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Study on Weeds Abundance on Rice Fields in Mycorrhizal Inoculation and Different Planting Methods

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Abstract

The increasing demand for rice and the increasing population growth rate require sustainable rice production. Direct seeding of rice (DSR) combined with the use of arbuscular mycorrhizal fungi (AMF) is needed to achieve sustainable food production. This study aims to determine the effect of the planting method and mycorrhizal inoculation on the diversity, composition and dominance of weeds in a rice field for the sustainability of agricultural production. The research used a split-plot design with three replications. The main plot was the planting method consisting of on row, drum seeder and transplanting, while the subplot was mycorrhizal inoculation divided into with mycorrhizal inoculation and without mycorrhizal inoculation. The observed variables were light penetration, weeds population, weeds composition, weeds biomass, summed dominance ratio and community coefficient. The results showed that there were 34 kinds of weeds consisting of 13 families and the dominant weed was annual weeds, most of which were broadleaf weeds. The dominant weed was *Alternanthera sessilis* (L.) R. Br. ex DC. (sessile joyweed). The planting methods affected the weed population in 24 days after sowing (DAS) and the composition of broadleaf weeds in 24 DAS but did not affect weed biomass. The AMF inoculation did not affect weed population, composition, or biomass. It is necessary to find mycorrhizal species that can affect weed growth.

Keywords: annual weeds; cropping system; dominance; sessile joyweed; weed control

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INTRODUCTION

Rice is a staple food for more than 90% of the Indonesian population. The data from the Central Bureau of Statistics recorded that Indonesian rice consumption in 2020 reached 29.37 million tons (Pryanka and Zuraya, 2020). This number continues to increase, in line with the increasing rate of population growth, so sustainable production is needed. Sustainable production can only be achieved through sustainable agriculture. In implementing sustainable agriculture, a production process must pay attention to ecological, economic and social sustainability to ensure that the existing resources keep producing for the future generations (Saraswati and Sumarno, 2008; Behnassi et al., 2011; Rivai and Anugrah, 2016).

Currently, efforts to meet the national demand for rice sustainably from domestic supply are constrained by the reduction in rice fields due to land degradation, land conversion and a stagnant number of farmers. In Indonesia, 48.3 million hectares of degraded land were recorded (Wahyunto and Dariah, 2014) and the conversion of rice fields to non-agricultural function land nationally between 2013 to 2015 ranged from 100 to 4,750 ha year^{-1} (Mulyani et al., 2016).

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On the other side, the number of lowland rice farmers aged over 50 years old was 52% and aged 20 to 39 years old was 18% (Kadir, 2019). Based on these conditions, we have serious problem for agricultural sustainability. A proper rice planting method combined with the use of arbuscular mycorrhizal fungi (AMF) coating on seed is needed to achieve sustainable food production.

Direct seeding of rice (DSR), which divided into on row and drum seeder, is one solution to overcome labor shortage and increase rice production. DSR has the advantages of reducing number of labors, water and shortening rice production period; and hence, it can increase the cropping index and reduce planting costs (Zarwazi et al., 2015). Spacing in transplanting method makes weeds control easier, but this method requires many labor for planting rice, stagnation rice seeds when transplanted and longer rice production. DSR has the potential to replace transplanting, but this planting method has a drawback, namely that weeds grow at the same time with the rice seeds and thus the weeds variety and number are higher compared to transplanting. Irregular spacing in DSR makes weeds control difficult; it causes greater stress to rice plants when compared to transplanting (Matloob et al., 2015; Dass et al., 2017).

Dass et al. (2017) reported that the potential loss of rice yield due to weeds in puddled transplanted rice was 50 to 60% and with DSR was 70 to 80%, while Ramzan (2003) reported the potential losses of rice yield due to weeds in dryland DSR, wetland DSR and transplanting were 74%, 53% and 48%, respectively. De Datta (1981) also found that the losses of rice yield due to weeds were 34%, 45% and 6% in transplanting, DSR in lowland and rainfed land and in upland rice, individually. The research results of Khan et al. (2017) showed that close spacing has a positive effect in suppressing density and reducing weed dry weight in rice plants in Bangladesh. In Pakistan, the results of study by Fahad et al. (2015) exposed that close spacing will affect the growth and number of seeds of *Galium aparine* and *Lepidium sativum* weeds that grow and affect loss of wheat yields. In Indonesia, Antralina et al. (2014) research showed that wide spacing of 35 cm x 35 cm increased the dry weight of weeds at 60 and 90 days after planting (DAP).

Sustainable agriculture is management of resources for agriculture to satisfy the human requirements whilst maintaining or enhancing the quality of environment and conserving natural resources (Sinha, 2009; Sharma et al., 2021). Three main goals of sustainable agriculture are environmental health, economic profitability and social equity (Verma et al., 2015). AMF in sustainable agriculture has an important role in environmental health. Indirectly AMF plays a role in improving soil structure, as well as increasing nutrient solubility and weathering of the parent material (biogeochemical). Meanwhile, AMF indirectly increases water absorption, improves nutrient uptake, reduces the use of chemical fertilizer, protects plants from root pathogens and toxic elements, increases production growth hormone and improves plant resistance against dryness and moisture extreme (Nurhayati, 2012; Johns, 2014; Yilmaz and Karik, 2022). In order to compete with weeds, mycorrhizal inoculation can be applied to increase the growth of rice plants grown in DSR method.

