DROUGHT TOLERANCE OF TWO RICE VARIETIES AND ITS RESPONSE TO TWO DIFFERENT SOIL CONDITIONS

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Abstract

Sudden climatic changes such as drought will hit hard on farms especially on the vulnerable local farmers of Indonesia that are far from science and technology. The aim of this experiment was to study the drought tolerance ability of two varieties of rice e.g. Ciherang and Towuti grown in two different soils. The vigorous of 21 days old rice seedlings were grown in a glasshouse and irrigated with different amount of water (67ml, 133ml, 200ml as a control and 267 ml) per day. After a week of treatment the growth, visual symptom changes, and electrophysiological effects were then observed for four weeks on weekly basis. The result showed that a treatment of 67ml-water and 133ml-water inhibited plant growth on both varieties in fertile soil and caused plant death after four weeks. While on arid soil both varieties of rice were found to be more tolerant to 133ml of water than on the 67ml water treatment. Drought stress (67 ml water) has caused the decline of electric potential differences (PD) of Towuti in the ranges of 32.50 mV - 47.50mV and 55mV - 67mV in each fertile and arid soil from its PD control at each 57.50mV - 120.00mV and 77.50mV - 80.00mV respectively. While on the Ciherang variety, drought stress has caused the decline of PD both in fertile and arid soil from approximately in range of 77.50mV - 92.0mV and 85.00mV - 122.50mV to each 42.50mV - 72.50mV to 72.50mV - 85mV. We concluded that both varieties of rice Towuti and Ciherang were more tolerant on arid soil than fertile soil in response to drought stress. The result will be beneficial to the local farmers and help maintain their farming practice during dry conditions.

Keywords: *drought tolerance, growth, potential difference, rice*

Introduction

Sudden climatic changes such as drought will hit hard on farms especially on the vulnerable local farmers of Indonesia that are far away from science and technology. As the major consumption of carbohydrate for nearly 90% Indonesians, drought will be a constraint for the farmer to provide. More than 90% of world rice production is produced and consumed in Asia [1]. Reduced irrigated land in Indonesia and competition for water and also drought conditions has caused declining rice production in Indonesia. Roughly around 50% of the world's rice production is affected by drought [2], which is around 40% of food required by half the people worldwide [3].

Drought stress may affect physiologic and agronomic parameter [4]; disturbing the equilibrium relations between water and plant and the structure of cell's biologic membrane and create basic disorder in rice growth and decrease the performance. Drought affected plant growth and development [5]; leaf growth and chrorophyll content [3], but the effects varied between varieties.

Rice were found to vary genetically in abiotic stress [6], length of leaf is negatively related with osmotic stress. Thus the length of the leaf decreases with the rise on solute potential [3,14]. Drought effect on seed yield is due to the relation with duration of watering from flowering until physiological maturity [7].

Growth rate were affected by water with leaf area were one of the important factor on the growth on the water stress [8].Goldsworthy and Fisher, 1992 3]. Water was important during photosynthetis and translocation of nutrients [3] Water deficit resulted in photosynthentic inhibitation, reducing the turgidity of stomata. Stomata density was related to the plant's survival to drought [9, 10].

The green plant tissues react to light variations by changes in their surface electric potential, by means ionic basis of the light-induced electrical responses [11] i.e., light-induced changes in ion fluxes and concentrations from the mesophyll and epidermal leaves tissues [12,13]. In the research we measured the adaptive respon to change in water stress by measuring the light induced change, in leaf bioelectric potential, similar to Mg effects on the activity of plasma membrane transporter during dark/light transition as Hariadi &Shabala 2004 [14]. .

Two varieties rice i.e. Towuti and Ciherang were tested on their tolerance on the drought condition on the different level on two soils, fertile and arid soil. Electrical potential different (PD) were measured in in better in supporting the drought stress indicator which also has been beneficial in the secreening technique on stress response such as in beans [14].

