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SHORT COMMUNICATION: MORPHOPHYSIOLOGICAL RESPONSE TO PARTIAL SUBMERGENCE AND WATER DEFICIT IN NORTH SULAWESI LOCAL RICE

RESPONS MORFOFISIOLOGIS PADI LOKAL SULAWESI UTARA TERHADAP KEBANJIRAN DAN KEKERINGAN

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Abstract

Flood and drought are two disasters that resulted in crop failure, including rice production. The objective of this study was to evaluate the morphophysiological characteristics of North Sulawesi local rice (*Oryza sativa* L.) cultivars as response to partial submergence and water deficit at the vegetative phase based on plant height, number of leaves, root length and volume, and leaf total chlorophyll concentration. The factorial experiment in Completely Randomized Design consisted of four rice cultivars (Superwin, Ombong, Temo, and Burungan) and three treatments (well-watered, partial submerged, and water deficit). The treatments commenced at four-fully-expanded leaf stage for 14 days. Plant height and leaf number were recorded on day 0 (before the treatments commenced), 7, and 14 after treatments. The length and volume of roots as well as total chlorophyll were recorded at 14 days after treatment. Root length was potential indicator of partial submergence and water deficit as it was higher under partial submergence and water deficit than well-watered. Root volume was potential indicator of partial submergence as it was larger under partial submergence than water deficit and well-watered. The partial submergence and water deficit tolerance of North Sulawesi local rice should be further evaluated based on the other characteristics.

***Keywords*:** Morphophysiological; Partial submergence; Rice; Water deficit

Abstrak

Kebanjiran dan kekeringan merupakan bencana alam yang mengakibatkan kegagalan panen, termasuk produksi beras. Penelitian ini bertujuan untuk mengkaji karakterisitik morfofisiologis pada padi (Oryza sativa *L.) lokal Sulawesi Utara sebagai respons terhadap kebanjiran dan kekeringan pada fase vegetatif berdasarkan tinggi tanaman, jumlah daun, panjang, dan volume akar serta kandungan klorofil daun. Percobaan faktorial dalam Rancangan Acak Lengkap ini menggunakan empat kultivar padi (Superwin, Ombong, Temo, dan Burungan) serta tiga perlakuan (diairi, digenangi, dan tidak diairi). Perlakuan dimulai pada saat tanaman mempunyai empat daun yang berkembang penuh selama 14 hari. Tinggi tanaman dan jumlah daun diamati pada hari ke-0 (sebelum perlakuan dimulai), hari ke-7, dan 14 setelah perlakuan. Panjang dan volume akar serta kandungan klorofil daun diukur pada 14 hari setelah perlakuan. Panjang akar merupakan indikator yang potensial untuk kebanjiran dan kekeringan karena panjang akar saat kebanjiran dan kekeringan lebih besar daripada diairi. Volume akar merupakan indikator yang potensial untuk kebanjiran karena volume akar saat kebanjiran lebih besar daripada saat kekeringan dan diairi. Toleransi padi lokal Sulawesi Utara terhadap kebanjiran dan kekeringan perlu dievaluasi lebih lanjut berdasarkan karakteristik lainnya.*

***Kata Kunci**: Kebanjiran; Kekeringan; Morfofisiologis; Padi*

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INTRODUCTION

Indonesia is a country that has suffered from many natural disasters, including floods and droughts according to the National Agency for Disaster Management research reports (BNPB, 2013). Between 2000 and 2011, 77% of the national disasters that occurred were hydrometeorological disasters. It was estimated that there were 300,000 ha of paddy fields that had been damaged by flooding and water deficits in Indonesia, and crop failure occurred in 60,000 ha of paddy fields (Manikmas, 2008). One cause of these disasters was the impact of global climate change in Indonesia, including high rainfall in several places so that sea-level rise which resulted in submergence and due to global climate change in Indonesia also caused prolonged water shortages.

