Physiological Evaluation of Different Rice Genotypes to Two Salinity Level during Seedling Stage under Hydroponic System

S. Lakshmi¹, V. Ravichandran¹*, L. Arul² and K. Krishna Surendar³

¹Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore, 641 003, Tamil Nadu, India.
²Department of Plant Biotechnology, Tamil Nadu Agricultural University, Coimbatore, 641 003, Tamil Nadu, India.
³Department of Rice, Tamil Nadu Agricultural University, Coimbatore, 641 003, Tamil Nadu, India.

Authors’ contributions

This work was carried out in collaboration among all authors. Author SL designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors VR and LA managed the analyses of the study. Author KKS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2020/v32i830317
Editor(s):
(1) L. S. Ayeni, Adeyemi College of Education, Nigeria.
Reviewers:
(1) Dhriti Kapoor, Lovely Professional University, India.
(2) Syed Mubashar Sabir, University of Poonch Rawalakot, Pakistan.
Complete Peer review History: http://www.sdiarticle4.com/review-history/58640

ABSTRACT

Hydroponics study was conducted to screen eight rice genotypes (CO 51, ADT 53, ADT 37, IR 64, CO 43, ASD 16, Pokkali; TRY 3) under salinity stress on early seedling stage. Two Saline treatments (75 and 100 mM NaCl) were given at 15 days old seedling; observations were recorded at 10 days after salt stress. Results showed that shoot length, root length, total fresh and dry weight, shoot and root fresh weight, shoot and root dry weight and root- shoot ratio were reduced under saline conditions compared to control. Na⁺ ion Concentration and Na⁺/K⁺ ratio was higher in saline treatments than control. However, K⁺ ion absorption decreased with increasing salinity level. Electrolyte leakage and osmotic potential had increasing trend with increasing level of salinity. In this study, rice genotypes Pokkali, TRY 3 and CO 43 perform as tolerant; CO 51, ADT 53 and ASD

*Corresponding author: E-mail: ravilux67@gmail.com;
1. INTRODUCTION

Rice (Oryza sativa L.) is most important cereal crop that feeds more than half of the world’s population and it is a staple food in world, particularly in Asia. In world-wide production of agricultural commodity; rice had third place next to sugarcane and wheat [1]. Growth and productivity of rice is more sensitive to abiotic stress [2]. Among these abiotic stresses salinity is the key factor that negatively influences the rice crop growth. In world 800 million ha of lands are extremely affected by salinity that includes 20% of irrigated lands [3]. Yield loss in rice due to salt stress reaches 50-100% [4]. Rice comes under salt sensitive crop and its growth and yield are severely affected by the increased level of soluble salts in soils [5].

Rice is salt sensitive crop but it is recommended to grown under salt affected soils because it has the ability to grow in wet land conditions [4]. Plant response to salinity is depending on growth stages of crop, environmental factors, soil salt composition [6]. Early seedling stage and reproductive stage is much more affected by salinity than tillering stage. According to [7] Salinity is a major threat for agricultural production and it causes both osmotic and ionic stress which leads to severe growth reduction. Salinity stress causes late germination and reduced seedling growth [8].

High salt concentration disturbs the key physiological processes like Photosynthesis, respiration, nitrogen fixation and carbohydrate metabolism [9]. Salinity causes reduction in plant dry weight by two fold as compared to plants grown in control conditions [10]. Both plant morphological and metabolic activities are heavily affected by high salt concentrations. According to [11] Salinity screening of rice was more effective at seedling stage because the variations at this stage are more prominent.

Important management strategy to overcome yield loss under rice condition is to develop the salt tolerant cultivars. Most population in the world consumes rice as stable food, so there is a need to increase the rice production by alleviating these abiotic stresses. Hydroponic screening of rice genotypes is depending on the ability of the seedling to flourish in salinized nutrient solution. Hydroponic screening is done under controlled conditions has benefit because it is free from soil related stress factors. Aim of the current study is to evaluate the physiological basis of eight rice genotypes tolerance to salt stress at seedling stage under hydroponic system.

2. MATERIALS AND METHODS

The Hydroponics experiment was conducted in Glass house at Department of crop physiology, Tamil Nadu agricultural university, Coimbatore.

2.1 Experimental Materials

In this study eight rice genotypes were taken including namely CO 51, ADT 53, ADT 37, IR 64, CO 43, ASD 16, Pokkali, and TRY 3. W were used as tolerant check [12] and IR 64 [13] as susceptible check. The rice genotypes were collected from Paddy breeding station, Tamil Nadu agricultural university, Coimbatore.

