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Study on Morphological and Physiological Characters of Ponda merah Accession against Drought and Shade Stresses

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The aim of this study was to examine the growth and yield of Gorontalo local upland rice against drought and shade stresses based on morphological and physiological character. The study was conducted between May to October, 2017 in West Bulotadaa Village, Sipatana District, Gorontalo. The accession of rice studied was Gorontalo local upland rice Ponda Merah accession, 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 Ponda Merah accession was able to adapt well to drought stress, shade stress, and combination of both. Ponda Merah accession was able to produce milled dry grain of 1,64 tons hectare^{-1} under drought stress condition, 2,87 tons hectare^{-1} under 25% shade condition, 1.51 tons hectare-1 under drought + shade 25 % stress condition, 1,27 tons hectare^{-1} in 50% shade condition, and 0,96 tons hectare^{-1} in drought + 50% shade condition.

Keywords: upland rice, tolerance, stress, drought, shade

INTRODUCTION

Food security is the Indonesian government's main program implemented to meet the nation's food needs. Improvement of food security is aimed at achieving security in the food sector by ensuring that each individual/household is able to be fed from national food production, which is reflected in the availability of adequate, quality, safe, equitable, and affordable food in all regions of Indonesia (Suharyanto, 2011). The target of the food security program is to increase national rice production so that all rice needs can be met from within the country. Increasing national rice production capacity can be done by utilizing potential uncultivated land. According to (Sukarman et al., 2012), dry land in Indonesia is still quite extensive, but its availability for the development of crop agriculture still faces various biophysical obstacles, such as soil fertility, and competes with non-food and non-agricultural cultivations.

Limited supply of water on dry land is the main obstacle in the cultivation of dry land rice varieties because rice plants need enough water during their growth phase. Water limitation also makes farming on dry land impossible to be performed throughout the year.

Light deficit in the cultivation of upland rice plants, which are classified as plants needing enough supply of light, can cause disruption of metabolic processes which in return have implications in the decrease of photosynthetic rates and decrease of carbohydrate synthesis (Yeo et al., 1994). This factor directly affects the low level productivity of upland rice varieties which are grown in the shades. Drought stress is an environmental factor that causes water to be unavailable to plants. Drought stress manifests in the unavailability of water in the roots and large water demand in leaf areas where the rate of evapotranspiration exceeds the rate of water absorption by roots (Hamim 2004). Drought stress is the most significant stress that affects the growth and production of crops. This condition can trigger physiological, biochemical, and molecular responses (Kalefetoğlu and Ekmekçi, 2005).

Both single and double stresses suffered by plants will reduce the yields of upland rice accession. One effective effort to overcome this obstacle is by testing and identifying the morphological and physiological characteristics of rice plant varieties against drought and low light intensity and their relevance to growth and yield. Therefore, this study was conducted to determine the growth and yield of Gorontalo local upland rice varieties against drought and field shade stresses.

MATERIALS 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 accession, 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 stress) (Sulistyono et al., 2012). 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 + 25% shade, drought + 50% 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 ground water 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, water supply was given continuously and the flooding of the water level was maintained at 1.5 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 condition 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 fertilizer 200 kg N/Ha, P fertilizer 100 kgP_2O_5/ha and K fertilizer 50 kg K_2O/ha which were given 1 week after planting. The data obtained was analyzed by variance. If an influence were found, then the test would be continued by using the Honestly significance difference (HSD) test at the 5% real level. The variables observed were:

1-Root length, measured from the base to the end of the root,

2-Leaf width, measured based on the method of length x width. The calculation of leaf width is based on the following equation (Sitompul, 2016).

