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Salinity Effect on the Growth and Yield of TR9 Rice Variety

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ABSTRACT Rice, being a major staple food, is crucial to more than half of the world's population. However, the ever-increasing problem of salinity had reduced the productivity of rice in many paddy fields around the world. In this study, the growth and yield performance of TR9 rice variety were compared at different salinity levels to determine the salt tolerance of the rice. A pot experiment was conducted in the net house of Faculty of Sustainable Agriculture (FSA), Universiti Malaysia Sabah. The experimental design used was completely randomized design (CRD) and each treatment consisted of five replicates. The salinity treatments used were different concentrations of seawater of 0% (control), 2.5%, 5%, 7.5% and 10% which were applied throughout the planting process. The data was analyzed using One-way ANOVA and LSD was applied to compare means. No significant difference (P>0.05) were observed in flag leaf length, number of unfilled grains per panicle, 100-grains weight, number of panicles per plant and free proline content in roots. Conversely, plant height, number of tillers per hill, percentage of productive tillers, panicle length, number of grains per panicle, number of filled grains per panicle, harvest index and free proline content in leaves shown significant difference (P<0.05) between the treatments. It was concluded that the rice performance under treatment S1 (control) was better compared to the rice plants treated under treatment S2 (2.5% seawater). The rice yield obtained in treatment S1 was 2.88 tons/ha more than in treatment S2. Further studies on the effects of various salinity levels and stress duration on TR9 rice variety should be conducted for better yield.

KEYWORDS: Salinity, Rice Growth, Rice Yield, Salt Tolerance
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INTRODUCTION

Rice (*Oryza sativa* L.) is a crop cultivated over an extremely wide range of habitats. It is of greatest importance as one of the top five food crops for the world's population, especially in tropical Asia where about nine-tenths of the World's rice is produced and consumed. Rice feeds more than half of the world's population and 40% more rice would be required by 2030 to meet the demand of the burgeoning population among rice consuming countries (Khush, 2005). High population growth increases the freshwater requirement for the communities and reduces both available land and freshwater for agriculture. These conditions made paddy cultivators go for rice cultivation in marginal land using marginal quality of water for irrigation. Shortage of freshwater and continuous drought created lots of problems in rice production. These agricultural lands in the world suffer from salinity (Kijne, 2006).

Salinity is said to be one of the most important abiotic stresses, limiting crop production in arid and semiarid regions where soil salt content is naturally high, and precipitation may be insufficient for leaching. Salinity and other soil toxicities in rice crops are likely to be much more problematic in some areas, which are worsened in the face of rapid global environmental changes of elevated temperature, rise in sea level and erratic rainfall distributions (Takeda & Matsuoka, 2008). The increasing level of salinity affected the water uptake by plants from the soil. The process of extraction of water is getting less easily, aggravating water stress conditions. This causes nutrient imbalance and results in the accumulation of elements that are toxic to plants, reducing water infiltration when the level of one salt element-sodium is high. In many areas, soil salinity is the factor limiting plant growth (Al-Eryani, 2004).

Rice is considered as relatively tolerant to salinity at the germination stage while young seedling stage and early reproductive stages, for instance, panicle initiation and pollination are the most salinity-sensitive growth stages, directly affecting the crop yield (Zeng *et al*., 2001; Laffitte *et al*., 2004). Rice production is severely affected by the deposition of soluble salts in the soils of arid and semi-arid climates of the world (Ashraf *et al*., 2008). Salinity affects rice seedling growth, rice grain yield, decreases seedling establishment and yield components such as spikelet number and number of tiller (Zeng *et al*., 2003). However, superior response to vegetative stage stress is associated with better performance under reproductive stage stress, but the strategies that appear to be successful at the reproductive stage may be counterproductive when stress occurs at flowering (Pantuwan *et al*., 2002).

During reproductive development, the tolerant genotypes tend to exclude salt from flag leaves and developing panicles (Yeo and Flowers, 1986). In rice, salt tolerance increases during tillering and maturity stage, whereas at the flowering stage it decreases. Tolerance of salinity differs from plant to plant as well as at different ontogenetic stages. Compared to other crops like bread wheat and barley, rice is the most sensitive crop to salinity (Munns & Tester, 2008). Thus, this study aimed to determine the effects of salinity on the growth and yield of TR9 rice variety.

