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Growth of Upland Rice in Variable Soil Water-holding Capacity.

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ABSTRACT

The experiment of upland rice (*Oryza sativa* L.) species of cv. *Bakala* and *Pehela* from South-east Sulawesi, and cv. *Ernina* and *Leimea* from East Timor were conducted – during March to August 2015 in different soil water levels: 25%, 50%, 100% and 150% water holding capacity (WHC). This experiment was designed in 4x4 Randomized Block Design referring to the utilization of four WHC and four rice cultivars. Each treatment was completed with three replications. This experiment was conducted in a plastic house as pot culture at Faculty of Agriculture, Halu Oleo University. A significant difference between treatment was tested by Duncan's Multiple Range Test, $p \leq 0.05$. The results indicated that water application at the different level of WHC did not significantly affect plant height, root and shoot dry matter, rice maturity and grain weight but it was significantly affected the number of maximum tillers, flowering stage, number of productive tillers, number of filling grain per panicle, and dry weight of grain. All cultivars showed with highest significant differences on agronomic performance, except on root/shoot ratio. Through this series of experiment, it is concluded that cv. *Bakala* and *Pehela* which are originally from Southeast Sulawesi produced higher grain dry matter than those of cv. *Ernina* and *Leimea* from East Timor. Cv. *Bakala* was found more adaptable to dry condition (25 % WHC) and cv. *Pehela* to normal moisture soil condition (100 % WHC).
Keywords: Agronomic, Diversity, Soil, Water-holding capacity, Upland rice.

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INTRODUCTION

Upland rice contribution to total rice production in Indonesia is very low compared with wetland rice production, due to the reason that upland rice cultivation is still traditionally done by shifting-cultivation, slashing and burning, rain fed, and without fertilizer and pesticides application [1], [2], [3]. The centre of upland rice production in Southeast Sulawesi Province is located in Konawe and South Konawe Regencies both covering an estimated cultivated area of 8.175 ha to 10.243 ha, with approximate total production at 25,034 t to 32,121 ton year^{-1} . The productivity of upland rice in both regions were still low (3.062 to 3.136 t/ha) dry grain, respectively [1] [4]. Many efforts have to be done to increase upland rice production through the development upland rice that tolerant to shade [5], increasing seed viability [6], even through plant breeding [7].

Land preparation, seed production and seeding by *Tolakinese* (a local ethnic) were previously explained by [2] and [3]. Slashing and burning was commonly commenced in August to October (during dry season period), and keeping cool-dawn during rainy season in November, and seeding conducted in December to January (during rainy season period), circularly. Cropping system of upland rice was mono-culture, or mixed-strip culture with corn and some kinds of vegetable. The distance of rice seeding was 25cm x 40cm inserted in among corn or vegetable rows, without fertilizer and pesticide treatments. Traditional farmers protected their crops from wild pigs and sparrows by making fence and bird-guards around. Harvest time of upland rice was in May by a farmer group who was contributing in prior land preparation and rice seeding.

MATERIALS AND METHODS

The experiment was conducted from April to August 2015, in a plastic house at Field Centre of Faculty of Agriculture, Halu Oleo University. There were four levels of water application: 25%, 50%, 100% and 150% of maximum soil water holding capacity (WHC) using 8.0 kg/pot air dried soil. These water application was equivalent to 920 ml/pot for 25% WHC (W-1), 1,840 ml/pot for 50% WHC (W-2), 3,680 ml/pot for 100% WHC (W-3) and 5,520 ml/pot for 150% WHC (W-4). Pot size was 25.0 cm diameter x 30.0 cm height. Measurement of WHC was explained in [8]. Fertilize on each pot with NPK (15:15:15) was 300 kg ha^{-1} divided into two times application. First, It was 200 kg ha^{-1} as basal application and second, 100 kg ha^{-1} at 40 days after seeding (DAS).

There were four cultivars tested, i.e. *cv. Bakala* (Cv-1), *cv. Ernina* (Cv-2), *cv. Pehela* (Cv-3) and *cv. Leimea* (Cv-4). Cv-1 and Cv-3 were collected from Lalosinga and Lalekaa villages, Palangga and Mowila Districts of South Konawe Regency, Province of Southeast Sulawesi as shown in **Figure 1**, while cultivars *Ernina* and *Leimea* were introduced from Timor Leste. Each pot was seeded with three seeds and then thinned out to two plants/pot. One plant was harvested in 70 days after seeding and the rest one after the mature stage.