Leaf Width (cm^2) = c x l x w

c : constant
l : Leaf Length
w : Leaf Width

3-Relative Growth rate (RGR), the growth rate of plant measured by the original dry weight. RGR is used to determine the individual growth of plant (Sitompul, 2016).

$$\text{RGR } (g.g^{-1}.day^{-1}) = \frac{\ln(w2)-\ln(w1)}{t2-t1}$$

w : plant's dry weight (g. $plant^{-1}$)
t : observation time (day)

4-Net Assimilation rate (NAR), the ability of the leaf to yield biomass by each leaf width per time (Sitompul, 2016):

$$\text{NAR } (g.cm^{-2}.day^{-1}) = \frac{(W2-W1)(\ln(A2)-\ln(A1))}{(T2-T1)(A2-A1)}$$

W : Total Dry Weight
A : Leaf Width
T : Observation Time

5-Total productive tillers/seedlings, measuring all tillers/seedlings in each plant's clump. Observation was conducted in the end of generative phase.

6-Empty grain percentage (%), the comparison of weighted grain and empty grain against the total grains,

7-Crop production.

RESULTS

Observation of plant growth in this study took place in July to October, 2017. The average air temperature in the study locations ranged from 26 to 27.2 ^{0}C. Monthly rainfall distribution according to the Institute for Meteorology and Geophysics in the study locations between July and August was medium with monthly rainfall between 100 - 300 mm, while in September and October rainfall was low at between 0-100 mm.

The results of the variance analysis showed a real interaction between drought and shade treatments on root length and leaf area, relative growth rate, net assimilation rate, productive tillers, percentage of empty grain, and yield variables.

The root size of Ponda Merah accession with treatment of drought + 0% shade was longer on all plant ages compared to other treatments (Table 1).

The root lenght of Ponda Merah accession treated with drought + shade 50% stress was shorter at the age of 120 and 150 days after planting and was not significantly different from the control treatment, drought control + 25% shade, and drought control + 50% shade. According to Farooq et al., (2008), drought stress tends to increase plant root length and crown root ratio. This is due to the effort of the plant to reach deeper soil layers, because in general the deeper layers have greater moisture than the soil in the upper layers (Breseghello et al., 2008).

The size of Leaf of drought control treatment + 50% shade was wider at plant age 60, 120 and 150 days after planting and leaf size drought control treatment + 25% shade 90 days after planting wider than other treatments. Meanwhile, the leaf size of plant treated with drought + 0% shade stresses tended to be narrow at plant age 120 and 150 days after planting (Table 2). Tolerant shaded plant will maximize the captured of sunlight by widening the leaves. According to (Mohr and Schopfer 1995), the leaf of shaded plants will be thinner and wider due to the reduction of shades and mesophyll cells.

The relative growth rate of Ponda Merah accession was higher at the beginning of the observation and decreased with the increasing of age. But this did not apply to the control treatment and drought + 25% shade control treatment. The second relative growth rate of this treatment increased at the age of 90-120 days after planting and then fell at the time of harvest. At the end of the observation, the treatment of drought + shade of 25% stresses showed higher relative growth rate and the control treatment had a relatively lower growth rate than other treatments (Table 3). The results of study by Maisurah (2015) stated that drought stress causes inhibition of leaf area increase, relative growth rate, and net assimilation rate.

Net assimilation rate of drought control treatment + 0% shade in 120-150 days after planting period was not significantly different from net assimilation rate of drought control + 25% shade, drought control + 50% shade, drought stress + 0% shade, and drought stress + shade 50 %. The net assimilation rate of drought stress + 25% shade was higher, i.e 2.13 $mg.cm^{-2}.\ day^{-1}$ compared to other treatments. (Table 4).

The relative growth rate (RGR, $g\ g^{-1}day^{-1}$) is therefore a key variable in influential models in plant ecology (Grime 2001). The net assimilation rate of plants reflects plant growth performance under specified condition (Tomlinson et al., 2014). Net Assimilation rate to be the primary determinant of relative growth rate. Net assimilation rate had an effect on the relative growth rate. Increasing the value of the net assimilation rate would result in an increase in the relative growth rate. The coefficient of determination (R2) between the relative growth rates at the age of 90 to 120 days after planting was 8.70% and at age 120-150 days after planting was 9.72%. This explains that the net assimilation rate affected the relative growth rate which was at 4.69% in observations at 60-90 days after planting, and increased in the age of 90 to 120 days after planting to 8.70% and to 9.72% at the age of 120- 150 days after planting. This is in line with the results of Shipley (2006) stating that the Net Assimilation Rate (NAR) determines the relative growth rate (RGR) and (Setyowati et al., 2014) who stated that the NAR value is positively correlated with RGR so that this NAR can be used as the main determinant of the RGR value.

