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Effects of different salinity levels on rice production

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ABSTRACT

Background: Salinity is one of major problems for rice production. **Objective:** We tested if different salinity conditions affect production of local rice variety. Rice variety of MR219 was cultivated under different saline conditions and yield and plant parameters were evaluated. **Results:** Root and shoot length decreased gradually with increasing saline concentration in soil solution. Chlorophyll (Chl) content decreased under salinity condition than control but soil pH was unchanged except 6 ds salinity which significantly reduced soil pH. Relative water content (RWC) decreased with increasing salinity condition in soil solution. Plant height and tiller numbers also decreased with increasing salinity in soil. Other parameters, panicle length, panicle per pot, grain per plant and weight of grains showed similar to the plant height. **Conclusion:** These results suggest that local variety, MR219, is saline susceptible and need to pay attention in agronomic practices for sustainable crop production.

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INTRODUCTION

Rice provides about 32% of total calorie uptake in Asia. About 729 million tonnes rice per year is produced globally and 661 million tonnes of that is produced in Asia (FAO, 2012). Environmental stresses, salinity, drought and high temperature, affect rice production but salinity is one of more devastating factors in arid and semi-arid environments (Khan *et al*., 2003; Azhar *et al*., 2007). As a result, the changing global climate leads to stress on growth and development of rice plants. Therefore, sustain approaches should be undertaken to minimize the detrimental effects of climate changes on rice plant (IRRI, 2008). Insufficient drainage and use of low quality of irrigation water (Binzel and Reuveni, 1994) increases salinity of about 7% of the lands surface and 5% of cultivated lands in the world (Flowers *et al*., 1997). Salinity covers about 400 million hectares lands in the world (Flowers *et al*., 2000), of which 54 million are found in south and south East Asia (Akbar and Ponnamperuma, 1982). In Peninsular Malaysia, about 50% of lands are considered unsuitable for agriculture which is referred as problematic soils in which salinity covers 5% of total lands (Sani, 1991). Salinity is the second major obstacle to reduce rice production after drought condition. Therefore, production of rice under saline condition is under pressure because salinity may cause plant demise, growth and development (Galvani, 2007; Roychoudhury *et al*., 2008) and reduced yield up to 50% (Zeng *et al*., 2002).

Salinity reached to a serious condition in irrigated rice soil in semiarid and arid climates that seasonal increases of salinity in topsoil can hardly be avoided (Asch *et al*., 1997). Rice plant is considered as moderately sensitive to saline condition (Mori and Kinoshita, 1987). Therefore, the most economic and sustain way to overcome the effects of salinity on rice production. Salinity affects rice growth in all stages starting from germination to maturity (Manneh, 2004).

Salinity affects plant growth during developmental stages and the sensitivity to crops varies from one growth stage to another in rice (Akbar and Yabuno, 1974). The aim of this study was to provide information on the effects of different flooding levels on rice production of local variety.

Methodology:

Agronomic practices:

Experiment was carried out under rain shelter at Gong Badak campus, Universiti Sultan Zainal Abidin. Rice plants were grown in a pot measuring 25 cm x 25 cm x 35 cm. There were four different salinity treatments, S0 (distilled water), S1 (NaCl solution was applied to maintain at 2 ds level in soil), S2 (NaCl solution was applied to maintain at 4 ds level in soil) and S3 (NaCl was applied to maintain at

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Australian Journal of Basic and Applied Sciences, 9(5) March 2015, Pages: 524-530

6 ds level in soil), were presented as completely randomized design (CRD) with five replicates.

Seed sowing, irrigation and fertilizer application:

Rice seeds of variety MR 219 were used in these studies. The experimental pots were placed at the open field under rain shelter and standard agronomic practices were maintained to control insect, disease and weeds (Sarwar and Khanif, 2005a, 2005b, 2005c, and 2005d). Two holes (1 and 5 cm above the soil level in the pot) were made at pots to maintain respective irrigation treatments. Fertilizer was applied according to the previous study (Jahan *et al*., 2004; Sarwar 2004, Sarwar *et al*., 2004).

