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Response of upland rice (*Oryza sativa* L.) cultivars to different shade levels in sandy soil

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ABSTRACT

The study aimed to determine the response of upland rice to different shade levels. The experiment was conducted in Srigading Village, Sanden District, Bantul Regency, Yogyakarta from July 2016 to March 2017. The experimental design applied was the split-plot design with three replications. The main plot was the shade level consisting of three levels of 0 %, 25 %, and 50 %. The sub plot was the upland rice cultivar consisting of three cultivars, which were 'Inpago 8', 'Situ Patenggang', and 'Batutegi'. The results showed that the shade levels given increased the plant height and leaf area. Conversely, the shade level of 50% significantly decreased the maximum number of tillers, the number of productive tillers, total plant dry weight, and the productivity. Meanwhile, there was no significant effect of the shade levels on root/shoot ratio, panicle length, percentage of filled grains per panicle, number of filled grains per panicle, and 1000-grains weight.

INTRODUCTION

Light plays an important role in the process of growth and development of rice crops. The process of receiving light by plants can lead to competition both between the leaves and between plants despite the abundant availability. Photosynthesis is a process of energy formation strongly influenced by the presence of sunlight, although in the photosynthesis process, only about 1 % to 1.5 % of sunlight is used (Gardner et al., 2008). Limitations of light in the process of growth and development of rice plants is one factor that can lead to low production produced by plants. Besides, the low rate of increase in production and the continuing decline in food production in Indonesia were caused by low and declining productivity of food crops, as well as a decrease in expansion of agricultural land area, especially in productive agricultural land in Java. The combination of the those factors ensures that the production growth rate tends to decrease from year to year (Hutapea et al., 2012). In order to fulfill the food needs, several challenges are faced. The number of challenges increases with the increasing population. Consequently, the efforts continue to be made both on productive lands and on drylands. Utilization of productive lands can be done by the intensification of land, whereas that of drylands is constrained by low land productivity due to soil erosion. The constraint needs to be overcome so that the sustainability of farming can be attained (Widarto and Susilo, 2004).

One of the alternatives to cope the problem is the cultivation of upland rice in mixed cropping system, as well as intercropping with the estate crops. This alternative is used as a strategy to increase crop yield per unit area of land per unit of time so that it directly impacts on the increasing the need for food, family nutrition, and also for environmental conservation (Shiddieq et al., 2017). One of the issues faced in the development of upland rice crops as intercropping plants is the amount of received light. Therefore, upland rice cultivar that are able to adapt to such conditions are required. Plants have the ability to form a strategy in dealing with the limitations of light due to shade by avoiding and tolerance mechanisms (Vandenbussche et al., 2005; Gommers et al., 2013; Fraser et al., 2016). Several studies have been carried out to utilize areas under trees that have limited light for crop production, including soybeans cultivation under teak plantations (Jati et al., 2017; Sinaga et al., 2016), peanuts cultivation under shade (Sundari et al., 2005), and some other crops cultivation under the conditions of limited light. This study was expected to give an idea of the existence of upland rice cultivars that could grow and develop under limited light in sandy soil. Sandy soil in Srigading Village, Sanden District, Bantul Regency has physical characteristics of 97 % sand, 2 % dust and 1 % clay. Meanwhile, its chemical characteristics includes very low organic C (0.24 %), 0.01 % N-total, 10 % available K, 21 % P_2O_5, and soil pH of 6.93. Therefore, this study aimed to determine the growth and yield of three upland rice cultivars under different shade levels in sandy soils.

MATERIALS AND METHODS

The experiment was conducted in Srigading Village, Sanden District, Bantul Regency, Yogyakarta from July 2016 to March 2017. The materials used were rice seeds of three cultivars ('Inpago 8', 'Situ Patenggang', and 'Batutegi'), black shade net, urea fertilizer, SP-36 fertilizer, and KCl fertilizer. The tools used included pen, meter, rope, leaf area meter, scissors, knife, plastic bag, paper bag, weigh, oven, light intensity meter and planting tools.

