A study on the growth of Gorontalo local upland rice Ponda merah accession against drought and shade stresses

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Abstract. The aim of this study was to determine the vegetative growth response of Gorontalo local upland rice Ponda Merah accession against drought and shade stresses. The study was conducted in Sipatana Village, West Bulotadaa Subdistrict, Gorontalo City, from May to October 2017, examined using randomized block design with 4 replications. The first factor observed was the drought treatment which consisted of two levels; irrigation until the inundation height of 1.5 cm and irrigation carried out if the potential of groundwater reaches -30 to -35.9 kPa. The second factor was shades which consisted of 3 levels; 0% shade, 25% shade, and 50% shade. The results showed that Gorontalo local upland rice Ponda merah accession was able to adapt well to drought stress, shade stress, and combination of both which were characterized by high values of plant dry weight 49.88 g under drought stress condition, 84.08 g under 50% shade condition and 44.61 g in drought + 50% shade condition and chlorophyll content 0.148 mg.g\(^{-1}\) under drought stress condition, 0.168 mg.g\(^{-1}\) under 50% shade condition and 0.202 mg.g\(^{-1}\) in drought + 50% shade condition.

1. Introduction
Rice is a critical food commodity consumed by the majority of the Asian population, especially in Indonesia. The rice production in Indonesia in 2017 reached 51.28 quintals/acre with an average consumption of 1.571 kg per capita [1]. The production of rice generally relies on agriculture intensification. The fact that agriculture fields are repurposed, especially rice fields, triggers production decrease and in turn drylands below stand are used as land alternatives for agriculture intensification, especially for rice plant.

Dryland is a piece of land that is not saturated in water most time of the year. Cultivation in dryland, especially dryland below stands, possesses some challenges, namely drought and annual shades. The scarcity of water in dryland causes agricultural efforts to be impossible to be performed all year round. In addition, low light intensity is also an added factor that hinders plant growth.

Gorontalo is a province possessing diverse a genetic resources which give great potential for creating accessions with high adaptability to drought and shade stresses. The use of adaptive local accessions as genetic source in a stress-ridden location can help improve the plant’s resistance to abiotic stresses because it has sizable genetic variations and resistance against environmental stresses. Therefore, this research is conducted in order to find the responses of vegetative growth of Gorontalo local upland rice Ponda Merah accession against drought and shade stresses.
2. Material and Methods
This research was conducted in Bulotadaa village, Sipatana District, Gorontalo, Indonesia from May to October, 2017. The rice seeds used were Gorontalo local upland rice variety, called Ponda Merah.
The study was conducted using randomized block design with 4 replications. The first factor observed was drought treatment which consisted of two levels; irrigation to 2.5 cm inundation height (control) and irrigation carried out if the potential of groundwater reaches -30 to -35.9 kPa (drought treatment) [2]. The second factor was shades consisting of 3 levels; 0% shade, 25% shade, and 50% shade. There were 6 combinations of treatments namely control, drought + 0% shade, drought + 25% shade, drought + 0% shade, drought + 25% shade, and drought + 50% shade treatments.

The research was carried out in a cultivation medium with plastic roofing and supported by bamboo poles with a size of 3 x 3 x 1.8 m. Rice seeds were planted on a cultivation soil measuring 3 x 3 m with a spacing of 25 x 25 cm, which was previously excavated at the depth of 20 cm with PE plastic placed on the bottom of the soil to prevent the movement of groundwater which was not meant to be added as a part of the research. For the regulation of drought treatment, the irrigation was adjusted to the treatment conditions. For irrigation treatment, the water supply was given continuously and the flooding of the water level was maintained at 2.5 cm from the ground. For drought treatment, the addition of water was based on the measurement of groundwater potential carried out by a Tensiometer. Samples were taken randomly based on visual appearance, which included leaf winding and also based on the appearance of soil conditions of the plants experiencing drought stress. Drought treatment was given after the plant reached 4 weeks of age after planting (Days After Planting/DAP). The planting media used soil and manure with a ratio of 1: 1. The first fertilization used Urea and NPK fertilizers which were given 1 week after planting and second fertilization. In other words, urea was given 7 weeks after planting.