Yield and Yield Parameters:

Yield and yield parameters were measured according to previous studies (Chelah *et al*., 2011, Jahan *et al*., 2012). Plant height was measured with a measuring tape (Jahan *et al*., 2014a; Syuhada *et al*., 2014). Filled grains were separated using salt solution and counted as previously described (Jahan *et al*., 2012).

Determination of Root And Shoot Length:

Ten germinated seeds were planted in tray under control greenhouse environment. After three weeks of growth, seedlings were uprooted and washed with distilled water to remove soil. The root length of seedlings from each replicate was measured in cm from the base of hypocotyl to the tip of longest root. The shoot length of seedlings from each replication was measured in cm from the base of hypocotyl to the top of shoot (Jahan *et al*., 2014b; Munirah *et al*., 2015).

Measurement of electric conductivity and soil pH:

Electrical conductivity (EC) is the ability of a material to transmit (conduct) an electrical current and is commonly expressed in units of milliSiemens per meter (mS/m; Khairi *et al*., 2015b). Sensors (pH and EC) were calibrated before using in each time and measured by using EC meter and pH meter (Jahan *et al*., 2013a).

Measurement of chlorophyll content, chlorophyll fluorescence and relative water content (RWC) in Leaves:

The SPAD-502 chlorophyll meter was used to acquire a rapid estimation of leaf chlorophyll content according to Syuhada *et al*. (2014). Relative water content was measured according to previous studies (Jahan *et al*., 2013b; Khairi *et al*., 2015a).

Statistical Analysis:

The data were analysed for analysis of variance (ANOVA). The means were compared using Duncan's Multiple Range Test (DMRT) at 5% level using the Minitab and MS Excel software according to Nozulaidi *et al*. (2015).

Results

Effect of Different Salinity Levels on Root Length And Shoot Length:

Figure 1 shows the effects of salinity on root and shoot growth. Root growth significantly decreased under 2 dS/m salinity level compared to that of control (Fig. 1a). Root growth gradually decreased with increasing salinity level in soil indicating dose dependency. Shoot length showed similar to root length (Fig. 1b). Where, shoot length decreased with increasing salinity level in soil solution.

Effects of salinity levels on Chl content, soil pH and RWC:

Chlorophyll contents in leaves of MR219 were presented in Figure 2. Chlorophyll contents in leaves of plants were significantly different where treatment S4 (6 ds) significantly decreased Chl content in leaves compared than other treatments. These results indicate that lower concentration of salinity levels from 0 ds to 4 ds did not affect chlorophyll content in leaves.

Figure 2b shows soil pH data in soil at different salinity conditions. Soil pH was found significantly different in different saline soils. Where treatment S4 (6 ds) showed significant effect on soil pH than other treatments. Relative water content was measure and presented in Figure 2c. It is stated that RWCs were significantly different in leaves of MR219 plants under different salinity conditions. Where RWC in leaves of MR219 plants decreased with increasing salinity levels (Fig. 2c). RWC in leaves at salinity 2 ds condition was significantly lower than control where RWC in leaves at salinity 4 ds and 6 ds conditions was significantly lower than salinity at 2 ds condition. This indicates that RWC in leaves seems to be dose dependent on soluble salts in soil.

Yield and Yield Parameters:

The height was measured to find out the effect of salinity levels on the plant height. The plant height of the MR219 plant showed significantly different under different salinity levels (Fig. 3a). Where, the plant height gradually decreased with increasing salinity levels in soil solution. The salinity level of ds2 significantly decreased the height of the MR219 plant which indicates that MR219 plants showed sensitivity to saline condition. A similar result was found when data were compared between two different salinity levels. Salinity levels significantly affected tiller numbers in MR219 plants. The effect of salinity was gradually increased with increasing salinity in soil. Saline condition at 6 ds reduced tiller number about 50% compared to the control condition. Even though when salinity was at 2 ds, MR219 plant produced significantly lower tillers number and was about 15% lower than the control.