AMF is a group of obligate biotrophic soil fungi that cannot sustain growth and reproduction when separated from the host plant. AMF helps the absorption of nutrients and water to accelerate the growth rate, improve the quality and viability of plant seeds and increase plant growth and productivity (de Andrade et al., 2015; Wardhika et al., 2015; Pel et al., 2018). On average, the use of mycorrhizae in upland rice can increase crop yields by 25% (Syamsiyah et al., 2014), in sorghum, it increases the yield of sap by 29.88% (Anggarini et al., 2013) and in maize, giving mycorrhizae increases cob weight per meter square by 17.9% (Hartanti et al., 2014). Moreover, AMF plays a role in ecological sustainability, such as improving physical, chemical and biological properties (Hidayat et al., 2020).

The interaction between planting method and the use of mycorrhizae through a symbiotic mutualism between rice plants and mycorrhizae will affect the type/diversity, composition and dominance of the weeds. The planting method will influence the space and light penetration into the soil, while AMF will contribute to the structure, biology and chemistry of the soil, making it is specific for the growth of certain weeds (Syamsiyah et al., 2014; Indrawan et al., 2017; Hidayat et al., 2020). The control process occurs when the environmental factors for weeds to grow are limited. It is possible since the combination of the two treatments will affect the microclimate in which the plant grows.

In addition, the response of weeds to mycorrhizae varies widely: some can grow well with mycorrhizae, while the remaining are stunted due to the presence of mycorrhizae (Jordan et al., 2000; Saraswati and Sumarno, 2008; Rinaudo et al., 2010). Weeds in one area will experience changes based on the underlying environmental factors (Susanti et al., 2021).

In sustainable agriculture, ecological approaches such as competition between cultivated plants, competition between the diversity of weed species and plant spacing have been proven to reduce the use of herbicides dose up to 50% (Dass et al., 2017). Research by Adeux et al. (2019) showed that weed diversity affects the high and low yield of winter cereals through competition and dominance of a certain weed species. High rice density (i.e., 400 plants m^{-2}) can suppress *Cyperus iria* growth. Tiller number per plant was decreased by 73 to 88%, leaf number by 85 to 94%, leaf area by 85 to 98%, leaf biomass by 92 to 99% and inflorescence biomass by 96 to 99% (Awan et al., 2015). Research by Veiga et al. (2011) revealed that biomass of *Echinochloa crus-galli*, *Setaria viridis* and *Solanum nigrum* was significantly reduced by AMF *Glomus intraradices*, while none of the weeds significantly benefited from inoculation with this AMF. This study aims to determine the effect of planting method and mycorrhizal inoculation on the weed diversity, weed composition and dominance for the sustainability of agricultural production.

MATERIALS AND METHOD

The research was conducted in Sengon Village, Prambanan Sub-district, Klaten Regency, Central Java Province of Indonesia, in May to August 2020. The village is located at -7.77591° south latitude 110.51731° east longitude, with an altitude of 169 m above sea level and a temperature of 24 to 28°C. The equipment used includes agricultural equipment, stationery, drum seeder, *caplak jarwo* (plant distance meter) 2:1 (Figures 1 and 2), square frames 0.5 × 0.5 m^2 in size for weed sampling, lux meters, ovens and digital scales. The materials were rice variety of Inpari 42 GSR (green super rice), AMF obtained from the Faculty of Agriculture, Universitas Gadjah Mada (UGM) at a dose of 5 g kg^{-1} of seeds applied through coating rice seeds, fertilizer (250 kg of urea, 100 kg ha^{-1} SP-36 and KCl 50 kg ha^{-1}), insecticides (acephate at a dose of 1.5 g l^{-1}, chlorantraniliprole and thiamethoxam at a dose of 150 ml ha^{-1} and dimehypo 1.5 ml l^{-1}). Rice seed coating was performed by soaking the seeds in water for 24 hours and then draining and curing for 24 hours, after which the seeds were given mycorrhizae at a dose of 5 g kg^{-1} of seed. Furthermore, the seeds were allowed to stand for 15 minutes and then sown in the nursery.

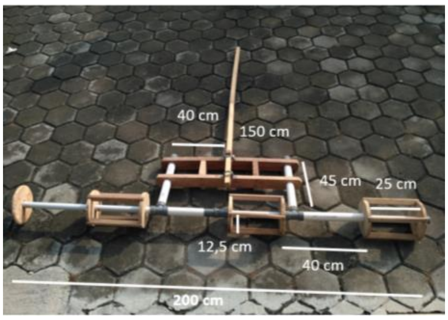

Figure 1. *Caplak jarwo* 2:1
(Pustika et al., 2015)

Figure 2. Drum seeder
(Pustika et al., 2015)

This research used a split-plot design with three replications. The first factor was planting methods, including drum seeder, on row table and transplanting as controls. The second factor was mycorrhizal inoculation, namely with mycorrhizal inoculation and without mycorrhizal inoculation. There were six combinations of the treatment, comprising mycorrhizal inoculation on row, mycorrhizal inoculation drum seeder, mycorrhizal inoculation transplanting, without mycorrhizae transplanting, without mycorrhizae on row and without mycorrhizae drum seeder. The irrigation system was intermittent. The observed variables were light penetration, weed population, weed composition, weed biomass, summed dominance ratio and community coefficient.

