Increasing Rice (*Oryza sativa* L.) Productivity and Farmer's Income through the Implementation of Modified Double Rows Planting System

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RA and RWA designed the study. Authors RA, RWA, Slameto and RDT performed the statistical analysis and wrote the protocol. Authors RA, RWA and MJM wrote the first draft of the manuscript. Authors RA, RWA, Martias, Fitriani and MJM managed the analyses of the study. Authors RA, RWA, Fitriani, Martias and MJM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Rice (*Oryza sativa* L.) productivity in Indonesia is leveling off. The study aims to determine the effect of the Jejer Manten double rows modified planting system on the growth, productivity, and economic feasibility of the rice farming system. The study was conducted in Lampung Province, Indonesia from 2016 to 2018. The study was arranged using a split-plot design with 3 replications. The

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treatment consisted of two factors namely: planting system (S_1 = Jajar Tegel, S_2 = Jajar Legowo double rows 2:1, and S_3 = Jejer Manten double rows modification) and rice varieties (V_1 = Ciherang; V_2 = Inpari 10). The results of the study showed that the Jejer Manten planting system produced higher growth and productivity than Jajar Tegel and Jajar Legowo planting system. During the three years of research, the application of the Jejer Manten planting system increased productivity by 6.04-32.27% compared to Jajar Tegel and 13.78-28.92% compared to the Jajar Legowo planting system. Economically, based on the analysis of marginal benefit-cost ratio (MBCR), the application of the Jejer Manten planting system was more feasible than the Jajar Tegel planting system (MBCR = 6.32) and Jajar Legowo planting system (MBCR = 8.18). Based on these results, it is recommended to apply the Jejer Manten planting system as a new technology to increase rice production and support of food self-sufficiency program of Indonesia.

Keywords: *Planting system; jejer manten; variety; productivity; rice.*

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the strategic food crop commodities in Indonesia. It is the major crop for small farms. Rice is also the food staple and domestic demand for rice is very large [1]. The Government of Indonesia through the Ministry of Agriculture continues to increase rice production and productivity in order to meet the increasing domestic needs which in line with an increase in human population [2]. However, rice production in Indonesia is leveling off, so that several efforts are needed to increase the productivity. Indonesia's rice crop area in 2018 was 11.37 million hectares with a productivity of 5.20 tons.ha⁻¹. It decreased to 10.68 million hectares with a productivity of 5.11 tons.ha⁻¹ in 2019 and became 10.66 million hectares with a productivity of 5.12 tons.ha⁻¹ in 2020 [3]. One of rice cultivation technology effort in cropping systems in particular by modifying of plant distance or planting rows from "tiles" system that has been used by farmers to double rows system called "Jajar Legowo" (Legowo) 2:1, and modification of double rows system pattern called "Jejer Manten".

Jajar Legowo planting system is a way of rice planting by adjusting spacing between the clumps and between rows, resulting in compaction clump and plant population per unit area of paddy [4]. According to Sandiani [5], the basic principle of the Jajar Legowo planting system is to make all hedge row is at the edge to influence the edge (border effect). The research results of Setyanto and Kartikawati [6] showed that the rice plants are planted regularly in the form of tiles, turns on the edge (near the edge) were higher 1.5 to 2 times compared with the part in mapped fields production. Jajar Legowo planting system left the room wide and extending between two rows with a width of 40 cm, while the distance in rows 20 cm and the distance in

rows legowo parallel of 12.5 cm. The number of plants per ha of the Jajar Legowo planting system is determined by the width of legowo, plant spacing within and between rows, the number of rows between two legowo rows.

Jajar Legowo planting system is applied by changing from the spacing of symmetric (tiles) should be planting Jajar Legowo to set spacing between the clumps and rows, that is resulting in compaction clumps of plants. It can be an increasing plant population per unit area compared with the Jajar Tegel planting system [7]. All of the plants of the Jajar Legowo planting system produced edge of plants which usually provides better results for border effects [6,8]. With row empty (legowo), plants absorbed nutrients by the roots become more perfect that affect of growth and production. Meanwhile, according to the of Agriculture of Indonesia [9], legowo is a technique developed to harness the influence of row edge of the rice plant more so that plants better grow and the result is higher, it cause the vast border effect and hallway mapped fields so that the grain produced is pithier and increase grain yield significantly compared with Jajar Tegel planting system [10,11, 12].

