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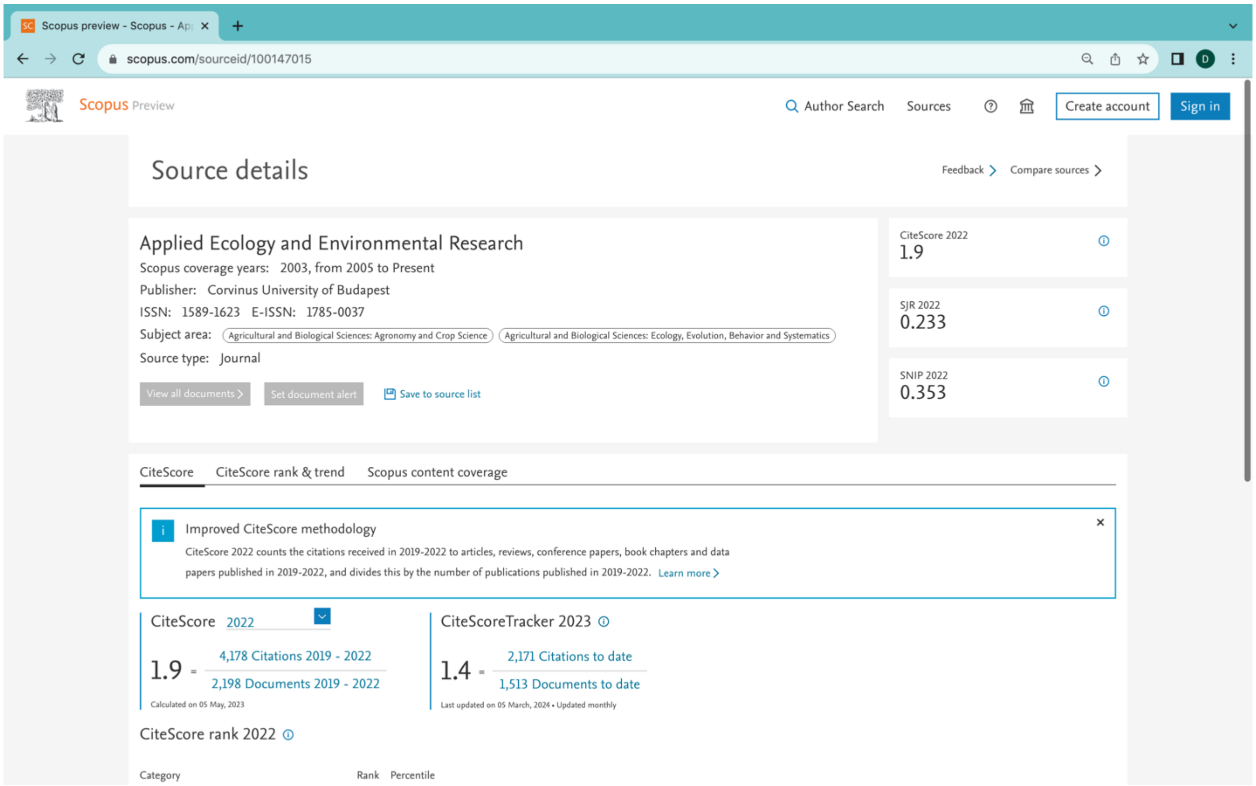

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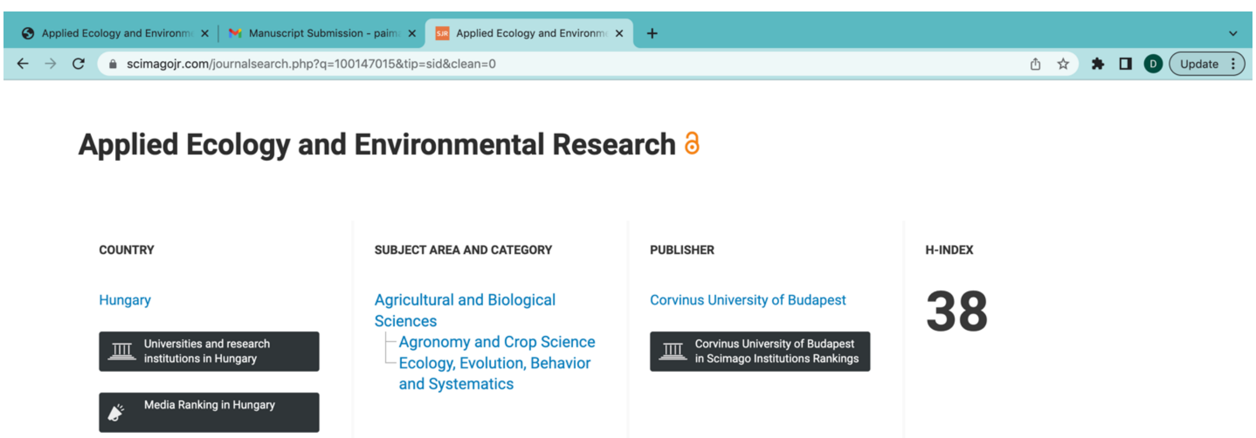

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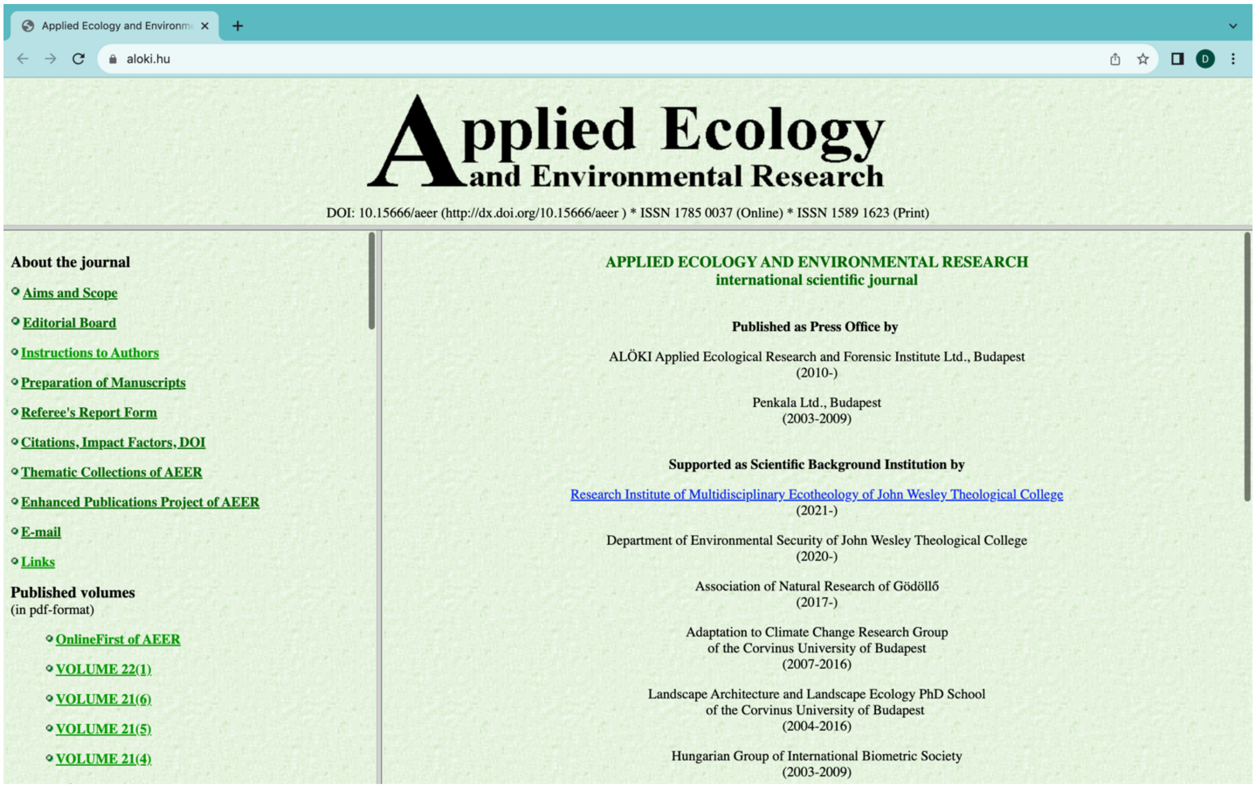

Manuscript Submission: 7 Maret 2024

a. Cover Letter

COVER LETTER

To Applied Ecology and Environmental Research

Dear Editor,

I would like to send an original article entitled: **THE EFFECT OF SPACING ON THE GROWTH AND YIELD OF RICE IN DIFFERENT VARIETIES AND PLANTING SEASONS** for Applied Ecology and Environmental Research 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 Applied Ecology and Environmental Research. 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 Applied Ecology and Environmental Research. Here I attach the manuscript.

Thank you

Best regards,

Paiman

Universitas PGRI Yogyakarta, Indonesia

b. Manuscript for Submission:

THE EFFECT OF SPACING ON THE GROWTH AND YIELD OF RICE IN DIFFERENT VARIETIES AND PLANTING SEASONS

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Abstract. Indonesia experiences two distinct seasons: the rainy and dry seasons. The use of optimal spacing during each season will impact rice growth and yield. Additionally, utilizing adaptable superior varieties can increase rice yield. This study aimed to know the effect of optimal spacing on the growth and yield of rice in different varieties and planting seasons. The research was conducted in rice fields during both the rainy and dry seasons. The study was arranged in a nested design. The Padjajaran Agritan and Ciherang were used in the study. Each rice variety was planted to three different spacings: 15 × 15, 20 × 20, and 25 × 25 cm, with each spacing replicated three times. Results indicated that the number of productive tillers, dry shoot weight, and grain dry weight clump^{-1} were higher when planted with a spacing of 25 × 25 cm than 15 × 15 or 20 × 20 cm for both varieties. Conversely, the total grain dry weight per hectare was greater with a spacing of 15 × 15 cm. No significant differences were observed in the growth and yield of rice between the Padjajaran Agritan and Ciherang varieties. The grain dry weight produced by Padjajaran Agritan and Ciherang were 6.25 and 6.35 tons ha^{-1} in the rainy season but decreased to 5.11 and 4.75 tons ha^{-1} in the dry season. The research findings suggest that a spacing of 15 × 15 cm is optimal for both the Padjajaran Agritan and Ciherang varieties when planted in either the rainy or dry season. However, the growth and yield of rice are higher in the rainy season than in the dry season in semi-technical irrigated rice fields. Consequently, we recommend utilizing closer spacing and drought-resistant superior varieties to maximize rice yield in the dry season.

Keywords: solar radiation, superior variety, irrigated, water availability

Introduction

Climate change is closely related to the seasons in a region. Indonesia is located in the tropics, so every year it has rainy and dry seasons (Suwartapradja, 2022). During the rainy season, monsoon winds blow from Asia towards Australia, bringing more moisture, and transforming into rainfall in the Indonesian region. Generally, the rainy season in Indonesia occurs from October to March. Conversely, during the dry season, monsoon winds blow from Australia towards Asia, passing through Indonesia with less moisture. This results in reduced rainfall in Indonesia. Typically, the dry season in Indonesia occurs from April to

November (BMKG, 2019). Climate elements such as rainfall, solar radiation, and air temperature always fluctuate throughout the year or from year to year. Climate change will impact the growth and yield of crops, especially rice crops (Jamil and Chairunnisya, 2023).

The rice plant (*Oryza sativa* L.) is one of the staple food crops that produce rice to meet daily basic needs in Indonesia. Increasing rice productivity is also influenced by local climate and weather conditions, especially rainfall. Water plays a crucial role in the growth and yield of rice. Water requirements are not a constraint for rice cultivation in technically irrigated fields. Rice cultivation can be done up to three times a year. However, in practice, rice cultivation can be optimally done only twice a year, namely in the first and second planting. In the third planting, water-only needs during the vegetative growth phase. However, in the generative growth phase, there is a water shortage leading to decreased rice yield. This condition often occurs in semi-technical irrigated rice fields in Yogyakarta, Indonesia. According to Pool et al. (2023), one of the most significant problems in rice production is the high water requirement of this crop.

Geographically, Yogyakarta is a region located in the central-southern part of Java Island and directly bordering the Indian Ocean. This region has two seasons, namely the rainy and dry seasons. It has several types of rice fields, including technically irrigated, semi-technical, and rainfed fields. Therefore, rice productivity varies depending on water availability in these fields. It is important to recognize that maximizing rice productivity requires the implementation of optimal spacing and the utilization of superior varieties adaptable to drought stress.

The rainy season is characterized by a decrease in average daily air temperature, shorter sunlight exposure, low solar radiation, high rainfall, and cloudy skies. However, the opposite occurs during the dry season (Jaenudin et al., 2020). Sunlight radiation and temperature are the most important factors in increasing rice productivity. When sunlight radiation and temperature increase significantly, it will result in a decrease in rice yield (Kawasaki and Herath, 2011). In addition, high daytime temperatures in the tropics are already close to optimal levels, and the increase in intensity and frequency of heat waves coinciding with sensitive reproductive phases can lead to significant damage to rice production (Mohanty et al., 2013). During the dry season, the sunlight intensity is abundant, but water availability becomes a limiting factor for rice cultivation in semi-technical irrigated fields.

Rice cultivation in the dry season usually produces higher yields, if water is available (Voe et al., 2011). Water is one of the essential components required by plants in large quantities for their growth and development. Approximately 85-90% of the fresh weight of plant cells and tissues is water. Water deficiency can reduce cell turgor and increase the concentration of macromolecules. Additionally, it also affects cell membranes and the chemical activity potential of water within plant tissues. Water deficiency disrupts metabolic processes and ultimately affects plant growth and yield. To increase rice yield in semi-technical irrigated fields, it is advisable to select superior varieties with short-lived, adaptable, and high production. Hindarwati et al. (2021) stated that superior varieties can increase rice productivity.

The Ciherang variety is a superior variety with a harvesting period ranging from 116 to 125 days after planting (DAP). It has a yield potential of up to 8.5 tons ha^{-1}, but the average yield is around 6.0 tons ha^{-1}. This variety thrives when planted in lowland irrigated paddy fields up to 500 m above sea level (Suprihatno et al., 2009). Similarly, the Padjajaran Agritan variety is a superior variety with a shorter growth duration and higher yield potential. The plant's age is 105 days after planting with a potential yield of 11.0 tons ha^{-1}, but the average yield is 7.8 tons ha^{-1}. This variety is best grown in lowland irrigated rice fields up to 600 m above sea level (Thamrin et al., 2023). The use of short-lived and drought-tolerant varieties can help alleviate crop failure issues during the generative phase due to water scarcity (Viandari et al., 2022). Padjajaran Agritan variety have harvest age shorter than Ciherang.

The number of productive tillers for the Ciherang variety is 19.40 stems, harvested at 122.5 DAP, yielding 11.01 tons ha^{-1} during the rainy season (Rahmawati et al., 2019). Additionally, the number of panicles $clump^{-1}$ was 10.78, and the weight of 1000 dry grains was 24.33 g (Safi'e et al., 2022). Furthermore, the number of productive tillers was 21.5 stems, harvested at 122 days, with a weight of 1000 dry grains being 29.5 g (Desi et al., 2023). In dry seasons, the harvesting age was 125 DAP, and the grain yield was 9.84 tons ha^{-1}. But in the rainy season, the grains yield 4.81 tons ha^{-1} (Santosa and Suryanto, 2015). The Padjajaran Agritan variety produced 10.25 panicles $clump^{-1}$, with a weight of 1000 dry grains of 25.65 g, and a productivity of 4.80 tons ha^{-1} when planted in irrigated paddy fields from March to July or early in the dry season (Damiri et al., 2022). The chlorophyll content index of Padjajaran Agritan was 17.037 at the age of 56-68 DAP (Munibah et al., 2022). In addition, maximum rice growth and yield are also determined by the use of optimal spacing.

Optimal spacing ensures that plants grow well both above and below the soil surface by utilizing solar radiation and nutrients. However, closer spacing will encourage mutual shadowing and intra-specific competition between plants (Oni et al., 2023). Rice yield depended on the number of panicles/m^2 and the seeds number/panicles. The spacing that gave the higher number of panicles/m^2 was 15 × 15 cm and it gave a good yield (Marie-Noel et al., 2021). In line with research by Htwe et al. (2021), somewhat a spacing that was rather closer with two seedlings per hole could increase rice yield with higher resource use efficiency.

The optimum spacing that gave maximum yield $clump^{-1}$ was 25 × 25 cm (Reuben et al., 2016). In addition, a spacing of 25 × 25 cm during the dry season seemed more promising for higher rice production (Michael and Ali, 2020). The absorption efficiency of solar radiation in the rice canopy was higher at a spacing of 25 × 25 cm than at 20 × 20 cm. Increasing the absorption efficiency of solar radiation would increase the number of panicles $clump^{-1}$ and the number of spikelets $clump^{-1}$ even with alternate wetting and drying irrigation methods during the wet season (Setiobudi and Sembiring, 2009).

Research on the influence of variety and spacing on the growth and yield of rice conducted in the rainy and dry seasons has not been previously undertaken by researchers. This study is expected to contribute to the optimal spacing for each variety cultivated during the rainy and dry seasons. The research is still limited to semi-technical irrigated paddy fields. Based on the literature above, this study aimed to know the optimal spacing on the growth and yield of rice in different varieties and planting seasons.

Materials and methods

Study area

This study was conducted in the rainy season from December 2022 to April 2023 with an average sunlight intensity of 876.3 lux and an average maximum air temperature of 30.7 °C. The dry season lasted from June to Oktober 2023 with an average sunlight intensity of 953.9 lux and an average maximum air temperature of 31.1 °C. The experimental location was carried out in Minggir Sub-district, Sleman Regency, Special Region of Yogyakarta, Indonesia with an elevation of 110 m above sea level. Geographically, Sleman Regency is situated between 110°33′ 00″ - 110°13′ 00″ East Longitude and 7°34′51″ - 7°47′30″ South Latitude.

Materials and tools

The study used the Padjajaran Agritan and Ciherang varieties. The fertilizers of urea and NPK Phonska were used. Bamboo stakes and plastic film were used as supports and treatment labels. Hand plows and rakes were used for the first and second soil tillage. A hoe was used to create treatment plots and irrigation channels. A sickle was used to cut rice stalks during harvest. The chlorophyll meter CCM-200 plus was used to measure leaf greenness. The Binder FD 115 oven was used to dry stems and leaves. A light meter was used to measure sunlight intensity. The digital scales model DS-880 was used to measure the dry weight of the shoots and grains

Experimental design

The study was conducted in rice fields during rainy and dry seasons. The experiment was arranged in a nested design. This research used two rice varieties, namely Padjajaran Agritan and Ciherang. Each rice variety consisted of three spacings, i.e., 15 × 15, 20 × 20, and 25 × 25 cm. Each spacing was replicated three times. Randomization was carried out for the spacing treatment of each rice variety. The research flow can be seen in *Fig. 1*.

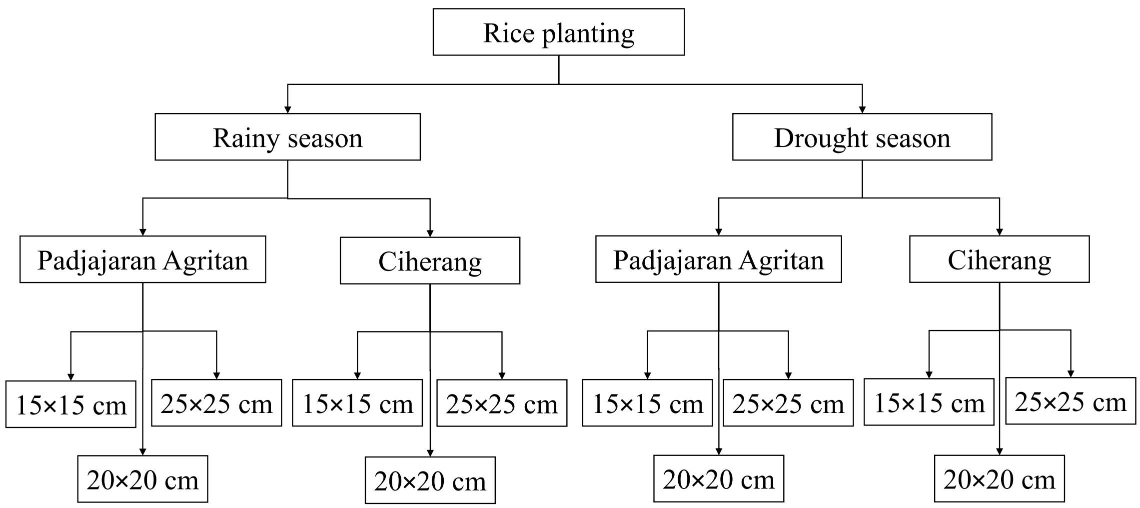


Figure 1. *The flow diagram in research activity*

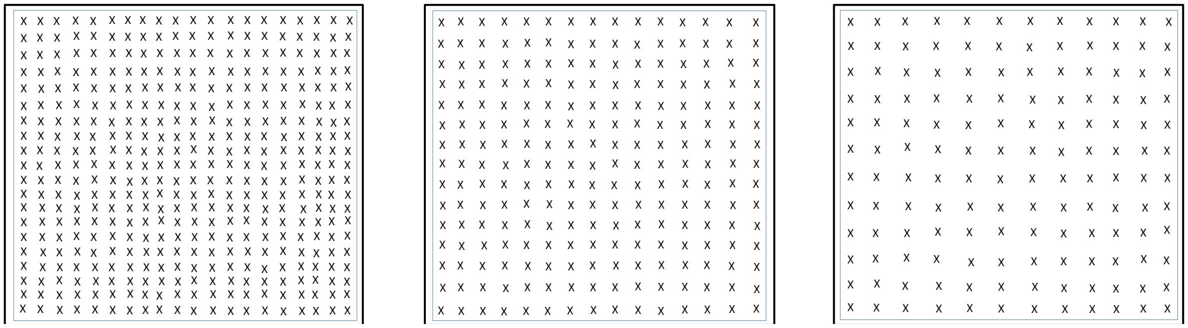
Research procedures

Rice cultivation in the rainy season

The first study was conducted during the rainy season. Plows were used for the initial tillage, followed by harrows to level the soil surface. After tillage was completed, nine treatment plots were established for spacing in both the Padjajaran Agritan and Ciherang varieties, making a total of 18 treatment plots. Randomization was carried out for the spacing treatment in both varieties in each planting season. The distance between treatment plots was 0.5 meters for each rice variety.

Rice seeds were soaked in water for three hours before being placed in the seedbed to ensure uniform imbibition. Subsequently, the soaked seeds were removed from the water and drained. Following this, the seeds were wrapped in newsprint overnight. Afterward, the seeds were placed on the prepared surface of the seedbed. The rice seedlings were ready for planting in the treatment plot at the age of 18 DAP.

The size of the treatment plot was 3 × 3 square meters (m^2) (see *Fig. 2*). The number of rice seedlings planted in each treatment plot depended on the spacing. For a spacing of 15 × 15 cm, 400 seedlings were needed (see *Fig. 2a*); for a spacing of 20 × 20 cm, 225 seedlings were used (see *Fig. 2b*); while a spacing of 25 × 25 cm required 144 seedlings (see *Fig. 2c*). Only one rice seedling was planted per planting hole.



15 × 15 cm (a) | 20 × 20 cm (b) | 25 × 25 cm (c)

Figure 2*. The number of rice seedlings in each spacing*

Fertilizer doses of 225 kg ha^{-1} urea and 225 kg ha^{-1} NPK Phonska 15-15-15 were recommended (BPPP, 2014). Urea and NPK Phonska fertilizers were applied twice each. The first application comprised 40% of the recommended dose at 15 DAP, and the second application comprised 60% of the recommended dose at 30 DAP. Watering was carried out as needed by the plants. Weed control was conducted twice, at 14 and 34 DAP. Pest control was implemented to manage plantoppers. Rice harvesting was conducted at 104 DAP for the Padjajaran Agritan variety and at 116 DAP for the Ciherang variety.

Rice cultivation in the dry season

The research in the dry season was conducted similarly to that in the rainy season. However, during the dry season, the water availability for irrigating rice plants was severely limited. Watering was performed once a week, and sometimes it was delayed.

Parameter

Observations of research data were conducted on sunlight intensity (lux), number of productive tillers (steams clump^{-1}), leaf greenness index (units), shoot dry weight, and grain dry weight (g clump^{-1} and tons ha^{-1}).

Statistical analysis

Observational data were analyzed by analysis of variance (ANOVA) at the 5% significance levels. Duncan's new multiple range test (DMRT) at 5% significance levels was used to determine the difference between treatments (Gomez and Gomez, 1984).