The data obtained were analyzed by variance. If influence were found, then the test would be continued by using the Least significance different test at the 5% real level. The variables observed were: (1). Root dry weight, which is measured by scaling the dry weight of the root after being heated in the oven at 80°C for 48 hours, (2). Plant dry weight, which is measured by scaling the dry weight of the crown after being heated in the oven at 80°C for 48 hours, (3). Specific leaf area, measured of leaf area used ruler, which involves illustrating the thickness of the leaf [3] with the following formula:

\[
\text{Specific Leaf Area (SLA)} = \frac{LA}{LW}
\]

Where: SLA: Specific Leaf Area(cm².g⁻¹),
LA: Leaf’s Area (cm²),
LW: Specific Leaf’s Dry Weight

Crop growth rate, which involves illustrating the ability of plants to produce dry matter as a result of assimilation per unit area of land per unit time, with the following formula [4]:

\[
\text{Crop Growth Rate (CGR)} = \frac{w2-w1}{t2-t1} \times \frac{1}{GA}
\]

Where: CGR : Crop Growth Rate (gr. cm².hr⁻¹),
w2 : Dry Weight at the end of observation (gr plant⁻¹),
w1 : Dry Weight at the beginning of observation (gr plant⁻¹),
t2 : End of observation time (day),
t1 : Begin of observation time (day),
GA : Planting distance (cm²).

Leaf chlorophyll, which is analyzed and sampled at the vegetative phase (50-60 days after planting) and the generative phase (100-110 days after planting). The sample is taken from the second from the top leaf [5]. Leaf’s starch and glucose levels [6]. The analysis of the leaf is conducted at 60-90 days after planting.
3. Result and Discussion

3.1 Climatic condition of the research location
Plant growth observation took place from July to October 2017. The average air temperature in the observation location ranged from 26.0 to 27.2 °C. According to the Institute for Meteorology and Geophysics, the monthly rainfall distribution in the study locations in July and August was classified as a medium with monthly rainfall between 100 - 300 mm, while in September and October it was low, between 0-100 mm.

3.2 Interaction effects between drought and shade treatments on root dry weight variable
The results of the variance analysis showed significant interactions between drought and shade treatments on root dry weight, plant dry weight, leaf area and plant growth rate variables. The root dry weight of the plant with drought + shade control treatment was 25% lower and not significantly different from the root dry weight of plant with drought control + 50% shade treatment (Table 1).

The treatment of drought + 0% shade stresses resulted in higher root dry weight at 9.15 g, and this was significantly different from other treatments on plants at the age of 150 days. This was due to the fact that plants that were given drought stress were not irrigated until the groundwater potential reached -30 to -35.9 kPa and so this condition stimulated the growth of enlarged and elongated roots for maximum water absorption. [7] stated that in drought conditions, tolerant plants have the maximum ability to draw water with the expansion and depth of the root system and the ability of plants to maintain turgor pressure through osmotic potential decrease.

Table 1. Average interaction effects between drought and shade treatments on root dry weight variable

| Treatments       | Root dry weight (gr) | 0% shade | 25% Shade | 50% Shade |
|------------------|----------------------|----------|-----------|-----------|
|                  |                      | 60 days  | 90 days   | 120 days  | 150 days  |
| Control          | 1.96 a               | 1.67 a   | 1.54 a    |
| Drought stress   | 1.56 a               | 1.94 a   | 1.80 a    |
|                  |                      | 90 days  | 120 days  | 150 days  |
| Control          | 6.11 ab              | 4.43 c   | 5.38 b    |
| Drought stress   | 6.46 a               | 6.68 a   | 6.92 a    |
|                  |                      | 120 days | 150 days  |
| Control          | 7.39 d               | 7.15 e   | 6.96 e    |
| Drought stress   | 9.06 a               | 8.23 b   | 7.66 c    |
|                  |                      | 150 days |            |
| Control          | 7.86 c               | 7.14 d   | 7.34 d    |
| Drought stress   | 9.15 a               | 8.39 b   | 7.80 c    |

Numbers followed by the same letters in each column are not significantly different at α = 5%

