Growth and Yield Performance of Upland and Lowland Rice Varieties Under Narrow-Wide Row Planting Systems in East Nusa Tenggara, Indonesia

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ABSTRACT

Appropriate plant spacing and new superior rice varieties are essential factors in achieving high yields. This study aimed to evaluate rice varieties and jajar legowo planting systems that increase growth and yield during the dry season in East Nusa Tenggara. The research was arranged in a split plot in a randomized complete block design with two replications. The rice varieties (main plot) consisted of upland rice (Inpago 8 and Inpago 12) and lowland rice (Inpari 32 and Ciherang). The planting systems (sub-plot) consisted of a square system 20 cm × 20 cm, jajar legowo 2:1 (30 – 60) cm × 15 cm, jajar legowo 2:1 (25 – 50) cm × 12.5 cm, jajar legowo 2:1 (20 – 40) cm × 10 cm, and jajar legowo 4:1 (20 – 40) cm × 10 cm. The results indicated that Inpago 12 planted with the jajar legowo 2:1 (25 – 50) cm × 12.5 cm resulted in higher growth and yield than those planted with the square system. All tested varieties were not significantly different, while the planting systems were statistically different. The planting system of jajar legowo 2:1 (25 – 50) cm × 12.5 cm obtained higher growth and yield than other planting systems.

Keywords: Grain yield; Inpago 8; Inpago 12; Jajar legowo, Planting systems

ABSTRAK

Penggunaan jarak tanam yang tepat dan varietas padi unggul baru merupakan faktor penting untuk mencapai hasil yang tinggi. Penelitian ini bertujuan untuk mengevaluasi varietas padi dan sistem tanam jajar legowo yang dapat meningkatkan pertumbuhan dan hasil padi selama musim kemarau di Nusa Tenggara Timur. Rancangan petak terpisah digunakan dalam penelitian ini yang disusun dalam rancangan acak kelompok dengan dua ulangan. Varietas padi sebagai petak utama terdiri atas padi gogo (Inpago 8 dan Inpago 12) dan padi sawah (Inpari 32 dan Ciherang). Sistem tanam sebagai anak petak terdiri atas sistem bujur sangkar 20 cm × 20 cm, jajar legowo 2:1 (30 – 60) cm × 15 cm, jajar legowo 2:1 (25 – 50) cm × 12,5 cm, jajar legowo 2:1 (20 – 40) cm × 10 cm, dan jajar legowo 4:1 (20 – 40) cm × 10 cm. Hasil penelitian menunjukkan bahwa Inpago 12 yang ditanam dengan jajar legowo 2:1 (25 – 50) cm × 12,5 cm menghasilkan pertumbuhan dan hasil yang lebih tinggi dibandingkan sistem bujur sangkar. Semua varietas yang diuji tidak berbeda nyata, sedangkan sistem tanam secara statistik berbeda dari yang lain. Sistem tanam jajar legowo 2:1 (25 – 50) cm x 12,5 cm menghasilkan pertumbuhan dan hasil gabah yang lebih tinggi dibandingkan sistem tanam lainnya.

Kata kunci: *Hasil gabah; Inpago 8; Inpago 12; Jajar legowo, Sistem tanam*

INTRODUCTION

Increasing rice productivity is a big challenge in Indonesia due to climatic and soil conditions. Thus, rice cultivation techniques are needed depending on land conditions' characteristics. East Nusa Tenggara is an area in Indonesia with a dry climate, relatively low annual rainfall, and low soil fertility conditions. The rice productivity in this area is relatively low (4.1 t ha^{-1}) and is below the national average (BPS-Statistics of Nusa Tenggara Timur Province, 2022).Several technologies have been applied to increase rice productivity, but the yield has not been as expected. The low pro-

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ductivity of rice is caused by improper cultivation technology, for example, the use of inappropriate varieties and planting systems. Increasing rice yields through improved cultivation technology can meet the rice needs in this area, especially lowland rice areas (OECD/FAO, 2021).

