 https://doi.org/10.1051/e3sconf/202236104002

Growth and yield response of rice based on different planting distances in rainfed field

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Abstract. Planting distance is one of the important aspects in cultivation management. The study aimed to determine the response of rice plants at various planting distance based on the components of growth and yield. It was conducted in a rainfed rice field covering an area of approximately 1 ha during the Second Planting Season in Pemalang Regency used a Randomized Block Design (RBD) using planting distances as a single factor, which consisted of Jajar legowo 2: 1/40 (12.5 cm x 25 cm x 40 cm); 2: 1/50 (15 cm x 25 cm x 50 cm) and conventional planting distance/Tegel spacing system (20 cm x 20 cm), repeated five times. The observed variables include growth and yield components. Data were analyzed by means of variance (Anova) followed by the Least Significant Difference (LSD) test. The results of the study showed that the Jajar legowo 2: 1/40 planting system was observed to be able to produce the highest number of tillers, even though the Jajar legowo 2: 1/50 resulted in the highest plant height, number of full grains, and produced the highest HDG of 5,619 tons ha^{-1} compared to other planting distances.

1 Introduction

Rice productivity in Rainfed Fields (RF) has been inadequate due to a lack of water for plant growth throughout the dry season. Rainfed fields depend on rainfall for irrigation, which contribute to lower rice cultivation index. Rainfed fields, as according [1], is sub-optimal or less productive land. Intensification through improved rice cultivation technique is one of the strategies to enhance lowland rice production. According to [2], there are several techniques for increasing rice production. The use of technology in rainfed fields must be adjusted to the soil, agro-ecosystem, and socioeconomic characteristics of the people.

Rainfed Fields (RF) have the potential to be transformed into food production centers [3]. It covers 3.41 million hectares in Indonesia. The largest rainfed field on the island of Java is in Central Java (278,608 acres) [1]. As a food production center, rainfed fields has made a considerable contribution thus far. In 2017, total national rice production was 79.5 million

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tons, with 12.7 million tones (16.4%) coming from RF. Pemalang is one of the Central Java regencies with a potential rainfed fields area of 6,083 acres [4].

Rice cultivation in rainfed fields poses a significant threat. Rainfed fields face challenges such as an inadequate water availability, nutrient imbalances, and low productivity (1-2 t/ha) [5-7]. Planting tolerant varieties, balanced fertilization, and spacing are all options for dealing with these issues. Rice production is determined by the availability of nutrients, light intensity, and growth space. Systems are dependent on their environment to grow and produce well, including temperature and solar radiation [8,9].

The Jajar legowo planting system is a rice-growing technique aiming for increasing yield. This technology is a variation on the Tegel spacing system (conventional) technology that farmers typically utilize. The cropping system is a very important factor because it is related to the success of rice cultivation. Jajar legowo planting system is a method of increasing agricultural productivity. The jajar legowo planting strategy has a considerable impact on enhancing the yield of lowland rice plants, according to research by [10-12]. Furthermore, according to [13,14], weather has a significant influence on rice growth and yield. The weather component is made up of solar radiation, temperature, rainfall, relative humidity, and wind speed. The jajar legowo relates to the spacing that farmers are used to in paddy fields. The planting system involves altering the spacing between clumps and between rows, resulting in rice clumps being compacted in rows and the distance between them being widened. As a result, the border effect benefits all of the rice clumps [15] .

Cropping patterns in jajar legowo alternate between two or four rows of rice plants and one unplanted row [15]. The jajar legowo 2:1 planting system will develop a total plant population of 213,300 clumps per ha, which is a 33.31 percent higher over the Tegel (25x25) cm pattern, which provides only 160,000 clumps/ha, leading to enhanced crop productivity. Furthermore [16] reported that this approach is convenient in terms of fertilization, weeding, and pest and disease control. Finally, this system has the potential to increase rice productivity by 10-15% [17]. The success of the jajar legowo planting system needs to be supported by the use of modern tools such as jajar legowo 4:1 seeders, jajar legowo dipsticks 2:1 and transplanters (seedling planting tools) in order to shorten planting time and the workforce [15].

This is the simplest innovation for farmers to adopt because it is both inexpensive and practical. The goal of this study was to determine the response of Inpari 32 variety at various spacings based on the components of growth and production in rainfed fields

2 Method

The study was conducted from March to July 2020 on rainfed fields covering approximately 1 ha in Bodeh village, Bodeh District, Pemalang Regency. The research site is a rainfed fields that was previously a sugarcane field. The water is pumped from an artesian well. Rice seeding is done using a '*culik*' system, which is done earlier, before land processing. This research used a randomised block design with a single factor, namely different spacing treatments. The spacing treatment of the jajar legowo 2:1 system used three spacings, which include (1) Jajar legowo 2:1/40 (12.5 cm x 25 cm x 40 cm), (2) Jajar legowo 2:1/50 (15 cm x 25 cm x 50 cm), and (3) jajar legowo 2:1/50 (15 cm x 25 cm x 50 cm) and (3) Tegel (20 cm x 20 cm). The rice used was the New Superior Variety Inpari 32. All treatments were conducted out six times.