Red Ponda accession rice is a rice variant that is tolerant to drought stress. This is because the roots of this plant have extensive branching and roots that function to absorb water and nutrients from the soil. In addition, the root stem diameter of this variant is larger than the sensitive accessions. [8] stated that since plants acquire water through roots, any plasticity in root architecture also enables plants to respond to a changing environment. For example, root often grows thicker, deeper, and larger in response to drought in rice genotypes.
3.3 Interaction effects between drought and shade treatments on leaf specific area variable

Leaf specific area gives information about the thickness of the leaf. Leaf specific area for plants with drought + 50% shade stresses was greater (Table 2). This shows that Red Ponda rice variety given this treatment had thinner leaf compared to that of other treatments. [9] claimed that that one of the leaf shade characters was an increase in leaf area ratio to leaf weight (specific leaf area). Furthermore according to [10] also claimed that the tolerant genotype leaves are wider and thinner than the sensitive genotype leaves at a low light intensity.

Wide and thin leaf allows more surface area for light, which is then passed on to the deeper layer quickly so that photosynthesis takes place maximally. There was a greater increase in the palisade layer of the genotype of upland rice and shade-tolerant soybeans caused by the shade stress compared to the sensitive genotype, causing the leaves to become thicker. The change in the characteristics is a form of protection against low light [11].

Table 2. Average interaction effects between drought and shade treatments a specific leaf area variable

| Treatments          | Spesific Leaf Area (cm² gr⁻¹) | 0% shade | 25% shade | 50% shade |
|---------------------|-------------------------------|----------|-----------|-----------|
|                     |                               |          | 60 days   | 90 days   | 120 days  |
| Control             |                               | 83.45    | 86.91     | 96.96     |
|                     |                               | 69.62    | 72.23     | 66.02     |
| Drought stress      |                               | 70.71    | 98.07     | 81.05     |
|                     |                               | 74.03    | 73.55     | 59.34     |
| Control             |                               | 80.91    | 120.15    | 89.40     |
|                     |                               | 71.33    | 70.89     | 90.07     |
| Drought stress      |                               | 67.45    | 71.88     | 72.52     |
|                     |                               | 78.27    | 75.21     | 84.66     |

Numbers followed by the same letters in each column are not significantly different at α = 5%

3.4 Interaction effects between drought and shade treatments on crop growth rate variable

The crop growth rate at 150 days after planting plant with drought + shade 0% control treatment was higher than other types of treatments, followed by plant with drought + 25% shade control treatment during the preparation phase. In contrast, plants with drought + 0% shade, drought + 25% shade, drought + 50% shade, and control stress + shade 50% treatments had lower growth rates which were not significantly different from one and another. The results of the study showed that the condition with the shade ≤ 25% from normal conditions allowed the plant to maintain normal growth. Refers to [12] research that Numerous experimental data and related reports have confirmed that low light markedly affects agronomic and physiological traits of rice plants, hampering the underlying physiological metabolisms, including photosynthesis, respiration, antioxidant characteristic as well as the conversion and distribution of carbon and nitrogen.
Table 3. Average interaction effects between drought and shade treatments on crop growth rate variable

| Treatments          | Crop Growth Rate (mg g⁻¹ day⁻¹) | 0% shade | 25% shade | 50% shade |
|---------------------|---------------------------------|----------|-----------|-----------|
|                     |                                 | 60 days  | 90 days   | 120 days  |
| Control             |                                 | 0.97⁻a   | 0.64⁻b    | 0.29⁻d    |
| Drought stress      |                                 | 0.44⁻c   | 0.31⁻d    | 0.18⁻e    |
|                     |                                 | 90 days  | 120 days  | 150 days  |
| Control             |                                 | 0.39⁻c   | 0.32⁻d    | 0.53⁻a    |
| Drought stress      |                                 | 0.46⁻b   | 0.49⁻ab   | 0.43⁻bc   |
|                     |                                 | 120 days | 150 days  |           |
| Control             |                                 | 0.62⁻a   | 0.63⁻a    | 0.35⁻b    |
| Drought stress      |                                 | 0.43⁻b   | 0.34⁻b    | 0.43⁻b    |
|                     |                                 | 150 days |           |           |
| Control             |                                 | 0.56⁻a   | 0.44⁻b    | 0.35⁻c    |
| Drought stress      |                                 | 0.34⁻c   | 0.37⁻c    | 0.35⁻c    |