The new high-yielding variety that can adapt to the dry or rainy seasons has a chance to overcome the problem. The varieties grown in the rice production system are classified into upland rice and lowland rice (Saito et al., 2018). Upland rice is often produced on dry terrain with a slope of around 15%, and the soil is rarely flooded; therefore, supplemental water is frequently required (Han et al., 2022; Saito et al., 2018). Upland rice's advantage is demonstrated by how well it adapts to agroecology and different soil types (Taridala et al., 2019). Upland rice varieties have good water use efficiency to adapt to limited water availability conditions (Melandri et al., 2021). Certain upland rice varieties have the desired characteristics, especially in terms of aroma, color, size, and shape, so these qualities are related to the popularity and preferences of farmers (Phapumma et al., 2020). For most of the growing season, lowland rice, including mangrove swamps, deep water, and irrigated lowland, is submerged (Komatsu et al., 2022; Saito et al., 2018).

Growing environmental factors for crops, such as narrow-wide plant spacing and the utilization of new high-yielding cultivars suitable for specific land conditions in lowland rice ecosystems, should be considered to achieve high yields (Purwanto et al., 2020). The planting system is an essential factor that should be considered in rice cultivation. It is related to the high yields that can be achieved (Paulina et al., 2020).A planting method known as *Jajar Legowo* has a pattern of multiple rows of plants (often two or four rows) separated by empty rows. The plants that should be planted in the empty rows are inserted into the rows (Abdulrachman et al., 2013). Increased side plants are the goal of the jajar legowo planting system (border effect) (Asnawi et al., 2021). The previous studies reported that the jajar legowo planting system affected rice growth (Sartika et al., 2021) and increased grain yield per hectare and rice yield components, including the panicles per hill, number of grains per panicle and 1000-grain weight (Liu et al., 2019; Susilastuti et al., 2018; Suweta et al., 2021).

Additionally, the jajar legowo planting system makes crop maintenance, such as fertilization and weed, insect, and disease control, easier by placing vacant rows parallel to the rows of plants. Jajar legowo planting system provides the second-largest share after site-specific fertilization to increase grain yields and rice farmers' incomes (Erythrina & Zaini, 2013).This study aimed to evaluate rice varieties and the *jajar legowo* planting system in improving growth and yield during the dry season in the Southwest Sumba Regency, East Nusa Tenggara. The impact of this study is increasing rice production in this area, which can meet the needs of regional rice. The enhancement of rice production is expected to be sustainable so that the welfare of farmers can be achieved. Applying the appropriate planting system using *jajar legowo* will provide ideal growing conditions for plants. Moreover, *jajar legowo* should be combined with the rice varieties according to plant morphology and land conditions.

MATERIALS AND METHODS

Research Study Site

The research was conducted during the dry season from June to September 2021 on a farmers' lowland in Wewewa Timur District, Southwest Sumba Regency, East Nusa Tenggara Province, Indonesia. The experimental field was at an altitude of ±400 meters above sea level.

Soil Physicochemical Characteristics

The soil samples were taken 20 cm in depth before tillage to determine the initial condition of soil characteristics at the study site. The soil sample consisted of four sample units representing the overall field conditions, where one sample unit was a composite of five sub-samples taken in a diagonal pattern. Soil analysis of physicochemical properties was performed at the Soil Testing Laboratory, Indonesian Soil Research Institute, Bogor, Indonesia.

Research Materials

The research materials used were Inpago 8, Inpago 12, Inpari 32, and Ciherang rice varieties. Inpago 8 and Inpago 12 are upland rice varieties, while Inpari 32 and Ciherang are irrigated lowland rice varieties. The selection of varieties depends on the preferences of local farmers, especially rice quality and marketability. Ciherang is a commercial variety (control) that local farmers commonly cultivate. Inpago 8, Inpago 12, and Inpari 32 are new rice varieties that have never been cultivated by local farmers, which will be introduced to them and compared in this study.

Experimental Design

This research was conducted using experimental field methods. A split plot was applied in this trial dan was set up using a randomized complete block design (RCBD). The main plots were four rice varieties: Inpago 8, Inpago 12, Inpari 32, and Ciherang. The subplots were five different planting systems. The planting system and planting density per hectare are shown in Table 1. The square plant spacing (20 cm x 20 cm) served as a control, which local farmers commonly practice. The plant spacing in the *jajar legowo* was adjusted from wide to narrow compared to the optimum spacing. The number of treatments consisted of 20 combinations with two replications. The size of each plot was 36 m^2 (6 m x 6 m), and the boundary between the treatment plots was made with a width of 1 m.