After five years of ongoing activities of Field School of Integrated Plant Management (SLPTT), the application of the Jajar Legowo planting system is very slowly adopted by farmers in Lampung Province generally and especially in Pesawaran regency with some reasons such as difficulty to do, the additional costs of planting, and difficult to carry out weeding by using the traditional tool called "gosrok." Added by Erythrina et al. [10], although the yield of grain higher than the Jajar Tegel planting system, Jajar Legowo technology components are difficult to be adopted by farmers. Application of the Jajar Legowo double

rows planting system increased paddy productivity by 19-22% compare to conventional planting systems [13,14,15] and an increase in farmers' income by 10.45% [16].

Jejer Manten planting system abbreviated "Jerman" or "Twin Seeds" is a cropping system engineering which was performed by a group of farmers in Pesawaran regency and developed and scientifically studied by BPTP Lampung [17]. Jejer Manten planting system is also intended to utilize the effects of roadside plants as happened in the Jajar Legowo planting system, but it does easier for farmers to plant and weeding using the "gosrok" tool. Moreover, the Jejer Manten planting system has several advantages compared with the Jajar Legowo planting system, such as less seed number, easy to do, have the effect of a more perfect crop edge, easy weeding with "gosrok" tool, and higher productivity of 5-10% than Jajar Legowo planting system. The number of plants in the Jajar Tegel planting system of 160,000 plants, Jajar Legowo 2:1 planting system of 213,000 plants [18], and Jejer Manten planting system of 192,000 plants, resulting in Jejer Manten planting system save seed 14.58% compared with Jajar Legowo and 20% higher than Jajar Tegel planting system [17]. Since the position of twin plants was adjacent, it caused nutrient absorption of plants more efficient and distributed evenly.

The results of Asnawi and Arief [17] study showed that the application of the Jejer Manten planting system was able to increase rice productivity by 6.70% compared with the Jajar Tegel planting system and increased by 28.92% compared with the Jajar Legowo 2:1 planting system. However, their study was carried out in Pesawaran regency with geographical and soil conditions that are different from other regencies in Lampung Province. This study introduced a new variety of rice (Inpari 10). The natural and geographical conditions, as well as different varieties, is are thought to affect the response of plants to light and nutrients because of the mistreatment of different planting systems. Therefore, this study aims to determine the effect of the Jejer Manten double-rows modified planting system on the growth, production, and economic feasibility of the rice farming system.

2. MATERIALS AND METHODS

2.1 Experimental Site

This research was conducted in Lampung Province, Indonesia for three consecutive years,

namely in East Lampung regency in 2017, Central Lampung regency in 2017, and Pesawaran regency in 2018 during the dry season. These locations are the centers for rice production in Lampung Province. The land used is irrigated paddy field with a research area of three hectares per location.

2.2 Planting Materials

Two varieties were used in this study, namely Inpari 10 and Ciherang. Inpari 10 is the new high-yielding rice variety released by Indonesian Agency for Agricultural Research and Development (IAARD) while Ciherang is a variety that most widely grown by farmers in Lampung Province as well as around the country. The Inpari 10 has a potential yield of 7 tons.ha⁻¹ and is resistant to brown planthopper biotypes 1 and 2, while the Ciherang has a potential yield of 5-7 tons.ha⁻¹ and is resistant to brown planthopper biotypes 2 and 3 [19].

2.3 Research Design

This study was arranged in a split-plot design with factorial pattern 2x3. Each treatment was replicated three times. The treatment consisted of two factors, namely, the planting system and rice varieties. The first factor as main plot was the planting systems (S1 = Jajar Tegel, S2 = Jajar Legowo double rows 2:1, and S3 = Jejer Manten double rows modification). The second factor as the sub-plot was rice varieties (V1 = Ciherang; V2 = Inpari 10). Jajar Tegel's planting system used a spacing of 25 cm x 25 cm (Fig. 1). Jajar Legowo's double rows planting system used a spacing of 25 cm x 50 cm x 12.5 cm (Fig. 2), while Jejer Manten's double-rows modification planting system used a spacing of 30 cm x 5 cm x 30 cm (Fig. 3).

