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Shoot elongation rate in North Sulawesi local rice (*Oryza sativa* L.) under flooding and drought stress at the vegetative phase was different from the reproductive phase

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A study was carried out to compare the shoot elongation rate as response to flooding and drought stress in four cultivars of North Sulawesi local rice (Superwin, Ombong, Temo and Burungan) at the vegetative and reproductive phases. The flooding and drought treatments were applied for 14 days in the glasshouse using polyvinyl chloride (PVC) pots (500 mm height and 125 mm diameter). The treatments at the vegetative phase consisted of watering until 100% field capacity or control (WW), no watering or drought (WD), and 50 cm submergence above the pots (WL). The treatments at the reproductive phase were watering until 100% field capacity or control (WW), watering until 50% field capacity or drought (WD), and 50 cm submergence above the pots (WL). At the vegetative phase, the shoot elongation rates in Superwin, Ombong, and Burungan under drought were lower than under control and flooding. At the reproductive phase, however, the shoot elongation rates in Ombong, Temo, Burungan under flooding were higher than under control and drought.

Keywords:drought, flooding, glasshouse, reproductive, vegetative.

INTRODUCTION

Global warming resulted in the climate change that largely affected many aspects in our life including agriculture sector. In agriculture sector, crop plants are the most sensitive organism to climate change because generally crop plants are annual plants that are relative sensitive to water shortage and water surplus. The decrease of plant production is a consequence of the extreme climate phenomenon such as uncertain flooding and drought. Regarding with this condition, it is required to apply the strategy of adaptation, i.e. applying the appropriate planting periods, planting the superior cultivars that are tolerant to drought, flooding and salinity as well as developing water conservation management to anticipate this climate change (Surmaini et al., 2011).

One of the principal strategy of economy development in Indonesia is developing Indonesia economy corridor. The development theme of Celebes-North Moluccas corridor is The Production Centre and Processing of National Agricultural, Plantation and Fishery Product and the strategic purpose is increasing the capability of Celebes area to be national food security pillar by food production increment. This purpose is important because Celebes is the top three food producers in Indonesia that contribute 10% of national rice production (Menko Bidang Perekonomian RI, 2011). Therefore, the local rice cultivars of North Sulawesi that are resistant to drought and flooding are required to achieve this strategic purpose.

Rice is the principal source of carbohydrate that is consumed by almost 3 billion worldwide inhabitants besides maize, sago palm and other edible tubers. Rice plants are able to fulfill about 60-80% calorie of Indonesian people (Damardjati, 1988). There are three groups of rice based on the environmental conditions, i.e. lowland rice with irrigation system, rainfed lowland rice and rainfed upland rice (Bouman et al., 2007).

Rice cultivars with high stable yields and high adaptation to numerous environmental condition are required to be developed in countries with increasing rice consumption, including Indonesia (Akter et al., 2014). The promising rice cultivars that are adapted to various environmental condition should be evaluated because the environmental factors of rice fields, such as types of land use, types of soil, techniques of cultivation, cropping patterns on growing season, are very diverse in Indonesia (Aryana and Wangiyana, 2016). The potency of biodiversity of local rice cultivars in North Sulawesi has not yet been used to ensure the availability of food source. This condition is caused by limited information of superior characteristics as drought and/or flooding resistant rice cultivars. Flooding caused by high rainfall in the wet season often inundates rice fields, whereas drought happens in the dry season (Hermanasari et al., 2011).

The evaluation of drought and/or flooding resistance in local rice cultivars such as Superwin, Ombong, Temo and Burungan(Kadis Pertanian dan Peternakan Provinsi Sulut 2013) as source of North Sulawesi germplasm is required to be carried out.This study compared the shoot elongation rate among these four local rice cultivars in North Sulawesi at the vegetative and reproductive stages. The results of this study could be considered to decide whether these four local rice cultivars could be used in the adaptation strategy for anticipating climate change resulted from global warming. The availability of these drought and flooding resistant local rice cultivars would increase the capability of North Sulawesi Province as the pillar of national food security by achieving some targeted programs. These programs were self-sufficiency in rice that was delayed in 2010, "The achievement of 10 million ton surplus in rice production" and the availability of rice reserves under emergency condition.

