Drought Stress Effects and Silica Fertilizer Applications on the Growth and Yield of Black Rice (Oryza sativa L.)

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Abstract. The objective of this study was to analyse the effects of drought stress and silica application on black rice (Oryza sativa L.) growth and yield. The first factor was drought stress (P0 = control, P1 = drought stress during tillering stage (25-40 days after planting/ DAP), P2 = drought stress during flowering stage (50-65 DAP), P3 = drought stress during seed formation (65-80 DAP)). The second factor was the application of silica fertiliser (S0 = without silica, S1 = with silica). The data obtained were analysed by analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) 5%. The observed variables showed that drought stress had a significant effect on plant height, total number of shoots, number of productive shoots, number of grains per panicle, weight of grains and weight of grains per panicle. Silica application increased plant height, total number of shoots, number of productive shoots, weight of grains, and weight of grains per panicle.

Keyword: Drought Stress Effects, Silica Fertilizer Applications, GrowthBlack Rice

1. Introduction

Rice production in Indonesia is 54,649,202 tons in 2020 (Badan Pusat Statistics, 2020), which is sufficient for the consumption of the Indonesian population of about 270 million people. Increasing rice production is a must to feed the entire Indonesian population. Rice has different colors such as white, red and black. In Indonesia, most people use white rice (Oryza sativa L.) and red rice (Oryza nivara). There is black rice, but it was only grown in Toraja Indonesia. The nutritional content of rice is about 360 kcal of energy, 6.6 g of protein, 0.56 g of fat, and 79.34 g of carbohydrate [1].

Black rice is a local variety that is distinguish from white rice and other rice colors [2]. Nowadays, black rice is very popular since it usefull for diabetics. The glycemic index of black rice is low about 42.3 [3]. Black rice also has a high antosianin, which is useful as an antioxidant [4]. It is also found that Toraja black rice is consumed by many people nowadays [5]. Black rice is not tolerant to drought stress as the number of panicles and productive shoots decreases [6].

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Rice has three phases of growth. They are the vegetative phase, the reproductive phase, and the maturation phase [7]. Each of these phases is crucial for the growth of rice under drought stress conditions. Drought stress during plant growth affects physiological and biochemical processes that lead to changes in plant anatomy and morphology.

Silica is an essential nutrient required by plants [8], but not all silica has a positive effect on plant growth [9]. Silica (Si) has a positive function in plant resistance to drought stress, both under biotic and abiotic conditions. Silica increases plant resistance to drought stress through physiological and biochemical processes related to amino acid proline activity , anti occidative activity, and fenol. These chemicals are active during the physiological mechanism to maintain the physical process during drought stress [10].

This study is conducted to investigate the application silica during plant growth, especially during drought stress.

2. Methods

The study was conducted in the greenhouse of the Faculty of Agriculture, Sriwijaya University, from August to November 2021. The black rice used was Jeliteng Black Rice. A randomised block design was used. The first treatment included P1 drought during vegetative stage (25-40 days after planting), P2 drought during generative stage (50-65 days after planting), and P3 (65-80 days after planting). The second treatment included silica applications: S0 (without silica) and S1 (with silica). Data were analysed using analysis of variance (ANOVA). Parameters being observed included plant height, total number of shoots, productive shoots, number of grains per panicle, weight of grains per panicle, and weight of 100 seeds.

3. Result and Discussion

3.1 Plant Height (cm)

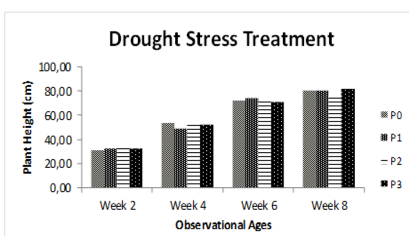

Figure 1. Plant Height During Drough Stress.

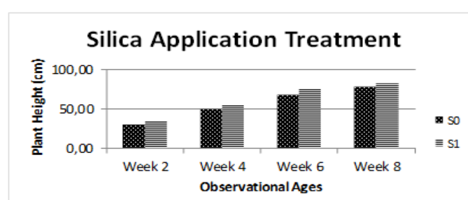

Figure 2. Plant Heigh on Silica aplication.