2.2 Experimental Setup and Treatment Details

The seeds of eight rice genotypes were soaked in distilled water for initiating the pre germination process called sprouting. Then the sprouted seeds were directly sown in Hydroponic system. Seeds were placed in thermacoal sheet covered by nylon mesh and then it is floated on solution. The hydroponics system contains Yosidha nutrient solution [14]. Details of nutrient element concentration are shown in Table 1. The nutrient solution is replaced by fresh nutrients once in 5 days. Salinity screening of rice at seedling stage in hydroponic setup was done based on standard protocol [15] given by IRRI. The experiment was conducted by completely randomized design with three treatments (0, 75 and 100 mM NaCl) and four replications. First treatment is control setup (Non- saline) and another two treatments are conducted under saline condition by using two different salt concentration i.e., 75 and 100 mM of NaCl [16]. Salt stress was imposed at 15 days old seedling grown in yosidha nutrient solution.

Keywords: Rice; salinity; hydroponics; Na+/ k+ ratio; tolerant; susceptible.
Table 1. Components of nutrient solution

| Stock no | Reagent (AR grade)          | Preparation g/L | Concentration of stock / L of nutrient solution (ml) |
|----------|-----------------------------|-----------------|---------------------------------------------------|
| Stock I  | NH$_4$NO$_3$                | 91.4            | 1.25                                              |
| Stock II | NaH$_2$PO$_4$.2H$_2$O       | 35.6            | 1.25                                              |
| Stock III| K$_2$SO$_4$                 | 71.4            | 1.25                                              |
| Stock IV | CaCl$_2$.2H$_2$O            | 117.35          | 1.25                                              |
| Stock V  | MgSO$_4$.7H$_2$O            | 324             | 1.25                                              |
| Stock VI | (NH$_4$)$_6$Mo$_7$O$_2$.4H$_2$O | 0.074        | 1.25                                              |
|          | ZnSO$_4$.7H$_2$O            | 0035            |                                                   |
|          | H$_3$BO$_3$                 | 0.934           |                                                   |
|          | CuSO$_4$.5H$_2$O            | 0.031           |                                                   |
|          | FeCl$_3$.6H$_2$O            | 7.7             |                                                   |
|          | C$_6$H$_8$O$_7$.H$_2$O      | 11.9            |                                                   |

2.3 Nutrient Solution

The nutrient solution contains both macro and micro nutrients in appropriate proportion. Macronutrients were prepared separately and kept in jam bottles for storage. Each element in the micronutrient solution is dissolved separately in 50 ml of distilled water and then mixed together by using magnetic stirrer and volume is made up to 1000ml. These mixture is dissolved by using distilled water it contains pH less than 5.5 and EC is 1.3. pH of the nutrient is maintained at 4.5 to 5.3 and pH is monitored everyday by using portable pH meter. Any deviation in pH from 4.5 to 5.3 it is adjusted by using HCl or NaOH. Components of nutrient solution are given in Table 1.

2.4 Data Collection

Observations were taken at 10 days after salt stress. Shoot length was measured from base of stem to tip of the leaf and root length was measure from collar region to longer root tip. Seedling weight was measured manually. Shoot and root fresh weight also measured separately. Dry weight of the seedling was taken by drying the plants in hot air oven at 50°C for 3 days. Dry shoot and root weight was also measured. The root shoot ratio was calculated by dry weight basis using following formula:

$$\text{Root shoot ratio} = \frac{\text{Dry weight of root}}{\text{Dry weight of shoot}}$$

Visual leaf drying score was calculated by using modified Standard Evaluation Score (SES) [17]. Sodium and potassium content was estimated by flame photometer. Electrolyte leakage was estimated by using the method of Wu and [19]. It is expressed as %.

Osmotic potential was determined by using osmometer (Vapro Model 5520 Wescor Inc., Logan, UT, USA) [20]. It is expressed as MPa. Reduction percentage was calculated for all parameter based on this conversion.

$$\% \text{Reduction} = \frac{\text{Mean of control} - \text{Mean of stress}}{\text{Mean of control}} \times 100$$

2.5 Statistical Analysis

Data on different parameters analyzed during the research work were subjected to an analysis of variance depends on Factorial Completely Randomized Design (FCRD) [21].