The experimental design applied was the split-plot design with three replications. The main plot was the shade level consisting of three levels, which were 0 % (without shade), 25 % and 50 %. Shade level treatment is to regulate the amount of light transmitted to plants by regulating the thickness of the black shade net to 25% and 50% then comparing them with the treatment of without shade. The sub plot was the upland rice cultivar consisting of 3 cultivars, namely 'Inpago 8', 'Situ Patenggang', and 'Batutegi'.

Shading installation was done by using black shade net adjusted to the shade levels of 0% (without shade), 25%, and 50%. First, a skeletal construction of bamboo was made with the width adjusted to the width of the plot to be shaded. In this study, the size of each plot was 2 m × 2.5 m with a distance between plots of 0.5 m so that it took 9 m for three cultivars tested. The treatment without shade was left open with the same plot size as shade treatment. The black shade net was installed on the construction of a bamboo frames that had been built with a height of 2 m. The crop maintenance was performed refersring to the Integrated Crop and Resource Management (ICM) of upland rice crops adapted to the conditions at the research site.

The observed variables consisted of plant height, leaf area, root/shoot ratio, crop growth rate (CGR), net assimilation rate (NAR), number of maximum tillers, number of productive tillers, total plant dry weight, panicle length, percentage of filled grains, number of filled grains per plant, 1000-grains weight, and productivity. Data were analyzed using analysis of variance (ANOVA) and mean differences were compared with Duncan's Multiple Range Test (DMRT) at α= 5% significance level.

RESULTS AND DISCUSSION

Plant height

As shown in Figure 1, plant height increased with the increasing levels of the shade. The tallest plants were obtained in low light intensity (50% shade level) from 3 to 12 weeks after planting (WAP). Figure 2 illustrates the plant height of three cultivars, showing that 'Batutegi' was the tallest at 12 WAP, followed by 'Inpago 8', and 'Situ Patenggang'.

Figure 1 shows that the plant height is increased as affected by different shade levels. The higher the shade levels, the taller the plant. The presence of different levels of shade results in different plant heights due to cell elongation as a result of an increase in the gibberellins and auxins hormones within the plants, thereby resulting an increase in nodes so that the plant will be taller (Moelyohadi, 1999; Sopandie, et al., 2003). Differences in plant height among cultivars were enhanced the genetic factors of the three cultivars.

Table 2 shows that different shade levels did not significantly affect the root/shoot ratio. The root/shoot ratio shows the mutual relationship between

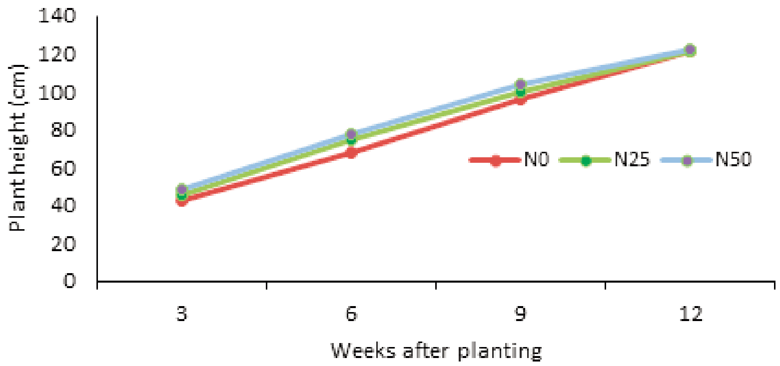

Figure 1. Plant height of upland rice under different shade levels (%) at 3–12 weeks after planting in sandy soil. *Without shade or 0% shade (N0), 25% shade level (N25) and 50% shade level (N50).