Land preparation was completed by cultivating the land perfectly using a tractor. Manure from cattle was given at the same time as tillage at a dose of 2 tons ha^{-1}. The beds were made with a size 7 m x 5 m with a bed height of 10 cm and the width between beds of 20 cm.

Light penetration is the amount of light reaching the soil surface after passing through the plant (rice) canopy which is not reflected back and can be utilized by life under the plant canopy. Light penetration (%) is obtained by measuring light intensity at the top and bottom of the plant canopy using a HS1010 light meter. In this study, light penetration to the soil surface was calculated using a formula in Equations 1 and 2 (Palijama et al., 2012; Onarely et al., 2016).

$$\text{Li} = \frac{\text{(A-B)}}{\text{A}} \times 100\% \quad (1)$$

$$\text{LP} = 100\% - \text{Li} \quad (2)$$

Where; Li = light interception (%); A = light intensity above the plant canopy (lux); B = light intensity under the plant canopy (lux).

Weed samplings were taken three times: before seeding (pre sowing), 24 DAS (days after sowing) and 39 DAS. In direct seeded rice, the critical period of weed competition has been reported to be from 15 to 45 days after seeding (Kumar and Ladha, 2011). The difference between sampling date in 29 DAS and 34 DAS was that in DSR, the canopy of rice plants in 39 DAS had been fully formed and began to close the space between plants. Weed sampling was carried out using quadratic method in the form of a square of 0.5 m x 0.5 m in size with three samplings per plot (Zarwazi et al., 2016; Rosmanah and Alfayanti, 2017; Putra et al., 2018). Weeds in the sample box were taken and identified descriptively by comparing with the weeds that had been separated by type (i.e broadleaf, grass and sedges) and reference (Tjitrosoepomo et al., 1987; Caton et al., 2010; Naidu, 2012). Weed biomass was obtained by weighing weed samples that had been heated in an oven at 80°C until a constant weight obtained. Summed dominance ratio describes the relationship of domination between one weed to other weeds. Weed summed dominance ratio was calculated using the following formula in Equations 3, 4, 5 and 6 (Mangoensoekarjo and Soejono, 2015; Susanti et al., 2021; Susilawati et al., 2021).

$$\text{SDR} = \frac{\text{RDs + RF + RD}}{3} \times 100\% \quad (3)$$

$$\text{RDs} = \frac{\text{density of one species}}{\text{density of all species}} \times 100\% \quad (4)$$

$$\text{RF} = \frac{\text{frequency of one species}}{\text{frequency of all species}} \times 100\% \quad (5)$$

$$\text{RD} = \frac{\text{dominance of one species}}{\text{dominance of all species}} \times 100\% \quad (6)$$

Where; SDR = summed dominance ratio; RDs = relative density; RF = relative frequency; RD = relative dominance

Community coefficient was to determine the diversity of weed communities between locations based on Mangoensoekarjo and Soejono (2015) (Equation 7).

$$\text{C} = \frac{(2\times\text{w})}{(\text{a+b})} \times 100\% \quad (7)$$

Where; C = community coefficient; a + b = summed dominance ratio of all types of weeds at locations a and b; w = the lower summed dominance ratio of each pair of weed types from the two locations.

Analysis of variance (ANOVA) based on a split plot design using SAS 9.4 (SAS Institute) 2002 to 2012 at α 5% error was used to determine the effect of treatments. Furthermore, on the results of variance, a further test was carried out with the least significant difference (LSD).

RESULTS AND DISCUSSION

Light penetration to the soil surface

There was no interaction between planting method and mycorrhizal inoculation on light transmitted by the rice plants canopy in 24 DAS and 39 DAS. Planting method significantly affected the percentage of light transmitted by the plant canopy to the soil surface. Less light was transmitted in DSR than in the transplanting method. Table 1 presents that the light penetration percentage between plants grown in drum seeder and on row had no difference. The same trend also occurred in the inoculated and those were not inoculated plants with mycorrhizae. Mycorrhizal inoculation gave no effect to the amount of light transmitted by the plant. According to Jabran and Chauhan

(2015), light is an important factor for weed seed germination and weed growth. The technique of manipulating sunlight by using black plastic sheet one week before sowing raised the soil temperature up to 50°C and suppressed the growth of grass weeds (64%) and broadleaf weeds (51%).