3. RESULTS

3.1 Shoot and Root Length

Shoot length and root length of rice genotypes was significantly decreased with increasing salt concentrations (Table 2). But there is difference observed between eight rice genotypes. Maximum shoot length of 68.5 cm, 66.7 cm and 64.9 cm (Control, 75 and 100 mM NaCl respectively) and root length of 9.9 cm, 9.5 cm and 9.1 cm (Control, 75 and 100 mM NaCl respectively) was observed in tolerant check Pokkali. Minimum Shoot length 40 cm, 36.7 cm and 34.9 cm (Control, 75 and 100 mM NaCl respectively) and root length 6.8 cm, 6.5 cm and 6 cm (Control, 75 and 100 mM NaCl respectively) was observed in susceptible check IR 64. Next to Pokkali, higher shoot length and
root length was observed in TRY 3 and CO 43. The other four genotypes namely, CO 51, ADT 53, ASD 16 and ADT 37 have shoot and root length lesser than tolerant genotypes and had high shoot and root length than susceptible genotypes. Reduction percentage was higher in IR 64, ADT 37 and ASD 16 and lower in Pokkali, TRY3 and CO 43.

3.2 Fresh and Dry Weight

Total fresh and dry weight of the seedlings had decreasing trend with increasing salinity level (Table 3). Maximum fresh weight 2.42 g, 2.35 g and 2.30 g in control, 75 and 100 mM NaCl respectively and dry weight 2.24 g, 1.87 g and 1.55 g in control, 75 and 100 mM NaCl respectively was observed in tolerant check Pokkali. Minimum fresh weight 1.35 g, 1.01 g and 0.75 g in control, 75 and 100 mM NaCl respectively and dry weight 1.22 g, 0.70 g and 0.42 g in control, 75 and 100 mM NaCl was recorded in susceptible check IR 64, so the fresh and dry weight was higher in tolerant genotypes than the susceptible genotypes. Apart from these 2 genotypes TRY 3 and CO 43 perform as tolerant and had high seedling weight and CO 51, ADT 53, ASD 16 and ADT 37 performed as moderately tolerant and susceptible; had higher seedling weight than IR 64 and lower than Pokkali. Maximum reduction percentage in dry weight was observed in IR 64 about 26.77%, 60.02% (75 mM and 100 mM stress respectively) and minimum reduction was observed in tolerant genotypes namely Pokkali followed by TRY 3 and CO 43. Shoot and root fresh weight (Table 4), Shoot and root dry weight (Table 5) was also had same decreasing trend with increasing salt concentrations.

3.3 Root Shoot Ratio

Root shoot ratio was also decreased with increasing salinity (Fig. 1). Highest root shoot ratio 0.29, 0.28 and 0.28 (Control, 75 and 100 mM NaCl respectively) was observed in tolerant check Pokkali; TRY 3 0.28, 0.26 and 0.25 (Control, 75 and 100 mM NaCl respectively) and CO 43 0.25, 0.22, 0.20 (Control, 75 and 100 mM NaCl respectively). Lowest root shoot ratio 0.11, 0.05 and 0.05 (Control, 75 and 100mM NaCl respectively) was observed in susceptible check IR 64. Other genotypes namely CO 51, ADT 53, ADT 37 and ASD 16 performed as moderately tolerant and susceptible; had lower ratio than Pokkali and higher ratio than IR 64. Reduction percentage was lower about 2.58%, 3.81% (75 mM and 100 mM stress respectively) in Pokkali and higher in IR 64 i.e., about 53.51%, 54.31% (75 mM and 100 mM stress respectively).

3.4 Leaf Drying Score

Out of eight rice genotypes used in this study, Pokkali is highly tolerant, TRY 3, CO 43, CO 51 genotypes are tolerant, ADT 53, ASD 16 genotypes are moderately tolerant, ADT 37 is susceptible and IR 64 is highly susceptible (Table 7) based on the visual appearance of the seedling (Figs. 2, 3 and 4). Seedling score was predicted based on the standard evaluation score (Table 6) given by IRRI (2003).

