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Weed Growth and Lowland Rice Production as Affected by Planting Patterns and Rice Varieties

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Abstract

Weeds are one of the most limiting factors in rice cultivation. This study aims to evaluate the effects of rice planting patterns on the prevalence of several weed species, *Cyperus iria, Echinochloa crus-galli, Fimbristylis miliacea, Leptochloa chinensis, Ludwigia octovalvis, and Spenoclea zeylanica*, and to discuss the implications on rice production systems. The research was conducted in IPB Sawah Baru experimental farm in Bogor, West Java, Indonesia, from December 2017 to April 2018. The experiment was arranged in a randomized block design with two factors, rice varieties and rice planting methods. The rice varieties, "IPB 3S" and "Ciherang", were assigned as the main plot, whereas planting methods, i.e. 25x25 tile, Legowo 2:1 (double rows), Legowo 4:1 (quadruple rows), as sub-plots. The results showed that in the "IPB 3S" plots *L. octovalvis* shoot dry weight decreased by 33.0%, the root dry weight of *L. chinensis* roots decreased by 22.6%, and the number of *S. zeylanica* weed leaves decreased by 28.4% compared to the plots planted with "Ciherang". With legowo 2:1 planting method the dry weights of *L. octovalvis* decreased by 21.5%, *L. octovalvis* by 1.7%, and *L. chinensis* by 4.4%, and the number of weeds *E. crus-galli* by 7.0 % compared to Tegel 25x25 method. *L. chinensis* seemed to be a dominant weed at both vegetative and generative stage of rice development.

Keywords: canopy coverage, weeds, planting methods, rice varieties

Introduction

Rice is one of the most important human food crops in the world; it is a staple food for more than 60% world population, including in Indonesia. Rice production in Indonesia reached close to 80 million tons milled dry grain (MPD) in 2016, or an increase of 5% compared to 2015 (Kementan, 2016). Rice production in Indonesia needs to increase to meet the increasing food demands. Efforts to increase rice production should focus on improving the cultivation technology, including evaluation of rice planting patterns.

Lowland rice is generally grown under rainfed, in which soil is puddled for transplanting or wet seeding. "Jajar legowo", or "legowo" planting system is a relatively new cropping model to grow rice in Indonesia. In legowo planting system rice seeds were sown alternately between two or more rows of rice, leaving one row vacant (BB Padi, 2013). The use of legowo planting pattern aims to increase air circulation and sunlight penetration to the crops (Balitbangtan 2013). Legowo planting method increased plant height, dry weight, number of productive tillers, and eventually the productivity of rice, by 6.47 tons dry grains per ha (Pratiwi 2016; Hatta 2012; Primilestari and Edi 2015; Anggraini et al., 2013). Another planting pattern is *tegel*, where rice crops are planted with a distance of 25 x 25 cm. Tegel is the most commonly adopted planting pattern by Indonesian rice growers.

Legowo planting method allowed more rice population (180,250 plants per ha) than tegel, (140 625 plants per ha), so the *Legowo* system can potentially produce higher grain yields (Ikhwani et al., 2013). The increase rice population can suppress weed growth through reducing light penetration to the soil surface (Wersal and Madsen, 2013).

Rice competition with weeds may disrupt and suppress the vegetative growth of rice (Guntoro et al., 2009), which may cause 50 to 60% yield loss (Saito et al., 2010; Dass et al., 2016). The decline in rice production is through competition with rice crops for resources, including light, nutrients, water and space (Khaliq et al., 2013; Galal and Shehata, 2015). This study aims to evaluate the effects of rice planting patterns on weed prevalence, and to discuss the implications on rice production systems.

Materials and Methods

Experimental Site

The field experiment was carried out in the Sawah Baru experimental farm of IPB, Dramaga, Bogor (106.736284, -6.561721), 250 m above sea level, from December 2017 to April 2018. Measurement of plant dry weight and weed dry weight was carried out in the Postharvest Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University.