The result will be beneficial to the local farmers and help maintain their farming practice during dry conditions also as the information on the agriculture and raising and managing of the planting system that has been developed in dry condition such as tropical aerobic system [2].

Continually reduction of irrigated paddy fields and population growth in Indonesia would threat the food security especially with the demand on the 1821 calory a day for adults which may equal to 0.88kg of rice [15]. With the population predicted to increase in around a quarter billion in the next 2025, it will be an urgent reason to seek alternatives in growing rice, on possible lands while preserving the precious irrigated paddy. The possible way on attempting the result is by investigating the tolerance of the varieties rice to drought. Two rice planting management had been practiced i.e. irrigated field that refer to the fertile soil; the other is arid soil, that mostly do not have irrigation and planted during the rainy season. With climate change conditions the possibility of having long dry seasons will likely be high. It means that the competition for water access will be very high even for irrigated paddy due to shortages of water caused by long dry season.

Materials and Methods / Experimental

Media growth

The experiment was conducted in a randomized block design (RBD) with five replications. The seeds of two varieties of rice (*Oryza sativa)*; Towuti and Ciherang; were selected for homogenity and were germitated on sand. Healthy and homogenic 21 day -old seedlings were then transplated to plastic pots containing two different soils; fertile and arid soil. The rice seedlings were then grown in a glasshouse and irrigated with different amount of water (67ml, 133ml, 200ml as a control and 267 ml) per day.

After a week of treatment, the growth, visual symptom changes, and electrophysiology were observed for a month on weekly basis.

Leaf surface electrical potentials were measured using standard extracellular electrodes as described in Shabala 1997[13] and Hariadi & Shabala [14. The electrodes was made by glass micro-capillary with a tip diameter of approximately 50µm filled with 2 % agar made up 1 M KCl [13].

Three leaves were measured simultaneously using four channels electrometer (build by Biophysics Lab., Faculty of Science, University of Tasmania, Hobart Australia). Light treatment was given as light ON/OFF manually switches of 20 minutes duration [13, 14]. Two of 28 watt cool white LED-array configured as 4 paralleled strings of 7 LEDs in series was used. All measurement of leaf surface electrical potentials were performed in Faraday cage in a controlled room temperature at 27 $\pm$ 2 ^{o}C. The results were then analyzed using Anova.

Results and Discussion

Growth Measurement

There has been increased leaf area in every weeks on the rice grown on 200ml water (control), in every weeks in fertile and arid soil, showing that the rice were healthy in both two varieties Towuti and Ciherang. Treatment of 67ml showed the smallest growth on leaf area compared to other treatment. In the variety Towuti the leaf area declined every week in accordance to longer duration of stress water/drought condition, while on the treatment of 133ml of water, the average leaf area increased until the third week then was reduced on the fourth week in the fertile soil, and stay on that level on the arid soil, but the leave area were smaller than control (Fig.1).From the figure it can be seen that the leaf area of the Towuti variety was greater with sufficient water (200ml and 267 ml) than less water in every week both in the fertile and arid soil.