Results

Rice growth

Observations of rice growth included the number of productive tillers (stems clump^{-1}), leaf greenness (units), and shoot dry weight. After analyzing using analysis of variance (ANOVA), it was found that spacing significantly influenced rice growth. However, there was no significant difference in rice growth between the Padjajaran Agritan and Ciherang varieties. There were differences in rice growth between the rainy and dry seasons. For further clarification, the results of the DMRT at the 5% significance levels for rice growth can be seen in Tables 1, 2, and 3.

Table 1. *Effect of spacing on the number of productive tillers (stems clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season 15.9 p						Dry season 9.6 q					
Varieties						**Varieties**					
Pajajaran Agritan 15.5 p			Ciherang 16.3 p			Pajajaran Agritan 9.5 p			Ciherang 9.6 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
9.3 z	15.9 y	21.3 x	10.3 z	15.7 y	22.9 x	7.6 z	9.0 y	12.1 x	7.3 z	8.9 y	12.7 x

Remarks: The means followed by the same character in a row is not significantly different by DMRT at 5% significant levels.

Table 2. *Effect of spacing on the shoot dry weight (g clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season 19.35 p						Dry season 10.75 q					
Varieties						**Varieties**					
Pajajaran Agritan 21.04 p			Ciherang 17.66 p			Pajajaran Agritan 10.36 p			Ciherang 11.15 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
11.58 z	18.41 y	33.13 x	12.19 z	17.38 y	23.43 x	8.16 z	10.13 y	12.78 x	8.89 z	11.49 y	13.04 x

Remarks: The means followed by the same character in a row is not significantly different by DMRT at 5% significant levels.

Table 3. *Effect of spacing on the leaf greenness index (units) in different varieties and planting seasons*

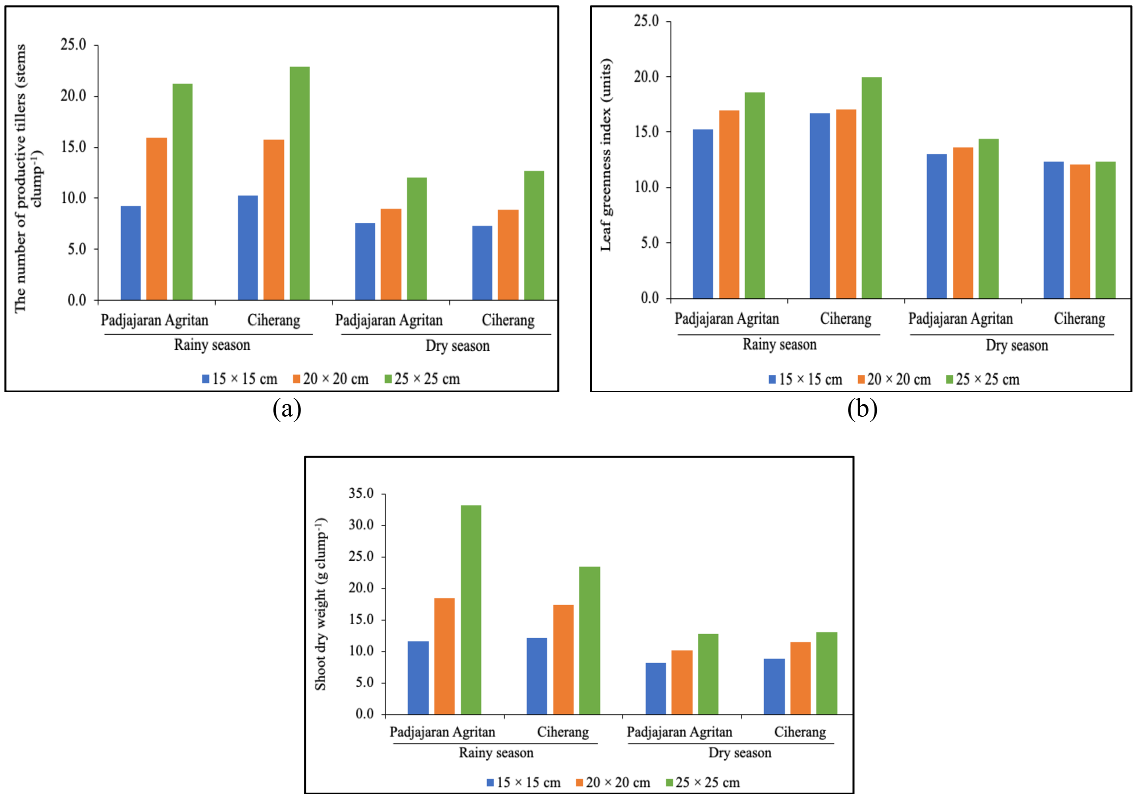
Planting seasons											
Rainy season 17.4 p						Dry season 12.9 q					
Varieties						**Varieties**					
Pajajaran Agritan 16.9 p			Ciherang 17.9 p			Pajajaran Agritan 13.7 p			Ciherang 12.3 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
15.3 x	16.9 x	18.6 x	16.7 x	17.1 x	19.9 x	13.0 x	13.7 x	14.4 x	12.3 x	12.1 x	12. 4 x

Remarks: The means followed by the same character in a row is not significantly different by DMRT at 5% significant levels.

Tables 1 and 2 indicate that a spacing of 25 × 25 cm resulted in the number of productive tillers and shoot dry weight higher than in 15 × 15 cm or 20 × 20 cm in both varieties. There were no differences in the number of productive tillers and shoot dry weight produced by the Padjajaran Agritan and Ciherang varieties in both planting seasons. The number of productive tillers and shoot dry weight produced in the rainy season was higher than in the dry season.

Table 3 explains that there was no difference in leaf greenness index between those planted in spacings of 15 × 15, 20 × 15, and 25 × 25 cm in both varieties. There was no difference in leaf greenness between Padjajaran Agritan and Ciherang varieties planted in both planting seasons. The leaf greenness index of rice was higher in the rainy season than in the dry season.

The effect of spacing on rice growth in different varieties and planting seasons can be explained in *Figs. 3a, 3b* and *3c*.



(c)

Figure 3. *The effect of spacing on the number of productive tillers (a), and shoot dry weight (b), and leaf greenness index (c) in different varieties and planting season*

Rice yield

The observation data of rice yield were the grain dry weight clump^{-1} and ha^{-1}. Based on the data analysis using ANOVA, it was found that spacing had a significant effect on rice yield clump^{-1}, but not per hectare. There was no significant difference in rice yield between the Padjajaran Agritan and Ciherang varieties, either per clump or ha. Differences in rice yield clump^{-1} were observed between the rainy and dry seasons, but not on a per hectare. For clarity, the results of the DMRT at the 5% significant levels for rice yield clump^{-1} and ha^{-1} can be shown in Tables 4 and 5.

Table 4. *Effect of spacing on the grain dry weight (g clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season 25.57 p						Dry season 19.17 q					
Varieties						**Varieties**					
Pajajaran Agritan 25.74 p			Ciherang 25.39 p			Pajajaran Agritan 19.86 p			Ciherang 18.47 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
14.70 z	24.47 y	38.05 x	15.91 z	26.04 y	34.23 x	13.71 z	20.97 y	24.91 x	13.46 z	17.37 y	24.59 x

Remarks: The means followed by the same character in a row is not significantly different by DMRT at 5% significant levels.

Table 5. *Effect of spacing on the shoot dry weight (tons ha^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season 6.29 p						Dry season 4.93 q					
Varieties						**Varieties**					
Pajajaran Agritan 6.25 p			Ciherang 6.35 p			Pajajaran Agritan 5.11 p			Ciherang 4.75 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
6.53 x	6.12 x	6.09 x	7.07 x	6.51 x	5.48 y	6.01 x	5.24 x	3.98 y	5.98 x	4.34 y	3.94 y

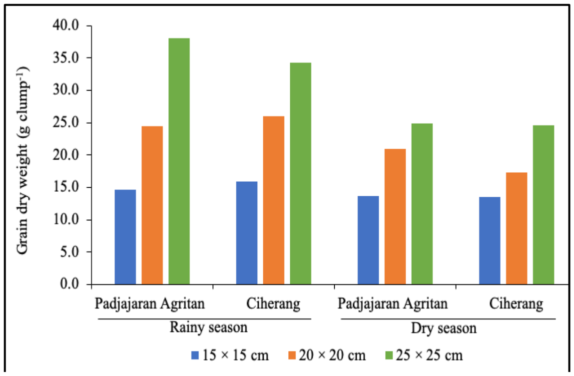
Remarks: The means followed by the same character in a row is not significantly different by DMRT at 5% significant levels.

Table 4 shows that a spacing of 25 × 25 cm resulted in grain dry weight clump^{-1} higher than in 15 × 15 cm or 20 × 20 cm in both varieties. There was no difference in grain dry weight produced by the Padjajaran Agritan and Ciherang varieties in both planting seasons. Rice plants cultivated in the rainy season yielded grain dry weight per clump higher than in the dry season.

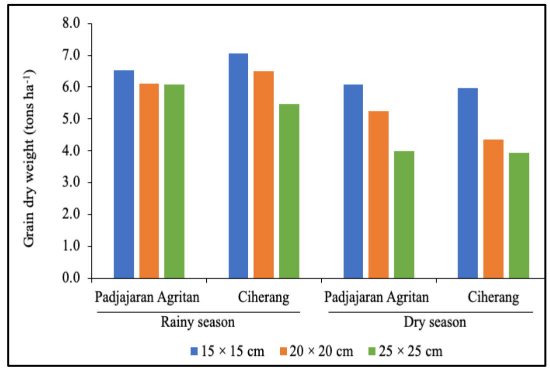
Table 5 indicates that there was no difference in grain dry weight per hectare at the three spacings in the Padjajaran Agritan variety that was cultivated during the rainy season. However, spacings of 15 × 15 and 20 × 20 cm resulted in grain dry weight per hectare higher than in 25 × 25 cm in the Ciherang variety that was cultivated during the rainy season. The same trend occurred in the Padjajaran Agritan variety cultivated during the dry season.

However, a spacing of 15 × 15 cm yielded the highest grain dry weight per hectare than in 20 × 20 and 25 × 25 cm in the Ciherang variety during the dry season. There was no difference in grain dry weight per hectare produced by the Padjajaran Agritan and Ciherang varieties in both planting seasons. Rice plants that were cultivated during the rainy season yielded grain dry weight per hectare higher than in the dry season.

The effect of spacing on the rice yield (g clump^{-1} and tons ha^{-1}) in different varieties and planting seasons can be presented in *Figs. 4a* and *4b*.



(a)



(b)

Figure 4*. The effect of spacing on the grain dry weight (g clump^{-1}) (a) and (tons ha^{-1}) (b)) in different varieties and planting season*

Discussion

The growth components observed were the number of productive tillers, leaf greenness index, and dry shoot weight. In contrast, the yield components observed were only grain dry weight per clump and hectare. Rice growth and yield were higher obtained at a spacing of 25 × 25 cm than 15 × 15 or 20 × 20 cm for both varieties, except for the leaf greenness index. At wider spacing, there was lower competition among plants for water and nutrients in the soil, so the number of tillers per clump formed was greater. Additionally, sunlight interception by the plant canopy per clump was higher, and air circulation among plants was better for CO_2 uptake during photosynthesis. These agronomic factors could support metabolic processes, resulting in better rice growth and yield per clump.

On the contrary, the grain dry weight per hectare was higher at a spacing of 15 × 15 cm. This higher yield was due to the higher plant population per hectare (444,444 clumps) compared to 20 × 20 cm (250,000 clumps), or 25 × 25 cm (160,000 clumps). The spacing of 15 × 15 cm was the optimum spacing that could provide maximum grain dry weight per hectare. According to De-yang et al. (2016), increasing plant density is one strategy to increase grain yields because it can increase the potential capacity of the plant canopy to capture solar radiation. And also increases absorb water and nutrients.

There was no difference in rice growth and yield per clump or hectare between both varieties, whether planted in the rainy or dry season. This indicates that both varieties exhibit similar growth and yield. However, when considering the harvesting age, the Padjajaran Agritan variety has a shorter maturity period, thus requiring less total water compared to the Ciherang variety. According to Noviana et al. (2021), early maturing and superior varieties can be utilized to increase the cropping index and rice production.

The research showed that rice yield per hectare in the rainy season was higher than in the dry season. Ideally, rice growth and yield should be higher in the dry season due to abundant sunlight for photosynthesis. In study showed that leaf greenness occurred higher in the rainy season than in the dry season, so the photosynthetic process in rice leaf better. The higher carbohydrate yield can support better shoot growth and grain filling. However, in the dry season, insufficient groundwater availability could lead to reduced growth and yield of rice. Water availability became a limiting factor for rice growth and yields in the study. Water availability caused a reduction in the leaf greenness index of rice plants so the photosynthetic process inhibitation. Because the rice fields for the research were semi-technical irrigated rice fields, so during the dry season, there was a water shortage in rice growth, especially during the generative growth phase. According to Arsal et al. (2020), irrigation water supply is crucial to compensate for the groundwater needs during the dry season.

Abundant sunlight intensity in the dry season can increase air temperature and decrease air humidity around the rice plant. High air temperature has an impact on increasing transpiration from the plant body. If the plant loses a lot of water, then it negatively affects cell division, growth, and protoplasm within the leaves. Water stress causes a decrease in photosynthesis activity, resulting in a reduction in rice growth and yield. However, the Padjajaran Agritan and Ciherang varieties can still adapt well to water scarcity conditions. According to Sukkeo et al. (2017), high temperatures harm rice grain yield during panicle development, anthesis, and grain filling. In line with the opinion of Sanwong et al. (2023), high temperature affects the reduction of grain yield and quality.

Conclusion

In conclusion, the number of productive tillers, dry shoot weight, and grain dry weight clump^{-1} were higher when planted with a spacing of 25 × 25 cm than 15 × 15 or 20 × 20 cm for both varieties. Conversely, the total grain dry weight per hectare was greater with a spacing of 15 × 15 cm. No significant differences were observed in the growth and yield of rice between the Padjajaran Agritan and Ciherang varieties. The grain dry weight produced by Padjajaran Agritan and Ciherang were 6.25 and 6.35 tons ha^{-1} in the rainy season but decreased to 5.11 and 4.75 tons ha^{-1} in the dry season. The research findings suggest that a spacing of 15 × 15 cm is optimal for both the Padjajaran Agritan and Ciherang varieties when planted in either the rainy or dry season. However, the growth and yield of rice are higher in the rainy season than in the dry season in semi-technical irrigated rice fields. Consequently, we recommend utilizing closer spacing and drought-resistant superior varieties to maximize rice yield in the dry season.

Acknowledgements. We would like to express our gratitude to the Institute for Research and Community Service, Universitas PGRI Yogyakarta, for granting permission and providing financial support for this research. Additionally, we extend our appreciation to the Faculty of Agriculture, Universitas PGRI Yogyakarta, for providing laboratory facilities and equipment for this study.

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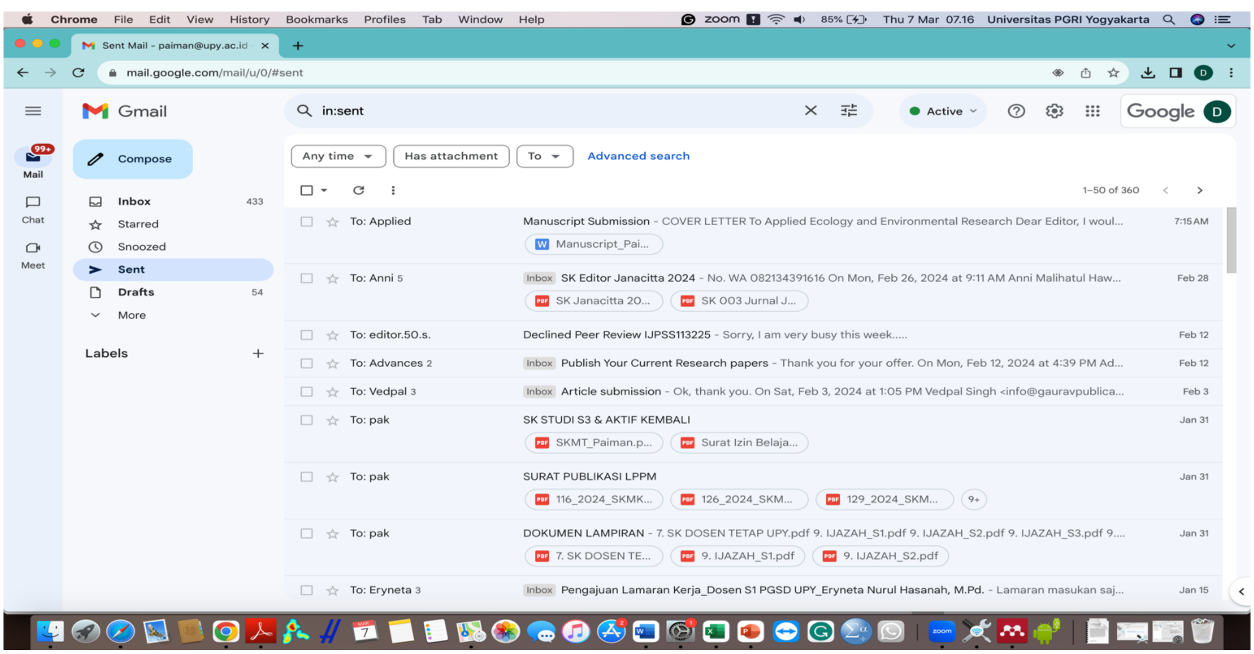

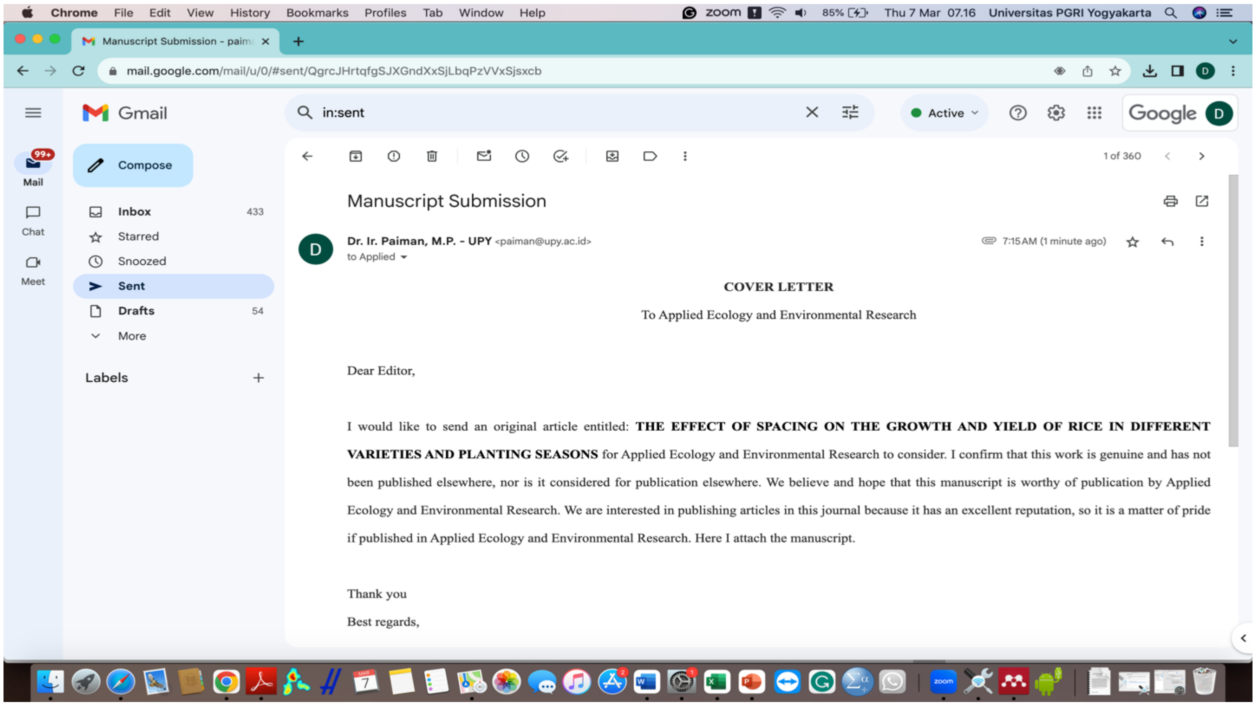
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Dr. Ir. Paiman, M.P. - UPY <paiman@upy.ac.id>
to Applied

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COVER LETTER

To Applied Ecology and Environmental Research

Dear Editor,

I would like to send an original article entitled: **THE EFFECT OF SPACING ON THE GROWTH AND YIELD OF RICE IN DIFFERENT VARIETIES AND PLANTING SEASONS** for Applied Ecology and Environmental Research 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 Applied Ecology and Environmental Research. 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 Applied Ecology and Environmental Research. Here I attach the manuscript.

Thank you

Best regards,

Reply from Journal AEER about submitted manuscript: **9 Maret 2024**

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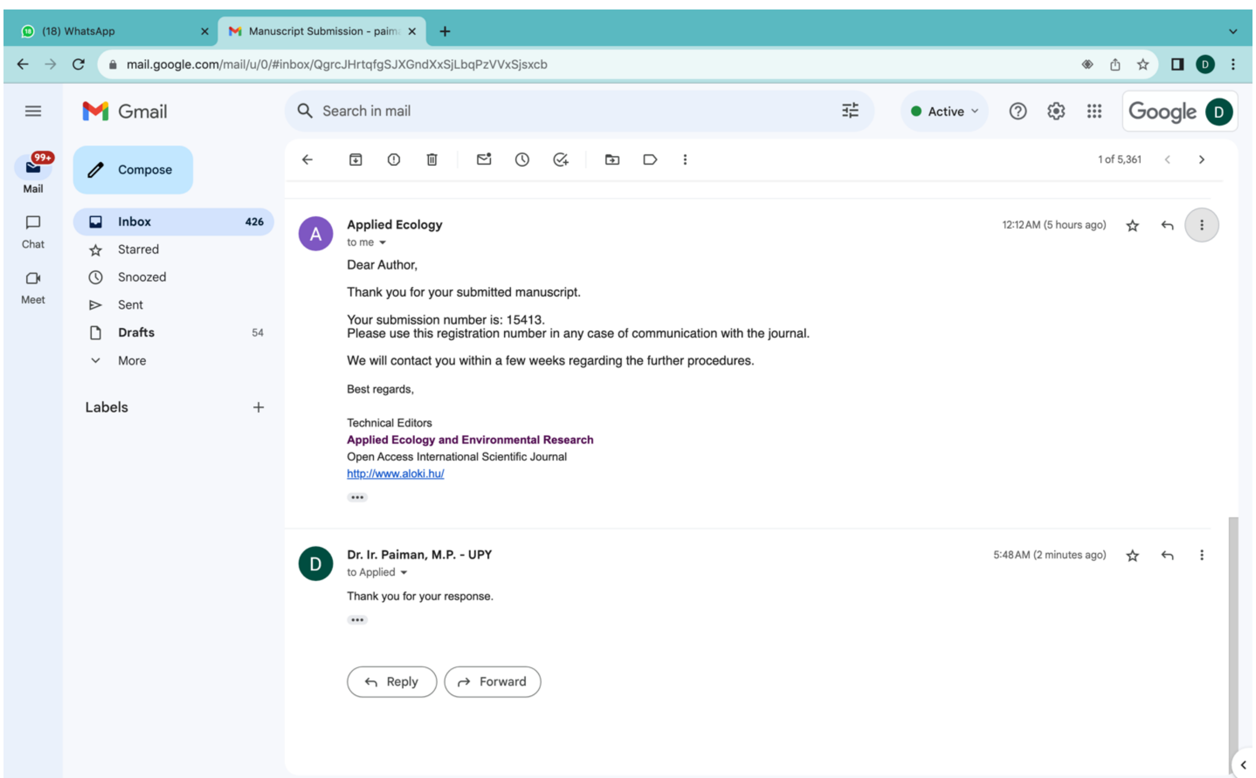
Applied Ecology
to me

12:12 AM (5 hours ago)

Dear Author,

Thank you for your submitted manuscript.

Your submission number is: 15413.
Please use this registration number in any case of communication with the journal.

We will contact you within a few weeks regarding the further procedures.

Best regards,

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Dr. Ir. Paiman, M.P. - UPY
to Applied

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Thank you for your response.

