Drought Resistance Analysis of the North Sulawesi Local Rice Based on the Root Characters

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Abstract. Rice is one of the important staple foods in Indonesia with carbohydrate as its major component. Rice germplasm is so diverse in Indonesia including in North Sulawesi Province, which has 4 local rice cultivars, i.e Superwin, Ombong, Temo and Burungan. Regarding with the food security program in this province as well as in Indonesia, a study was conducted to evaluate root characters (the number of adventitious roots, maximum root length, root dry mass, root:shoot ratio, the number of hardpan penetrated roots) as response to drought in these North-Sulawesi local rice cultivars grown in the soil mixture at the vegetative phase. The drought treatment consisted of three different intensities (watering until 100% field capacity/DA, watering until 50% field capacity/½TA and no watering/TA) for 2 weeks in the glasshouse experiment using polyvinyl chloride (PVC) pots with 125 mm height and 60 mm diameter. In general, the drought treatment decreased the number of adventitious roots, root dry mass, and root:shoot ratio The roots of Temo and Burungan were able to penetrate the hardpan (mixture of paraffin and vaseline that was equal to 12 bar hardness) under drought, but the capacities were low. Based on the root characters, Temo and Burungan had higher drought resistance than the other cultivars. The results of this research enriched the information of drought resistant rice selection that was easy, cheap and fast in the plant breeding program in North Sulawesi.

Keywords: Root hardpan penetration, vegetative phase, drought, glasshouse

Introduction

One of the main strategies in the economic development in Indonesia is developing economical corridor. The theme of economic corridor development in Sulawesi-Moluccas is "Centre of Production and Processing in National Agricultural, Plantation and Fishery Products" and the strategic aim is to increase the capability of Sulawesi area as the core of national food security program by increasing food production. This objective is very important as Sulawesi is the third food producer in Indonesia and contributes 10% of national rice production [1]. The appropriate selection method, therefore, is required to support this program by obtaining the drought-resistant rice.

Drought in the agricultural regions resulted in up to 50% yield losses or even complete crop failure [2]. The agricultural production in Indonesia, including in North Sulawesi, declined because of the long dry season. Drought negatively affected 29.222 ha rice field and there was 3.872 ha unproductive field during 2001-2006 [3]. The rice production in 89.197 ha field decreased drastically from about 447.672 tons to 34.643 tons in January-August 2009 as reported by the Department of Agriculture and Husbandry in North Sulawesi Province. In addition, the 14.164 ha lowland rice field was not productive [4]. The resistant-local-rice cultivars will be critically required for supplying rice availability in the dry season in North Sulawesi as well as in Indonesia.

Root characters influenced the plant capability to resist against drought. The rice root system was very sensitive to the low soil water content. Root system variation in rice was closely related to drought resistance [5]. Root was an important plant organ for water exploration and extraction, but it was relatively less studied rather than other plant organs. This research aimed to evaluate root characters (the number of adventitious roots, maximum root length, root dry mass, root:

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shoot ratio, the number of hardpan penetrated roots) as response to drought in the North-Sulawesi local rice cultivars (Superwin, Ombong, Temo and Burungan) grown in the soil mixture at the vegetative phase. The drought treatment consisted of three different intensities (watering until 100% field capacity/DA, watering until 50% field capacity/½TA and no watering/TA) for 2 weeks in the glasshouse experiment.

Materials and Methods

The experiment consisted of 4 North-Sulawesi local rice cultivars (Superwin, Ombong, Temo and Burungan) grown in 3 water regimes and 3 replicates, in a randomized complete block design. Seeds of rice were surface-sterilized with 2% commercial bleach for 2 min, washed with deionized water, and placed on the moist filter paper in Petri dishes in a dark cabinet. After 2 days, germinated seeds were sown at 10 mm depth. The 500 g of media in each pot (polyvinyl chloride /PVC) with 125 mm height and 60 mm diameter) was supplied, prior to planting, with a basal fertilizer (5g/10 L water) comprising 20% N total, 15% P_2O_5, 15% K_2O, 1% MgSO4, Mn, B, Cu, Co, Zn, aneurine, lactoflavine, nicotinic acid amide. The media was the mixture of garden soil, manure and bran (5:1:1) [6]. All pots were watered to field capacity by weight every second day until they were at the 2 fully-expanded leaf stage and the treatments were commenced. The hardpan layer (the mixture of paraffin and vaseline that was equal to 12 bar hardness) was used as pot base [7]. A week after sowing, gravel was added to the soil layer and each pot was placed above the plastic container that contained basal fertilizer. This condition enabled the roots grew through the hardpan [8]. The three water regimes were watering until 100% field capacity (DA), watering until 50% field capacity (½TA) and no watering (TA) at the vegetative stage for 2 weeks in the glasshouse.

The number of adventitious roots and penetrated roots through the hardpan were collected; the maximum root length was measured. Plant samples were dried at 70°C for 48 h and dry mass was recorded. The total root and total-above ground dry mass were recorded and root:shoot ratio was calculated. Soil water content was calculated as 100 x (fresh mass – dry mass)/dry mass. Fresh mass of each soil sample was recorded, the soil was dried at 105°C for 24 h, and the dry mass recorded [8]. Data were analyzed using ANOVA and least significant difference (lsd) was used to identify significant differences ($P < 0.05$, unless otherwise stated).