METHODOLOGY

Study Site and Materials Used

A pot experiment was conducted in the insect-proof net house of Faculty of Sustainable Agriculture (FSA), Universiti Malaysia Sabah (UMS), Sandakan Campus, Malaysia. This study was started from March until November 2018. The TR9 rice variety was used in this study.

Seed Preparation

Two hundred seeds were counted, and a germination test was carried out. The successfully germinated rice seeds having plumule and radicle were selected with > 90% germination percentage. Healthy growing rice seedlings sown in germinating trays were shifted out to the insect-proof net house at 7 days after sowing (DAS) and placed under shade to harden off the seedlings.

Transplanting

Transplanting of rice seedlings from germination trays into actual planting pots was carried out in between 18 to 21 DAS. Healthy rice seedlings were selected and transplanted into 25 pots located in the insect-proof net house. The rice seedlings were planted into a depth of 2 cm, followed by compressing the soil surrounded it. An adequate amount of water was provided to the newly transplanted seedlings to avoid transplanting shock. For each treatment, one seedling was planted in a pot for five replicates. Thus, a total of 25 rice seedlings were planted in 25 respective pots (CSISA, 2015).

Seawater Collection and Analysis

For the treatments, different concentrations of diluted seawater were applied to rice plant as the factor affecting the growth and yield production of TR9 rice. Seawater was obtained from Pantai Pasir Putih, Sandakan, Sabah whereby it was collected at a depth of not more than 1 to 2 inches below the surface near sea shorelines and stored in a tightly sealed non-transparent glass or plastic bottle. The samples were stored in room temperature until further analysis. The salinity of the seawater was measured using electrical conductivity (EC) meter (Eutech CyberScan CD 650). This is to determine the salinity reading of the seawater samples.

Salinity Treatments

Collected seawater was diluted using tap water. In this study, five treatments including tap water (control), 2.5%, 5%, 7.5% and 10% concentration of seawater were utilized. The salinity of these five treatments was monitored and maintained in different pots of rice plant respectively throughout the planting process. To examine and control the salinity in each treatment, the salinity of the irrigation water was taken every two days using electrical conductivity (EC) meter, from the water sample taken at the surface of each pot. The approximate reading of salinity for each treatment was shown in Table 1.

Table 1 Salinity used for each treatment

Treatment	Concentration of Seawater (%)	Salinity (ppt)
S1 (Control)	0	~ 0.417
S2	2.5	~ 2.186
S3	5	~ 4.671
S4	7.5	~ 6.887
S5	10	~ 8.624

* S: Treatment

Fertilizer Application

Common fertilizers used for TR9 rice planting was straight fertilizers of nitrogen (urea), phosphorus (P_2O_5) and potassium (K_2O). The recommended rate for nitrogen was 60-90 kg/ha separated in two applications as top dressing as well as 30 kg/ha of phosphorus and potassium respectively as basal fertilizer (Jabatan Pertanian Sabah, 2010). The rates of fertilizers and times of application were presented in Table 2.

Table 2 Fertilizers rates and time of application

Fertilizer	**Ratio**	**Rates/ha**	**Rates/pot**	**Application Time**
Urea	46:0:0	45 kg	0.69 g	Vegetative stage
Urea	46:0:0	45 kg	0.69 g	Tillering stage
P_2O_5	0:60:0	30 kg	0.35 g	Tillering stage
K_2O	0:0:25.9	30 kg	0.81 g	Tillering stage

* ha: hectare

Data Collecting and Analysis

(A) Vegetative Growth

The parameters for vegetative growth were taken at the interval of seven days throughout the planting phases. Vegetative growth parameter includes plant height, number of tillers per hill, percentage of productive tillers, panicle length and flag leaf length (Mobasser *et al*., 2009; Okuno *et al*., 2014).

a) *Plant Height*

Plant height was measured from the base to the tip of the highest leaf using a measuring tape.

b) *Number of Tillers per Hill*

The number of tillers was counted starting from the active tillering until the maximum tillering stage.

c) *Percentage of Productive Tillers*

Tiller can produce panicle with at least one grain attached to it is called the productive tiller. The percentage of productive tillers was calculated using formula 1:

$$\text{Percentage of productive tillers (\%)} = \frac{\text{Number of panicle produced}}{\text{Total number of tiller produced per hill}} \times 100\% \quad (1)$$

d) Panicle Length

Panicle length was measured from the neck node (panicle base node) to the end of the panicle using a measuring tape.

e) Flag Leaf Length

Flag leaf length was measured from the tips of the leaf to the end part. The measurement was collected at the day of harvest.