Plant Materials

The materials used were seeds of two varieties of rice, "IPB 3S" (a new line) (NPT), and an improved rice variety "Ciherang" (INV), NPK fertilizer, urea, the seeds of broadleaf weeds *Ludwigia octovalvis* (Jacq.) Raven (LUDOC) and *Spenoclea zeylanica* Gaertn (SPDZE), grass *Echinochloa crus-galli* (ECHG) and *Leptochloa chinensis* (L.) Nees (LEFCH), *Cyperus iria* L (CYPIR), and *Fimbristylis miliacea* (L.) Vahl (FIMMI). The equipment used includes lux meters, a digital camera, 1 m x 1 m quadrants, balance sheets and an oven.

Methods

The light intensity was measured above and below the rice canopy at 11.00 am - 01.00 pm weekly starting from the 4th weeks using a lux meter. Points of measurement are shown in Figure 1.

The light intensity is determined by the following formula:

$$\mathrm{LI} = \frac{\mathrm{LT}}{\mathrm{LU}}\, x\, 100\%$$

where:
LI = light intensity
LT = light intensity above the rice canopy
LU = light intensity under the rice crops

Canopy Coverage and Growing Space of Rice

The canopy coverage and the growing space of rice plants were measured using digital images. The use of digital image analysis can also be used for an indirect plant canopy sampling (Stewart et al., 2007). Digital images were obtained using a Nikon Coolpix S3700 digital camera (Nikon Corp, Japan) with a resolution of 20.1 megapixels. The camera was mounted on an aluminum stand with a height of 160 cm which was marked by using a 100 m x 100 m quadrant. There were three quadrant sampling and two camera taking points for every quadrant so there were six points for each experimental plot. Images were saved by the camera automatically and sequentially in Joint Photographic Experts Group (JPEG) image format.

Image Analysis

The canopy coverage was obtained from images taken from above the rice crops. The edited image was matched with the quadrant area using the Paint 3D application, and the saved as the JPEG format. The edited images were processed using the software Image canopy v3.6. The image of the crops and the ground area were separated based on colors where the plants were green and the soil was red, followed by calculation of the percentage of plant canopy closure. The data was analyzed using the SAS 9.4.
The growing space was obtained from images taken from two positions, the side and the front position of the plant. The images were edited using the Image J application, where the plants and empty spaces between the plants are separated as above.

The growing space of rice plants was calculated using the De Wit (1960) formula with modification:

$$\mathrm{GS} = \frac{EQ}{EP}\, x\, 100\%$$

where:
GS = Growing space (%)
EQ = area of quadrant (cm)
EP = crop coverage (cm^{-2})

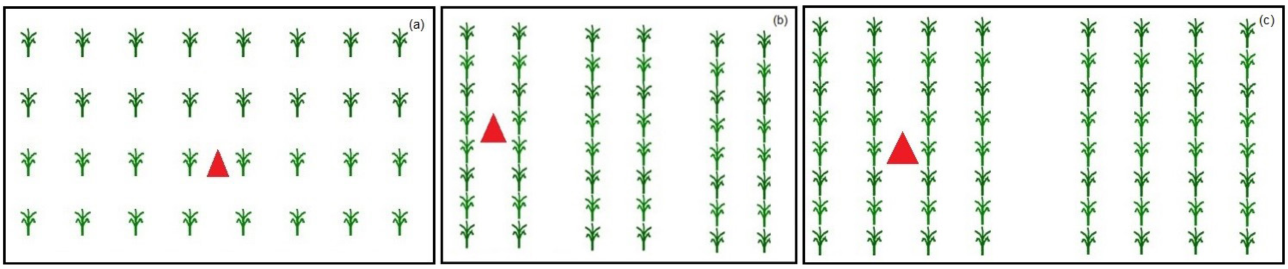

Figure 1. Triangle marker indicates points of measurement in 25x25 tile planting pattern (a), Legowo 2:1 (double rows) (b), Legowo 4:1 (quadruple rows) (c)

Plant Growth Measurement

Weed sampling was collected from an area of 1m x 1m using a quadrant at 28 and 49 day after planting (DAP). Identification and analysis of weed vegetation were carried out using the summed dominance ratio (SDR) method (Heddy, 2012). Weed dry weight was measured by after drying the shoots in an oven at 80^{0}C for 3 x 24 hours. Species that have an SDR above the average value are grouped as the dominant species. SDR was calculated using the following formula:

$$\text{Summed Dominance Ratio (SDR)} = \frac{KN+RDW+RF}{3} x\ 100\%$$

where
RD = Relative density, RDW= Relative dry weight, RF = Relative frequency

Growth and development of six weed species, *L. octovalvis*, *S. zeylanica*, *E. crus-galli*, *L. chinensis*, *C. iria*, *F. miliacea,* were examined. Measurements were conducted on weed shoot dry weight, root length, root wet weight, root dry weight, weed height, number of leaves, stem diameter, number of branches, and number of flowers per plant at eight weeks after rice planting. For every experimental plot, five individual plants from each weed species were collected for measurement.