Agronomy variables observed were plant height, tiller number, panicle length, grain number/panicle, 1,000-grain weight, percentage of grain hollow, and productivity (kg/ha). Socio-economic variables observed were input farming as the purchase cost of seeds, fertilizers, and pesticides, as well as labor costs for land preparation, planting, plant maintenance, fertilizing, pest and diseases, clean weeding, and harvesting. Determination of plant samples for each treatment was carried out at random sample of 20 plants/treatment or total sample of 360 plants (6 treatments x 3 replicates x 20 plants). The total number of yields component samples was 60 panicles per plot plant or a total

sample of 1,080 panicles (6 treatments x 3 replicates x 20 plants x 3 plants panicles). The number of plot sampling was 3 times/treatment or total plot of tile of 54 plots (6 treatments x 3 replicates x 3 plots), with a plot size of tile 2 m x 5 m or 10 m².

2.4 Data Analysis

Vegetative data analyzed was plant growth in 2016 while the generative data (yield) analyzed was data of 2016, 2017, and 2018. The vegetative and generative data were analyzed statistically using analysis of variance (ANOVA). When the F-test for the treatment was significant ($P \leq 0.05$), treatments were compared using a Duncan Multiple Range Test (DMRT) with a significance value of 5%, while the socio-economic data were analyzed by revenue, R/C ratio, and MBCR analysis. The economic analysis performed in the analysis of farm income and farm feasibility analysis (R/C ratio). According to Pudaka et al. [20], farm income is the difference between revenue and all expenses incurred, calculated as follows:

TL = Y.Py - $\sum X_i \cdot P_i$, where:

TL = Revenue rice farm

Y = Rice production (kg)

Py = Price of rice grain (IDR)

X_i = Use of factor i^{th}

P_i = Price factor of i^{th}

The feasibility effort is made to assess the possible benefits (profitability) or losses obtained from the farming system. The analysis was used to calculate the Return-Cost Ratio (R/C ratio) based on the amount of revenue and costs incurred for planting systems. If the R/C > 1, means the business was profitable. If the R/C < 1, means the business was not profitable, while if the R/C ratio = 1 means the business gained no profit, but did not have a loss either (breakeven point). R/C ratio can be analyzed using the formula:

$$R/C \text{ ratio} = \frac{\text{Total revenue (IDR)}}{\text{Total cost production (IDR)}}$$

According to Swastika [21] and Kaliky and Widodo [22], to evaluate and calculate whether the application of the Jejer Manten planting system and Jajar Legowo planting system are more feasible than the Jajar Tegel planting system, the calculation of the ratio of marginal gross receipts on variable costs or marginal benefit-cost ratio (MBCR) should be done using the following formula:

$$MBCR = \frac{\text{Revenue B} - \text{Revenue P}}{\text{Total costs B} - \text{Total cost of P}}$$

Where:

B = Technology of Jejer Manten planting system

P = Technology of Jajar Tegel or Jajar Legowo planting system

Figure 1. Jajar Tegel planting system

Figure 2. Jajar Legowo planting system

Figure 3. Jejer Manten planting system

If $MBCR < 1$, then the Jejer Manten planting system is not profitable compared to Jajar Tegel or Jajar Legowo planting system. If $MBCR > 1$, then the Jejer Manten planting system deserves to be recommended.

3. RESULTS AND DISCUSSION

3.1 Growth and Productivity

Results of analysis of variance in Table 1 show that plant height was not affected by all treatments. The number of the productive tiller is only affected by the planting systems. Panicle length, number of grain/panicle, and 1,000-grain weight are only affected by the rice varieties. The percentage of empty grain is influenced by the interaction between the planting systems and varieties, while rice productivity is affected by the planting systems and varieties.

