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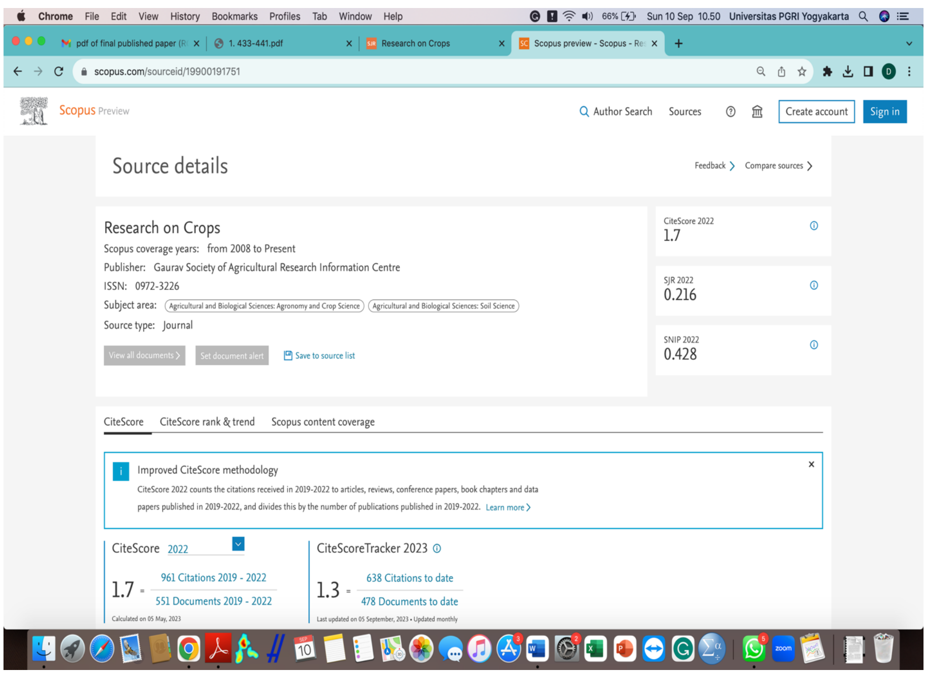

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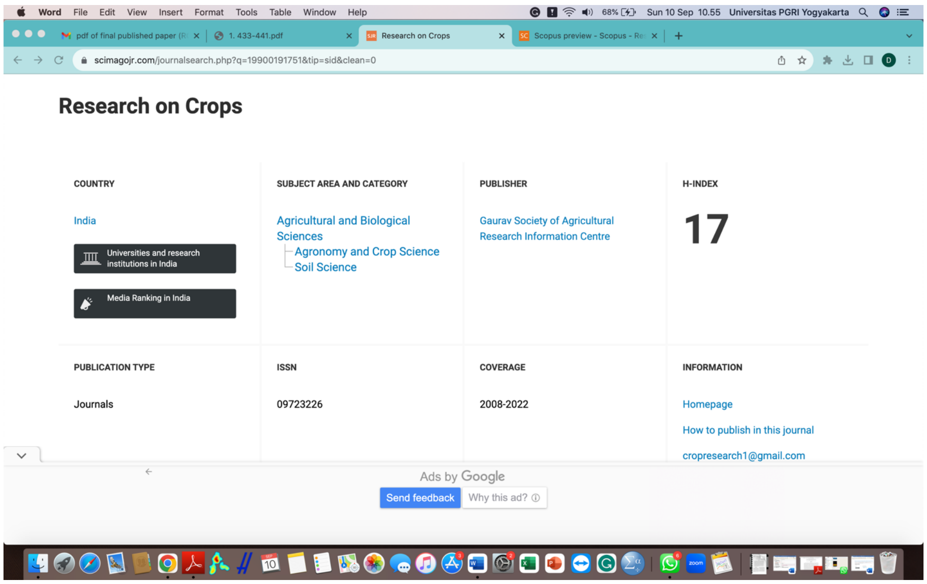

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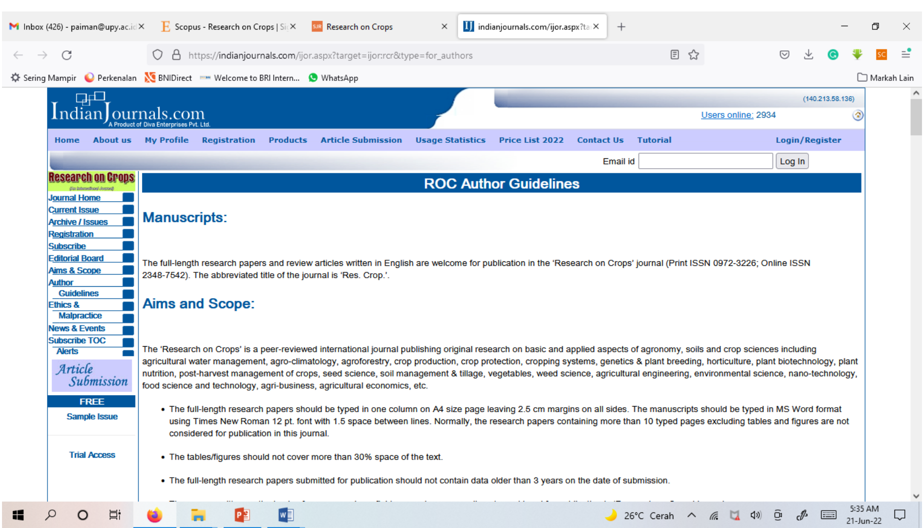

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COVER LETTER

To Research on Crops

Dear Editor,

I would like to send a **review article** entitled: “The Advantages of Jajar Legowo Planting System in Rice (Oryza sativa L.) Cultivation” for Research on Crops to consider. I confirm that this work is genuine and has not been published elsewhere, nor is it considered for publication elsewhere. We believe and hope that this manuscript is worthy of publication by Research on Crops. We are interested in publishing articles in this journal because it has an excellent reputation, so it is a matter of pride if published in Research on Crops. Here I attach the manuscript.

Thank you
Best regards,

Paiman
Universitas PGRI Yogyakarta, Indonesia

The Advantages of Jajar Legowo Planting System in Rice (Oryza sativa L.) Cultivation

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ABSTRACT

Rice is an important rice-producing crop for the staple food of the world population, especially in Indonesia. However, national rice production has not been able to meet food needs so rice imports are still needed. Mostly, farmers in Indonesia still use the traditional planting system, namely the Tegel planting system (TPS). New innovations are needed to increase rice production. One of the innovations is to modify the TPS which can provide higher rice yield. This new technology is called the "Jajar Legowo" planting system which is abbreviated "Jarwo" planting system (JPS). The JPS is starting to be developed in Indonesia, especially on Java Island. Therefore, this review article aimed to know the advantages of the JPS in rice cultivation compared to the TPS. The available literature reviewed suggested that there were several factors that support the success of the JPS in increasing rice yield, namely rice variety, rice fields, and plant spacing. The advantage of the JPS could inhibit weed growth in the soil surface around rice clumps. Besides, it could increase crop populations per hectare compared to the TPS. The literature reviewed shows that the JPS of the 2:1 type can give rice yield per hectare higher than the types of 3:1, 4:1, or others. Recommended plant spacing for use in JPS is 25 × 12.5 × 50 cm. Further, the review article has made a suggestion that the JPS of the 2:1 type can be applied in rice cultivation, especially in irrigated fields.

Key words : Jarwo planting system, rice fields, Tegel planting system, rice variety, plant spacing

Running headline: Jarwo planting system in rice cultivation

INTRODUCTION

Rice (*Oryza sativa* L.) is a rice-producing crop widely cultivated in Indonesia, especially on Java Island. Statistic data for 2013-2015 showed that the area of paddy fields in Java is 39.9% (3,223,503 ha) of the total area in Indonesia (8,087,393 ha) (Anonymous, 2015). Rice production is continuously increasing from year to year to meet national food needs. So far, farmers have used a Tegel planting system (TPS) in the form of boxes or tiles. In this system, the use of plant spacing between clumps is very regular. Rice cultivation with TPS can provide quite a high yield. However, rice yield needs to be improved again, and this traditional rice of TPS needs to be modified.

New innovations are needed to increase rice production. One of the innovations is to modify the TPS which can provide higher rice yield. This new technology is called the “Jajar Legowo” planting system which is abbreviated “Jarwo” planting system (JPS). The word “Jajar” means parallel (parallel rows of crops). The word “Legowo” comes from the words “lego” and “dowo”. The word “lego” means width (the spacing between rows of crops is wide), and the word “dowo” means long (rows of crops that are long). Words of Jajar Legowo, lego, and dowo are in Javanese. The JPS is a rice planting system with two or more rows of crops parallel and interspersed with one empty row. Between the clumps on the edge, the row is inserted into one plant. Two or more rows of crops and empty rows constitute one unit of Jarwo. A planting system that uses two rows of crops per unit of Jarwo is called JPS of 2:1 type, then if there are three rows of crops per unit of Jarwo is called JPS of 3:1 type, and so on. The JPS has long been introduced to farmers in Indonesia, but until now, only a few have implemented it correctly.

The JPS can increase the crop population dan rice yield per hectare. In addition, crop population can also suppress weed disturbances around cultivated crops. Therefore, the use of the right type of JPS needs to be known and applied to rice cultivation by farmers. Relating to the application of this new technology, several factors support the success of JPS, including rice variety, rice fields, and plant spacing.

Rice variety

The use of new superior varieties can increase rice yields in cultivation. Based on age, rice varieties can be classified into four groups, including long-life (> 151 days after sowing (DAS)), medium-life (125-150 DAS), short-life (105-124 DAS), and brief-life (90-104 DAS) (BBPPADI, 2016). Short to brief-life variety has a harvest age of < 124 DAS. Based on the age of the rice variety can be used to determine the plant spacing in JPS. If the life of the crops is short, it can be applied for tight spacing and vice versa.

In Indonesia, superior varieties with short life and high production are classified into two groups, including “Inbrida padi sawah irigasi” (Indonesian) is abbreviated Inpari or inbred rice irrigated fields (English). “Hibrida padi” (Indonesian) is abbreviated Hipa or hybrid rice (English).

The Inpari and Hipa varieties with short to brief life can be planted to increase the productivity of irrigated fields. The two groups of rice varieties are shown in Table 1.

Table 1. Inpari and Hipa varieties with short life and high production.

New superior varieties	Harvest age (DAS)	Potential yield (tons/ha)	Average yield (tons/ha)
Inpari 11	105	8.8	6.5
Inpari 13	99	8.0	6.6
Inpari 18	102	9.5	6.7
Inpari 19	102	9.5	6.7
Inpari Sidenuk	104	9.1	6.9
Inpari Padjajaran Agritan	105	11,0	7.8
Inpari Cakrabuana Agritan	104	10.2	7.5
HIPA 12 SBU	105	10.5	8.9
HIPA 13	105	9.9	7.5

Source: Suprihatno *et al*. (2009).

Table 1 shows that new superior varieties with a harvest age of 99-105 DAS had a potential yield of 6.5-8.9 tons/ha. Each of the new superior variety had different habitus and production properties. A large selection of the new superior varieties can be cultivated. Preferably, the choice of superior varieties was based on the soil fertility and water availability in the paddy fields. Inpari and Hipa varieties had a potential high yield to be cultivated in JPS types.

Hybrid varieties had a much higher weed competitiveness index than Inbrida (Ahmed *et al*., 2021). the production difference depends on each variety characteristic (Nestor *et al*., 2020). The use of competitive varieties was an effective and technically sustainable method of weed control (Nagargade *et al*., 2018). Biological management and regulation of weeds can be made by planting varieties that are more competitive on light (Perthame *et al*., 2022). Based on these literature sources, it shows that the use of hybrid varieties in JPS is more able to suppress weed growth than non-hybrid.

Rice fields type

The availability of water in rice fields will determine the choice of plant spacing in rice fields. Rainfed soil is better to use a tight spacing, on the contrary, the soil is ribbed with a wide spacing. Research results by Nwokwu (Nwokwu, 2015), plant spacing of 30 × 30 cm could provide the highest rice yield in irrigated fields. Meanwhile, the results of other studies show that a higher grain yield per hectare occurred at a plant spacing of 20 × 20 cm in wetland rice fields (Saju *et al*., 2019; Saju & Thavaprakaash, 2020). In contrast to the results of subsequent studies, it indicates that plant spacing affects rice growth and yield in paddy fields. Using wider plant spacing in irrigated fields is better because water availability supports rice growth. Waterlogging in the soil surface can suppress weed germination and growth. Preferably, closer plant spacing is better in rainfed fields than irrigated ones because of low water availability and dense weed growth. The use of wider or closer plant spacing needs appropriate with paddy fields in JPS types.

Plant spacing

The plant spacing factor will determine the weed species that grow in paddy fields. The use of wide planting distances will give weeds the opportunity to grow freely. The growth of weeds can be reduced by narrow plant spacing in rows. According to Thi *et al*. (2020), the yield loss caused by weeds depends on weed species and density, weed-rice associations, growth duration, and weed distribution. Added by Kashyap *et al*. (2022), weeds density and dry weight negatively correlated with rice yields, so more weed populations on paddy fields will decrease rice yield. The literature explained that the presence of weeds in paddy fields reduced rice growth and yield. The use of narrow plant spacing can suppress weed density and growth, but competition between crops is very high. To avoid competition, it can be anticipated by the spacing between rows is wide, and otherwise in rows is tightened. Therefore, it is necessary to determine the best JPS type with optimal plant spacing.

The literature review above shows that most previous studies still discuss TPS in traditional rice cultivation. In addition, the use of plant spacing from previous studies still varies. The rice yield per unit area is still low too. Therefore, there is a need for new technology to increase rice yield to meet national food needs. Research about the use of JPS has not been done by many researchers before. Information about the JPS for farmers is still limited. Therefore, a more detailed literature review is needed article review about the JPS. It is hoped that this review can contribute more complete information about the advantages of the JPS in rice cultivation in rice fields compared to the TPS. This literature review focuses more on the development of JPS on irrigated land. Therefore, this review article aimed to know the advantages of the JPS in rice cultivation compared to the TPS.

Differences in the Planting system

The difference between the JPS and TPS is the plant spacing used. TPS is a traditional rice planting system that has long been developed, but JPS is a new technology planting system from TPS modifications.

Tegel planting system

The floor planting system is a rice planting system with planting distances formed into boxes like tiles. The plant spacing used is usually 15 × 15 cm, 20 × 20 cm, 25 × 25 cm, or 30 × 30 cm. An optimal crop population was needed to maximize rice yield. In Indonesia, optimal plant spacing was recommended at 25 × 25 cm for irrigated fields. Strengthened research results by Anwari *et al*. (2019), a plant spacing of 25 × 25 cm produced the highest performance for most agro-morphological properties. The number of rice saplings and grains per panicle was high. Using a 25 × 25 cm plant spacing was the best and could provide maximum rice yield. The TPS with plant spacing of 25 × 25 cm can be seen in Fig. 1.

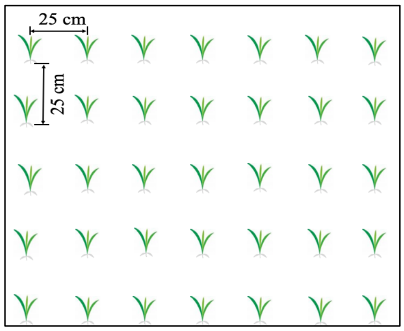

Fig. 1. The TPS with plant spacing of 25 × 25 cm.

Fig. 1 shows that TPS with 25 × 25 cm plant spacing could produce a rice crop population of 160,000 clumps/ha and the optimum plant spacing. This statement was supported by Daba and Mekonnen (2022), the inter-row plant spacing of 25 cm was an agronomically feasible and economic spacing for rice cultivation. Added support from Reuben *et al*. (2016), the optimum plant spacing of rice crops was found at 25 × 25 cm and gave the maximum yield per hectare.

Furthermore, some research results showed closer spacing in rows of 25 × 15 cm (direct seed planting system) and 20 × 10 cm (transplanting system) could result in higher production and minimal weed disturbance (Salma *et al*., 2017). It further explained that the planting density in the row could increase the grain produced from more panicles per unit (Hu *et al*., 2020). And further reinforced that the decrease in the density and dry weight of the maximum weed occurred at a row spacing of 15 cm (Ali *et al*., 2019), weed-free crops with a plant spacing of 25 × 15 cm could give rice yields higher. The spacing of 15 cm in a row was the best spacing (Islam *et al*., 2020). It can be summarized that the best spacing between rows was 25 cm and rows can be narrowed to 10-15 cm. Therefore, the TPS with a spacing of 25 × 25 cm can be changed into 25 × 12.5 cm.