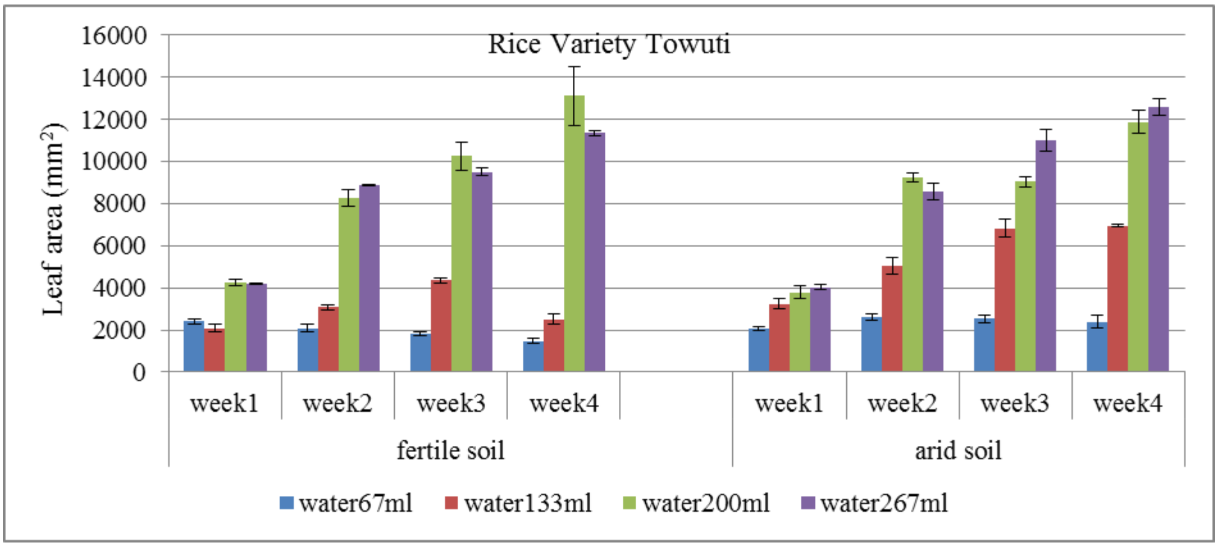

Figure1. Leaf area of Towuti variety grown in different watering treatments in fertile soil and arid soil during four weeks of observation

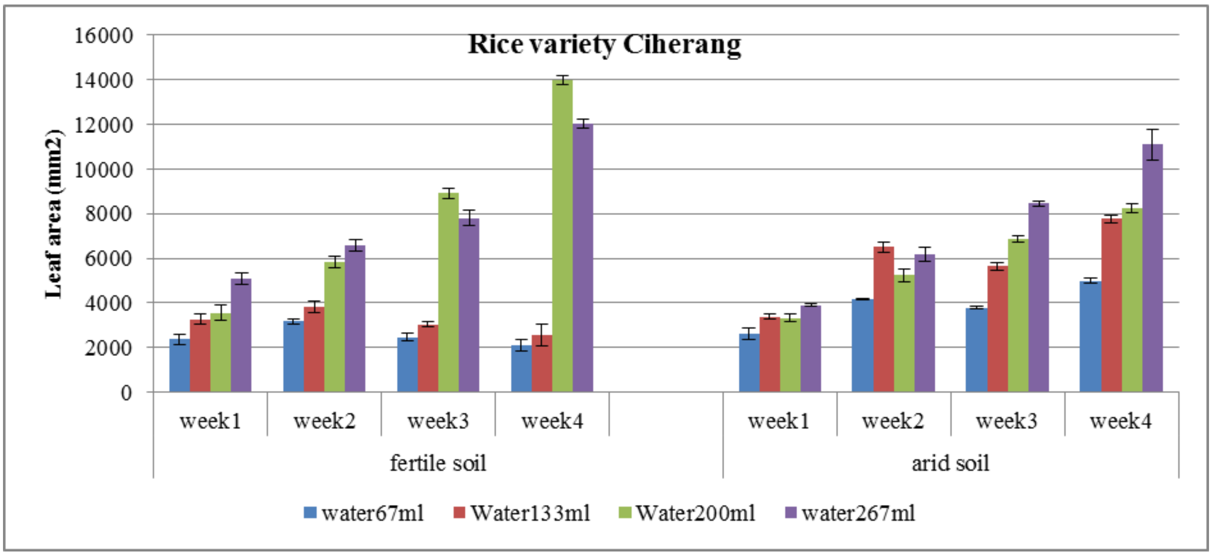

Figure 2. Leaf area of Ciherang variety grown in different watering treatments in fertile soil and arid soil during four weeks of observation

On the Ciherang the average leaf area increased every week under treatment of 267ml water and control (200ml of water) for the plants grown in the fertile and arid soil. The increase in average leaf area trend was also noticeable during treatment of 67ml and 133ml water on the Ciherang variety grown on arid soil for lenghtly week, but a declining trend was observed on the Ciherang grown on fertile soil (Figure 2).