(B) Yield Components

Yield components were taken once the rice plants reach their maturity. The parameters taken were the total number of grains per panicle, number of filled grains per panicle, number of unfilled grains per panicle, 100-grains weight, number of panicles per plant, extrapolated yield, and harvest index.

a) Total Number of Grains per Panicle

The number of grains per panicle is set during panicle differentiation, which is about a week after internode elongation, the shift from vegetative growth to reproductive growth in the plant. The total number of grains per panicle refers to the total number of filled and unfilled grains in a panicle. The total number of grains per panicle was counted manually once the panicle had been harvested.

b) Number of Filled Grains per Panicle

Grains that have rice inside are considered as filled grains. After the panicles have been harvested, grains were threshed and bulked manually from each panicle. Filled grains were then being separated from the unfilled grains (empty grains). The number of filled grains was counted and the percentage of filled grains per panicle was calculated using formula 2 (Cock *et al*., 1976):

$$\text{Percentage of filled grains per panicle (\%)} = \frac{\text{Number of filled grains}}{\text{Total number of grains per panicle}} \text{ x } 100\% \quad (2)$$

c) Number of Unfilled Grains per Panicle

Unfilled grains were sorted out from the total number of grains per panicle, counted and recorded. The percentage of unfilled grains per panicle was calculated using formula 3:

$$\text{Percentage of unfilled grains per panicle} = 100\% - \text{Percentage of filled grains per panicle} \quad (3)$$

d) 100-Grains Weight

In this study, 100-grains were randomly taken, counted, and weighed using an electronic weighing machine.

e) Number of Panicles per Plant

The total number of panicles was calculated and recorded at the day of harvest.

f) Extrapolated Yield

The extrapolated yield of rice grains was calculated using two formulae which are the number of hills per hectare (formula 4) followed by determining the extrapolated yield (formula 5) (Sinong, 2016).

$$\text{Number of hills per hectare} = \frac{\text{Area of one hectare } (m^2)}{\text{Planting distance between hills between rows x Planting distance between hills within row}} \quad (4)$$

$$\text{Extrapolated yield (t/ha)} = \frac{\text{Number of hills per hectare x Mean of filled grains weight}}{1{,}000 \text{ g x } 1{,}000 \text{ g}} \quad (5)$$

g) *Harvest Index*

Harvest Index (HI) for grain crops was defined as the dry weight of grains divided by the total aboveground biomass (grains and straw). At the end of harvesting, the harvest index of rice grains was calculated using formula 6.

$$\text{Harvest Index (HI)} = \frac{\text{Grain dry weight per plant}}{\text{Total aboveground biomass}} \quad (6)$$

(C) Free proline Content

The free proline content in fresh leaf and roots samples were estimated following the procedure of Bates *et al*. (1973).

(D) Experimental Design and Statistical Analysis

This experiment was carried out in a Completely Randomized Design (CRD). There were five treatments with different salinity levels (0, 2.5, 5, 7.5 and 10%). Five replicates for each treatment and a total of 25 pots were used in this study. The collected data was analyzed with One-way Analysis of Variance (ANOVA) using the Statistical Analysis Software (SAS 9.4). Least Significant Difference (LSD) test at 0.05 level of probability was used to compare between means when ANOVA showed significant treatment effects of this study.

RESULT AND DISCUSSION

Effects of Different Salinity Levels on the Vegetative Growth of TR9 Rice Variety

Data for vegetative growth were collected and recorded weekly after transplanting the rice seedlings to the pots except for panicle length. The parameters of plant height, number of tillers per hill, percentage of productive tillers and panicle length showed significant difference ($P<0.05$) whereas no significant difference was showed in flag leaf length of the rice plants at the end of planting.

Figure 1 showed the plant height had increased gradually until 35 days after transplanting (DAT) for all treatments. From 35 DAT onwards, a greater increased in plant height was observed in rice plants under treatment S1 (control) until 84 DAT. However, a constant growth was observed in treatment S5 on the plant height starting from 35 DAT to 98 DAT. There was a significant difference ($P<0.05$) on the plant height of TR9 rice variety under five different levels of salinity at 98 DAT (Figure 2). Decreased stem growth was caused by the increasing amount of salinity (Janssen *et al*., 2016). The growth of rice plants affected by salinity was due to the high concentration of salts in the soil solution that interferes with balanced absorption of essential nutritional ions by plants. In addition, the presence of a high concentration of soluble salts through their high osmotic pressures restricts the water uptake by the roots, thus affecting the growth of rice plants (Tester & Devenport, 2003).