Jarwo Planting system

The closer spacing could increase rice yields with higher resource usage efficiency (Htwe *et al*., 2021). Next, the TPS with 25 × 12.5 cm plant spacing could modify into 25 × 12.5 × 50 cm in JPS. It can explain that the number of 25 cm indicated the spacing between rows. The number of 12.5 cm was spacing in rows (border), while the number of 50 cm was an empty row (twice the width between rows).

The JPS is one of the planting systems in rice farming fields (Istiyanti, 2021). The closer spacing caused a lower leaf area per clump due to light, nutrients, and water limitations. At wide spacing, crops can capture more light because the shade effect between crops is less (Mondal *et al*., 2013) in TPS. Therefore it needs to be modified with JPS. In JPS, the closer spacing in rows was more advantageous, as long as the spacing between rows was loose. There are several types of JPS have been developed in Indonesia, including 2:1 (consisting of two rows of crops and one row without crops), 3:1 (consisting of three rows of crops and one row without crops), and 4:1 (consisting of four rows of crops and one row without crops).

As an illustration, the JPS of 2:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 2.

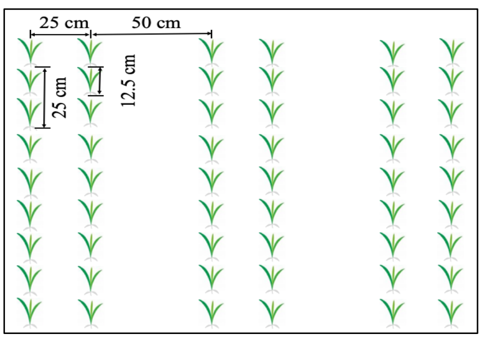

Fig. 2. The JPS of 2:1 type with a plant spacing of 25 × 12.5 × 50 cm.

Fig. 2 explains the planting system where the spacing between rows and in rows of crops is 25 and 12.5 cm, then there is one empty row (without crops). the JPS of 2:1 type with 25 × 12.5 × 50 cm produced more crop populations (192,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 32%. The crop population higher per unit area effectively increased rice yield and suppressed weeds' dry weight. According to Abdulrachman *et al*. (2012), the JPS of 2:1 type with a spacing of 25 × 12.5 × 50 cm could increase rice yield between 9.63-15.44% compared to the TPS. Supported by Kurniawan *et al*. (2021), the JPS had a noticeable effect on the number of saplings at the age of 55 DAP, the panicle's length, and the dry yield grain harvested.

For more details, the JPS of 3:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 3.

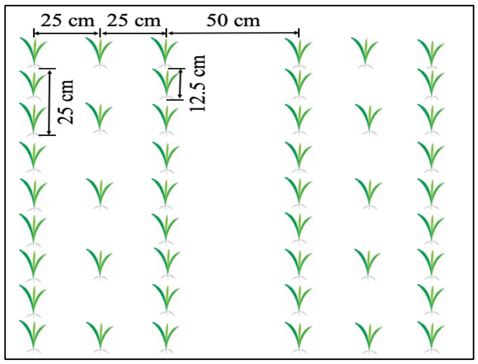

Fig. 3. The JPS of 3:1 type with a plant spacing of 25 × 12.5 × 50 cm.

Fig. 3 shows that the spacing between rows is 25 cm. For the spacing in rows, one row in the middle used a spacing of 25 cm, while in both rows at the border with a spacing of 12.5 cm, then there was one empty row (without crops). The JPS of 3:1 type with 25 × 12.5 × 50 cm produced more crop populations (184,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 15%.

To be able to facilitate understanding of the JPS of 4:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 4.

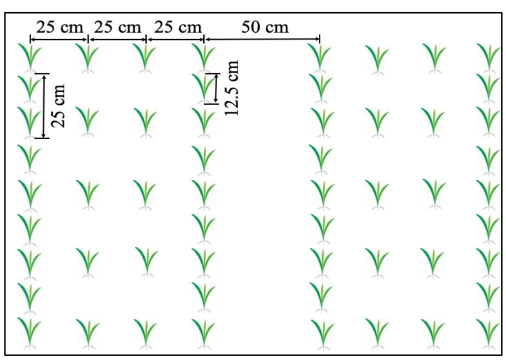

Fig. 4. The JPS of 4:1 type with a plant spacing of 25 × 12.5 × 50 cm.

Fig. 4 shows that the spacing between rows is 25 cm. For the spacing in rows, two rows in the middle used a spacing of 25 cm, while in both rows at the border with a spacing of 12.5 cm, then there was one empty row (without crops). The JPS of 4:1 type with 25 × 12.5 × 50 cm produced more crop populations (179,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 11.87%.

Of the three types of JPS, it can be explained that the highest rice yield was found in the JPS of 2:1 type because two rows of existing crops act as border crops. All crops will get a better microclimate. The growing weeds in rows could suppress due to the spacing in closer rows. The JPS types of 3:1 and 4:1 show that the crop population per unit area was decreasing, Furthermore, rice yield decreased and weed growth increased.

Advantages of Jarwo Planting System

Currently, the JPS has begun to be developed by farmers and provides higher rice yield than the TPS by increasing the crop population per unit area. In addition, this planting system can facilitate the control of pests, diseases, weeds, and fertilization. Mainly, the advantages of JPS are minimizing weed competition and increasing rice yield per hectare.

Minimizing the weed competition

Weed disturbances always appear in the cultivation of crops, especially rice. A closer plant spacing could suppress weed growth, but weeding was still necessary. Weeding could reduce weed density and dry weight (Kuotsu & Singh, 2020). The closer spacing in rows has not been a concern for farmers. Using rice crops as weed competitors was a very environmentally friendly weed management approach (Ramesh *et al*., 2017). The use of closer plant spacing in rows can be used as an integrated weed management program (Sunyob *et al*., 2012). The JPS can control weeds through the use of closer spacing in rows. The rice canopy has a role in reducing the beam of light to the soil surface. Canopy shading can suppress weed growth.

The quality and quantity of rice yields could improve by reducing weed competition (Antralina *et al*., 2015). The presence of weed growth could loss of 50–60% of rice yield (transplanting systems) and 70–80% (direct-seed planting systems) (Dass *et al*., 2017). It further explained that uncontrolled weed growth could decrease grain yield by 30-36% in rice with a transplanting system (Kumar *et al*., 2018). Furthermore, uncontrolled weeds in paddy fields could reduce yields by up to 75% on direct seed planting systems (Shekhawat *et al*., 2020). Weed could cause 57% of rice grain yield to decline in the direct seed planting system (Malik *et al*., 2021). It was quite clear that the presence of weeds greatly reduced rice yields in rice fields. Therefore, using JPS could suppress weed growth in rows, except in one empty row (without crops). The closer plant spacing in rows could reduce the weed dry weight and increase rice yield. JPS with closer plant spacing had an important role in minimizing weed competition.

The JPS can provide a different space than the TPS to get sunlight. The crop absorbed more sunlight, so photosynthesis proceeds smoothly, and then carbohydrate was produced (Susilastuti *et al*., 2018). The quality of light affected the level of CO_2 assimilation. Differences in the penetration of light quality in leaves and absorption by photosystems changed the rate of CO_2 assimilation in C_3 weed that grew under rice canopy (Sun *et al*., 2012). The weed species of *Commelina benghalensis* and *Cyperus rotundus* experience a noticeable increase in leaf area (161 and 46%, respectively) if they grew in the shade. Likewise, the thickness of the leaves in both types of weeds has decreased (Santos *et al*., 2015). Closer plant spacing in rows can block the radiance of sunlight to the soil surface so that weeds are depressed because of less sunlight. However, weeds still get sunlight, especially in empty rows only at the beginning of the growth of rice growth.

The use of superior varieties could contribute to managing weeds (Colbach *et al*., 2019). The rice canopy density affected the photomorphogenic of ultraviolet-B (UV-B, 280-320 nm) and will change the placement of the leaves. Furthermore, it will affect the light competition (Barnes *et al*., 1990). In reality, the height of *Phalaris minor* significantly increased as a result of shading. The total dry matter accumulation decreased by more than 80% under the shade (Mishra *et al*., 2020). The reduction of weed dry matter due to greater shading was used for roots and reproductive structures than the vegetation shoot tissues (Begna *et al*., 2002). The light availability affects weed growth. Weeds shaded by the rice canopy will be impaired in development. Furthermore, weeds are depressed in growth, unable to produce seeds, and will even die.

The most productive weeds in paddy fields used the C_4 photosynthesis pathway which had a higher potential efficiency in using light, water, and nitrogen than C_3 weeds (Nakamura *et al*., 2011). The main difference between the photosynthesis pathways of C_3 and C_4 was saving on carbon, water, and nitrogen (Lattanzi, 2010). This suggests that C_4 weeds will grow well if they get whole light during their growth. If a rice canopy shaded weeds, the weed will be depressed in growth. Unlike the C_3 weed, its growth will be better with non-full light. C_3 weeds can survive under rice canopy shading. A dense and even crop canopy can suppress the weed growth under it. However, C_3 weeds will be able to survive compared to C_4 under the shade of a crop canopy.

Increasing the rice yield per hectare

The rice canopy has an important role in capturing sunlight. The light intensity increase noticeably increases the leaves' orientation towards sunlight, thereby increasing the capacity of the photosynthesis (Tang *et al*., 2022). Furthermore, the results showed that the JPS can increase rice yield compared to the JPS. The JPS of the 2:1 type provided the best results on crop height, number of saplings, and grain yield per unit area (Megasari *et al*., 2021). Technological engineering with the JPS of 2:1 type could produce a higher rice yield (7-8 tons/ha) than the JPS (only 4-5 tons/ha) (Muslimin *et al*., 2021). Next, the resulting study shows that the highest rice production was found in the JPS of 2:1 (6.57 tons/ha) compared to the JPS of 4:1 type (5.57 tons/ha) and TPS (5.09 tons/ha) (Giamerti & Yursak, 2013). The JPS of 2:1 type has advantages over other types of JPS and TPS. The insertion of rice clumps into border crops in rows can increase the plant population per hectare. Rice crops in the edge rows still get a good microclimate so that they can produce optimally. The rice yield obtained in JPS of 4:1 type is lower than JPS 2:1 type because the crop population per hectare is lower.

The JPS implementation could increase rice production by 34.7 and 35.5% in 2019 and 2020 compared to TPS (Kusumawati *et al*., 2022). Furthermore, the JPS could increase rice production by up to 33.07% compared to the TPS. The revenue/cost (R/C) value of the JPS was obtained at 1.87. The JPS could benefit farmers' (Rawung *et al*., 2021). The increasing rice production in the JPS of 2:1 type was more significant because there was an increase in the rice clumps number per unit area and more edge crops. The rice clumps on the border in the row had better growth and development than those in the middle row. Border crops get more light intensity. These conditions will lead to higher rice yield and grain quality. Using GPS can provide higher benefits for rice farmers than TPS.

CONCLUSION

The available literature reviewed suggested that there were several factors that support the success of the JPS in increasing rice yield, namely rice variety, rice fields, and plant spacing. The advantage of the JPS could inhibit weed growth in the soil surface around rice clumps. Besides, it could increase crop populations per hectare compared to the TPS. The literature reviewed shows that the JPS of the 2:1 type can give rice yield per hectare higher than the types of 3:1, 4:1, or others. Recommended plant spacing for use in JPS is 25 × 12.5 × 50 cm. Further, the review article has made a suggestion that the JPS of the 2:1 type can be applied in rice cultivation, especially in irrigated fields.

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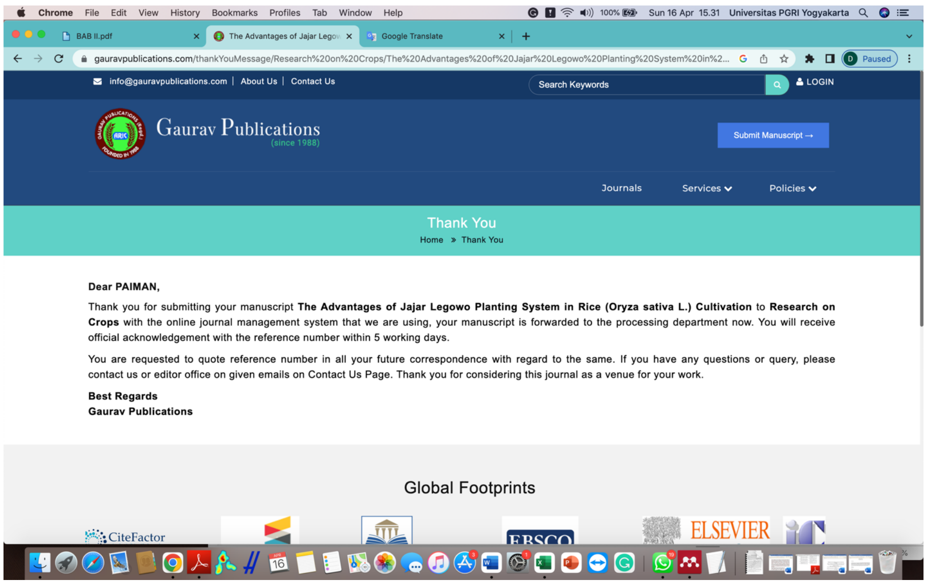

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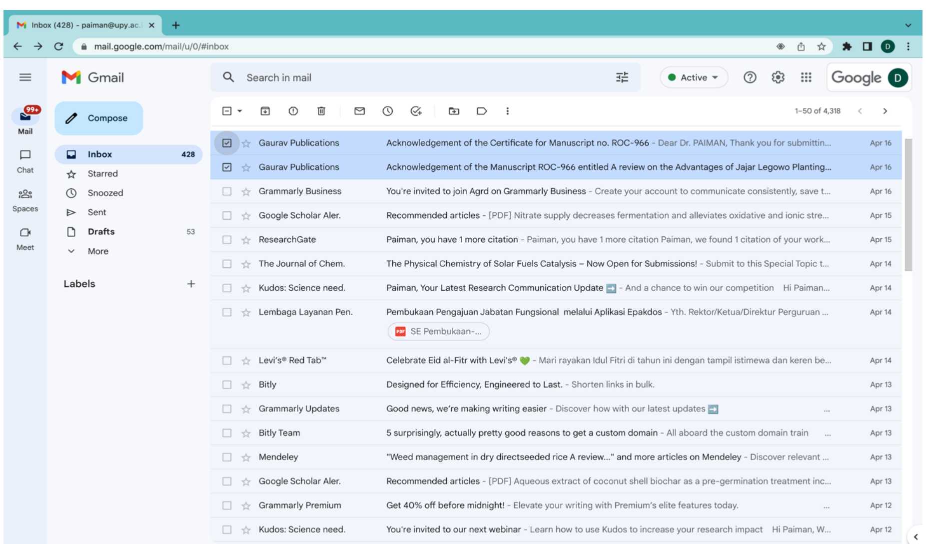