Table 1. Light penetration to soil surface in different planting methods and mycorrhizae applications

Treatment	Light penetration (%)	
	24 DAS	39 DAS
Planting		
OR	65.78[b]	45.75[b]
DS	73.37[b]	49.94[b]
TP	87.99[a]	83.63[a]
Mycorrhiza		
MI	74.26[p]	54.86[p]
WM	77.16[p]	64.68[p]
CV (%)	13.03	20.80
Mean	75.71	59.77
Interaction	-	-

Note: OR = on row; DS = drum seeder; TP = transplanting; MI = with mycorrhizal inoculation; WM = without mycorrhizal inoculation; LP = light penetration. The number followed by the same letter in the same column in each treatment showed that there was no significant difference based on the LSD test. Sign - indicated that there was no interaction between planting method and mycorrhizal inoculation

The difference in light penetration was due to tighter spacing in on row when compared to transplanting. In drum seeder, seeds were sowed through holes in a pipe so the plant population per unit area was more than transplanting. Different planting methods that regulated how to grow seeds/seedlings have caused differences in number of seeds, spacing between plants and plant densities; and therefore, the amount of light penetrated the soil surface was also varying. The research of Putra et al. (2018) has concluded that the proportion of plants has a significant effect on the percentage of direct light to the soil surface. The proportion of upland rice and soybean plants 0:100 can withstand direct light to the soil surface well then followed by the proportion 20:80, 40:60 and 60:40. Gao et al. (2010) research have shown that plant canopy architecture and row arrangement are the determining factors for the passage of light to the ground.

Mycorrhizal inoculation did not cause differences in the light penetrated to the soil surface. It is suspected that the existence of indigenous mycorrhizae infecting both rice roots that were not treated and treated with mycorrhizal inoculation caused no difference in the light penetration through plants in both treatments. Mycorrhizae influenced light intensity by increasing the nutrient uptake to improve plant growth such as the formation of plant canopy, but in an environmental condition rich of nutrients, plants responded slowly to the presence of mycorrhizae. Research by Halim et al. (2016) revealed that application of mycorrhizae on Ultisol soils in the Abenggi area of South Konawe Regency, Southeast Sulawesi Province, which had low/marginal fertility rates, could increase plant height, stem diameter, stover weight and maize crops production to 2.86 ton ha^{-1}.

Table 2 presents that there was no interaction between planting method and mycorrhizal inoculation on the number of weed populations on 24 DAS and 39 DAS. Planting method affected the number of weed population in 24 DAS, but not in 39 DAS. In 24 DAS, the most common weed population was obtained in on row, followed by drum seeder and transplanting, while in 39 DAS, the highest weed population was obtained in transplanting, followed by on row and drum seeder.

The number of growing weed populations depended on the weed seeds and rhizome that could germinate in the tillage layer after receiving light and water. *Alternanthera sessilis* (L.) R. Br. ex DC. (19.81%), *Marsilea crenata* C. Presl (18.13%) and *Leptochloa chinensis* (L.) Nees (17.52%) were dominant in DSR and transplanting. In DSR 24 DAS, weed population was more than transplanting. In DSR, weed seeds and rhizome from the seed bank during tillage germinated and grew together with rice seeds. In these conditions, weeds can germinate and grow rapidly because the plant canopy has not been formed; and thus, there were no competitors or obstacles in obtaining growth factors. Wet rice field condition and the absence of standing water in the early growth made weeds in DSR more abundance in than in transplanting. In transplanting, weed seeds and rhizome or stolon germinated when the rice plant grew and had a canopy, so weeds received competition in getting water and growing space, causing weed population to be not as much as in DSR.

Table 2. Weed population on 24 DAS and 39 DAS per 0.25 m^2

Treatment	Weed population (species)	
	24 DAS	39 DAS
Planting		
OR	79.81[a]	25.50[a]
DS	69.08[a]	25.19[a]
TP	37.67[b]	27.11[a]
Mycorrhiza		
MI	58.02[p]	28.04[p]
WM	66.35[p]	23.83[p]
CV (%)	21.02	36.80
Mean	62.18	25.93
Interaction	-	-

Note: OR = on row; DS = drum seeder; TP = transplanting; MI = with mycorrhizal inoculation; WM = without mycorrhizal inoculation. The number followed by the same letter in the same column shows that there is no significant difference based on the LSD test. Sign - indicates that there is no interaction between planting method and mycorrhizal inoculation

The formation of a rice plant canopy was an important limiting factor in weed population increase, because rice plants canopy blocked light and thus inhibited the germination of weed seeds. In 39 DAS, the plant canopy was perfectly formed and blocked light penetration to soil surface. Reduced light penetrated to soil surface would inhibit weed seed germination that influence weed population (Christina et al., 2021). Research by Singh et al. (2017) showed shades on rice PR 114 and PR 115 on 56 DAS and 70 DAS in year 2012 and 70 DAS year 2013 had significantly reduced the germination of *Echinochloa crus-galli*. The effect of shades on mature weeds due to the obstruction of light received by the weeds would inhibit the process of seed formation and the formation of new vegetative reproduction tools. Providing 50% shade on *Bidens pilosa*, *Paspalum conjugatum* and *Cuphe balsamona* weeds reduced the number of flowers by 25.50%, 2.27% and 7.73% and the number of seeds by 37.81%, 3.24%, 15.78% (Mahfudz, 2006).

Figure 3 demonstrates the regression between the light penetration 24 DAS and population. There was a tendency for smaller weed populations as light penetrated from the plants to increase. In early growth stage, light was needed for weed seeds to stimulate the germination process; germinated seeds still had food reserves to grow; and therefore, the light needed during the germination process was not much. Extreme light percentage would cause weed seeds and rhizome or stolon on the dry soil surface to die or inhibit the germination.