Fields Preparation

Soil tillage was carried out using a tractor before planting. Seedlings were planted in nurseries before being transplanted into the rice field. Seedlings were transplanted 18 days after sowing for all treatments, and 2-3 seedlings per hill were planted. Irrigation was carried out through water channels to meet water needs during the plant growth period. Essential fertilizer was given in each plot at a rate of 250 kg NPK and 150 kg urea per hectare during the growing season. Fertilization was applied twice, 14 days after transplanting (DAT) and 35 DAT with a dose of each application that was half the total dose per growing season. Control of weeds, pests, and diseases was carried out regularly according to farmer practices.

Rice Growth and Yield Observation

Growth, yield components, and yield were recorded. Plant growth was measured on morphological characters, including plant height, number of tillers per hill, flag leaf length, and

Table 1. Planting density of each planting system (hectare)

Planting system	Code	Plant density per hectare
Square 20 cm × 20 cm	Tegel	250,000
Jajar legowo 2:1 (30 cm – 60 cm) × 15 cm	Jrw-A	148,148
Jajar legowo 2:1 (25 cm – 50 cm) × 12.5 cm	Jrw-B	213,333
Jajar legowo 2:1 (20 cm – 40 cm) × 10 cm	Jrw-C	333,333
Jajar legowo 4:1 (20 cm – 40 cm) × 10 cm	Jrw-D	400,000

flag leaf width. Yield components were recorded, including the number of productive tillers per hill, panicle length, filled grains per panicle, unfilled grains per panicle, 1000-grain weight, and grain weight per plant. When the grain was physiologically ready for harvest when 90–95 percent of the grain turned yellow, the crop was harvested (seed moisture content ±22-27%). Grain yields for all plots were obtained using the area sample method according to the treatment of the planting system. The sampling area for each plot according to the planting system was 6.76 m^2 (2.6 m × 2.6 m) for a square system (Tegel), 6.48 m^2 (2.7 m × 2.4 m) for Jrw-A, 6 m^2 (3 m × 2 m) for Jrw- B, 6 m^2 (2.4 m × 2.5 m) for Jrw-C, and 6 m^2 (3 m × 2 m) for Jrw-D (Asnawi et al., 2021; Makarim et al., 2017). The grain yield harvested from the sample area of each plot was measured for its moisture content and converted to hectares.

Statistical Analysis

All recorded data were statistically processed using analysis of variance (ANOVA) with a *P* value of 0.05. The Fisher's Least Significant Difference (LSD) test was used to compare the mean values between treatments with a *P* value of 0.05. R Studio version 1.4.1103 and R software version 4.0.3 were utilized for this statistical analysis.

RESULTS AND DISCUSSION

Climate and Soil Physicochemical Characteristics

The climate in the study area had an annual rainfall of 1,850 mm and an annual number of rainy days of 152 days. The average annual temperature was 26.5 °C, while the minimum and maximum temperatures were 20.6 °C and 33.4 °C, respectively. The average annual relative humidity was 82%, while the minimum and maximum humidity were 46% and 97%, respectively. Monthly weather indicated that the dry season happened from June to September 2021, which was the growing season. In this study, monthly rainfall was less than 100 mm, with an average rainy day of 13 days.