Rice was harvested when the 90 to 95% of the grains has yellow color. The yields of rice consisted of dry weight of rice per plant, dry grain weight per plot, and dry milled grain weight per plot. Measurement was conducted on five sample plants per plot.

Experimental design

The experiment used a split plot in a randomized block design with two factors. The first factor (main plots) was the two rice cultivars varieties, “IPB 3S” and “Ciherang”. The second factor was the method of planting (sub-plots), 25x25 tile, Legowo 2:1 (double rows), Legowo 4:1 (quadruple rows) (Figure 1). Overall there were six treatments with four replications, so there were a total of 24 experimental units. Rice seedlings were transplanted to the field at 21 days after sowing. Weed seeds from the previous season of the same field (5 g of each weed species) were collected. The weed seeds were directly spread over the plots at three days after rice seedlings were transplanted. The land was flooded at 15 cm depth following rice transplanting until 15 day before harvest, except when fertilizer was applied where the land was kept in an aerobic environment for a week. NPK fertilizer was applied at the rate of 150 kg N and 350 kg NPK per hectare.

Results and Discussion

Weed Domination

The results of the analysis of weed vegetation when rice crops were 28 and 49 DAP showed that there were five dominant weed species in the experimental site, i.e. *C. iria* (CYPIR), *E. crus-galli* (ECHCG), *F. miliacea* (FIMMI), *L. chinensis* (LEFCH), *L. octovalvis* (LUDOC), and *S. zeylanica* (SPDZE). There was a shift in weed dominance at 28 and 49 DAP in “IPB 3S” and “Ciherang” plots. The shift in weed dominance also occurred in the planting pattern 25x25 tile, legowo 2:1 and 4:1 (Table 1). At 28 DAP the most dominant weed in the “IPB 3S” plots with legowo 2:1 planting pattern was *L. chinensis* (55.1%), followed by *S. zeylanica* (28.3%) with legowo 4:1. The most dominant weed in the “Ciherang” plots was *L. chinensis* (58.6%) with legowo 2:1 planting pattern, followed by *L. octovalvis* (23.4%) with legowo 2:1. At 49 DAP the most dominant weed in the 3B IPB plot was *L. chinensis* (54.3%) with legowo 4:1 planting pattern, followed by *S. zeylanica* (27.9%) with legowo 4:1. The most dominant weed in the “Ciherang” plot was *L. chinensis* (62.6%) with 25x25 tile planting pattern, followed by *S. zeylanica* (21.1%) with legowo spacing 2: 1 (Table 1).

The dominance of *L. chinensis* in the rice plots is possibly because this weed species has originally dominated the experimental site, so that there are many seeds already stored in the soil. At the time of tillage, the weed seeds that initially buried in the soil had possibly raised and germinated (Fitrian et al. 2013).

Light Intensity, Canopy Coverage, and Rice Growing Space

The light intensity that reached the soil surface decreased with increasing age of the rice crops due to canopy closure. The soil surface under “IPB 3S” received 38.3% less light penetration compared to that of “Ciherang”. With the legowo 2:1 and 4:1 planting pattern the light intensity decreased by 23.9 and 19.8%, respectively, compared to 25x25 tiles. *Legowo* 2:1 and 4:1 planting pattern resulted in the light intensity to be lower than 25x25 *tiles*. These results agreed with Bradley (2006) in that high crop density can decrease light penetration.