Rice (*Oryza sativa* L.) as an important crop plant supplied the food requirement for most of the world's inhabitants, especially in the continental Asia, including Indonesia (Indraswati et al., 2015). About 95% of the Indonesian population depend on rice as food source and consume rice 200% higher than the average world rice consumption, i.e. 139 kg per year (Setiawan et al., 2016). In accordance with Statistics Indonesia research report on rice production in 2019 was estimated at 54.60 million tons or decreased by 4.60 million tons compared to 2018 (BPS, 2020).

Rice plants in Indonesia have been subjected to submergence and water deficit stress. Extreme water deficits are called drought stress. Drought stress can decrease the agricultural production until 50% or even result in crop failure when the stress becomes worse (Sopandie, 2013). Rice plants indicated certain morphological and physiological responses under submergence and drought stress. Rice is most sensitive to submergence at the vegetative phase, which is about one week after planting (Yulianida et al., 2014). The rice plant height increased gradually under submergence (Ikhwani, 2013; Poluan et al., 2017). Submergence caused the leaf surface to be covered with water so that the leaves turned yellow (senescence), thereby inhibiting carbon fixation in the photosynthesis process during and after submergence. Inhibited carbon fixation resulted in decreased photosynthesis, so that the leaves were damaged. Responses to submergence consisted of decreased yields, slow harvest and changes in plant growth components and yield components (Ikhwani, 2013) as well as a decrease in the number of leaves (Poluan et al., 2017). Water deficit affected all aspects of plant growth, such as physiological, biochemical, anatomical, and morphological processes. The level of losses in plants due to drought depended on several factors, including the time drought commenced, the intensity and the duration of water deficit (Nio, 2010). Water deficit induced by polyethylene glycol 8000 in local rice from North Sulawesi decreased the content of chlorophyll a and total (Nio et al., 2019) and the relative water content of the leaves (Nio et al., 2021).

Sulawesi is the third biggest rice producer in Indonesia and supports 10% of national rice production. North Sulawesi has potential to be the center of rice cultivation. Biodiversity of potential North Sulawesi local rice cultivars, such as Superwin, Ombong, Temo, and Burungan, are required for guaranteeing the availability of crop plants during the wet and dry season (Nio et al., 2019). Information about the ability of North Sulawesi local rice to respond submergence and water deficit stress based on morphological and physiological aspects are still lacking. This study aimed to evaluate the morphophysiological characters of North Sulawesi local rice (Superwin, Ombong, Temo and Burungan) as response to partial submergence and water deficit at the vegetative phase based on plant height, number of leaves, root length and volume, and leaf chlorophyll concentration.

MATERIALS AND METHODS

This research was conducted from January to March 2017 in a greenhouse located in Manado, North Sulawesi under the guidance of the Ecology Laboratory of the Biology Department, Faculty of Mathematics and Natural Sciences, Sam Ratulangi University. The seed materials used in this study were North Sulawesi local rice cultivars (Superwin, Ombong, Temo, and Burungan), soil, salt, commercial bleach solution, NPK and Gandasil-D® fertilizers, and water. Also plastic bags, plastic pots (volume 1,500 mL), buckets, dippers, small shovels, tweezers, white markers, paper envelopes, hot plates and analytical scales were used in this study. Rice plants were planted in

mixed soil media (created using a combination of garden soil, manure and husks= at ratio of 5:1:1) that was enriched by mixing 6 g of NPK fertilizer with 7 kg of mixed soil media (Palit et al., 2015).

Procedures

The factorial experiment used in our Completely Randomized Design included seed selection, plant maintenance, partial submerged and water deficit treatment, and data collection. The rice seeds were selected by soaking the seeds in salt water for 2–3 hours in order to get qualified seeds. The qualified seeds were collected and sterilized using a 2% commercial bleach solution to rinse the seeds three times for 2–3 minutes for each rinse, washed with boiled water three times and then the seeds were soaked for overnight. Before planting, each pot that already contained soil was watered until field capacity (Nio & Ludong, 2014). The seeds were planted on the planting medium in the pots (volume 1,500 mL). Three seeds were planted in each pot, then watered with a mixture of water and fertilizer (10 g of Gandasil D® fertilizer in 10 L of water) to field capacity every two days. After the plants were 12 days old, one plant was selected to be used in each pot. Watering the plants to field capacity was continued until the plants reached the four-fully-expanded-leaf stage (Nio & Ludong, 2014). Well-watered (control), partial submerged, and water deficit treatments were then commenced and lasted for 14 days. The control treatment was carried out by watering without fertilizer every two days. The pots and plants were placed in a water bath filled with water, so that the plants were submerged 15 cm above the surface of the media. There was no watering of the water deficit treatment plants.