Numbers followed by the same letters in each column are not significantly different at α = 5%

3.5 Interaction effects between drought and shade treatments on crop growth rate variable

Total chlorophyll of Red Ponda accessions with various treatments given in vegetative phase ranged from 0.182 mg g⁻¹ (drought control treatment + 25% shade) to 0.189 mg g⁻¹ (drought control treatment + 0% shade), while total chlorophyll for accessions with treatments given in the generative phase ranged between 0.148 mg g⁻¹ (drought stress treatment + 0% shade) to 0.216 mg g⁻¹ (drought control treatment + 25% shade). The difference in chlorophyll content in Red Ponda accessions is due to the rice’s classification as a plant that is able to adapt to water deficit and low light intensity through morphological, physiological, and biochemical adaptability which are all related to photosynthesis. With such characteristics, the research, despite being a small scale preliminary experiment, found that the accessions were capable of producing (Table 5).

The results showed that the starch content of the control plant with drought + shade was 0% higher (0.88 mg g⁻¹) than plants that were given stresses, both single stresses and double stresses. The starch content of plants with drought + shade treatment was 50% lower, which was 0.26 mg g⁻¹, compared to other treatments. The sugar content of the drought + shade control treatment was 0% higher, which was 1.03 mg g⁻¹, compared to plant with drought + 25% shade and drought + 50% shade treatments. The lowest sugar content was found in the plant with drought + 50% shade treatment, which was 0.49 mg g⁻¹. The starch and sugar content of plants that were not given stress treatment were higher than those with stresses given. This was due to water and light deficits that caused photosynthesis to be disrupted. [13] stated that carbohydrate metabolism is influenced by drought stress in several ways, namely increasing sugar levels and decreasing starch content. Furthermore, there is a correlation between sugar intake (sucrose) and a decrease in poly-saccharide. The decrease in starch level is considered as a factor that causes a drop in photosynthesis and an increase in hydrolysis.

Leaf sugar content affects the relative growth rate and dry weight of plants. The increase in leaf sugar content will result in an increase in plant growth rate and plant dry weight with a terminated coefficients of 60% and 90.1%. This shows that the contribution of leaf sugar content in influencing the plant growth rate and dry weight of plants is 60% and 0.91% respectively (Figure. 1).
Table 4. Physiology character Ponda merah accession against drought and shade stresses

| Treatments          | Physiology character | 0% shade | 25% shade | 50% shade |
|---------------------|----------------------|----------|-----------|-----------|
| Control             | Total chlorophyll in vegetative phase (mg.gr⁻¹) | 0.189    | 0.182     | 0.184     |
| Drought stress      |                      | 0.185    | 0.184     | 0.184     |
| Control             | Total chlorophyll in generative phase (mg.gr⁻¹) | 0.169    | 0.216     | 0.168     |
| Drought stress      |                      | 0.148    | 0.152     | 0.202     |
| Control             | leaf starch content (mg.gr⁻¹) | 0.88     | 0.69      | 0.37      |
| Drought stress      |                      | 0.64     | 0.44      | 0.26      |
| Control             | leaf sugar content daun (mg.gr⁻¹) | 1.03     | 1.02      | 0.57      |
| Drought stress      |                      | 0.69     | 0.64      | 0.49      |

Figure 1. Relationship between crop growth rate and leaf sugar content and crop dry weight and leaf sugar content in combination treatment between drought stress + 50% shade

4. Conclusions
Gorontalo local upland rice Red Ponda accession is a plant that is able to adapt to single stress, namely drought stress or shade stress, and a combination of drought and shade stresses. This is indicated by the plant’s ability to adapt in an environment where water and light are limited, shown through root dry weight, plant dry weight, leaf area, plant growth rate, and high content of chlorophyll, starch, and sugar. Gorontalo local upland rice Red Ponda accession’s dry weight variable value was 49.88 g, while plant with 50% shade treatment was 48.08 g, and plant with a combination of drought + 50% shade treatment was 44.61 g. In addition, the chlorophyll contents of plant with drought treatment was
0.148 mg.g⁻¹, plant with 50% shade treatment was 0.168 mg.g⁻¹, and plant with combination of drought + 50% shade treatment was 0.202 mg.g⁻¹.

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