The results indicated that drought stress during 15 days affected pollen formation (25-40 DAP), flower formation (50-65 DAP), and seed formation (65-80 DAP), which did not significantly affect plant height in the second and sixth weeks, but had a significant effect on plant height during fourth and eighth weeks after sowing.

Variant analysis showed that the application of silica (S1) had a significant effect on plant height at weeks 2 and 4 compared to without silica application and a significant effect at weeks 6 and 8 compared to without silica application

3.2 Total Number of Tillers

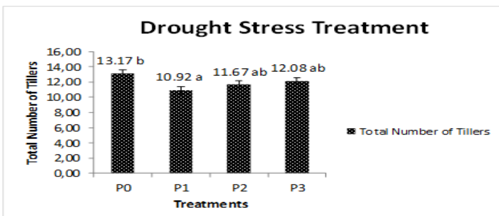

Figure 3. Total Number of Tillers on Drought Strees at Different Growth Phase.

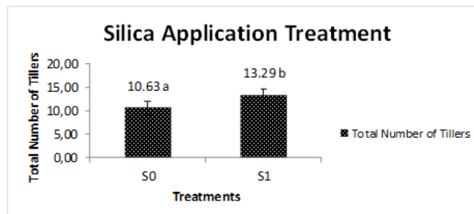

Figure 4. Total Number of Tillers on Silica Aplications.

Statistical analisis showed that drought strees gave significant effect on total number of tillers and silica aplications also gave highly signifivant effect on total number of tillers.

3.3 Number of Productive Tillers

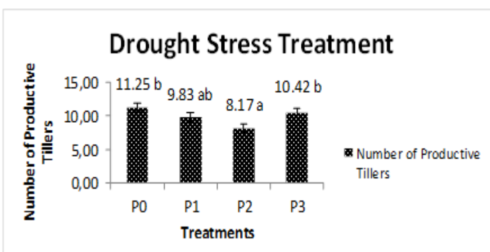

Figure 5. Productive Tillers During Drought Strees

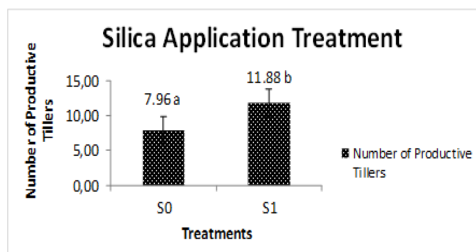

Figure 6. Productive Tillers During Silica Application

Statistical analisis showed that drought stress gave significant effect on number of productive tillers and silica aplications gave highly significant effect on number of productive tillers.

3.4 Number of Grains per Panicle

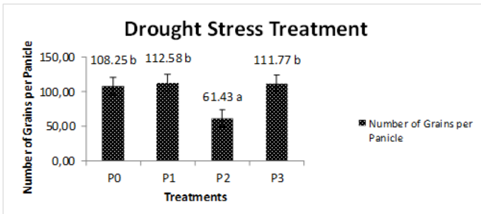

Figure 7. Number of Grains per Panicle during Drougt Strees.

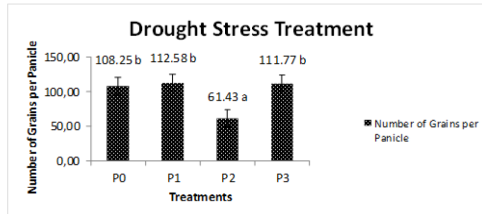

Figure 8. Number of Grains per Panicle during Silica Application.

Statistical analysis showed that drought stress gave significant effect on number of grains per panicle. The result showed that silica application did not give significant effect on number of grains per panicle.

3.5 Grains Weight per Clump (gram)

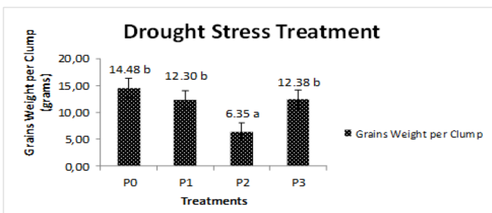

Figure 9. Grains Weight per Clump during Drought Stress Treatment.