Rice cultivation technology using rice seeds of the Inpari 32 variety (FS) at rates of up to 25 kg ha^{-1}. Seedlings were transplanted 15–20 days after seeding. Planting uses a jajar legowo 2:1 system and a planting board to form a spacing pattern based on the treatment. 2-3 seeds are used per planting hole. Organic fertilizer is applied before tillage, as is chemical fertilizer in the form of urea 300 kg ha^{-1}, SP 36 75 kg ha^{-1}, and KCl 50 kg ha^{-1}.

Plant height, number of tillers, panicle length, filled grains, empty grains, percentage of filled grains, 1000 grains weight, and yield (Harvested Dry Grains/HDG) were among the variables observed. The obtained data was then tested using analysis of variance (Test F) with 6 replications at a significant level of 5%. If a real effect is found, the Least Significant Difference (LSD) test is used with a significance level of 5%.

3 Result and discussion

3.1 Plant Height and the number of tillers

The results of the plant height analysis revealed that differences in plant spacing had a significant effect on plant height (Table 1). According to observations, rice planted at a jajar legowo 2:1/50 spacing has the highest plant height of the others, measured at 117.37 cm, followed by rice planted at a jajar legowo 2:1/40 spacing, measured at 115.14 cm. The lowest plant height was in the Tegel spacing system measured at 113.50 cm. These outcomes are brought about by the interaction of the genetic components of each diversity, supported by the capacity to quickly adapt to the growth environment in order to achieve optimal growth. Genetic and environmental factors are significant determinants of plant growth and production, according to [18, 19].

Table 1. Plant height and number of tillers at different spacings.

Spacing	Plant hieght (cm)	Number of tillers
Legowo 2:1/50	117.37 b	13.60 a
Legowo 2:1/40	115.14 a	17.71 a
Tegel spacing system	113.50 a	12.48 b

The analysis of variance result showed that the spacing treatment had a significant effect on the number of tillers. Rice plants grown under the jajar legowo 2:1/40 system produced more tillers on average than plants grown under the jajar legowo 2:1/50 system (Table 1). The 2:1/40 legowo planting system produced 41.9% more tillers than the Tegel spacing system. Similarly, the number of tillers produced by legowo 2:1/50 was 35.7% higher than that produced by the Tegel spacing system. (Table 1). The study's findings indicated that using jajar legowo spacing could increase the number of rice tillers. This result is consistent with the findings of previous research, which demonstrated that the jajar legowo planting system has the potential to increase crop yield. Furthermore, [20] reported that the jajar legowo planting system increased the number of tillers in the Inpari 30 and Inpari 32 varieties. The legowo row system's wide spacing allows for more plant space. Wide spacing between plants can help with air circulation and root development.

Tiller formation is a critical factor in the production of cereal crops such as rice, wheat, and barley, according to [21]. As the number of tillers increases, so does the leaf area, resulting in greater absorption of sunlight by the leaves, as indicated by an increase in the number of productive tillers. The number of productive tillers will have an impact on overall production because it will contribute to the addition of photosynthetic yields [22]. The findings of this study show the opposite. It is suspected that this was due to the fact that all plants received adequate nutrients and water for plant growth between treatments, as stated by [23] who stated that plant spacing had less influence than nutrient and water adequacy.

3.2 Yield Components

The data was analyzed using Duncan's multiple test to determine the effect of treatment on rice yield and production components. The results of the analysis are presented in Table 2.

Rice yields are determined by yield components, which are determined by plant genetics [24] and environmental factors (climate, nutrients in soil, and water).

Table 2. The results of data analysis of yield components, rice productivity, and harvested dry grains (HDG).

Yield component	**Spacing**		
	Tegel (20x20) cm	**Jajar legowo 2:1/40**	**Jajar legowo 2:1/50**
Length of panicle (cm)	26.11a	26.09a	26.51a
Number of Grains per panicle (grains)	147.97a	144.40a	151.53a
Number of full grains (grains)	112.50a	110.50a	118.23a
Number of empty grains (grains)	35.47a	32.91a	32.30b
Percentage of filled grains (%)	76 b	77 ab	78 a
Weight 1000 grains (gr)	27.02a	27.32a	27.38a
HDG (ton ha^{-1})	4,743a	5,220a	5,619a

The panicle length of VUB Inpari 30 with different spacings ranged from 26.09–26.11 cm, as shown in Table 2. Despite the fact that there was no statistically significant difference between treatments, the 2:1/50 legowo spacing system produced the longest panicle length. This finding differs from that of [25], who found that plant spacing had a significant effect on panicle length and number of tillers, but not on the yield component of lowland rice.

