Shading effect on generative characters of upland red rice of Southeast Sulawesi, Indonesia

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Abstract. Upland red rice (Oryza sativa) contains anthocyanin, a phenolic compounds that can act as antioxidants and functional food for human dietary. The content of functional food on upland red rice is influenced by shading condition, but the production is also influenced by environmental condition, especially the availability of light. The study aims is to assess and analyze the effect of shade on the growth and production of upland red rice. The research was conducted using the quantitative method to obtain the optimal shading condition that can increase the rice anthocyanin content and relatively high production. The research was arranged in split plot design, with shade as main plot and the different of cultivar as sub plot with three replications. The shading treatment consist of 4 levels as follows: n1=shade level < 25 %, n2=shade level 25-50%, n3=shade level 50-75% and n4=shade level > 75%. The cultivar tested were (v₁) = Labandiri, (v₂) = Jangkobembe, (v₃) = Ranggohitam, and (v₄) = Paedara. The rice planted in between teak wood trees with different age and level of canopy. The research reveals that shades had an effect in decreasing plant production (the higher level of shade, the higher the decrease level of production), but the shades can improve the quality of red rice through the increase of anthocyanin content.

1. Introduction

Rice is very important staple food in Indonesia. Demand for rice as a staple food continuously increase from year to year, due to high population growth and changes in consumption patterns [1]. To achieve stable production conditions, the increase in rice production must be at least in line with the growth of population [2]. Indonesia together with China, India, Bangladesh and Vietnam are major rice producers [3, 4], but Indonesia is also the main rice consumer [5].

Various efforts have been done to increase rice production. The main strategy in maintaining rice sustainability is through the increasing rice production [3, 6] and lowering rice consumption while promoting local food such as sago [7]. Upland rice can be developed on sub-optimal land, either on (1) dry land through the development of upland rice-based farming or (2) as an insertion plant under plantation stands or forestry crops in intercropping or agroforestry patterns [5, 8, 9, 10, 11].

The development of plant under the stand of plantation crop or forestry will be limited by solar radiation that will in turn affect growth and production [12, 13, 14, 15]. Low light intensity may cause decrease in performance of generative character but can affect in the increasing of anthocyanin levels.
Therefore, the research is very important to get right combination between anthocyanin content increase with the least growth and rice production decrease to compensate the increase.

2. Material and Method
This research was conducted in Teak Wood Botanical Garden Halu Oleo University from April to October 2014. The research conducted in split plot design, with shade as main plot and the different of cultivar as sub plot, with three replication. The shading treatment consisted of 4 levels as follows: n1=shade level < 25 %, n2=shade level 25-50 %, n3=shade level 50-75% and n4= shade level >75%. The rice planted in between teak wood trees with different age and level of canopy. The cultivar tested were (v1) = Labandiri, (v2) = Jangkobembe, (v3) = Ranggohitam, and (v4) = Paedara. Several generative character included number of productive tiller, filled grain content, yield and anthocyanin content were examined. Statistical analyses were performed using two ways of analysis of variances (ANOVA) using the Statistical Package of Social Sciences (SPSS) program version 20 for Windows (Chicago, IL, USA). If the test result showed a significant difference, then tests of treatment differences were performed using Duncan’s multiple range test (DMRT) at α=0.05.

3. Results and Discussion

3.1. Productive Tiller
The result showed that shade level and cultivar have significantly affected number of productive tillers and there is no interaction between shade and cultivar on productive tillers. Generally the productive tillers decreased with higher shade levels and this occurred in all four cultivars tested (table 1).

Table 1. Effect of shade and cultivar on the productive tillers and percentage relative comparison (PRC) [1]

| Shade treatment | Number of productive tiller | Percentage relative comparison (PRC) |
|-----------------|----------------------------|-------------------------------------|
|                 | v1 | v2 | v3 | v4 | (%) | (%) | (%) | (%) |
| n1              | 11.49 | 10.51 | a | 9.88 | a | 10.00 | a | 100.00 | 100.00 | 100.00 | 100.00 |
|                 | p | q | r | qr | | | | | | | |
| n2              | 7.88 | 7.74 | b | 10.03 | a | 8.72 | b | 67.59 | 73.56 | 97.89 | 76.88 |
|                 | r | r | p | q | | | | | | | |
| n3              | 5.75 | 5.34 | c | 7.20 | b | 6.19 | c | 48.66 | 55.88 | 67.03 | 74.76 |
|                 | qr | r | p | q | | | | | | | |
| n4              | 4.45 | 4.34 | d | 4.80 | c | 5.24 | d | 37.85 | 40.21 | 48.93 | 52.62 |
|                 | q | q | pq | p | | | | | | | |

* Number followed by the same index in the same row, are not significantly different at Duncan's multiple Range Test (DMRT).