The result of soil analysis of physicochemical properties is shown in Table 2. Based on the criteria of the soil analysis results (Eviati & Sulaeman, 2009), the condition of the soil texture at the experimental site was categorized as silty clay, which was dominated by the composition of the clay particle fraction (52%), while the other particle fractions were sand (2%) and silt (45%). Soil acidity was classified as neutral (pH 6.9). Carbon (C), nitrogen (N), and the C/N ratio composition were moderate. Phosphorus (P) was classified as very high (P_2O_5 extracted by HCl 25%), and available P (Olsen) was classified as moderate. In comparison, potassium (K) content was classified as very

Table 2. Soil physicochemical characteristics at the study site

Soil properties	Value *(n=4)*	Soil properties	Value *(n=4)*
Soil particle fraction:		K_{-dd} (cmol(+)/kg)	0.13 ± 0.01
sand (%)	2 ± 1.0	Ca_{-dd} (cmol(+)/kg)	20.17 ± 0.61
silt (%)	45 ± 2.8	Mg_{-dd} (cmol(+)/kg)	0.54 ± 0.04
clay (%)	52 ± 3.8	Na_{-dd} (cmol(+)/kg)	0.12 ± 0.02
pH H_2O	6.9 ± 0.1	CEC (cmol(+)/kg)	21.77 ± 0.93
pH KCl	5.7 ± 0.1	BS (%)	96 ± 2.1
C/N	12 ± 0.0	Al^{3+} (cmol(+)/kg)	0 ± 0
C (%)	2.85 ± 0.08	H^+ (cmol(+)/kg)	0.21 ± 0.02
N (%)	0.24 ± 0.01	Fe (ppm)	81.9 ± 12.0
P_2O_5 HCl 25% (mg/100 g)	147 ± 17.9	Mn (ppm)	13.8 ± 3.1
P_2O_5 Olsen (ppm P)	13 ± 2.2	Cu (ppm)	2.6 ± 0.2
K_2O HCl 25% (mg/100 g)	8 ± 0.6	Zn (ppm)	1.5 ± 0.3

Remarks: CEC: cation exchange capacity, BS: base saturation

Table 3. Morphological traits of rice in different varieties and planting systems

Treatments	Plant height (cm)	Number of tillers per hill	Flag leaf length (cm)	Flag leaf width (cm)
Variety (V)				
Inpago 8	89.23	14.15	23.64	1.06
Inpago 12	88.64	13.71	24.32	1.13
Inpari 32	82.04	11.46	23.22	0.96
Ciherang	84.30	14.00	23.04	1.13
Planting (T)				
Tegel	83.93	12.48 c	21.48 c	1.09
Jrw-A	89.01	14.51 a	25.25 a	1.08
Jrw-B	85.71	14.19 ab	23.62 abc	1.05
Jrw-C	86.99	12.95 bc	24.97 ab	1.03
Jrw-D	84.63	12.52 c	22.45 bc	1.10
F value^				
F_V	0.25^{ns}	3.49^{ns}	0.10^{ns}	0.92^{ns}
F_T	0.85^{ns}	5.17^{**}	3.18^{*}	0.26^{ns}
$F_{V \times T}$	0.90^{ns}	3.16^{*}	1.17^{ns}	1.54^{ns}

Remarks: Means followed by the same letters in the same column are not significantly different from each other at P <0.05 according to Fisher's LSD test. ^: ANOVA, *: significant at P <0.05, **: significant at P <0.01, ns: not significant

low (K_2O extracted by HCl 25%). Exchangeable base cations such as calcium (Ca^{2+}) were very high, while K^+, magnesium (Mg^{2+}), and sodium (Na^+) were low. The cation exchange capacity (CEC) was moderate (21.77 cmol (+)/kg), while base saturation (BS) was very high (96%). It indicated that the soil conditions at the experimental site were quite fertile, where base cations dominated the colloid adsorption complex compared to acid cations (Al^+ and H^+). The content of soil micronutrients (Fe, Mn, Cu, and Zn) was also within sufficient limits.

Rice Growth

Rice growth indicates morphological characteristics, including plant height, number of tillers per clump, flag leaf length, and flag leaf width, contributing to crop yields. In the early growth phase, plants distribute and assimilate for leaf area growth to utilize sunlight efficiently. Growing crops will produce optimally (Gardner et al., 1991). According to Table 3, upland and lowland rice had no significant effect on all observed morphological characters, including plant height, number of tillers per hill, flag leaf length, and flag leaf width.