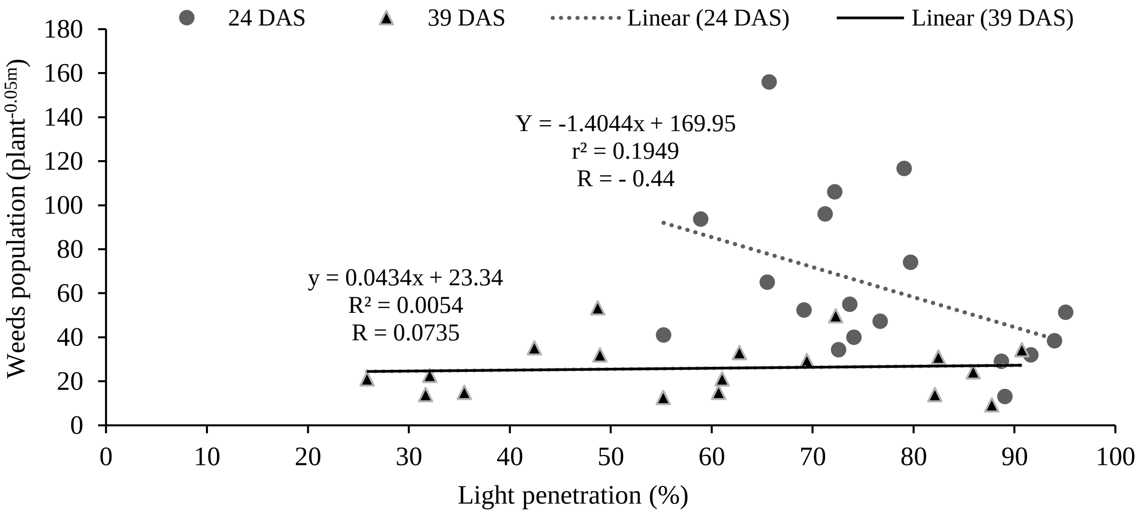

Figure 3. Light penetration regression and weeds population

In 39 DAS, the horizontal regression pattern shows that light penetration did not affect the weed population. The weed population development in 39 DAS was influenced by weed populations that could germinate and grew in 24 DAS. In 39 DAS, rice plant started to form a perfect canopy and then blocked the light reaching the soil surface, weed seeds that still received enough light would germinate, while weed seeds that did not receive enough light would remain dormant or die. The same trend also applied to weeds that had germinated and grown. In the presence of light, weeds could grow and carry out photosynthesis while weeds that did not receive enough light would die or have stunted growth. In transplanting, light penetrated was more than DSR; and thus, more weeds germinated, grew and developed quickly.

Table 3 shows that there was no interaction between planting method and mycorrhizal inoculation on broadleaf weeds, grasses and sedges in 24 DAS and 39 DAS. The mycorrhizae application did not affect the composition diversity amount of broadleaf weeds, grasses and sedges in 24 DAS and 39 DAS. In 24 DAS, planting method did not influence broadleaf weeds and sedges but affected grasses. There were more weeds in on row than drum seeder and transplanting.

Table 3. Weeds composition in 24 DAS and 39 DAS per 0.25 m^2

Treatment	Weeds composition (species) 24 DAS			Weeds composition (species) 39 DAS		
	G	S	G	S	G	S
Planting						
OR	3.17^{a}	1.59^{a}	1.33^{a}	2.89^{a}	1.26^{a}	0.93^{a}
DS	2.45^{a}	1.42^{ab}	1.39^{a}	3.61^{a}	1.21^{a}	0.84^{a}
TP	2.56^{a}	1.27^{b}	0.61^{a}	2.78^{a}	1.36^{a}	0.78^{a}
Mycorrhiza						
MI	2.89^{p}	1.37^{p}	1.18^{p}	2.96^{p}	1.25^{p}	0.81^{p}
WM	2.56^{p}	1.49^{p}	1.04^{p}	3.22^{p}	1.31^{p}	0.89^{p}
CV	22.29	16.13	23.50	19.23	19.56	30.25
Mean	2.72	1.43	1.11	3.09	1.28	0.85
Interaction	-	-	-	-	-	-

Note: OR = on row; DS = drum seeder; TP = transplanting; MI = with mycorrhizal inoculation; WM = without mycorrhizal inoculation; BL = broadleaf; G = grasses; S = sedges. The number followed by the same letter in the same column shows that there is no significant difference based on the LSD test. Sign - indicates that there is no interaction between planting method and mycorrhizal inoculation

In 24 DAS, weed seeds grew together with rice seeds. At the early growth stage, weed seeds on the soil surface and in the tillage germinated after getting enough water and light. When rice plant canopy was formed, it would block some of the light reaching the weeds. In this condition, shade-tolerant weeds would continue to grow, while weeds that intolerant to shade would die or stunt. Most of the broadleaf weeds were shade-tolerant so they still can grow and develop well in limited light.

Sedges found, namely *Fimbristylis miliacea* (L.) Vahl (globe fringe-rush) and *Cyperus iria* (L.) (rice flat sedge) have a means of reproduction in the form of seeds. When the seeds get enough light and water, they still can germinate. The light needed for weed seeds to germinate is not much because light is only a stimulus. Weed seeds need light to stimulate phytochromes, photomorphogenesis control pigments that are active when exposed to light and promote germination (Putra et al., 2018).