Plant height, leaf number, root length, and volume were measured as the morphological response, whereas the total chlorophyll concentration of a given plant leaf was measured as physiological response to partial submerged and water deficit treatments. Plant height was measured from the base of the plant to the longest leaf (Hermanasari et al., 2011). Leaf number was determined based on the number of green leaves, whereas yellowed or damaged leaves due to partial submergence and water deficit were excluded (Ikhwani & Makarim, 2010). Plant height and leaf number were recorded on day 0 (before the treatment commenced), and days 7, and 14 after treatment. After the roots were washed with water and soil remnant removed, root length was measured from the base to the tip of the root using a ruler. Root volume was determined as the difference between the water volume after and before the roots were put into the measuring cylinder (Munarso, 2011). The length and volume of roots as well as total chlorophyll were recorded on days 14 after treatment. Leaf total chlorophyll was extracted using 95% ethanol and the concentration was calculated based on the optical density measured at λ 649 and 665 nm using SP-3000 nano Optima® spectrophotometer (Sonke et al., 2019). Fresh mass of each soil sample was recorded, after which the soil was dried at 105 °C for 24 h, and then dry soil mass was recorded. Soil water content was calculated as 100 x (fresh mass - dry mass)/dry mass (Nio et al., 2011).

Data Analysis

Mean and standard errors were calculated using Microsoft Office Excel 2016. Data were analyzed using ANOVA and least significant difference (LSD) was used to identify significant differences ($P < 0.05$, unless otherwise stated).

RESULTS

Plant height as morphological response to partial submergence and water deficit was observed from day 0 to 14 in North Sulawesi local rice cultivars. The plant height in these four cultivars increased during 14 days of treatments. Rice cv. Burungan had the highest average plant height, followed by cv. Ombong, Temo, and Superwin at day 0, 7, and 14 days of treatment, respectively. Plant height of cv. Temo and Superwin was not significantly different between day 7 and 14. Plant height in cv. Burungan, Ombong, Temo, and Superwin at day 14 was 76.5, 67.2, 50.7, and 49.4 cm, respectively. Rice cv. Burungan had the highest plant height under partial submergence. Plant height in these four cultivars under partial submergence (65.4 cm) was 12% higher ($P < 0.05$) than under control (58.4 cm) and water deficit (59 cm) conditions. The plant height of these rice cultivars under water deficit was not significantly different from the well-watered condition (Figure 1).

