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Optimizing bioherbicide application timing and plant spacing to manage weed growth in rice (*Oryza sativa* L.) cultivation

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ABSTRACT

Weed management is crucial for successful rice cultivation. Bioherbicides derived from cogon grass extract offer a promising solution for weed control. Additionally, optimizing plant spacing has been recognized as an effective method to suppress weed growth. Thus, this study aims to investigate the impact of cogon grass extract application timing and plant spacing on weed growth in rice cultivation. The study was conducted from October 2022 to February 2023 in the Special Region of Yogyakarta, Indonesia. The study was 3 × 2 factorial and arranged in a randomized completely block design (RCBD). The first factor was the bioherbicide application timing: control (no application), three days before planting, and at the time of planting. The second factor was plant spacing: 15 × 15 and 25 × 25 cm. In total, there were six treatment combinations and three replications (replications as blocks). The research results indicated the application timing of bioherbicide did not significant effect on the growth of weed and rice, as well as the grain dry weight. *Fimbristylis miliacea* was obtained as the dominant weed species. Bioherbicide application at the time of planting could alter the composition of weed species compared to the control in plant spacing of 15 × 15 cm. Furthermore, the plant spacing of 25 × 25 cm resulted in higher grain and weed dry weight (19.40 g/clump and 45.00 g/0.25 m^2) compared to 15 × 15 cm (12.92 g/clump and 23.04 g/0.25 m^2). On the contrary, the grain dry weight per hectare was higher in 15 × 15 cm (5.74 t/ha) than in 25 × 25 cm (3.10 t/ha). The research findings indicate that closer plant spacing can suppress weed growth and increase the grain dry weight per hectare compared to wider plant spacing. We recommend that the use of cogon grass extract dosage needs to be increased above 50 L/ha.

Key words: Bioherbicide, cogon grass extract, plant spacing, rice, weed

INTRODUCTION

Rice plants are the main producers of rice to meet the food needs of the majority of Indonesians. The use of superior varieties and short-lived ones is the right choice to fulfil national food needs. As the population increases, the demand for rice continues to rise. However, every rice cultivation is always accompanied by the emergence of weeds around the plants. The presence of weeds significantly disrupts and harms rice growth and yield. So, it must be controlled.

Many methods of weed control with chemicals have been recommended, but biological control with cogon grass (*Imperata cylindrica* (L.) Beauv.) extract is not widely known. The cogon grass extract as a bioherbicide contains allelopathic compounds (Kato-Noguchi, 2022). These compounds can inhibit the germination of weed seeds in the soil by hindering enzyme activity through the degradation of food reserves in the seeds. As a result, the energy produced is low due to a decrease in germination power. In addition, weed growth control can also be achieved through plant spacing.

Closer plant spacing is a method of weed control through technical cultivation. The plant canopy plays a role in reducing the distribution of sunlight to the soil surface. As a result, weed growth is inhibited due to a lack of light (Listyowati *et al.*, 2022). The suitable plant spacing can enhance rice yield per hectare and suppress weed growth. In fertile land, a more spacious plant spacing is advisable, while in less fertile land, a closer spacing is recommended. Short-lived varieties are better suited for close spacing, whereas long-lived varieties are suitable for wider spacing. The use of superior rice varieties requires a looser plant spacing. Increasing plant spacing provides weeds with the opportunity to grow freely and subsequently interfere with the crop. Therefore, understanding the suitable plant spacing is essential.

Weeds are troublesome plants that adversely affect the growth and yield of plants. Extracts from certain weeds have the potential as bioherbicides because they can produce allelopathy (Erida *et al.*, 2019). Allelopathy is capable of reducing seed germination and slowing down the germination process. Allelopathic compounds can inhibit the activity of enzymes that degrade food reserves in seeds, resulting in very low energy production and decreasing germination potential.