Electrophysiology Measurement

From Figure 3 and 4, it can be seen that the two varieties, Towuti and Ciherang responded differently to water treatment on two different soil condition. In the Towuti grown on the the fertile soil the average of electrical PD on control (water 200ml) in range of 57.50mV ± 2.50mV and 120.00mV ± 14.71mV, and within 57.50 mV ± 2.50 mV and 77.50mV ± 2.50 mV and 80.00mV ± 4.08 mV for Towuti grown on the arid soil.

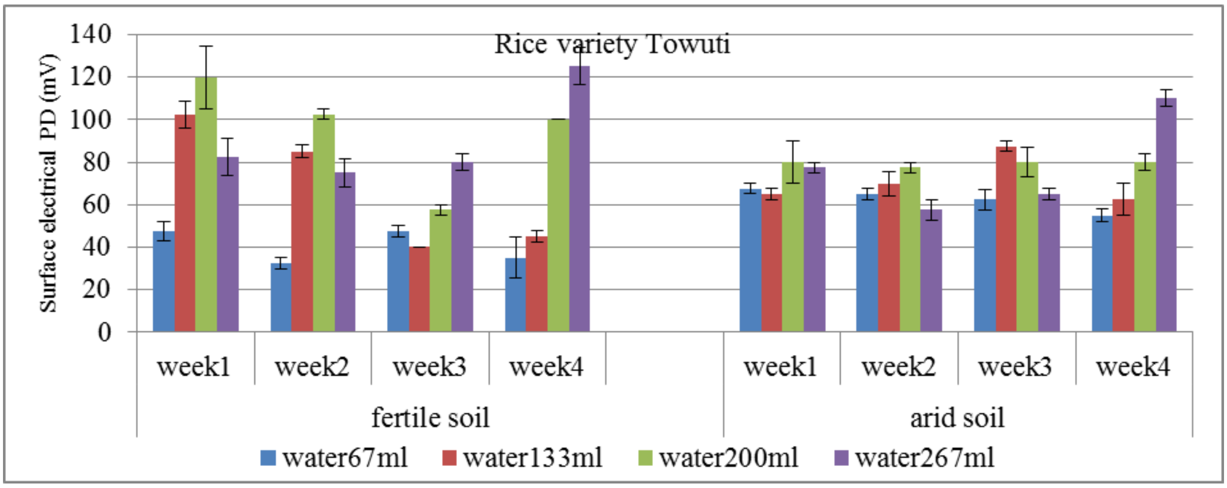

Figure 3. Electrical PD of rice variety Towuti grown in different volume watering in fertile soil and arid soil during observation of four weeks.