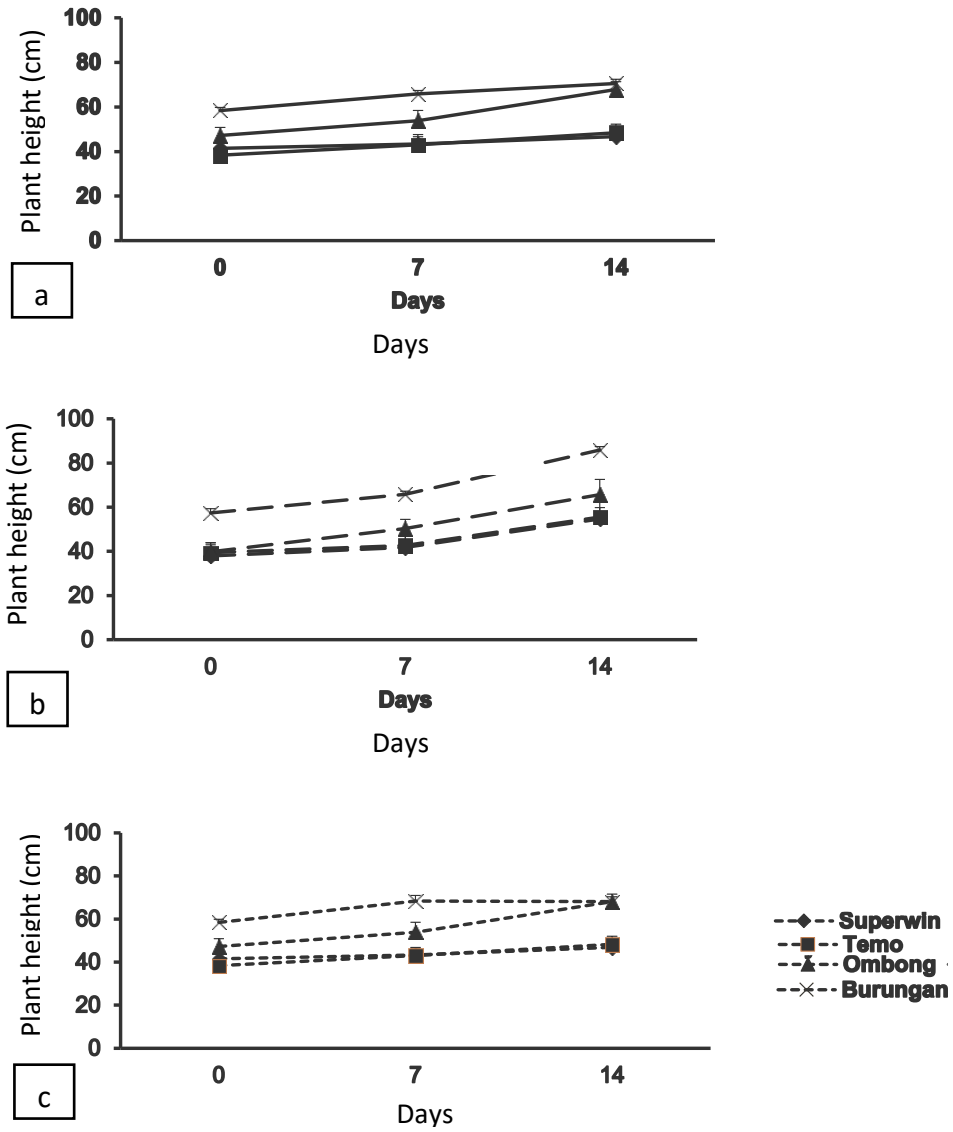

Figure 1. Plant height (mean ± SE, n= 8) in North Sulawesi local rice cultivars (Superwin, Ombong, Temo, and Burungan) under well-watered (a), partial submerged (b), and water deficit treatments (c) for 14 days

Leaf number was also observed as a morphological response to partial submergence and water deficit from day 0 to 14 in North Sulawesi local rice cultivars. The average of leaf number in cv. Superwin was the highest at day 0 (13 leaves) and day 7 (16 leaves); however, at day 14 the leaf number of Superwin (19 leaves) was not significantly different from Burungan. Rice cv. Temo had the lowest leaf number (6 leaves) and this leaf number was not significantly different from cv. Ombong (Figure 2).

Root length in rice cv. Superwin, Ombong, Temo, and Burungan under well-watered, partial submerged, and water deficit were observed for 14 days. The root in rice cv. Burungan (26.7 cm) was 21% longer than in Superwin (21.1 cm), Temo (22.1 cm), and Ombong (22.6 cm). Root length in Superwin, Temo, and Ombong was not significantly different. Root length in these four rice cultivars under water deficit (21.6 cm) and partial submerged (22.0 cm) were smaller than in well-watered condition (25.5 cm). The plant root length under partial submerged and water deficit conditions was not significantly different (Table 1).