In general, plant-derived bioherbicides contain phytotoxic allelochemicals or specific disease-carrying microbes (Hasan *et al.*, 2021). The advantages of using bioherbicides are that they contain no toxic organic secondary metabolites, that they are easy to acquire from the field, that they have no secondary metabolite mechanisms found in synthetic herbicides, that they have more than one secondary metabolite compound, and that they do not cause plant poisoning (Sihombing *et al.*, 2018). When bioherbicides are absorbed by weed seeds or roots, they disrupt the integrity of cell membranes and other essential biochemical processes. It should be noted that the cytotoxic effect on weeds is reflected in low levels of root cell division, low ability to absorb nutrients, growth hormones, and pigment synthesis, as well as low growth of reactive oxygen species (ROS), stress-related hormones, and abnormal antioxidant activity (Bayat *et al.,* 2019; Hasan *et al.*, 2021).

One type of weed with potential as a bioherbicide is *Imperata cylindrica* (Sari *et al.*, 2017). The roots of cogon grass can be used as a pre-emergence bioherbicide. Cogon grass root extract contains allelochemical compounds, specifically flavonoids. A concentration of 1% root extract of cogon grass is capable of inhibiting the growth of weed seeds located below the ground (Sari *et al.*, 2017). Furthermore, a concentration of 14% extract from cogon grass rhizomes can effectively control weeds such as *Ageratum conyzoides*, *Eleusine indica* and *Cyperus rotundus* (Lau *et al.*, 2021).

Extract cogon grass contains terpenoid, phenolic, and steroid compounds (Erida *et al.*, 2019). The extracts, leachates, root exudates, or growing medium of cogon grass also contained several allelochemicals, including phenolic acids, phenolic aldehydes, phenylpropanoids, flavonoids, quinones, fatty acids, terpenoids, simple phenolics, benzoic acids, and alkaloids (Kato-Noguchi, 2022). The application of cogon grass extract at the time of planting with a concentration of 30% could increase the number of panicles and the weight of dry rice grains in rice cultivation in polybags. It had a greater potential as a bioherbicide to suppress weed growth and increase rice yield (Paiman *et al.*, 2022).

The percentage of germination, germination rate, and seedling length of weed seeds such as *Amaranthus spinosus*, *Bidens biternata*, and *Tridax procumbens* could all be greatly suppressed by using cogon grass extract. *Tridax procumbens* had the highest level of sensitivity among weed seeds to the extract from the roots and rhizomes of cogon grass, followed by *Bidens biternata* and *Amaranthus spinosus*. Extracts from the roots and rhizomes of cogon grass exhibit significant potential as bioherbicides to inhibit the germination of weed seeds (Pujiwati, 2011). On the other hand, using close plant spacing can also suppress weed growth and increase yield per unit area. But, grain yield per clump decreases. The appropriate plant spacing can provide plants with the opportunity to grow well without competition from neighbouring plants for water, nutrients, and sunlight. The suitable plant spacing can enhance rice yield. Also, the use of plant spacing depends on the cultivated rice variety.

Rice plants with curved panicles were used for planting density was not too tight and not too loose, but rice plants with erect panicles were better with planting density quite tight (Yena *et al.*, 2018). Wide inter-row wine and spacing in narrow rows will be conducive to building a high-yield population to increase yields (Li *et al.*, 2016). If the spacing between rows was fixed at 30 cm, then the spacing in rows of 11-12 cm could increase plant population, and grain yield, and was the optimal plant spacing for rice cultivation (Yun *et al.*, 2020). Grain yield was maintained in a large number of plant populations, primarily through the effects of more tillers per plant and more grain per panicle in lower plant populations (Dunn *et al.*, 2020).

Plant spacing significantly influenced plant height, tiller number, and rice panicle length. A plant spacing of 15 × 15 cm provided the highest panicle count and good yield per square meter (Marie-Noel *et al.*, 2021). The optimal Jajar Legowo system involved skipping one row after every three rows at plant spacing of 15 × 15 cm, resulting in the highest grain yield (Rautaray, 2016). Consistent with subsequent research, the highest grain dry weight was found at a plant spacing of 15 × 15 cm compared to 20 × 20 cm and 25 × 25 cm (Rautaray, 2016). In line with further studies, plant density with a plant spacing of 15 × 15 cm resulted in the highest grain yield (4.71 t/ha), while the 25 × 25 cm treatment yielded a lower amount (4.09 t/ha) (Alogaidi *et al.*, 2019). Also supported by Faisul-ur-Rasool *et al.* (2012), closer spacing (15×15 cm) produced the maximum tillers number, leaf area index, dry matter accumulation, and rice yield. Plant spacing of 15 × 15 cm resulted in a yield of 8.97% greater than 20 × 20 cm because of better absorption of photosynthetically active light.

