marginal land typically has low plant quality and productivity due to poor nutrient content. In Kebumen Regency, one approach to agricultural extensification involves utilizing marginal coastal land.

Rice cultivation on marginal coastal land faces abiotic stress, such as salinity caused by the upward movement of salt from the subsoil to the soil surface. Generally, rice plants are sensitive to salinity (Masganti et al., 2023). However, rice is among the cereal crops recommended for saline land cultivation. In addition to salinity stress, rice plants experience drought stress during the dry season. Drought stress disrupts plant physiology and increases soil salinity, further exacerbating salinity stress. These combined stresses can poison rice plants, disrupt growth, and reduce seed yields. If the stress levels exceed the plant's tolerance, they may cause severe damage or even plant death.

In Kebumen Regency, salinity stress is a significant challenge for many farmers along the Southern Coast. Salinity stress in this region stunts rice plant growth and reduces productivity (Rahayu et al., 2020). During the dry season, drought stress compounds the issue, subjecting rice plants to dual stresses. Water shortages trigger biological stress, disrupting physiological processes and functional activities in plants (Mudhor et al., 2022). The combined impact of salinity and drought stresses contributes to declining rice production in Kebumen Regency. Another challenge is the limited knowledge and information farmers possess regarding high-yielding rice varieties resistant to salinity stress. Farmers in Kebumen Regency predominantly grow the same variety, particularly Ciherang, year after year.

To address these problems, solutions are needed to enhance the productivity of rice plants on saline land. These solutions include implementing technological innovations involving new superior rice varieties resistant to salinity. Such varieties are developed by cultivating rice plants in areas affected by salinity stress. This study was conducted to examine the response of superior rice varieties in the specific environment of the Southern Coast of Surorejan Village, Puring District, Kebumen Regency.

MATERIALS AND METHOD

This research was conducted in the specific environment of the Southern Coast of Surorejan Village, Puring District, Kebumen Regency in June-October 2024. Nine rice varieties tested in this study, i.e., Inpari 34 Salin Agritan, Inpari 35 Salin Agritan, Inpari Unsoed 79 Agritan, Inpari 47 WBC, IPB 12S, IPB13S, TP-Padi 1, TP-Padi 2, Ciherang, Cilamaya Muncul. The experiment was designed in a randomized complete block design (RCBD). Each variety was planted in field with 4 replications.

Soil samples were collected at a depth of approximately 20 cm from the top layer for analyzing soil salinity, soil pH, carbon-to-nitrogen ratio (C/N), and NPK content at Soil Laboratory of Jenderal Soedirman University. At the same time, rice seeds were sown using the dry seedbed method, where the seeds were spread evenly on seedbed 21 days before planting. Meanwhile, the planting land was prepared by hoeing or plowing using tractors to loosen the soil and remove remnants of previous plants and weeds. Planting was conducted using a square planting system with a spacing of 25 cm x 25 cm and a plot size of 4 m × 5 m.

Plant maintenance in rice cultivation was conducted to maximize growth. These activities included replanting around 5-7 days after planting (DAP). Irrigation was carried out during the vegetative phase, tillering, flowering, and filling of rice grains. Rice plants were fertilized twice: basic fertilization and subsequent fertilization. Basic fertilization involved applying compost or organic fertilizer before planting. Subsequent fertilization was administered when the plants were 7-14 DAP and during critical growth phases such as tillering and flowering. Pest control was done chemically using pesticides. Additionally, mechanical weeding was conducted at 21 DAP and 42 DAP to reduce competition for nutrients, water, and liquid detergent.

The variables observed in this study included plant height (cm), number of tillers, root length (cm), root dry weight (g), shoot dry weight (g), root-to-shoot ratio (g), age at 50% flowering (days after seeding - DAS), and plant lifespan (DAS). Plant height was measured from the base of the stem to the tip of the highest leaf when the plant was 8 weeks after transplanting (WAT). The number of tillers was recorded by counting the tillers at 8 WAT. Root length, root dry weight, shoot dry weight, and root-to-shoot ratio were determined using the destructive method, which involved removing all parts of the plant at 8 WAT. Root length was measured using a ruler, while roots and shoots were separated, dried in the sun, and then placed in an oven for 30 minutes. The dried samples were weighed using a digital scale, and the results were used to calculate the root-to-shoot ratio. The age at 50% flowering was observed every 3 days after the plot began flowering. The age of dead plants was recorded every 3 days if plants in a plot died.

The data obtained were analyzed using SPSS (Statistical Package for the Social Sciences) with ANOVA. The mean comparison was conducted by DMRT at α= 5% to determine the best-performing varieties.