The root volume in North Sulawesi local rice cultivars as morphological response to partial submergence and water deficit for 14 days is shown in Figure 3. Root volume in cv. Superwin, Ombong, Temo, and Burungan under well-watered, partial submerged, and water deficit conditions were significantly different ($P < 0.05$). Root volume in cv. Burungan (12.7 mm^3) and Superwin

(11.5 mm^3) under partial submerged was larger than under well-watered and water deficit conditions.

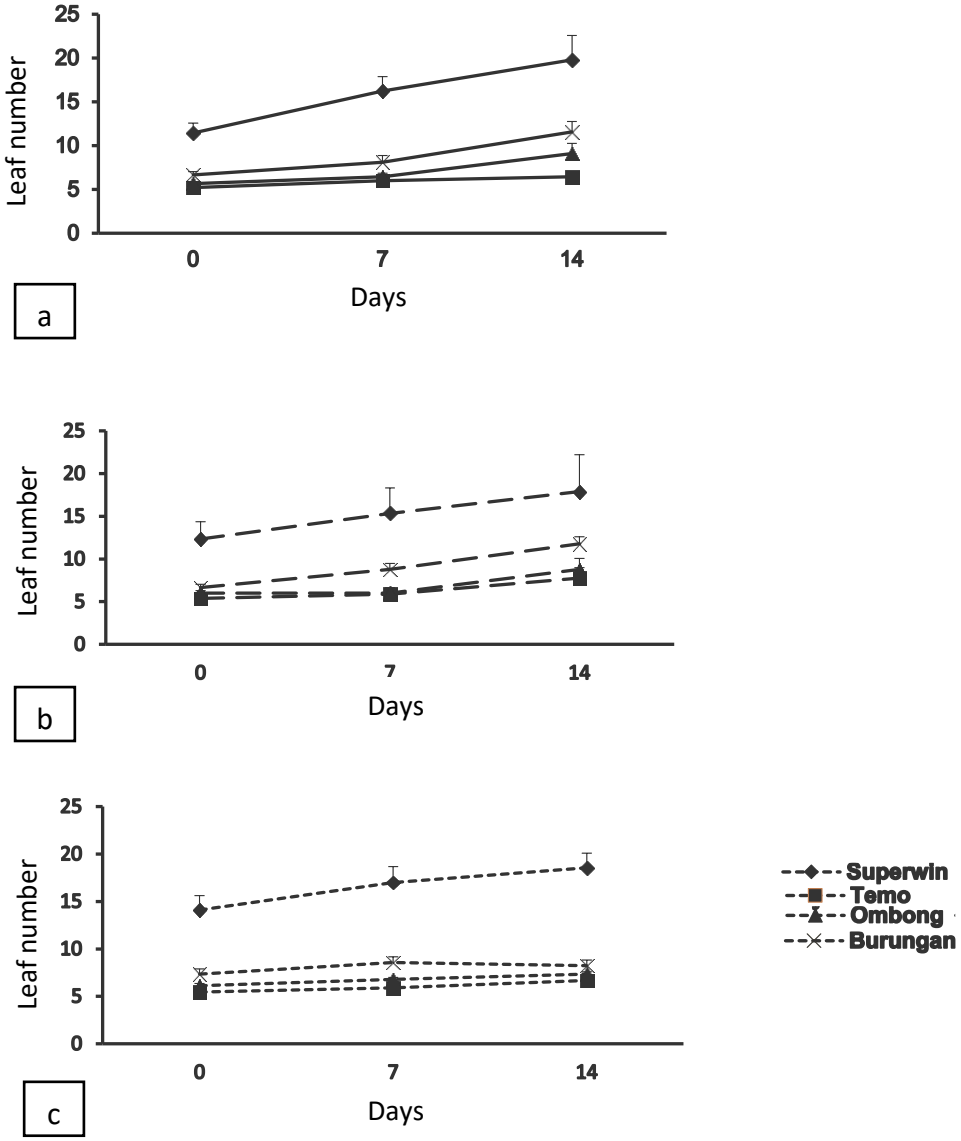

Figure 2. Leaf number (mean ± SE, n= 8) in North Sulawesi local rice cultivars (Superwin, Ombong, Temo, and Burungan) under well-watered (a), partial submerged (b), and water deficit treatments (c) for 14 days