Based on the analysis of variance, the high of rice plants were not affected by all treatments, but the average value on Table 2 shows that treatment of Jajar Tegel planting system and Inpari 10 tend to produce higher crops (105 cm) than the other treatments. On the other hand, the number of rice seedlings affected by the planting systems. The average value on Table 3 showed the highest number of seedlings produced by the Jajar Tegel planting system of 18.89 rods but were not significantly different with Jejer Manten planting system of 18.88 rods, while the lowest number of seedlings produced by the Jajar Legowo planting system of 15.78 rods.

Based on the average value in Table 4, Inpari 10 significantly had the longest panicle (25.6 cm) and the highest weight of 1,000 grains (30.9 g). Meanwhile, Ciherang generated the highest number of grains/panicle (160.5 grains).

Table 1. Analysis of variance of planting systems and varieties effect on rice growth and productivity in 2016

Treatment	Plant height (cm)	Seedling number (rod)	Panicle length (cm)	Grain number/panicle (grain)	Empty grain (%)	1000-grain weight (g)	Productivity (kg.ha ⁻¹)
Planting system (S)	ns	**	ns	ns	ns	ns	**
Variety (V)	ns	ns	**	**	ns	**	**
Interaction (SxV)	ns	ns	ns	ns	**	ns	ns

Notes: ns = non significant at 5% level; ** = significant at 5% level

Table 2. Effect of planting systems and varieties on plant height in 2016

Planting system	Varities	Plant height (cm)
Jajar Tegel	Ciherang	101.8 a
	Inpari 10	105.0 a
Jajar Legowo	Ciherang	101.2 a
	Inpari 10	101.8 a
Jejer Manten	Ciherang	100.9 a
	Inpari 10	102.1 a
CV (%)		5.55

Notes: Number followed by the same letter in each column is not significantly different of DMRT at 5% level.

Table 3. Effect of planting system on the number of seedlings in 2016

Planting system	Seedling number (rod)
Jajar Tegel	18.89 a
Jajar Legowo	15.78 b
Jejer Manten	18.88 a
CV (%)	23.76

Notes: Number followed by the same letter in each column is not significantly different of DMRT at 5% level

Table 4. Effect of varieties on the length of panicle, number of grain/panicle, and weight of 1,000 grains in 2016

Variety	Panicle length (cm)	Number of grain/ panicle (grain)	1,000-grain weight (g)
Ciherang	24.2 b	160.5 a	29.1 b
Inpari 10	25.6 a	149.5 b	30.9 a
CV (%)	4.94	13.17	3.11

Notes: The number followed by the same letter in each column is not significantly different of DMRT at 5% level.

The higher length of panicle and weight of 1,000 grains of Inpari 10 and the higher number of grain/panicle of Ciherang were caused by the interaction between genetic factors of each variety, supported by rapid adaptability towards the growth environment, resulting in optimal growth Koga et al. [23] and Kartika et al. [24] described that genetic and environmental factors have a close relationship that can not be separated from one another. When environmental factors are suitable for growth and crop production, it they will produce paddy with optimum performance. Additionally, Suprihatno et al. [25] reported that the average weight of 1,000 grains of s Inpari 10 is was 27.7 g while Ciherang was 2 28 g.

Based on the average values in Table 5, the highest percentage of empty grain produced by the interaction between Jajar Tegel planting system and Inpari 10 variety i.e. 29.1%, followed by the Jejer Manten planting system and Ciherang variety i.e. 28.1%, while the lowest percentage of empty grain produced by Jajar Legowo planting system and Inpari 10 which is 20.5%.

Based on the analysis of variance (Table 1), rice productivity is affected by the lowest treatment and rice varieties. However, the interaction between planting system and rice varieties is not significantly different. Fig. 4 showed that the highest of rice productivity was produced by the Jejer Manten planting system (5,714 kg.ha⁻¹), followed by the Jajar Tegel planting system (5,655 kg.ha⁻¹), and Jajar Legowo planting system (5,022 kg.ha⁻¹).