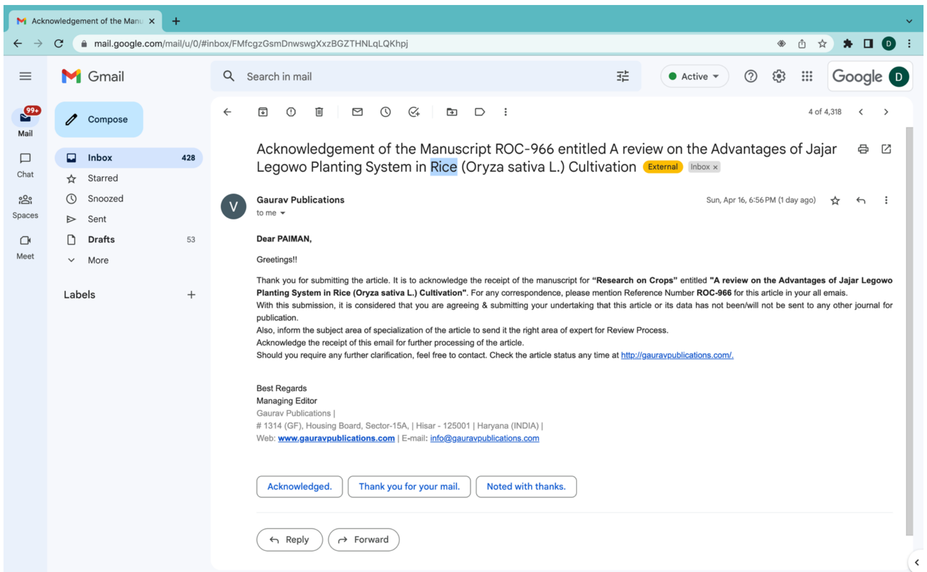

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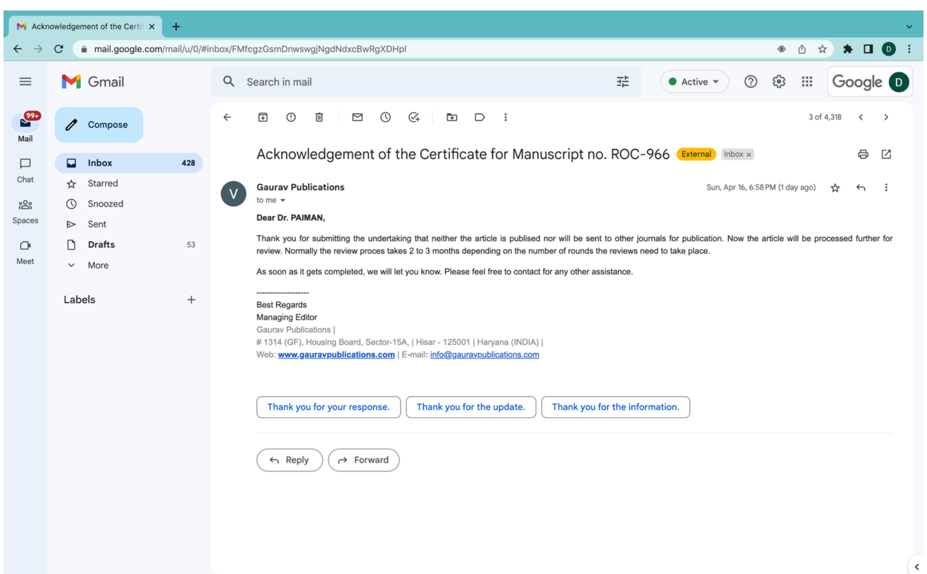

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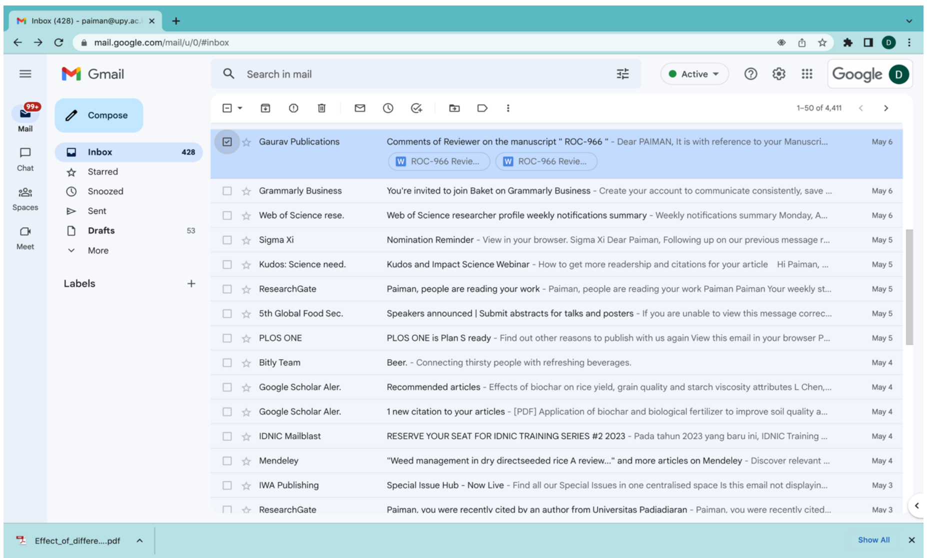

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A review on the advantages of Jajar Legowo planting system in rice (*Oryza sativa* L.) Cultivation

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ABSTRACT

Rice is an important crop for producing the staple food of the world's population, especially in Indonesia. However, national rice production has not been able to meet food needs so rice imports are still needed. Mostly, farmers in Indonesia still use the traditional planting system, namely the Tegel planting system (TPS). New innovations are needed to increase rice production. One of the innovations is to modify the TPS which can provide higher rice yield. This new technology is called the "Jajar Legowo" planting system which is abbreviated "Jarwo" planting system (JPS). This technology can increase a higher rice production than the conventional system. The JPS has been developed in Indonesia, but until now many farmers do not know the advantages of this technology. Therefore, this review article aimed to know the advantages of the JPS in rice cultivation compared to the TPS. Based on the literature available, there are several factors that support the success of the JPS in increasing rice yield, namely rice variety, rice fields, and plant spacing. The JPS of 2:1, 3:1, and 4:1 with a plant spacing of 25 × 12.5 × 50 cm could increase crop populations per hectare by 32%, 15%, and 11.87%, respectively than TPS with a plant spacing of 25 × 25 cm. The advantage of the JPS is that it could inhibit weed growth in the soil surface around rice clumps. Besides, increase in crop populations per hectare attainable compared to the TPS. The literature reviewed, JPS of the 2:1 type can give rice yield per hectare higher than the types of 3:1, 4:1, or others. Recommended plant spacing for use in JPS is 25 × 12.5 × 50 cm. Further, the review article has made a suggestion that the JPS of the 2:1 type can be applied in rice cultivation, especially in irrigated fields.

Key words : Jarwo planting system, rice fields, Tegel planting system, rice variety, plant spacing

INTRODUCTION

Rice (*Oryza sativa* L.) is a rice-producing crop widely cultivated in Indonesia, especially on Java Island. Statistic data for 2013-2015 showed that the area of paddy fields in Java is 39.9% (3,223,503 ha) of the total area in Indonesia (8,087,393 ha) (Anonymous, 2015). Rice production is continuously increasing from year to year to meet national food needs. So far, farmers have used a Tegel planting system (TPS) in the form of boxes or tiles. In this system, the use of plant spacing between clumps is very regular. Rice cultivation with TPS can provide quite a high yield. However, rice yield needs to be improved again, and this traditional rice of TPS needs to be modified.

New innovations are needed to increase rice production. One of the innovations is to modify the TPS which can provide higher rice yield. This new technology is called the "Jajar Legowo" planting system which is abbreviated "Jarwo" planting system (JPS). The word "Jajar" means parallel (parallel rows of crops). The word "Legowo" comes from the words "lego" and "dowo". The word "lego" means width (the spacing between rows of crops is wide), and the word "dowo" means long (rows of crops that are long). Words of Jajar Legowo, lego, and dowo are in Javanese. The JPS is a rice planting system with two or more rows of crops parallel and interspersed with one empty row. Between the clumps on the edge, the row is inserted into one plant. Two or more rows of crops and empty rows constitute one unit of Jarwo. A planting system that uses two rows of crops per unit of Jarwo is called JPS of 2:1 type, then if there are three rows of crops per unit of Jarwo is called JPS of 3:1 type, and so on. The JPS has long been introduced to farmers in Indonesia, but until now, only a few have implemented it correctly.

The JPS can increase the crop population dan rice yield per hectare. In addition, crop population can also suppress weed disturbances around cultivated crops. Therefore, the use of the right type of JPS needs to be known and applied to rice cultivation by farmers. Relating to the application of this new technology, there are several factors that support the success of JPS, including rice variety, rice fields, and plant spacing.

Rice variety

The use of new superior varieties can increase rice yields in cultivation. Based on age, rice varieties can be classified into four groups, including long-life (> 151 days after sowing (DAS)), medium-life (125-150 DAS), short-life (105-124 DAS), and brief-life (90-104 DAS) (BBPPADI, 2016). Short to brief-life variety has a harvest age of < 124 DAS. Based on the age of the rice variety can be used to determine the plant spacing in JPS. If the life of the crops is short, it can be applied for tight spacing and vice versa.

In Indonesia, superior varieties with short life and high production are classified into two groups, including "Inbrida padi sawah irigasi" (Indonesian) is abbreviated Inpari or inbred rice irrigated fields (English). "Hibrida padi" (Indonesian) is abbreviated Hipa or hybrid rice (English). The Inpari and Hipa varieties with short to brief life can be planted to increase the productivity of irrigated fields. The two groups of rice varieties are shown in Table 1.

Table 1 shows that new superior varieties of crop duration of 99-105 DAS with potential yield of 6.5-8.9 tons/ha. Each of the new superior variety had different habitus and production properties. A large selection of the new superior varieties can be cultivated. Preferably, the choice of superior varieties was based on the soil fertility and water availability in the paddy fields. Inpari and Hipa varieties had a potential high yield to be cultivated in JPS types.

Hybrid varieties had a much higher weed competitiveness index than Inbrida (Ahmed *et al*., 2021). the production difference depends on each variety characteristic (Nestor *et al*., 2020). The use of competitive varieties was an effective and technically sustainable method of weed control (Nagargade *et al*., 2018). Biological management and regulation of weeds can be made by planting varieties that are more competitive on light (Perthame *et al*., 2022). Based on these literature sources, it shows that the use of hybrid varieties in JPS is more able to suppress weed growth than non-hybrid.

Rice fields type

The availability of water in rice fields will determine the choice of plant spacing in rice fields. Rainfed soil is better to use a tight spacing, on the contrary, the soil is ribbed with a wide spacing. Research results by Nwokwu (Nwokwu, 2015), plant spacing of 30 × 30 cm could provide the highest rice yield in irrigated fields. Meanwhile, the results of other studies show that a higher grain yield per hectare occurred at a plant spacing of 20 × 20 cm in wetland rice fields (Saju *et al*., 2019; Saju & Thavaprakaash, 2020). In contrast to the results of subsequent studies, it indicates that plant spacing affects rice growth and yield in paddy fields. Using wider plant spacing in irrigated fields is better because water availability supports rice growth. Waterlogging in the soil surface can suppress weed germination and growth. Preferably, closer plant spacing is better in rainfed fields than irrigated ones because of low water availability and dense weed growth. The use of wider or closer plant spacing needs appropriate with paddy fields in JPS types.

Plant spacing

The plant spacing factor will determine the weed species that grow in paddy fields. The use of wide planting distances will give weeds the opportunity to grow freely. The growth of weeds can be reduced by narrow plant spacing in rows. According to Thi *et al*. (2020), the yield loss caused by weeds depends on weed species and density, weed-rice associations, growth duration, and weed distribution. Added by Kashyap *et al*. (2022), weeds density and dry weight negatively correlated with rice yields, so more weed populations on paddy fields will decrease rice yield. The literature explained that the presence of weeds in paddy fields reduced rice growth and yield. The use of narrow plant spacing can suppress weed density and growth, but competition between crops is very high. To avoid competition, it can be anticipated by the spacing between rows is wide, and otherwise in rows is tightened. Therefore, it is necessary to determine the best JPS type with optimal plant spacing.

The literature review above shows that most previous studies still discuss TPS in traditional rice cultivation. In addition, the use of plant spacing from previous studies still varies. The rice yield per unit area is still low too. Therefore, there is a need for new technology to increase rice yield to meet national food needs. Research about the use of JPS has not been done by many researchers before. Information about the JPS for farmers is still limited. Therefore, a more detailed literature review is needed article review about the JPS. It is hoped that this review article can contribute more complete information about the advantages of the JPS in rice cultivation in rice fields compared to the TPS. This literature review focuses more on the development of JPS in irrigated fields. Therefore, this review article aimed to know the advantages of the JPS in rice cultivation compared to the TPS.

Differences in the Planting system

The difference between the JPS and TPS is the plant spacing used. TPS is a traditional rice planting system that has long been developed, but JPS is a new technology planting system from TPS modifications.

Tegel planting system

The floor planting system is a rice planting system with planting distances formed into boxes like tiles. The plant spacing used is usually 15 × 15 cm, 20 × 20 cm, 25 × 25 cm, or 30 × 30 cm. An optimal crop population was needed to maximize rice yield. In Indonesia, optimal plant spacing was recommended at 25 × 25 cm for irrigated fields. Strengthened research results by Anwari *et al*. (2019), a plant spacing of 25 × 25 cm produced the highest performance for most agro-morphological properties. The number of rice saplings and grains per panicle was high. Using a 25 × 25 cm plant spacing was the best and could provide maximum rice yield (Fig. 1).

Fig. 1 shows that between row to row and plant to plant used the same spacing, and it is called square or tile planting. TPS with 25 × 25 cm plant spacing could produce a rice crop population of 160,000 clumps/ha and the optimum plant spacing. This statement was supported by Daba and Mekonnen (2022), the inter-row plant spacing of 25 cm was an agronomically feasible and economic spacing for rice cultivation. Added support from Reuben *et al*. (2016), the optimum plant spacing of rice crops was found at 25 × 25 cm and gave the maximum yield per hectare.

Furthermore, some research results showed closer spacing in rows of 25 × 15 cm (direct seed planting system) and 20 × 10 cm (transplanting system) could result in higher production and minimal weed disturbance (Salma *et al*., 2017). It further explained that the planting density in the row could increase the grain produced from more panicles per unit (Hu *et al*., 2020) and further reinforced that the decrease in the density and dry weight of the maximum weed occurred at a row spacing of 15 cm (Ali *et al*., 2019), weed-free crops with a plant spacing of 25 × 15 cm could give rice yields higher. The spacing of 15 cm in a row was the best spacing (Islam *et al*., 2020). It can be summarized that the best spacing between rows was 25 cm and rows can be narrowed to 10-15 cm. Therefore, the TPS with a spacing of 25 × 25 cm can be changed into 25 × 12.5 cm.

Jarwo Planting system

The closer spacing could increase rice yields with higher resource usage efficiency (Htwe *et al*., 2021). Next, the TPS with 25 × 12.5 cm plant spacing could modify into 25 × 12.5 × 50 cm in JPS. It can explain that the number of 25 cm indicated the spacing between rows. The number of 12.5 cm was spacing in rows (edge), while the number of 50 cm was an empty row (twice the width between rows).

The JPS is one of the planting systems in rice farming fields (Istiyanti, 2021). The closer spacing caused a lower leaf area per clump due to light, nutrients, and water limitations. At wide spacing, crops can capture more light because the shade effect between crops is less (Mondal *et al*., 2013) in TPS. Therefore, it needs to be modified with JPS. In JPS, the closer spacing in rows was more advantageous, as long as the spacing between rows was loose. There are several types of JPS have been developed in Indonesia, including 2:1 (consisting of two rows of crops and one row without crops), 3:1 (consisting of three rows of crops and one row without crops), and 4:1 (consisting of four rows of crops and one row without crops).

As an illustration, the JPS of 2:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 2.

Fig. 2 explains the planting system where the spacing between rows and in rows of crops is 25 and 12.5 cm, then there is one empty row (without crops). the JPS of 2:1 type with 25 × 12.5 × 50 cm produced more crop populations (192,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 32%. The crop population higher per unit area effectively increased rice yield and suppressed weeds' dry weight. According to Abdulrachman *et al*. (2012), the JPS of 2:1 type with a spacing of 25 × 12.5 × 50 cm could increase rice yield between 9.63-15.44% compared to the TPS. Supported by Kurniawan *et al*. (2021), the JPS had a noticeable effect on the number of saplings at the age of 55 DAP, the panicle's length, and the dry yield grain harvested.

For more details, the JPS of 3:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 3.

Fig. 3 shows that the spacing between rows is 25 cm. For the spacing in rows, one row in the middle used a spacing of 25 cm, while in both rows at the edge with a spacing of 12.5 cm, then there was one empty row (without crops). The JPS of 3:1 type with 25 × 12.5 × 50 cm produced more crop populations (184,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 15%.

To be able to facilitate understanding of the JPS of 4:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 4.

Fig. 4 shows that the spacing between rows is 25 cm. For the spacing in rows, two rows in the middle used a spacing of 25 cm, while in both rows at the edge with a spacing of 12.5 cm, then there was one empty row (without crops). The JPS of 4:1 type with 25 × 12.5 × 50 cm produced more crop populations (179,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 11.87%.

Of the three types of JPS, it can be explained that the highest rice yield was found in the JPS of 2:1 type because two rows have a loose growing space. All crops will get a better microclimate. The growing weeds in rows could suppress due to the spacing in closer rows. The JPS types of 3:1 and 4:1 show that the crop population per unit area was decreasing, Furthermore, rice yield decreased and weed growth increased.