Grasses have vegetative reproduction tools in the form of a rhizome/stolon. In the tillage process, this reproduction tool undergoes repeated fragmentation and is lifted up to the soil tillage layer. In DSR, when rice plant canopy was formed, it could shade the fragmented rhizomes and stolon and thus avoided them from drought. While in transplanting, rice seeds were transplanted in 14 DAS, so the land that had been cultivated and ready for planting was open to direct sunlight, which gave rise to grasses rhizomes and stolons on the soil surface as well as dry and dead tillage layers. In addition, most grasses in this study were intolerant to shades or categorized as C4; and consequently, when rice plant canopy was formed, it would cause weed growth to be stunted or died. Pre-planting weed control with soil solarization is more effective, because propagules weeds (seeds, tubers, stolons and rhizomes) in the soil were killed due to high temperatures. High temperatures would resulted in propagules to denature protein. Soil solarization could control weed propagules that were still capable of germinating. Weed sprouts died because of high soil temperature (Paiman et al., 2015; Abouziena and Haggag, 2016).

Table 3 shows planting method did not have a significant effect on the composition of broadleaf weeds, grasses and sedges on 39 DAS. There was no difference in the composition of broadleaf weeds, grasses and sedges in DSR and transplanting. Plant aging caused a decrease in light intensity, which was penetrated through plant canopy and this would cause changes in weed composition. In 39 DAS, planting method no longer gave different effects in grasses weeds composition; and therefore, the weed composition of broadleaf weeds, grasses and sedges was insignificantly different. The reduction of light intensity reaching soil surface would affect the number and quality of weed seeds germinated; weed seeds that did not receive light would be dormant and even if the seeds germinated, they could die. Meanwhile, the vegetative reproduction tools in the form of rhizomes and stolons that had not received light did not grow and thus reducing the number of population of broadleaf weeds, grasses and sedges. Research by Fahad et al. (2015) uncovered that lesser light reached the soil surface due to shades of plant canopy in 60 DAS, resulted in stunted germination and growth of *G. aparin* and *L. sativum* weeds. When weeds germinated after the plants had grown, the seeds would receive higher competition from cultivated plants, including nutrients and water (Singh et al., 2017).

Weeds biomass

Table 4 shows there is no interaction between planting method and mycorrhizal inoculation on weed biomass in 24 DAS and 39 DAS. Planting method and mycorrhizal inoculation had no effect on weeds biomass in 24 DAS and 39 DAS.

Biomass was the result of photosynthesis involving light and utilizing growth factors in its environment. In DSR 24 DAS, weed seeds grew together with rice plant seeds so weeds grew rapidly by utilizing abundant light and growth factors. When rice plants canopy began to form, light received by weeds decreased, causing the photosynthetic process of weeds disturbed and resulted in agitated biomass formation.

Table 4. Weeds biomass (dry weight) in 24 DAS and 39 DAS in different planting methods and mycorrhizal inoculation

Treatment	Weeds biomass (g)	
	24 DAS	39 DAS
Planting		
OR	2.41[a]	1.44[a]
DS	2.45[a]	1.69[a]
TP	2.01[a]	1.72[a]
Mycorrhiza		
MI	2.26[a]	1.67[a]
WM	2.32[a]	1.56[a]
CV (%)	22.18	25.46
Mean	2.29	1.62
Interaction	-	-

Note: OR = on row; DS = drum seeder; TP = transplanting; MI = with mycorrhizal inoculation; WM = without mycorrhizal inoculation. The number followed by the same letter in the same column shows that there is no significant difference based on the LSD test. Sign - indicates that there is no interaction between planting method and mycorrhizal inoculation

In 39 DAS, weed biomass responded similarly to all planting methods. Shades of rice plant canopy was an important factor in the weed biomass formation because plant canopy affected light penetration received by weeds. In 39 DAS, rice plant canopy was formed completely so the light percentage reaching the weeds was reduced significantly. Minimum light caused weeds to grow abnormally; they elongated/etiolated rapidly in search of light. In finite light conditions, weed's auxin was active and produced in large amounts that stimulated cell elongation. Etiolated weeds could not carry out a perfect photosynthesis, disturbing their biomass formation. Besides, the photosynthesis process of C4 weeds intolerant to shade would be inhibited or they even died. Research by Susanto and Sundari (2016) showed that 50% shades caused a decrease in soybeans weight by more than 50%. Limited space for growth and supply of solar energy caused a decrease in the ability of weeds to produce dry matter in the photosynthesis process consequently caused stunted weed growth (Putra et al., 2018).

Mycorrhizal inoculation did not result in an increase of weed biomass in all planting methods. Mycorrhizal inoculation did not affect light penetration through the rice plant canopy, received by weeds in all planting methods; and hence it did not affect biomass formation.