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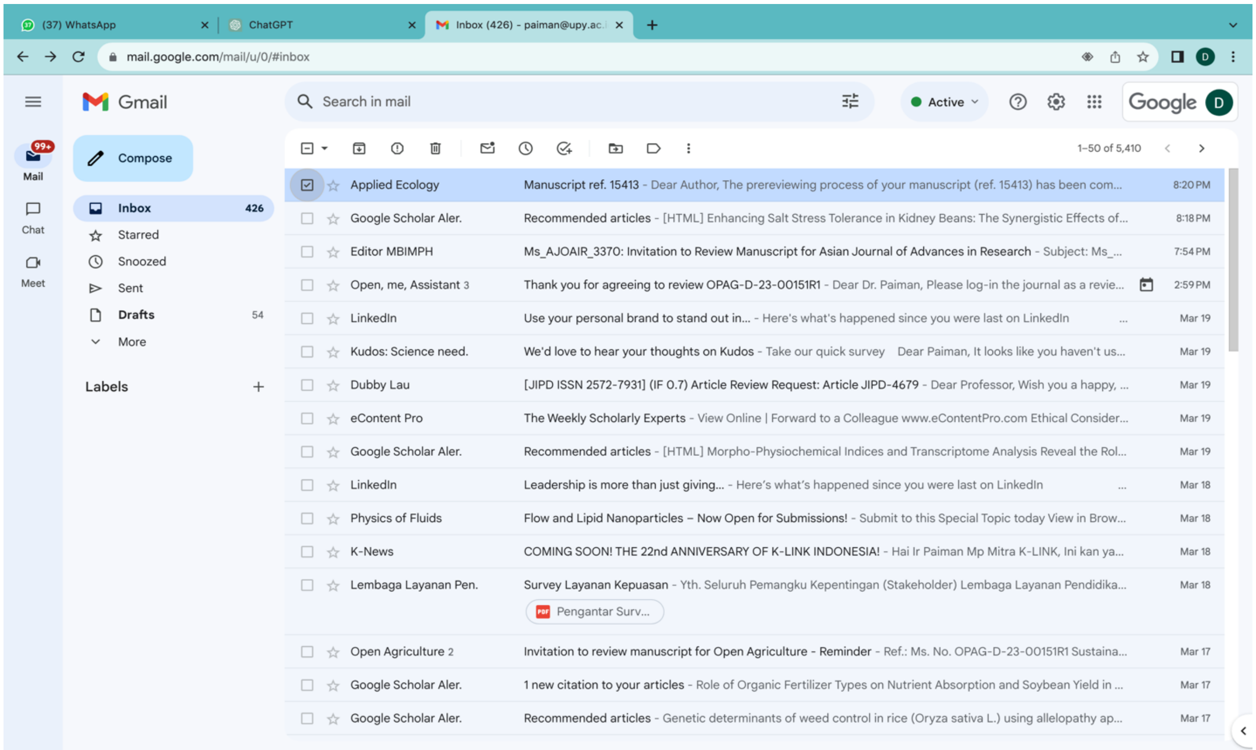

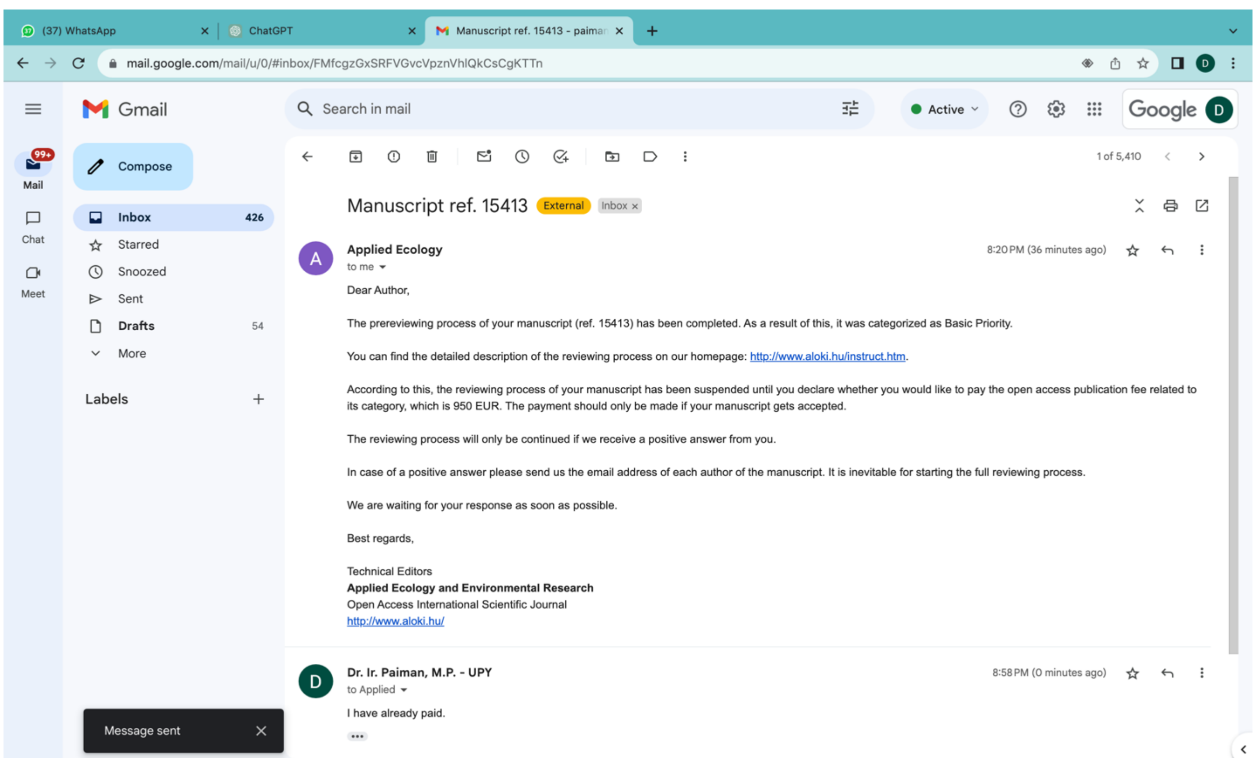

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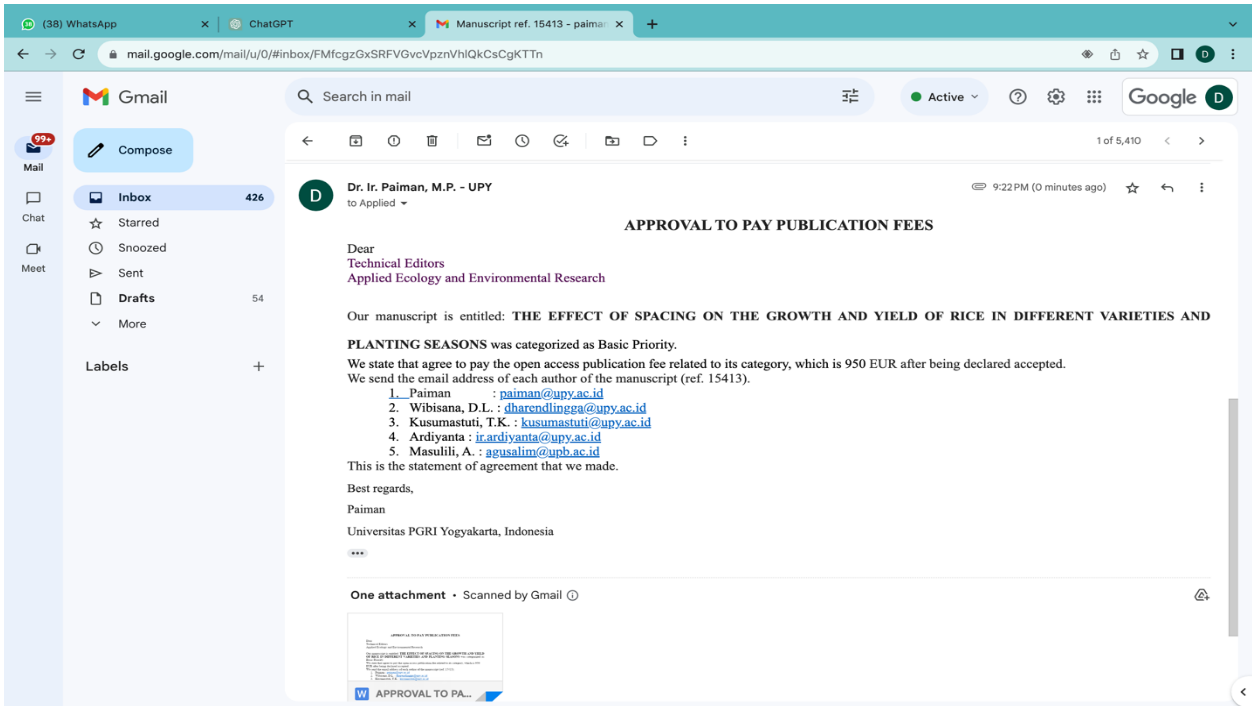

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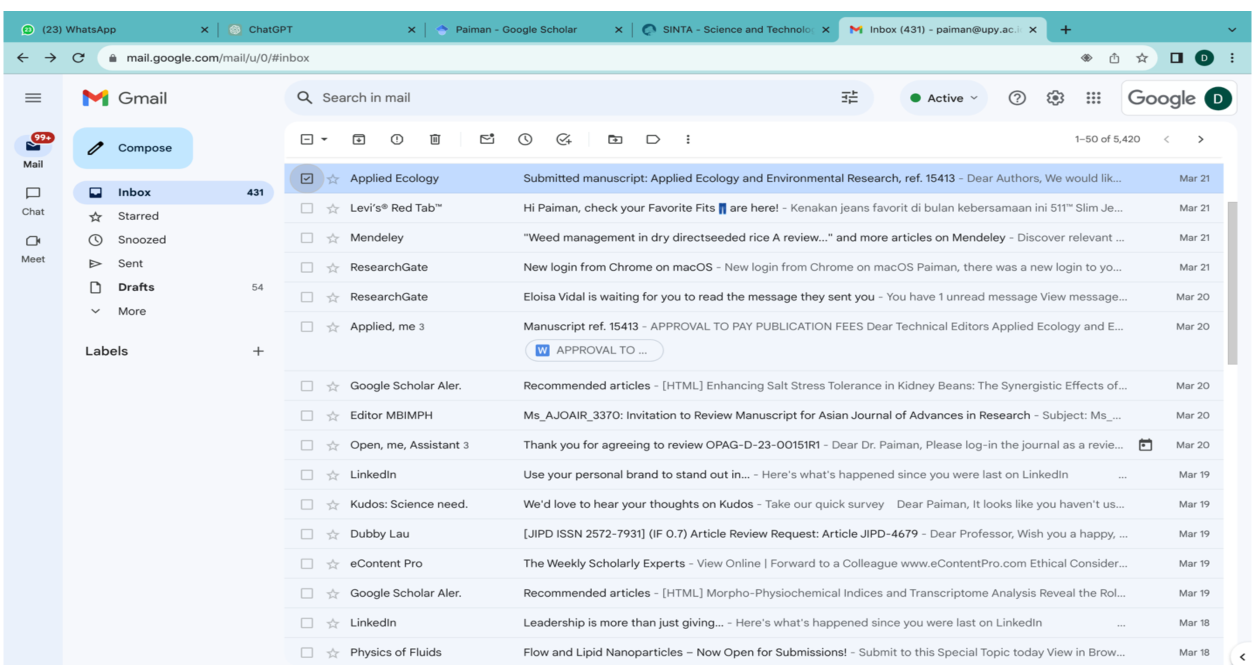

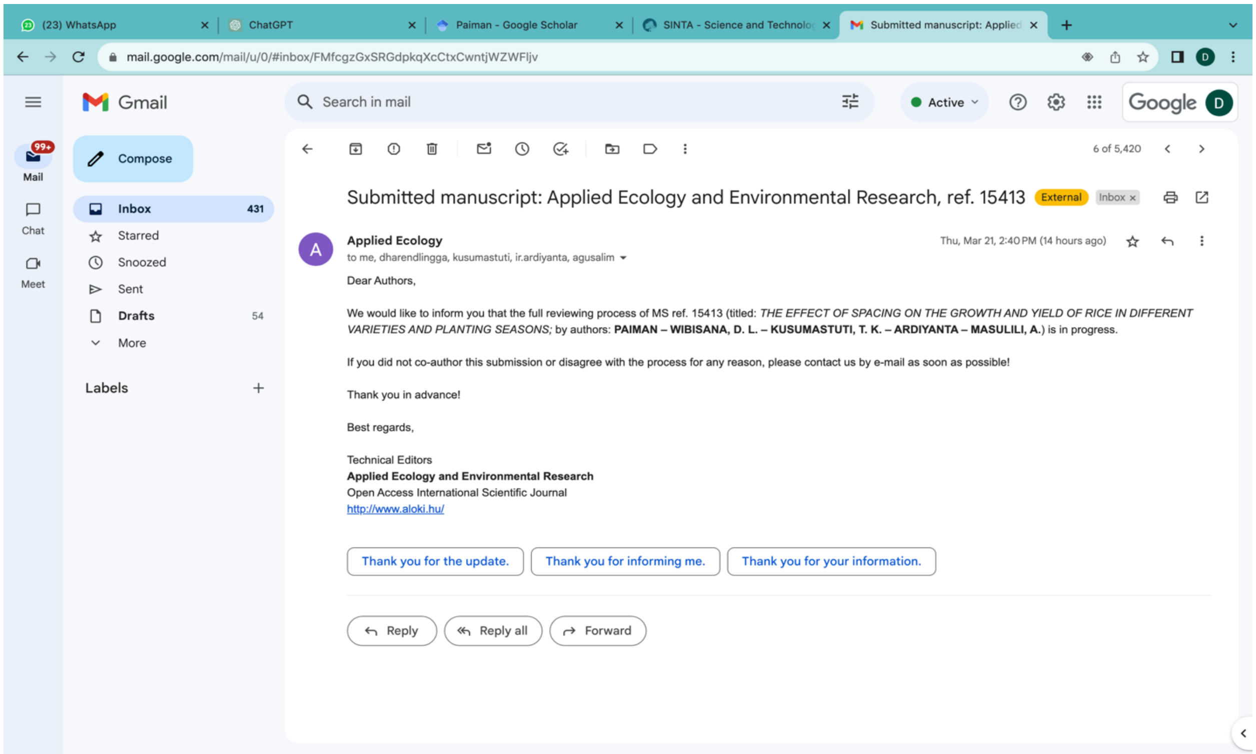

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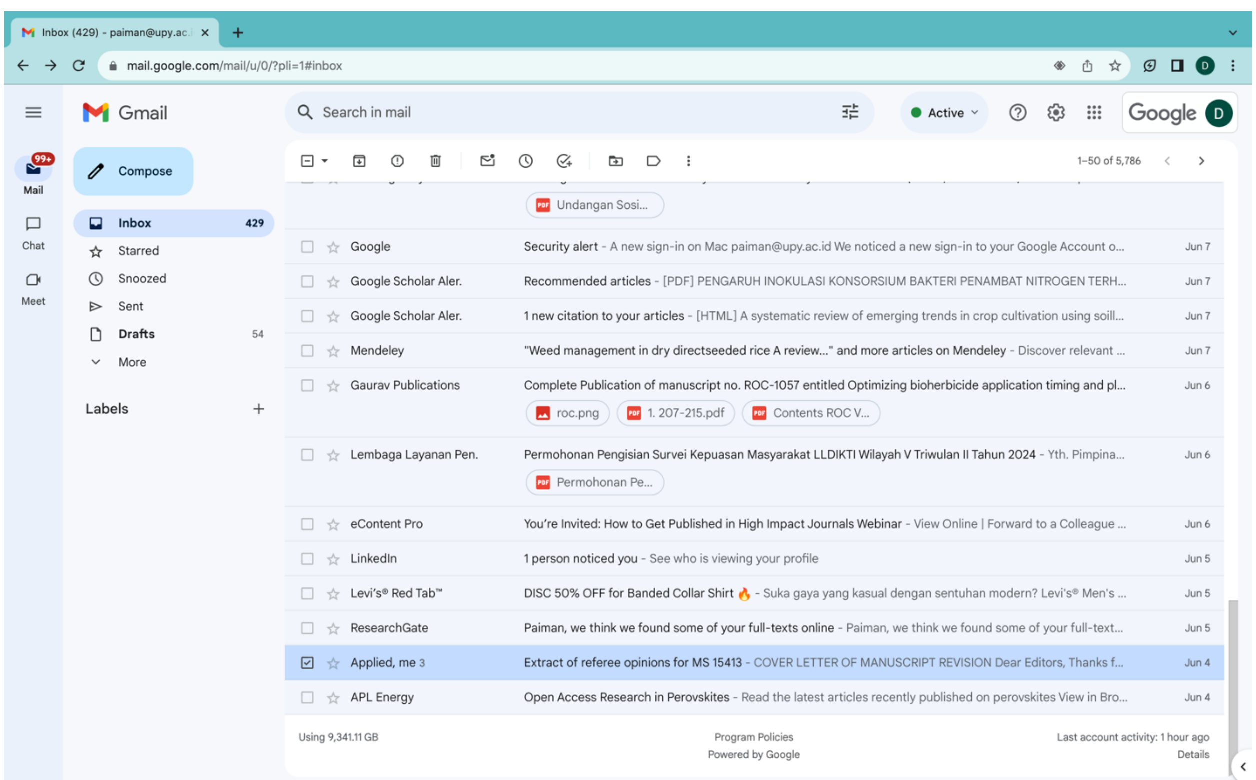
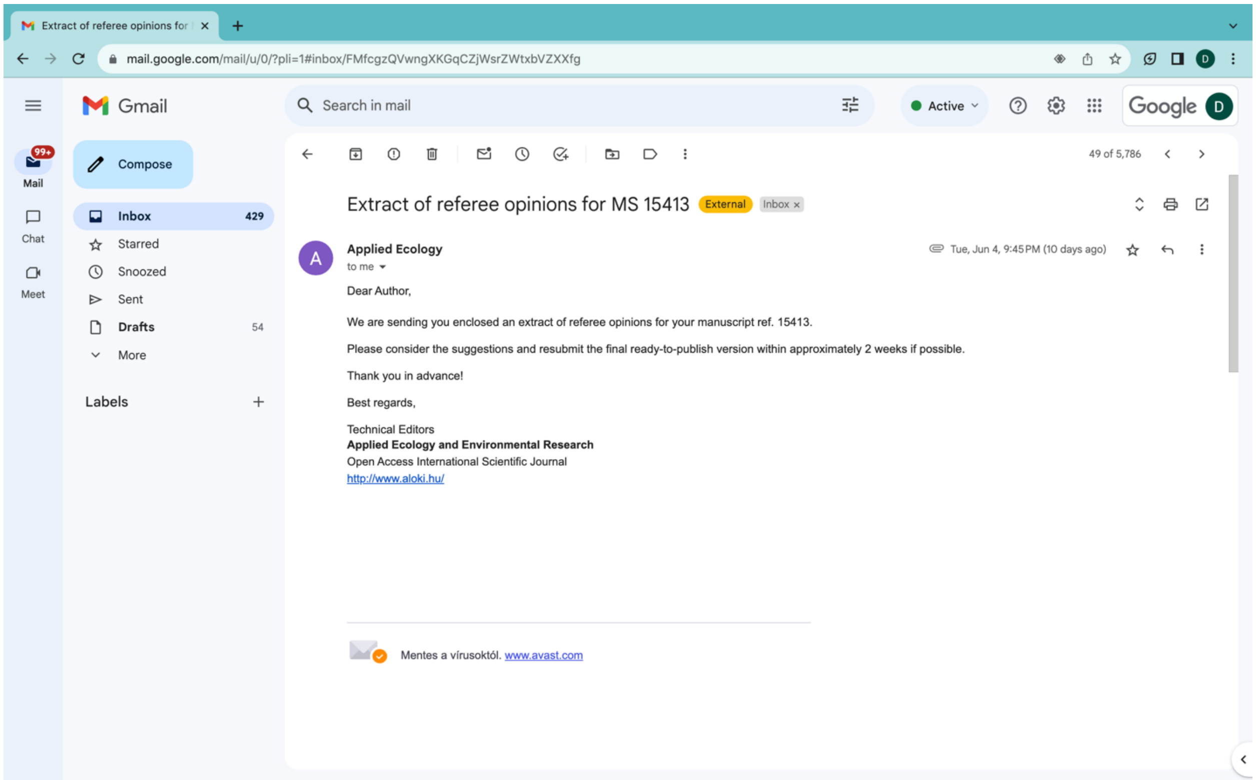




Komentar Reviewer:

Extract of referee opinions and editorial suggestions for manuscript ref. 15413

The authors set up an experiment to explore the optimum planting density of two rice varieties in the rainy and dry seasons in Indonesia. The authors highlighted in the Introduction that previous studies concluded that 15×15 cm spacing resulted in the optimum plant density and the presented study only confirmed this fact. The statistical analysis is inappropriate because ANOVA completed with Duncan's Multiple Range tests is not suitable for comparing factors having only two levels (e.g. two seasons or two genotypes). The authors did not evaluate the growth of the plants. Growth is a process that indicates the trend in biomass production during the vegetation period. The authors simply evaluated the tiller number, shoot dry weight and yield at the end of the vegetation period but measuring plant phenological properties should be conducted in various plant growth stages to determine the growth.

Comments to the Authors:

1. Please indicate in lines 9-10, what Padjarajan Agritan and Ciherang are. It is not evident to readers that those are the tested varieties.
2. Please take into account that climate change is a long-term process, and it does not impact plant growth of annual plants directly but its consequences such as extreme weather conditions could.
3. The authors must underline how the presented study resulted in some improvements in the local agronomic practice. It was stated that in many previous studies, it was confirmed that 15×15 cm spacing is the optimum.
4. Adding the manufacturers of the experimental devices would be needed.

5. Please revise the following sentence: “Rice seedlings were ready for planting after 18 DAP (days after planting)”.
6. It must be specified what kind of herbicides and insecticides were applied during the study.
7. The authors should indicate either the amount of irrigation water or the soil water content during the experiments.
8. It must be specified how many plants were selected from each plot to determine the tiller number, leaf greenness, shoot dry weight and yield.
9. It must be taken into account that the statistical approach is not suitable for comparing two levels of a variable.
10. Many times, the language quality of the text limits its interpretability. E.g. “Tables 1 and 2 indicate that a spacing of 25 × 25 cm resulted in the number of productive tillers and shoot dry weight higher than in 15 × 15 cm or 20 × 20 cm in both varieties”.
11. The same information is presented in tabular form and graphs, but in this case, tables are more informative. Presenting the corresponding figures is unnecessary.
12. Presumably, the title of Table 5 is wrong. Shoot dry weight is indicated in its title but probably the yield quantities per hectare basis were displayed.

- Abstract should be limited to 200 words.
- Keywords: There should be at least 5 keywords to increase the chance of citation.
- In the title, please also mention the country of study.
- When first using an abbreviation, please write the whole name and abbreviation in brackets the first time.
- The English throughout needs revision and careful proofreading.
- There should be a photo included of the experimental culture or equipment in the M&M chapter if possible.
- The experimental conditions of the study should be described in detail in the M&M chapter (e.g. weather and soil conditions).

THE EFFECT OF SPACING ON THE GROWTH AND YIELD OF RICE IN DIFFERENT VARIETIES AND PLANTING SEASONS

The style of the manuscript requires considerable improvement. Reconsidering word order, word choices and concisions are necessary, especially in the abstract. In the introduction part the text improves but there are still issues that disrupt comprehensibility, thus a close revision is needed.

Issues involved:

Line 4: “Indonesia experiences two distinct seasons: the rainy and dry seasons.” ‘In Indonesia there are two seasons, the rainy and the dry season.’

Line 6: “This study aimed to know the effect of optimal spacing” ‘to investigate’ is suggested to be used instead of ‘know the effect of’

Line 8: “both the rainy and dry seasons” ‘the’ is not needed

Line 9-10: “The Padjajaran Agritan and Ciherang were used in the study.” This sentence should be clarified

Line 37:" The rice plant (Oryza sativa L.) is one of the staple food crops that produce rice to meet daily basic needs in Indonesia." This sentence should be clarified

Line 41-43: "Rice cultivation can be done up to three times a year. However, in practice, rice cultivation can be optimally done only twice a year, namely in the first and second planting." These sentences should be merged and concised: "Rice cultivation can be done up to three times a year, however, optimally only twice a year."

Perbaikan manuskrip sesuai dengan komentar Reviewer:

AN ITEMIZED RESPONSE SHEET

1. Respond to all issue/referee opinions/editor suggestions
2. All amendments made are highlighted in yellow on the revision paper.