Advantages of Jarwo Planting System

Currently, the JPS has begun to be developed by farmers and provides higher rice yield than the TPS by increasing the crop population per unit area. In addition, this planting system can facilitate the control of pests, diseases, weeds, and fertilization. Mainly, the advantages of JPS are minimizing weed competition and increasing rice yield per hectare.

Minimizing the weed competition

Weed disturbances always appear in the cultivation of crops, especially rice. A closer plant spacing could suppress weed growth, but weeding was still necessary. Weeding could reduce weed density and dry weight (Kuotsu & Singh, 2020). The closer spacing in rows has not been a concern for farmers. Using rice crops as weed competitors was a very environmentally friendly weed management approach (Ramesh *et al*., 2017). The use of closer plant spacing in rows can be used as an integrated weed management program (Sunyob *et al*., 2012). The JPS can control weeds through the use of closer spacing in rows. The rice canopy has a role in reducing the beam of light to the soil surface. Canopy shading can suppress weed growth.

The quality and quantity of rice yields could improve by reducing weed competition (Antralina *et al*., 2015). The presence of weed growth could loss of 50–60% of rice yield (transplanting systems) and 70–80% (direct-seed planting systems) (Dass *et al*., 2017). It further explained that uncontrolled weed growth could decrease grain yield by 30-36% in rice with a transplanting system (Kumar *et al*., 2018). Furthermore, uncontrolled weeds in paddy fields could reduce yields by up to 75% on direct seed planting systems (Shekhawat *et al*., 2020). Weed could cause 57% of rice grain yield to decline in the direct seed planting system (Malik *et al*., 2021). It was quite clear that the presence of weeds greatly reduced rice yields in rice fields. Therefore, using JPS could suppress weed growth in rows, except in one empty row (without crops). The closer plant spacing in rows could reduce the weed dry weight and increase rice yield. JPS with closer plant spacing had an important role in minimizing weed competition.

The JPS can provide a different space than the TPS to get sunlight. The crop absorbed more sunlight, so photosynthesis proceeds smoothly, and then carbohydrate was produced (Susilastuti *et al*., 2018). The quality of light affected the level of CO_2 assimilation. Differences in the penetration of light quality in leaves and absorption by photosystems changed the rate of CO_2 assimilation in C_3 weed that grew under rice canopy (Sun *et al*., 2012). The weed species of *Commelina benghalensis* and *Cyperus rotundus* experience a noticeable increase in leaf area (161 and 46%, respectively) if they grew in the shade. Likewise, the thickness of the leaves in both types of weeds has decreased (Santos *et al*., 2015). Closer plant spacing in rows can block the radiance of sunlight to the soil surface so that weeds are depressed because of less sunlight. However, weeds still get sunlight, especially in empty rows only at the initial of the growth of rice growth.

The use of superior varieties could contribute to managing weeds (Colbach *et al*., 2019). The rice canopy density affected the photomorphogenic of ultraviolet-B (UV-B, 280-320 nm) and will change the placement of the leaves. Furthermore, the change in light quality represented under shading (Chen et al., 2019). In reality, the height of *Phalaris minor* significantly increased as a result of shading. The total dry matter accumulation decreased by more than 80% under the shade (Mishra *et al*., 2020). The reduction of weed dry matter due to greater shading was used for roots and reproductive structures than the vegetation shoot tissues (Begna *et al*., 2002). The light availability affects weed growth. Weeds shaded by the rice canopy will be impaired in development. Furthermore, weeds are depressed in growth, unable to produce seeds, and will even die.

The most productive weeds in paddy fields used the C_4 photosynthesis pathway which had a higher potential efficiency in using light, water, and nitrogen than C_3 weeds (Nakamura *et al*., 2011). The main difference between the photosynthesis pathways of C_3 and C_4 was saving on carbon, water, and nitrogen (Lattanzi, 2010). This suggests that C_4 weeds will grow well if they get whole light during their growth. If a rice canopy shaded weeds, the weed will be depressed in growth. Unlike the C_3 weed, its growth will be better with non-full light. C_3 weeds can survive under rice canopy shading. A dense and even crop canopy can suppress the weed growth under it. However, C_3 weeds will be able to survive compared to C_4 under the shade of a crop canopy.

Increasing the rice yield per hectare

The rice canopy has an important role in capturing sunlight. The light intensity increase noticeably increases the leaves' orientation towards sunlight, thereby increasing the capacity of the photosynthesis (Tang *et al*., 2022). Furthermore, the results showed that the JPS can increase rice yield compared to the JPS. The JPS of the 2:1 type provided the best results on crop height, number of saplings, and grain yield per unit area (Megasari *et al*., 2021). Technological engineering with the JPS of 2:1 type could produce a higher rice yield (7-8 tons/ha) than the JPS (only 4-5 tons/ha) (Muslimin *et al*., 2021). Next, the resulting study shows that the highest rice production was found in the JPS of 2:1 (6.57 tons/ha) compared to the JPS of 4:1 type (5.57 tons/ha) and TPS (5.09 tons/ha) (Giamerti & Yursak, 2013). The JPS of 2:1 type has advantages over other types of JPS and TPS. The insertion of rice clumps into edge crops in rows can increase the plant population per hectare. Rice crops in the edge rows still get a good microclimate so that they can produce optimally. The rice yield obtained in JPS of 4:1 type is lower than JPS 2:1 type because the crop population per hectare is lower.

The JPS implementation could increase rice production by 34.7 and 35.5% in 2019 and 2020 compared to TPS (Kusumawati *et al*., 2022). Furthermore, the JPS could increase rice production by up to 33.07% compared to the TPS. The revenue/cost (R/C) value of the JPS was obtained at 1.87. The JPS could benefit farmers' (Rawung *et al*., 2021). The increasing rice production in the JPS of 2:1 type was more significant because there was an increase in the rice clumps number per unit area and more edge crops. The rice clumps on the edge in the row had better growth and development than those in the middle row. Edge crops get more light intensity. These conditions will lead to higher rice yield and grain quality. Using JPS can provide higher benefits for rice farmers than TPS.

CONCLUSION

The literature available suggested that there are several factors that support the success of the JPS in increasing rice yield, namely rice variety, rice fields, and plant spacing. The JPS of 2:1, 3:1, and 4:1 with a plant spacing of 25 × 12.5 × 50 cm could increase crop populations per hectare by 32%, 15%, and 11.87%, respectively than TPS with a plant spacing of 25 × 25 cm. The advantage of the JPS is that it could inhibit weed growth in the soil surface around rice clumps. Besides, increase in crop populations per hectare compared to the TPS. The literature reviewed, the JPS of the 2:1 type can give rice yield per hectare higher than the types of 3:1, 4:1, or others. Recommended plant spacing for use in JPS is 25 × 12.5 × 50 cm. Further, the review article has made a suggestion that the JPS of the 2:1 type can be applied in rice cultivation, especially in irrigated fields.

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Table 1. Inpari and Hipa varieties with short life and high production.

New superior varieties	Harvest age (DAS)	Potential yield (t/ha)	Average yield (t/ha)
Inpari 11	105	8.8	6.5
Inpari 13	99	8.0	6.6
Inpari 18	102	9.5	6.7
Inpari 19	102	9.5	6.7
Inpari Sidenuk	104	9.1	6.9
Inpari Padjajaran Agritan	105	11,0	7.8
Inpari Cakrabuana Agritan	104	10.2	7.5
HIPA 12 SBU	105	10.5	8.9
HIPA 13	105	9.9	7.5

Source: Suprihatno *et al*. (2009).

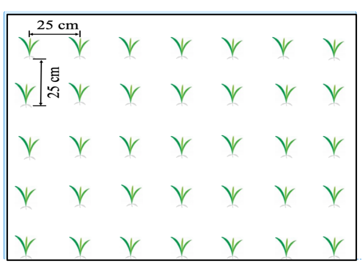

Fig. 1. The TPS with plant spacing of 25 × 25 cm.

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Check if row to row and plant to plant spacing same, since, it is square planting.

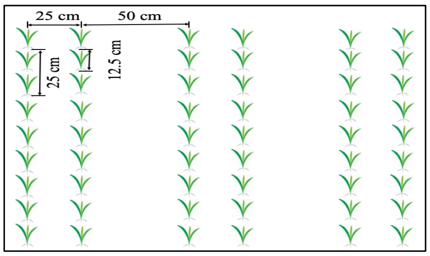

Fig. 2. The JPS of 2:1 type with a plant spacing of 25 × 12.5 × 50 cm.

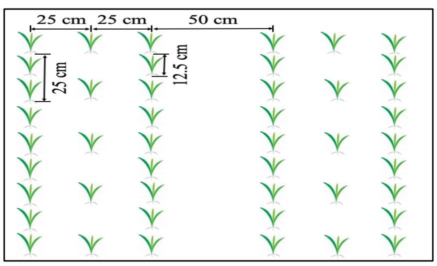

Fig. 3. The JPS of 3:1 type with a plant spacing of 25 × 12.5 × 50 cm.

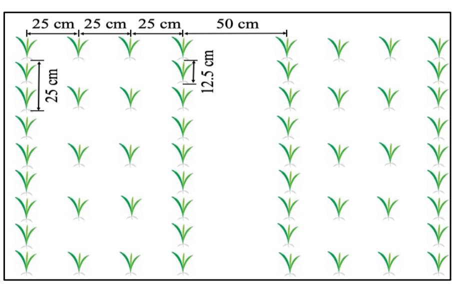

Fig. 4. The JPS of 4:1 type with a plant spacing of 25 × 12.5 × 50 cm.

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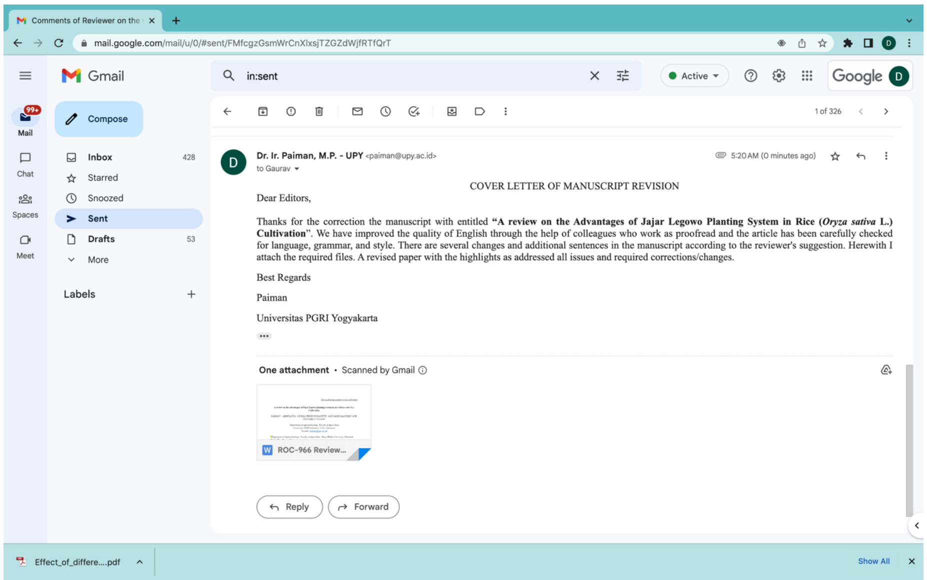

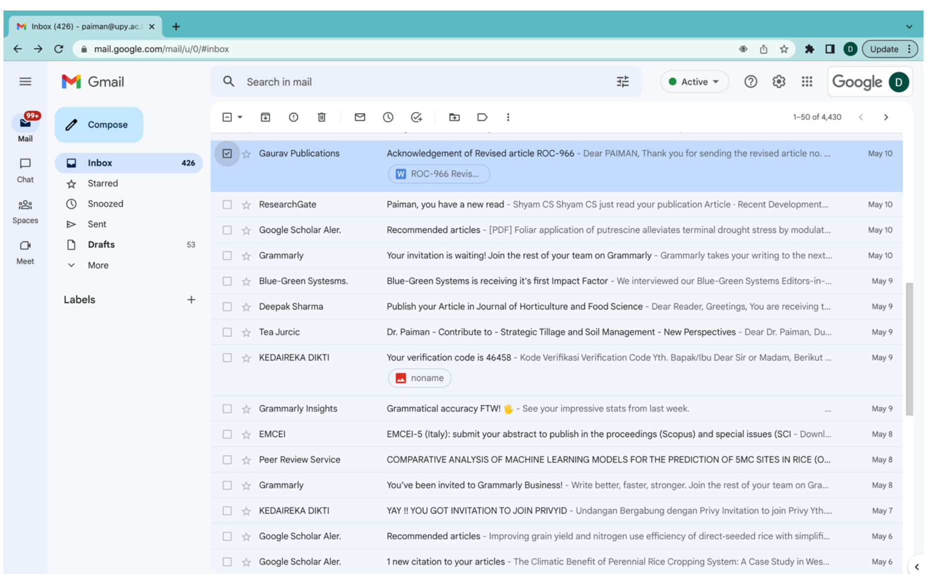

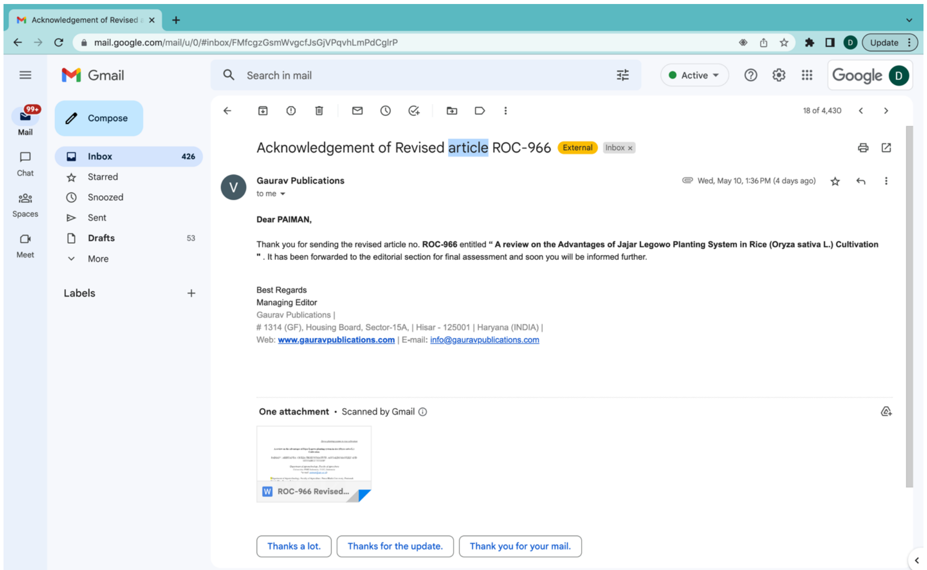

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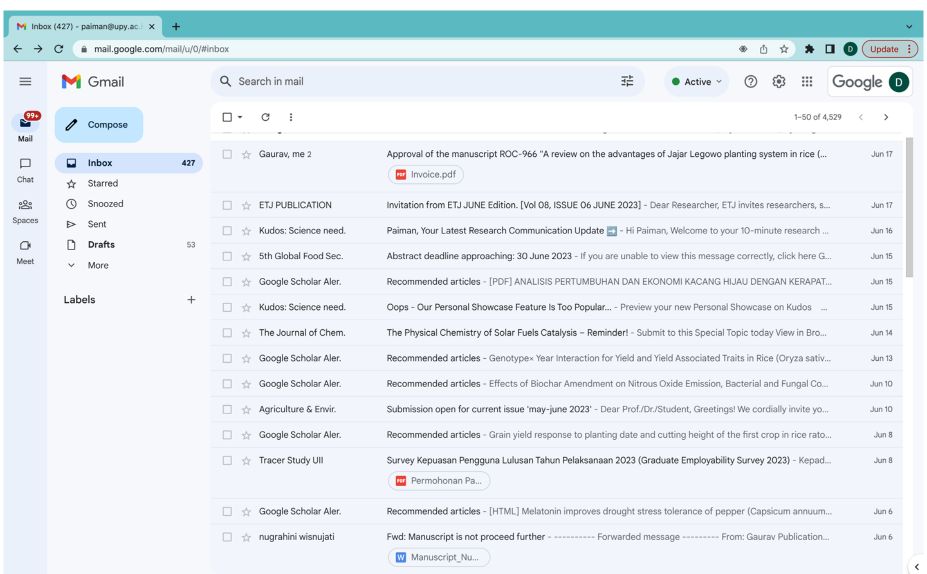