The planting system treatment significantly affected the number of tillers per hill and the length of the flag leaves, while the plant height and width of the flag leaves were not significantly affected. The study of Tsujimoto et al. (2021) explains that a lower number of tillers can lead to a wide leaf area. The growth and addition of new leaves may influence the leaf area index. The Jrw-A treatment had the most tillers per hill, but it was not significantly different from the Jrw-B treatment. In contrast, the Tegel and Jrw-D treatments showed lower tillers per hill. The Jrw-A treatment also demonstrated a higher response to the flag leaf length than the Tegel and Jrw-D treatments. However, it was not significantly different from the Jrw-B and Jrw-C treatments. The flag leaf length in the Jrw-A was 17.6% longer than that in the Tegel planting system. The spacing between plants in Jrw-A was wider than in the square planting system, and plant density was lower, so crops had more optimal growth space.

The number of tillers per hill depends on the type of rice cultivated and the environmental conditions (Komatsu et al., 2022).The number of tillers per hill was affected by the interaction between the

Table 4. The number of tillers per hill of rice varieties in different planting systems

Treatment	Number of tillers per hill			
	Inpago 8	Inpago 12	Inpari 32	Ciherang
Tegel	12.70 d-g	13.00 c-g	11.23 fgh	13.00 c-g
Jrw-A	14.50 a-e	13.60 b-f	14.73 a-e	15.20 a-d
Jrw-B	16.37 a	15.50 abc	11.50 fgh	13.40 c-f
Jrw-C	12.80 d-g	12.30 efg	10.60 gh	16.10 ab
Jrw-D	14.40 a-e	14.13 a-e	9.25 h	12.30 efg

Remarks: Means followed by different letters indicate significant differences at *P* <0.05 according to Fisher's LSD test

Table 5. Rice yield and yield components in different varieties and planting systems

Treatment	NPT	PL	NFG	NUG	PFG	WTG	GWP	GY
Variety (V)								
Inpago 8	13.49	20.63	134.10	24.54	84.20	24.23	24.71	4.80
Inpago 12	13.10	20.15	107.70	18.62	84.88	24.10	21.26	4.45
Inpari 32	11.28	20.47	114.01	17.19	86.58	25.54	19.70	5.04
Ciherang	13.28	20.17	119.26	17.42	87.22	25.60	23.65	4.71
Planting (T)								
Tegel	12.18 b	19.65 c	116.38	19.68	85.13	24.57 bc	20.61 bc	4.13 c
Jrw-A	13.89 a	20.78 ab	117.95	17.93	86.83	25.20 ab	27.43 a	4.57 bc
Jrw-B	13.71 a	21.18 a	126.23	19.31	86.72	25.90 a	25.33 ab	5.60 a
Jrw-C	12.14 b	20.15 abc	122.30	19.90	85.80	24.64 bc	19.75 c	4.54 bc
Jrw-D	12.01 b	20.01 bc	110.98	20.40	84.12	24.04 c	18.54 c	4.93 b
F value^								
F_V	1.76^{ns}	0.07^{ns}	1.14^{ns}	3.20^{ns}	2.64^{ns}	0.42^{ns}	1.20^{ns}	0.76^{ns}
F_T	4.64^{*}	3.13^{*}	0.50^{ns}	0.67^{ns}	1.45^{ns}	3.51^{*}	5.12^{**}	9.09^{***}
$F_{V \times T}$	2.52^{*}	0.66^{ns}	0.83^{ns}	1.87^{ns}	1.82^{ns}	3.06^{*}	1.03^{ns}	2.59^{*}

Remarks: Means followed by the same letters in the same column are not significantly different at *P* <0.05 according to Fisher's LSD test. ^: ANOVA, *: significant at *P* <0.05, **: significant at *P* <0.01, ***: significant at *P* <0.001, ^{ns}: not significant. NPT: number of productive tillers per plant, PL: panicle length (cm), NFG: number of filled grains per panicle, NUG: number of unfilled grains per panicle, PFG: percentage of filled grain (%), WTG: 1000-grain weight (g), GWP: grain weight per plant (g), GY: grain yield (t ha^{-1}) at 14% moisture content

planting system and variety (Table 4). For Inpago 8 and Inpago 12 varieties, the Jrw-B had more tillers per hill than the Tegel and Jrw-C planting system. It indicated that the number of tillers per hill of upland rice (Inpago 8 and Inpago 12) could be increased by the Jrw-B treatment. For the lowland rice varieties (Inpari 32 and Ciherang), the Jrw-A treatment had more tillers per hill than the Tegel and Jrw-D treatments. The Ciherang variety produced more tillers with the Jrw-C treatment, but the results were not significantly different from those with the Jrw-A treatment. The maximum number of tillers will impact the number of productive tillers, correlating with grain yield (Kaziu et al., 2019).