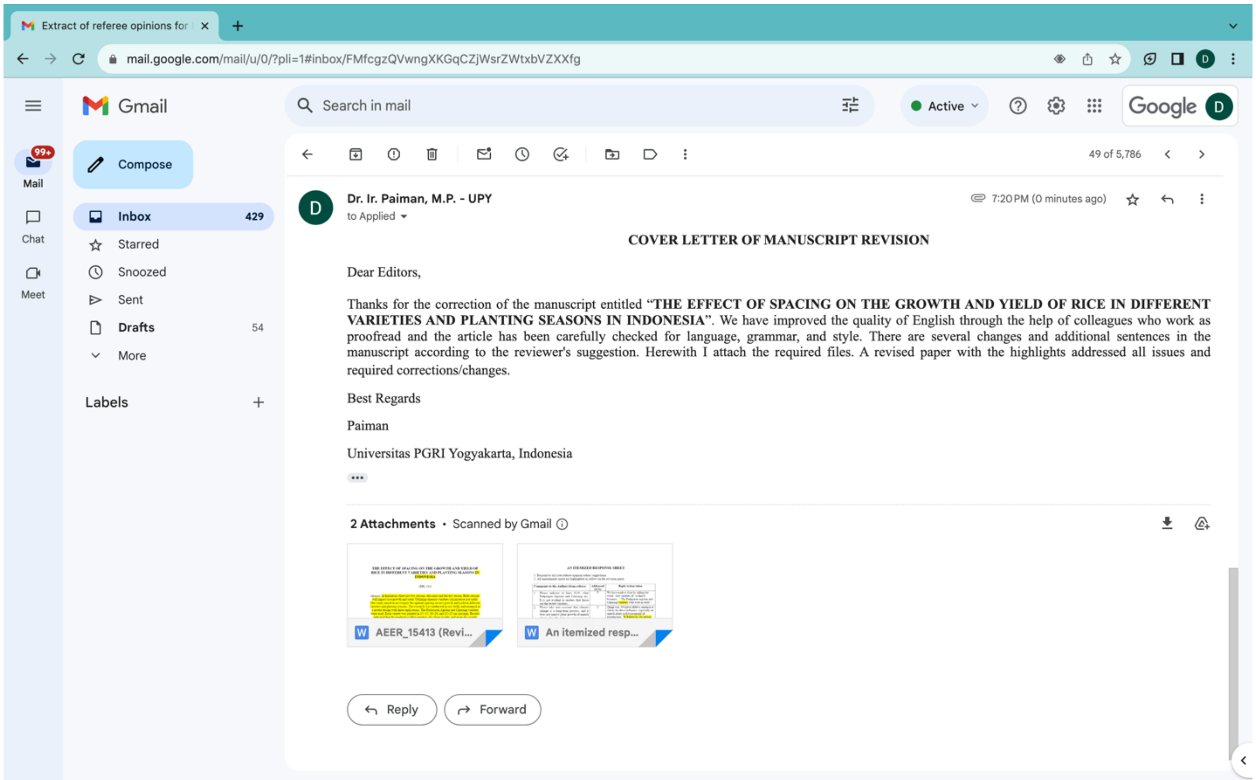
Comments to the Authors from referee:	Addressed (Y/N)	Reply/Action taken
1. Please indicate in lines 9-10, what Padjarajan Agritan and Ciherang are. It is not evident to readers that those are the tested varieties.	Y	We have made it clear by adding the word: "rice varieties of" so that it becomes: " The Padjajaran Agritan and Ciherang varieties were used in study"
2. Please take into account that climate change is a long-term process, and it does not impact plant growth of annual plants directly but its consequences such as extreme weather conditions could.	Y	Thank you. We have added a sentence to clarify the direct influence, especially on annual plants in fist paragraph of introduction. "In Indonesia, the annual climate change between the rainy and dry seasons has a significant impact on rice growth and yield. Water is abundant during the rainy season, but light intensity decreases. Conversely, in the dry season, water becomes limited, but light intensity increases. This condition plays a crucial role in rice cultivation".
3. The authors must underline how the presented study resulted in some improvements in the local agronomic practice. It was stated that in many previous studies, it was confirmed that 15×15 cm spacing is the optimum.	Y	We have explained the following: " Based on previous literature, it can be emphasized that the use of a planting distance of 15 × 15 cm or closer is an appropriate method for cultivating short-aged rice with a smaller habitus, especially for the Padjajaran Agritan and

		Ciherang varieties. With a denser planting pattern, the number of rice clumps per unit area will be greater, resulting in a higher grain yield compared to using a wider spacing. Conversely, the grain yield per clump is higher with a wider spacing than a denser one."
4. Adding the manufacturers of the experimental devices would be needed.	Y	We have added two instruments used for the research, namely: Thermo Hygrometer Clock HTC-2 was used to measure the air temperature of the research site. Lux Meter LUTRON LX-1128SD was used to measure the sunlight intensity
5. Please revise the following sentence: "Rice seedlings were ready for planting after 18 DAP (days after planting)".	Y	Thank You. We have corrected the sentence: Rice seedlings were ready for planting after 18 DAP.
6. It must be specified what kind of herbicides and insecticides were applied during the study.	Y	In this research, we only used the insecticide: Decis 25 EC 100ML to control the rice bug pest.
7. The authors should indicate either the amount of irrigation water or the soil water content during the experiments.	Y	We did not calculate the volume of water needed during the research. However, it was visually observed that during the rainy season, the amount of water was abundant from the vegetative growth stage to harvest. In contrast, during the dry season, the water needs were met during the vegetative growth stage, but the water-limited started from the generative growth stage to harvest.
8. It must be specified how many plants were selected from each plot to determine the tiller number, leaf greenness, shoot dry weight and yield.	Y	Observations of sunlight intensity and air temperature above the plant surface were conducted every two weeks during the research, but the leaf greenness index was carried out at 58 DAP. While the number of productive tillers, shoot dry weight, and grain dry weight were measured at harvest. Plant observations

		were made on 10 samples in each treatment plot.
9. It must be taken into account that the statistical approach is not suitable for comparing two levels of a variable.	N	We have added a statistical for comparing between treatments: The differences between planting season treatments or between varieties can be seen from the F calculated compared to the F table values, respectively. If the F calculated < F table, then there was no significant difference, and vice versa. Furthermore, if there were significant differences between planting distance treatments, then it was used Duncan's new multiple range test (DMRT) at 5% significance levels
10. Many times, the language quality of the text limits its interpretability. E.g. "Tables 1 and 2 indicate that a spacing of 25 × 25 cm resulted in the number of productive tillers and shoot dry weight higher than in 15 × 15 cm or 20 × 20 cm in both varieties".	Y	We have revised the sentence: Tables 1 and 2 indicate that a spacing of 25 × 25 cm resulted in a higher number of productive tillers and shoot dry weight compared to 15 × 15 cm or 20 × 20 cm spacing in both varieties
11. The same information is presented in tabular form and graphs, but in this case, tables are more informative. Presenting the corresponding figures is unnecessary.	Y	Thank you. We have removed the figures.
12. Presumably, the title of Table 5 is wrong. Shoot dry weight is indicated in its title but probably the yield quantities per hectare basis were displayed.	Y	Thank you. We've fixed it. ***Table 5****. Effect of spacing on the grain dry weight (tons ha*$^{-1}$*) in different varieties and planting seasons*
13. Abstract should be limited to 200 words.	Y	We have changed the abstract to 196 words
14. Keywords: There should be at least 5 keywords to increase the chance of citation.	Y	We added one keyword, namely climate
15. In the title, please also mention the country of study.	Y	We have added a research location with the word Indonesia in the title
16. When first using an abbreviation, please write the whole name and abbreviation in brackets the first time.	Y	Thank You. We have done it.

17. The English throughout needs revision and careful proofreading.	Y	Thanks for the advice. We have corrected errors from pharaprase, verb tenses, and grammar.
18. There should be a photo included of the experimental culture or equipment in the M&M chapter if possible.		Photo of rice crops at harvest have been added figure 3 in M&M.
19. The experimental conditions of the study should be described in detail in the M&M chapter (e.g. weather and soil conditions).	Y	Thank You. We have added information on the conditions of the research site to M&M in the sub-heading of study area.
Issues involved (Editor suggestions)	**Addressed (Y/N)**	**Reply/Action taken**
1. Line 4: "Indonesia experiences two distinct seasons: the rainy and dry seasons." 'In Indonesia there are two seasons, the rainy and the dry season.'	Y	Thanks for the advice. We have corrected this sentence.
2. Line 6: "This study aimed to know the effect of optimal spacing" 'to investigate' is suggested to be used instead of 'know the effect of'	Y	Thank You. We have repaired it
3. Line 8: "both the rainy and dry seasons" 'the' is not needed	Y	Thank You. We have deleted these words.
4. Line 9-10: "The Padjajaran Agritan and Ciherang were used in the study." This sentence should be clarified	Y	Thank You. We have added the word varieties to clarify.
5. Line 37:" The rice plant (Oryza sativa L.) is one of the staple food crops that produce rice to meet daily basic needs in Indonesia." This sentence should be clarified	Y	We have clarified it into the following sentence. The rice plant (Oryza sativa L.) is one of the staple food crops that produces rice to meet the daily basic needs of the majority of the Indonesian population.
6. Line 41-43: "Rice cultivation can be done up to three times a year. However, in practice, rice cultivation can be optimally done only twice a year, namely in the first and second planting." These sentences should be merged and concised: "Rice cultivation can be done up to three times a year, however, optimally only twice a year."	Y	Thanks for the advice. We have corrected this sentence.

Pengiriman manuscript yang telah diperbaiki: 14 Juni 2024



COVER LETTER OF MANUSCRIPT REVISION

Dear Editors,

Thanks for the correction of the manuscript entitled "**THE EFFECT OF SPACING ON THE GROWTH AND YIELD OF RICE IN DIFFERENT VARIETIES AND PLANTING SEASONS IN INDONESIA**". We have improved the quality of English through the help of colleagues who work as proofread and the article has been carefully checked for language, grammar, and style. There are several changes and additional sentences in the manuscript according to the reviewer's suggestion. Herewith I attach the required files. A revised paper with the highlights addressed all issues and required corrections/changes.

Best Regards

Paiman

Universitas PGRI Yogyakarta, Indonesia

Manuscript has been revised:

THE EFFECT OF SPACING ON THE GROWTH AND YIELD OF RICE IN DIFFERENT VARIETIES AND PLANTING SEASONS IN INDONESIA

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Abstract. In Indonesia, there are two seasons, the rainy and the dry season. Both seasons will impact rice growth and yield. Utilizing superior varieties can increase rice yield. This study aimed to investigate the optimal spacing on rice growth and yield in different varieties and planting seasons. The research was conducted in rice fields and arranged in a nested design with three replications. The Padjajaran Agritan and Ciherang varieties were used. Each variety was planted in 15×15, 20×20, and 25×25 cm spacings. Results indicated that the productive tillers number, dry shoot weight, and grain dry weight clump^{-1} were higher when planted in 25×25 cm compared to 15×15 or 20×20 cm for both varieties. Conversely, the total grain dry weight per hectare was greater with a spacing of 15×15 cm. The grain dry weight produced by Padjajaran Agritan and Ciherang were 6.25 and 6.35 tons ha^{-1} in the rainy season and 5.11 and 4.75 tons ha^{-1} in the dry season. The research findings show that a spacing of 15×15 cm is optimal for both varieties when planted in both seasons. The rice yields are higher in the rainy season. We recommend utilizing closer spacing to maximize rice yield.

Keywords: climate, irrigation, solar radiation, superior variety, water availability

Introduction

Climate change is closely related to the seasons in a region. Indonesia is located in the tropics, so every year it has rainy and dry seasons (Suwartapradja, 2022). During the rainy season, monsoon winds blow from Asia towards Australia, bringing more moisture, and transforming into rainfall in the Indonesian region. Generally, the rainy season in Indonesia occurs from October to March. Conversely, during the dry season, monsoon winds blow from Australia towards Asia, passing through Indonesia with less moisture. This results in reduced rainfall in Indonesia. Typically, the dry season in Indonesia occurs from April to November (BMKG, 2019). Climate elements such as rainfall, solar radiation, and air temperature always fluctuate throughout the year or from year to year. Climate change will impact the growth and yield of crops, especially rice crops (Jamil and Chairunnisya, 2023). In Indonesia, the annual climate change between the rainy and dry seasons has a significant impact on rice growth and yield. Water is abundant during the rainy season, but light intensity decreases. Conversely, in the dry season, water becomes limited, but light intensity increases. This condition plays a crucial role in rice cultivation.

The rice plant (*Oryza sativa* L.) is one of the staple food crops that produce rice to meet daily basic needs in Indonesia. Increasing rice productivity is also influenced by local climate and weather conditions, especially rainfall. Water plays a crucial role in the growth and yield of rice. Water requirements are not a constraint for rice cultivation in technically irrigated fields. Rice cultivation can be done up to three times a year, however, optimally only twice a year. In the third planting, water-only needs during the vegetative growth phase. However, in the generative growth phase, there is a water shortage leading to decreased rice yield. This condition often occurs in semi-technical irrigated rice fields in Yogyakarta, Indonesia. According to Pool et al. (2023), one of the most significant problems in rice production is the high water requirement of this crop.

Geographically, Yogyakarta is a region located in the central-southern part of Java Island and directly bordering the Indian Ocean. This region has two seasons, namely the rainy and dry seasons. It has several types of rice fields, including technically irrigated, semi-technical, and rainfed fields. Therefore, rice productivity varies depending on water availability in these fields. It is important to recognize that maximizing rice productivity requires the implementation of optimal spacing and the utilization of superior varieties adaptable to drought stress.

The rainy season is characterized by a decrease in average daily air temperature, shorter sunlight exposure, low solar radiation, high rainfall, and cloudy skies. However, the opposite occurs during the dry season (Jaenudin et al., 2020). Sunlight radiation and temperature are the most important factors in increasing rice productivity. When sunlight radiation and temperature increase significantly, it will result in a decrease in rice yield (Kawasaki and Herath, 2011). In addition, high daytime temperatures in the tropics are already close to optimal levels, and the increase in intensity and frequency of heat waves coinciding with sensitive reproductive phases can lead to significant damage to rice production (Mohanty et al., 2013). During the dry season, the sunlight intensity is abundant, but water availability becomes a limiting factor for rice cultivation in semi-technical irrigated fields.

Rice cultivation in the dry season usually produces higher yields, if water is available (Voe et al., 2011). Water is one of the essential components required by plants in large quantities for their growth and development. Approximately 85-90% of the fresh weight of plant cells and tissues is water. Water deficiency can reduce cell turgor and increase the concentration of macromolecules. Additionally, it also affects cell membranes and the chemical activity potential of water within plant tissues. Water deficiency disrupts metabolic processes and ultimately affects plant growth and yield. To increase rice yield in semi-technical irrigated fields, it is advisable to select superior varieties with short-lived, adaptable, and high production. Hindarwati et al. (2021) stated that superior varieties can increase rice productivity.

The Ciherang variety is a superior variety with a harvesting period ranging from 116 to 125 days after planting (DAP). It has a yield potential of up to 8.5 tons ha^{-1}, but the average yield is around 6.0 tons ha^{-1}. This variety thrives when planted in lowland irrigated paddy fields up to 500 m above sea level (Suprihatno et al., 2009). Similarly, the Padjajaran Agritan variety is a superior variety with a shorter growth duration and higher yield potential. The plant's age is 105 days after planting with a potential yield of 11.0 tons ha^{-1}, but the average yield is 7.8 tons ha^{-1}. This variety is best grown in lowland irrigated rice fields up to 600 m above sea level (Thamrin et al., 2023). The use of short-lived and drought-tolerant varieties can help alleviate crop failure issues during the generative phase due to water scarcity (Viandari et al., 2022). Padjajaran Agritan variety have harvest age shorter than Ciherang.

The number of productive tillers for the Ciherang variety is 19.40 stems, harvested at 122.5 DAP, yielding 11.01 tons ha^{-1} during the rainy season (Rahmawati et al., 2019). Additionally, the number of panicles $clump^{-1}$ was 10.78, and the weight of 1000 dry grains was 24.33 g (Safi'e et al., 2022). Furthermore, the number of productive tillers was 21.5 stems, harvested at 122 days, with a weight of 1000 dry grains being 29.5 g (Desi et al., 2023). In dry seasons, the harvesting age was 125 DAP, and the grain yield was 9.84 tons ha^{-1}. But in the rainy season, the grains yield 4.81 tons ha^{-1} (Santosa and Suryanto, 2015). The Padjajaran Agritan variety produced 10.25 panicles $clump^{-1}$, with a weight of 1000 dry grains of 25.65 g, and a productivity of 4.80 tons ha^{-1} when planted in irrigated paddy fields from March to July or early in the dry season (Damiri et al., 2022). The chlorophyll content index of Padjajaran Agritan was 17.037 at the age of 56-68 DAP (Munibah et al., 2022). In addition, maximum rice growth and yield are also determined by the use of optimal spacing.

Optimal spacing ensures that plants grow well both above and below the soil surface by utilizing solar radiation and nutrients. However, closer spacing will encourage mutual shadowing and intra-specific competition between plants (Oni et al., 2023). Rice yield depended on the number of panicles/m^2 and the seeds number/panicles. The spacing that gave the higher number of panicles/m^2 was 15 × 15 cm and it gave a good yield (Marie-Noel et al., 2021). Somewhat a spacing that was rather closer with two seedlings per hole could increase rice yield with higher resource use efficiency (Htwe et al., 2021). Based on previous literature, it can be emphasized that the use of a planting distance of 15 × 15 cm or closer is an appropriate method for cultivating short-aged rice with a smaller habitus, especially for the Padjajaran Agritan and Ciherang varieties. With a denser planting pattern, the number of rice clumps per unit area will be greater, resulting in a higher grain yield compared to using a wider spacing. Conversely, the grain yield per clump is higher with a wider spacing than a denser one.

The research result showed that the optimum spacing that gave maximum yield $clump^{-1}$ was 25 × 25 cm (Reuben et al., 2016). In addition, a spacing of 25 × 25 cm during the dry season seemed more promising for higher rice production (Michael and Ali, 2020). The absorption efficiency of solar radiation in the rice canopy was higher at a spacing of 25 × 25 cm than at 20 × 20 cm. Increasing the absorption efficiency of solar radiation would increase the number of panicles $clump^{-1}$ and the number of spikelets $clump^{-1}$ even with alternate wetting and drying irrigation methods during the wet season (Setiobudi and Sembiring, 2009).

Research on the influence of variety and spacing on the growth and yield of rice conducted in the rainy and dry seasons has not been previously undertaken by researchers. This study is expected to contribute to the optimal spacing for each variety cultivated during the rainy and dry seasons. The research is still limited to semi-technical irrigated rice fields. Based on the literature above, this study aimed to know the optimal spacing on the growth and yield of rice in different varieties and planting seasons.

Materials and methods

Study area

This study was conducted in the rainy season from December 2022 to April 2023 with an average sunlight intensity of 876.3 lux and an average maximum air temperature of 30.7 °C. The dry season lasted from June to Oktober 2023 with an average sunlight intensity of 953.9 lux and an average maximum air temperature of 31.1 °C. The experimental location was carried out in Minggir Sub-district, Sleman Regency, Special Region of Yogyakarta, Indonesia with an elevation of 110 m above sea level. The rice fields used for research was alluvial soil. Geographically, Sleman Regency is situated between 110°33′ 00″ - 110°13′ 00″ East Longitude and 7°34′51″ - 7°47′30″ South Latitude.

Materials and tools

The study used the Padjajaran Agritan and Ciherang varieties. The fertilizers of urea and NPK Phonska were used. Bamboo stakes and plastic film were used as supports and treatment labels. Decis 25 EC 100ML was used to control the plantoppers. Hand plows and rakes were used for the first and second soil tillage. A hoe was used to create treatment plots and irrigation channels. A sickle was used to cut rice stalks during harvest. The chlorophyll meter CCM-200 plus was used to measure leaf greenness. The Binder FD 115 oven was used to dry stems and leaves. The digital scales model DS-880 was used to measure the dry weight of the shoots and grains. Thermo Hygrometer Clock HTC-2 was used to measure the air temperature of the research site. Lux Meter LUTRON LX-1128SD was used to measure the sunlight intensity.

Experimental design

The study was conducted in rice fields during rainy and dry seasons. The experiment was arranged in a nested design. This research used two rice varieties, namely Padjajaran Agritan and Ciherang. Each rice variety consisted of three spacings, i.e., 15 × 15, 20 × 20, and 25 × 25 cm. Each spacing was replicated three times. Randomization was carried out for the spacing treatment of each rice variety. The research flow can be seen in *Fig. 1*.

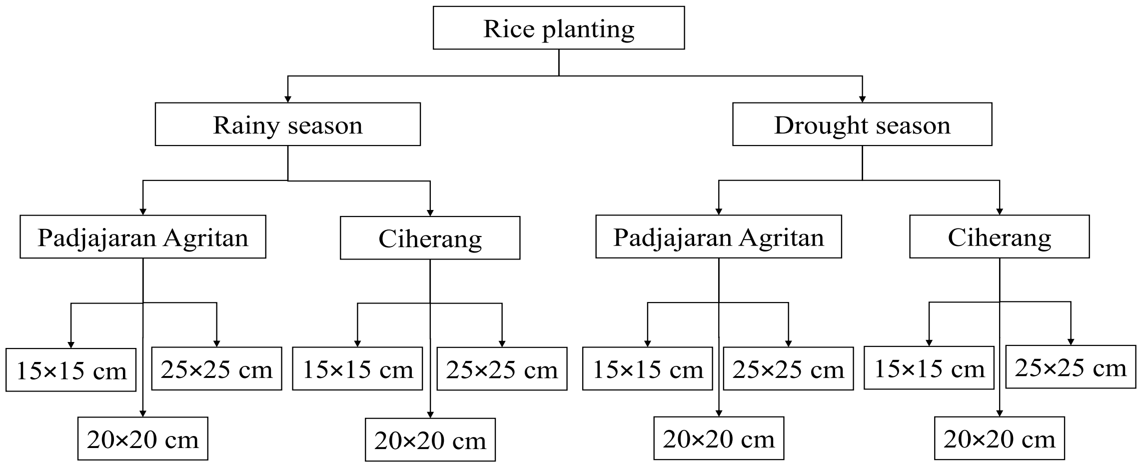


Figure 1. *The flow diagram in research activity*

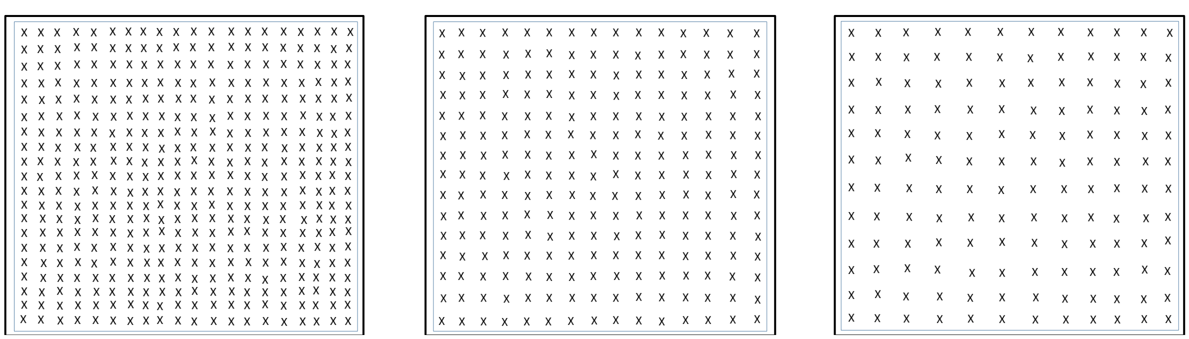
Research procedures

Rice cultivation in the rainy season

The first study was conducted during the rainy season. Plows were used for the initial tillage, followed by harrows to level the soil surface. After tillage was completed, nine treatment plots were established for spacing in both the Padjajaran Agritan and Ciherang varieties, making a total of 18 treatment plots. Randomization was carried out for the spacing treatment in both varieties in each planting season. The distance between treatment plots was 0.5 meters for each rice variety.

Rice seeds were soaked in water for three hours before being placed in the seedbed to ensure uniform imbibition. Subsequently, the soaked seeds were removed from the water and drained. Following this, the seeds were wrapped in newsprint overnight. Afterward, the seeds were placed on the prepared surface of the seedbed. Rice seedlings were ready for planting after 18 DAP.

The size of the treatment plot was 3 × 3 square meters (m^2) (see *Fig. 2*). The number of rice seedlings planted in each treatment plot depended on the spacing. For a spacing of 15 × 15 cm, 400 seedlings were needed (see *Fig. 2a*); for a spacing of 20 × 20 cm, 225 seedlings were used (see *Fig. 2b*); while a spacing of 25 × 25 cm required 144 seedlings (see *Fig. 2c*). Only one rice seedling was planted per planting hole.