The length of the panicle influences the amount of grain produced per panicle. [26] states that the optimum length of the panicle contributes to grains per panicle. Rice varieties with longer panicle structures tend to produce more grains per panicle [27]. These findings are consistent with a study [28] that found a positive correlation between the number of grains per panicle and panicle length.

The statistical analysis of the number of panicle grains in the three treatments (Table 2) revealed that the Jajar legowo 2:1/50 treatment had the most panicle grains, 151.53, compared to the others, though there was no difference between all treatments. The percentage of filled grain at the Tegel spacing system was 76%, followed by planting jajar legowo 2:1/40 (77%), and jajar legowo 2:1/50 (78%). The number of empty grains in the Tegel spacing system treatment was the lowest and statistically not different from the jajar legowo 2:1/50, but significantly different from the jajar legowo 2:1/40.

In terms of yield components, different spacings resulted in different grains filling capabilities between varieties. [29, 30] reported the same thing. The total assimilation tends to affect the ability to fill the bigger grains. According to [31], increasing plant populations significantly increased the number of panicles per m^2 but resulted in shorter panicle postures. [32] discovered that rice plant population density had an effect on the number of panicles per unit area and the number of grains per panicle, but had no effect on grains filling and grains yield.

The analysis of the average of the three spacing treatments reported that the highest 1000 grains weight was achieved with a jajar legowo 2:1/50 of 27.38 gr, and the lowest was at the Tegel spacing system of 27.02 gr. The weight of 1,000 grains produced in this study seemed to be higher than weight of 1,000 grains which stated by [33], who reported that the yield of 1,000 grains using VUB for lowland rice ranged from 25.42–26.60 g. The weight of 1,000 grains in the three treatments did not differ significantly. This demonstrates that the difference in spacing results in the same ability in grains formation and filling.

The analysis of variance showed that spacing had no significant effect on harvested dry grains (HDG) production (Table 2). The highest dry grains harvest yield was obtained at a jajar legowo 2:1/50 with a HDG yield of 5,619 tons ha^{-1}, followed by a jajar legowo 2:1/40 spacing with a HDG yield of 5.22 tons ha^{-1} and the resulting Tegel spacing system is 4.743

tons ha^{-1}. When compared to the Tegel spacing system, the jajar legowo system treatment can increase HDG production by up to 18.47%, whereas the 2:1/40 and jajar legowo 2:1/50 increases HDG production by 10%. The response of varieties to spacing is thought to be specific. According to [15], jajar legowo has the potential to increase plant population by 30–60% and productivity by 10-15% as a result of population growth. According to [34], plants with wider spacing between them produced more.

In addition to raising crop population, the jajar legowo system can improve the circulation of sunlight and air around the edge of the plant, allowing plants to photosynthesize more efficiently. In addition to increasing crop population, the use of jajar legowo increases air circulation and the intensity of sunlight around the edge of the plant, allowing plants to photosynthesize more effectively. One of the most important requirements for plant growth, survival, development, and productivity is light intensity [35]. Compared to the reduction in photosynthesis, the decrease in transpiration caused by the low intensity is not very significant. Low light intensity significantly reduces the rate of photosynthesis. Furthermore, reduced photosynthesis will interfere with metabolic activities and other physiological processes in plants, slowing plant growth [36].

3.3 Farmer's perception

The implementation of the jajar legowo planting system on rainfed rice fields gives rise to various farmer perceptions. Table 3 shows the farmers' comprehensive perceptions.

Table 3. Farmers' perceptions of the demonstration plot of the jajar legowo planting system on rainfed fields.

Description	Perceptions
New high yield varieties (VUB) and labelled seeds	Farmers believe that the use of VUB and labeled seeds can increase production.
Seed treatment	Farmers believe that seed treatment can increase seed growth to over 95% while also make it pest resistant.
Jajar legowo 2:1 planting system	Farmers were initially concerned that the plant population would decline due to the large amounts of unplanted land, resulting in lower productivity. Planting employees initially found it difficult because the practice took a long time, and they demanded better pay. After observing that the rice planting in harvest was higher than the Tegel (20 x 20) cm spacing system, the farmers were relieved and satisfied.
Complete and balanced fertilizer application	Farmers believe that comprehensive and balanced fertilization, applied in the proper amount and at the right time, can enhance grains yields. Furthermore, applying organic fertilizer prior to land use is thought to improve land quality and increase grains production.
Herbicide application	Farmers were first concerned that their rice would be deprived of water, poisoned, and die, but after learning the sort of herbicide used, they realized that pre-growing herbicides may decrease weeds while lowering costs.

4 Conclusion

Spacing affects the number of tillers and plant height, as well as the percentage of grain content. When compared to the Tegel spacing system, jajar legowo 2:1/50 can increase GKP production by up to 18.47%. When compared to the Tegel spacing system, the jajar legowo 2:1/40 has been shown to increase GKP by 10%. It is recommended that the jajar legowo planting system be used on a spacing of (25x25) cm between clumps in rows, 12.5 cm spacing in rows, and 50 cm between columns.

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