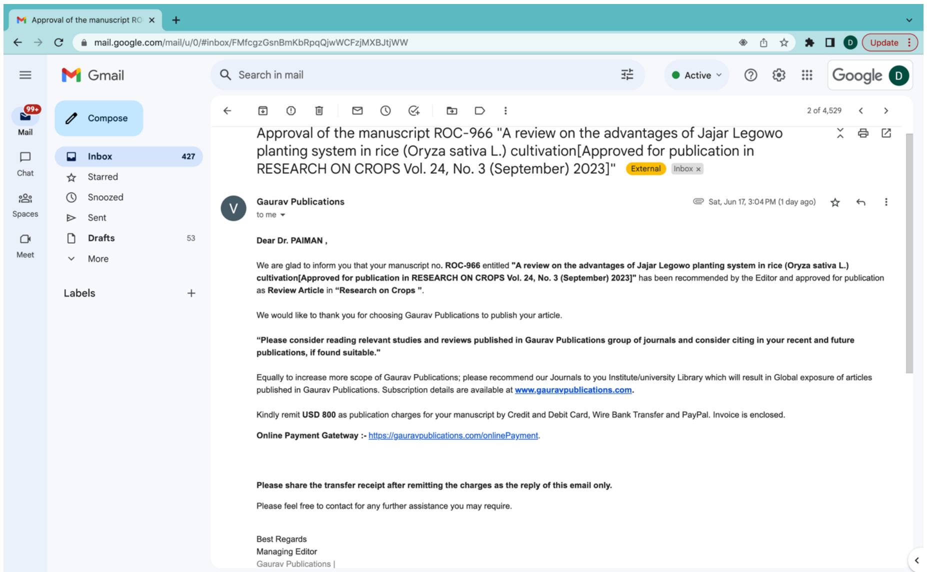

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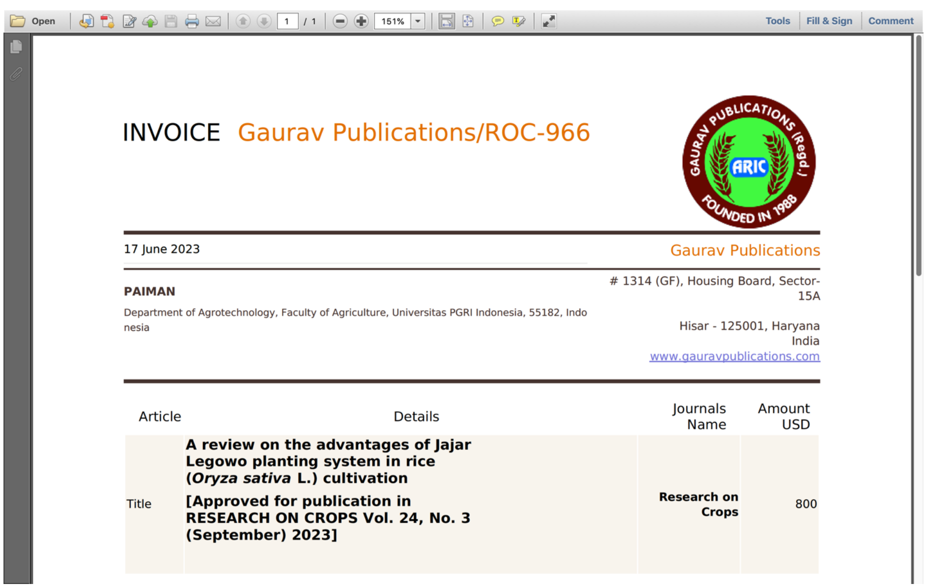

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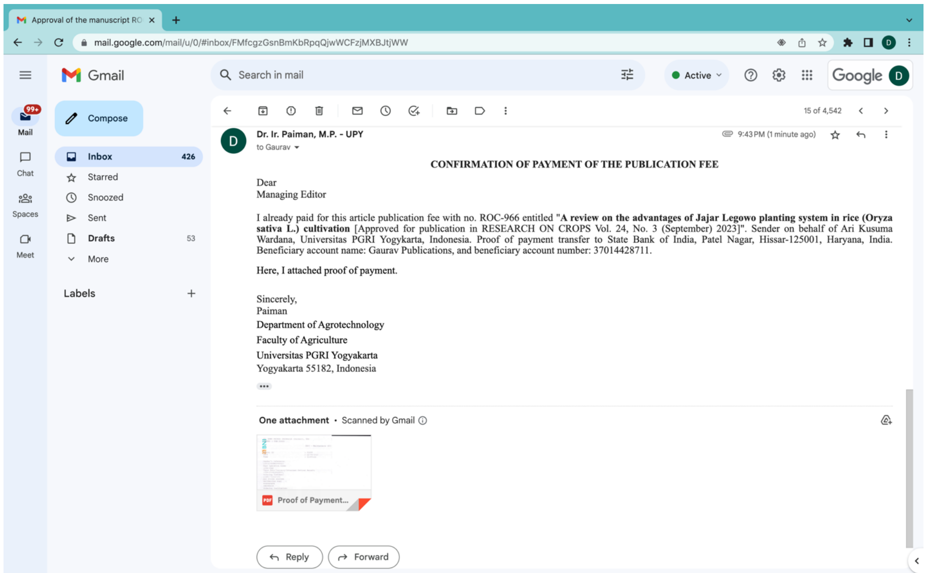

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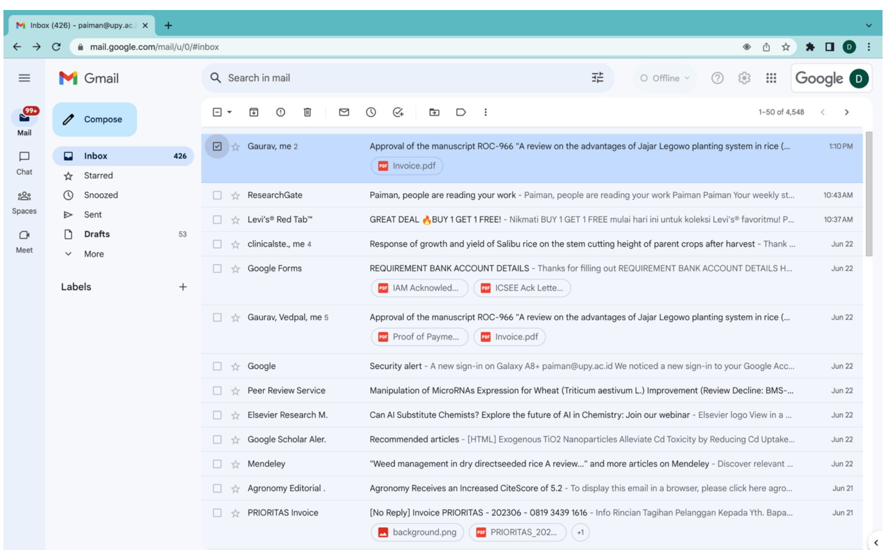

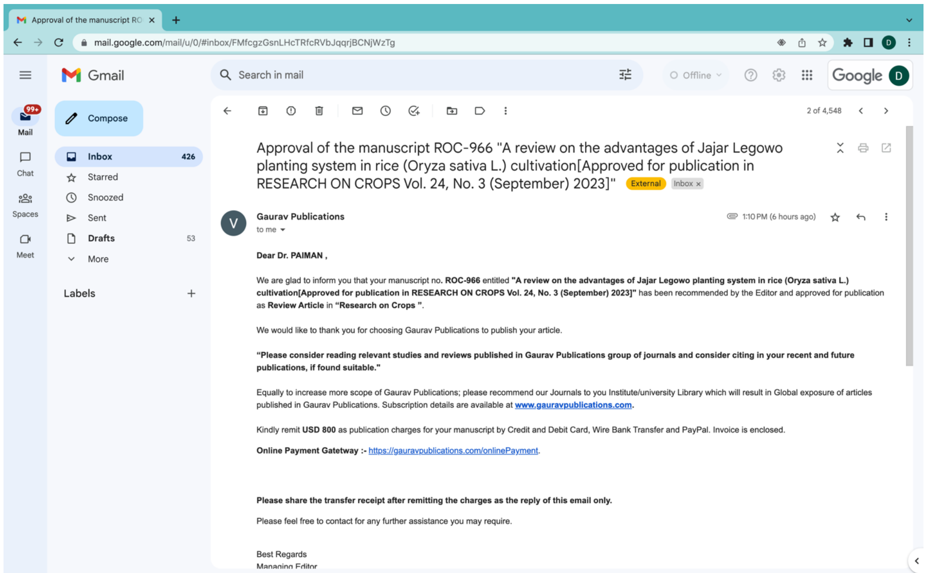

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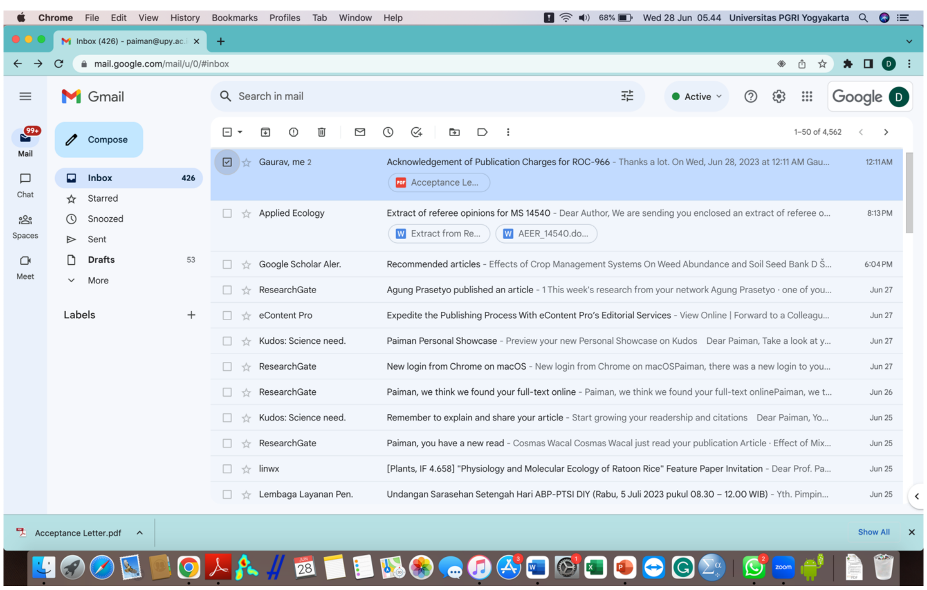

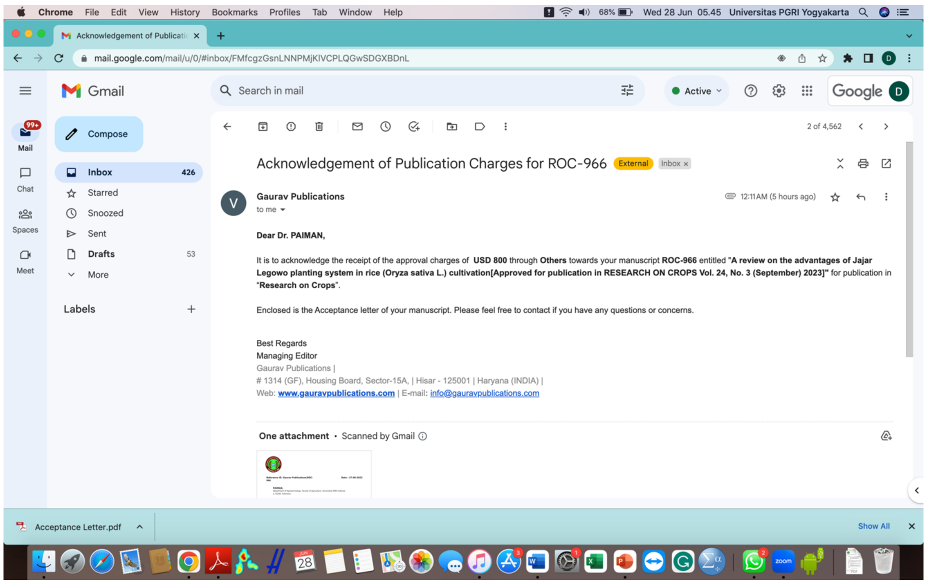

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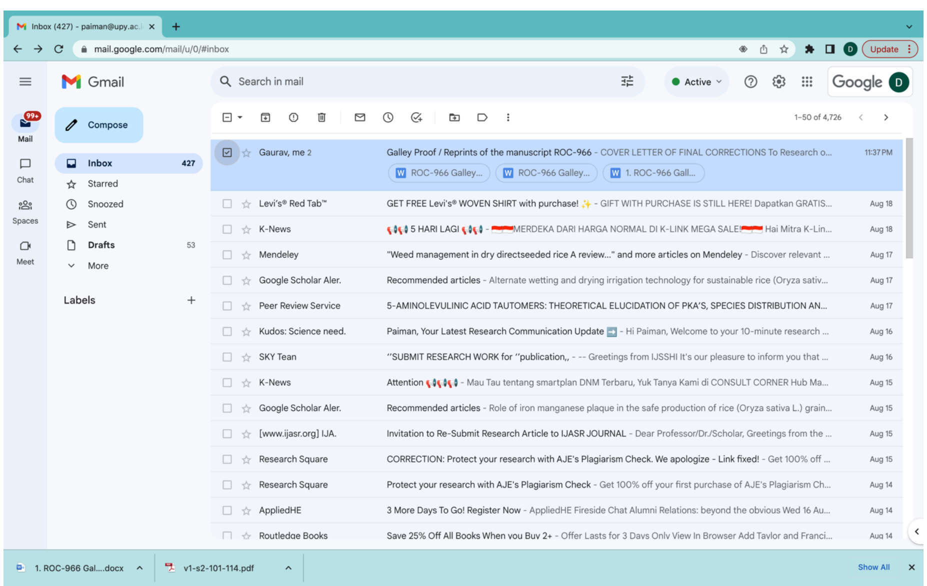

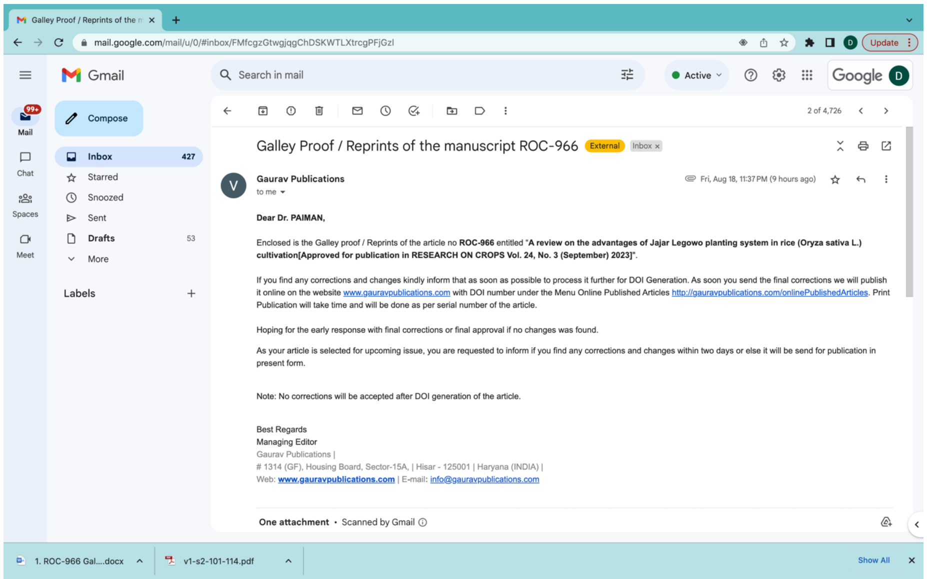

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A review on the advantages of Jajar Legowo planting system in rice (*Oryza sativa* L.) cultivation

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ABSTRACT

Rice is an important crop for producing the staple food of the world's population, especially in Indonesia. However, national rice production has not been able to meet food needs so rice imports are still needed. Mostly, farmers in Indonesia still use the traditional planting system, namely the Tegel planting system (TPS). New innovations are needed to increase rice production. One of the innovations is to modify the TPS which can provide higher rice yield. This new technology is called the "Jajar Legowo" planting system which is abbreviated "Jarwo" planting system (JPS). This technology can increase a higher rice production than the conventional system. The JPS has been developed in Indonesia, but until now many farmers do not know the advantages of this technology. Therefore, this review article aimed to know the advantages of the JPS in rice cultivation compared to the TPS. Based on the literature available, there are several factors that support the success of the JPS in increasing rice yield, namely rice variety, rice fields, and plant spacing. The JPS of 2:1, 3:1, and 4:1 with a plant spacing of 25 × 12.5 × 50 cm could increase crop populations per hectare by 32%, 15%, and 11.87%, respectively than TPS with a plant spacing of 25 × 25 cm. The advantage of the JPS is that it could inhibit weed growth in the soil surface around rice clumps. Besides, increase in crop populations per hectare attainable compared to the

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TPS. The literature reviewed, JPS of the 2:1 type can give rice yield per hectare higher than the types of 3:1, 4:1, or others. Recommended plant spacing for use in JPS is 25 × 12.5 × 50 cm. Further, the review article has made a suggestion that the JPS of the 2:1 type can be applied in rice cultivation, especially in irrigated fields.