MATERIALS AND METHODS

Preparation of Plants before Treatment

Rice seeds were submerged in salty water for 2 hours and the sunken seeds were used. The selected seeds were sterilized using 2% commercial bleaching for 2 minutes, then rinsed with sterilized water. The sterilized seeds were then germinated for 4-5 days in the containers filled with black sand that was watered until field capacity. The germinated seeds were sown at 10 mm depth in pots (1 germinated seed for each pot). The pot was polyvinyl chloride (PVC) pipes (125 mm diameter and 500 mm height) and filled with the media that consisted of soil, manure and rice husk with the ratio 5:1:1. The media in the pots was watered until field capacity before sowing (Nio et al., 2011; Nio and Ludong, 2013; Nio et al., 2018). All plants in the pots were maintained by watering them with fertilizer solution (10 g Gandasil D® in 10 L water) until field capacity. The components of Gandasil D was 20% N total, 15% P_2O_5, 15% K_2O, 1% $MgSO_4$, Mn, B, Cu, Co, Zn, aneurin, lactoflavine, and nicotinic acid amide. Some gravels were put on the surface of the media in the pots to reduce the evaporation during the experiment. The plants were watered until field capacity every second day until 30 days after sowing (for experiment at the vegetative phase) and 100 days after sowing (for the experiment at the reproductive phase), then the treatments commenced.

Experimental Design and Treatment Application

This experiment was conducted in the glasshouse and consisted of 4 local rice cultivars (Superwin, Ombong, Temo and Burungan) with 3 replicates. The treatments at the vegetative phase were watering until 100% field capacity or control (WW), no watering or drought (WD) and 50 cm submergence above the pots (WL). The treatments at the reproductive phase were watering until 100% field capacity or control (WW), watering until 50% field capacity or drought (WD), and 50 cm submergence above the pots (WL). The period of all treatments was 14 days.

Data Collection and Data Analysis

Plant height was measured on day 0 (before treatment) and 14 days after treatment. The shoot elongation rate was determined by dividing the difference between plant height at 14 days after treatment and at day 0 by the duration of treatment (Ikhwani et al., 2010). The collected data were analyzed using Microsoft Excell 2013. Analysis of variance (ANOVA) and least significant difference (lsd) were used to identify significant differences ($P < 0.05$).

RESULTS

The morphological response of North Sulawesi local rice cultivars to flooding and drought stress based on the rate of shoot length was evaluated at the vegetative and reproductive phases. The shoot elongation rate in North Sulawesi local rice cultivars (Superwin, Burungan, Ombong and Temo) were determined based on the measurement of plant height. This parameter was observed as the morphological response under flooding and drought stress for 14 days at the vegetative and reproductive phases. The shoot elongation rate in these local rice at the vegetative phase (0,5-3,1 cm/day) was 50% higher than at the reproductive phase (0,7-1,7 cm/day). This study showed that shoot elongation rate in North Sulawesi local rice under drought and flooding stress at the vegetative phase was higher than at the reproductive stage (Figure 1 and 2).

The shoot elongation rate as a response to flooding and drought stress in these local rice cultivars was not significant at the vegetative stage (Figure 1). The higher shoot elongation rates were observed in Ombong and Burungan under control (watering until 100% field capacity) and Ombong under flooding, i.e. 3.08-3.15 cm/day. The shoot elongation rates in Superwin (0.5-2.4 cm/day) was lower than in Burungan, Ombong and Temo. The shoot elongation rates in Superwin, Burungan and Ombong under drought stress were lower than their rates under control and flooding.