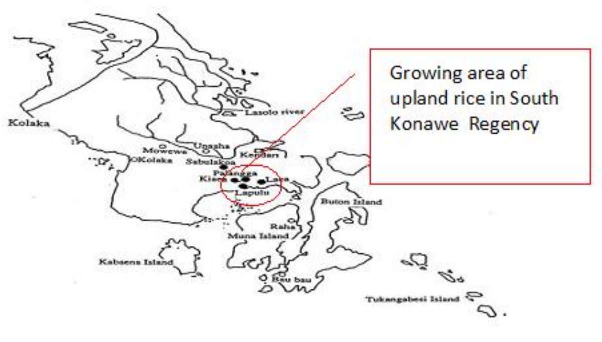

Figure 1. The map of Southeast Sulawesi Province and typical of upland rice farming in this region.

Soil moisture was maintained every two days by weighting pots and replaced of lost water. Chemical properties of soil and water used in this experiment were shown in **Table 1**. Soil pH was measured by calomel electrode method [9], total nitrogen by colorimetric method [10], P_2O_5 availability by Bray-2 [11], cation exchange capacity (CEC) by at atomic absorption spectrometer [12], exchangeable potassium, magnesium and calcium by ammonium acetate methods [13], and soil organic content by Walkley-Black method as explained in [14].

Table 1. Chemical properties of soil and water used in this experiment

Chemical Analysis	Soil	Chemical Analysis	Water
pH (H_2O)	4.95	pH (H_2O)	6.96
Total-N (%)	0.26	Total-N (%)	0.51
Bray-2 P_2O_5 (ppm)	8.24	Bray-2 P_2O_5 (ppm)	0.25
K_2O (me/100 g soil)	21.43	K (ppm)	8.42
Ca (me/100 g soil)	2.32	Ca (ppm)	0.97
Mg (me/100 soil)	0.50	Mg (ppm)	0.37
CEC (me/100 g soil)	24.28		
C-organic (%)	1.69		

Plant height, tiller number, flowering and maturity stage was measured during experiment, root and shoot dry weight measured after oven dried at 70° C for 24 hours. The experiment was designed in Randomized Block Design (four water levels x four upland rice cultivars) with three replications. Effect of treatment was evaluated by Duncan's Multiple Range Test (DMRT), $p \leq 0.05$ [15].

RESULTS AND DISCUSSION

Grain Characteristics Of Upland Rice Cultivars

Basic characteristics of upland rice varieties in this experiment was explained by [3]. Eighty per cent of evaluated cultivars was determined as non-glutinous rice and the rest was glutinous ones as shown at Table 2. Farmer respondents explained that most of local varieties are aromatic rice with grain characteristics shown in Table 2. Grain cultivars characteristics are shown in Table 2 that Cv-1 and Cv-3 were tailed and Cv-2 and Cv-4 were non-tailed types. Brown rice color was reddish and white for Cv-1, and reddish for Cv-2, Cv-3 and Cv-4. Specific grain weight in Table 2 showed that all tested cultivars were decreased in grain weight when grown under sub-optimal water level. Cv-1 (*Bakala*) was more adaptable under sub-optimal soil moisture if compared with the other cultivars. It is indicated that cultivar introduced from Timor Leste Cv-2 and Cv-4) were more sensitive compared that with local varieties (Cv-1 and Cv-3)

Table 2. Grain characteristics of upland rice cultivars from South Konawe Regency

Cultivar	Group	Color		Grain types	Grain weight (g/1000 grain)*	Germination rate (%)
		Husk	Rice			
Bakala (Cv-1)	Glutinous	Yellow	White	Long	27.05 a	94
Ernina (Cv-2)	Non-Glutinous	Yellow	Reddish	Short	21.42 c	90
Pehela (Cv-3)	Glutinous	Yellow	Reddish	Long	24.62 b	92
Leimea (Cv-4)	Non-Glutinous	Yellow	Reddish	Short	22.51 c	90

*Values in column followed by different character was significantly different (DMRT, p = 0.05)

Growth at Different Level of Water Application

All cultivars showed significantly different response on different levels of water application as shown by plant height (data not shown), leaf area index, number of maximum tiller, shoot and root biomass, days of maturity and grain production as explained below.

Leaf area index (LAI).

Leaf area of Cv-1 was significantly higher compared with the other cultivars as shown in Figure 2. Leaves parameters with chlorophyll content is important agronomic and biological characters in relation to photosynthetic and respiration activities. Such a possibility that higher of shoot, root and grain biomass production of Cv-1 (*Bakala*) confirmed a correlation with leaf area index as explained by [16]. The functional efficiency of leaf (sources) and re-translocation of photosynthetic results could be determined in the higher production of grain (sink).