Table 1. Root length (mean ± SE; n= 8) in North Sulawesi local rice cultivars (Superwin, Ombong, Temo, and Burungan) under well-watered, partial submerged and water deficit treatments for 14 days

	Root length (cm)			
Cultivar	Well-watered	Partial submerged	Water deficit	Mean
Superwin	22.15 ± 2.75	19.73 ± 3.71	21.51 ± 0.67	21.10 ± 1.50 a
Temo	26.70 ± 1.72	17.05 ± 3.65	22.46 ± 1.62	22.10 ± 1.60 a
Ombong	24.46 ± 2.96	22.56 ± 3.52	20.66 ± 1.54	22.60 ± 1.60 a
Burungan	29.68 ± 0.76	28.85 ± 1.67	21.45 ± 0.54	26.70 ± 0.10 b
Mean	25.50 ± 0.60 b	22.00 ± 1.70 a	21.60 ± 1.20 a	

Note: SE= standard error. significant differences (P <0.05) by Least Significant Difference (LSD) were indicated by different letters in the same row (for the treatment) and in the same column (for the cultivar)

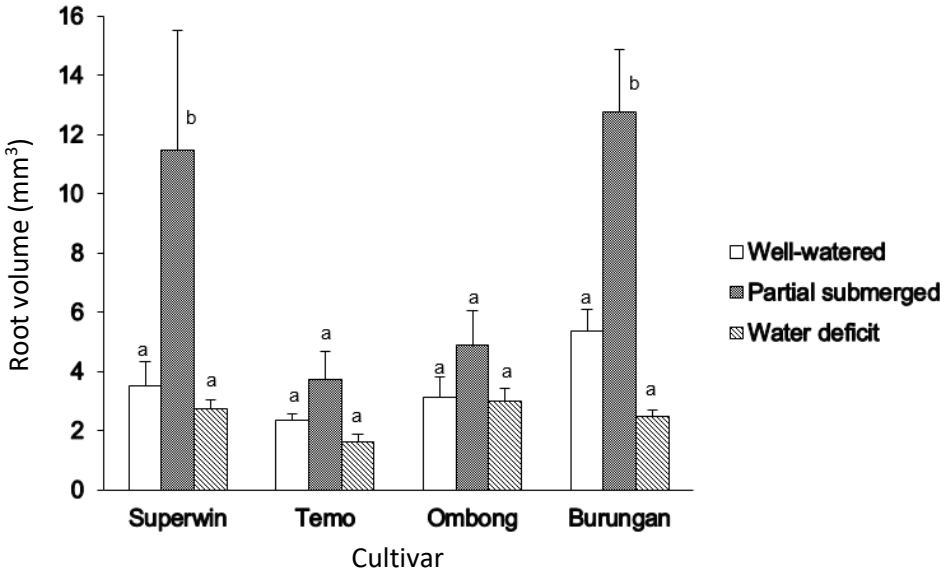

Figure 3. Root volume (mean ± SE, n= 8) in North Sulawesi local rice cultivars (Superwin, Ombong, Temo, and Burungan) under well-watered, partial submerged and water deficit treatments for 14 days. Significant differences (P <0.05) by LSD were indicated by different letters