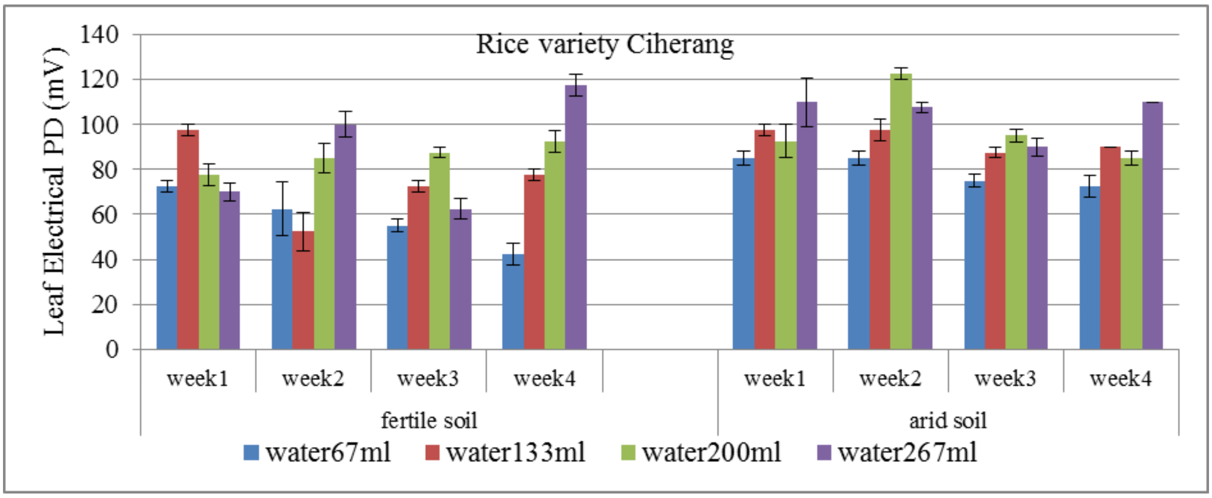

Figure 4. Electrical PD of rice variety Ciherang grown in different volume watering in fertile soil and arid soil

during observation of four weeks

From Figure 3 it can be seen that the value of electrical PD on the control had higher on the first and second week of measurement on fertile soil, then reduced on week three and increased on week four. While on arid soil the control's electrical PD tended to be constant (or not much different on PD value). Statistically on the Towuti variety grown on arid soil, there were no significant difference between the control and the 67ml; water 133ml; and water 267ml water treated Towuti. There was difference between the control and the 67ml and 267 ml water treated Towuti, also on week-4, but not for week-3.

The Ciherang responded differently to water stress. We had observed that there was a tendency of the reduced electrical PD on the 67ml water treated Ciherang both on fertile and arid soil on the duration of growth (Figure 4). The value of electrical PD of the 67ml water treated Ciherang on arid soil was the smallest. In the Ciherang grown on fertile soil the average electrical PD on the control were in range of 77.50 mV ± 4.78 mV and 92.50 mV ± 4.78 mV, on fertile soil and treatment of 67ml of water caused stress to be 42.50 mV ± 4.78 mV during week-4. Increasing water from normal to 267ml increased the electrical PD to 117.50 mV ± 4.78mV. On arid soil, not much reduction of electrical PD on the treatment of 67ml water, and increasing of electrical PD on treatment with 267ml water. It seems that the Ciherang variey was more tolerant to drought on arid soil than in fertile soil according to electrophysiological measurement.

Tolerance of Towuti and Ciherang on Drought Stress

Drought (water-67m) has significantly reduced leaf area of Towuti and Ciherang at first and second week experiments (Fig.1 and Fig.2) to its control both in fertile and arid soil. No symtoms stress were observed on the leaves until the second week (Fig. 5, Fig 6).While on the second week there was statistical difference for control and treatments of 67 and 133 ml of water, but no significant difference between the control and treatment 267ml of water. During week three there was difference between the control and other treatments, while on week four only treatment of 133ml water has not shown difference to the control.

No visual changes were observed on the Towuti variety grown on arid conditions under 67ml treatment of water during week-1 until week-3 of obeservation, the leaf was still green even thouh the leaf area declined. The stress symptoms of drought were noticable on week four with yellowish colour appearing on the leaf. While on the Towuti grown on the fertile soil stress sypmtoms were noticeable on week three, and the plant died on week-4 during 67ml treatment of water.

In the Ciherang variety, dried tip leaves were observed during week-3 of experiment under 133ml and 67ml treatment of water for plants grown on fertile soil. Leaves started to turn yellow. On the week four the leaf dried on treatment of 67ml water and yellow under 133ml water. On arid soil, early signs of yellowing were noticeable on week two on 267ml of water, followed by drying on the leaf tips, yellowing and dryness during week three, then dry during week four. Yellowing on the leaf was also observable on the Ciherang during week four of treatment under 200ml of water.