A significant difference (P<0.05) was obtained on the number of tillers per hill of rice plants affected by different levels of salinity treatments at 84 DAT (Figure 3). As the salinity levels increased, the number of effective tillers plant decreased. A negative linear relationship was observed in the number of tillers per hill with increased salinity levels. Salinity decreases the number of tillers while imposing before panicle emergence (Zeng & Shannon, 2000). Figure 4 showed significant difference (P<0.05) on the percentage of productive tillers between treatment S1 (control) and treatment S2. Application of seawater to rice plants has greatly affected the production of tillers and hence, affected the percentage of productive tillers. Rice yield, in common with many other small grain cereals, is highly dependent upon the number of fertile tillers per plant. Generally, the productive tillers emerged and developed early in the life cycle of the crop (Zeng *et al*., 2003). The salinity stress strongly influenced the distribution of spike-bearing tillers (Eugene *et al*., 1994). In addition, the salt stress happens during tiller emergence can inhibit their formation and can cause their abortion at later stages (Nicolas *et al*., 1994). As a result, the number of tillers and productive tillers were reduced at higher salinity levels.

Figure 5 showed significant difference (P<0.05) on the panicle length between control treatment (0% seawater) and treatment S2 (2.5% seawater). The panicle length of rice decreased with increased salinity levels. In addition, the reduction in seedling survival rates and stunted growth due to salinity is the major cause of the reduction in panicle length (Rad *et al*., 2012).

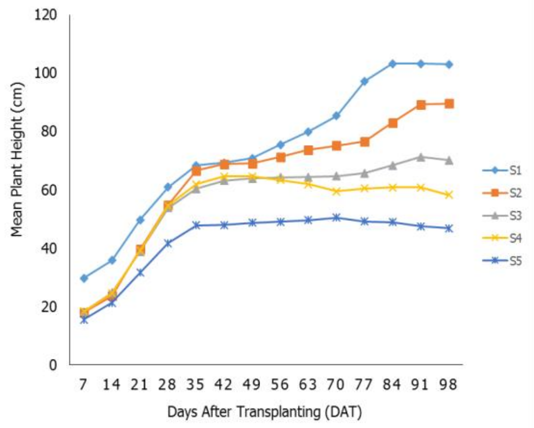

Figure 1. Mean plant height of TR9 rice variety under different salinity levels over the days after transplanting.

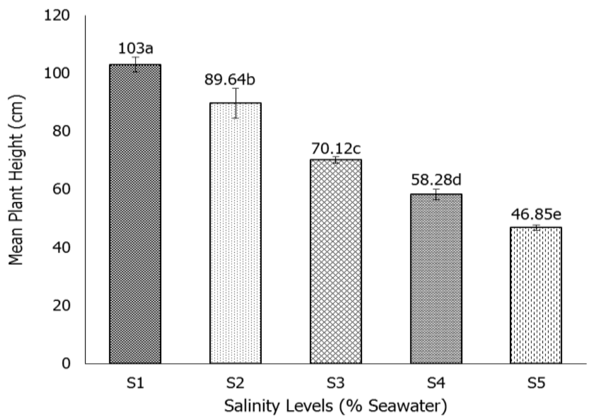

Figure 2. Mean plant height of TR9 rice variety under different levels of salinity at 98 days after transplanting.

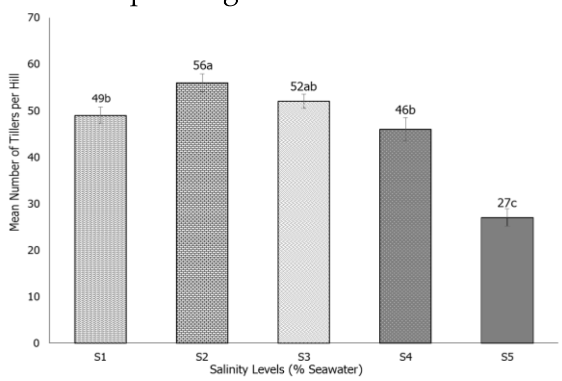

Figure 3. Effects of different salinity levels on the mean number of tillers per hill of TR9 rice variety at 84 days after transplanting.