Plant population had a significant effect on morphological and physiological characteristics as well as crop yield. The leaf area per clump was broader with a looser plant spacing. Additionally, wider plant spacing results in lower competition among plants, allowing them to acquire more nutrients. As a result, there were more tillers, a larger leaf area, and greater dry weight per cluster, as opposed to dense plant spacing (Mondal *et al.*, 2013). There was limited information available on the optimal row width needed to maximize grain yield potential (Dunn *et al.*, 2020). Superior rice varieties prefer a looser plant spacing for their growth compared to local varieties, but yield per unit area needs to be maximized using closer plant spacing.

Based on the literature review above, cogon grass extract as a bioherbicide has proven to be quite effective in biologically controlling weeds, particularly at a concentration of 30%. However, this bioherbicide has not yet been directly applied in rice fields, and the appropriate application timing in rice cultivation remains unknown. Additionally, it has been established from several previous studies that the use of close plant spacing (15 × 15 cm) in rice cultivation can effectively suppress weed growth and increase yield. However, the use of plant spacing has not been investigated in the cultivation of the short-lived rice of the Padjajaran Agritan variety.

Research about the application timing of cogon grass extract as a bioherbicide and the plant spacing to suppress weed growth and increase rice yield needs to be conducted. This study is expected to contribute insights into environmentally friendly weed control through biological and technical cultural approaches. Therefore, this research aimed to know the effect of application timing of cogon grass extract and plant spacing on weed growth in rice cultivation of the Padjajaran Agritan variety.

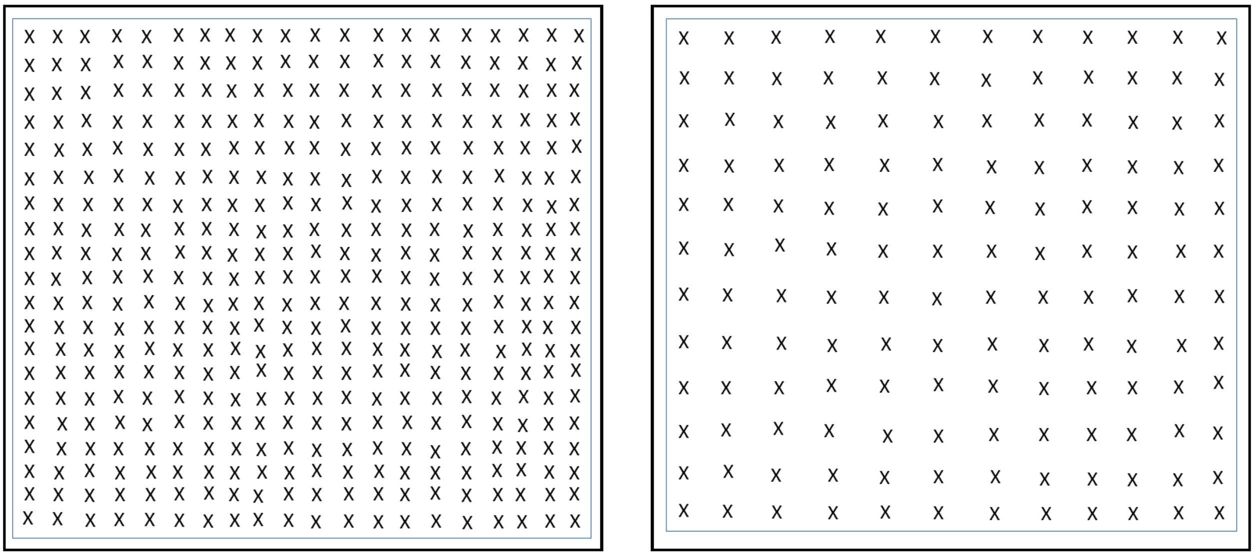
MATERIALS AND METHODS

Study Site

The research was conducted from October 2022 to February 2023 during the rainy season. The study was located in Minggir Sub-district, Sleman Regency, Special Region of Yogyakarta, Indonesia. The elevation of the location was 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.