The lowest shoot elongation rate was observed in Superwin under drought and flooding stress at the reproductive phase, i.e. 0.71-0.74 cm/day (Figure 2). The highest shoot elongation rate was in Burungan, Ombong and Temo under flooding stress, i.e. 1.67, 1.70 and 1.73 cm/day. The rate of shoot length in Burungan, Ombong and Temo under flooding stress were higher than under drought stress and control. The rate of shoot length in rice cultivars generally increased as response to flooding (Yulianida et al., 2014), whereas drought stress reduced the rate of shoot length in plants (Budiasih, 2009).

The drought stress at the vegetative phase decreased the shoot elongation rate in Superwin, Burungan dan Ombong, however, the drought stress at the reproductive phase reduced the shoot elongation rate only in Burungan and Ombong. Santoso (2008) reported that the increment of plant height commenced with the division and enlargement of the cells for shoot formation. The cells would divide and enlarge under turgid condition that was maintained by the water availability. Hoogenboom et al., (1987) demonstrated that shoot elongation rate of soybean decreased significantly for the plants that recievedreceived only rainfall and without supplemental irrigation during water deficit period. Santoso (2008) indicated that the increases of rice plant height in the soil with 25%, 50%, 75% and 100% of field capacity were 3.15, 3.44, 4.27 and 4.03 cm/day, respectively. Habiba (2015) showed that drought stress at the vegetative phase inhibited the increment of plant height in lowland rice cultivars, such as Inpari-10, Inpari-19, Inpari-23 and Inpari-24. The results of this study indicated that drought stress at the vegetative and reproductive stage did not affect the shoot elongation rate in Temo as one of the upland rice cultivar. The similar result was reported by Santoso (2008) that the increase of plant height in upland rice grown in the soil with lower water content was larger than in the soil with higher water content at the vegetative phase.

The shoot elongation rate during flooding period indicated the ability of rice cultivars to respond the environment condition with lower light intensity and CO_2 content (Ikhwani et al., 2010). The rice plant ability to lengthen the shoot was an adaptation strategy under stagnant partial flooding stress (Yulianida et al., 2014). The shoot elongation rate as response to flooding stress at the reproductive phase was significantly shown in Burungan and Ombong at the reproductive phase (Figure 2), however, this morphological response was not clearly observed at the vegetative phase (Figure 1). Shoot elongation in flooding-tolerant rice as response to submergence involved phytohormone, such as ethylene. This hormone initiated shoot elongation. With this shoot elongation the plant foliages were above the water surface and the plants were not suffering from the limitation of O_2 availability (Hattori et al., 2011). Under submergence condition, the metabolism of photosynthesis and respiration in most crop plants including rice were inhibited because of the deficiency of O_2 (Gribaldi et al., 2014) and the inhibition of direct exchange of CO_2 and O_2 between the cells and the air (Colmer and Pederson, 2008).