These results suggest that MR219 plant is susceptible to salinity soil. Panicle length was significantly different under different salinity levels (Fig.3b, open bars). Different salinity levels significantly decreased panicle length compare that the control. Where salinity levels 4 ds and 6 ds were insignificantly different and salinity levels 0 ds and 2 ds were significantly different. Different salinity treatments significantly affected panicle number per pot. In addition, panicle numbers per plants gradually decreased with increasing salinity concentrations in soil (Fig. 3b, closed bars). These results were consistent with Khatun *et al*. (1995) that primary branches per panicle are significantly reduced by salinity. Total grains per panicle were measured to justify the effect of salinity on yield. Figure 3c showed that total grains per panicle were significantly different. Where control treatment significantly increased total grains per panicle compared to salinity treatments. Total grains per panicle under saline treatments were also to be differentiated. Similarly, different salinity levels decreased yield with increasing salinity in soil solution.

Discussion:

Salinity is a worldwide problem and plays a vital role in determining the type of crop to be planted. The distribution of salt-affected lands is closely related to environmental factors, in particular arid and semi-arid climates. High soil salinity is the main cause of reduction of growth and crop productivity. It is widely believed that the inhibitory effects of saline stress on plant growth have been due to salt-induced osmotic stress, specific ion toxicity (Na^+ and Cl^- are main toxic ions), nutritional imbalance (Munns, 2009), oxidative stress, and hormonal imbalance in a variety of plants (Ashraf *et al*., 2008). In this study, plant root and shoot growth reduced by the effects of salinity (Fig. 1). These results support that plant growth affected by salt stress through disturbing homeostasis in water status and distribution of ionic salts and oxidative stress. In addition to that the plant growth extent of damage depends on the severity of stress, growth conditions and plant sensitivity to salinity (Kant *et al*., 2007).

Soil salinity beyond EC of 4 dSm^{-1} is considered moderate salinity while more than 8 dSm^{-1} becomes high. Extreme high salt stress conditions kills the plant but the moderate to low salt stress affect the plant growth rate and thereby manifest symptoms which could be associated with morphological, physiological or biochemical alterations. Chlorophyll content decreased in leaves during panicle initiation indicating of the effects of light reaction on plants. Previous study stated that less Chl content in plants accumulates less glutathione content (Jahan *et al*., 2011) which may affect plant growth and development (Jahan *et al*., 2014a). In relation to this, RWC content decreased in leaf which may suggest that plant might accumulate less water content due to increasing salt concentration in soil solution.

Most of the parameters, like low tillering, spikelet sterility, less florets per panicle, low 1000 grain weight and leaf scorching, are affected by salinity. This study reveals that different salinity levels affected yield and yield parameters differently (Fig 3). Salinity can severely reduce nutrients uptake by plants, water retaining capacity in plant body and production. Saline condition can make nutrients unavailable to the plants (Horneck *et al*., 2007). Zeng and Shannon (2000) stated that reduction of tiller number due to salinity condition may affect grain yield per plant. Responses of crop to salinity at various growth stages are depended to the concentration and duration of exposure to salt condition in soil (Shereen *et al*., 2005). The effect of salinity was observed at panicle initiation stage (Khatun and Flowers, 1995; Asch and Wopereis, 2001). In conclusion, this study suggests that local rice variety MR219 is saline susceptible and produce lower yield. Therefore, it is important to care about soil to reduce salinity effects on rice production.