RESULTS AND DISCUSSION

The coastal land in the south of Surorejan Village, Puring District, Kebumen Regency, is one of the marginal lands with the potential to be used for rice farming. However, under certain conditions, the salt content in the soil becomes very high, resulting in salinity stress. Salinity stress in rice planting in coastal areas can also increase during high tides. Global climate change has caused sea levels to rise, leading to increased seawater intrusion into land (Hairmansis, 2020). In addition to salinity stress, plants experience drought stress during the dry season. Drought stress affects the growth and development of rice plants, ultimately reducing rice productivity. Water shortage conditions trigger biological stress, disrupting physiological processes and functional activities in organisms (Mudhor et al., 2022).

The content of organic C in the soil affects its quality; higher organic C content indicates better soil quality. The soil sample test results showed very low organic C content (1.05%) (Table 1). Low levels of organic C reduce soil fertility and water retention capacity and affect the movement of soil organisms (Malesi et al., 2023).

The soil in this experiment also had low levels of N, P, and K-total elements, disrupting plant growth. Deficient N inhibits vegetative growth, P affects root development and flowering, and K deficiency affects grain formation and plant resistance to disease. Adequate and balanced N, P, and K nutrients are crucial for the growth and development of rice plants (Batubara et al., 2024).

In Table 1, soil pH was 6.55, while the Fe content was very high, and organic matter

Table 1. Test results of soil samples of the Southern Coast of Surorejan Village, Puring District, Kebumen Regency

Parameter	Unit	Test result	Method
C-organic	%	1.05	Spectrophotometry
N-total	%	0.09	Kjeldahl
P-total	P_2O_5 %	0.24	Spectrophotometry
K-total	K_2O %	0.06	AAS
Fe total	Ppm	2670.83	AAS
pH H_2O (1:2,5)	-	6.55	C
C/N ratio	-	12.05	Caculation
Organic Materials	%	1.82	Calculation
Electrical Conductivity	mmhos/cm	1.022	V

Source: The results of soil analysis conducted at the Soil Laboratory of Jenderal Soedirman University

content was low. High Fe levels cause toxicity in rice plants, and low organic matter affects the soil ability to maintain its components. Organic matter in soil provides energy for microorganisms to grow and reproduce. The salinity content was within a safe range (1.022 mmhos/cm, Table 1); however, during drought conditions, salinity levels may increase. This can occur naturally in dry and semi-arid areas or be induced by human activities such as irrigation, fertilizer application, and soil management (Muhammad et al., 2024).

There was a significant effect on plant height, number of tillers, shoot dry weight, and 50% flowering age. Root length, root dry weight, and the root-to-shoot ratio did not show significant differences (Table 2).

Plant Height

Nine superior rice varieties planted in the specific environment of the Southern Coast of Surorejan Village, Puring District, Kebumen Regency, exhibited different plant heights. The IPB 12S variety had the highest plant height (62.9 cm), which was not significantly different from IPB 13S (61.8 cm), Inpari 47 WBC (58.4 cm), Inpari 34 Salin Agritan (50.4 cm), Ciherang (49.2 cm), and Inpari 35 Salin Agritan (49.1 cm). TP-Padi 1 had the shortest plant height (21.4 cm) (Table 3).

Plant height increase is an indicator of growth, showing cell division and enlargement. Growth is influenced by plant variety and environmental suitability. The significant differences suggest that each variety has unique mechanisms for coping with salinity stress. Saline soil affects growth through increased ion concentration and Na+ accumulation, which raises osmotic pressure and inhibits water absorption. Na+ accumulation causes cell and tissue damage. High soil salinity reduces osmotic potential and the plant's ability to absorb water (Gerona et al., 2019).

Although the land used had salinity levels within safe limits, salinity increased due to climate change. Climate-induced drought exacerbates salinity levels, contributing to the salinization process (Karolinoerita and Annisa, 2020). Rice plants respond to drought stress by rolling their leaves and closing stomata to reduce transpiration. Drought stress negatively impacts rice plant morphology, biomass, crop yields, roots, and grain development (Bhandari et al., 2023). Water is critical for rice growth and production, making drought stress a major limiting factor.

Number of Tillers

Rice varieties demonstrated different numbers of tillers in the specific environment of the Southern Coast of Surorejan Village. Inpari 47 WBC had the highest number of tillers (8.9), followed by Inpari 35 Salin Agritan (8.1), IPB 12S (7.4), Ciherang (7), Inpari 34 Salin Agritan (6.2), TP-Padi 2 (5.4), IPB 13S (4.6), and Cilamaya Muncul (4.1). TP -Padi 1 had the least number of tillers (1.9) (Table 3).