Coverage of the rice canopy differs with rice varieties, but similar amongst planting patterns (Table 2). “IPB 3S” has dense canopy and had about 13.3% more coverage than “Ciherang”. Similar results had been reported (Wahyuti et al., 2013) that new types of rice have a canopy that is more efficient in utilizing

Table 1. Summed dominance ratio (SDR) of different weed species in different planting patterns of rice at 28 and 49 days after planting (DAP)

Weed species/Rice variety	Summed dominance ratio (%) in					
	25x25 Tile		Legowo 2:1		Legowo 4:1	
	28 DAP	49 DAP	28 DAP	49 DAP	28 DAP	49 DAP
"IPB 3S"						
L. chinensis	51.8*	48.5*	55.1*	44.8*	48.8*	54.3*
S. zeylanica	27.6*	20.3*	25.2*	25.5*	28.3*	27.9*
L. octovalvis	20.6	18.6	19.7	18.3	22.9	17.7
F. miliacea	0	7.2	0	4.7	0	0
C. iria	0	5.4	0	6.6	0	0
"Ciherang"						
L. chinensis	57.6*	62.1*	58.6*	51.1*	54.0*	36.2*
S. zeylanica	21.6*	14.2	18	25.1*	20.1	21.8
L. octovalvis	20.8	23.7*	23.4*	18.3	23.0*	23.3*
F. miliacea	0	0	0	5.6	2.9	11.3
C. iria	0	0	0	0	0	7.5

Notes: DAP: days after planting; *: dominant weed species

sunlight. The shape of the plant canopy can limit the light that reaches the soil surface (Jha and Norsworthy 2009). Rice varieties and planting pattern significantly affected the rice growing area (Table 2). The "IPB 3S" plots had 17% more growing space compared to "Ciherang" plots. Legowo 2:1 increased the growing space for rice by 1.9%, whereas in legowo 4:1 it decreased by 2.6% compared to 25x25 tiles.

The rice dry weight varies with varieties and planting patterns (Table 2). The dry weight of "IPB 3S" was 8% higher than that of the "Ciherang". The legowo 2:1 spacing and legowo 4:1 caused a decrease in rice dry weight by 8.6 and 14.1%, respectively, compared to 25x25 tiles. Weed dry weight at 28 and 49 DAP was affected by rice varieties and spacing (Table 2). At 28 DAP "IPB 3S" suppressed weed dry weight by 19.6% compared to "Ciherang". At legowo 2:1 and 4:1 spacing weed dry weight decreased by 8.9 and 16.4% compared to 25x25 tiles respectively. The weed dry weight was 18% lower in the "IPB 3S" plots that that of "Ciherang" at 49 DAP. At legowo 2:1 and 4:1 spacing weeds dry weight decreased by 21.4 and 16.8%, respectively, compared to 25x25 tiles. The Decrease in weed dry weight with legowo planting pattern was caused by the higher rice population than

Table 2. Light intensity, canopy coverage, growing space, rice and weed dry weight under different planting patterns

Treatment	LI (%)		CC (%)	GS (%)	DWR (g)	DRW (g)	
	7 WAP	8 WAP				28 DAP	49 DAP
Rice varieties							
"IPB 3S"	28.0b	18.8b	64.8a	86.0a	208.1a	23.8b	38.2b
"Ciherang"	35.1a	26.0a	57.2b	73.6b	191.5b	29.6a	45.1a
Planting pattern							
25x25 tile	34.5a	25.4a	61.5	85.4a	216.1a	29.2a	47.7a
Legowo 2:1	31.0b	20.5b	60.8	87.0a	197.6ab	26.6b	37.5b
Legowo 4:1	29.1b	21.2b	60.7	83.2b	185.6b	24.4b	39.7b
Interaction	ns	ns	ns	ns	ns	ns	ns

Notes: values followed by the same letter within the same column are not significantly different according to DMRT at 5%; LI: light intensity; CC: canopy coverage; GS: growing space; DRDW: rice dry weight of rice; WDW: weed dry weight; WAP: week after planting; DAP: day after planting; ns: not significant

25x25 tiles. Similar results were reported in Mahajan et al. (2010), Olsen (2012), and Marin and Weiner (2014), where average decrease in weed dry weight due to modification of planting pattern was 48.6 to 89.0%.

Weed Growth

The height and number of weed leaves were influenced by rice varieties and spacing (Table 3). *L. chinensis* was the tallest in the "IPB 3S" plots, whereas in the "Ciherang" plots *S. zeylanica* and F*. miliacea* growth was significantly suppressed (Table 3). *L. octovalvis* weeds were shorter with legowo 2:1 spacing by 1.7%, while in legowo 4:1 is increased by 7.4% compared to 25x25 tiles. *S. zeylanica* weeds have increased at legowo 2:1 and 4:1 spacing of 14.6 and 15.9% compared to 25x25 tiles. *L. chinensis* weeds decreased at legowo 2:1 and 4:1 by 4.4 and 5.9% compared to 25x25 tiles.