Experimental Design

The study was 3 × 2 factorial and arranged in a randomized completely block design (RCBD). The first factor was the application timing of bioherbicide consisting of three methods: control (no application), three days before planting, and at the time of planting. The second factor was the use of plant spacing, consisting of two kinds: 15 × 15 cm (close plant spacing) and 25 × 25 cm (wide plant spacing). In total, there were six treatment combinations. Each treatment combination



a. Plant spacing of 15 × 15 cm (400 seedlings)   b. Plant spacing of 25 × 25 cm (144 seedlings)

Fig. 1. Plot treatments of plant spacing of 15 × 15 cm (a) and 25 × 25 cm (b).

was repeated three times (replications as blocks), resulting in a total of 18 treatment plots. Treatment plots of plant spacing of 15 × 15 cm and 25 × 25 cm can be seen in Fig. 1.

Research Procedures

In this study, seeds of the Padjajaran Agritan variety were used. Before sowing, the seeds were soaked in water for three hours to ensure uniform imbibition. Subsequently, the seeds were lifted from the soaking medium, and the excess water was drained. After one day and one night, roots emerged from the base of the seeds. Plastic seedling trays measuring 50 × 60 cm with a height of 10 cm were used for seed germination. The germination medium consisted of a mixture of organic fertilizer and soil in a 1:1 ratio. The seeds were then sown on the surface of the germination medium at field capacity. Four days later, shoots emerged above the soil surface, and the seedlings were ready to be transplanted into the rice field at the age of 18 days after sowing.

Soil processing was conducted in two stages. The first stage of soil processing involved using a rotary plow to overturn and crush the soil. The second stage of processing utilized a harrow to level the soil. Subsequently, treatment plots were established with dimensions of 3 × 3 m, totaling 18 treatment plots. Drainage channels with a width of 0.5 m were created between the treatment plots. Treatment randomization was performed per block for all blocks.

In this research, cogon grass extract was used as a bioherbicide. The application timing of bioherbicide corresponds to the randomized treatment results. The control plot was without bioherbicide treatment, while the treatment plots involved the use of a 30% concentration of bioherbicide with a dosage of 45 ml/3 m^2 (50 L/ha). The application timing of bioherbicide was divided into two methods: three days before planting and at the time of planting. Bioherbicide was applied only once for each treatment in research. During the three days following the treatment, measures were taken to ensure that no external water entered the treatment plots.

The seedlings number that planted in each treatment plot depends on the plant spacing. For a plant spacing of 15 × 15 cm, 20 seedlings were planted in rows and 20 seedlings between rows, requiring a total of 400 seedlings per plot (Fig. 1a). Meanwhile, for a plant spacing of 25 × 25 cm, 12 seedlings were planted in rows and 12 seedlings between rows, requiring a total of 144 seedlings per plot (Fig. 1b). Only one rice seedling was planted per planting hole.

Recommended fertilizer usage was 225 kg/ha of urea and 225 kg/ha of NPK Phonska 15-15-15 (BPPP, 2014). Fertilizer application was divided into two stages. In the first stage, 40% of the recommended dosage was applied 15 days after planting (DAP). The second stage involved applying 60% of the recommended dosage at 35 DAP. Irrigation was carried out every four days after the treatment. Pest and disease control were implemented during the rice flowering stage to minimize the impact of brown planthoppers. Harvesting was conducted when the rice plants reached 104 DAP.

Parameters

Observations on weed growth were conducted at 60 days after transplanting (DAT) and included the number of weeds (individual/ 0.25 m^2), weed dry weight (g/0.25 m^2), weed dominance, and weed community coefficient (%). Observations on rice plants were performed on growth and yield components, including the tillers number (stalks/clump) observed at 60 DAT, plant dry weight (g/clump), panicles number (strands/clump), grain dry weight (g/clump), and hectare (ton/ha), all observed at 104 DAT.