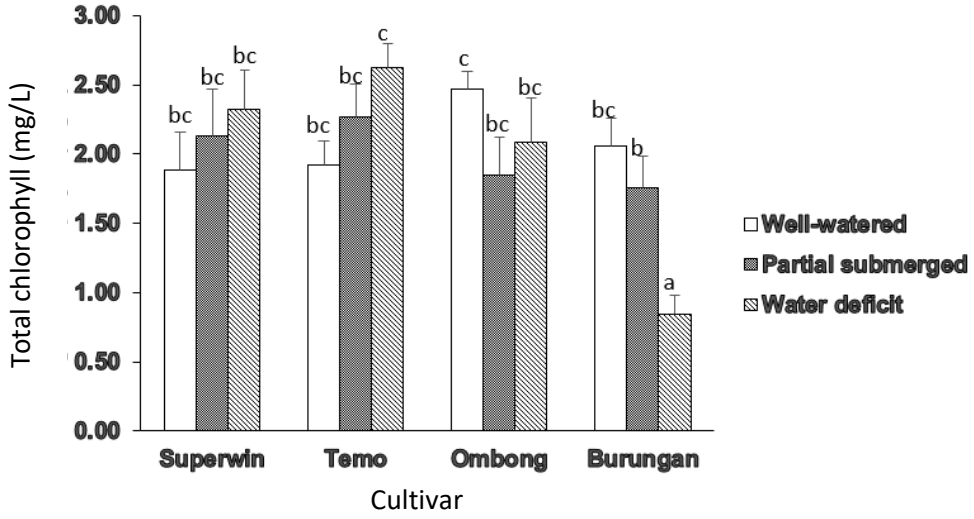

Figure 4. Concentration of leaf total chlorophyll (mean ± SE, n= 10) in North Sulawesi local rice cultivars (Superwin, Ombong, Temo, and Burungan) under well-watered, partial submerged and water deficit treatments for 14 days. Significant differences (P <0.05) by LSD were indicated by different letters

Total leaf chlorophyll concentration in four local rice cultivars in North Sulawesi was observed 14 days after partial submerged and water deficit treatments (Figure 4). Total leaf chlorophyll concentration in cv. Burungan under water deficit was lower (P <0.05) than in cv. Superwin, Ombong, and Temo under well-watered, partial submerged, and water deficit. Total leaf chlorophyll concentration in cv. Superwin, Ombong, and Temo under well-watered, partial submerged, and water deficit was not significantly different. Total leaf chlorophyll concentration in cv. Burungan under water deficit (0.85 mg/L) was lower (P <0.05) than under partial submerged (1.75 mg/L) and well-watered condition (2.06 mg/L).

Table 2. Soil water content (mean ± SE; n= 10) in North Sulawesi local rice cultivars (Superwin, Ombong, Temo, and Burungan) under well-watered, partial submerged and water deficit treatments for 14 days

Cultivar	Soil water content (%)		
	Well-watered	Partial submerged	Water deficit
Superwin	46.13 ± 7.55	62.88 ± 4.73	17.41 ± 4.19
Temo	53.33 ± 9.99	67.81 ± 14.10	17.26 ± 2.36
Ombong	53.93 ± 7.98	67.11 ± 12.92	14.28 ± 2.89
Burungan	50.90 ± 8.37	123.20 ± 56.50	12.83 ± 3.60
Mean	51.07 ± 4.12 b	80.23 ± 1.38 c	15.32 ± 4.91 a

Note: SE= standard error. significant differences (P <0.05) amongst the treatments by LSD were indicated by different letters in the same row

Soil water content in four local rice cultivars in North Sulawesi, i.e. Superwin, Ombong, Temo, and Burungan, under well-watered, partial submergence and water deficit for 14 days was shown in Table 2. Soil water content was significant different (P <0,05) among well-watered, partial submergence, and water deficit. Soil water content under water deficit, well-watered, and partial submergence was 15%, 51%, and 80%, respectively. Soil water content under water deficit was the lowest, on the other hand soil water content under partial submergence was the highest.

DISCUSSION

Partial submergence and water deficit stress affected all aspects of plant growth that were evaluated in this study, which was limited to some morphological and physiological aspects in North Sulawesi local rice (cv. Superwin, Ombong, Burungan, and Temo). The evaluated morphological characteristics consisted of plant height, leaf number, length and volume of the roots, whereas the physiological characteristic was total chlorophyll concentration of rice leaves.