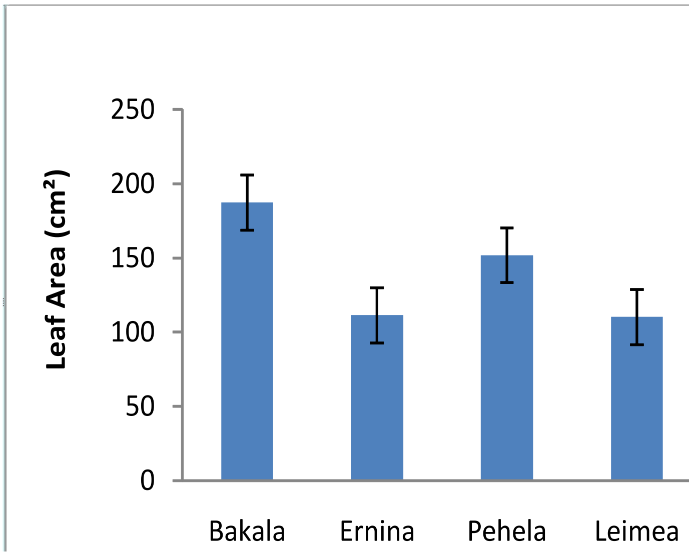

Figure 2. Leaf area of upland rice grown at different level of soil water holding capacity. Bars are standard error.

Number of Tillers

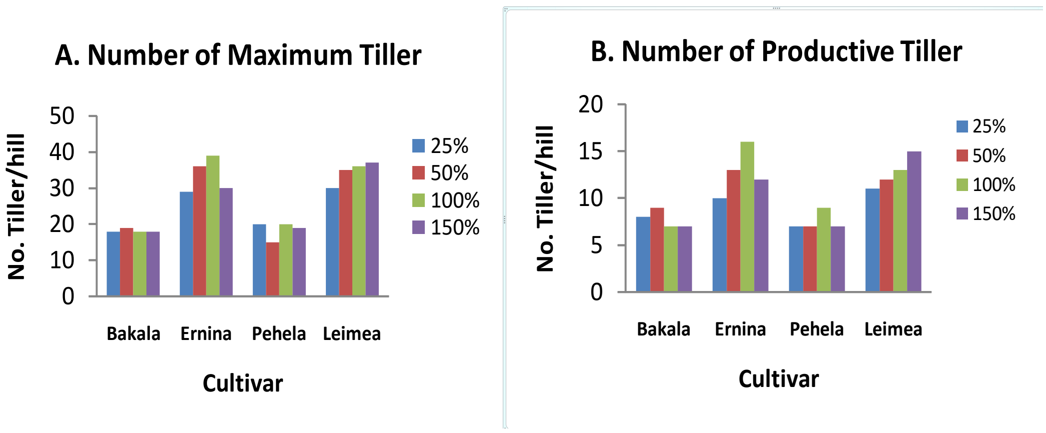

Figure 3. Number of maximum (A) and productive tillers (B) of upland rice grown at different level of soil water holding capacity.

The number of maximum and productive tiller of upland rice cultivars under different level of water application was significantly different on each cultivar as shown in Figure 3. The unique characteristic of Cv-1

(*Bakala*) and Cv-3 (*Pehela*) was that their tillers number did not decrease when water level decreased to 25% WHC, while Cv-4's (*Leimea*) was decreased when it was grown at dryer condition (data not shown). This indicated that local cultivars *e.g*. cultivar *Bakala* and *Pehela* were more adaptable to dry condition as well as they could grow at optimum water level (100% WHC). These findings also indicated that Cv-1 and Cv-3 might be more potential to adapt into rain fed paddy field environment.

Tiller number of each cultivar was various due to water application level and genetically potential. It was reported that, there were many factors affecting tiller production, *i.e.* water level, plant density, seedling age, seeding method and number of seed/hill [16] and [17]. Number of maximum tiller of all tested cultivars was not significantly affected by water level application. Cv-1 (*Bakala*) and Cv-3 (*Pehela*) produced lower number of tillers than those of Cv-2 (*Ernina)* and Cv-4 (*Leimea*) as shown in Figure 3.

Biomass Production

Root and shoot biomass production was significantly determined by water application as shown in Figure 4. The *Bakala, Ernina* and *Leimea* cultivars produced higher root biomass. In case of shoot dry matter , cultivar *Bakala* was much higher than those of three cultivars as shown in Figure 4 A. These phenomena showed that cultivar *Bakala* was more adaptable to the variable change of soil water condition as compared to the other three cultivars. The higher shoot production of cultivar *Bakala* might be induced by the higher root biomass production as shown in Figure 4 B. This indicated that higher of root biomass production is one of the important mechanism of cultivar in adapting the change of soil moisture, nutrient level, and respiration in the rhizosphere [18], [19], [20], and [21]. The same finding was observed on two local variety *e.g. cv. Ngalaru* and *cv. Uba* [3].