Key words : Jarwo planting system, rice fields, Tegel planting system, rice variety, plant spacing

INTRODUCTION

Rice (*Oryza sativa* L.) is a rice-producing crop widely cultivated in Indonesia, especially on Java Island. Statistic data for 2013-2015 showed that the area of paddy fields in Java is 39.9% (3,223,503 ha) of the total area in Indonesia (8,087,393 ha) (Anonymous, 2015). Rice production is continuously increasing from year to year to meet national food needs. So far, farmers have used a Tegel planting system (TPS) in the form of boxes or tiles. In this system, the use of plant spacing between clumps is very regular. Rice cultivation with TPS can provide quite a high yield. However, rice yield needs to be improved again, and this traditional rice of TPS needs to be modified.

New innovations are needed to increase rice production. One of the innovations is to modify the TPS which can provide higher rice yield. This new technology is called the “Jajar Legowo” planting system which is abbreviated “Jarwo” planting system (JPS). The word “Jajar” means parallel (parallel rows of crops). The word “Legowo” comes from the words “lego” and “dowo”. The word “lego” means width (the spacing between rows of crops is wide), and the word “dowo” means long (rows of crops that are long). Words of Jajar Legowo, lego, and dowo are in Javanese. The JPS is a rice planting system with two or more rows of crops parallel and interspersed with one empty row. Between the clumps on the edge, the row is inserted into one plant. Two or more rows of crops and empty rows constitute one unit of Jarwo. A planting system that uses two rows of crops per unit of Jarwo is called JPS of 2:1 type, then if there are three rows of crops per unit of Jarwo is called JPS of 3:1 type, and so on. The JPS has long been introduced to farmers in Indonesia, but until now, only a few have implemented it correctly.

The JPS can increase the crop population dan rice yield per hectare. In addition, crop population can also suppress weed disturbances around cultivated crops (Jenal Mutakin *et al*., 2021). Therefore, the use of the right type of JPS needs to be known and applied to rice cultivation by farmers. Relating to the application of this new technology, there are several factors that support the success of JPS, including rice variety, rice fields, and plant spacing.

Rice Variety

The use of new superior varieties can increase rice yields in cultivation. Based on age, rice varieties can be classified into four groups, including long-life (> 151 days after sowing (DAS)), medium-life (125-150 DAS), short-life (105-124 DAS), and brief-life (90-104 DAS) (BBPPADI, 2016). Short to brief-life variety has a harvest age of < 124 DAS. Based on the age of the rice variety can be used to determine the plant spacing in JPS. If the life of the crops is short, it can be applied for tight spacing and vice versa.

In Indonesia, superior varieties with short life and high production are classified into two groups, including “Inbrida padi sawah irigasi” (Indonesian) is abbreviated Inpari or inbred rice irrigated fields (English). “Hibrida padi” (Indonesian) is abbreviated Hipa or hybrid rice (English). The Inpari and Hipa varieties with short to brief life can be planted to increase the productivity of irrigated fields. The two groups of rice varieties are shown in Table 1.

Table 1 shows that new superior varieties of crop duration of 99-105 DAS with potential yield of 6.5-8.9 t/ha. Each of the new superior variety had different habitus and production properties. A large selection of the new superior varieties can be cultivated. Preferably, the choice of superior varieties was based on the soil fertility and water availability in the paddy fields. Inpari and Hipa varieties had a potential high yield to be cultivated in JPS types.

Hybrid varieties had a much higher weed competitiveness index than Inbrida (Ahmed *et al*., 2021). the production difference depends on each variety characteristic (Nestor *et al*., 2020). The use of competitive varieties was an effective and technically sustainable method of weed control (Nagargade *et al*., 2018). Biological management and regulation of weeds can be made by planting varieties that are more competitive on light (Perthame *et al*., 2022). Based on these literature sources, it shows that the use of hybrid varieties in JPS is more able to suppress weed growth than non-hybrid.

Rice Fields Type

The availability of water in rice fields will determine the choice of plant spacing in rice fields (Singh and Maiti, 2016). Rainfed soil is better to use a tight spacing, on the contrary, the soil is ribbed with a wide spacing. Research results by Nwokwu (Nwokwu, 2015), plant spacing of 30 × 30 cm could provide the highest rice yield in irrigated fields. Meanwhile, the results of other studies show that a higher grain yield per hectare occurred at a plant spacing of 20 × 20 cm in wetland rice fields (Saju *et al*., 2019; Saju and Thavaprakaash, 2020). In contrast to the results of subsequent studies, it indicates that plant spacing affects rice growth and yield in paddy fields. Using wider plant spacing in irrigated fields is better because water availability supports rice growth. Waterlogging in the soil surface can suppress weed germination and growth (Paiman *et al*., 2022). Preferably, closer plant spacing is better in rainfed fields than irrigated ones because of low water availability and dense weed growth. The use of wider or closer plant spacing needs appropriate with paddy fields in JPS types.

Plant Spacing

The plant spacing factor will determine the weed species that grow in paddy fields. The use of wide planting distances will give weeds the opportunity to grow freely. The growth of weeds can be reduced by narrow plant spacing in rows. According to Thi *et al*. (2020), the yield loss caused by weeds depends on weed species and density, weed-rice associations, growth duration, and weed distribution. Added by Kashyap *et al*. (2022), weeds density and dry weight negatively correlated with rice yields, so more weed populations on paddy fields will decrease rice yield. The literature explained that the presence of weeds in paddy fields reduced rice growth and yield. The use of narrow plant spacing can suppress weed density and growth, but competition between crops is very high. To avoid competition, it can be anticipated by the spacing between rows is wide, and otherwise in rows is tightened. Therefore, it is necessary to determine the best JPS type with optimal plant spacing.

The literature review above shows that most previous studies still discuss TPS in traditional rice cultivation. In addition, the use of plant spacing from previous studies still varies. The rice yield per unit area is still low too. Therefore, there is a need for new technology to increase rice yield to meet national food needs. Research about the use of JPS has not been done by many researchers before. Information about the JPS for farmers is still limited. Therefore, a more detailed literature review is needed article review about the JPS. It is hoped that this review article can contribute more complete information about the advantages of the JPS in rice cultivation in rice fields compared to the TPS. This literature review focuses more on the development of JPS in irrigated fields. Therefore, this review article aimed to know the advantages of the JPS in rice cultivation compared to the TPS.

Differences in the Planting System

The difference between the JPS and TPS is the plant spacing used. TPS is a traditional rice planting system that has long been developed, but JPS is a new technology planting system from TPS modifications.

Tegel Planting System

The floor planting system is a rice planting system with planting distances formed into boxes like tiles. The plant spacing used is usually 15 × 15 cm, 20 × 20 cm, 25 × 25 cm, or 30 × 30 cm. An optimal crop population was needed to maximize rice yield. In Indonesia, optimal plant spacing was recommended at 25 × 25 cm for irrigated fields. Strengthened research results by Anwari *et al*. (2019), a plant spacing of 25 × 25 cm produced the highest performance for most agro-morphological properties. The number of rice saplings and grains per panicle was high. Using a 25 × 25 cm plant spacing was the best and could provide maximum rice yield (Fig. 1).

Fig. 1 shows that between row to row and plant to plant used the same spacing, and it is called square or tile planting. TPS with 25 × 25 cm plant spacing could produce a rice crop population of 160,000 clumps/ha and the optimum plant spacing. This statement was supported by Daba and Mekonnen (2022), the inter-row plant spacing of 25 cm was an agronomically feasible and economic spacing for rice cultivation. Added support from Reuben *et al*. (2016), the optimum plant spacing of rice crops was found at 25 × 25 cm and gave the maximum yield per hectare.

Furthermore, some research results showed closer spacing in rows of 25 × 15 cm (direct seed planting system) and 20 × 10 cm (transplanting system) could result in higher production and minimal weed disturbance (Salma *et al*., 2017). It further explained that the planting density in the row could increase the grain produced from more panicles per unit (Hu *et al*., 2020) and further reinforced that the decrease in the density and dry weight of the maximum weed occurred at a row spacing of 15 cm (Ali *et al*., 2019), weed-free crops with a plant spacing of 25 × 15 cm could give rice yields higher. The spacing of 15 cm in a row was the best spacing (Islam *et al*., 2020). It can be summarized that the best spacing between rows was 25 cm and rows can be narrowed to 10-15 cm. Therefore, the TPS with a spacing of 25 × 25 cm can be changed into 25 × 12.5 cm.

Jarwo Planting System

The closer spacing could increase rice yields with higher resource usage efficiency (Htwe *et al*., 2021). Next, the TPS with 25 × 12.5 cm plant spacing could modify into 25 × 12.5 × 50 cm in JPS. It can explain that the number of 25 cm indicated the spacing between rows. The number of 12.5 cm was spacing in rows (edge), while the number of 50 cm was an empty row (twice the width between rows).

The JPS is one of the planting systems in rice farming fields (Istiyanti, 2021). The closer spacing caused a lower leaf area per clump due to light, nutrients, and water limitations. At wide spacing, crops can capture more light because the shade effect between crops is less (Mondal *et al*., 2013) in TPS. Therefore, it needs to be modified with JPS. In JPS, the closer spacing in rows was more advantageous, as long as the spacing between rows was loose. There are several types of JPS have been developed in Indonesia, including 2:1 (consisting of two rows of crops and one row without crops), 3:1 (consisting of three rows of crops and one row without crops), and 4:1 (consisting of four rows of crops and one row without crops).

As an illustration, the JPS of 2:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 2.

Fig. 2 explains the planting system where the spacing between rows and in rows of crops is 25 and 12.5 cm, then there is one empty row (without crops). the JPS of 2:1 type with 25 × 12.5 × 50 cm produced more crop populations (192,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 32%. The crop population higher per unit area effectively increased rice yield and suppressed weeds' dry weight. According to Abdulrachman *et al*. (2012), the JPS of 2:1 type with a spacing of 25 × 12.5 × 50 cm could increase rice yield between 9.63-15.44% compared to the TPS. Supported by Kurniawan *et al*. (2021), the JPS had a noticeable effect on the number of saplings at the age of 55 DAP, the panicle's length, and the dry yield grain harvested.

For more details, the JPS of 3:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 3.

Fig. 3 shows that the spacing between rows is 25 cm. For the spacing in rows, one row in the middle used a spacing of 25 cm, while in both rows at the edge with a spacing of 12.5 cm, then there was one empty row (without crops). The JPS of 3:1 type with 25 × 12.5 × 50 cm produced more crop populations (184,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 15%.

To be able to facilitate understanding of the JPS of 4:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 4.

Fig. 4 shows that the spacing between rows is 25 cm. For the spacing in rows, two rows in the middle used a spacing of 25 cm, while in both rows at the edge with a spacing of 12.5 cm, then there was one empty row (without crops). The JPS of 4:1 type with 25 × 12.5 × 50 cm produced more crop populations (179,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 11.87%.

Of the three types of JPS, it can be explained that the highest rice yield was found in the JPS of 2:1 type because two rows have a loose growing space. All crops will get a better microclimate. The growing weeds in rows could suppress due to the spacing in closer rows. The JPS types of 3:1 and 4:1 show that the crop population per unit area was decreasing, Furthermore, rice yield decreased and weed growth increased.

Advantages of Jarwo Planting System

Currently, the JPS has begun to be developed by farmers and provides higher rice yield than the TPS by increasing the crop population per unit area. In addition, this planting system can facilitate the control of pests, diseases, weeds, and fertilization. Mainly, the advantages of JPS are minimizing weed competition and increasing rice yield per hectare.

Minimizing the Weed Competition

Weed disturbances always appear in the cultivation of crops, especially rice. A closer plant spacing could suppress weed growth, but weeding was still necessary. Weeding could reduce weed density and dry weight (Kuotsu and Singh, 2020). The closer spacing in rows has not been a concern for farmers. Using rice crops as weed competitors was a very environmentally friendly weed management approach (Ramesh *et al*., 2017). The use of closer plant spacing in rows can be used as an integrated weed management program (Sunyob *et al*., 2012). The JPS can control weeds through the use of closer spacing in rows. The rice canopy has a role in reducing the beam of light to the soil surface. Canopy shading can suppress weed growth.

The quality and quantity of rice yields could improve by reducing weed competition (Antralina *et al*., 2015). The presence of weed growth could loss of 50–60% of rice yield (transplanting systems) and 70–80% (direct-seed planting systems) (Dass *et al*., 2017). It further explained that uncontrolled weed growth could decrease grain yield by 30-36% in rice with a transplanting system (Kumar *et al*., 2018). Furthermore, uncontrolled weeds in paddy fields could reduce yields by up to 75% on direct seed planting systems (Shekhawat *et al*., 2020). Weed could cause 57% of rice grain yield to decline in the direct seed planting system (Malik *et al*., 2021). It was quite clear that the presence of weeds greatly reduced rice yields in rice fields. Therefore, using JPS could suppress weed growth in rows, except in one empty row (without crops). The closer plant spacing in rows could reduce the weed dry weight and increase rice yield. JPS with closer plant spacing had an important role in minimizing weed competition.

The JPS can provide a different space than the TPS to get sunlight. The crop absorbed more sunlight, so photosynthesis proceeds smoothly, and then carbohydrate was produced (Susilastuti *et al*., 2018). The quality of light affected the level of CO_2 assimilation. Differences in the penetration of light quality in leaves and absorption by photosystems changed the rate of CO_2 assimilation in C_3 weed that grew under rice canopy (Sun *et al*., 2012). The weed species of *Commelina benghalensis* and *Cyperus rotundus* experience a noticeable increase in leaf area (161 and 46%, respectively) if they grew in the shade. Likewise, the thickness of the leaves in both types of weeds has decreased (Santos *et al*., 2015). Closer plant spacing in rows can block the radiance of sunlight to the soil surface so that weeds are depressed because of less sunlight. However, weeds still get sunlight, especially in empty rows only at the initial of the growth of rice growth.

The use of superior varieties could contribute to managing weeds (Colbach *et al*., 2019). The rice canopy density affected the photomorphogenic of ultraviolet-B (UV-B, 280-320 nm) and will change the placement of the leaves. Furthermore, the change in light quality represented under shading (Chen *et al*., 2019). In reality, the height of *Phalaris minor* significantly increased as a result of shading. The total dry matter accumulation decreased by more than 80% under the shade (Mishra *et al*., 2020). The reduction of weed dry matter due to greater shading was used for roots and reproductive structures than the vegetation shoot tissues (Begna *et al*., 2002). The light availability affects weed growth. Weeds shaded by the rice canopy will be impaired in development. Furthermore, weeds are depressed in growth, unable to produce seeds, and will even die.

The most productive weeds in paddy fields used the C_4 photosynthesis pathway which had a higher potential efficiency in using light, water and nitrogen (Keerthi *et al*., 2023) than C_3 weeds (Nakamura *et al*., 2011). The main difference between the photosynthesis pathways of C_3 and C_4 was saving on carbon, water, and nitrogen (Lattanzi, 2010). This suggests that C_4 weeds will grow well if they get whole light during their growth. If a rice canopy shaded weeds, the weed will be depressed in growth. Unlike the C_3 weed, its growth will be better with non-full light. C_3 weeds can survive under rice canopy shading. A dense and even crop canopy can suppress the weed growth under it. However, C_3 weeds will be able to survive compared to C_4 under the shade of a crop canopy.