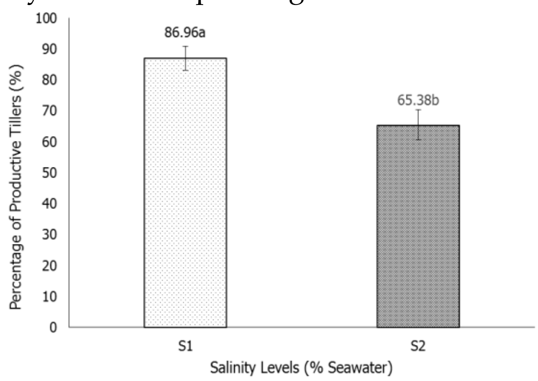

Figure 4. Percentage of productive tillers of TR9 rice variety under different levels of salinity.

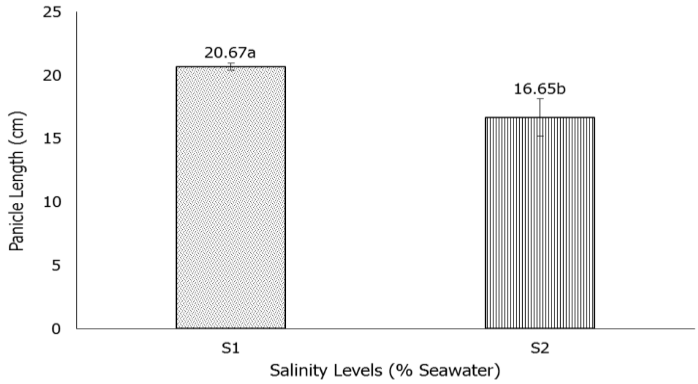

Figure 5. Effects of different salinity levels on the panicle length of TR9 rice variety at 130 DAT.

Different alphabet letters presented on different treatments indicate a significant difference at P<0.05.

Effects of Different Salinity Levels on the Yield Components of TR9 Rice Variety

The parameters for yield components of TR9 rice were obtained after harvest. There was a significant difference (P<0.05) on the number of grains per panicle between treatment S1 and S2 of TR9 rice plants (Figure 6). The number of grains per panicle was the most salt-sensitive yield components while fertility and grains weight were less sensitive to salinity (Zeng & Shannon, 2000). Salt stress may cause sterility of panicle during fertilization, which will then lead to a decline in grain setting, pollen-bearing capacity and decrease the stigmatic surface (Abdullah *et al*., 2001).

Figure 7 showed significant difference (P<0.05) on the number of filled grains per panicle when different levels of salinity were applied to the rice plants. One of the main causes of decreased in grain yield under salinity stress is lack of transformation of carbohydrates to vegetative growth as well as the development of spikelets (Hussain *et al*., 2017). Significant reduction in the translocation of soluble sugar contents to superior and inferior spikelets and the inhibition of starch synthetase activity during grain development are the reasons behind lower rice grain yield under salinity stress (Abdullah *et al*., 2001).

Figure 8 showed significant difference (P<0.05) on the harvest index between treatment S1 and S2. Harvest index of TR9 rice variety experienced a decreased when the rice plants were treated with salinity. Harvest index is also known as the yield indicator. In this study, the grains dry weight obtained in treatment S1 (285.94 g) was higher than treatment S2 (65.35 g). When the grains dry weight is high, the sink strength increase, resulted in more assimilate in leaf and stem translocated to the grain. The high amount of assimilates stored in the grain was used for further development and grain fillings. Thus, treatment S1 with higher grains dry weight indicated a higher harvest index compared to treatment S2 (Asseng & van Herwaarden, 2003).

There was a decreased in the extrapolated yield in treatment S2 as compared to treatment S1 (Figure 9). The reduction in yield under saline condition was due to reduced growth because of decrease in water uptake, the toxicity of sodium and chloride in the shooting cell as well as reduced the photosynthesis (Juan *et al*., 2005). The grain yield also was significantly reduced by salinity at 3.9 dS/m and 6.5 dS/m which are equivalent to 2.15 ppt and 3.58 ppt respectively (Zeng & Shannon, 2000). Generally, yield components such as the number of grains per panicle, panicle length, the number of tillers per hill, 100 grains weight and increased sterility are all severely affected with the increased salinity stress levels regardless of the season and development stage (Ghosh *et al*., 2016). All these yield components are linked to one another regarding the final grain yield.