Yield and Yield Components

After entering the production phase, most of the dry matter formed and stored is transferred to the generative part of the crop so that the distribution for the growth of leaves, roots, and stems is limited. After entering the production phase, a high proportion of the generated and stored dry matter is moved to the crop's generative component, limiting the distribution for the growth of leaves, roots, and stems (Suryaningndari et al., 2018).Table 5 shows the effect of varieties and applications of planting systems on rice's yield and yield components. The interaction effect between varieties and planting systems were found in the number of productive tillers per hill, 1000-grain weight, and grain yield

Table 6. The number of productive tillers per hill of upland and lowland rice cultivars under different planting systems

Treatment	Number of productive tillers per hill			
	Inpago 8	Inpago 12	Inpari 32	Ciherang
Tegel	12.00 c-g	12.70 b-g	11.00 f-h	13.00 b-g
Jrw-A	13.90 a-e	12.88 b-g	14.48 a-c	14.30 a-d
Jrw-B	15.73 a	14.95 ab	11.38 e-h	12.80 b-g
Jrw-C	12.00 c-g	11.60 e-h	10.50 gh	14.48 a-c
Jrw-D	13.80 a-e	13.38 a-f	9.05 h	11.80 d-g

Remarks: Means followed by different letters in the same column indicate significant differences at *P* <0.05 according to Fisher's LSD test

Table 7. A 1000-grain weight of upland and lowland rice varieties under different planting systems

Treatment	1000-grain weight			
	Inpago 8	Inpago 12	Inpari 32	Ciherang
Tegel	23.61 de	25.63 a-d	24.33 cde	24.70 b-e
Jrw-A	23.76 de	24.85 bcd	27.15 a	25.02 a-d
Jrw-B	24.34 cde	26.16 abc	26.23 abc	26.88 ab
Jrw-C	24.04 cde	22.57 ef	25.81 a-d	26.13 abc
Jrw-D	25.41 a-d	21.28 f	24.19 cde	25.29 a-d

Remarks: Means followed by different letters in the same column indicate significant differences at *P* <0.05 according to Fisher's LSD test

Table 8. Rice grain yield of upland and lowland rice under different planting systems

Treatment	Grain yield (t ha^{-1})			
	Inpago 8	Inpago 12	Inpari 32	Ciherang
Tegel	3.86 fg	3.62 g	4.69 c-g	4.33 d-g
Jrw-A	4.72 c-f	4.09 efg	5.08 b-e	4.38 c-g
Jrw-B	6.16 ab	6.34 a	5.46 abc	4.43 c-g
Jrw-C	4.23 d-g	3.94 fg	4.76 c-f	5.22 bcd
Jrw-D	5.05 cde	4.25 d-g	5.24 bcd	5.17 b-e

Remarks: Means followed by different letters in the same column indicate significant differences at P <0.05 according to Fisher's LSD test

per hectare. The results indicated that the varieties did not significantly affect the rice yield and yield components. The planting system significantly affected the number of productive tillers per hill, panicle length, 1000-grain weight, and grain weight per plant.

In contrast, the number of filled grains, unfilled grains, and percentage of filled grains per panicle were not significantly affected. The Jrw-B treatment tended to produce a higher average number of productive tillers per hill, panicle length, 1000-grain weight, and grain weight per plant than the Tegel and Jrw-D treatments. Still, it was not significantly different from the Jrw-A treatment. The average panicle length on the Jrw-B treatment was 7% longer than the Tegel treatment, but it was not substantially different from the Jrw-A and Jrw-C planting systems.