15 × 15 cm (a) 20 × 20 cm (b) 25 × 25 cm (c)

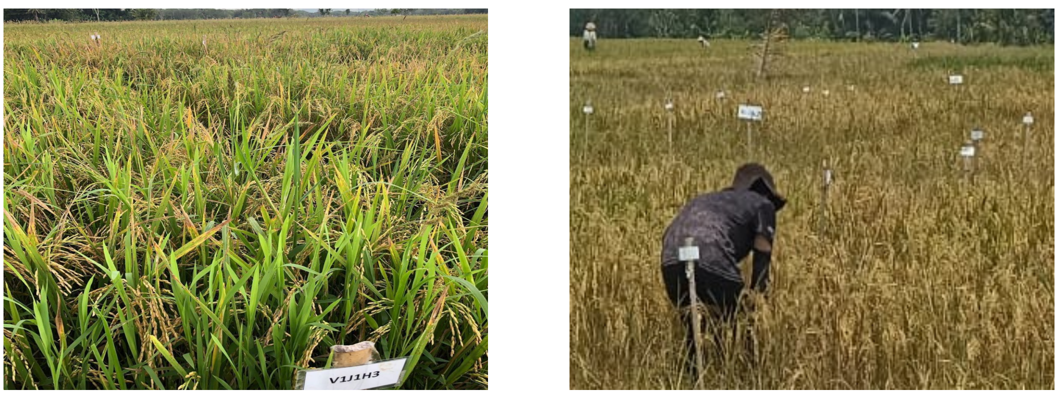
Figure 2. *The number of rice seedlings in each spacing*

Fertilizer doses of 225 kg ha^{-1} urea and 225 kg ha^{-1} NPK Phonska 15-15-15 were recommended (BPPP, 2014). Urea and NPK Phonska fertilizers were applied twice each. The first application comprised 40% of the recommended dose at 15 DAP, and the second application comprised 60% of the recommended dose at 30 DAP. Watering was carried out as needed by the plants. Weed control was conducted twice, at 14 and 34 DAP used hand manually. Pest control was implemented to manage plantoppers and used Decis 25 EC 100ML. Rice harvesting was conducted at 104 DAP for the Padjajaran Agritan variety and 116 DAP for the Ciherang variety. Water irrigation was visually observed that during the rainy season, the amount of water was abundant from the vegetative growth stage to harvest.

Rice cultivation in the dry season

The research in the dry season was conducted similarly to that in the rainy season. The water needs were met during the vegetative growth stage, but the water-limited started from the generative growth stage to harvest. Watering was performed once a week, and sometimes it was delayed.

The photo of the experimental culture in the rainy and dry seasons can be seen in *Fig. 3a* and *3b*.



a. Rice cultivation in rainy season b. Rice cultivation in dry season

Figure 3*. The photo of the experimental culture in the rainy (a) and dry seasons (b)*

Parameter

Observations of research data were conducted on sunlight intensity (lux), air temperature (ºC), number of productive tillers (steams clump^{-1}), leaf greenness index (units), shoot dry weight, and grain dry weight (g clump^{-1} and tons ha^{-1}). Observations of sunlight intensity and air temperature above the plant surface were conducted every two weeks during the research, but the leaf greenness index was carried out at 58 DAP. While the number of productive tillers, shoot dry weight, and grain dry weight were measured at harvest. Plant observations were made on 10 samples in each treatment plot.

Statistical analysis

Observational data were analyzed by analysis of variance (ANOVA) at the 5% significance levels. The differences between planting season treatments or between varieties can be seen from the F calculated compared to the F table values, respectively. If the F calculated < F table, then there was no significant difference, and vice versa. Furthermore, if there were significant differences between planting distance treatments, then it was used Duncan's new multiple range test (DMRT) at 5% significance levels (Gomez and Gomez, 1984).

Results

Rice growth

Observations of rice growth included the number of productive tillers (stems clump^{-1}), leaf greenness (units), and shoot dry weight. After analyzing using analysis of variance (ANOVA), it was found that spacing significantly influenced rice growth. However, there was no significant difference in rice growth between the Padjajaran Agritan and Ciherang varieties. There were differences in rice growth between the rainy and dry seasons. For further clarification, the results of the DMRT at the 5% significance levels for rice growth can be seen in Tables 1, 2, and 3.

Table 1. *Effect of spacing on the number of productive tillers (stems clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season 15.9 p						Dry season 9.6 q					
Varieties						**Varieties**					
Pajajaran Agritan 15.5 p			Ciherang 16.3 p			Pajajaran Agritan 9.5 p			Ciherang 9.6 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
9.3 z	15.9 y	21.3 x	10.3 z	15.7 y	22.9 x	7.6 z	9.0 y	12.1 x	7.3 z	8.9 y	12.7 x

Remarks: The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels.

Table 2. *Effect of spacing on the shoot dry weight (g clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season 19.35 p						Dry season 10.75 q					
Varieties						**Varieties**					
Pajajaran Agritan 21.04 p			Ciherang 17.66 p			Pajajaran Agritan 10.36 p			Ciherang 11.15 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
11.58 z	18.41 y	33.13 x	12.19 z	17.38 y	23.43 x	8.16 z	10.13 y	12.78 x	8.89 z	11.49 y	13.04 x

Remarks: The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels.

Table 3*. Effect of spacing on the leaf greenness index (units) in different varieties and planting seasons*

Planting seasons											
Rainy season 17.4 p						Dry season 12.9 q					
Varieties						**Varieties**					
Pajajaran Agritan 16.9 p			Ciherang 17.9 p			Pajajaran Agritan 13.7 p			Ciherang 12.3 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
15.3 x	16.9 x	18.6 x	16.7 x	17.1 x	19.9 x	13.0 x	13.7 x	14.4 x	12.3 x	12.1 x	12. 4 x

Remarks: The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels.

Tables 1 and 2 indicate that a spacing of 25 × 25 cm resulted in higher number of productive tillers and shoot dry weight compared to 15 × 15 cm or 20 × 20 cm in both varieties. There were no differences in the number of productive tillers and shoot dry weight produced by the Padjajaran Agritan and Ciherang varieties in both planting seasons. The number of productive tillers and shoot dry weight produced in the rainy season was higher than in the dry season.

Table 3 explains that there was no difference in leaf greenness index between those planted in spacings of 15 × 15, 20 × 15, and 25 × 25 cm in both varieties. There was no difference in leaf greenness between the Padjajaran Agritan and Ciherang varieties that were planted in both planting seasons. The leaf greenness index of rice was higher in the rainy season compared to the dry season.

Rice yield

The observation data of rice yield were the grain dry weight clump^{-1} and ha^{-1}. Based on the data analysis using ANOVA, it was found that spacing had a significant effect on rice yield clump^{-1}, but not per hectare. There was no significant difference in rice yield between the Padjajaran Agritan and Ciherang varieties, either per clump or ha. Differences in rice yield clump^{-1} were observed between the rainy and dry seasons, but not on a per hectare. For clarity, the results of the DMRT at the 5% significant levels for rice yield clump^{-1} and ha^{-1} can be shown in Tables 4 and 5.

Table 4*. Effect of spacing on the grain dry weight (g clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season 25.57 p						Dry season 19.17 q					
Varieties						**Varieties**					
Pajajaran Agritan 25.74 p			Ciherang 25.39 p			Pajajaran Agritan 19.86 p			Ciherang 18.47 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25

14.70 z	24.47 y	38.05 x	15.91 z	26.04 y	34.23 x	13.71 z	20.97 y	24.91 x	13.46 z	17.37 y	24.59 x

Remarks: The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels.

***Table 5**. Effect of spacing on the grain dry weight (tons ha^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season 6.29 p						Dry season 4.93 q					
Varieties						**Varieties**					
Pajajaran Agritan 6.25 p			Ciherang 6.35 p			Pajajaran Agritan 5.11 p			Ciherang 4.75 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
6.53 x	6.12 x	6.09 x	7.07 x	6.51 x	5.48 y	6.01 x	5.24 x	3.98 y	5.98 x	4.34 y	3.94 y

Remarks: The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels.

Table 4 shows that a spacing of 25 × 25 cm resulted in grain dry weight clump^{-1} higher than in 15 × 15 cm or 20 × 20 cm in both varieties. There was no difference in grain dry weight produced by the Padjajaran Agritan and Ciherang varieties in both planting seasons. Rice plants cultivated in the rainy season yielded grain dry weight per clump higher than in the dry season.

Table 5 indicates that there was no difference in grain dry weight per hectare at the three spacings in the Padjajaran Agritan variety that was cultivated during the rainy season. However, spacings of 15 × 15 and 20 × 20 cm resulted in grain dry weight per hectare higher than in 25 × 25 cm in the Ciherang variety that was cultivated during the rainy season. The same trend occurred in the Padjajaran Agritan variety cultivated during the dry season.

However, a spacing of 15 × 15 cm yielded the highest grain dry weight per hectare than in 20 × 20 and 25 × 25 cm in the Ciherang variety during the dry season. There was no difference in grain dry weight per hectare produced by the Padjajaran Agritan and Ciherang varieties in both planting seasons. Rice plants that were cultivated during the rainy season yielded grain dry weight per hectare higher than in the dry season.

Discussion

The growth components observed were the number of productive tillers, leaf greenness index, and dry shoot weight. In contrast, the yield components observed were only grain dry weight per clump and hectare. Rice growth and yield were higher obtained at a spacing of 25 × 25 cm than 15 × 15 or 20 × 20 cm for both varieties, except for the leaf greenness index. At wider spacing, there was lower competition among plants for water and nutrients in the soil, so the number of tillers per clump formed was greater. Additionally, sunlight interception by the plant canopy per clump was higher, and air circulation among plants was better for CO_2 uptake during photosynthesis. These agronomic factors could support metabolic processes, resulting in better rice growth and yield per clump.

On the contrary, the grain dry weight per hectare was higher at a spacing of 15 × 15 cm. This higher yield was due to the higher plant population per hectare (444,444 clumps) compared to 20 × 20 cm (250,000 clumps), or 25 × 25 cm (160,000 clumps). The spacing of 15 × 15 cm was the optimum spacing that could provide maximum grain dry weight per hectare. According to De-yang et al. (2016), increasing plant density is one strategy to increase grain yields because it can increase the potential capacity of the plant canopy to capture solar radiation. And also increases absorb water and nutrients.

There was no difference in rice growth and yield per clump or hectare between both varieties, whether planted in the rainy or dry season. This indicates that both varieties exhibit similar growth and yield. However, when considering the harvesting age, the Padjajaran Agritan variety has a shorter maturity period, thus requiring less total water compared to the Ciherang variety. According to Noviana et al. (2021), early maturing and superior varieties can be utilized to increase the cropping index and rice production.

The research showed that rice yield per hectare in the rainy season was higher than in the dry season. Ideally, rice growth and yield should be higher in the dry season due to abundant sunlight for photosynthesis. In study showed that leaf greenness occurred higher in the rainy season than in the dry season, so the photosynthetic process in rice leaf better. The higher carbohydrate yield can support better shoot growth and grain filling. However, in the dry season, insufficient groundwater availability could lead to reduced growth and yield of rice. Water availability became a limiting factor for rice growth and yields in the study. Water availability caused a reduction in the leaf greenness index of rice plants so the photosynthetic process inhibitation. Because the rice fields for the research were semi-technical irrigated rice fields, so during the dry season, there was a water shortage in rice growth, especially during the generative growth phase. According to Arsal et al. (2020), irrigation water supply is crucial to compensate for the groundwater needs during the dry season.

Abundant sunlight intensity in the dry season can increase air temperature and decrease air humidity around the rice plant. High air temperature has an impact on increasing transpiration from the plant body. If the plant loses a lot of water, then it negatively affects cell division, growth, and protoplasm within the leaves. Water stress causes a decrease in photosynthesis activity, resulting in a reduction in rice growth and yield. However, the Padjajaran Agritan and Ciherang varieties can still adapt well to water scarcity conditions. According to Sukkeo et al. (2017), high temperatures harm rice grain yield during panicle development, anthesis, and grain filling. In line with the opinion of Sanwong et al. (2023), high temperature affects the reduction of grain yield and quality.

Conclusion

In conclusion, the number of productive tillers, dry shoot weight, and grain dry weight clump^{-1} were higher when planted with a spacing of 25 × 25 cm than 15 × 15 or 20 × 20 cm for both varieties. Conversely, the total grain dry weight per hectare was greater with a spacing of 15 × 15 cm. No significant differences were observed in the growth and yield of rice between the Padjajaran Agritan and Ciherang varieties. The grain dry weight produced by Padjajaran Agritan and Ciherang were 6.25 and 6.35 tons ha^{-1} in the rainy season but decreased to 5.11 and 4.75 tons ha^{-1} in the dry season. The research findings suggest that a spacing of 15 × 15 cm is optimal for both the Padjajaran Agritan and Ciherang varieties when planted in either the rainy or dry season. However, the growth and yield of rice are higher in the rainy season than in the dry season in semi-technical irrigated rice fields. Consequently, we recommend utilizing closer spacing and drought-resistant superior varieties to maximize rice yield in the dry season.

Acknowledgements. We would like to express our --

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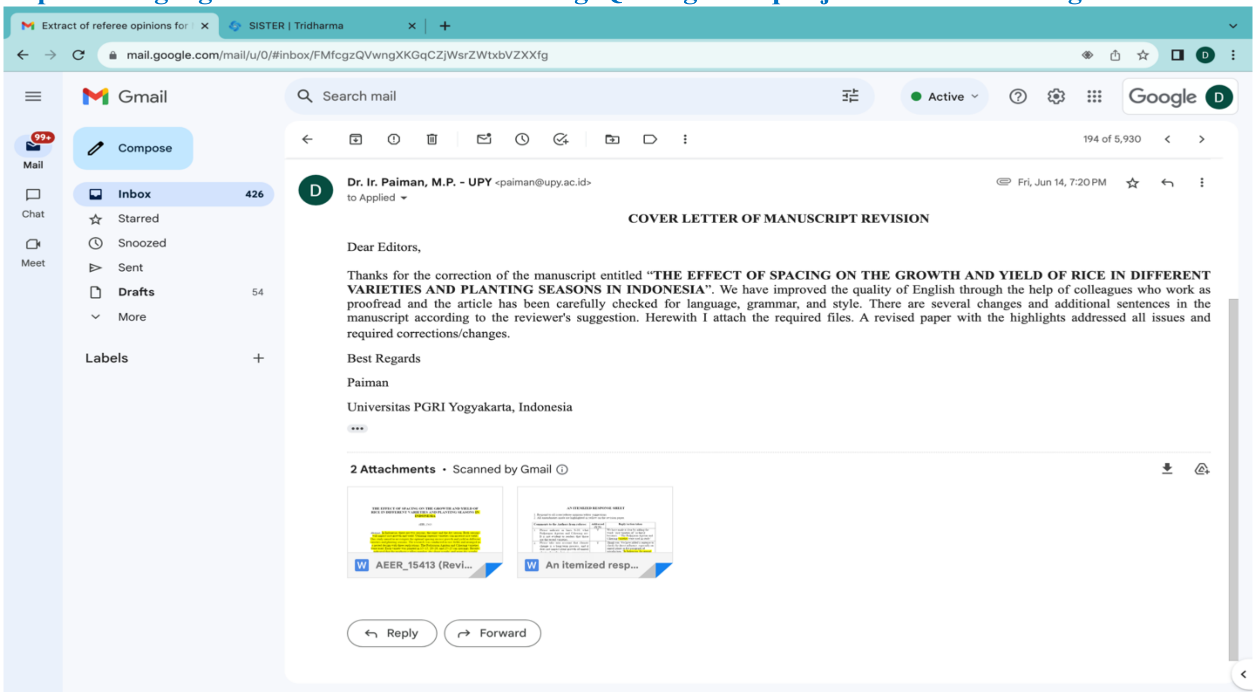

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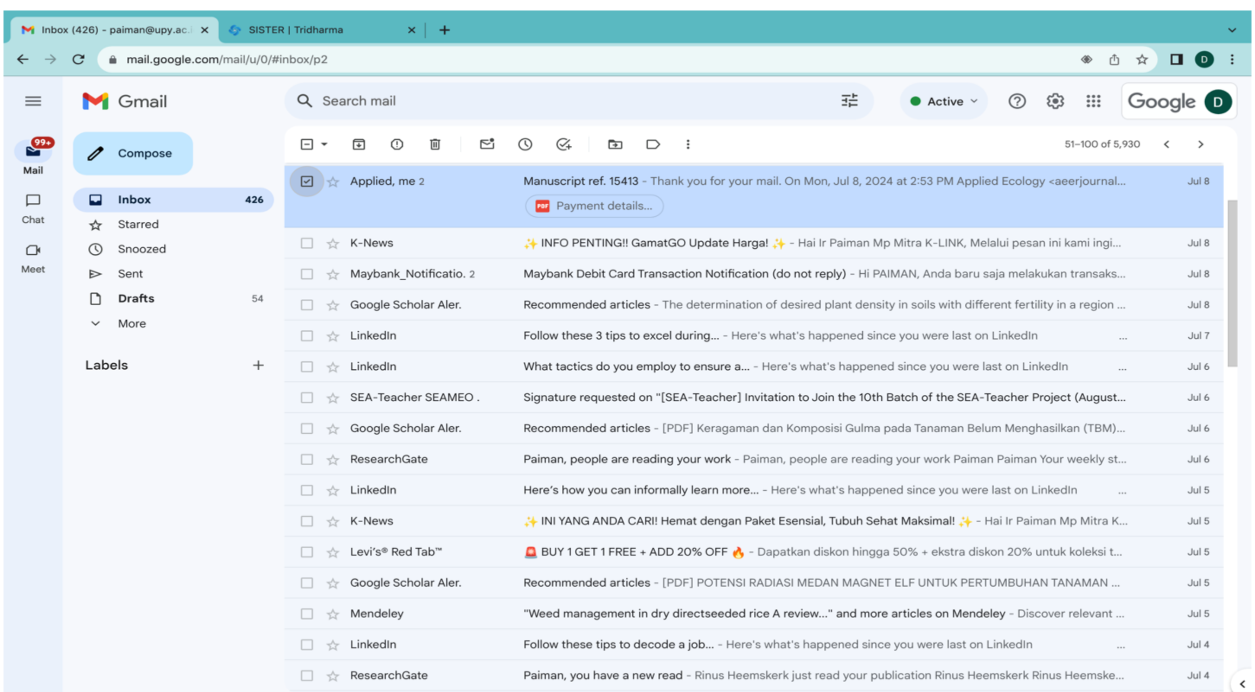

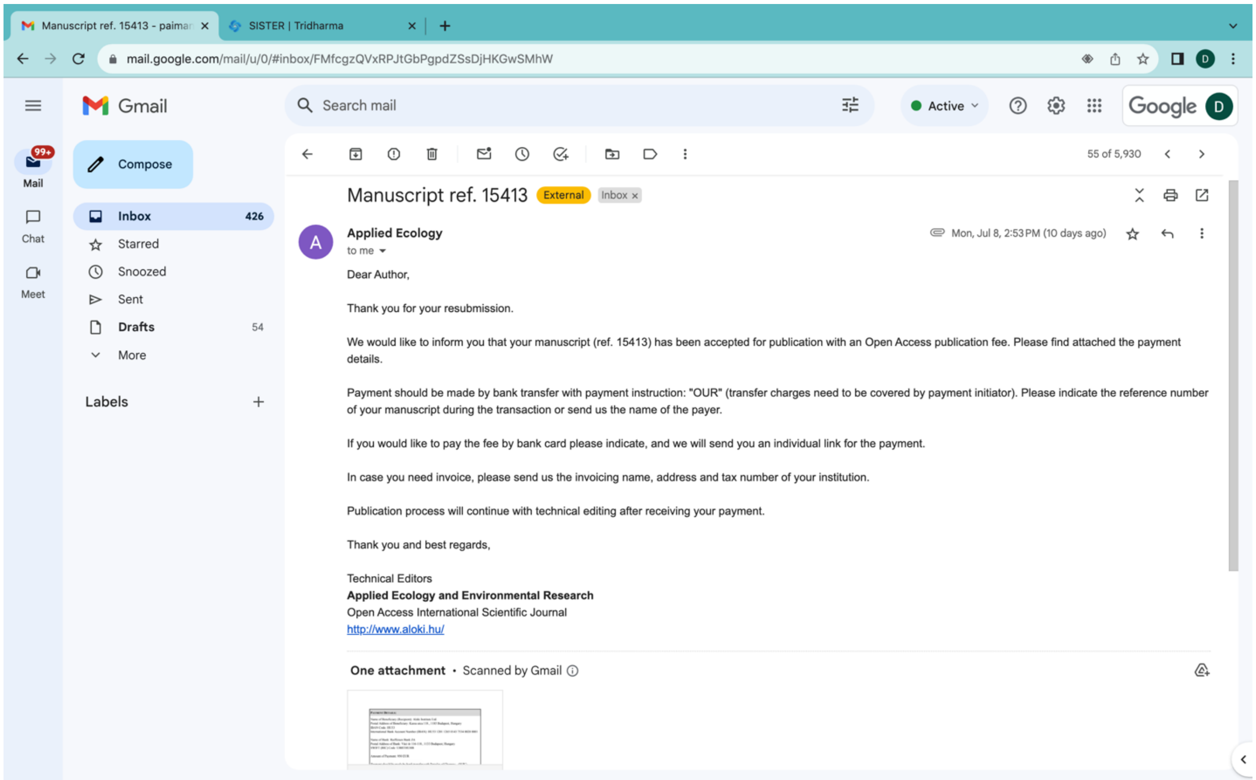

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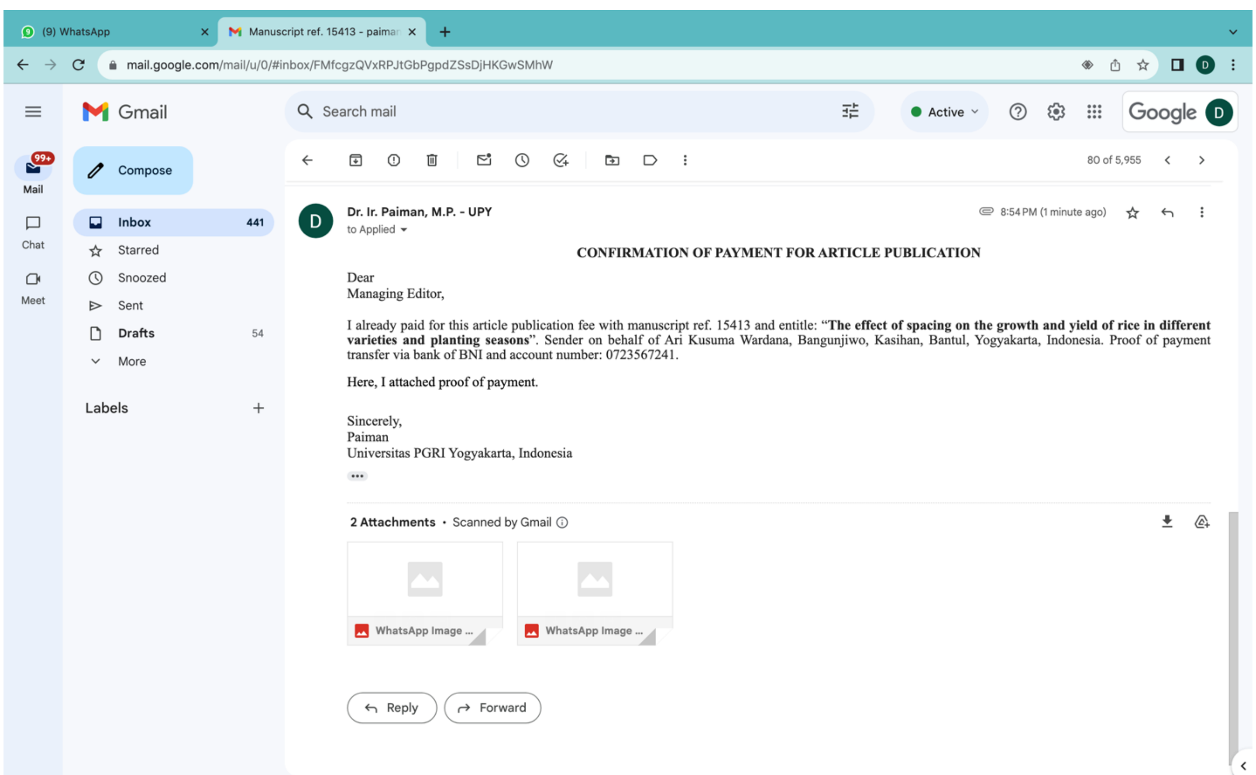