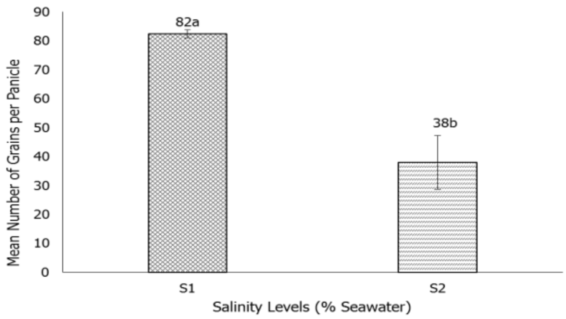

Figure 6. Effects of different salinity levels on the mean number of grains per panicle of TR9 rice variety.

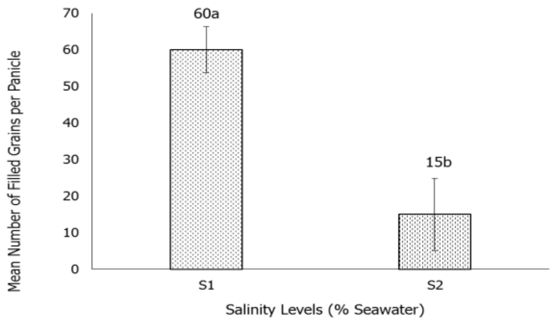

Figure 7. Mean number of filled grains per panicle of TR9 rice variety under different levels of salinity.

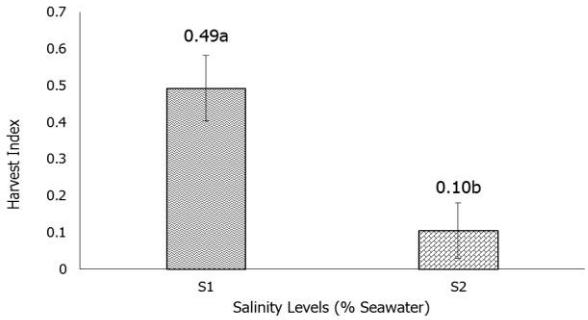

Figure 8. Harvest index of TR9 rice variety under two different levels of salinity.

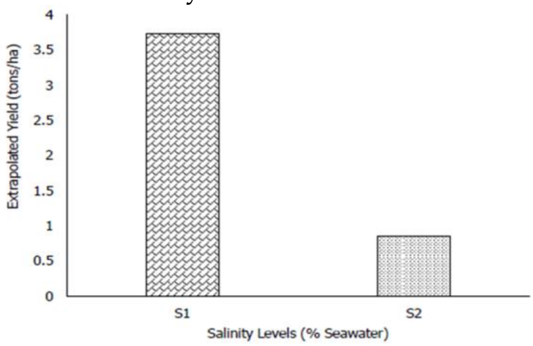

Figure 9. The extrapolated yield of TR9 rice variety under different levels of salinity.

Different alphabet letters presented on different treatments indicate a significant difference at P<0.05.

Free Proline Content

A significant difference (P<0.05) was shown on the free proline content in the leaves of rice plants treated under salinity throughout the days of planting (Figure 10). Treatment S2 had the highest proline content (0.53 µmole/g fresh weight) compared to treatment S1, 0.04 µmole/g fresh weight in leaves. Water uptake by plants was inhibited by soil salinization and caused an ionic imbalance. This condition will lead to ionic toxicity and osmotic stress. Hence, to withstand salt stress, plants will accumulate compatible solutes such as proline, which decreases the cytoplasmic osmotic potential and facilitates water absorption (Pottosin *et al*., 2014).