Leaf chlorosis, undersized leaf growth were common symptoms for many plant deficiencies, such as Mg or Fe [16]. Magnesium is an essential nutrient that plays a key role in plant photosynthesis [11]. Photosynthesis is a key phenomenon, which contributes substantially to the plant growth and development [17]. It possibly the drought condition altering the ultrastructure of the organelles and concentration of various pigments and metabolites including enzymes involved in this process as well as stomatal regulation [17].Drought stress attributed directly to the stomatal limitations for diffusion of gases, which ultimately alters photosynthesis and the mesophyll. It has been found that in regulating drought responses, large K^+ efflux, alkalisation of apoplastic pH (H^+ influx), and large Ca^{2+} efflux of leaf mesophyll may serve as chemical signals, leading to stomatal closure, reduced photosynthesis and growth [18].

The green plant tissues react to light variations by changes in their surface electric potential, by means ionic basis of the light-induced electrical responses [11], i.e., light-induced changes in ion fluxes and concentrations from the mesophyll and epidermal leaves tissues [12].

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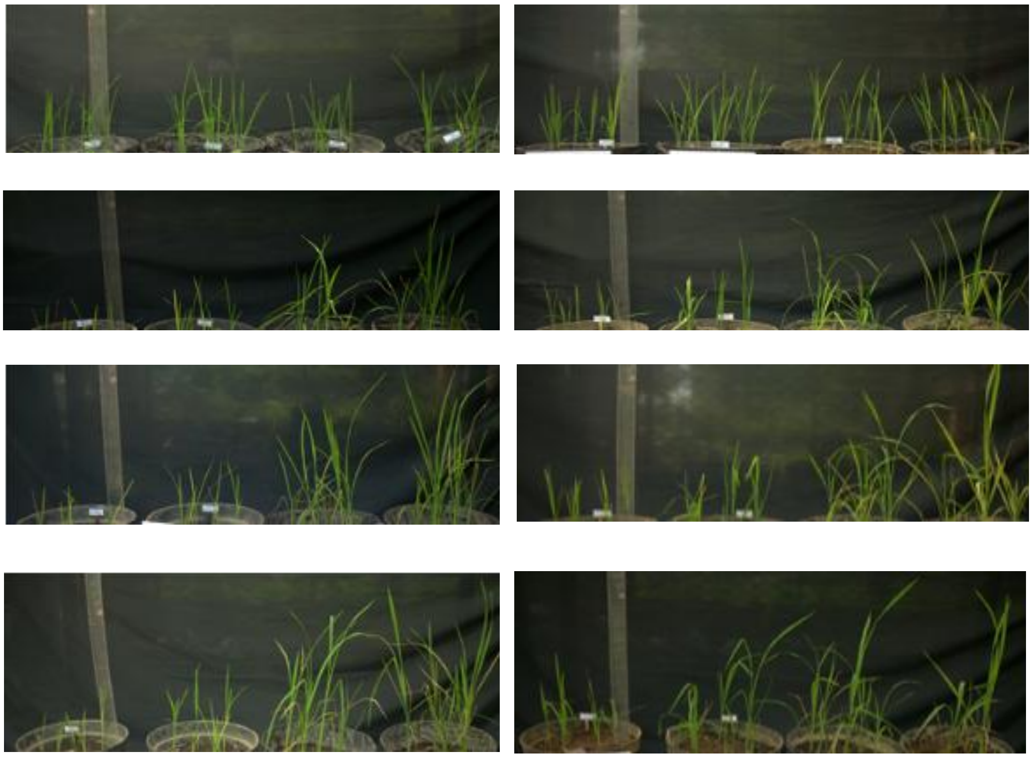
Week-1