Biplot analysis in Figure 2 explains the total diversity that can be explained was 84.33%. The figure showed that the Net assimilation rate (NAR) and Relative growth rate (RGR) and root length were the most variables affected by drought and shade stresses. The angle formed between these variables is less than 90^0 which indicated a positive correlation between the Net assimilation rate (NAR) and the Ralative growth rate (RGR). The longest magnitude in the Relative growth rate (RGR) variable indicated that the RGR was the most dominant variable in determining rice yield. The results of study by Osone, Ishida, & Tateno (2008) stated that the RGR is the product of NAR and SLA, where NAR is widely the net result of carbon gain (namely photosynthesis) and carbon losses (i.e. respiration, exudation, and volatilization) shown per unit leaf area. According to Shipley, (2006) if one had to choose a single growth component then the best indicator of RGR would be NAR, irrespective of plant type or whether the comparison was made in a constant environment or across environments

Both drought + 50% shade stress treatment and drought + 50% shade control treatment had a smaller number of productive seedlings/tillers, 4.00 tillers and 5.25 tillers respectively. This result was not significantly different from drought + 50% shade control treatment. The empty grain percentage of plants treated with drought + shade was 50% higher and significantly different from other treatments. Meanwhile, the control treatment had a lower empty grain percentage at 12.25% (Table 5).

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

Treatments	Root Length (cm)					
	0% Shade		25% Shade		50% Shade	
	-----------60 dap ------------					
Control	13,25	c	11,88	d	13,53	c
Drought stress	16,30	a	14,93	b	12,28	d
HSD 5%	0,97					
	-----------90 dap ------------					
Control	14,35	c	15,18	bc	15,00	bc
Drought stress	17,98	a	16,98	a	16,78	ab
HSD 5%	1,79					
	-----------120 dap ------------					
Control	16,13	bc	16,40	bc	16,60	bc
Drought stress	19,85	a	17,70	b	15,60	c
HSD 5%	1,66					
	-----------150 dap ------------					
Control	16,03	c	16,53	c	17,63	bc
Drought stress	19,98	a	18,60	ab	16,38	c
HSD 5%	1,89					

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

Table 2. Average of effect interaction between drought and shade treatments on leaf area variable

Treatments	Leaf area (cm^2)					
	0% Shade		**25% Shade**		**50% Shade**	
	-----------60 dap ------------					
Control	1035,69	a	1129,67	a	1169,36	a
Drought	592,07	b	1082,04	a	979,41	a
HSD 5%	201,81					
	-----------90 dap ------------					
Control	1453,70	bc	1595,06	a	1588,21	ab
Drought	1217,31	d	1456,33	bc	1380,27	c
HSD 5%	138,23					
	-----------120 dap ------------					
Control	1825,13	c	2027,36	ab	2052,68	a
Drought	1649,38	d	2005,58	b	1843,97	c
HSD 5%	30,12					
	-----------150 dap ------------					
Control	1999,55	c	2194,55	a	2208,05	a
Drought	1934,87	d	2153,10	b	1981,34	c
HSD 5%	33,40					

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

Table 3. Average of interaction effect between drought and shade treatments on relative growth rate variable

Treatments	Relative growth rate ($mg.g^{-1}.day^{-1}$)					
	0% Shade		25% Shade		50% Shade	
	-----------60-90 dap ------------					
Control	6,51	b	6,25	b	11,54	a
Drought	9,54	a	10,95	a	10,79	a
HSD 5%	2,29					
	-----------90-120 dap ------------					
Control	8,21	ab	9,65	a	5,81	b
Drought	7,03	b	5,88	b	8,19	ab
HSD 5%	2,57					
	-----------120-150 dap ------------					
Control	3,58	c	4,72	b	4,38	bc
Drought	4,10	bc	6,98	a	4,74	b
HSD 5%	0,82					