Increasing the Rice Yield per Hectare

The rice canopy has an important role in capturing sunlight. The light intensity increase noticeably increases the leaves' orientation towards sunlight, thereby increasing the capacity of the photosynthesis (Tang *et al*., 2022). Furthermore, the results showed that the JPS can increase rice yield compared to the JPS. The JPS of the 2:1 type provided the best results on crop height, number of saplings, and grain yield per unit area (Megasari *et al*., 2021). Technological engineering with the JPS of 2:1 type could produce a higher rice yield (7-8 t/ha) than the JPS (only 4-5 t/ha) (Muslimin *et al*., 2021). Next, the resulting study shows that the highest rice production was found in the JPS of 2:1 (6.57 t/ha) compared to the JPS of 4:1 type (5.57 t/ha) and TPS (5.09 t/ha) (Giamerti & Yursak, 2013). The JPS of 2:1 type has advantages over other types of JPS and TPS. The insertion of rice clumps into edge crops in rows can increase the plant population per hectare. Rice crops in the edge rows still get a good microclimate so that they can produce optimally. The rice yield obtained in JPS of 4:1 type is lower than JPS 2:1 type because the crop population per hectare is lower.

The JPS implementation could increase rice production by 34.7 and 35.5% in 2019 and 2020 compared to TPS (Kusumawati *et al*., 2022). Furthermore, the JPS could increase rice production by up to 33.07% compared to the TPS. The revenue/cost (R/C) value of the JPS was obtained at 1.87. The JPS could benefit farmers' (Rawung *et al*., 2021). The increasing rice production in the JPS of 2:1 type was more significant because there was an increase in the rice clumps number per unit area and more edge crops. The rice clumps on the edge in the row had better growth and development than those in the middle row. Edge crops get more light intensity. These conditions will lead to higher rice yield and grain quality. Using JPS can provide higher benefits for rice farmers than TPS.

CONCLUSION

The literature available suggested that there are several factors that support the success of the JPS in increasing rice yield, namely rice variety, rice fields, and plant spacing. The JPS of 2:1, 3:1, and 4:1 with a plant spacing of 25 × 12.5 × 50 cm could increase crop populations per hectare by 32, 15 and 11.87%, respectively than TPS with a plant spacing of 25 × 25 cm. The advantage of the JPS is that it could inhibit weed growth in the soil surface around rice clumps. Besides, increase in crop populations per hectare compared to the TPS. The literature reviewed, the JPS of the 2:1 type can give rice yield per hectare higher than the types of 3:1, 4:1, or others. Recommended plant spacing for use in JPS is 25 × 12.5 × 50 cm. Further, the review article has made a suggestion that the JPS of the 2:1 type can be applied in rice cultivation, especially in irrigated fields.

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Table 1. Inpari and Hipa varieties with short life and high production.

New superior varieties	Harvest age (DAS)	Potential yield (t/ha)	Average yield (t/ha)
Inpari 11	105	8.8	6.5
Inpari 13	99	8.0	6.6
Inpari 18	102	9.5	6.7
Inpari 19	102	9.5	6.7
Inpari Sidenuk	104	9.1	6.9
Inpari Padjajaran Agritan	105	11,0	7.8
Inpari Cakrabuana Agritan	104	10.2	7.5
HIPA 12 SBU	105	10.5	8.9
HIPA 13	105	9.9	7.5

Source: Suprihatno *et al*. (2009).

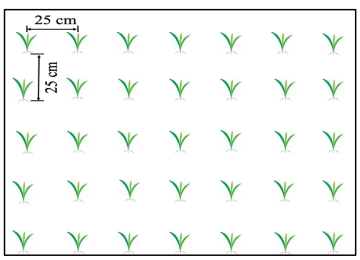

Fig. 1. TPS with plant spacing of 25 × 25 cm.

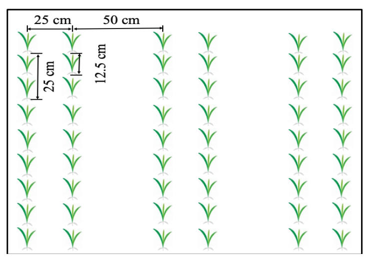

Fig. 2. JPS of 2:1 type with a plant spacing of 25 × 12.5 × 50 cm.

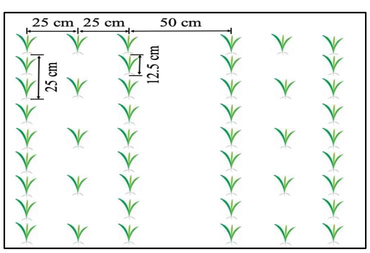

Fig. 3. JPS of 3:1 type with a plant spacing of 25 × 12.5 × 50 cm.

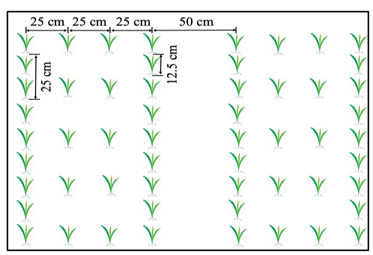

Fig. 4. JPS of 4:1 type with a plant spacing of 25 × 12.5 × 50 cm.

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A review on the advantages of Jajar Legowo planting system in rice (*Oryza sativa* L.) cultivation

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ABSTRACT

Rice is an important crop for producing the staple food of the world's population, especially in Indonesia. However, national rice production has not been able to meet food needs so rice imports are still needed. Mostly, farmers in Indonesia still use the traditional planting system, namely the Tegel planting system (TPS). New innovations are needed to increase rice production. One of the innovations is to modify the TPS which can provide higher rice yield. This new technology is called the "Jajar Legowo" planting system which is abbreviated "Jarwo" planting system (JPS). This technology can increase a higher rice production than the conventional system. The JPS has been developed in Indonesia, but until now many farmers do not know the advantages of this technology. Therefore, this review article aimed to know the advantages of the JPS in rice cultivation compared to the TPS. Based on the literature available, there are several factors that support the success of the JPS in increasing rice yield, namely rice variety, rice fields, and plant spacing. The JPS of 2:1, 3:1, and 4:1 with a plant spacing of 25 × 12.5 × 50 cm could increase crop populations per hectare by 32%, 15%, and 11.87%, respectively than TPS with a plant spacing of 25 × 25 cm. The advantage of the JPS is that it could inhibit weed growth in the soil surface around rice clumps. Besides, increase in crop populations per hectare attainable compared to the

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TPS. In the literature reviewed, JPS of the 2:1 type can give rice yield per hectare higher than the types of 3:1, 4:1, or others. Recommended plant spacing for use in JPS is 25 × 12.5 × 50 cm. Further, the review article has made a suggestion that the JPS of the 2:1 type can be applied in rice cultivation, especially in irrigated fields.

Key words : Jarwo planting system, rice fields, Tegel planting system, rice variety, plant spacing

INTRODUCTION

Rice (*Oryza sativa* L.) is a rice-producing crop widely cultivated in Indonesia, especially on Java Island. Statistic data for 2013-2015 showed that the area of paddy fields in Java is 39.9% (3,223,503 ha) of the total area in Indonesia (8,087,393 ha) (Anonymous, 2015). Rice production is continuously increasing from year to year to meet national food needs. So far, farmers have used a Tegel planting system (TPS) in the form of boxes or tiles. In this system, the use of plant spacing between clumps is very regular. Rice cultivation with TPS can provide quite a high yield. However, rice yield needs to be improved again, and this traditional rice of TPS needs to be modified.

New innovations are needed to increase rice production. One of the innovations is to modify the TPS which can provide higher rice yield. This new technology is called the "Jajar Legowo" planting system which is abbreviated "Jarwo" planting system (JPS). The word "Jajar" means parallel (parallel rows of crops). The word "Legowo" comes from the words "lego" and "dowo". The word "lego" means width (the spacing between rows of crops is wide), and the word "dowo" means long (rows of crops that are long). Words of Jajar Legowo, lego, and dowo are in Javanese. The JPS is a rice planting system with two or more rows of crops parallel and interspersed with one empty row. Between the clumps on the edge, the row is inserted into one plant. Two or more rows of crops and empty rows constitute one unit of Jarwo. A planting system that uses two rows of crops per unit of Jarwo is called JPS of 2:1 type, then if there are three rows of crops per unit of Jarwo is called JPS of 3:1 type, and so on. The JPS has long been introduced to farmers in Indonesia, but until now, only a few have implemented it correctly.

The JPS can increase the crop population dan rice yield per hectare. In addition, crop population can also suppress weed disturbances around cultivated crops (Mutakin *et al*., 2021). Therefore, the use of the right type of JPS needs to be known and applied to rice cultivation by farmers. Relating to the application of this new technology, there are several factors that support the success of JPS, including rice variety, rice fields, and plant spacing.

Rice Variety

The use of new superior varieties can increase rice yields in cultivation. Based on age, rice varieties can be classified into four groups, including long-life (> 151 days after sowing (DAS)), medium-life (125-150 DAS), short-life (105-124 DAS), and brief-life (90-104 DAS) (BBPPADI, 2016). Short to brief-life variety has a harvest age of < 124 DAS. Based on the age of the rice variety can be used to determine the plant spacing in JPS. If the life of the crops is short, it can be applied for tight spacing and vice versa.

In Indonesia, superior varieties with short life and high production are classified into two groups, including "Inbrida padi sawah irigasi" (Indonesian) is abbreviated Inpari or inbred rice irrigated fields (English). "Hibrida padi" (Indonesian) is abbreviated Hipa or hybrid rice (English). The Inpari and Hipa varieties with short to brief life can be planted to increase the productivity of irrigated fields. The two groups of rice varieties are shown in Table 1.

Table 1 shows that new superior varieties of crop duration of 99-105 DAS with potential yield of 6.5-8.9 t/ha. Each of the new superior variety had different habitus and production properties. A large selection of the new superior varieties can be cultivated. Preferably, the choice of superior varieties was based on the soil fertility and water availability in the paddy fields. Inpari and Hipa varieties had a potential high yield to be cultivated in JPS types.

Hybrid varieties had a much higher weed competitiveness index than Inbrida (Ahmed *et al*., 2021). The production difference depends on each variety characteristic (Nestor *et al*., 2020). The use of competitive varieties was an effective and technically sustainable method of weed control (Nagargade *et al*., 2018). Biological management and regulation of weeds can be made by planting varieties that are more competitive on light (Perthame *et al*., 2022). Based on these literature sources, it shows that the use of hybrid varieties in JPS is more able to suppress weed growth than non-hybrid.

Rice Fields Type

The availability of water in rice fields will determine the choice of plant spacing in rice fields (Singh and Maiti, 2016). Rainfed soil is better to use a tight spacing, on the contrary, the soil is ribbed with a wide spacing. Research results by Nwokwu (Nwokwu, 2015), plant spacing of 30 × 30 cm could provide the highest rice yield in irrigated fields. Meanwhile, the results of other studies show that a higher grain yield per hectare occurred at a plant spacing of 20 × 20 cm in wetland rice fields (Saju *et al*., 2019; Saju and Thavaprakaash, 2020). In contrast to the results of subsequent studies, it indicates that plant spacing affects rice growth and yield in paddy fields. Using wider plant spacing in irrigated fields is better because water availability supports rice growth. Waterlogging in the soil surface can suppress weed germination and growth (Paiman *et al*., 2022). Preferably, closer plant spacing is better in rainfed fields than irrigated ones because of low water availability and dense weed growth. The use of wider or closer plant spacing needs appropriate with paddy fields in JPS types.

Plant Spacing

The plant spacing factor will determine the weed species that grow in paddy fields. The use of wide planting distances will give weeds the opportunity to grow freely. The growth of weeds can be reduced by narrow plant spacing in rows. According to Thi *et al*. (2020), the yield loss caused by weeds depends on weed species and density, weed-rice associations, growth duration, and weed distribution. Added by Kashyap *et al*. (2022), weeds density and dry weight negatively correlated with rice yields, so more weed populations on paddy fields will decrease rice yield. The literature explained that the presence of weeds in paddy fields reduced rice growth and yield. The use of narrow plant spacing can suppress weed density and growth, but competition between crops is very high. To avoid competition, it can be anticipated by the spacing between rows is wide, and otherwise in rows is tightened. Therefore, it is necessary to determine the best JPS type with optimal plant spacing.

The literature review above shows that most previous studies still discuss TPS in traditional rice cultivation. In addition, the use of plant spacing from previous studies still varies. The rice yield per unit area is still low too. Therefore, there is a need for new technology to increase rice yield to meet national food needs. Research about the use of JPS has not been done by many researchers before. Information about the JPS for farmers is still limited. Therefore, a more detailed literature review is needed article review about the JPS. It is hoped that this review article can contribute more complete information about the advantages of the JPS in rice cultivation in rice fields compared to the TPS. This literature review focuses more on the development of JPS in irrigated fields. Therefore, this review article aimed to know the advantages of the JPS in rice cultivation compared to the TPS.

Differences in the Planting System

The difference between the JPS and TPS is the plant spacing used. TPS is a traditional rice planting system that has long been developed, but JPS is a new technology planting system from TPS modifications.

Tegel Planting System

The Tegel planting system is a rice planting system with plant spacing formed into boxes like tiles. The plant spacing used is usually 15 × 15 cm, 20 × 20 cm, 25 × 25 cm, or 30 × 30 cm. An optimal crop population was needed to maximize rice yield. In Indonesia, optimal plant spacing was recommended at 25 × 25 cm for irrigated fields. Strengthened research results by Anwari *et al*. (2019), a plant spacing of 25 × 25 cm produced the highest performance for most agro-morphological properties. The number of rice saplings and grains per panicle was high. Using a 25 × 25 cm plant spacing was the best and could provide maximum rice yield (Fig. 1).

Fig. 1 shows that between row to row and plant to plant used the same spacing, and it is called square or tile planting. TPS with 25 × 25 cm plant spacing could produce a rice crop population of 160,000 clumps/ha and the optimum plant spacing. This statement was supported by Daba and Mekonnen (2022), the inter-row plant spacing of 25 cm was an agronomically feasible and economic spacing for rice cultivation. Added support from Reuben *et al*. (2016), the optimum plant spacing of rice crops was found at 25 × 25 cm and gave the maximum yield per hectare.

Furthermore, some research results showed closer spacing in rows of 25 × 15 cm (direct seed planting system) and 20 × 10 cm (transplanting system) could result in higher production and minimal weed disturbance (Salma *et al*., 2017). It further explained that the planting density in the row could increase the grain produced from more panicles per unit (Hu *et al*., 2020) and further reinforced that the decrease in the density and dry weight of the maximum weed occurred at a row spacing of 15 cm (Ali *et al*., 2019), weed-free crops with a plant spacing of 25 × 15 cm could give rice yields higher. The spacing of 15 cm in a row was the best spacing (Islam *et al*., 2020). It can be summarized that the best spacing between rows was 25 cm and rows can be narrowed to 10-15 cm. Therefore, the TPS with a spacing of 25 × 25 cm can be changed into 25 × 12.5 cm.

Jarwo Planting System

The closer spacing could increase rice yields with higher resource usage efficiency (Htwe *et al*., 2021). Next, the TPS with 25 × 12.5 cm plant spacing could modify into 25 × 12.5 × 50 cm in JPS. It can explain that the number of 25 cm indicated the spacing between rows. The number of 12.5 cm was spacing in rows (edge), while the number of 50 cm was an empty row (twice the width between rows).

The JPS is one of the planting systems in rice farming fields (Istiyanti, 2021). The closer spacing caused a lower leaf area per clump due to light, nutrients, and water limitations. At wide spacing, crops can capture more light because the shade effect between crops is less (Mondal *et al*., 2013) in TPS. Therefore, it needs to be modified with JPS. In JPS, the closer spacing in rows was more advantageous, as long as the spacing between rows was loose. There are several types of JPS have been developed in Indonesia, including 2:1 (consisting of two rows of crops and one row without crops), 3:1 (consisting of three rows of crops and one row without crops), and 4:1 (consisting of four rows of crops and one row without crops).

As an illustration, the JPS of 2:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 2.

Fig. 2 explains the planting system where the spacing between rows and in rows of crops is 25 and 12.5 cm, then there is one empty row (without crops). the JPS of 2:1 type with 25 × 12.5 × 50 cm produced more crop populations (192,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 32%. The crop population higher per unit area effectively increased rice yield and suppressed weeds' dry weight. According to Abdulrachman *et al*. (2012), the JPS of 2:1 type with a spacing of 25 × 12.5 × 50 cm could increase rice yield between 9.63-15.44% compared to the TPS. Supported by Kurniawan *et al*. (2021), the JPS had a noticeable effect on the number of saplings at the age of 55 DAP, the panicle's length, and the dry yield grain harvested.