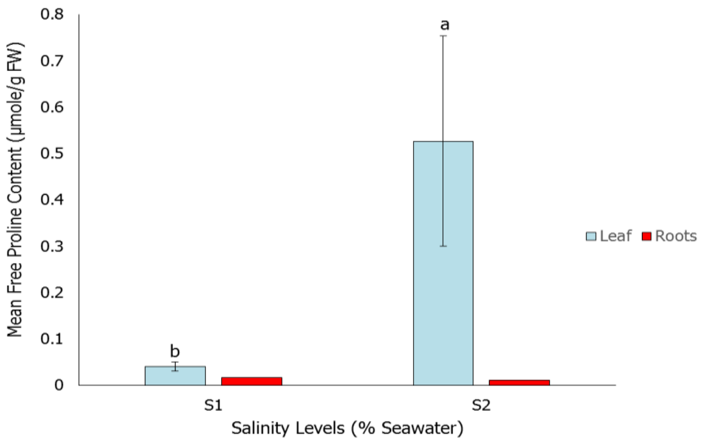

Figure 10. Mean free proline content in the leaves and roots of TR9 rice variety under two different salinity levels.

Different alphabet letters presented on different treatments indicate a significant difference at P<0.05.

There was no significant difference (P>0.05) obtained on the number of unfilled grains per panicle, 100-grains weight, and the number of panicles per plant of TR9 rice when treated with different levels of salinity. For treatments S3, S4 and S5 with 5.0%, 7.5% and 10.0% of seawater, no data were obtained on the percentage of productive tillers, panicle length, number of grains per panicle, number of filled grains per panicle, harvest index, extrapolated yield and free proline content as rice plants treated under these salinity levels were not successfully survived till the day of harvesting which is at 130 DAS.

CONCLUSION

The study revealed that different levels of salinity had significant effects on the plant height, number of tillers per hill, percentage of productive tillers, panicle length, number of grains per panicle, number of filled grains per panicle, harvest index and free proline content in the leaves of TR9 rice variety. The Tolerable salinity level of TR9 rice variety was < 3.97 dS/m. There was a 78% yield reduction of rice under saline condition compared to non-saline condition.

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REFERENCES

[1] Abdullah, Z., Khan, M. A. & Flowers, T. J. 2001. Causes of Sterility in Seed Set of Rice under Salinity Stress. *Journal of Agronomy and Crop Science*, 187, 25-32.

[2] Al-Eryani, A. R. A. A. 2004. Effects of Salinity on Yield and Postharvest Quality of Tomato (*Lycopersicon esculentum* Mill.). *Doctoral Dissertation*. Universiti Putra Malaysia.

[3] Ashraf, M. Y., Khan, A. H. & Naqvi, S. S. M. 2008. Effect of Salinity on Seedling Growth and Solute Accumulation in Two Wheat Genotypes. *Rachis*, 10, 30-31.

[4] Asseng, S. & van Herwaarden, A. F. 2003. Analysis of the Benefits to Wheat Yield from Assimilates Stored Prior to Grain Filling in a Range of Environments. *Plant and Soil*, 256, 217–219.

[5] Bates, L. S., Waldren, R. P. & Teare, I. D. 1973. Rapid Determination of Free Proline for Water Stress Studies. *Plant and Soil*, 39(1), 205-207.

[6] Cook, J., Yoshida, S. & Forno, D. A. 1976. *Laboratory Manual for Physiological Studies of Rice*. International Rice Research Institute, Philippines.

[7] CSISA. 2015. *Operational Manual for Mechanical Transplanting of Rice*. International Maize and Wheat Improvement Center and International Rice Research Institute.

[8] Eugene, V. M., Scott, M. L., Leland, E. F. & Catherine, M. G. 1994. Tiller development in salt-stressed wheat. *Crop Science*, 34, 1594-1603.

[9] Ghosh, B., Md, N. A. & Gantait, S. 2016. Response of Rice under Salinity Stress: A Review Update. *Rice Research*, 1-8.

[10] Hussain, S., Zhang, J. H., Zhong, C., Zhu, L. F., Cao, X. C., Yu, S. M., James, A. B., Hu, J. J. & Jin, Q. Y. 2017. Effects of Salt Stress on Rice Growth, Development Characteristics, and the Regulating Ways: A Review. *Journal of Integrative Agriculture*, 16(11), 2357-2374.

[11] Jabatan Pertanian Sabah. 2010. *Varieti Padi Seri Sabah (TR9)*. Kementerian Pertanian dan Industri Makanan Negeri Sabah. Malaysia.

[12] Janssen, M. M., Geison, E., Bertoni, T. & Zimmerman, M. 2016. The Effects of Two Levels of Salinity on Wisconsin Fast Plants. *Master of Science Dissertation*. Augustana College.