The plant height of Burungan cultivar was the highest compared to Superwin, Temo, and Ombong under partial submergence, thus Burungan was more adaptive to this stress as reported by Poluan et al. (2017). This study showed that plant height under partial submergence for 14 days was higher than the well-watered condition. Rohmah (2016) also reported that plant height of soybean under submergence of 200% field capacity was greater than 100% field capacity. Submergence insreased the content of ethylene and giberrelic acid that was expected to stimulate the plant height. Ahmadikhah and Marufinia (2016) reported that plant height in rice under water deficit was lower than well-watered. In this study, however, plant height under water deficit was not different form well-watered. Further evaluation was still required to determine whether these results could be attributed to the drought tolerance in these North Sulawesi local rice as hundred of genes controlled morphophysiological responses of rice under water deficit, such as genes that regulated plant height and root length (Ma et al., 2016).

In this study partial submergence and water deficit did not cause differences in the leaf number of four rice cultivars. Poluan et al. (2017), however, reported that leaf number in Superwin decreased under partial submergence. The declined leaf number would inhibit photosynthesis process and the plants would die. This different result observed in this study may be attributed to the differences in pot size (1,500 mL in this study compared to 600 mL (Poluan et al., 2017)) and treatment duration (14 days compared to 20 days).

Root length in these four rice cultivars under water deficit and partial submerged were smaller than in well-watered condition. It was also reported that the roots of soybean cv. Grobogan under submergence were shorter than under well-watered condition (Rohmah, 2016), because the mitosis of root cells was inhibited and resulted in a decrease of root length during waterlogging (Hossain & Uddin, 2011). The root length of several maize genotypes such as PT-17, PT-12, PT-BC9 and MR14 under water deficit was also smaller than well-watered (Efendi & Azrai, 2010). Root volume in rice cv. Burungan and Superwin were also larger than other cultivars under well-watered, partial submerged, and water deficit conditions. Munarso (2011) reported a similar result in which the root

volume of hybrid rice plants under submergence was larger than under water deficit or intermittent irrigation. Mangansige et al. (2018) also reported that root volume of cv. Superwin, Ombong, Temo, and Burungan was not different between well-watered condition and PEG-8000-induced-water deficit.

Reduced chlorophyll concentration in rice under mild and severe water deficit compared with normal condition was also reported by Ahmadikhah and Marufinia (2016), this indicated considerable sensitivity of chlorophyll concentration to water deficit. Tjolleng et al. (2019) also reported that total chlorophyll concentration under partial submergence was not different form well-watered in rice because of the short duration of partial submergence. Long-term partial submergence resulted in changes in root morphology, so that absorption of nutrients would be disrupted and lack of nutrient elements would occur in plants and the leaves commenced to turn yellow. Leaf yellowing was caused by the chlorophyll breakdown or inhibition of chlorophyll formation due to disruption of cell activity.

Soil water content was important to determine the amount of soil water that was absorbed by rice plants under water stress. Soil water content under water deficit was lower than well-watered and the plant absorbed more water in the root area under submergence and the ability of soil particles to hold water, causing the water volume increased in the soil (Koda, 2017). The soil was saturated with water under submergence condition. Water saturation conditions resulted in a decrease in root permeability and water absorption of by roots was inhibited that influenced turgor pressure. Plants absorbed more water in the root area and the ability of soil particles to hold water increased under submergence, causing an increase in the water volume in the soil (Permatasari et al., 2014).

The treatments in this study included of well-watered, partial submergence and water deficit. These treatments resulted in different soil water content that influenced rice plants growth. Soil water content under water deficit was the lowest, on the other hand soil water content under partial submergence was the highest. The length and volume of root were potential indicators for partial submergence and water deficit in North Sulawesi local rice at the vegetative phase. Root length was potential indicator of partial submergence and water deficit as it was higher under partial submergence and water deficit than well-watered. Root volume was potential indicator of partial submergence as it was larger under partial submergence than water deficit and well-watered.

CONCLUSION AND SUGGESTIONS

It was concluded that root length was potential to be used as an indicator of partial submergence and water deficit in North Sulawesi local rice cultivars (Superwin, Ombong, Temo, and Burungan), as well as root volume as an indicator of partial submergence. The partial submergence and water deficit tolerance of North Sulawesi local rice cultivars should be further evaluated based on the other morphophysiological, anatomical, biochemical, and molecular characteristics.

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