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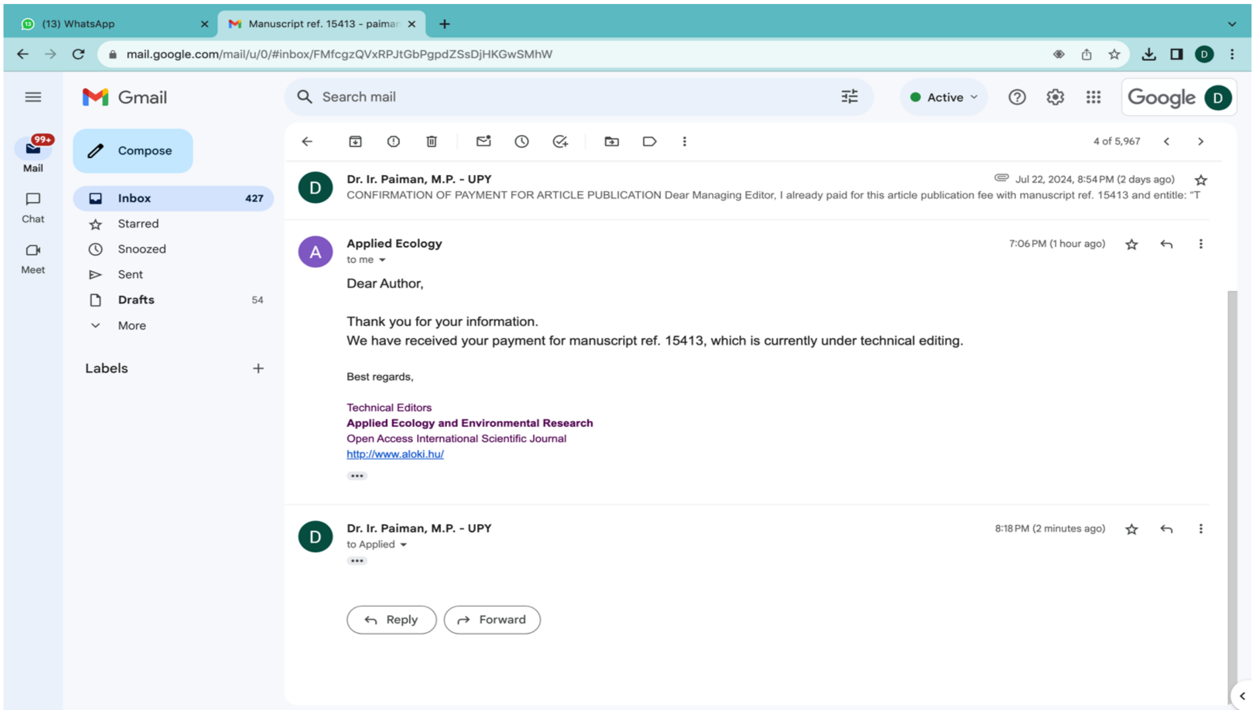

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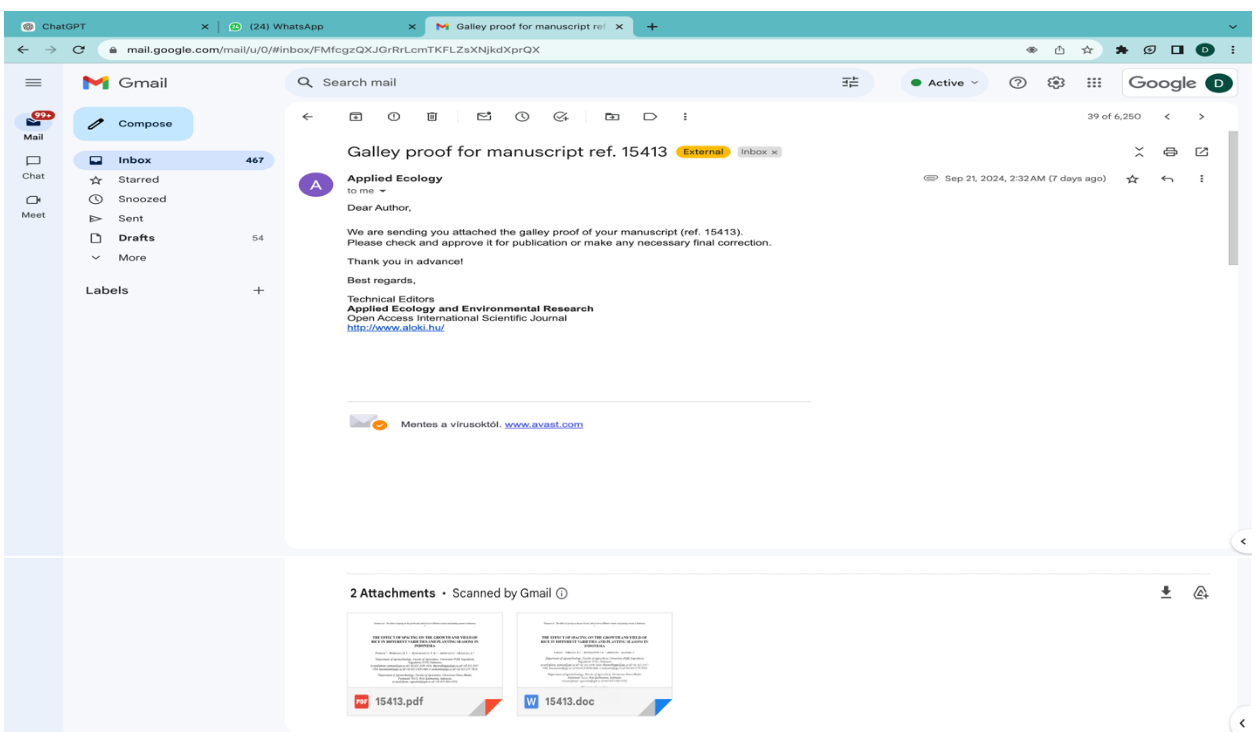

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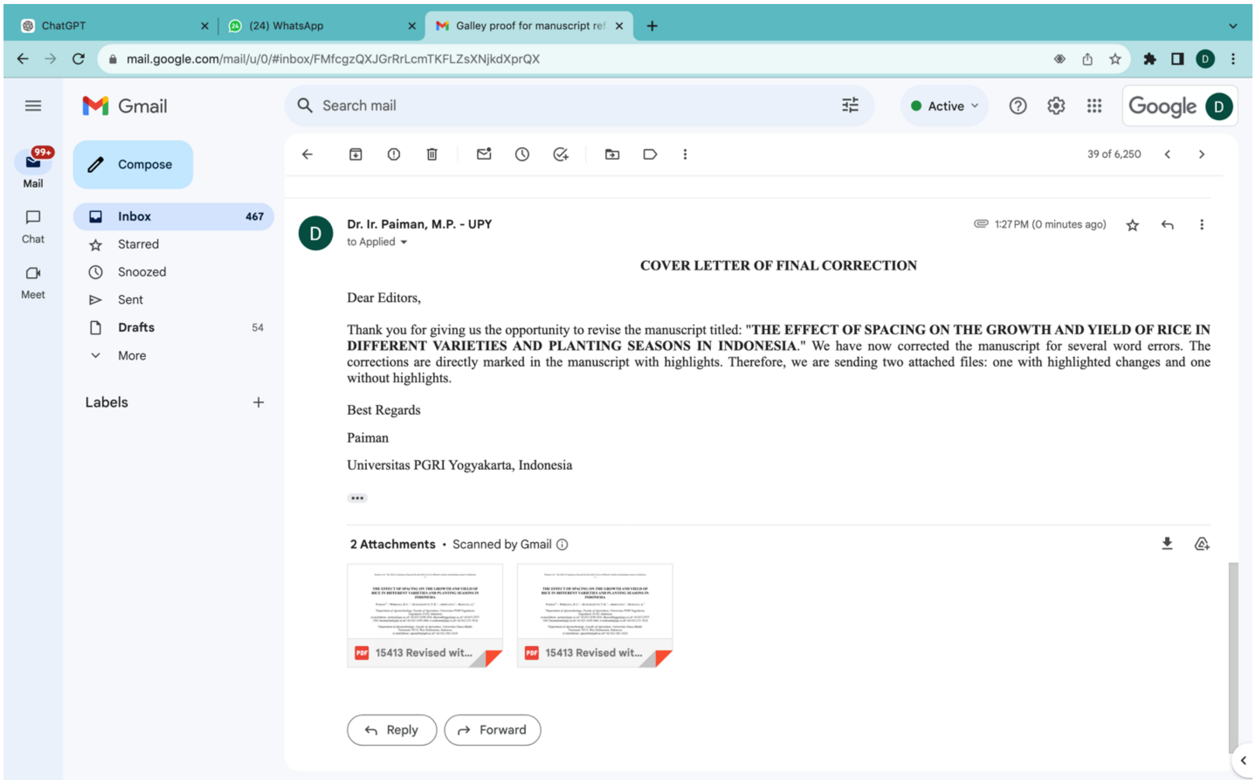
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THE EFFECT OF SPACING ON THE GROWTH AND YIELD OF RICE IN DIFFERENT VARIETIES AND PLANTING SEASONS IN INDONESIA

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Abstract. In Indonesia, there are two seasons, the rainy and the dry season. Both seasons will impact rice growth and yield. Utilizing superior varieties can increase rice yield. This study aimed to determine the optimal spacing for rice growth and yield across different varieties and planting seasons. The research was conducted in rice fields and arranged in a nested design with three replications. The Padjajaran Agritan and Ciherang varieties were used. Each variety was planted in spacings of 15×15, 20×20, and 25×25 cm. Results indicated that the productive tillers number, dry shoot weight, and grain dry weight clump^{-1} were higher when planted in 25×25 cm compared to 15×15 or 20×20 cm for both varieties. Conversely, the total grain dry weight per hectare was greater with a spacing of 15×15 cm. The grain dry weight produced by Padjajaran Agritan and Ciherang were 6.25 and 6.35 tons ha^{-1} in the rainy season and 5.11 and 4.75 tons ha^{-1} in the dry season. The research findings show that a spacing of 15×15 cm is optimal for both varieties when planted in both seasons. The rice yields are higher in the rainy season. We recommend utilizing closer spacing to maximize rice yield.
Keywords: climate, irrigation, solar radiation, superior variety, water availability

Introduction

Climate change is closely related to the seasons in a given region. Indonesia is located in the tropics, so every year it has rainy and dry seasons (Suwartapradja, 2022). During the rainy season, monsoon winds blow from Asia towards Australia, bringing more moisture, and transforming it into rainfall in Indonesia. Generally, the rainy season in Indonesia occurs from October to March. Conversely, during the dry season, monsoon winds blow from Australia towards Asia, passing through Indonesia with less moisture. This results in reduced rainfall during the dry season in Indonesia. Typically, the dry season in Indonesia spans from April to November (BMKG, 2019). Climate elements such as rainfall, solar radiation, and air temperature fluctuate continuously throughout the year. Climate change impacts the growth and yield of crops, especially rice crops (Jamil and Chairunnisya, 2023). In Indonesia, the annual climate change between the rainy and dry seasons has a significant impact on rice growth and yield. Water is abundant during the rainy season, although light intensity decreases. Conversely, in the dry season, water becomes limited, but light intensity increases. This condition plays a crucial role in rice cultivation.

The rice plant (*Oryza sativa* L.) is one of the staple food crops that produce rice to meet daily basic needs in Indonesia. Increasing rice productivity is also influenced by local climate and weather conditions, especially rainfall. Water is crucial for the growth and yield of rice. Water requirements are not a constraint for rice cultivation in technically irrigated fields. Rice cultivation can be done up to three times a year, however, it is optimal to plant only twice a year. In the third planting, water is only needed during the vegetative growth phase. However, during the generative growth phase, a water shortage often occurs, leading to decreased rice yields. This issue is common in semi-technical irrigated rice fields in Yogyakarta, Indonesia. According to Pool et al. (2023), one of the most significant problems in rice production is the high water requirement of this crop.

Geographically, Yogyakarta is a region located in the central-southern part of Java Island and directly bordering the Indian Ocean. This region experiences two seasons: the rainy and the dry seasons. It has several types of rice fields, including technically irrigated, semi-technical, and rainfed fields. Consequently, rice productivity varies depending on water availability in these fields. It is important to recognize that maximizing rice productivity requires the implementation of optimal planting spacing and the utilization of superior varieties that are adaptable to drought stress.

The rainy season is characterized by a decrease in average daily air temperature, shorter sunlight exposure, low solar radiation, high rainfall, and cloudy skies. Conversely, the opposite occurs during the dry season (Jaenudin et al., 2020). Sunlight radiation and temperature are the most important factors in increasing rice productivity. When sunlight radiation and temperature increase significantly, rice yields may actually decrease (Kawasaki and Herath, 2011). In addition, high daytime temperatures in the tropics are often close to optimal levels, and the increase in intensity and frequency of heat waves during sensitive reproductive phases can cause significant damage to rice production (Mohanty et al., 2013). During the dry season, the sunlight intensity is abundant, but water availability becomes a limiting factor for rice cultivation in semi-technical irrigated fields.

Rice cultivation in the dry season usually produces higher yields, provided that water is available (Voe et al., 2011). Water is one of the essential components required by plants in large quantities for their growth and development; approximately 85-90% of the fresh weight of plant cells and tissues is water. Water deficiency can reduce cell turgor and increase the concentration of macromolecules. Additionally, it also affects cell membranes and the chemical activity of water within plant tissues. Water deficiency disrupts metabolic processes and ultimately affects plant growth and yield. To increase rice yield in semi-technical irrigated fields, it is advisable to select superior varieties with short-lived, adaptable, and high production. Hindarwati et al. (2021) noted that superior varieties can increase rice productivity.

The Ciherang variety is a superior variety with a harvesting period ranging from 116 to 125 days after planting (DAP). It has a yielding up to 8.5 tons ha^{-1}, but the average yield is around 6.0 tons ha^{-1}. This variety thrives when planted in lowland irrigated paddy fields up to 500 m above sea level (Suprihatno et al., 2009). Similarly, the Padjajaran Agritan variety is a superior variety with a shorter growth duration and higher yield potential. It matures at 105 DAP with a potential yield of 11.0 tons ha^{-1}, but the average yield is 7.8 tons ha^{-1}. This variety is best grown in lowland irrigated rice fields up to 600 m above sea level (Thamrin et al., 2023). The use of short-lived and drought-tolerant varieties can help alleviate crop failure issues during the generative phase due to water scarcity (Viandari et al., 2022). The Padjajaran Agritan variety has a shorter harvest than Ciherang.

The number of productive tillers for the Ciherang variety was 19.40 stems, harvested at 122.5 DAP, yielding 11.01 tons ha^{-1} during the rainy season (Rahmawati et al., 2019). Additionally, the number of panicles $clump^{-1}$ was 10.78, and the weight of 1000 dry grains was 24.33 g (Safi'e et al., 2022). Furthermore, another measurement indicated 21.5 productive tillers, harvested at 122 DAP, with a 1000-grain weight of 29.5 g (Desi et al., 2023). In dry seasons, the harvesting age was 125 DAP, and the grain yield was 9.84 tons ha^{-1}. In contrast, during the rainy season, the grains yield 4.81 tons ha^{-1} (Santosa and Suryanto, 2015). The Padjajaran Agritan variety produced 10.25 panicles $clump^{-1}$, with a 1000-grain weight of 25.65 g, and a productivity of 4.80 tons ha^{-1} when planted in irrigated paddy fields from March to July or early in the dry season (Damiri et al., 2022). The chlorophyll content index of Padjajaran Agritan was 17.037 at 56-68 DAP (Munibah et al., 2022). In addition, maximum rice growth and yield are also determined by the use of optimal spacing.

Optimal spacing ensures that plants grow well both above and below the soil surface by utilizing solar radiation and nutrients. However, closer spacing will encourage mutual shadowing and intra-specific competition between plants (Oni et al., 2023). Rice yield depends on the number of panicles/m^2 and the number of seeds/panicles. The spacing that gave the higher number of panicles/m^2 was 15 × 15 cm and it gave a good yield (Marie-Noel et al., 2021). A spacing that is closer, with two seedlings per hole, could increase rice yield and improve resource use efficiency (Htwe et al., 2021). Based on previous literature, it can be emphasized that a using plant spacing of 15 × 15 cm or closer is an appropriate method for cultivating early-maturing rice varieties with a smaller habitus. With a denser planting pattern, the number of rice clumps per unit area will be greater, resulting in a higher grain yield than that obtained with wider spacing. Conversely, the grain yield per clump is higher with wider spacing than with denser spacing.

The research result showed that the optimum spacing that produced the maximum yield clump^{-1} was 25 × 25 cm (Reuben et al., 2016). Additionally, a spacing of 25 × 25 cm during the dry season is correlated with higher rice production (Michael and Ali, 2020). The absorption efficiency of solar radiation in the rice canopy was greater at a spacing of 25 × 25 cm compared to at 20 × 20 cm. Increasing the absorption efficiency of solar radiation would inhance the number of panicles clump^{-1} and the number of spikelets clump^{-1} even when using alternate wetting and drying irrigation methods during the wet season (Setiobudi and Sembiring, 2009).

Research on the influence of variety and spacing on the growth and yield of rice conducted in the rainy and dry seasons has not been previously undertaken by researchers. This study aimed to contribute to identifying the optimal spacing for each variety cultivated in these seasons. The research is limited to semi-technical irrigated rice fields. Based on existing literature, This study aimed to determine the optimal spacing for rice growth and yield across different varieties and planting seasons.

Materials and methods

Study area

This study was conducted in the rainy season from December 2022 to April 2023 with an average sunlight intensity of 876.3 lux and an average maximum air temperature of 30.7 °C. The dry season lasted from June to October 2023 with an average sunlight intensity of 953.9 lux and an average maximum air temperature of 31.1 °C. The experiments were conducted in Minggir Sub-district, Sleman Regency, Special Region of Yogyakarta, Indonesia with an elevation of 110 m above sea level. The rice fields used for research were alluvial soil. Geographically, Sleman Regency is situated between 110°33′ 00″ - 110°13′ 00″ East Longitude and 7°34′51″ - 7°47′30″ South Latitude.

Materials and tools

The study used the Padjajaran Agritan and Ciherang varieties. Urea and NPK Phonska fertilizer were used. Bamboo stakes and plastic film were used as supports and treatment labels. Decis 25 EC 100ML was used to control the planthoppers. Hand plows and rakes were used for the first and second soil tillage. A hoe was used to create treatment plots and irrigation channels. A sickle was used to cut rice stalks during harvest. The CCM-200 plus chlorophyll meter was used to measure leaf greenness. The Binder FD 115 oven was used to dry stems and leaves. The digital scales model DS-880 was used to measure the dry weight of the shoots and grains. Thermo Hygrometer Clock HTC-2 was used to measure the air temperature of the research site. Lux Meter LUTRON LX-1128SD was used to measure the sunlight intensity.

Experimental design

The study was conducted in rice fields during the rainy and the dry seasons. The experiment was arranged in a nested design. This research used two rice varieties, namely Padjajaran Agritan and Ciherang varieties. Each rice variety consisted of three spacings, i.e., 15 × 15, 20 × 20, and 25 × 25 cm. Each spacing was replicated three times. Randomization was applied for the spacing treatment of each rice variety. The research flow can be seen in *Figure 1*.

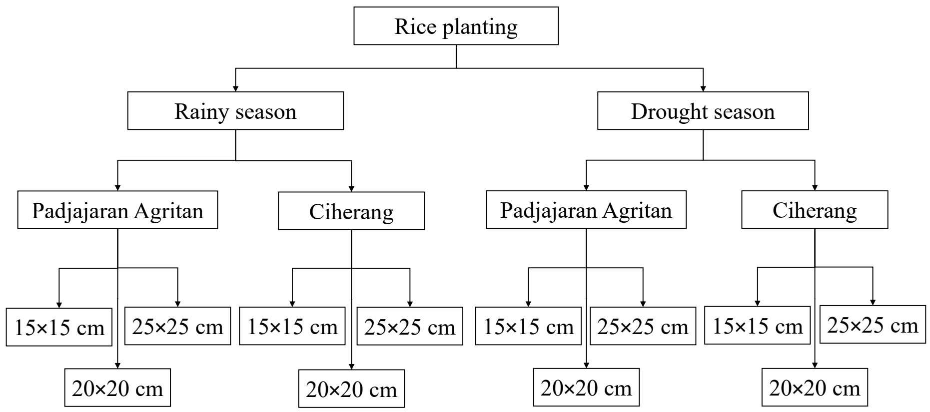


Figure 1. *The flow diagram in research activity*

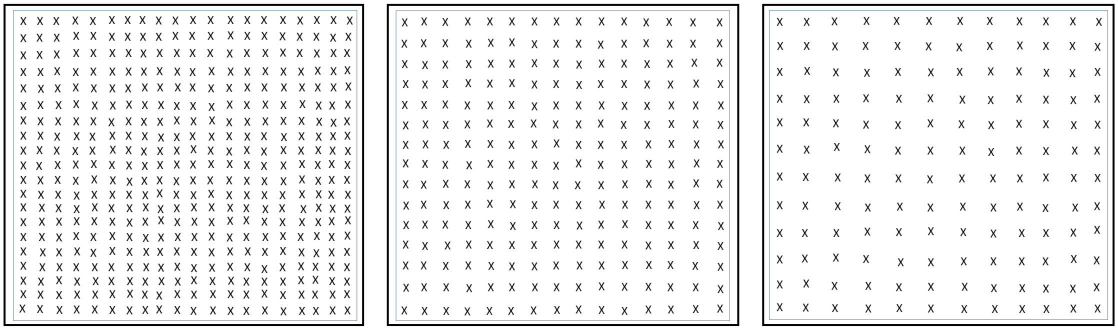
Research procedures

Rice cultivation in the rainy season

The first phase of the study was conducted during the rainy season. Plows were used for the initial tillage, followed by harrows to level the soil surface. After tillage was completed, nine treatment plots were established for spacing in both the Padjajaran Agritan and Ciherang varieties, resulting in a total of 18 treatment plots. Randomization was carried out for the spacing treatment in both varieties in each planting season. A distance of 0.5 meters was maintained between treatment plots for both rice variety.

Rice seeds were soaked in water for 3 hours to promote even absorption, after soaking, the seeds were drained and wrapped in newsprint overnight. The next day, they were placed on the prepared surface of the seedbed. The rice seedlings were ready planting after 18 DAP.

The size of the treatment plot was 3 × 3 square meters (m^2) (see *Fig. 2*). The number of rice seedlings planted in each plot varied according to the spacing: for a spacing of 15 × 15 cm, 400 seedlings were needed (see *Fig. 2a*); for 20 × 20 cm, 225 seedlings were used (see *Fig. 2b*), and 25 × 25 cm required 144 seedlings (see *Fig. 2c*). Only one rice seedling was planted per planting hole.



15 × 15 cm (a) | 20 × 20 cm (b) | 25 × 25 cm (c)

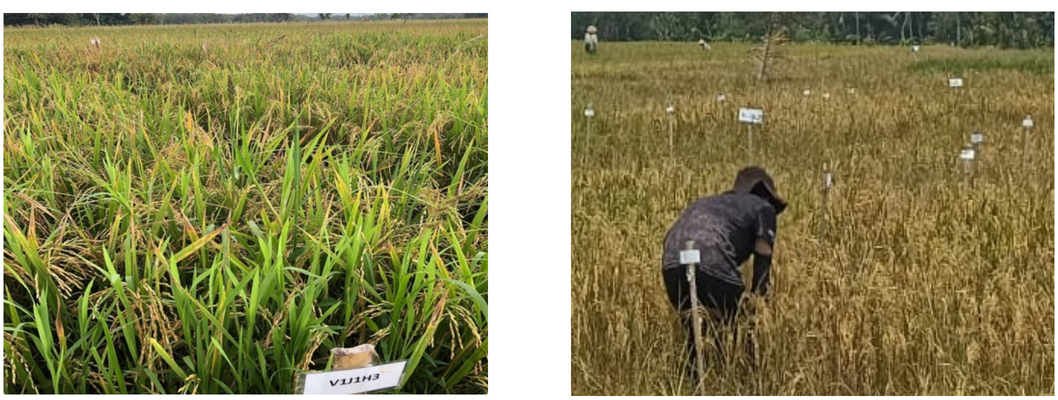
Figure 2. *The number of rice seedlings in each spacing*

Fertilizer doses of 225 kg ha^{-1} for urea and 225 kg ha^{-1} for NPK Phonska 15-15-15 were recommended (BPPP, 2014). Both urea and NPK Phonska fertilizers were applied twice each. The first application included 40% of the recommended dose at 15 DAP, while the second application included 60% at 30 DAP. Watering was carried out as needed by the plants. Weed control was conducted manually twice, at 14 and 34 DAP. Pest control was implemented to manage planthoppers and used Decis 25 EC 100ML. Rice harvesting occured at 104 DAP for the Padjajaran Agritan variety and at 116 DAP for the Ciherang variety. It was visually observed that during rainy season, water avaibility was abundant from the vegetative growth stage to harvest.

Rice cultivation in the dry season

The research in the dry season was conducted similarly to that in the rainy season. The water needs were met during the vegetative growth stage; however water limitation began during the generative growth stage and continued until harvest. Watering was performed once a week, although there were occasions when it was delayed.