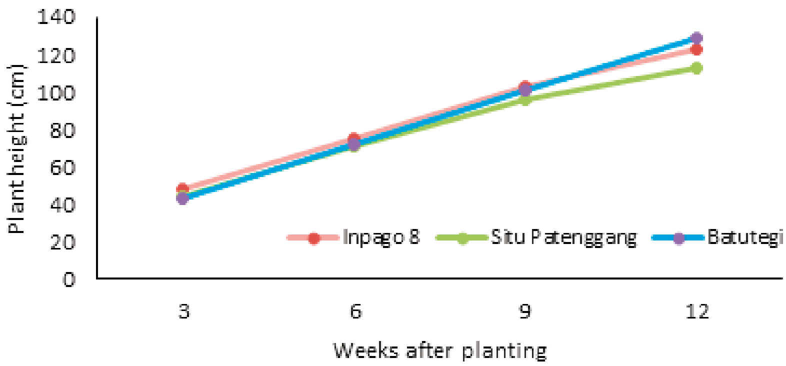

Figure 2. Plant height of three upland rice cultivars at 3–12 weeks after planting in sandy soil

the root and the shoot. In some plants, leaf weight will increase faster than root weight under low light conditions so that the root/shoot ratio is smaller (Sitompul and Guritno, 1995).

As shown in Figure 1 and Figure 2, an increase of plant height occurred under different shade levels and rice cultivars. Plant height is one of indicators to observe the growth and development of a plant that can be influenced by environmental factors, genetic factors, and other factors.

Leaf area

Leaf area of upland rice at 6 and 9 weeks after planting was not significantly affected by different shade levels and rice cultivars (Table 1). Table 1 shows no significant difference in leaf area between cultivars, but this present finding was contrasted to the experimental result reported by Sulistyono et al. (2002), suggesting that the decrease of light intensity result in the morphological changes such as leaf area expansion and the decrease in leaf thickness. This is probably caused by the cultivars used in this study could be cultivated in an intercropping system so that it could adapt to low light intensity (Jamil et al., 2014).

Root/shoot ratio

Root/shoot ratio of upland rice cultivars at 6 and 9 weeks after planting was not significantly affected by different shade levels and rice cultivars (Table 2).

Crop Growth Rate (CGR) and Net Assimilation Rate (NAR)

According to Table 3, the CGR of the upland rice cultivars was significantly affected by the shade levels, in which the CGR of plants under 0 % and 25 % shade levels differed from that of plants under 50 % shade level. On the contrary, the NAR of the upland rice cultivars was not significantly affected by the shade levels. Besides, the CGR of the upland rice cultivars was not significantly affected by upland rice cultivars, but the NAR of 'Inpago 8' and 'Batutegi' were

Table 1. Leaf area of upland rice cultivars at 6 and 9 weeks after planting in sandy soil.

Treatment	6 WAP	9 WAP
Shades (%)		
0	1130.85 a	2044.62 a
25	1209.31 a	2519.32 a
50	793.85 a	1839.05 a
Cultivars		
Inpago 8	914.31 p	1580.58 p
Situ Patenggang	1164.04 p	2346.77 p
Batugegi	1055.67 p	2475.63 p
Interaction	(-)	(-)
CV	27.99	25.09

Remarks: Means followed by the same letters in a column in the same treatment were not significantly different based on DMRT at α= 5% levels. Sign (-) indicated no significant interaction found between the factors tested.

Table 2. Root/shoot ratio of upland rice cultivars at 6 and 9 weeks after planting in sandy soil

Treatment	6 WAP	9 WAP
Shades (%)		
0	0.16 a	0.10 a
25	0.17 a	0.09 a
50	0.15 a	0.11 a
Cultivars		
Inpago 8	0.16 p	0.10 p
Situ Patenggang	0.13 p	0.11 p
Batugegi	0.17 p	0.09 p
Interaction	(-)	(-)
CV	24.31	18.21

Remarks: Means followed by the same letters in a column in the same treatment were not significantly different based on DMRT at α= 5% levels. Sign (-) indicated no significant interaction found between the factors tested.

significantly higher than that of 'Situ Patenggang'.

Three different cultivars showed similar root/shoot ratio. As shown in Table 3, 50 % shade level resulted in the lowest value of CGR. Gardner et al. (2008) stated that CGR is an increase in plant weights in crops calculated per unit of land per unit of time. The lowest CGR value at a 50 % shade level was suspected to be caused by a lack of received light, and it would directly affect the photosynthesis and assimilation rate. However, the NAR values in this study were not significantly different under different shade levels.