The results showed that weeds from the grass group are generally taller than other weed groups. This is in accordance with the results of research by Chauhan et al. (2015) who reported that grass weeds were generally taller than broadleaf weeds.

Rice varieties and planting pattern significantly affected the weed growth, indicated by different leaf number of the weed species (Table 3). *L. octovalvis* in the 3B IPB plots is the most dominant weed in terms of leaf number compared to other weed species, whereas *S. zeylanica* had 28.4% less leaves compared to those grown with "Ciherang". The number of *L. octovalvis* leaves has increased in the planting distance of Legowo 2:1 by 8.9%, whereas in the Legowo 4:1 spacing it has decreased by 6.3% compared to 25x25 tiles. In this study, the number of weed leaves in plots with high rice population density did not decrease, which is different from the results of research by Awan et al. (2015) who reported that increasing rice population from 100 to 400 per meter had reduced the weed leaves by 68-84%.

Rice varieties did not significantly affect the root length of all weed species. Planting patterns, however, significantly affected the length of *L. octovalvis* weed roots (Table 4). *L. chinensis* in "Ciherang" plots had longer roots compared to other weed species. In terms of planting pattern, *L. octovalvis* roots in legowo 2:1 and 4:1 were 28.3 and 31.1% longer compared to those with 25x25 tiles.

Rice varieties significantly affected the dry weight of *E. crus-galli* and *L. chinensis* roots, whereas planting pattern affected *S. zeylanica* and *L. chinensis* 's

Table 3. The height and number of leaves of weeds as affected by rice varieties and planting pattern

Treatment	LUDOC	SPDZE	ECHCG	LEFCH	CYPIR	FIMMI
			Plant height (cm)			
Rice varieties						
"IPB 3S"	109.4	82.4	116.2	134.6	114.0	58.8
"Ciherang"	104.1	85.1	117.6	132.7	113.7	60.6
Planting patterns						
25x25 tile	104.6b	74.8b	119.3	138.4a	115.7	61.3
Legowo 2:1	102.8b	87.6a	113.5	132.3b	**111.8**	59.8
Legowo 4:1	112.9a	88.9a	118.0	130.2b	114.1	57.9
Interaction	ns	ns	ns	ns	ns	ns
			Number of weed leaves per plant			
Rice varieties						
"IPB 3S"	63	22b	29	24	9	16
"Ciherang"	60	31a	23	23	9	16
Planting patterns						
25x25 tile	61ab	19b	29	23	9	14
Legowo 2:1	67a	37a	26	24	8	16
Legowo 4:1	57b	31ab	23	21	8	17
Interaction	ns	ns	ns	ns	ns	ns

Notes: numbers followed by the same letter on the same column are not significantly different in the DMRT test level of 5%; LUDOC: *L. octovalvis*; SPDZE: *S. zeylanica*; ECHCG: *E. crus-galli*; LEFCH:*L. chinensis*; CYPI: *C. iria*; FIMMI: *F. milacea*; ns: not significant

Table 4. Weed root length and root dry weight as affected by rice varieties and planting pattern

Treatment	LUDOC	SPDZE	ECHCG	LEFCH	CYPIR	FIMMI
			Root length (cm)			
Rice varieties						
“IPB 3S”	18.8	7.8	21.7	21.3	9.0	6.5
“Ciherang”	18.0	9.0	19.2	22.4	9.3	6.5
Planting patterns						
25x25 tile	14.2b	7.2	20.9	21.9	9.4	5.9
Legowo 2:1	19.8a	9.7	19.8	23.6	8.9	6.4
Legowo 4:1	20.6a	8.2	20.6	20.0	9.1	7.3
Interaction	ns	ns	ns	ns	ns	ns
			Root dry weight (g)			
Rice varieties						
“IPB 3S”	0.51	0.39	1.84a	0.89b	0.1	0.1
“Ciherang”	0.38	0.4	1.00b	1.16a	0.2	0.1
Planting patterns						
25x25 tile	0.33b	0.28b	1.54	0.96b	0.14	0.04
Legowo 2:1	0.59a	0.56a	1.45	1.30a	0.13	0.05
Legowo 4:1	0.41ab	0.35b	1.27	0.83b	0.15	0.06
Interaction	ns	ns	ns	ns	ns	ns