Results and discussion

The drought treatment decreased the number of adventitious roots (Fig. 1) and root dry mass (Fig. 2), i.e. the largest number was in DA and followed by ½ TA and TA treatment. The maximum root length was not different among the 4 rice cultivars and the treatments (data not shown). In addition, drought reduced the root:shoot ratio in the North Sulawesi local rice, except in Burungan. The root:shoot ratio in Burungan under water deficit (TA) was larger than in ½ TA and DA treatments (Fig. 3). The root hardpan penetration was observed in 4 rice cultivars under DA, in Ombong and Temo under ½ TA, and in Temo and Burungan under TA. The largest root hardpan penetration was in Temo and followed by Burungan, Ombong and Superwin (Table 1 and Fig. 4).

In general, soil water content in the treatments of watering until 100% field capacity (DA) and watering until 50% field capacity (½ TA) were 4-5 times larger than in treatment of no watering (TA) for Superwin, Ombong, Temo, and Burungan. Soil water content in DA, ½ TA, and TA were 27-35%, 23-35% and 6-8% respectively.

The root characters that supported the exploration and extraction of water were root depth, root density and root:shoot ratio [9, 10]. As one response to water deficit, the proportion of photosynthate supply to deeper layers in rice increased and accounted for maintenance of deep root mass [11] Translocation of photosynthate to deeper roots supported faster water extraction and plant growth in rainfed lowland rice under water deficit [12,13]. Root:shoot ratio was potential as dorught-tolerant indicator in rice at the vegetative phase [6]. This study indicated that the drought resistance in Burungan was higher than three other cultivars as the increased root:shoot ratio was observed in Burungan under drought.

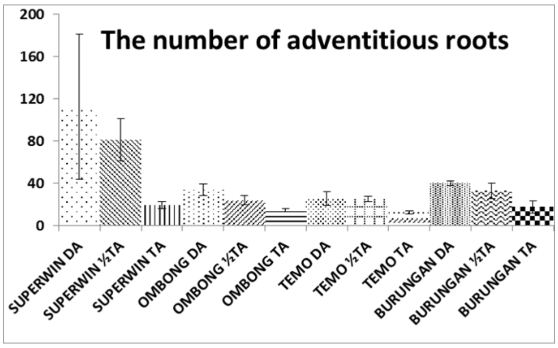

Figure 1. The number of adventitious roots in rice cultivar Superwin, Ombong, Temo and Burungan 2 weeks after drought treatments (watering until 100% field capacity/DA, watering until 50% field capacity/½TA and no watering/TA).

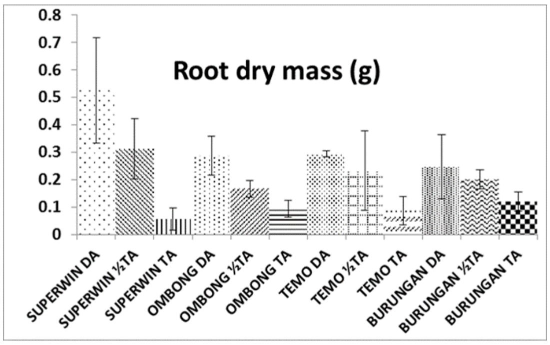

Figure 2. Root dry mass in rice cultivar Superwin, Ombong, Temo and Burungan 2 weeks after drought treatments (watering until 100% field capacity/DA, watering until 50% field capacity/½TA and no watering/TA).

The evaluation of root hardpan penetration was an efficient method to study drought resistance in plants. The bigger root ability to penetrate soil layer, the larger root distribution for absorbing water and solutes [5, 7]. The results showed that roots of Superwin, Ombong, Temo and Burungan were able to penetrate the hardpan, however, the ability was not significant under drought and the hardpan penetration was observed only in Temo and Burungan.

In general, Temo and Burungan were potential to be cultivated in the limited water availability conditions based on this evaluation of root characters. The further and detailed experiments, however, are still required to strengthen this conclusion.

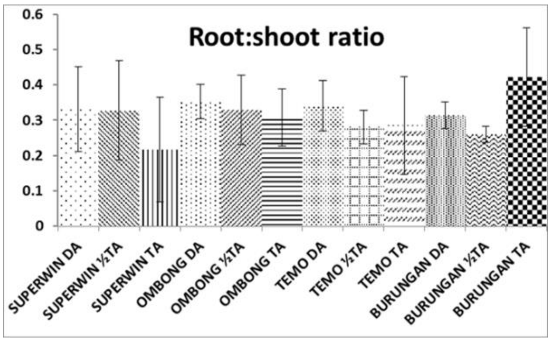

Figure 3. Root dry mass in rice cultivar Superwin, Ombong, Temo and Burungan 2 weeks after drought treatments (watering until 100% field capacity/DA, watering until 50% field capacity/½TA and no watering/TA).

Table 1. The number of hardpan penetrated roots in rice cultivar Superwin, Ombong, Temo dan Burungan 2 weeks after drought treatments (watering until 100% field capacity/DA, watering until 50% field capacity/½TA and no watering/TA)

Cultivar	Treatment		
	DA	½ TA	TA
Superwin	2	0	0
Ombong	5	2	0
Temo	9	7	1
Burungan	9	0	1

Figure 4. The roots that penetrated hardpan.

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Conclusion

The drought resistance analysis in the North Sulawesi local rice cultivars based on the root characters showed that root:shoot ratio was potential as drought resistance indicator. The root:shoot ratio in Burungan under drought was higher than under well-watered. The root hardpan penetration under drought was observed in Temo and Burungan, however, the capacities were low. It could be concluded that Temo and Burungan were potential to be cultivated in the limited water area.

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