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

Table 4. Average of interaction effect between drought and shade treatments on the net assimilation rate variable

Treatments	Net assimilation rate ($mg.cm^{-2}$ day^{-1})					
	0% Shade		25% Shade		50% Shade	
	-----------60-90 dap ------------					
Control	1,91	ab	1,50	b	2,54	a
Drought	2,51	a	2,38	a	2,39	a
HSD 5%	0,69					
	-----------90-120 dap ------------					
Control	2,75	a	2,72	a	1,67	b
Drought	2,11	ab	1,49	b	2,34	ab
HSD 5%	0,79					
	-----------120-150 dap ------------					
Control	1,37	b	1,61	b	1,44	b
Drought	1,40	b	2,13	a	1,54	b
HSD 5%	0,34					

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

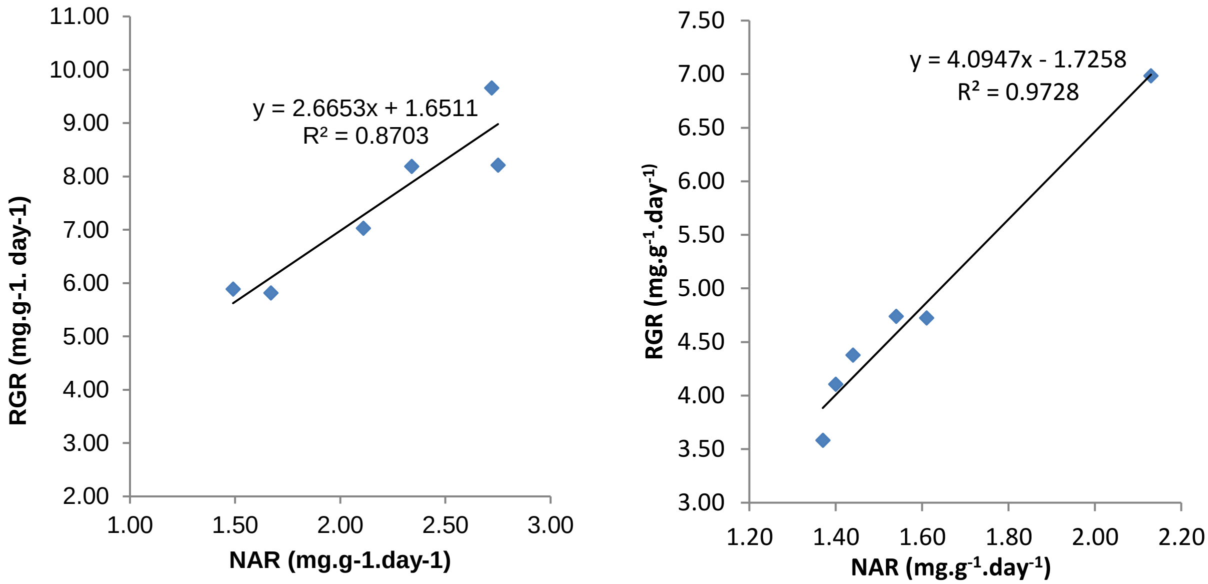

Figure 1. Relationship between relative growth rate (RGR) and net assimilation rate (NAR)