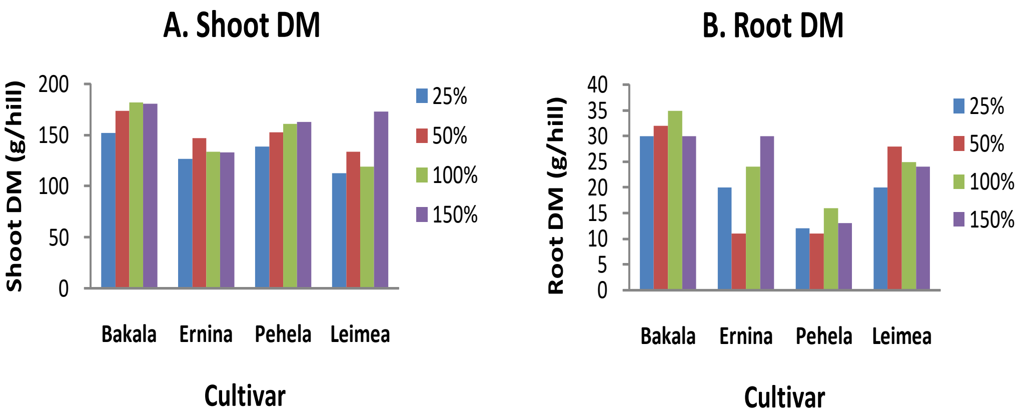

Figure 4. Shoot (A) and root (B) dry matter (DM) of upland rice at 70 days after seeding (DAS) grown at different level of soil water holding capacity.

Dry soil condition (at 25% WHC) has significantly hindered panicle emergence on cultivar *Bakala* and cultivar *Pehela* (Figure 5 A) and hindered panicle emergence following the decrease in SWHC to 25 % as shown in Figure 5. B. Harvesting days of upland rice was not significant influenced by different water treatment (data not shown), however, maturity stage was significantly dependant on water treatment. Dry soil condition (at 25% WHC) was significantly hindered panicle emergence on cultivar *Bakala* and cultivar *Pehela* as shown in Figure 5 B. The obstruction of panicle emergence was significantly delayed grain maturity on cultivar *Bakala* and *Pehela*. Those cultivars were harvested at 112 and 114 DAS, which was longer than 96 DAS of cultivar *Ernina* and *Leimea* harvesting days.

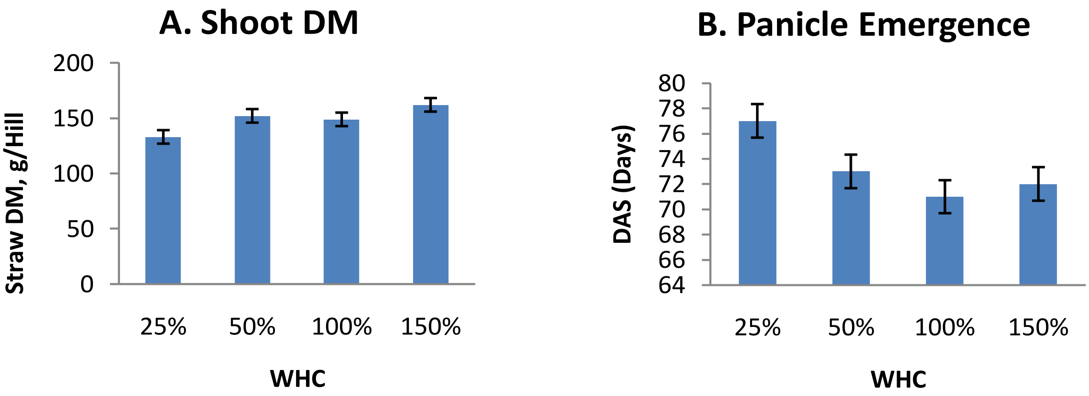

Figure 5. Shoot DM (A) and days of panicle emergence (B) of upland rice grown at different level soil water holding capacity. DM and DAS are same with an explanation in Figure 4. Bars are standard error.

CONCLUSION

This experiment concluded that all cultivars of upland rice was shown difference responses to soil water regimes application. The lower soil water holding capacity (dryer condition) was significantly reduced shoot dry matter, root biomass and panicle emergence. Water shortage in the rhizosphere of upland rice at panicle emergence was the main obstacle and sensitive stage of upland rice production

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