Table 2. Summary of analysis of variance on 9 varieties of rice plants at the Southern Coast of Surorejan Village, Puring District, Kebumen Regency

Variables	F Value	Proba-bility
Plant height	6.91	0.00**
Number of tillers	1.97	0.01*
Root length	1.37	0.26
Root dry weight	1.03	0.45
Shoot dry weight	2.90	0.02*
Root or shoot ratio	0.88	0.55
Age of flowering	2.76	0.02*
Age of plant Dead	4.59	0.002**

Note: **=significant different at 1% error level; *=significantly different at 5% error level

The significant differences in the number of tillers are attributed to genetic factors. Good genetics promote optimal tiller production. Environmental stress from salinity and drought reduces tiller numbers in intolerant varieties. High salinity inhibits water and nutrient absorption, affecting metabolism and overall growth (Tse et al., 2022). Drought and salinity stress reduce water availability, limiting nutrient uptake. Water availability significantly affects plant growth and morphological changes, leading to reduced growth rates (Fadhilah et al., 2021).

Shoot Dry Weight

Differences in rice varieties affected shoot dry weight in the Southern Coast of Surorejan Village. IPB 12S had the heaviest shoot dry weight, while TP-Padi 1 had the lowest (Table 3). Shoot dry weight depends on nutrient availability and root absorption capacity. Limited absorption inhibits vegetative growth, reducing dry weight. Photosynthesis, which produces assimilates, is affected by suboptimal conditions. High salinity reduces biomass production by limiting water and mineral absorption (Gian et al., 2021). Stomatal closure under salinity stress reduces photosynthesis, lowering assimilate production and shoot dry weight.

Age at 50% Flowering

Rice varieties differed in their 50% flowering age. Inpari 34 Salin Agritan and Inpari 35 Salin Agritan had the shortest flowering age (99.75 DAS), followed by IPB 12S (101.25 DAS), IPB 13S (105.25 DAS), and TP-Padi 1 (108 DAS). TP-Padi 2 and Cilamaya Muncul had the longest flowering age (108 DAS) (Table 3).

The flowering age is determined by genetic and environmental factors. Salinity and drought stress delay flowering by inhibiting nutrient absorption and water availability. Drought during the flowering phase increases the percentage of empty grains, lowering yield (Ariyadi et al., 2022).

Age of Plant Death

The age of plant death varied across rice varieties. Inpari 34 Salin Agritan had the longest lifespan (105.50 DAS), followed by Inpari 47 WBC (103.75 DAS), IPB 12S (99.75 DAS), TP-Padi 2 (99.75 DAS), IPB 13S (97.50 DAS), Inpari 35 Salin Agritan (95 DAS), Cilamaya Muncul (94.75 DAS), and Ciherang (92.25 DAS). TP-Padi 1 had the shortest lifespan (46 DAS) (Table 3).

Genetic differences influence adaptability and lifespan. Salinity stress inhibits growth from germination to the vegetative phase, while drought stress disrupts metabolism, affecting physiology and morphology. High Fe levels in the soil cause toxicity, damaging plant cells. Fe poisoning disrupts nutrient absorption by limiting root development due to iron oxide accumulation on roots (Tiara et al., 2019).

CONCLUSION

Rice varieties significantly influenced plant growth under salinity and drought stress. The IPB 12S variety demonstrated superior performance with higher plant height and the heaviest shoot dry weight. The Inpari 47 WBC variety excelled in producing the highest number of tillers. Inpari 34 Salin Agritan showed the best performance in terms of 50% flowering age and plant death age. Based on the study results, the best-performing varieties were IPB 12S, Inpari 47 WBC, and Inpari 34 Salin Agritan.

Table 3. Results of further tests on 9 varieties of rice plants along the Southern Coast of Surorejan Village, Puring District, Kebumen Regency

Variety	Plant height (cm)	Number of tillers	Weight dry shoot (g)	Age of flowering (days)	Age of dead plants (days)
Inpari 34 Salin Agritan	50.4 bcd	6.2 ab	2.8 a	99.8 a	105.5 b
Inpari 35 Salin Agritan	49.1 bcd	8.1 b	3.4 a	99.8 a	95.0 b
Inpari 47 WBC	58.4 cd	8.9 b	3.3 a	107.0 b	103.8 b
IPB 12S	62.9 d	7.4 b	9.0 b	101.3 ab	99.8 b
IPB 13S	61.8 d	4.6 ab	3.8 a	105.3 ab	97.5 b
TP-Padi 1	21.4 a	1.9 a	0.6 a	106.3 ab	46.0 a
TP-Padi 2	44.5 bc	5.4 ab	1.5 a	108.0 b	99.8 b
Ciherang	49.2 bcd	7.0 ab	3.8 a	107.0 b	92.3 b
Cilamaya Muncul	37.1 b	4.1 ab	1.8 a	108.0 b	94.8 b

Note: Numbers followed by the same letter in the same column are not significantly different according to DMRT at α=5%

The implementation of research findings on rice cultivation requires a comprehensive breeding strategy, including the development of climate-resistant rice varieties, selection of superior seeds, adoption of modern technology, and effective land-water management. Additionally, agricultural extension services are essential, including farmer training, technology dissemination, consultation, and agricultural demonstrations.

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