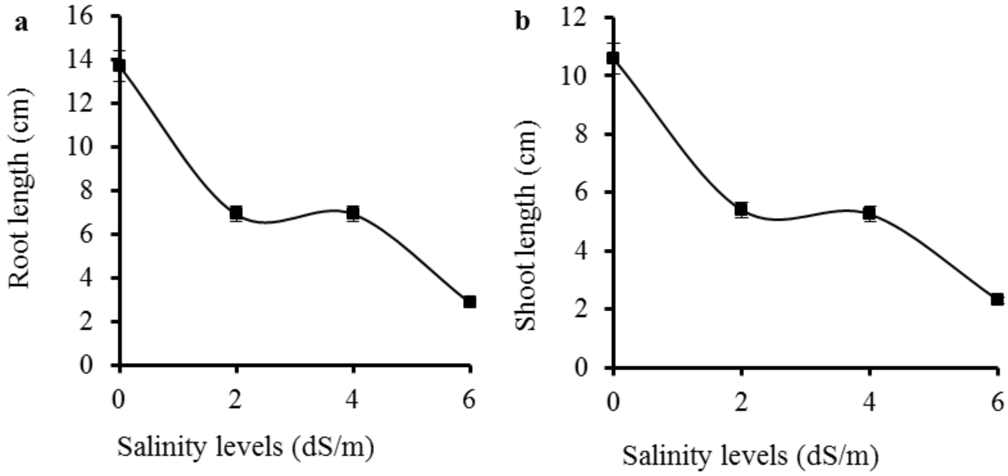

Fig. 1: Effect of different salinity conditions on root (a) and shoot (b) length.

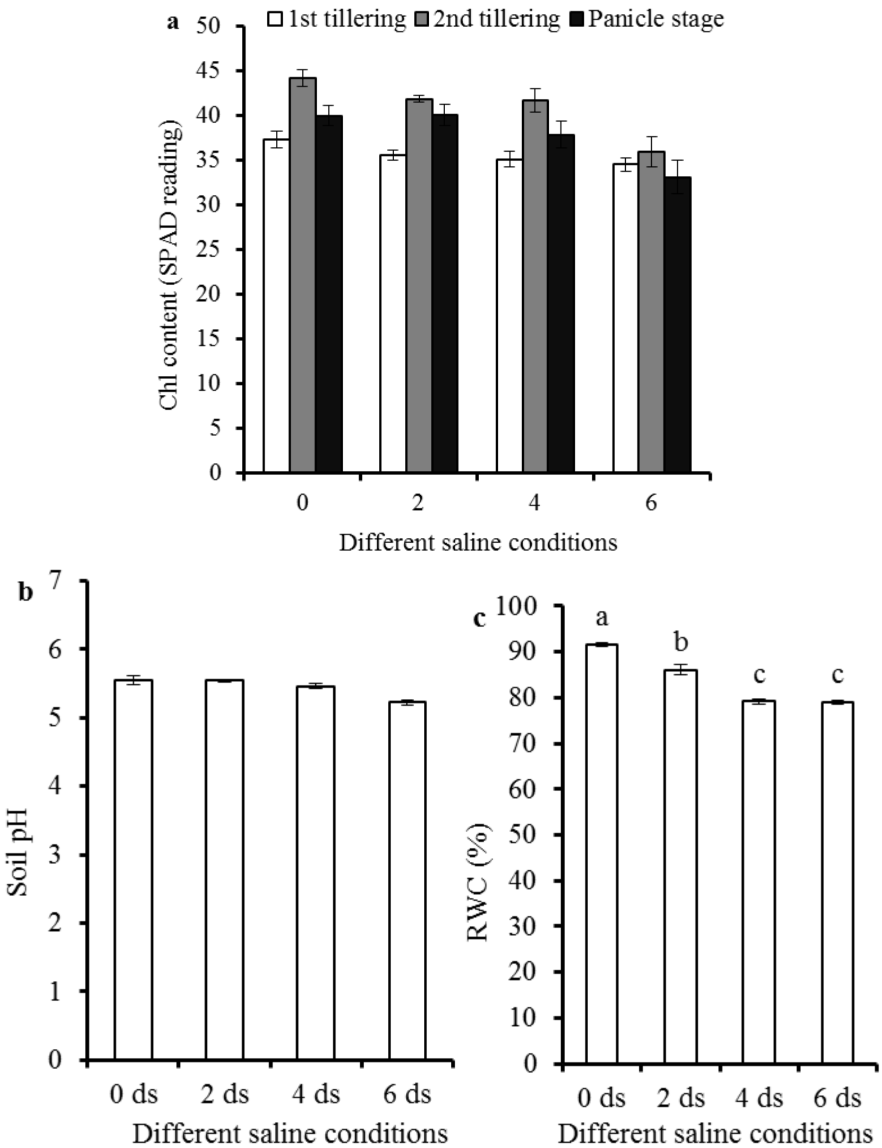

Fig. 2: Effect of different salinity conditions on chlorophyll content (a), soil pH (b) and relative water content (c).