[13] Juan, M., Rivero, R. M., Romero, L. & Ruiz, J. M. 2005. Evaluation of Some Nutritional and Biochemical Indicators in Selecting Salt-resistant Tomato Cultivars. *Environmental and Experimental Botany*, 54(3), 193-201.

[14] Khush, G. S. 2005. What will it Take to Feed 5 Billion Rice Consumers in 2030? *Plant Morphology Biology*, 59, 1-6.

[15] Kijne, J. W. 2006. Biotic Stress and Water Scarcity: Identifying IRANAN. *Journal of Soil and Waters Sciences Spring*, 20(1), 73-83.

[16] Laffitte, H. R. Ismail, A. & Bennet, J. 2004. *Abiotic Stress Tolerance in Rice for Asia: Progress and Future. In New Directions for a Diverse Planet*. Proceedings for the 4th International Crop Science Congress, Brisbane, Australia, 26, 1-17.

[17] Mobasser, H. R., Yadi, R., Azizi, M., Ghanbari, A. M. & Samdaliri, M. 2009. Effect of Density on Morphological Characteristics Related-Lodging on Yield and Yield Components in Varieties Rice (*Oryza Sativa* L.). *Iran Journal of Agricultural and Environmental Science,* 5(6), 745-754.

[18] Munns, R. & Tester, M. 2008. Mechanisms of Salinity Tolerance. *Annual Review of Plant Biology*, 59, 651-681.

[19] Nicolas, M. E., Munns, R., Samarakoon, A. B. & Gifford, R. M. 1994. Elevated CO_2 improves the growth of wheat under salinity. *Australian Journal of Plant Physiology*, 20**,** 349-360.

[20] Okuno, A., Hirano, K., Asano, K., Takase, W., Masuda, R., Morinaka, Y. & Matsuoka, M. 2014. New Approach to Increasing Rice Lodging Resistance and Biomass Yield Through the Use of High Gibberellin Producing Varieties. *PLoS One*, 9(2), e86870.

[21] Pantuwan, G., Fukai, S., Cooper, M., Rajatasereekul, S. & O'Toole, J. C. 2002. Yield Response of Rice (*Oryza sativa* L.) Genotypes to Different Types of Drought Under Rainfed Lowlands- Part 3, Plant Factors Contributing to Drought Resistance. *Field Crops Research*, 73, 181-200.

[22] Pottosin, I., Velarde-Buedía, A. M., Bose, J., Zepeda-Jazo, I., Shabala, S. & Dobrovinskaya, O. 2014. Crosstalk Between Reactive Oxygen Species and Polyamines in Regulation of Ion Transport across the Plasma Membrane. Implications for Plant Adaptive Responses. *Journal of Experimental Botany*, 65(5), 1271-1283.

[23] Rad, H. E., Aref, F. & Rezaei, M. 2012. Response of Rice to Different Salinity Levels during Different Growth Stages. *Research Journal of Applied Sciences, Engineering and Technology*, 4, 3040-3047.

[24] Sinong, G. F. 2016. Effect of different Rates of NPK Fertilizer Application on Growth and Yield on Several Sabah Local Traditional Paddy Varieties. *Bachelor of Agricultural Science Dissertation*. Universiti Malaysia Sabah.

[25] Takeda, S. & Matsuoka, M. 2008. Genetic Approaches to Crop Improvement: Responding to Environmental and Population Changes. *Nature Reviews Genetics*, 9(6), 444.

[26] Tester, M. & Davenport, R. 2003. Na^+ Tolerant and Na^+ Transport in Higher Plants. *Annals of Botany*, 91, 503-527.

[27] Yeo, A. & Flowers, T. 1986. Salinity Resistance in Rice (*Oryza sativa* L.) and a Pyramiding Approach to Breeding Varieties for Saline Soils. *Australian Journal Plant Physiology*, 13, 161-173.

[28] Zeng, L. & Shannon, M. C., 2000. Salinity Effects on Seedling Growth and Yield Components of Rice. *Crop Science*, 40, 996-1003.

[29] Zeng, L., Scott, M., Lesch, C. & Grieve, M. 2003. Rice Growth and Yield Respond to Changes in Water Depth and Salinity Stress. *Agriculture Water Management*, 59, 67-75.

[30] Zeng, L., Shannon, M. C. & Lesch, S. M. 2001. Timing of Salinity Stress Affects Rice Growth and Yield Components. *Agricultural Water Management*, 48, 191-206.