The Jrw-A was not significantly different from the Jrw-B treatment. The lowest grain weight per plant was found in the Jrw-D treatment, which was relatively similar to those in the Jrw-C and Tegel treatments. It indicated that applying a planting system with narrower spacing and a higher population per hectare on the Tegel, Jrw-C, and Jrw-D treatments reduced grain weight per plant compared to the Jrw-A and Jrw-B treatments, which had a wider spacing with a lower population. It was related to the level of competition among plants. Planting systems with high densities tend to have a higher level of competition related to environmental factors for crop growth, such as sunlight, water, air, temperature, humidity, and nutrients. Wider spacing between plants will allow more sunlight to reach the planting area, which is suitable for photosynthesis (Khairullah et al., 2021). Caine et al. (2019) mention that the high crop density causes competition for sunlight, CO_2, water, and nutrients. In addition, a dense canopy will decrease the quality of the light plants get. In this study, the average monthly rainfall during the growing season was relatively low (<100 mm/month), and the water supply from irrigation canals was also limited during the dry season. It caused the adequacy of water for plants to be less than optimal, especially in treatments with higher plant populations (Tegel, Jrw-C, and Jrw-D). The condition of sufficient water was a very critical factor during the formation and filling of grain.

Moreover, the soil conditions at the study site had relatively low levels of macronutrients such as K and Mg. The low soil nutrient content could be a limiting factor for other soil nutrients. Potassium and Mg were nutrients that had essential roles in photosynthesis, thereby increasing grain production (Tränkner et al., 2018). The Jrw-B treatment produced the highest grain yield compared to other treatments. It indicated that this plant spacing was more proper according to the land conditions at the study site.

Not all tillers produce panicles, but only productive tillers have panicles. The panicle is a part that has a high portion of the dry weight of rice (Suryaningndari et al., 2018). The interaction between planting systems and cultivars significantly affected the number of productive tillers per hill (Table 6). Rice cultivars of different genotypes respond differently to water and nutrient supplies (Zhang et al., 2020). Moreover, the number of productive tillers is determined by genetic factors and environmental factors, such as the intensity of sunlight (Hafni et al., 2019).The upland rice (Inpago 8 and Inpago 12) tended to have more productive tillers per hill in the Jrw-B treatment. Meanwhile, with the Jrw-A and Jrw-C treatments, the lowland rice (Inpari 32 and Ciherang) tended to have more productive tillers per hill.

The application of the Jrw-A treatment showed a similar response in which the number of productive tillers produced was relatively high for each variety, either Inpago 8, Inpago 12, Inpari 32, or Ciherang. In the Inpari 32 variety, the narrower spacing treatment showed a decreasing pattern in the number of productive tillers per hill. Inpari 32 planted using the Jrw-D treatment showed a significant decrease in productive tillers per hill, whereas the Jrw-D treatment had a denser spacing than the other treatments. The reduction of the productive tillers per hill of the Inpari 32 variety reached 37% between the Jrw-A and Jrw-D treatments. The Jrw-A treatment had a wider spacing with lower plant density than the other treatments, so the competition among plants was also lower. Suhendrata (2017) states that wider spacing impacts a higher number of productive tillers. It indicated that a planting system with wider rows would expand the sunlight capture area for plants, but the planting density would be lower. The wide spacing will provide space for tiller growth and maximum sunlight all leaves receive to photosynthesize and produce grain (Megasari et al., 2020). Adaptability and the number of productive tillers produced show different responses among varieties. They are determined by interactions between genotypes and the environment that are favorable or following plant growth and development (Hafni et al., 2019). Management of plant spacing needs to be considered to obtain the appropriate plant density so that the plants get optimal water supply, nutrient uptake, and sunlight intensity for the growth of the number of productive tillers.