Among planting systems (Fig. 4), the application of the Jejer Manten planting system increased productivity by 6.04% compared to the Jajar Tegel planting system and increased by 13.78% compared to the Jajar Legowo planting system. On the other hand, the Tegel Jajar planting system improves productivity by 12.60% compared to Jajar Legowo planting system. In 2017, the application of the Jejer Manten planting system increase productivity by 32.27%

compared to the Jajar Tegel planting system and increased by 25.13% compared to the Jajar Legowo planting system. In 2018, the application of the Jejer Manten planting system increase productivity by 6.69 % compared to the Jajar Tegel planting system and increased by 28.92% compared to the Jajar Legowo planting system. Even though the plant population per hectare of the Jajar Legowo planting system is more than the Jajar Tegel planting system, in the current study, rice production of Jajar Legowo was lower than Jajar Tegel.

The results of this research are inversely proportional to the results of Witjaksono [15] who reported that f the Jajar Legowo planting system produce higher productivity (16.4%) than the Jajar Tegel planting system. Inversely, the application of the Jajar Tegel planting system in this study increased by 6.04% compared with the Jajar Legowo planting system. According to the previous studies, the Jajar Legowo planting system increase productivity by 10-25% compared with Jajar Tegel. The differences in production were suspected due to the competition in the sunlight exposure and the absorption of nutrients by plants in each planting system. On the condition of the distance between the mainline, which is almost the same as between the two planting systems, the opportunity for each plant to gain the highest light exposure was obtained in the Jajar Tegel planting system (25 x 25 cm). In the Jajar Legowo planting system, only plants at the edge of distance line (50 cm) obtained ~~in~~ more light than other sides. The spacing of the rows (12.5 cm) gained less sideline light for growing.

Sunlight has a significant role in photosynthetic activity. A decline in photosynthetic activity will be cause the changes in physiological and morphological characteristics of the plant [26]. The impact is a decrease in plant productivity. Insufficient light exposure stops the chlorophyll from working at peak performance. It will reduce photosynthesis activity because chlorophyll amount is correlated with photosynthesis activity [27] Pembengo et al. [28] added that the

Table 5. Effect of interaction between planting system and varieties on the empty grain in 2016

Planting Systems	Varieties	Empty grain (%)
Jajar Tegel	Ciherang	25.4 b
	Inpari 10	29.1 a
Jajar Legowo	Ciherang	26.2 b
	Inpari 10	20.5 c
Jejer Manten	Ciherang	28.1 a
	Inpari 10	22.0 c
CV (%)		22.63

Notes: The number followed by the same letter in each column is not significantly different from DMRT at 5% level

Fig. 4. Effect of planting system on the rice productivity (kg.ha⁻¹) in 2016-2018

efficiency of light used is a critical component in plant growth and development. It is related to the production and accumulation of biomass from energy interception.

Light intensity is among important requirements for plant growth, development, survival, and crop productivity [29]. Yustiningsih [30] and Khairil et al. [31] reported that the low light intensity would cause a reduction in the transpiration process, compared to the process of photosynthesis, so that plant is became taller. However, at very low light intensity, it will reduce the rate of photosynthesis to a considerable extent. The reduced rate of photosynthesis would disrupt metabolic activity and other physiological processes in plants that eventually will decrease plant growth rate. Wardlaw [32] stated that plants that grow in more sheltered areas have lower results of compensation point assimilation compared with plants growing in places that

received more sunlight. The reduction of chlorophyll in plants is in line with photosynthesis assimilates, indicated by a decrease in dry matter content [33].

More sunlight that enters the Jejer Manten planting system treatment into plants causes more nutrients to be absorbed by plants. Nemali and van Iersel [33] stated that the environment affects the absorption of nutrients and optimizing fertilizer concentration. Chozin et al. [34] revealed that the intensity of solar radiation reaching plants would affect the microclimate and plants' photosynthetic activity. These conditions can cause disruption of metabolic processes and a decrease in the rate of photosynthesis and carbohydrate synthesis, which has implications for decreasing plant growth and production [34]. Increasing light intensity leads to increased water used efficiency [35,36,37].