3.5 Na and K Content

Sodium ion (Na⁺) concentration was increased with increasing amount of salinity (Fig. 5). Susceptible genotypes recorded higher sodium content than tolerant genotypes. Higher sodium content was observed in susceptible check IR 64 6.89%, 8.43% and 8.65% (Control, 75 and 100 mM NaCl respectively) and ADT 37; 6.59%, 8.21% and 8.60% (Control, 75 and 100 mM NaCl respectively). Lower sodium content was recorded in tolerant check Pokkali 4.42%, 6.45% and 7.63% (Control, 75 and 100 mM NaCl respectively), TRY 3; 5.01%, 6.66% and 7.65% (Control, 75 and 100 mM NaCl respectively) and CO 43; 5.17%, 6.78% and 7.77% (Control, 75 and 100 mM NaCl respectively). Other moderately tolerant (ADT 53) and moderately susceptible (ASD 16) and susceptible (ADT 37) genotypes recorded higher sodium content than Pokkali and had lower sodium content than IR 64.

Potassium ion (K⁺) absorption was decreased with increasing salinity (Fig. 6). Maximum K⁺ content was observed in tolerant check Pokkali 4.01%, 3.48% and 2.61% (Control, 75 and 100mM NaCl respectively), TRY 3; 3.67%, 2.87% and 1.82% (Control, 75 and 100 mM NaCl respectively) and CO 43; 3.42%, 2.56% and 1.76% (Control, 75 and 100 mM NaCl respectively). Minimum K⁺ content was observed in susceptible check IR 64 i.e. 2.29%, 1.46% and 2.23% (Control, 75 and 100 mM NaCl respectively). Other moderately tolerant (ADT 53) and moderately susceptible (ASD 16) and susceptible (ADT 37) genotypes recorded higher potassium content than IR 64 and had lower potassium content than Pokkali.
Table 2. Effect of different salinity level on shoot length and root length (cm) of rice genotypes

| Genotypes | Shoot length (cm) | Root length (cm) |
|-----------|------------------|------------------|
|           | Control | 75 mM NaCl | % Reduction | 100 mM NaCl | % Reduction | Control | 75 mM NaCl | % Reduction | 100 mM NaCl | % Reduction |
| CO 51     | 43.8    | 42.4       | 3.20        | 40.2        | 8.2         | 8.5      | 8.1        | 4.71        | 7.7         | 9.41        |
| ADT 53    | 42.2    | 39.8       | 5.69        | 37.9        | 10.2        | 7.9      | 7.4        | 6.01        | 7.1         | 10.13       |
| ADT 37    | 40.1    | 37.0       | 7.73        | 35.2        | 12.2        | 7.3      | 6.8        | 6.85        | 6.5         | 10.96       |
| IR 64     | 40.0    | 36.7       | 8.25        | 34.9        | 12.8        | 6.8      | 6.3        | 7.35        | 6.0         | 11.76       |
| CO 43     | 45.7    | 44.3       | 3.06        | 42.3        | 7.4         | 8.9      | 8.5        | 4.49        | 8.1         | 8.99        |
| ASD 16    | 40.7    | 37.8       | 7.13        | 36.9        | 9.3         | 7.7      | 7.2        | 6.49        | 6.9         | 10.39       |
| Pokkali   | 68.5    | 66.7       | 2.66        | 64.9        | 5.3         | 9.9      | 9.5        | 4.04        | 9.1         | 8.08        |
| TRY 3     | 47.3    | 45.9       | 2.96        | 44.1        | 6.8         | 9.2      | 8.8        | 4.35        | 8.4         | 8.70        |

Table 3. Effect of different salinity level on total fresh and dry weight of rice genotypes

| Genotypes | Total fresh weight (g) | Total dry weight (g) |
|-----------|------------------------|----------------------|
|           | Control | 75 mM NaCl | 100 mM NaCl | Control | 75 mM NaCl | 100 mM NaCl |
| CO 51     | 1.76    | 1.59       | 1.40        | 1.58    | 1.34       | 1.10        |
| ADT 53    | 1.66    | 1.38       | 1.23        | 1.50    | 1.25       | 0.92        |
| ADT 37    | 1.46    | 1.10       | 0.86        | 1.35    | 0.99       | 0.54        |
| IR 64     | 1.35    | 1.01       | 0.75        | 1.22    | 0.70       | 0.42        |
| CO 43     | 1.86    | 1.71       | 1.55        | 1.71    | 1.45       | 1.16        |
| ASD 16    | 1.57    | 1.27       | 1.06        | 1.41    | 1.10       | 0.70        |
| Pokkali   | 2.42    | 2.35       | 2.30        | 2.24    | 1.87       | 1.55        |
| TRY 3     | 1.94    | 1.85       | 1.73        | 1.96    | 1.56       | 1.33        |