Figure 4 presents that light penetration regression analysis of weed biomass in 24 DAS shows a negative trend, meaning that the increasing percentage of light penetrated to the soil surface decreases weed biomass. The higher the percentage of light reaching the soil surface affected the amounts of weeds germinated or growth. This was in accordance with the correlation between light penetration and weed populations in 24 DAS; the more weeds germinated and grew. This condition affected the amount of weed biomass. The light penetration horizontal regression pattern of weed biomass in 39 DAS shows that the increase in light penetration did not always increase weed biomass. In 39 DAS, rice plant canopy was perfectly formed so the percentage of light penetration was not as abundant as that in 24 DAS. In this condition, only tolerant weeds could grow and carry out the photosynthetic process to form biomass. Tolerant broadleaf weed was capable of dominating when there was a reduction in sunlight because it was still able to carry out photosynthesis (Putra et al., 2018).

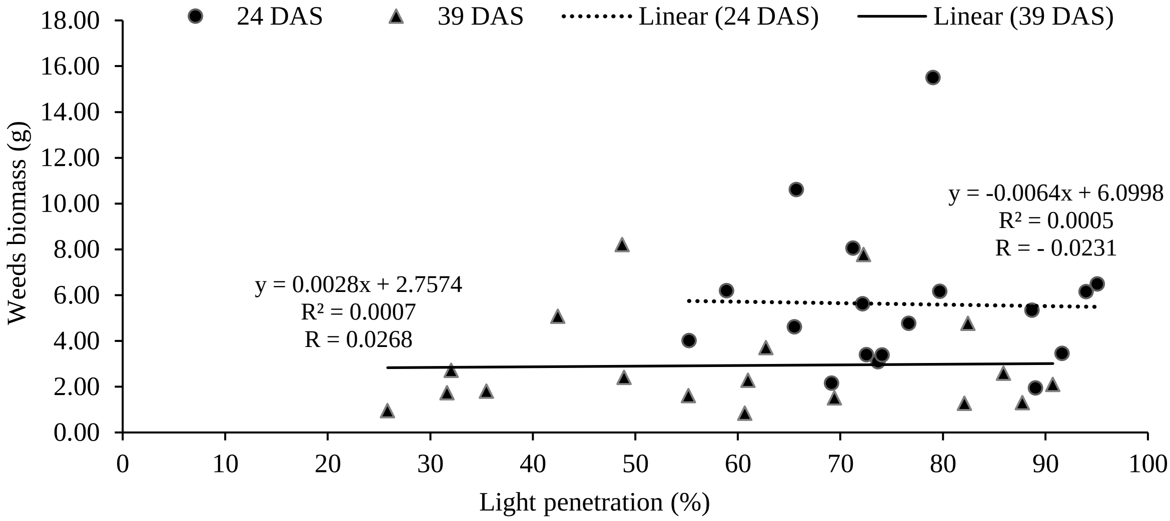

Figure 4. Light penetration and weeds dry biomass regression

Summed dominance ratio

Weed vegetation analysis yielded 34 species of weeds, which were divided into 13 families, consisting of 23 species of broadleaf weeds (67.65%), nine species of grasses (26.47%) and two species of sedges (5.88%). According to the life cycle, weeds were divided into 19 perennial weeds and 15 annual weeds. The 34 species were 17 species in pre-sowing, 11 species of weeds in mycorrhizal inoculation transplanting, 15 species of weeds in mycorrhizal inoculation drum seeder, 13 species of weeds in mycorrhizal inoculation on row, 15 species of weeds in without mycorrhizae transplanting, 16 species of weeds in without mycorrhizae drum seeder and 12 species of weeds in without mycorrhizae on row. There was more species of weed in pre-sowing than those having grown. For three months before planted, the land was a piece of fallow paddy field, a rice field with an open condition allowed various species of weeds to grow by taking benefits of the existing resources. The competition occurred at that time was between weed species until a stable community condition achieved. When plants started to grow, different planting methods and mycorrhizal inoculations affected the degree of competition between weeds and rice plants. In DSR, weeds grew together with rice plants; and therefore, the competition between both started from the early growth stage. While in transplanting, weeds started to grow when the rice plants had fully grown so weeds experienced high competition. The number of weed species depended on the ability of weeds to compete with other weeds and rice plants in taking nutrients, water and growing space.

Table 5. Summed dominance ratio (%) of 10 dominant weeds species

Weeds species	SDR							
	Pre-sowing	MITP	MIDS	MIOR	WMTP	WMDS	WMOR	Average
Alternanthera sessilis (L.) R. Br. ex DC	31.09	16.50	12.31	22.20	16.57	15.15	24.87	19.81
Marsilea crenata C. Presl	0.77	23.71	22.42	21.50	28.49	17.86	12.17	18.13
Leptochloa chinensis (L.) Nees	0.00	21.20	20.31	17.29	18.39	26.39	19.09	17.52
Cynodon dactylon (L.) Pers.	10.33	8.10	4.77	8.20	14.61	5.65	6.45	8.30
Fimbristylis miliacea (L.) Vahl	0.00	4.85	7.75	7.62	1.07	6.87	9.81	5.42
Lindernia procumbens (Krock.) Philcox	0.00	1.54	6.26	5.71	4.95	9.25	7.04	4.97
Echinochloa colana (L.) Link	10.03	7.72	7.00	1.32	3.51	1.80	2.68	4.87
Cyperus iria L.	0.00	4.49	4.16	5.28	3.70	5.36	4.59	3.94
Monochoria vaginalis (Burm.f.) Presl	0.00	5.02	6.50	1.83	6.25	2.87	3.40	3.69
Echinochloa crus-galli (L.) Beauv.	0.00	3.83	2.75	3.12	1.52	8.19	6.27	3.67