Notes: values followed by the same letters within the same column are not significantly different according to the DMRT test at 5%; LUDOC: *L. octovalvis*; SPDZE: *S. zeylanica*; ECHCG: *E. crus-galli*; LEFCH: *L. chinensis*; CYPIR: *C. iria*; FIMMI: *F. milacea*; ns: not significant

(Table 4). The root dry weight of *E. crus-galli* in “IPB 3S” plots was 45.6% more compared to those of “Ciherang”. Treatment of legowo 2:1 and 4:1 spacing caused an increase in dry weight of *L. octovalvis* weed roots of 44.1 and 19.5% respectively compared to 25x25 tiles, S. *zeylanica* weeds experienced an increase in legowo spacing of 2:1 and 4:1 each -one of 50.0 and 20.0% compared to 25x25 tiles. The root dry weight of L. chinensis with legowo 2:1 spacing increased by 35%, while at legowo 4:1 spacing it decreased by 16%, compared to 25x25 tiles.

Weed Development

Rice varieties did not significantly affect stem diameter and number of *L. octovalvis* and *S. zeylanica* weed branches. Plant spacing significantly affected stem diameter and number of *S. zeylanica* weed branches (Table 5). *S. zeylanica* weeds have a larger stem diameter compared to *L. octovalvis* weeds, but the number of *L. octovalvis* weed branches is greater than *S. zeylanica* weeds. The weed stem diameter of *S. zeylanica* increased by 29.2 and 21.2 % in legowo 2:1 and 4:1 spacing compared to those with 25x25 tiles. The number of *S. zeylanica* weed branches increased by 43.5 and 17.2 % with legowo 2:1 and 4:1 spacing compared to those with 25x25 tiles. This result is different from the study of Chauhan et al. (2011b) which shows that denser rice population decreased the number of weed branches.

Rice varieties did not significantly affect the number of weed tillers, whereas planting patterns had significant effects particularly on *E. crus-galli* and *L. chinensis* (Table 6). *E. crus-galli* weeds in “IPB 3S” plots had a higher number of tillers compared to the other weed species. Tiller number in grass weeds was the smallest in legowo 4:1 planting pattern. The number of tillers of *E. crus-galli* decreased in legowo 4:1 spacing by 32.4% compared to 25x25 tiles. The decrease in the number of tillers was likely due to the increasing rice population. This result is different from the research by Awan et al. (2015) that high crop population suppressed the number of weed tillers by 55-79%.

Rice varieties significantly affected the number of *S. zeylanica* flowers, whereas planting patterns significantly affected the number of *L. octovalvis* and *S. zeylanica* (Table 7). In the “Ciherang” plots the number of *L. octovalvis* flowers is higher when compared to other types of weeds in the same plot.

The number of *S. zeylanica* flowers in the “IPB

Table 5. Stem diameter and number of weed branches as affected by rice varieties and planting patterns

Treatment	Stem diameter (mm)		Number of branches	
	LUDOC	SPDZE	LUDOC	SPDZE
Rice varieties				
"IPB 3S"	5.1	7.7	13	6
"Ciherang"	4.7	7.8	14	7
Planting pattern				
25x25 tile	4.1	6.3b	12	5b
Legowo 2:1	5.3	8.9a	14	8a
Legowo 4:1	5.3	8.0a	15	6b
Interaction	ns	ns	ns	ns

Notes: values followed by the same letters within the same column were not significantly different according to DMRT at 5%; LUDOC: *L. octovalvis*; SPDZE: *S. zeylanica*; ns: not significant.