G 0.03  0.05**  0.003  0.007**
T 0.02  0.03**  0.002  0.005**
G x T 0.04  0.09**  0.006  0.013**
### Table 4. Effect of different salinity level on shoot and root fresh weight of rice genotypes

| Genotypes | Shoot fresh weight (g) | Root fresh weight (g) |
|-----------|-----------------------|-----------------------|
|           | Control | 75 mM NaCl | 100 mM NaCl | Control | 75 mM NaCl | 100 mM NaCl |
| CO 51     | 1.31    | 1.20       | 1.08       | 0.45    | 0.39       | 0.32       |
| ADT 53    | 1.23    | 1.08       | 0.96       | 0.43    | 0.30       | 0.27       |
| ADT 37    | 1.11    | 0.87       | 0.69       | 0.35    | 0.23       | 0.17       |
| IR 64     | 1.04    | 0.81       | 0.62       | 0.31    | 0.20       | 0.13       |
| CO 43     | 1.40    | 1.30       | 1.19       | 0.46    | 0.41       | 0.36       |
| ASD 16    | 1.18    | 1.01       | 0.85       | 0.39    | 0.26       | 0.21       |
| Pokkali   | 1.80    | 1.75       | 1.73       | 0.62    | 0.60       | 0.57       |
| TRY 3     | 1.46    | 1.39       | 1.32       | 0.48    | 0.46       | 0.41       |

Table 4. Effect of different salinity level on shoot and root fresh weight of rice genotypes

| Genotypes | Shoot dry weight (g) | Root dry weight (g) |
|-----------|----------------------|---------------------|
|           | Control | 75 mM NaCl | % Reduction | 100 mM NaCl | % Reduction | Control | 75 mM NaCl | % Reduction | 100 mM NaCl | % Reduction |
| CO 51     | 1.23    | 1.12       | 9.33        | 0.99       | 20.08      | 0.35    | 0.22       | 36.69       | 0.11       | 68.35       |
| ADT 53    | 1.18    | 1.06       | 10.78       | 0.83       | 29.60      | 0.32    | 0.19       | 39.68       | 0.08       | 73.81       |
| ADT 37    | 1.08    | 0.86       | 20.79       | 0.52       | 52.17      | 0.26    | 0.13       | 51.43       | 0.02       | 92.38       |
| IR 64     | 1.00    | 0.61       | 38.85       | 0.41       | 59.15      | 0.22    | 0.09       | 60.67       | 0.01       | 95.96       |
| CO 43     | 1.35    | 1.21       | 10.04       | 1.03       | 23.61      | 0.36    | 0.24       | 34.48       | 0.13       | 64.14       |
| ASD 16    | 1.13    | 0.95       | 16.00       | 0.65       | 42.44      | 0.29    | 0.15       | 46.96       | 0.06       | 80.87       |
| Pokkali   | 1.74    | 1.49       | 14.22       | 1.29       | 26.15      | 0.50    | 0.38       | 24.88       | 0.27       | 46.77       |
| TRY 3     | 1.56    | 1.28       | 18.24       | 1.18       | 24.32      | 0.40    | 0.28       | 29.38       | 0.14       | 64.38       |

### Table 5. Effect of different salinity level on shoot and root dry weight of rice genotypes

| Genotypes | Shoot dry weight (g) | Root dry weight (g) |
|-----------|----------------------|---------------------|
|           | Control | 75 mM NaCl | % Reduction | 100 mM NaCl | % Reduction | Control | 75 mM NaCl | % Reduction | 100 mM NaCl | % Reduction |
| CO 51     | 1.23    | 1.12       | 9.33        | 0.99       | 20.08      | 0.35    | 0.22       | 36.69       | 0.11       | 68.35       |
| ADT 53    | 1.18    | 1.06       | 10.78       | 0.83       | 29.60      | 0.32    | 0.19       | 39.68       | 0.08       | 73.81       |
| ADT 37    | 1.08    | 0.86       | 20.79       | 0.52       | 52.17      | 0.26    | 0.13       | 51.43       | 0.02       | 92.38       |
| IR 64     | 1.00    | 0.61       | 38.85       | 0.41       | 59.15      | 0.22    | 0.09       | 60.67       | 0.01       | 95.96       |
| CO 43     | 1.35    | 1.21       | 10.04       | 1.03       | 23.61      | 0.36    | 0.24       | 34.48       | 0.13       | 64.14       |
| ASD 16    | 1.13    | 0.95       | 16.00       | 0.65       | 42.44      | 0.29    | 0.15       | 46.96       | 0.06       | 80.87       |
| Pokkali   | 1.74    | 1.49       | 14.22       | 1.29       | 26.15      | 0.50    | 0.38       | 24.88       | 0.27       | 46.77       |
| TRY 3     | 1.56    | 1.28       | 18.24       | 1.18       | 24.32      | 0.40    | 0.28       | 29.38       | 0.14       | 64.38       |
Fig. 1. Effect of different salinity level on root-shoot ratio of rice genotypes