For more details, the JPS of 3:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 3.

Fig. 3 shows that the spacing between rows is 25 cm. For the spacing in rows, one row in the middle used a spacing of 25 cm, while in both rows at the edge with a spacing of 12.5 cm, then there was one empty row (without crops). The JPS of 3:1 type with 25 × 12.5 × 50 cm produced more crop populations (184,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 15%.

To be able to facilitate understanding of the JPS of 4:1 type with a plant spacing of 25 × 12.5 × 50 cm can be seen in Fig. 4.

Fig. 4 shows that the spacing between rows is 25 cm. For the spacing in rows, two rows in the middle used a spacing of 25 cm, while in both rows at the edge with a spacing of 12.5 cm, then there was one empty row (without crops). The JPS of 4:1 type with 25 × 12.5 × 50 cm produced more crop populations (179,000 clumps/ha) than TPS with 25 × 25 cm (160,000 clumps/ha) or an increase in the crop populations of 11.87%.

Of the three types of JPS, it can be explained that the highest rice yield was found in the JPS of 2:1 type because two rows have a loose growing space. All crops will get a better microclimate. The growing weeds in rows could suppress due to the spacing in closer rows. The JPS types of 3:1 and 4:1 show that the crop population per unit area was decreasing, Furthermore, rice yield decreased and weed growth increased.

Advantages of Jarwo Planting System

Currently, the JPS has begun to be developed by farmers and provides higher rice yield than the TPS by increasing the crop population per unit area. In addition, this planting system can facilitate the control of pests, diseases, weeds, and fertilization. Mainly, the advantages of JPS are minimizing weed competition and increasing rice yield per hectare.

Minimizing the Weed Competition

Weed disturbances always appear in the cultivation of crops, especially rice. A closer plant spacing could suppress weed growth, but weeding was still necessary. Weeding could reduce weed density and dry weight (Kuotsu and Singh, 2020). The closer spacing in rows has not been a concern for farmers. Using rice crops as weed competitors was a very environmentally friendly weed management approach (Ramesh *et al*., 2017). The use of closer plant spacing in rows can be used as an integrated weed management program (Sunyob *et al*., 2012). The JPS can control weeds through the use of closer spacing in rows. The rice canopy has a role in reducing the beam of light to the soil surface. Canopy shading can suppress weed growth.

The quality and quantity of rice yields could improve by reducing weed competition (Antralina *et al*., 2015). The presence of weed growth could loss of 50–60% of rice yield (transplanting systems) and 70–80% (direct-seed planting systems) (Dass *et al*., 2017). It further explained that uncontrolled weed growth could decrease grain yield by 30-36% in rice with a transplanting system (Kumar *et al*., 2018). Furthermore, uncontrolled weeds in paddy fields could reduce yields by up to 75% on direct seed planting systems (Shekhawat *et al*., 2020). Weed could cause 57% of rice grain yield to decline in the direct seed planting system (Malik *et al*., 2021). It was quite clear that the presence of weeds greatly reduced rice yields in rice fields. Therefore, using JPS could suppress weed growth in rows, except in one empty row (without crops). The closer plant spacing in rows could reduce the weed dry weight and increase rice yield. JPS with closer plant spacing had an important role in minimizing weed competition.

The JPS can provide a different space than the TPS to get sunlight. The crop absorbed more sunlight, so photosynthesis proceeds smoothly, and then carbohydrate was produced (Susilastuti *et al*., 2018). The quality of light affected the level of CO_2 assimilation. Differences in the penetration of light quality in leaves and absorption by photosystems changed the rate of CO_2 assimilation in C_3 weed that grew under rice canopy (Sun *et al*., 2012). The weed species of *Commelina benghalensis* and *Cyperus rotundus* experience a noticeable increase in leaf area (161 and 46%, respectively) if they grew in the shade. Likewise, the thickness of the leaves in both types of weeds has decreased (Santos *et al*., 2015). Closer plant spacing in rows can block the radiance of sunlight to the soil surface so that weeds are depressed because of less sunlight. However, weeds still get sunlight, especially in empty rows only at the initial of the growth of rice growth.

The use of superior varieties could contribute to managing weeds (Colbach *et al*., 2019). The rice canopy density affected the photomorphogenic of ultraviolet-B (UV-B, 280-320 nm) and will change the placement of the leaves. Furthermore, the change in light quality is represented under shading (Chen *et al*., 2019). In reality, the height of *Phalaris minor* significantly increased as a result of shading. The total dry matter accumulation decreased by more than 80% under the shade (Mishra *et al*., 2020). The reduction of weed dry matter due to greater shading was used for roots and reproductive structures than the vegetation shoot tissues (Begna *et al*., 2002). The light availability affects weed growth. Weeds shaded by the rice canopy will be impaired in development. Furthermore, weeds are depressed in growth, unable to produce seeds, and will even die.

The most productive weeds in paddy fields used the C_4 photosynthesis pathway which had a higher potential efficiency in using light, water, and nitrogen (Keerthi *et al*., 2023) than C_3 weeds (Nakamura *et al*., 2011). The main difference between the photosynthesis pathways of C_3 and C_4 was saving on carbon, water, and nitrogen (Lattanzi, 2010). This suggests that C_4 weeds will grow well if they get whole light during their growth. If a rice canopy shaded weeds, the weed will be depressed in growth. Unlike the C_3 weed, its growth will be better with non-full light. C_3 weeds can survive under rice canopy shading. A dense and even crop canopy can suppress the weed growth under it. However, C_3 weeds will be able to survive compared to C_4 under the shade of a crop canopy.

Increasing the Rice Yield per Hectare

The rice canopy has an important role in capturing sunlight. The light intensity increase noticeably increases the leaves' orientation towards sunlight, thereby increasing the capacity of the photosynthesis (Tang *et al*., 2022). Furthermore, the results showed that the JPS can increase rice yield compared to the JPS. The JPS of the 2:1 type provided the best results on crop height, number of saplings, and grain yield per unit area (Megasari *et al*., 2021). Technological engineering with the JPS of 2:1 type could produce a higher rice yield (7-8 t/ha) than the JPS (only 4-5 t/ha) (Muslimin *et al*., 2021). Next, the resulting study shows that the highest rice production was found in the JPS of 2:1 (6.57 t/ha) compared to the JPS of 4:1 type (5.57 t/ha) and TPS (5.09 t/ha) (Giamerti and Yursak, 2013). The JPS of 2:1 type has advantages over other types of JPS and TPS. The insertion of rice clumps into edge crops in rows can increase the plant population per hectare. Rice crops in the edge rows still get a good microclimate so that they can produce optimally. The rice yield obtained in JPS of 4:1 type is lower than JPS 2:1 type because the crop population per hectare is lower.

The JPS implementation could increase rice production by 34.7 and 35.5% in 2019 and 2020 compared to TPS (Kusumawati *et al*., 2022). Furthermore, the JPS could increase rice production by up to 33.07% compared to the TPS. The revenue/cost (R/C) value of the JPS was obtained at 1.87. The JPS could benefit farmers' (Rawung *et al*., 2021). The increasing rice production in the JPS of 2:1 type was more significant because there was an increase in the rice clumps number per unit area and more edge crops. The rice clumps on the edge in the row had better growth and development than those in the middle row. Edge crops get more light intensity. These conditions will lead to higher rice yield and grain quality. Using JPS can provide higher benefits for rice farmers than TPS.

CONCLUSION

The literature available suggested that there are several factors that support the success of the JPS in increasing rice yield, namely rice variety, rice fields, and plant spacing. The JPS of 2:1, 3:1, and 4:1 with a plant spacing of 25 × 12.5 × 50 cm could increase crop populations per hectare by 32%, 15%, and 11.87%, respectively than TPS with a plant spacing of 25 × 25 cm. The advantage of the JPS is that it could inhibit weed growth in the soil surface around rice clumps. Besides, increase in crop populations per hectare compared to the TPS. In the literature reviewed, the JPS of the 2:1 type can give rice yield per hectare higher than the types of 3:1, 4:1, or others. Recommended plant spacing for use in JPS is 25 × 12.5 × 50 cm. Further, the review article has made a suggestion that the JPS of the 2:1 type can be applied in rice cultivation, especially in irrigated fields.

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Table 1. Inpari and Hipa varieties with short life and high production.

New superior varieties	Harvest age (DAS)	Potential yield (t/ha)	Average yield (t/ha)
Inpari 11	105	8.8	6.5
Inpari 13	99	8.0	6.6
Inpari 18	102	9.5	6.7
Inpari 19	102	9.5	6.7
Inpari Sidenuk	104	9.1	6.9
Inpari Padjajaran Agritan	105	11,0	7.8
Inpari Cakrabuana Agritan	104	10.2	7.5
HIPA 12 SBU	105	10.5	8.9
HIPA 13	105	9.9	7.5

Source: Suprihatno *et al*. (2009).

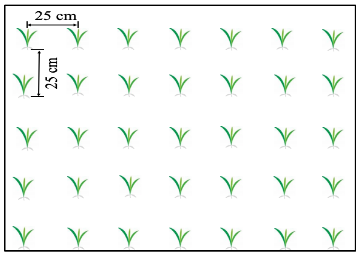

Fig. 1. TPS with plant spacing of 25 × 25 cm.

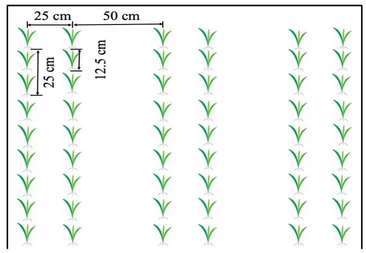

Fig. 2. JPS of 2:1 type with a plant spacing of 25 × 12.5 × 50 cm.

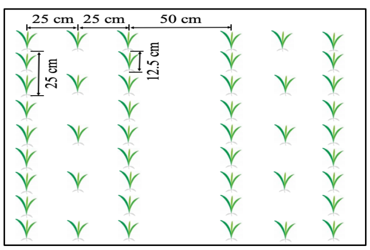

Fig. 3. JPS of 3:1 type with a plant spacing of 25 × 12.5 × 50 cm.

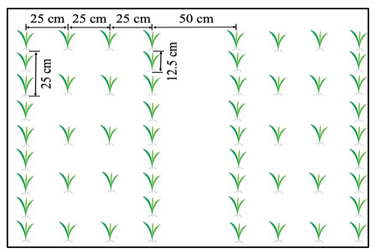

Fig. 4. JPS of 4:1 type with a plant spacing of 25 × 12.5 × 50 cm.

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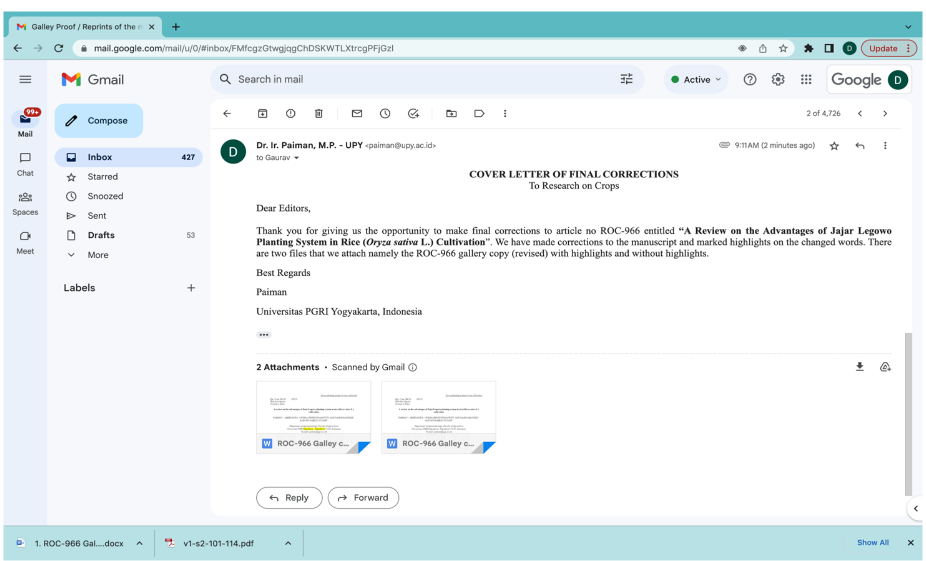


COVER LETTER OF FINAL CORRECTIONS
To Research on Crops

Dear Editors,

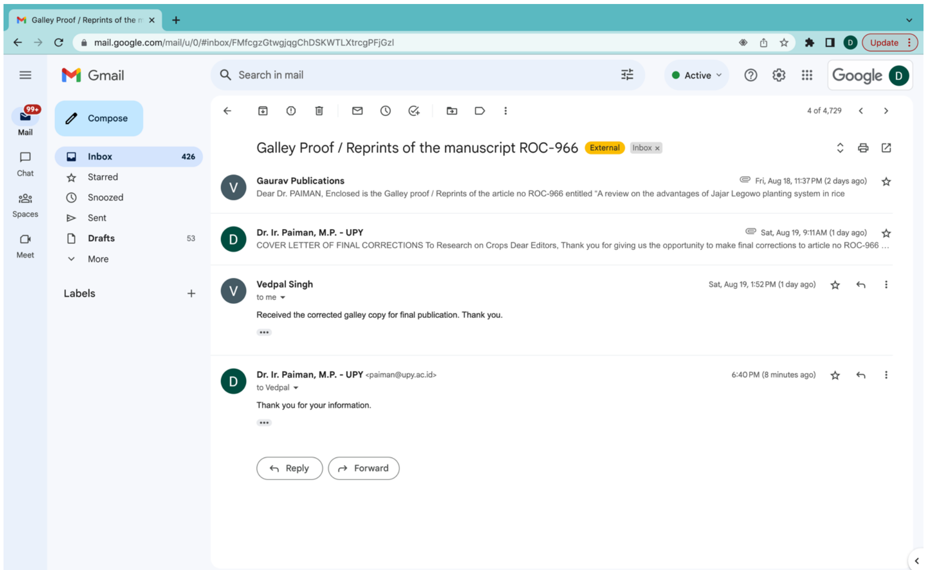
Thank you for giving us the opportunity to make final corrections to article no ROC-966 entitled **"A Review on the Advantages of Jajar Legowo Planting System in Rice (*Oryza sativa* L.) Cultivation"**. We have made corrections to the manuscript and marked highlights on the changed words. There are two files that we attach namely the ROC-966 gallery copy (revised) with highlights and without highlights.

Best Regards

Paiman

Universitas PGRI Yogyakarta, Indonesia

The final correction has been received: 19 Agustus 2023



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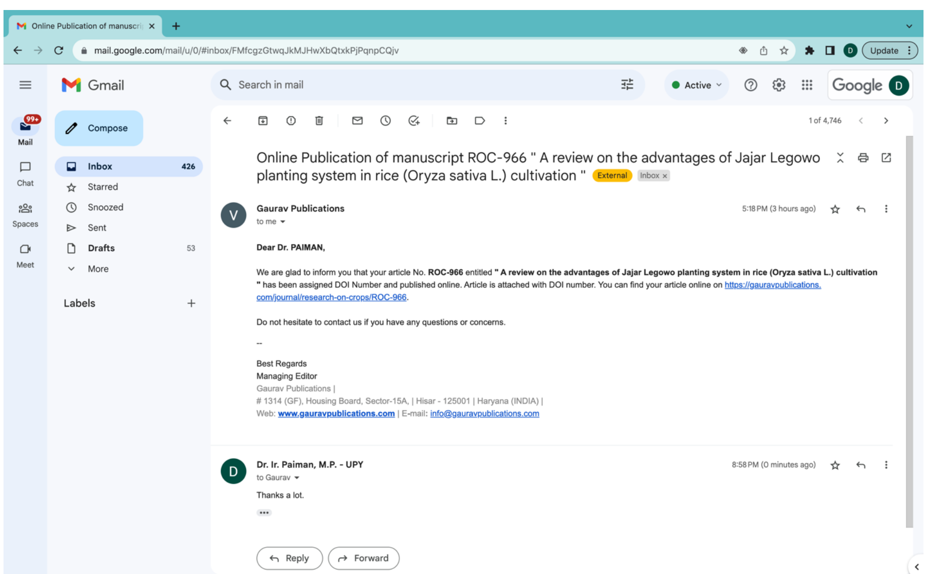

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