Week-2

Week-3

Week-4



(a) 67ml 133ml 200ml 267ml (b). 67ml 133ml 200ml 267ml

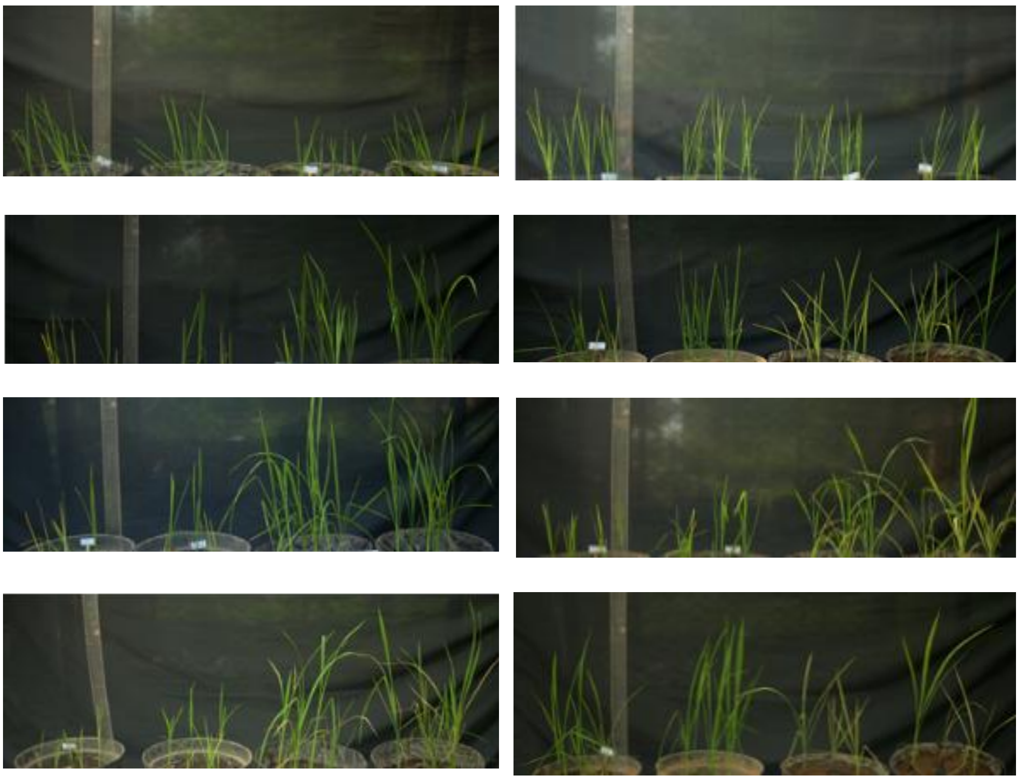
Figure 5. Visual symptoms of rice variety Towuti grown on the drought condition. (a) in fertile soil and (b) in the arid soil

Week-1

Week-2

Week-3

Week-4



(a)67ml 133ml 200ml 267ml (b). 67ml 133ml 200ml 267ml

Figure 6. Visual symptoms of rice variety Ciherang grown on the drought condition(a) in fertile soil and (b) in

the arid soil

Symtom stress were Growth rate were affected by water with leaf area were one of the important factor on the growth on the water stress [8] Water was important during photosynthetis and translocation of nutrients [3] Water deficit resulted in photosynthentic inhibitation, reducing the turgidity of stomata. Stomata density was related to the plant's survival to drought [9.10]. By knowing the symtom and adaptability the rice varieties on the water stress mightbe applied to the strategies managemen in saving water [20].

Conclusion

This finding suggested that the growth, visual symptom changes, and electrophysiological effects were then observed weekly for four weeks after one week of treatment. The result showed that a treatment of 67ml water and 133ml water inhibited plant growth on both varieties in fertile soil and caused plant death after four weeks. While on arid soil both varieties of rice were found to be more tolerant to 133ml of water than on the 67ml water treatment.

Drought stress (67 ml water) has caused the decline of electric potential differences (PD) of Towuti in the ranges of 32.50 mV – 47.50mV and 55mV-67mV in each fertile and arid soil from its PD control at each 57.50mV-120.00mV and 77.50mV-80.00mV respectively. While on the Ciherang variety, drought stress has caused the decline of PD both in fertile and arid soil from approximately in range of 77.50mV-92.0mV and 85.00mV-122.50mV to each 42.50mV-72.50mV to 72.50mV-85mV. We conclude that both varieties of rice Towuti and Ciherang were more tolerant on arid soil than fertile soil in response to drought stress. The result will be beneficial to the local farmers and help maintain their farming practice during dry conditions.

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