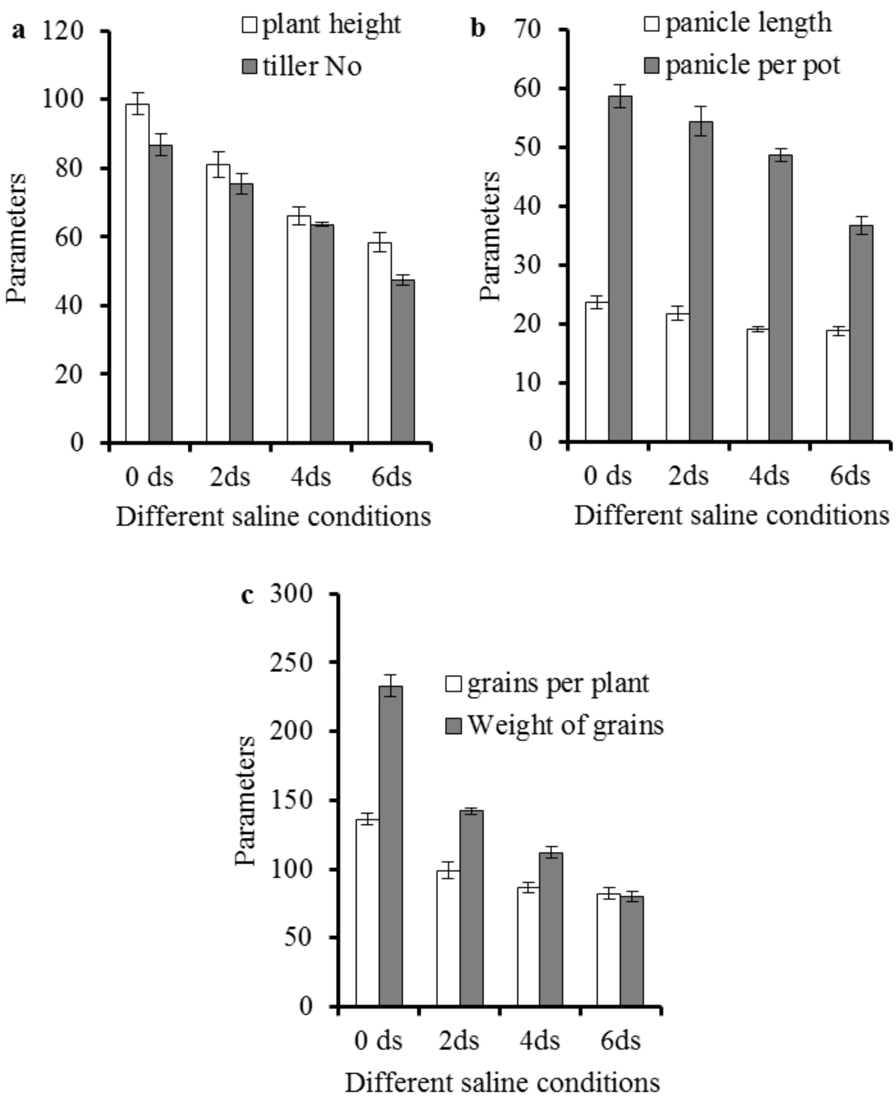

Fig. 3: Effect of different salinity conditions on yield and yield parameters; a, plant height (open bars) and tiller numbers (closed bars), b, panicle length (open bars) and panicle per pot (closed bars) and c, grain per plant (open bars) and weight of grains (closed bars).

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