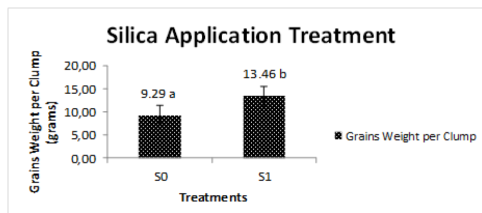

Figure 10. Grains Weight per Clump during Silica Appication.

Statistical analysis showed that drought stress gave highly significant effect to grain weight per clump.

Filled Grains Weight per Panicle (gram)

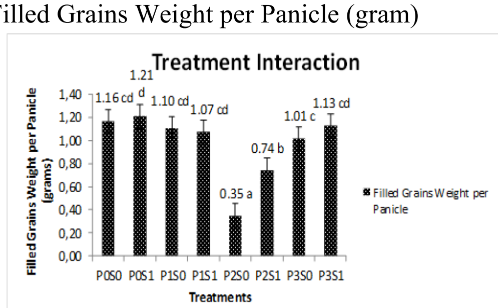

Figure 11. Filled Grain Weight per Panicle (gram)

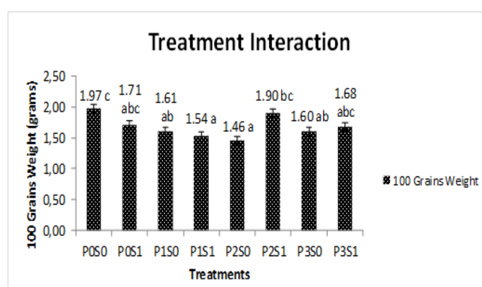

Figure 12. Weight of 100 Seeds on Treatment Interaction.

The analysis results showed that there were variations in all observed parameters. Plant height was observed at 2, 4, 6 and 8 weeks after planting. Based on plant growth, it was found that drought periods had significant effects on all parameters recorded. Plant height was found to be affected by drought during plant growth and development. In general, it was shown that plant growth during drought stress had less significant effects on all observed parameters. It can be shown that the rice plant in week 4 exposed to drought conditions had the lowest plant height, as well as the plant growth during drought in week 8. It can be concluded that the rice plant during the vegetative stage faced an obstacle that could interfere with cell division. It was also found that plant height was significantly affected by water conditions during plant growth [9]. In addition, drought conditions could affect cell division and elongation. Water deficits during vegetative growth have significant effects on plant growth and development because water is required for physiological processes such as cell organ formation, cell tension, stomata opening and closing, and other physiological processes during plant growth and development [11].

The application of silica showed better growth and development compared to plants without silica application [12]. Silica application increased plant height and photosynthesis [13]. Silica could be involved in plant division and elongation, so rice plants show better growth and development [14].

The use of silica had a significant effect on the maximum number of productive shoots compared to without silica application (15). The accumulation of assimilate during photosynthesis could increase the number of shoots and the formation of shoots. It was also found that the number of shoots increased after silica application, since it is required for cell division during plant growth and development [16].

Drought significantly affected flower formation, resulting in decreasing ofn seed formation. Drought stress during flower formation was very sensitive to seed formation compared to the application of silica during the generative phase [17].

The number of seeds was also affected by drought stress (18). Rice plants under drought stress 15 days after pollen formation recovered after irrigation, and the rice plants grew in better condition. The recovery was enhanced by the opening of stomata and the increase of photosynthesis, which could improve the growth and development of the plant. Drought periods during flower formation showed that seed formation decreased significantly. Water was required for flower formation. Drought stress under these conditions could affect seed formation.

The weight of 100 seeds showed no significant difference. During droughts, the rice plant reduced leaf area to reduce transpiration. In other words, droughts reduced carbohydrate synthesis and sink formation. Droughts during the reproductive phase affected assimilation transfer from leaves to seed formation.

4. Conclusion

1. Drougt stress decreased plant height and number of total tillers, productive tillers, number of seed and weight of 100 seeds.
2. Aplication of silica gave significant effect on plant growth, such as plant height, total number of tiller, number of productive tillers and weight of 100 seed but there was no significant effect on number of seeds.

3. There was interaction between drought strees and silica application.

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