Number of maximum tillers and number of productive tillers

The number of maximum tillers and the number of productive tillers were significantly affected by the shade levels. The number of maximum tillers and the number of productive tillers under 0 % and 25 % shade levels were the same but significantly higher than those under 50 %. Meanwhile, 'Situ Patenggang' had the highest number of tillers, which was 12.7 tillers per hill.

The number of maximum tillers and the number

Table 3. Crop growth rate (g.dm^{-2}.week^{-1}) and net assimilation rate (g.dm^{-2}.week^{-1}) of upland rice cultivars in sandy soil

Treatment	CGR	NAR
Shades (%)		
0	1.54 a	0.17 a
25	1.41 a	0.22 a
50	1.10 b	0.28 a
Cultivars		
Inpago 8	0.23 p	1.55 p
Situ Patenggang	0.18 p	1.10 q
Batugegi	0.25 p	1.40 p
Interaction	(-)	(-)
CV	16.42	25.93

Remarks: Means followed by the same letters in a column in the same treatment were not significantly different based on DMRT at α= 5% levels. Sign (-) indicated no significant interaction found between the factors tested.

Table 4. Number of maximum tillers and number of productive tillers of upland rice cultivars in sandy soil

Treatment	Number of maximum tillers	Number of productive tillers
Shades (%)		
0	12.40 a	8.92 a
25	10.33 ab	7.37 ab
50	8.55 b	5.33 b
Cultivars		
Inpago 8	9.81 pq	7.22 p
Situ Patenggang	12.70 p	8.04 p
Batugegi	8.77 q	6.37 p
Interaction	(-)	(-)
CV	20.60	12.88

Remarks: Means followed by the same letters in a column in the same treatment were not significantly different based on DMRT at α= 5% levels. Sign (-) indicated no significant interaction found between the factors tested.

of productive tillers, as shown in Table 4, informed that there was a significant difference as affected by shade levels and cultivars. It was seen that the lower light intensity as a result of shading would cause the lower number of maximum tillers and number of productive tillers. The high number of maximum tillers in upland rice under shading condition would cause the decreased production because it would markedly make a competition of light between individuals so that the tillers in the deeper part would only act as a parasite (Sulistyono et al., 2002).

Total plant dry weight

Total plant dry weight of upland rice at 6 and 9 weeks after planting were significantly affected by shade levels. Total plant dry weight of upland rice at 6 and 9 weeks after planting under shade levels of 0 % and 25 % were the same and higher than that

Table 5. Total plant dry weight (g per hill) of upland rice cultivars at 6 and 9 weeks after planting in sandy soil.

Treatment	6 WAP	9 WAP
Shades (%)		
0	9.61 a	21.14 a
25	7.51 ab	18.34 a
50	5.53 b	13.62 b
Cultivars		
Inpago 8	6.54 q	18.19 p
Situ Patenggang	9.04 p	17.30 p
Batugegi	7.10 pq	17.61 p
Interaction	(-)	(-)
CV	14.33	11.42

Remarks: Means followed by the same letters in a column in the same treatment were not significantly different based on DMRT at α= 5% levels. Sign (-) indicated no significant interaction found between the factors tested.

Table 6. Panicle length (cm), percentage of filled grains per panicle (%), number of filled grains per panicle, and 1000-grains weight (g) of upland rice cultivars in sandy soil.

Treatment	Panicle length	Percentage of filled grain per panicle	Number of filled grains per panicle	1000-grains weight
Shades (%)				
0	23.60 a	91.26 a	138.97 a	25.17 a
25	23.33 a	89.62 a	131.53 a	25.19 a
50	22.43 a	86.71 a	100.46 a	24.40 a
Cultivars				
Inpago 8	24.42 p	88.63 q	101.03 q	27.14 p
Situ Patenggang	21.62 q	91.53 p	110.52 pq	25.20 pq
Batugegi	23.33 p	87.43 q	159.41 p	22.42 q
Interaction	(-)	(-)	(-)	(-)
CV	2.92	5.51	12.78	8.43

Remarks: Means followed by the same letters in a column in the same treatment were not significantly different based on DMRT at α= 5% levels. Sign (-) indicated no significant interaction found between the factors tested.

under 50 % level of shading (Table 5). Total plant dry weight of upland rice at 6 weeks after planting was significantly different, but total dry weight of upland rice at 9 weeks after planting varied from 17.3 g per hill to 18.2 g per hill and were not significantly different between cultivars.