Notes: MITP = mycorrhizal inoculation transplanting; MIDS = mycorrhizal inoculation drum seeder; MIOR = mycorrhizal inoculation on row; WMTP = without mycorrhizae transplanting; WMDS = without mycorrhiza drum seeder; WMOR = without mycorrhizal on row

Table 5 presents the summed dominance ratio of 10 dominant weeds during pre-sowing and when the plants had grown. According to the calculation of the summed dominance ratio, the three dominant weeds were *M. crenata* C. Presl. (Water clover), *A. sessilis* (L.) R. Br. ex DC. (sessile joyweed), *L. chinensis* (L.) Nees (Chinese sprangletop).

In general, broadleaf weeds dominated more in pre-planting and when the plants had grown, than grasses and sedges. In accordance with weed vegetation analysis, many of the broadleaf weeds found were annual weeds reproducing with seeds. Seeds produced by broadleaf weeds were uncountable, light and easily spread on the soil surface and/or on the tillage layer. The broadleaf weeds dominance assumed came from pre-planted weed seeds and weed seed banks of the previous planting period that were lifted up during tillage and germinated quickly receiving light and water. The dominance of broadleaf weeds in various planting methods and weeding regime was possible due to the weed seed banks. Most broadleaf weeds were originally dormant and grew due to disturbed environmental conditions such as tillage activities (Khan et al., 2017; Maqsood et al., 2018; Putra et al., 2018; Kusmiyati et al., 2020).

Grasses are weeds that reproduce generatively with seeds and vegetatively with rhizomes and stolons. The number of seeds produced by grass-type weeds was inferior; and hence, the weeds produced using seeds were not as abundant as broadleaf weeds. Meanwhile, when the vegetative reproduction tools for grasses were repeatedly cut and lifted up during soil processing or tillage, the weeds could die because of drying up. The same thing happened to sedges, which this reproduced using seeds and tubers. There were not many seeds produced and the tubers, when cut during repeated soil cultivation, would dry out after being exposed to sunlight. Grasses weeds and sedges are C4 plants that have vegetative propagation tools that can be controlled at tillage so that germination can be suppressed (Kolberg et al., 2018; Putra et al., 2018; Rojas and Rodríguez, 2019).

Community coefficient

Community coefficient is a value that shows the similarity of weed vegetation communities from two different areas or communities (Prasetyo and Zaman, 2016; Umiyati et al., 2019). Table 6 shows the community coefficient of weeds in two different locations compared, namely without mycorrhizae transplanting:without mycorrhizae drum seeder and without mycorrhizae transplanting:without mycorrhizae on row with a value of less than 75%, compared to the treatment in another location with a value of more than 75%. The coefficient with less than 75% means the state of weed vegetation between the two locations was different or heterogeneous (not uniform). It showed a change in weed composition occurring in 24 DAS to 39 DAS. In 24 DAS, there were more grasses in DSR than transplanting because weeds grew together with the seeds of cultivated plants, thus, they can grow freely due to no competitors and the growth factors needed were abundant. Meanwhile, in 39 DAS, light penetration in DSR was fewer than transplanting so grasses in transplanting could still germinate and grow more than DSR.

Table 6. Weeds community coefficient in different planting methods and mycorrhizae applications

Treatment	MITP	MIDS	MIOR	WMTP	WMDS	WMOR
MITP		83.63	82.02	87.77	85.77	76.52
MIDS			82.01	78.30	82.94	79.80
MIOR				78.27	84.23	83.71
WMTP					72.98	71.41
WMDS						81.38
WMOR						

Notes: MITP = mycorrhizal inoculation transplanting; MIDS = mycorrhizal inoculation drum seeder; MIOR = mycorrhizal inoculation on row; WMTP = without mycorrhizae transplanting; WMDS = without mycorrhiza drum seeder; WMOR = without mycorrhizal on row

A coefficient of more than 75% means the weed vegetation conditions between two locations were not different or homogeneous (uniform) (Mangoensoekarjo and Soejono, 2015; Kurniadie et al., 2016; Widaryanto, 2017). It shows that, in general, the growth, diversity and population of weeds in 24 DAS and 39 DAS were not affected by planting methods or mycorrhizal inoculation. The effectiveness of mycorrhizae in the field was influenced by environmental factors, such as the availability of nutrients in the soil. Even though the light was limited, nutrients sufficiency allowed weeds to grow and produce biomass. Biotic and abiotic factors at the rhizosphere, community and ecosystem such as light and nutrient may affect the effectiveness relation plants and mycorrhizae (Johnson et al., 1997Ronsheim, 2012; Panjaitan et al., 2018).

CONCLUSIONS

This study concluded that planting method and mycorrhizal inoculation have no effect on the diversity, composition and dominance of weeds in rice fields. The dominance of broadleaf weeds in various planting methods is possible due to the weed seed banks, which grow due to disturbed environmental conditions such as tillage activities. To prevent the weeds propagation, it is important to control weeds at the age of 14 to 39 DAS. On a small-scale, mechanical control is an alternative choice for effective and environmentally friendly weeds management.

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