The photo of the experimental culture in the rainy and dry seasons can be seen in *Figure 3a* and *b*.



(a) Rice cultivation in rainy season | (b) Rice cultivation in dry season

Figure 3. *The photo of the experimental culture in the rainy (a) and dry seasons (b)*

Parameter

Observations of research data were conducted on sunlight intensity (lux), air temperature (°C), number of productive tillers (steams clump^{-1}), leaf greenness index (units), shoot dry weight, and grain dry weight (g clump^{-1} and tons ha^{-1}). Measurements of sunlight intensity and air temperature above the plant surface were taken every two weeks throughout the research period. The leaf greenness index was assessed at 58 DAP. The number of productive tillers, shoot dry weight, and grain dry weight were measured at harvest. Plant observations were made using 10 samples from each treatment plot.

Statistical analysis

Observational data were analyzed by analysis of variance (ANOVA) at the 5% significance level. Differences between planting season treatments or varieties were assessed by comparing the calculated F value to the F table values. If the calculated F value is less than the tabled F value, there is no significant difference, and vice versa. If significant are found between plant spacing treatments, Duncan's new multiple range test (DMRT) is applied at the 5% significance level (Gomez and Gomez, 1984).

Results

Rice growth

Observations of rice growth included the number of productive tillers (stems clump^{-1}), leaf greenness (units), and shoot dry weight. Analysis of variance (ANOVA) indicated that spacing significantly influenced rice growth. However, there was no significant difference in growth between the Padjajaran Agritan and Ciherang varieties. Notably, differences in rice growth were observed between the rainy and dry seasons. For further clarification, the results of the DMRT at the 5% significance level for rice growth can be found in *Tables 1, 2,* and *3*.

Tables 1 and *2* indicate that a spacing of 25 × 25 cm resulted in higher number of productive tillers and shoot dry weight compared to 15 × 15 cm or 20 × 20 cm in both varieties. There were no differences in the number of productive tillers and shoot dry weight produced by the Padjajaran Agritan and Ciherang varieties in both planting seasons. Additionally, the number of productive tillers and shoot dry weight produced in the rainy season were higher in the rainy season than in the dry season.

Table 1. *Effect of spacing on the number of productive tillers (stems clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season						Dry season					
15.9 p						9.6 q					
Varieties						**Varieties**					
Pajajaran Agritan			Ciherang			Pajajaran Agritan			Ciherang		
15.5 p			16.3 p			9.5 p			9.6 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
9.3 z	15.9 y	21.3 x	10.3 z	15.7 y	22.9 x	7.6 z	9.0 y	12.1 x	7.3 z	8.9 y	12.7 x

The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels

Table 2. *Effect of spacing on the shoot dry weight (g clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season						Dry season					
19.35 p						10.75 q					
Varieties						**Varieties**					
Pajajaran Agritan			Ciherang			Pajajaran Agritan			Ciherang		
21.04 p			17.66 p			10.36 p			11.15 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
11.58 z	18.41 y	33.13 x	12.19 z	17.38 y	23.43 x	8.16 z	10.13 y	12.78 x	8.89 z	11.49 y	13.04 x

The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels

Table 3. *Effect of spacing on the leaf greenness index (units) in different varieties and planting seasons*

Planting seasons											
Rainy season						Dry season					
17.4 p						12.9 q					
Varieties						**Varieties**					
Pajajaran Agritan			Ciherang			Pajajaran Agritan			Ciherang		
16.9 p			17.9 p			13.7 p			12.3 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
15.3 x	16.9 x	18.6 x	16.7 x	17.1 x	19.9 x	13.0 x	13.7 x	14.4 x	12.3 x	12.1 x	12. 4 x

The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels

Table 3 explains that there was no difference in leaf greenness index among rice plants spaced at 15 × 15, 20 × 15, and 25 × 25 cm for both varieties. Additionally, there was no difference in leaf greenness between the Padjajaran Agritan and Ciherang varieties in both planting seasons. The leaf greenness index was higher in the rainy season compared to the dry season.

Rice yield

The observation data for rice yield included both the grain dry weight clump^{-1} and ha^{-1}. Based on the data analysis using ANOVA, spacing significantly effected in rice yield clump^{-1}, but not ha^{-1}. There was no significant difference in rice yield between the Padjajaran Agritan and Ciherang varieties, either clump^{-1} or ha^{-1}. Differences in rice yield clump^{-1} were observed between the rainy and dry seasons, but no differences were noted on a ha^{-1} basis. For clarity, the results of the DMRT at the 5% significant level for rice yield clump^{-1} and ha^{-1} are presented in *Tables 4* and *5*.

Table 4. *Effect of spacing on the grain dry weight (g clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season						Dry season					
25.57 p						19.17 q					
Varieties						**Varieties**					
Pajajaran Agritan			Ciherang			Pajajaran Agritan			Ciherang		
25.74 p			25.39 p			19.86 p			18.47 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
14.70 z	24.47 y	38.05 x	15.91 z	26.04 y	34.23 x	13.71 z	20.97 y	24.91 x	13.46 z	17.37 y	24.59 x

The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels

Table 5. *Effect of spacing on the grain dry weight (tons ha^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season						Dry season					
6.29 p						4.93 q					
Varieties						**Varieties**					
Pajajaran Agritan			Ciherang			Pajajaran Agritan			Ciherang		
6.25 p			6.35 p			5.11 p			4.75 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
6.53 x	6.12 x	6.09 x	7.07 x	6.51 x	5.48 y	6.01 x	5.24 x	3.98 y	5.98 x	4.34 y	3.94 y

The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels

Table 4 shows that a spacing of 25 × 25 cm resulted in higher grain dry weight clump^{-1} compared to 15 × 15 cm or 20 × 20 cm for both varieties. There was no difference in grain dry weight produced by the Padjajaran Agritan and Ciherang varieties across both planting seasons. Additionally, rice plants cultivated in the rainy season yielded a higher grain dry weight clump^{-1} than those in the dry season.

Table 5 indicates that there was no difference in grain dry weight ha^{-1} among the three spacings for the Padjajaran Agritan variety cultivated during the rainy season. However, for the Ciherang variety in the same season, spacings of 15 × 15 and 20 × 20 cm resulted in a higher grain dry weight ha^{-1} than in 25 × 25 cm. A similiar trend was observed for the Padjajaran Agritan variety cultivated during the dry season.

However, a spacing of 15 × 15 cm yielded the highest grain dry weight ha^{-1} in the Ciherang variety compared to the spacings of 20 × 20 and 25 × 25 cm during the dry season. There was no difference in grain dry weight ha^{-1} between Padjajaran Agritan and Ciherang varieties in either planting season. Additionally, the rice plants cultivated during the rainy season produced a higher grain dry weight ha^{-1} than those grown in the dry season.

Discussion

The observed growth components included the number of productive tillers, leaf greenness index, and dry shoot weight. In contrast, the yield components measured were grain dry weight clump^{-1} and ha^{-1}. For both varieties, rice growth and yield were higher at a spacing of 25 × 25 cm than 15 × 15 or 20 × 20 cm for both varieties, except for the leaf greenness index. Wider spacing reduced competition among plants for water and nutrients in the soil, resulting in a greater number of tillers clump^{-1}. Additionally, the plant canopy's ability to intercept sunlight was improved, air circulation among plants enhanced CO_2 uptake during photosynthesis. These agronomic factors supported metabolic processes, leading to better rice growth and yield clump^{-1}.

On the contrary, the grain dry weight per hectare was higher at a spacing of 15 × 15 cm. This higher yield was attributed to the greater plant population per hectare (444,444 clumps) compared to 20 × 20 cm (250,000 clumps), and 25 × 25 cm (160,000 clumps). Thus, a spacing of 15 × 15 cm was identified as the optimum spacing for maximizing grain dry weight ha^{-1}. According to De-yang et al. (2016), increasing plant density is a strategy to enhance grain yields, as it boosts plant anopy's capacity to capture solar radiation and increases absorption of water and nutrients.

There was no difference in rice growth and yield clump^{-1} or ha-1 between the two varieties, regardless whether they were planted in the rainy or dry season. This indicates that both varieties exhibit similar growth and yield characteristics. However, the Padjajaran Agritan variety has a shorter maturity period, thus requiring less total water compared to the Ciherang variety. According to Noviana et al. (2021), early-maturing and superior varieties can be effectively utilized to increase the cropping index and enhance rice production.

The research showed that rice yield ha^{-1} in the rainy season was higher than in the dry season. Ideally, rice growth and yield should be higher in the dry season due to abundant sunlight for photosynthesis. However, the study found that leaf greenness was higher in the rainy season than in the dry season, which enhanced the photosynthetic process in rice leaves. The higher carbohydrate yield supports better shoot growth and grain filling. Conversely, in the dry season, insufficient groundwater availability can lead to reduced growth and yield of rice. Water availability became a limiting factor for rice growth and yields in the study. The lack of water caused reduction in the leaf greenness index of rice plants, inhibiting the photosynthetic process. Since the research was conducted in semi-technical irrigated rice fields, water shortage during the dry season particularly affected growth during the generative growth phase. According to Arsal et al. (2020), an adequate irrigation water supply is crucial to meet groundwater needs during the dry season.

Abundant sunlight intensity in the dry season can increase air temperature and decrease air humidity around the rice plant. High air temperature impact transpiration rates, leading to increased water loss from the plant. Excessive water loss negatively affects cell division, growth, and the protoplasm within the leaves. Water stress results in decreased photosynthesis activity, ultimately reducing rice growth and yield. However, the Padjajaran Agritan and Ciherang varieties can still adapt well to conditions water scarcity. According to Sukkeo et al. (2017), high temperatures adversely affect rice grain yield during panicle development, anthesis, and grain filling. This is supported by Sanwong et al. (2023), who note that high temperature lead to reduction in both grain yield and quality.

Conclusion

In conclusion, the number of productive tillers, dry shoot weight, and grain dry weight clump^{-1} were higher when planted with a spacing of 25 × 25 cm than 15 × 15 or 20 × 20 cm for both varieties. Conversely, the total grain dry weight per hectare was greater with a spacing of 15 × 15 cm. No significant differences were observed in the growth and yield of rice between the Padjajaran Agritan and Ciherang varieties. The grain dry weight produced by Padjajaran Agritan and Ciherang were 6.25 and 6.35 tons ha^{-1} in the rainy season but decreased to 5.11 and 4.75 tons ha^{-1} in the dry season. The research findings suggest that a spacing of 15 × 15 cm is optimal for both the Padjajaran Agritan and Ciherang varieties when planted in either the rainy or dry season. However, the growth and yield of rice are higher in the rainy season than in the dry season in semi-technical irrigated rice fields. Consequently, we recommend utilizing closer spacing and drought-resistant superior varieties to maximize rice yield in the dry season.

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Manuscript without Higlights:

THE EFFECT OF SPACING ON THE GROWTH AND YIELD OF RICE IN DIFFERENT VARIETIES AND PLANTING SEASONS IN INDONESIA

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Abstract. In Indonesia, there are two seasons, the rainy and the dry season. Both seasons will impact rice growth and yield. Utilizing superior varieties can increase rice yield. This study aimed to determine the optimal spacing for rice growth and yield across different varieties and planting seasons. The research was conducted in rice fields and arranged in a nested design with three replications. The Padjajaran Agritan and Ciherang varieties were used. Each variety was planted in spacings of 15×15, 20×20, and 25×25 cm. Results indicated that the productive tillers number, dry shoot weight, and grain dry weight clump^{-1} were higher when planted in 25×25 cm compared to 15×15 or 20×20 cm for both varieties. Conversely, the total grain dry weight per hectare was greater with a spacing of 15×15 cm. The grain dry weight produced by Padjajaran Agritan and Ciherang were 6.25 and 6.35 tons ha^{-1} in the rainy season and 5.11 and 4.75 tons ha^{-1} in the dry season. The research findings show that a spacing of 15×15 cm is optimal for both varieties when planted in both seasons. The rice yields are higher in the rainy season. We recommend utilizing closer spacing to maximize rice yield.
Keywords: climate, irrigation, solar radiation, superior variety, water availability

Introduction

Climate change is closely related to the seasons in a given region. Indonesia is located in the tropics, so every year it has rainy and dry seasons (Suwartapradja, 2022). During the rainy season, monsoon winds blow from Asia towards Australia, bringing more moisture, and transforming it into rainfall in Indonesia. Generally, the rainy season in Indonesia occurs from October to March.

Conversely, during the dry season, monsoon winds blow from Australia towards Asia, passing through Indonesia with less moisture. This results in reduced rainfall during the dry season in Indonesia. Typically, the dry season in Indonesia spans from April to November (BMKG, 2019). Climate elements such as rainfall, solar radiation, and air temperature fluctuate continuously throughout the year. Climate change impacts the growth and yield of crops, especially rice crops (Jamil and Chairunnisya, 2023). In Indonesia, the annual climate change between the rainy and dry seasons has a significant impact on rice growth and yield. Water is abundant during the rainy season, although light intensity decreases. Conversely, in the dry season, water becomes limited, but light intensity increases. This condition plays a crucial role in rice cultivation.

The rice plant (*Oryza sativa* L.) is one of the staple food crops that produce rice to meet daily basic needs in Indonesia. Increasing rice productivity is also influenced by local climate and weather conditions, especially rainfall. Water is crucial for the growth and yield of rice. Water requirements are not a constraint for rice cultivation in technically irrigated fields. Rice cultivation can be done up to three times a year, however, it is optimal to plant only twice a year. In the third planting, water is only needed during the vegetative growth phase. However, during the generative growth phase, a water shortage often occurs, leading to decreased rice yields. This issue is common in semi-technical irrigated rice fields in Yogyakarta, Indonesia. According to Pool et al. (2023), one of the most significant problems in rice production is the high water requirement of this crop.

Geographically, Yogyakarta is a region located in the central-southern part of Java Island and directly bordering the Indian Ocean. This region experiences two seasons: the rainy and the dry seasons. It has several types of rice fields, including technically irrigated, semi-technical, and rainfed fields. Consequently, rice productivity varies depending on water availability in these fields. It is important to recognize that maximizing rice productivity requires the implementation of optimal planting spacing and the utilization of superior varieties that are adaptable to drought stress.

The rainy season is characterized by a decrease in average daily air temperature, shorter sunlight exposure, low solar radiation, high rainfall, and cloudy skies. Conversely, the opposite occurs during the dry season (Jaenudin et al., 2020). Sunlight radiation and temperature are the most important factors in increasing rice productivity. When sunlight radiation and temperature increase significantly, rice yields may actually decrease (Kawasaki and Herath, 2011). In addition, high daytime temperatures in the tropics are often close to optimal levels, and the increase in intensity and frequency of heat waves during sensitive reproductive phases can cause significant damage to rice production (Mohanty et al., 2013). During the dry season, the sunlight intensity is abundant, but water availability becomes a limiting factor for rice cultivation in semi-technical irrigated fields.

Rice cultivation in the dry season usually produces higher yields, provided that water is available (Voe et al., 2011). Water is one of the essential components required by plants in large quantities for their growth and development; approximately 85-90% of the fresh weight of plant cells and tissues is water. Water deficiency can reduce cell turgor and increase the concentration of macromolecules. Additionally, it also affects cell membranes and the chemical activity of water within plant tissues. Water deficiency disrupts metabolic processes and ultimately affects plant growth and yield. To increase rice yield in semi-technical irrigated fields, it is advisable to select superior varieties with short-lived, adaptable, and high production. Hindarwati et al. (2021) noted that superior varieties can increase rice productivity.

The Ciherang variety is a superior variety with a harvesting period ranging from 116 to 125 days after planting (DAP). It has a yielding up to 8.5 tons ha^{-1}, but the average yield is around 6.0 tons ha^{-1}. This variety thrives when planted in lowland irrigated paddy fields up to 500 m above sea level (Suprihatno et al., 2009). Similarly, the Padjajaran Agritan variety is a superior variety with a shorter growth duration and higher yield potential. It matures at 105 DAP with a potential yield of 11.0 tons ha^{-1}, but the average yield is 7.8 tons ha^{-1}. This variety is best grown in lowland irrigated rice fields up to 600 m above sea level (Thamrin et al., 2023). The use of short-lived and drought-tolerant varieties can help alleviate crop failure issues during the generative phase due to water scarcity (Viandari et al., 2022). The Padjajaran Agritan variety has a shorter harvest than Ciherang.

The number of productive tillers for the Ciherang variety was 19.40 stems, harvested at 122.5 DAP, yielding 11.01 tons ha^{-1} during the rainy season (Rahmawati et al., 2019). Additionally, the number of panicles $clump^{-1}$ was 10.78, and the weight of 1000 dry grains was 24.33 g (Safi'e et al., 2022). Furthermore, another measurement indicated 21.5 productive tillers, harvested at 122 DAP, with a 1000-grain weight of 29.5 g (Desi et al., 2023). In dry seasons, the harvesting age was 125 DAP, and the grain yield was 9.84 tons ha^{-1}. In contrast, during the rainy season, the grains yield 4.81 tons ha^{-1} (Santosa and Suryanto, 2015). The Padjajaran Agritan variety produced 10.25 panicles $clump^{-1}$, with a 1000-grain weight of 25.65 g, and a productivity of 4.80 tons ha^{-1} when planted in irrigated paddy fields from March to July or early in the dry season (Damiri et al., 2022). The chlorophyll content index of Padjajaran Agritan was 17.037 at 56-68 DAP (Munibah et al., 2022). In addition, maximum rice growth and yield are also determined by the use of optimal spacing.

Optimal spacing ensures that plants grow well both above and below the soil surface by utilizing solar radiation and nutrients. However, closer spacing will encourage mutual shadowing and intra-specific competition between plants (Oni et al., 2023). Rice yield depends on the number of panicles/m^2 and the number of seeds/panicles. The spacing that gave the higher number of panicles/m^2 was 15 × 15 cm and it gave a good yield (Marie-Noel et al., 2021). A spacing that is closer, with two seedlings per hole, could increase rice yield and improve resource use efficiency (Htwe et al., 2021). Based on previous literature, it can be emphasized that a using plant spacing of 15 × 15 cm or closer is an appropriate method for cultivating early-maturing rice varieties with a smaller habitus. With a denser planting pattern, the number of rice clumps per unit area will be greater, resulting in a higher grain yield than that obtained with wider spacing. Conversely, the grain yield per clump is higher with wider spacing than with denser spacing.

The research result showed that the optimum spacing that produced the maximum yield $clump^{-1}$ was 25 × 25 cm (Reuben et al., 2016). Additionally, a spacing of 25 × 25 cm during the dry season is correlated with higher rice production (Michael and Ali, 2020). The absorption efficiency of solar radiation in the rice canopy was greater at a spacing of 25 × 25 cm compared to at 20 × 20 cm. Increasing the absorption efficiency of solar radiation would inhance the number of panicles $clump^{-1}$ and the number of spikelets $clump^{-1}$ even when using alternate wetting and drying irrigation methods during the wet season (Setiobudi and Sembiring, 2009).

Research on the influence of variety and spacing on the growth and yield of rice conducted in the rainy and dry seasons has not been previously undertaken by researchers. This study aimed to contribute to identifying the optimal spacing for each variety cultivated in these seasons. The research is limited to semi-technical irrigated rice fields. Based on existing literature, This study aimed to determine the optimal spacing for rice growth and yield across different varieties and planting seasons.

Materials and methods

Study area

This study was conducted in the rainy season from December 2022 to April 2023 with an average sunlight intensity of 876.3 lux and an average maximum air temperature of 30.7 °C. The dry season lasted from June to October 2023 with an average sunlight intensity of 953.9 lux and an average maximum air temperature of 31.1 °C. The experiments were conducted in Minggir Sub-district, Sleman Regency, Special Region of Yogyakarta, Indonesia with an elevation of 110 m above sea level. The rice fields used for research were alluvial soil. Geographically, Sleman Regency is situated between 110°33′ 00″ - 110°13′ 00″ East Longitude and 7°34′51″ - 7°47′30″ South Latitude.

Materials and tools

The study used the Padjajaran Agritan and Ciherang varieties. Urea and NPK Phonska fertilizer were used. Bamboo stakes and plastic film were used as supports and treatment labels. Decis 25 EC 100ML was used to control the planthoppers. Hand plows and rakes were used for the first and second soil tillage. A hoe was used to create treatment plots and irrigation channels. A sickle was used to cut rice stalks during harvest. The CCM-200 plus chlorophyll meter was used to measure leaf greenness. The Binder FD 115 oven was used to dry stems and leaves. The digital scales model DS-880 was used to measure the dry weight of the shoots and grains. Thermo Hygrometer Clock HTC-2 was used to measure the air temperature of the research site. Lux Meter LUTRON LX-1128SD was used to measure the sunlight intensity.

Experimental design

The study was conducted in rice fields during the rainy and the dry seasons. The experiment was arranged in a nested design. This research used two rice varieties, namely Padjajaran Agritan and Ciherang varieties. Each rice variety consisted of three spacings, i.e., 15 × 15, 20 × 20, and 25 × 25 cm. Each spacing was replicated three times. Randomization was applied for the spacing treatment of each rice variety. The research flow can be seen in *Figure 1*.

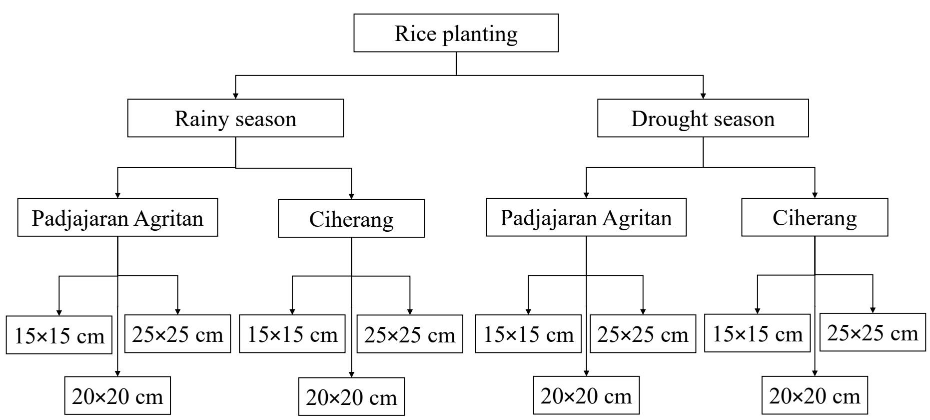


Figure 1. *The flow diagram in research activity*

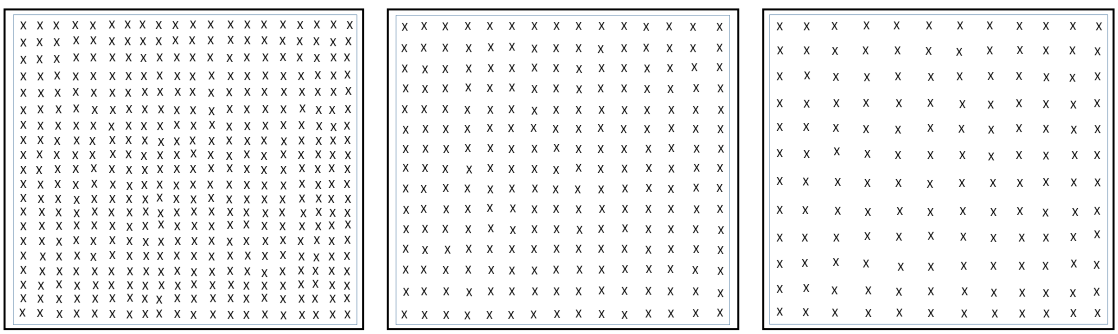
Research procedures

Rice cultivation in the rainy season

The first phase of the study was conducted during the rainy season. Plows were used for the initial tillage, followed by harrows to level the soil surface. After tillage was completed, nine treatment plots were established for spacing in both the Padjajaran Agritan and Ciherang varieties, resulting in a total of 18 treatment plots. Randomization was carried out for the spacing treatment in both varieties in each planting season. A distance of 0.5 meters was maintained between treatment plots for both rice variety.

Rice seeds were soaked in water for 3 hours to promote even absorption, after soaking, the seeds were drained and wrapped in newsprint overnight. The next day, they were placed on the prepared surface of the seedbed. The rice seedlings were ready planting after 18 DAP.

The size of the treatment plot was 3 × 3 square meters (m^2) (see *Fig. 2*). The number of rice seedlings planted in each plot varied according to the spacing: for a spacing of 15 × 15 cm, 400 seedlings were needed (see *Fig. 2a*); for 20 × 20 cm, 225 seedlings were used (see *Fig. 2b*), and 25 × 25 cm required 144 seedlings (see *Fig. 2c*). Only one rice seedling was planted per planting hole.