Tabel 6. The number of weed tillers as affected by rice varieties and planting patterns

Treatment	Number of tillers			
	ECHCG	LEFCH	CYPIR	FIMMI
Rice varieties				
"IPB 3S"	7	5	2	4
"Ciherang"	6	5	3	4
Planting patterns				
25x25 tile	7a	5a	3	4
Legowo 2:1	7a	5a	2	4
Legowo 4:1	5b	4b	2	4
Interaction	ns	ns	ns	ns

Notes: values followed by the same letters within the same column are not significantly different according to DMRT test at 5%; ECHCG: *E. crus-galli*; LEFCH: *L. chinensis*; CYPIR: *C. iria*; FIMMI: *F. milacea*; ns: not significant

3S" plots was 20% less compared to those in the "Ciherang" plots. *L. octovalvis* had 23.2% more flowers with legowo 2:1 and 19.2% with legowo 4:1 spacing compared to 25x25 tiles. In contrast, *S. zeylanica* had 43.7% and 22.4% more flowers than those in 25x25 tiles.

Combination of rice variety and planting pattern can cause a decrease in light intensity and growing space between rows, whereas changes in the percentage of canopy closure were only affected by rice varieties. This study showed that the light intensity on the soil surface decreased as the rice canopy expanded. The canopy of "IPB 3S" is more extensive, causing a lower light intensity underneath the crops. Wahyuti et al. (2013) reported that new types of rice have a more efficient canopy to intercept light. In addition, Jha and Norsworthy (2009) reported that the shape of the plant canopy affects the light that can reach the soil surface. A larger crop population with 4:1 legowo planting pattern increased canopy coverage so reducing the amount of light reaching the soil surface. Legowo planting pattern has a narrow spacing with a large number of rice populations, therefore allowing the rice crops to compete for light by developing canopy faster (Chauhan and Johnson, 2011).

The number of *L. octovalvis* leaves was reduced with Legowo 4:1 planting pattern, likely due to a higher rice population (Tabel 3). These results are consistent with the research of Awan et al. (2014) that a higher rice population could impede the weed growth, indicated by a decrease of leaf number by 68-84% (Awan et al., 2015). Increasing rice population with the legowo planting pattern also reduced the weed shoot dry weight (Mahajan et al., 2010) and the reduction can reach 48.6 to 89% (Olsen et al., 2012; Marin and Weiner, 2014).

The stem diameter of S*. zeylanica* was larger in legowo 2:1 compared to 25x25 tiles. *L. octovalvis* however, had more branches with this planting pattern, which

Table 7. The number of weed flowers per plant as affected by rice varieties and planting patterns at 8 week after planting (WAP)

Treatment	Number of flowers					
	LUDOC	SPDZE	ECHCG	LEFCH	CYPIR	FIMMI
Rice varieties						
“IPB 3S”	54	5b	4	3	8	14
“Ciherang”	55	6a	3	3	8	11
Planting pattern						
25x25 tile	46b	4b	4	3	9	13
Legowo 2:1	60a	8a	4	4	8	13
Legowo 4:1	57ab	6ab	3	3	8	12
Interaction	ns	ns	ns	ns	ns	ns

Notes: numbers followed by the same letter on the same column are not significantly different according to DMRT at 5%; LUDOC: *L. octovalvis*; SPDZE: *S. zeylanica*; ECHCG: *E. crus-galli*; LEFCH: *L. chinensis*; CYPIR: *C. iria*; FIMMI: *F. milacea*; ns: not significant.

is different from the research of Chauhan et al. (2011) which showed that interference with rice population density reduced the number of weed branches. The number of weed grass seedlings decreases with the increases in the rice population. This is in accordance with study by Awan et al. (2015) that the dense crop population suppressed the number of weed tillers by 55 to 79%, which eventually reduced their flower production.

The weed growth in “IPB 3S” plots was suppressed compared to that in “Ciherang”, likely because “IPB 3S” grow faster. Controlling the growth of grass type weeds is very important due to their relatively fast growth. The planting pattern with a high rice population was able to suppress the growth of grass type weeds through limiting growing space available. Legowo 2:1 planting pattern results in higher yield of rice grains and this increase was likely due to the higher rice population. Rice population per ha with 25x25 tile system is 160,000 hills, whereas 2:1 Legowo and 4:1 Legowo were 213,300 and 256,000 hills, respectively.

Conclusion

“IPB 3S” have dense canopy thus reduced the amount of light reaching the ground, resulting in reduced the growth and development of weeds as indicated by decreases in weed leaf number, root dry weight, dry weight, and number of branches in “IPB 3S” plots. Legowo 2:1 spacing decreased light intensity between rice rows, increased the growing space for the rice crops, suppressed weed growth, decreased weed height and shoot dry weight.

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