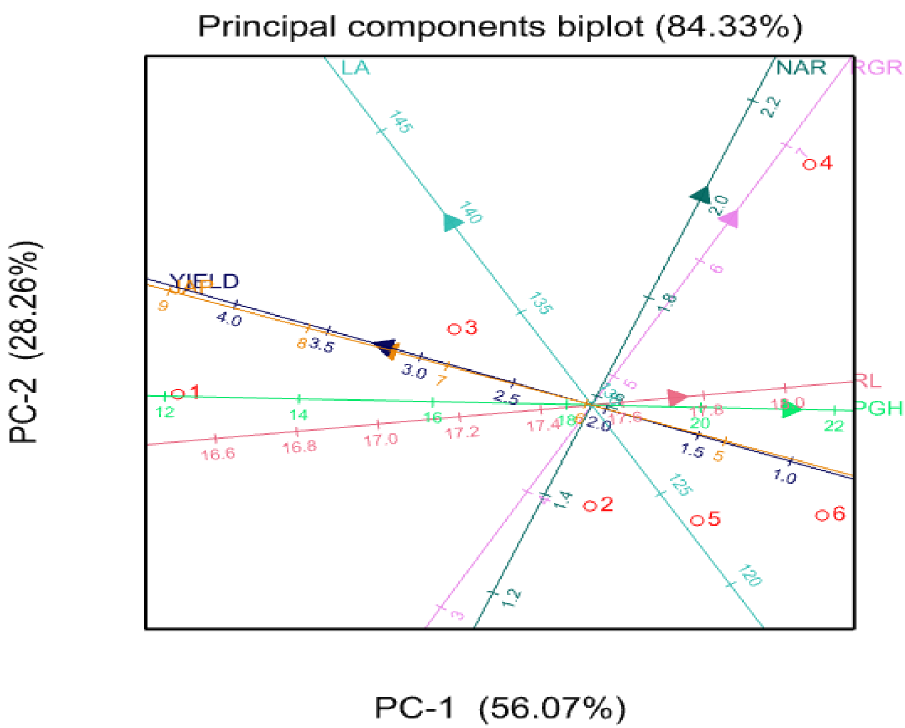

Figure 2. Principal component biplot Morphological and Physiological Character of Ponda merah

Table 5. Average effect of interaction between drought and shade treatments on the yield component variable

Treatments	Yield component					
	0% Shade		25% Shade		50% Shade	
	-----------Total productive tllers------------					
Control	8,50	a	7,00	b	4,50	cd
Drought	6,50	b	5,25	c	4,00	d
HSD 5%	1,08					
	-----------Empty grain percentage (%) ------------					
Control	12,25	f	17,75	d	19,00	c
Drought	16,50	e	20,75	b	24,00	a
HSD 5%	0,79					
	-----------Yield (ton.ha^{-1} mdg)------------					
Control	4,20	a	2,87	b	1,27	c
Drought	1,64	c	1,51	c	0,96	c
HSD 5%	**0,91**					

Numbers followed by the same letters in each column are not significantly different at α = 5%
mdg : Milled Dry Grains

Ponda Merah accession was able to produce 1.64 tons. hectare^{-1} milled dry grain under drought stress condition, 2.87 tons. hectare^{-1} under 25% shade condition, 1.51 tons. hectare^{-1} under drought + 25 % shade stress condition, 1.27 tons. hectare^{-1} in 50% shade condition, and 0.96 tons. hectare^{-1} in drought + 50% shade stress condition

CONCLUSION

Gorontalo local upland rice Ponda Merah accession is a plant that is able to adapt to both single stress condition and combination of drought and shade stress condition. This is characterized by the ability of the plant to continue growing in the environment where water and light are limited indicated by root extension, leaf area, relative growth rate, net assimilation rate, and relatively high yield components. Gorontalo upland rice Ponda Merah accession is able to produce milled dry grain of 1.64 tons hectare^{-1} under drought stress condition, 2.87 tons. hectare^{-1} under 25% shade stress condition, 1.51 tons hectare^{-1} under drought + 25% shade stress condition, 1.27 tons hectare^{-1} in 50% shade stress conditions, and 0.96 tons hectare^{-1} in drought + 50% shade stress condition.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

AA designed and performed the experiments and also wrote the manuscript. AA, LS, and BG, performed of local upland rice and carried out the data analysis. AA and MDM designed experiments and reviewed the manuscript. All authors read and approved the final version.

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