15 × 15 cm (a) | 20 × 20 cm (b) | 25 × 25 cm (c)

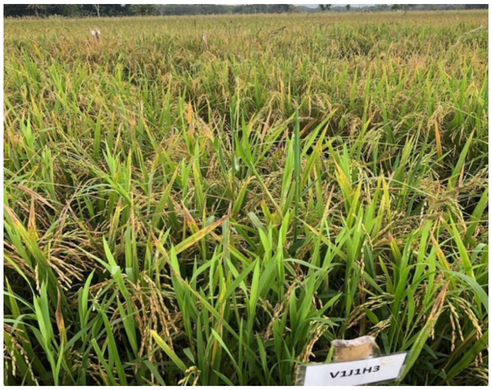
Figure 2. *The number of rice seedlings in each spacing*

Fertilizer doses of 225 kg ha^{-1} for urea and 225 kg ha^{-1} for NPK Phonska 15-15-15 were recommended (BPPP, 2014). Both urea and NPK Phonska fertilizers were applied twice each. The first application included 40% of the recommended dose at 15 DAP, while the second application included 60% at 30 DAP. Watering was carried out as needed by the plants. Weed control was conducted manually twice, at 14 and 34 DAP. Pest control was implemented to manage planthoppers and used Decis 25 EC 100ML. Rice harvesting occured at 104 DAP for the Padjajaran Agritan variety and at 116 DAP for the Ciherang variety. It was visually observed that during rainy season, water avaibility was abundant from the vegetative growth stage to harvest.

Rice cultivation in the dry season

The research in the dry season was conducted similarly to that in the rainy season. The water needs were met during the vegetative growth stage; however water limitation began during the generative growth stage and continued until harvest. Watering was performed once a week, although there were occasions when it was delayed.

The photo of the experimental culture in the rainy and dry seasons can be seen in *Figure 3a* and *b*.



(a) Rice cultivation in rainy season

(b) Rice cultivation in dry season

Figure 3. *The photo of the experimental culture in the rainy (a) and dry seasons (b)*

Parameter

Observations of research data were conducted on sunlight intensity (lux), air temperature (°C), number of productive tillers (steams clump^{-1}), leaf greenness index (units), shoot dry weight, and grain dry weight (g clump^{-1} and tons ha^{-1}). Measurements of sunlight intensity and air temperature above the plant surface were taken every two weeks throughout the research period. The leaf greenness index was assessed at 58 DAP. The number of productive tillers, shoot dry weight, and grain dry weight were measured at harvest. Plant observations were made using 10 samples from each treatment plot.

Statistical analysis

Observational data were analyzed by analysis of variance (ANOVA) at the 5% significance level. Differences between planting season treatments or varieties were assessed by comparing the calculated F value to the F table values. If the calculated F value is less than the tabled F value, there is no significant difference, and vice versa. If significant are found between plant spacing treatments, Duncan's new multiple range test (DMRT) is applied at the 5% significance level (Gomez and Gomez, 1984).

Results

Rice growth

Observations of rice growth included the number of productive tillers (stems clump^{-1}), leaf greenness (units), and shoot dry weight. Analysis of variance (ANOVA) indicated that spacing significantly influenced rice growth. However, there was no significant difference in growth between the Padjajaran Agritan and Ciherang varieties. Notably, differences in rice growth were observed between the rainy and dry seasons. For further clarification, the results of the DMRT at the 5% significance level for rice growth can be found in *Tables 1, 2,* and *3*.

Tables 1 and *2* indicate that a spacing of 25 × 25 cm resulted in higher number of productive tillers and shoot dry weight compared to 15 × 15 cm or 20 × 20 cm in both varieties. There were no differences in the number of productive tillers and shoot dry weight produced by the Padjajaran

Agritan and Ciherang varieties in both planting seasons. Additionally, the number of productive tillers and shoot dry weight produced in the rainy season were higher in the rainy season than in the dry season.

Table 1. *Effect of spacing on the number of productive tillers (stems clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season						Dry season					
15.9 p						9.6 q					
Varieties						**Varieties**					
Pajajaran Agritan			Ciherang			Pajajaran Agritan			Ciherang		
15.5 p			16.3 p			9.5 p			9.6 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
9.3 z	15.9 y	21.3 x	10.3 z	15.7 y	22.9 x	7.6 z	9.0 y	12.1 x	7.3 z	8.9 y	12.7 x

The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels

Table 2. *Effect of spacing on the shoot dry weight (g clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season						Dry season					
19.35 p						10.75 q					
Varieties						**Varieties**					
Pajajaran Agritan			Ciherang			Pajajaran Agritan			Ciherang		
21.04 p			17.66 p			10.36 p			11.15 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
11.58 z	18.41 y	33.13 x	12.19 z	17.38 y	23.43 x	8.16 z	10.13 y	12.78 x	8.89 z	11.49 y	13.04 x

The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels

Table 3. *Effect of spacing on the leaf greenness index (units) in different varieties and planting seasons*

Planting seasons											
Rainy season						Dry season					
17.4 p						12.9 q					
Varieties						**Varieties**					
Pajajaran Agritan			Ciherang			Pajajaran Agritan			Ciherang		
16.9 p			17.9 p			13.7 p			12.3 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
15.3 x	16.9 x	18.6 x	16.7 x	17.1 x	19.9 x	13.0 x	13.7 x	14.4 x	12.3 x	12.1 x	12. 4 x

The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels

Table 3 explains that there was no difference in leaf greenness index among rice plants spaced at 15 × 15, 20 × 15, and 25 × 25 cm for both varieties. Additionally, there was no difference in leaf greenness between the Padjajaran Agritan and Ciherang varieties in both planting seasons. The leaf greenness index was higher in the rainy season compared to the dry season.

Rice yield

The observation data for rice yield included both the grain dry weight clump^{-1} and ha^{-1}. Based on the data analysis using ANOVA, spacing significantly effected in rice yield clump^{-1}, but not ha^{-1}. There was no significant difference in rice yield between the Padjajaran Agritan and Ciherang varieties, either clump^{-1} or ha^{-1}. Differences in rice yield clump^{-1} were observed between the rainy and dry seasons, but no differences were noted on a ha^{-1} basis. For clarity, the results of the DMRT at the 5% significant level for rice yield clump^{-1} and ha^{-1} are presented in *Tables 4* and *5*.

Table 4. *Effect of spacing on the grain dry weight (g clump^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season						Dry season					
25.57 p						19.17 q					
Varieties						**Varieties**					
Pajajaran Agritan			Ciherang			Pajajaran Agritan			Ciherang		
25.74 p			25.39 p			19.86 p			18.47 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
14.70 z	24.47 y	38.05 x	15.91 z	26.04 y	34.23 x	13.71 z	20.97 y	24.91 x	13.46 z	17.37 y	24.59 x

The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels

Table 5. *Effect of spacing on the grain dry weight (tons ha^{-1}) in different varieties and planting seasons*

Planting seasons											
Rainy season						Dry season					
6.29 p						4.93 q					
Varieties						**Varieties**					
Pajajaran Agritan			Ciherang			Pajajaran Agritan			Ciherang		
6.25 p			6.35 p			5.11 p			4.75 p		
Spacings (cm)			**Spacings (cm)**			**Spacings (cm)**			**Spacings (cm)**		
15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25	15×15	20×20	25×25
6.53 x	6.12 x	6.09 x	7.07 x	6.51 x	5.48 y	6.01 x	5.24 x	3.98 y	5.98 x	4.34 y	3.94 y

The means followed by the same character in a row are not significantly different by DMRT at 5% significant levels

Table 4 shows that a spacing of 25 × 25 cm resulted in higher grain dry weight clump^{-1} compared to 15 × 15 cm or 20 × 20 cm for both varieties. There was no difference in grain dry weight produced by the Padjajaran Agritan and Ciherang varieties across both planting seasons.

Additionally, rice plants cultivated in the rainy season yielded a higher grain dry weight clump^{-1} than those in the dry season.

Table 5 indicates that there was no difference in grain dry weight ha^{-1} among the three spacings for the Padjajaran Agritan variety cultivated during the rainy season. However, for the Ciherang variety in the same season, spacings of 15 × 15 and 20 × 20 cm resulted in a higher grain dry weight ha^{-1} than in 25 × 25 cm. A similiar trend was observed for the Padjajaran Agritan variety cultivated during the dry season.

However, a spacing of 15 × 15 cm yielded the highest grain dry weight ha^{-1} in the Ciherang variety compared to the spacings of 20 × 20 and 25 × 25 cm during the dry season. There was no difference in grain dry weight ha^{-1} between Padjajaran Agritan and Ciherang varieties in either planting season. Additionally, the rice plants cultivated during the rainy season produced a higher grain dry weight ha^{-1} than those grown in the dry season.

Discussion

The observed growth components included the number of productive tillers, leaf greenness index, and dry shoot weight. In contrast, the yield components measured were grain dry weight clump^{-1} and ha^{-1}. For both varieties, rice growth and yield were higher at a spacing of 25 × 25 cm than 15 × 15 or 20 × 20 cm for both varieties, except for the leaf greenness index. Wider spacing reduced competition among plants for water and nutrients in the soil, resulting in a greater number of tillers clump^{-1}. Additionally, the plant canopy's ability to intercept sunlight was improved, air circulation among plants enhanced CO_2 uptake during photosynthesis. These agronomic factors supported metabolic processes, leading to better rice growth and yield clump^{-1}.

On the contrary, the grain dry weight per hectare was higher at a spacing of 15 × 15 cm. This higher yield was attributed to the greater plant population per hectare (444,444 clumps) compared to 20 × 20 cm (250,000 clumps), and 25 × 25 cm (160,000 clumps). Thus, a spacing of 15 × 15 cm was identified as the optimum spacing for maximizing grain dry weight ha^{-1}. According to De-yang et al. (2016), increasing plant density is a strategy to enhance grain yields, as it boosts plant anopy's capacity to capture solar radiation and increases absorption of water and nutrients.

There was no difference in rice growth and yield clump^{-1} or ha-1 between the two varieties, regardless whether they were planted in the rainy or dry season. This indicates that both varieties exhibit similar growth and yield characteristics. However, the Padjajaran Agritan variety has a shorter maturity period, thus requiring less total water compared to the Ciherang variety. According to Noviana et al. (2021), early-maturing and superior varieties can be effectively utilized to increase the cropping index and enhance rice production.

The research showed that rice yield ha^{-1} in the rainy season was higher than in the dry season. Ideally, rice growth and yield should be higher in the dry season due to abundant sunlight for photosynthesis. However, the study found that leaf greenness was higher in the rainy season than in the dry season, which enhanced the photosynthetic process in rice leaves. The higher carbohydrate yield supports better shoot growth and grain filling. Conversely, in the dry season, insufficient groundwater availability can lead to reduced growth and yield of rice. Water availability became a limiting factor for rice growth and yields in the study. The lack of water caused reduction in the leaf greenness index of rice plants, inhibiting the photosynthetic process. Since the research was conducted in semi-technical irrigated rice fields, water shortage during the dry season particularly affected growth during the generative growth phase. According to Arsal et al. (2020), an adequate irrigation water supply is crucial to meet groundwater needs during the dry season.

Abundant sunlight intensity in the dry season can increase air temperature and decrease air humidity around the rice plant. High air temperature impact transpiration rates, leading to increased water loss from the plant. Excessive water loss negatively affects cell division, growth, and the protoplasm within the leaves. Water stress results in decreased photosynthesis activity, ultimately reducing rice growth and yield. However, the Padjajaran Agritan and Ciherang varieties can still adapt well to conditions water scarcity. According to Sukkeo et al. (2017), high temperatures adversely affect rice grain yield during panicle development, anthesis, and grain filling. This is supported by Sanwong et al. (2023), who note that high temperature lead to reduction in both grain yield and quality.

Conclusion

In conclusion, the number of productive tillers, dry shoot weight, and grain dry weight clump^{-1} were higher when planted with a spacing of 25 × 25 cm than 15 × 15 or 20 × 20 cm for both varieties. Conversely, the total grain dry weight per hectare was greater with a spacing of 15 × 15 cm. No significant differences were observed in the growth and yield of rice between the Padjajaran Agritan and Ciherang varieties. The grain dry weight produced by Padjajaran Agritan and Ciherang were 6.25 and 6.35 tons ha^{-1} in the rainy season but decreased to 5.11 and 4.75 tons ha^{-1} in the dry season. The research findings suggest that a spacing of 15 × 15 cm is optimal for both the Padjajaran Agritan and Ciherang varieties when planted in either the rainy or dry season. However, the growth and yield of rice are higher in the rainy season than in the dry season in semi-technical irrigated rice fields. Consequently, we recommend utilizing closer spacing and drought-resistant superior varieties to maximize rice yield in the dry season.

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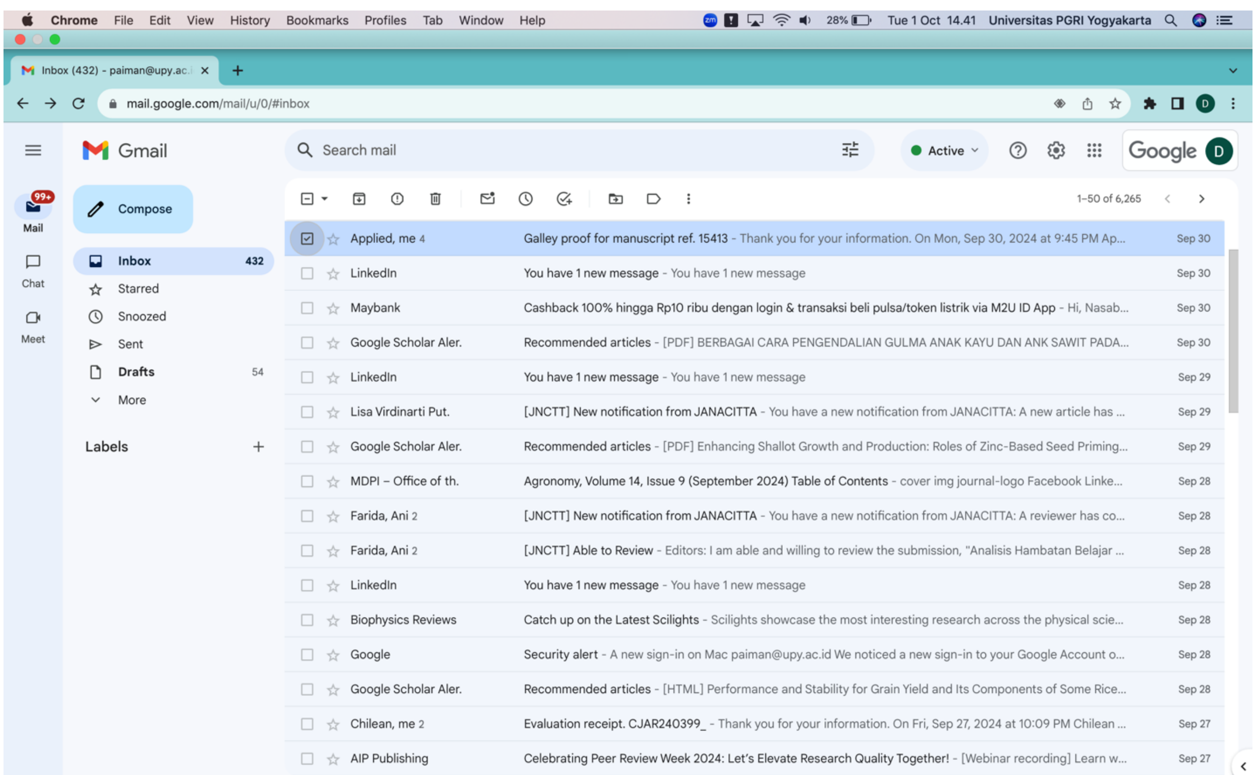

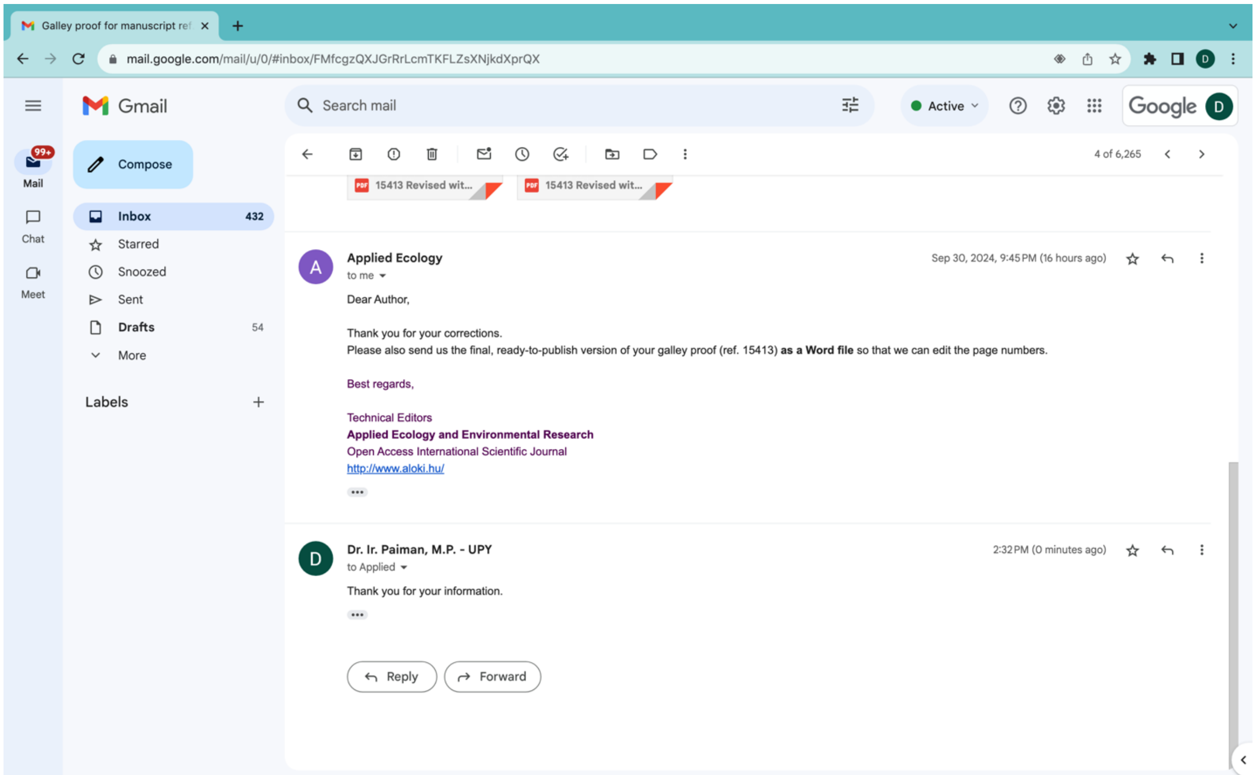

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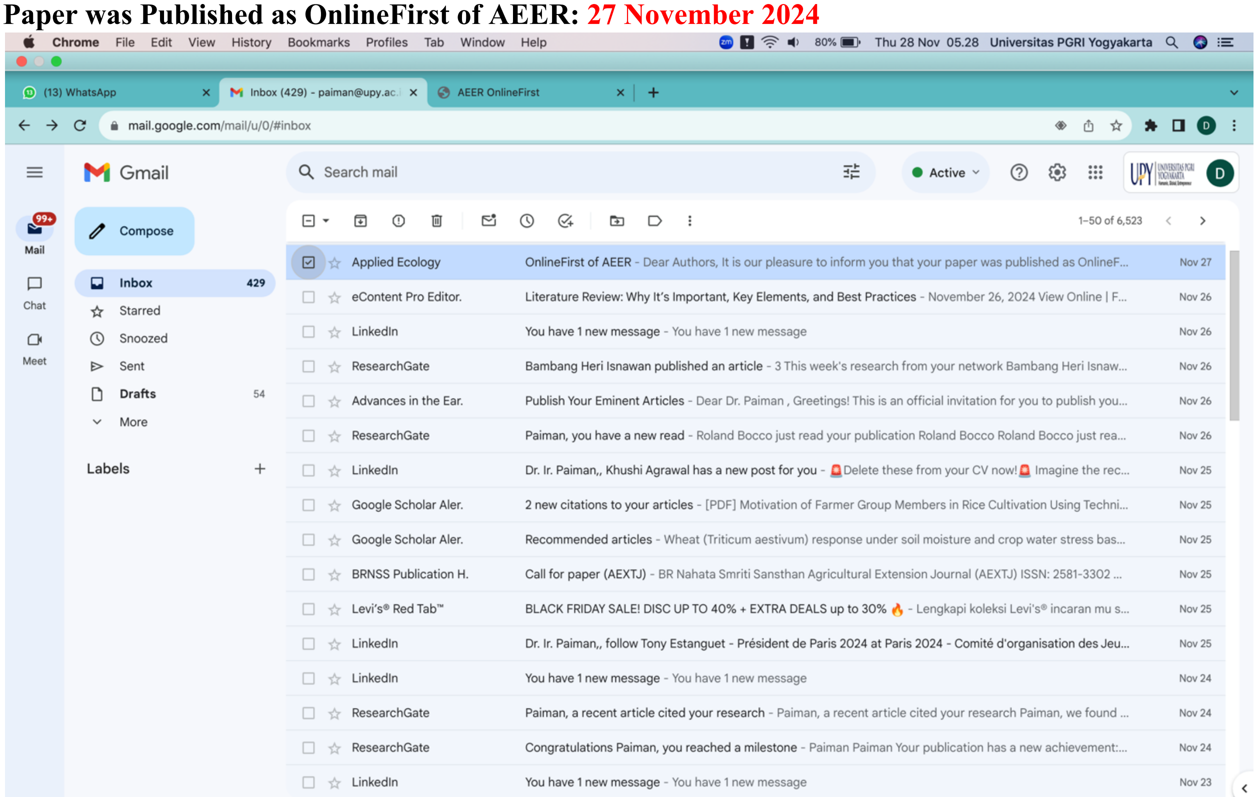

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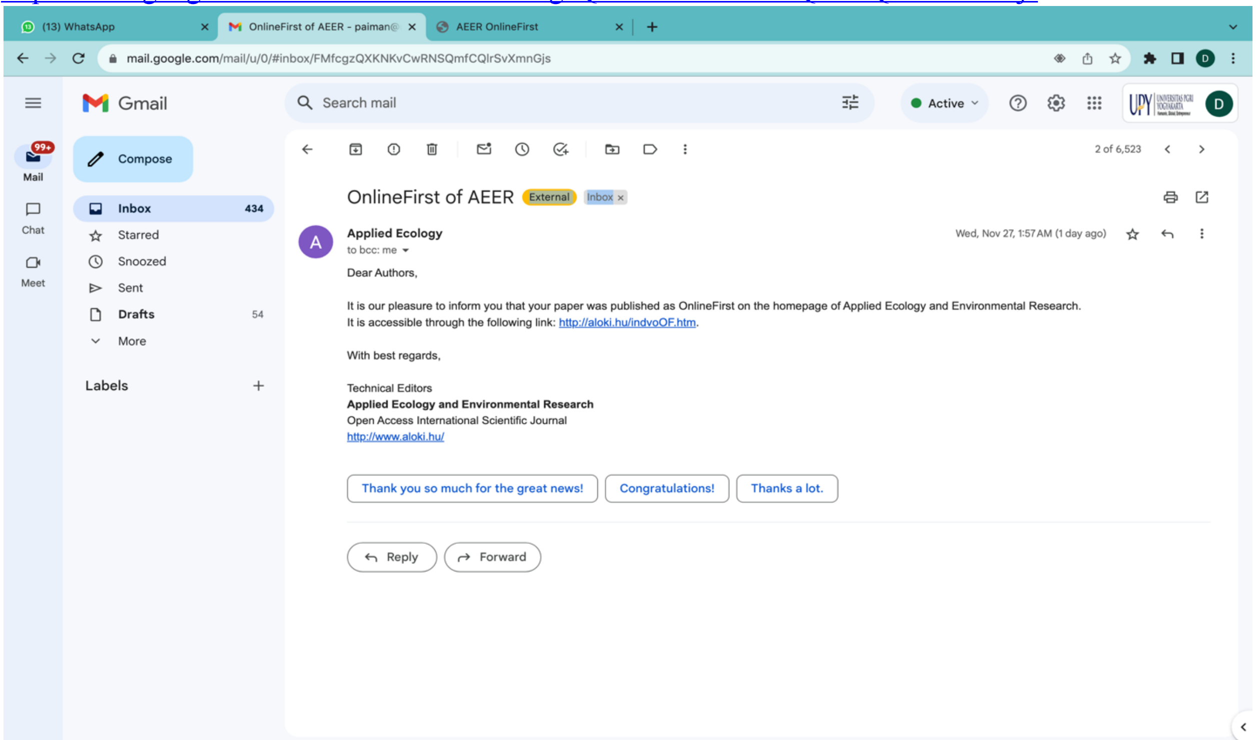

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