The interaction between varieties and planting systems showed a significant difference in the 1000-grain weight (Table 7). The 1000-grain weight of Inpari 32 under the Jrw-A treatment was higher than that under the Tegel treatment, but it did not significantly differ from that under the Jrw-B or Jrw-C treatments. A 1000-grain weight produced was 27.2 g with this treatment combination. The Inpago 8 variety with the Jrw-D planting system gave a 1000-grain weight of 25.41 g. The Jrw-B treatments increased the productive tillers per hill in the Inpago 12 and Ciherang varieties. Combining these treatments resulted in an average number of tillers per hill of 26.16 for Inpago 12 and 26.88 for Ciherang. The Tegel treatment showed a lower 1000-grain weight for the Inpago 8, Inpari 32, and Ciherang varieties. Meanwhile, in the Inpago 12 variety, the Jrw-D treatment showed a lower 1000-grain weight than the Jrw-A, Jrw-B, and Tegel treatments, but it was not significantly different from that resulted by the Jrw-C treatment. This combination treatment only resulted in a 1000-grain weight of 21.28 g or 23% lower than the Jrw-B treatment for the Inpago 12 variety.

The interaction effect between varieties and planting systems showed a significant difference in grain yield per hectare at 14% moisture content (Table 8). The highest grain yield was achieved in the combination between the Inpago 12 variety and the Jrw-B treatment compared to the Tegel treatment, but it was not significantly different from the Inpago 8 and Inpari 32 variety. The average grain yield per hectare in the Inpago 12 variety treated with the Jrw-B planting system was 6.3 t/ha or 75% higher than that treated with the Tegel treatment.

The Inpago 8 variety was also more suitable to be planted with the Jrw-B treatment, where the grain yield was not significantly different from the Inpago 12 variety. The Jrw-B treatment produced a higher grain yield than the Tegel, Jrw-A, Jrw-B, Jrw-C, and Jrw-D treatments. The jajar legowo 2:1 planting system has a higher border effect than the square or jajar legowo 4:1 planting system (Asnawi et al., 2021). The plants' location influences the increase in photosynthesis at the edge of the row, where they receive relatively more maximum sunlight. The competition for nutrients and water among border plants is somewhat lower (Aklilu, 2020).

Water conditions in the research location were limited, with relatively low rainfall. Upland rice varieties (Inpago 8 and Inpago 12) responded to limited water conditions better than lowland rice varieties (Ciherang and Inpari 32). It indicated that upland rice was efficient in water use, so there was no significant decrease in grain yield. Upland rice generally has specific characteristics such as water-saving ability and drought-resistant (Bernier et al., 2008). In response to drought stress, there were different root characteristics between upland and lowland rice, the relationship between agronomic and physiological traits (Sandar et al., 2022).

In addition, the soil nutrient content at the study site might also affect the increase in grain yield. The nutrient content of N (0.24% N) and P (13 ppm P) in the soil was high and medium, respectively, while K (0.13 cmol(+)/kg) and Mg (0.54 cmol(+)/kg) were low (Table 2). Zhang et al. (2020) reported that the root system of upland rice was more sensitive to N fertilizer than the root system of lowland rice. The availability of nutrients around the roots is then transported into the plant for the photosynthesis process to assimilate. Furthermore, it will be translocated to the grain. The more assimilate transferred to the grain, the higher the grain yield (Siregar, 2018). Upland rice with proper spacing showed a better response to grain yield. Applying jajar legowo 2:1 planting system (Jrw-B treatment) could optimize nutrient uptake for upland rice varieties. The study of Amanah et al. (2017) also reported that the planting system of jajar legowo 2:1 increased the N uptake, N content in a shoot, and yield per hectare. Plant spacing with the jajar legowo 2:1 planting system tends to produce higher grain yields, while narrow spacing impacts lower grain yields.

CONCLUSION

The planting system of jajar legowo 2:1 (25 cm – 50 cm) × 12.5 cm produced better morphological traits and obtained higher yield components than Tegel (20 cm × 20 cm). The upland rice variety (Inpago 12) treated with the planting system of jajar legowo 2:1 (25 cm – 50 cm) × 12.5 cm produced the highest grain yields (6.3 t/ha), and it is suitable for the dry season at lowland in this location. A narrower row spacing with jajar legowo 2:1 (20 cm – 40 cm) × 10 cm and jajar legowo 4:1 (20 cm – 40 cm) × 10 cm might be an alternative to the Ciherang and Inpari 32 varieties. Thus, selecting appropriate rice varieties and planting systems must consider morphological traits and planting density to achieve high yields for specific land conditions.

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