Statistical Analysis

Observational data were analyzed by analysis of variance (ANOVA) at P = 0.05 probability levels with the software IBM SPSS Statistic 23. In addition, Duncan's new multiple range test (DMRT) at P = 0.05 probability levels was used to test the difference between treatment averages. To determine the dominant weed species and weed community sift, the summed dominance ratio (SDR) and coefficient of weed community were used.

RESULTS AND DISCUSSION

Number and Dry Weight of Weeds

The timing of the bioherbicide application did not have a significant effect on the number and dry weight of weeds. However, only the plant spacing had an impact on the weed dry weight. The average number and dry weight of weeds can be seen in Table 1.

Table 1 shows that a plant spacing of 25 × 25 cm resulted in a higher weed dry weight compared to 15 × 15 cm. Wider plant spacing contributed to a heavier weed dry weight. In wider plant spacing, sunlight penetration can reach the soil surface, and then support weed growth. The weed dry weight at a plant spacing of 15 × 15 cm was lower than that at 25 × 25 cm. It indicates that closer plant spacing is more effective in suppressing weed growth because the plant canopy quickly covers the soil surface. Sunlight penetration to the soil surface is lower, so inhibits weed growth. In line with Fahad *et al.* (2015), less weed growth was seen at narrow row spacing (11 cm) compared to wider row spacing (15 and 23 cm) in wheat crops. In line with the research result by Chauhan and Johnson (2010), narrowing the row spacing could decrease weed growth and seed production, as well as increase the grain yield of rice.

Dominance of Weed Species

In this study, three types of weeds were identified based on their morphology, namely sedges, grasses, and broad-leaved weeds, with a total of nine weed species overall. The effect of the combination of bioherbicide application timing and plant spacing on the SDR of each weed species can be seen in Table 2.

Table 2 indicates that the identified sedges included *Cyperus brevifolius*, *Cyperus rotundus*, and *Scorpus mucrontus*. The grass weeds identified in this study were *Cynodon dactylon*, *Echinochloa colona*, *Echinochloa crus-*

Table 1. Effect of bioherbicide application and plant spacing on the weed growth per plot

Treatments	Parameter of observations	
	Weed number (individual/0.25 m^2)	Weed dry weight (g/0.25 m^2)
Timing of bioherbicide application		
Control	58.17 a	32.08 a
Three days before planting	41.67 a	28.97 a
At the time of planting	44.67 a	41.01 a
Plant spacing (cm)		
15 × 15	41.22 p	23.04 q
25 × 25	55.11 p	45.00 p

Remarks: According to DMRT at P = 0.05 probability levels, there is no significant difference between the numbers in the same column followed by the same characters.

Table 2. Summed dominance ratio (SDR) (%) of each weed species

S. No.	Weed species	SDR (%)					
		J_1B_0	J_1B_1	J_1B_2	J_2B_0	J_2B_1	J_2B_2
1.	*Cyperus brevifolius* (Rottb.) Rassk.	0.00	2.56	0.00	0.00	0.00	0.00
2.	*Cyperus rotundus* L.	0.00	0.00	13.58	10.86	5.26	4.05
3.	*Scirpus mucronatus* L.	10.72	6.29	4.06	6.35	0.00	3.24
4.	*Cynodon dactylon* (L.) Pers.	4.92	7.57	10.51	12.45	5.50	8.10
5.	*Echinochloa colona* (L.) Link.	5.55	9.70	16.75	6.73	4.27	5.94
6.	*Echinochloa crus-galli* (L.) P. Beauv.	18.90	8.49	0.00	12.37	27.1	9.42
7.	*Fimbristylis miliacea* (L.) Vahl.	47.48	50.54	44.34	51.21	50.3	52.26
8.	*Limnocharis flava* (L.) Buch	0.00	7.87	2.91	0.00	0.00	6.66
9.	*Monochoria vaginalis* (Burm.f.) C.Presl.	12.39	6.95	7.82	0.00	7.49	10.29