Panicle length, percentage of filled grains per panicle, number of filled grains per panicle, and 1000-grains weight

Panicle length, the percentage of filled grains per panicle, number of filled grains per panicle, and 1000-grains weight were not significantly affected by the shade levels (Table 6). The panicle length of 'Situ Patenggang' cultivar was 21.62 cm, which was significantly shorter than that of 'Inpago 8' and 'Batutegi'. The percentage of filled grains per panicle of 'Inpago 8' and 'Batutegi' were the same and significantly lower than that of 'Situ Patenggang' (91.53 %). Weight of 1000 grains of 'Batutegi' cultivar was 22.42 g, and it was significantly lower than that of 'Inpago 8' and 'Situ Patenggang'.

A significant difference was found in the total plant dry weight as affected by different shade levels

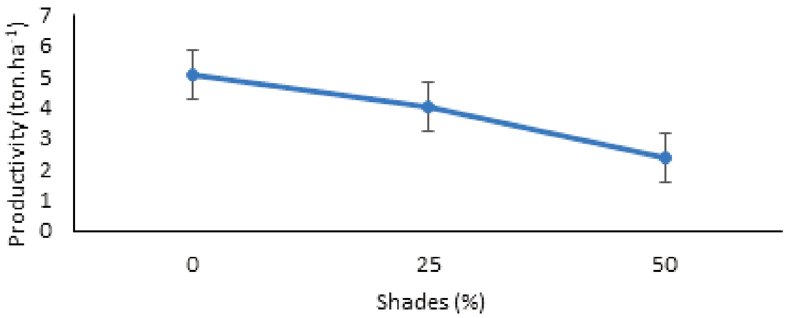

Figure 3. Effect of shades level (%) on productivity (ton.ha^{-1}) of upland rice cultivars in sandy soil

(Table 5). The 50 % shade level caused the lowest total plant dry weight, but there was no significant difference in the total plant dry weight between plants under 0 % and 25 % shade levels. Dry weight is part of the absorption efficiency and utilization of solar radiation available during the growing season. The increased dry weight showed increased absorption efficiency and utilization of solar radiation by the canopy so that the resulting assimilate will increase (Gardner et al., 2008). The earlier experiment using dieffenbachia plants demonstrated that the shading did not significantly affect the dry weight of the plant (Wirawati, 2006).

The plant yield components such as panicle length, the percentage of filled grains per panicle, the number of filled grain per panicle, and 1000-seeds weight of upland rice cultivars did not show significantly different responses to the shade levels (Table 6). This result might occur because the shading up to 50 % level still had not affected the observed variables. Corresponding to the fact, the three cultivars grown in this study could be cultivated in intercropping system. Specifically, all the tested cultivars were well-grown and well-developed under low light intensity (Romdon et al., 2014). However, a significant difference was found in yield components as affected by different cultivars, and it was likely due to the genetic factor.

Productivity of upland rice

The result of the statistical analysis indicated that there was significant difference in the productivity. As shown in the graph, the lowest productivity was obtained under the higher shade level.

Figure 3 shows the productivity level of three upland cultivars under different shade levels. The higher shade level would lower the productivity level. One of the decreasing factors in productivity level was affected by the number of grains. Alridiwirsah et al. (2015) suggested that the decrease in light intensity is due to the shade levels, thereby affecting the number of grains. The lower the light intensity, the lower the grain yield. Different upland rice cultivars affected the productivity level depending on the cultivar resistance to the shade level (Wang et al., 2015).

CONCLUSIONS

The results showed that the increased shade levels increased the plant height and leaf area. The number of maximum tillers and the number of productive tillers, as well as the total plant dry weight and the productivity, under the 50% shade level significantly decreased. Meanwhile, the other observed variables, including root/shoot ratio, panicle length, percentage of filled grains per panicle, number of filled grains per panicle and 1000-grains weight upland rice showed no significantly different responses.

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