Based on rice varieties planted (Fig. 5), the highest rice productivity was produced by Ciherang (5,645 kg.ha⁻¹), followed by Inpari 10 (5,283 kg.ha⁻¹). These results were in agreement with the research of Suprihatno et al. [25], that found the average yield of Ciherang was 6 tons.ha⁻¹ with a potential yield of 8.5 tons.ha⁻¹, while the average production of Inpari 10 was 4.08 tons.ha⁻¹ with a potential yield of 7 tons.ha⁻¹. The high productivity of Ciherang is thought to be caused by the effect of the interaction of the genetic factors owned by Ciherang in producing rice better rice production than Inpari 10.

3.2. Socio-economy Analysis

The analysis of farming in Table 6 showed that the application of the Jejer Manten planting system produces net revenue of IDR. 13,597,133

with an R/C value of 2.47, Jajar Legowo 2:1 IDR. 11,167,400 with an R/C value of 2.25, and Jajar Tegel IDR. 13.3985 million with an R/C value of 2.45. Lower acceptance of the Jajar Legowo 2:1 planting system was caused by lower productivity, besides higher labor costs, particularly cost for planting. The wages for planting rice using Jajar Tegel and Jejer Manten planting systems is IDR. 700,000.ha⁻¹, whereas for Jajar Legowo 2: 1, the wage is higher than other planting systems (IDR. 800,000.ha⁻¹).

The results of analysis marginal benefit-cost ratio (MBCR) in Table 7 demonstrated that the application of the Jejer Manten planting system is more feasible than the Jajar Tegel planting system, with an MBCR value of 6.32 and Jajar Legowo 2:1 planting system, with an MBCR value of 8.18.

Table 6. Results of farming system analysis of for the application of the Jajar Tegel, Jajar Legowo, and Jejer Manten

Item	Jajar Tegel	Jajar Legowo 2:1	Jejer Manten
Material Inputs:			
Seeds (IDR)	250,000	250,000	250,000
Urea fertilizer (IDR)	380,000	380,000	380,000
NPK Phonska fertilizer (IDR)	780,000	780,000	780,000
Organic fertilizer (IDR)	1,200,000	1,200,000	1,200,000
Herbicides (IDR)	110,000	110,000	110,000
Pesticides (IDR)	120,000	120,000	120,000
Total of Material (IDR)	2,840,000	2,840,000	2,840,000
Labor Cost:			
Tillage (IDR)	1,250,000	1,250,000	1,250,000
Nursery (IDR)	150,000	150,000	150,000
Rice planting (IDR)	700,000	800,000	700,000
Fertilization 1 st (IDR)	100,000	100,000	100,000
Fertilization 2 nd (IDR)	100,000	100,000	100,000
Fertilization 3 th (IDR)	100,000	100,000	100,000
Weeding 1 st (IDR)	200,000	200,000	200,000
Weeding 2 nd (IDR)	200,000	200,000	200,000
Harvest/sharing 6:1 (IDR)	3,581,500	3,180.600	3,618,867
Total of Labor Cost (IDR)	6,381,500	6,080.600	6,418,867
Total of Cost Production (IDR)	9,221,500	8,920.600	9,258,867
Gross revenue (IDR)	22,620,000	20,088.000	22,856,000
Net revenue (IDR)	13,398,500	11,167,400	13,597,133
R/C ratio	2.45	2.25	2.47

Source: Data analyzed, 2016.

Table 7. Marginal benefit cost ratio (MBCR) value of the Jajar Manten planting system on Jajar Tegel and Jajar Legowo planting system

No.	Planting system comparison	MBCR value
1.	Jejer Manten vs. Jajar Tegel	6.32
2.	Jejer Manten vs. Jajar Legowo 2:1	8.18

Source: Data analyzed, 2016.

Fig. 5. Effect of variety on rice productivity (kg.ha⁻¹) in 2016

4. CONCLUSIONS

Jejer Manten's double-rows modification planting system showed higher growth and rice production than Jajar Tegel's and Jajar Legowo's during the three years of research. Jejer Manten's double rows modification planting system is more feasible than Jajar Tegel and Jajar Legowo's planting systems. In support of the food self-sufficiency program of Indonesia and increase rice productivity, it is necessary to apply new technology such as Jejer Manten double rows planting system that is easy to do and no extra charge for rice cultivation.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by the personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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