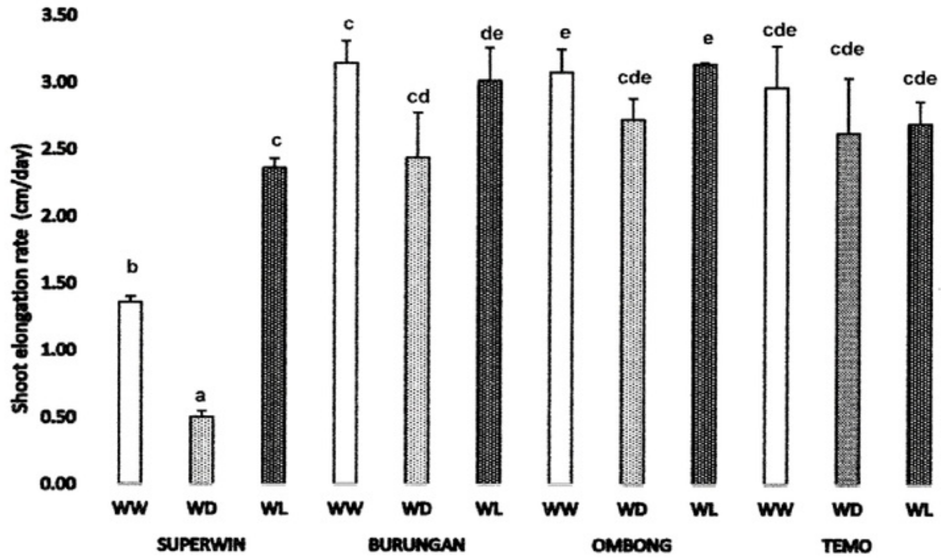

Figure 1. The shoot elongation rates in rice cv. Superwin, Ombong, Temo, Burungan after 14 days of drought and flooding stress (watering until 100% field capacity or control/ WW, no watering or drought/WD) and 50 cm submergence above the pots/WL) at the vegetative phase. Values are mean ± SE (n = 3). Significant differences (P<0.05) amongst the treatments wereindicated by different letters.

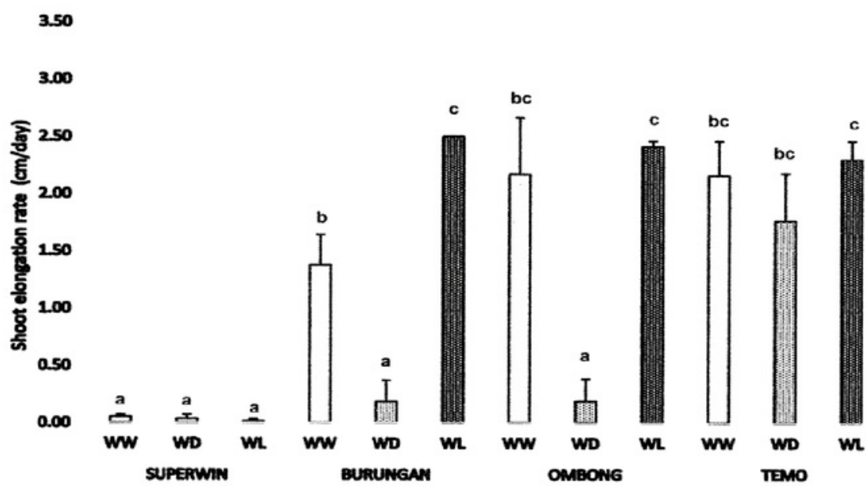

Figure 2.The shoot elongation rates in rice cv. Superwin, Ombong, Temo, Burungan after 14 days of drought and flooding stress(watering until 100% field capacity or control/WW, watering until 60% field capacity/WD and 50 cm submergence above the pots/WL) at the reproductive phase. Values are mean ± SE (n = 3). Significant differences (P<0.05) amongst the treatments were indicated by different letters

The evaluation of flooding and drought resistance in North Sulawesi local rice cultivars based on the shoot elongation rate revealed that morphological response at the reproductive phase was more significant than at the vegetative phase. Based on the shoot elongation rate as stress indicator at the reproductive phase, Temo was potential as flooding and drought resistant rice cultivar, whereas Burungan and Ombong were potential as flooding resistant rice cultivars.

CONCLUSION

The shoot elongation rates in rice cv. Superwin, Ombong dan Burungan under drought at the vegetative phase were lower than under watering until 100% field capacity and flooding stress for 14 days. The shoot elongation rates in rice cv. Ombong, Temo and Burungan under flooding at the reproductive phase were higher than under watering until 100% field capacity and drought stress for 14 days

CONFLICT OF INTEREST

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

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AUTHOR CONTRIBUTIONS

SAN designed the experiment, analyzed the data and also wrote the manuscript. RS collected the samples and carried out the laboratory work. DPML conducted the experiment in the glasshouse. All authors read and approved the final version.

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