Remarks: J_1 = Plant spacing of 15 × 15 cm, J_2 = Plant spacing of 25 × 25 cm, B_0 = Control, B_1 = Three days before planting, and B_2 = At the time of planting.

galli, and *Fimbristylis miliacea*. Several types of broad-leaved weeds found in this research were *Limnocharis flava* and *Monochoria vaginalis*. *Fimbristylis miliacea* was the dominant weed species followed by *Echinochloa crus-galli* in this study. It can be explained that grass weeds more dominate in rice cultivation than other types of weeds. It was supported by Kurniadie *et al.* (2019), *Fimbristylis miliacea* was a dominant weed species in conventional and organic rice cultivation.

Weed Community Shift

Based on Table 2, the weed community coefficient (C%) can be calculated between weed communities, both among the application timing of bioherbicide and plant spacing treatments. The results of the weed community coefficient are presented in Tables 3 and 4.

Table 3 indicates that the coefficient of weed community in the comparison between the control and application timing of bioherbicide at the time of planting was 66.69% in a plant spacing of 15 × 15 cm. It shows a shift in the weed species composition due to the application timing of bioherbicide at the time of planting. In other words, there is a difference in the weed species that grow in these two communities. Meanwhile, for the other communities, there is no shift in the weed species community because their community coefficients were >75%.

Growth and Yield of Rice

Observations on the growth and yield of rice included the tillers number, plant dry weight, panicles number, grain dry weight per clump, and hectare. The application timing of bioherbicide did not have a significant effect on all the observed parameters. However, the plant spacing significantly influenced all the observed parameters. The average tillers number, plant dry weight, panicles number, grain dry weight per clump, and hectare can be seen in Table 5.

Table 4 indicates that a plant spacing of 25 × 25 cm resulted in tillers number (12.51 stem), plant dry weight (14.91 g), panicles number (10.71 strands), and grain dry weight

Table 3. Weed community coefficient between application timing of bioherbicide in each plant spacing

Plant spacing (cm)	Comparison between application timing of bioherbicide	Weed community coefficient (C%)	Information
15 × 15	1. Control and three days before planting	79.68	Homogeny
	2. Control and at the time of planting	66.69	No homogeny
	3. Three days before planting and at the time of planting	75.53	Homogeny
25 × 25	1. Control and three days before planting	77.70	Homogeny
	2. Control and at the time of planting	81.96	Homogeny
	3. Three days before planting and at the time of planting	81.03	Homogeny

(19.40 g) per clump, respectively. Plant spacing of 25 × 25 cm was given growth and yield component per clump higher than in 15 × 15 cm. The higher tillers number, plant dry weight, and panicles number at wider plant spacing correlated with the grain dry weight per clump. The result of this study was supported by Dass *et al.* (2017), wider plant spacing significantly increased rice yield compared with closer plant spacing. In line with Anwari *et al.* (2019), yield components like tillers number and grain per panicle were found in plant spacing 25 × 25 cm compared to 10 × 10 cm, 15 × 15 cm, or 20 × 20 cm.

A plant spacing of 25 × 25 cm could yield higher grain dry weight per clump because of a better microclimate compared to closer plant spacing. It caused lower competition among plants for nutrients, improved water access, and smoother air circulation. Rice plants could grow well so that the size of the habitus was larger. Additionally, sunlight distribution was more even across the entire plant body, leading to enhanced photosynthesis. These conditions resulted in a more efficient carbohydrate-filling process for all seeds in the panicle. With a greater seed number per clump and a heavier weight per seed, the total grain dry weight was higher. On the other hand, sunlight penetration to the soil surface could benefit weeds to support their growth.