** n1 = shade level < 25 %; n2 = shade level 25-50 %; n3 = shade level 50-75% and n4 = shade level > 75%. v1=Cultivar Labandiri; v2=Cultivar Jangkobembe; v3=Cultivar Ranggohitam; v4=Cultivar Paedara

Based on table 1 it is apparent that the highest number of productive tillers was found in Labandiri cultivars (11.49 tillers), followed by Jangkobembe cultivar (10.51 tillers), Paedara cultivar (10.00 tillers) and Ranggohitam cultivar (9.88 tillers) at the shade level under 25%. Based on the percentage relative comparison (PRC), using a light shade treatment (n1) as a control, it appears that the higher shade level, the smaller the number of productive tiller and it as also indicated by the smaller number PRC.
3.2. Percentage Filled Grain and Yield

The result showed that at the shade level under 25%, the highest percentage of filled grain was found in Labandiri cultivar (93.4%), followed by Ranggo hitam (93.2%), Jangkobembe (90.6%) and the lowest in Paedara (73.9%) as seen on table 2. The highest production found on Jangkobembe cultivar (4.11 t ha\(^{-1}\)), followed by Ranggo hitam (3.74 t ha\(^{-1}\)), Labandiri (3.63 t ha\(^{-1}\)) and Paedara (1.91 t ha\(^{-1}\)).

Shading increase the anthocyanin levels of upland rice and the level of increase depends on the type of cultivar. The increase anthocyanin levels as a result of shade level also occurred in the Labandiri cultivars, followed by Ranggo hitam and Paedara cultivars.

### Table 2. Effect of shade and cultivar on the percentage filled grain, production and percentage relative comparison (PRC) [1]

| Shade treatment | Percentage filled grain | Percentage relative comparison (PRC) |
|-----------------|-------------------------|-------------------------------------|
|                 | \(v_1\) | \(v_2\) | \(v_3\) | \(v_4\) | 100.0 | 100.0 | 100.0 | 100.0 |
| \(n_1\)         | 93.4   | 90.6   | 93.2   | 73.9   |
| \(n_2\)         | 83.6   | 81.7   | 83.4   | 54.2   |
| \(n_3\)         | 66.4   | 47.0   | 54.6   | 48.8   |
| \(n_4\)         | 42.4   | 38.5   | 37.8   | 28.2   |

| Production (ton ha\(^{-1}\)) | Percentage relative comparison (PRC) |
|------------------------------|-------------------------------------|
| \(v_1\) | \(v_2\) | \(v_3\) | \(v_4\) | 100.0 | 100.0 | 100.0 | 100.0 |
| \(n_1\) | 3.63   | 4.11   | 3.74   | 1.91   |
| \(n_2\) | 2.34   | 2.60   | 2.92   | 0.94   | 64.4 | 63.26 | 78.07 | 49.11 |
| \(n_3\) | 1.28   | 0.97   | 0.83   | 0.66   | 35.26 | 23.60 | 22.19 | 34.55 |
| \(n_4\) | 0.49   | 0.51   | 0.34   | 0.30   | 13.49 | 12.40 | 9.09  | 15.71 |

* Number followed by the same index in the same row, are not significantly different at Duncan’s multiple Range Test (DMRT).

** \(n_1\) = shade level < 25 %; \(n_2\) = shade level 25-50 %; \(n_3\) = shade level 50-75 % and \(n_4\) = shade level > 75%.

\(v_1\) = Cultivar Labandiri; \(v_2\) = Cultivar Jangkobembe; \(v_3\) = Cultivar Ranggo hitam; \(v_4\) = Cultivar Paedara

Based on PRC at higher shade levels (\(n_1\) and \(n_4\)), there was a decrease in the percentage of filled grain drastically by nearly half, except in the Labandiri cultivar with PRC of 71.09%. It appears that the percentage filled grain decreases with the higher shade level. Further results in Table 2 showed that the percentage filled grain decreases due to increases in shade level. On yield parameter, a similar pattern also found. Based on Table 2, in the shade level 25-50\% (\(n_2\)), it is apparent that the highest crop production founded in Ranggo hitam cultivar (\(v_3\)) with grain production of 2.92 ton ha\(^{-1}\), then followed by Jangkobembe cultivar (\(v_2\)) of 3.74 ton ha\(^{-1}\), Labandiri (\(v_1\)) 2.34 ton ha\(^{-1}\) and Paedara (\(v_4\)) of 1.91 ton ha\(^{-1}\). Based on percentage relative comparison (PRC) of filled grain, it appears that in medium shade level (\(n_2\)), grain production decreased and the biggest percentage decrease occurred in Paedara cultivar with PRC value 49.1\%, and then followed by Jangkobembe cultivar with PRC value 63.3\%, Labandiri with PRC relatively 64.4\% and the smallest decrease in Ranggo hitam with PRC value of 78.1\%.

3.3. Anthocyanin Content

Shading increase the anthocyanin levels of upland rice and the level of increase depends on the type of cultivars (figure 1). The highest increase of anthocyanin levels due to shade occurred in Jangkobembe cultivar. For the other three cultivars, the anthocyanin content also increased as an effect of shading, but the increase was not as large as in the Jangkobembe cultivar. The increase anthocyanin levels as a result of shade level also occurred in the Labandiri cultivars, followed by Ranggo hitam and Paedara cultivars.
4. Conclusion
The results showed that shade might decrease the growth and production of rice, but at the same time the anthocyanin content increase in line with the increasing of shade level. The shade level decrease the productive tiller and yield on Labandiri, Jangkobembe and Paedara cultivar. At the same time, the shade increase anthocyanin content on Jangkobembe and Ranggohitam cultivar. The best cultivar for yield and anthocyanin under shade condition found in Ranggohitam cultivar.

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