However, a plant spacing of 15 × 15 cm could provide a higher grain dry weight per hectare compared to 25 × 25 cm. In closer plant spacing, the population density per hectare was higher, leading to a higher yield per hectare. The highest radiation use efficiency was obtained at close plant spacing which resulted in a higher amount of biomass for energy production. Following the opinion of Ya-Jie *et al.* (2016), higher density was applied to increase panicles and grains number for higher yield per unit area. Supported by Marie-Noel *et al.* (2021), the highest panicle number/m^2 was found in plant spacing of 15 × 15 cm but not obtained in 20 × 20 cm, 25 × 25 cm, or 30 × 30 cm. In contrast with the study results by Asghar *et al.* (2021), the highest grain yield of 6.75 t/ha was obtained in plant spacing of 23 × 23 cm followed by 5.46 t/ha from 18 × 18 cm. No in line with the study results by Neupane (2022), loose plant spacing (20 × 20 cm) was given superior morphophysiological and yield components and resulted in a grain yield of 8.53 t/ha higher than 6.47 t/ha in tight plant spacing (20 × 10 cm).

The use of a plant spacing of 15 × 15 cm resulted in plant populations higher than 25 × 25 cm, with 444,444 plants/ha higher than 160,000 plants/ha. Total grain yield per hectare could be increased by close plant spacing. The plant population at a plant spacing of 15 × 15 cm was almost three times higher than 25 × 25 cm. The panicles number per

Table 4. Weed community coefficient between plant spacing in application time of bioherbicide

Application timing of bioherbicide	Comparison between plant spacing	Weed community coefficient (C%)	Information
Control	15 × 15 and 25 × 25 cm	76.67	Homogeny
Three days before planting	15 × 15 and 25 × 25 cm	75.51	Homogeny
At the time of planting	15 × 15 and 25 × 25 cm	76.40	Homogeny

Table 5. The effect of application timing of bioherbicide and plant spacing on the growth and yield of rice

Treatments	Parameters				
	Tillers number (stem/clump)	Plant dry weight (g/clump)	Panicles number (strands/clump)	Grain dry weight	
				(g/clump)	(t/ha)
Application timing of bioherbicide					
Control	10.57 a	9.97 a	9.06 a	14.90 a	4.15 a
Three days before planting	11.37 a	13.93 a	9.13 a	16.58 a	4.32 a
At the time of planting	10.73 a	12.94 a	9.50 a	17.00 a	4.80 a
Plant spacing (cm)					
15 × 15	9.27 q	10.75 q	7.75 q	12.92 q	5.74 p
25 × 25	12.51 p	14.91 p	10.71 p	19.40 p	3.10 q

Remarks: According to DMRT at P = 0.05 probability levels, there is no significant difference between the numbers in the same column followed by the same characters.

hectare was found to be higher at a plant spacing of 15 × 15 cm which was 3,444,441 panicles greater than 1,713,600 panicles in 25 × 25 cm. It means that a greater panicle number could support the total grain dry weight per hectare, although the total grain dry weight per panicle was lower. Deng *et al.* (2022) explained that increasing light utilization by the canopy was a major way to increase photosynthesis and rice productivity.

In this study, the Padjajaran Agritan variety was used, which has short-lived growth, fewer tillers, and a smaller plant size. Therefore, using a closer plant spacing was the best solution to achieve a higher yield per hectare by intercepting more solar radiation. It can be concluded that using a closer plant spacing for rice varieties with a compact habitus is more advantageous because it can capture and harness more sunlight penetration. Additionally, the growth of weeds under the plant canopy can be inhibited.

CONCLUSION

In conclusion, the the application timing of bioherbicide did not affect significantly on growth of weed and rice, as well as the grain dry weight. *Fimbristylis miliacea* was obtained as the dominant weed species. Bioherbicide application at the time of planting could alter the composition of weed species compared to the control in plant spacing of 15 × 15 cm. Furthermore, the plant spacing of 25 × 25 cm resulted in higher grain and weed dry weight (19.40 g/clump and 45.00 g/0.25 m^2) compared to 15 × 15 cm (12.92 g/clump and 23.04 g/0.25 m^2). On the contrary, the grain dry weight per hectare was higher in 15 × 15 cm (5.74 t/ha) than in 25 × 25 cm (3.10 t/ha). The research findings indicate that closer plant spacing can suppress weed growth and increase the grain dry weight per hectare compared to wider plant spacing. We recommend that the use of cogon grass extract dosage needs to be increased above 50 L/ha.

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