Fig. 2. Effect of non-saline treatment on rice genotypes

Fig. 3. Effect of 75 mM salinity on rice genotypes
Table 6. Modified standard evaluation score (SES) of visual salt injury at seedling stage (IRRI, 2003)

| Score | Observation                                                   | Tolerance          |
|-------|---------------------------------------------------------------|--------------------|
| 1     | Normal growth, no leaf symptoms                               | Highly tolerant    |
| 3     | Nearly normal growth, but leaf tips or few leaves whitish and rolled | Tolerant           |
| 5     | Growth severely retarded; most leaves rolled; only a few are elongating | Moderately tolerant |
| 7     | Complete cessation of growth; most leaves dry; some plants dying | Susceptible        |
| 9     | Almost all plants dead or dying                               | Highly susceptible |

Table 7. Effect of different salinity level on leaf drying score of rice genotypes

| Genotypes | Control | 75 mM NaCl | 100 mM NaCl | % Reduction | % Reduction |
|-----------|---------|------------|-------------|-------------|-------------|
| CO 51     | 1       | 3          | 3           | 72.36       | 98.70       |
| ADT 53    | 1       | 3          | 5           | 61.52       | 85.35       |
| ADT 37    | 1       | 7          | 9           | 55.20       | 76.86       |
| IR 64     | 1       | 7          | 9           | 55.38       | 72.42       |
| CO 43     | 1       | 1          | 3           | 1.73        | 1.92        |
| ASD 16    | 1       | 5          | 7           | 1.96        | 2.18        |
| Pokkali   | 1       | 1          | 1           | 2.74        | 3.08        |
| TRY 3     | 1       | 1          | 3           | 2.63        | 3.65        |

Table 8. Effect of different salinity level on osmotic potential (MPa) of rice genotypes

| Genotypes | Control | 75 mM NaCl | % Reduction | 100 mM NaCl | % Reduction |
|-----------|---------|------------|-------------|-------------|-------------|
| Co 51     | -1.35   | -2.32      | -72.36      | -2.68       | -98.70      |
| ADT 53    | -1.28   | -2.07      | -61.52      | -2.37       | -85.35      |
| ADT 37    | -1.18   | -1.83      | -55.20      | -2.08       | -76.86      |
| IR 64     | -1.12   | -1.73      | -55.38      | -1.92       | -72.42      |
| Co 43     | -1.43   | -2.44      | -70.58      | -2.86       | -100.18     |
| ASD 16    | -1.24   | -1.96      | -58.59      | -2.18       | -76.36      |
| Pokkali   | -1.64   | -2.74      | -67.74      | -3.08       | -88.23      |
| Try 3     | -1.50   | -2.63      | -74.71      | -2.92       | -94.51      |

Fig. 4. Effect of 100 mM salinity on rice genotypes
Fig. 5. Effect of different salinity level on Na\(^+\) content (%) of rice genotypes

Fig. 6. Effect of different salinity level on K\(^+\) content (%) of rice genotypes

Fig. 7. Effect of different salinity level on Na\(^+\)/K\(^+\) ratio of rice genotypes
Na\(^+\)/K\(^+\) ratio was increased with increasing salinity in all genotypes (Fig. 7). Maximum Na\(^+\)/K\(^+\) ratio was observed in IR 64; 3.01, 5.77 and 7.09 (Control, 75 and 100 mM NaCl respectively). Minimum Na\(^+\)/K\(^+\) ratio was observed in Pokkali about 1.10%, 1.85% and 2.92% (Control, 75 and 100 mM NaCl respectively) and CO 43; 1.51, 2.65 and 4.41% (Control, 75 and 100 mM NaCl respectively). Na\(^+\)/K\(^+\) ratio were lower in tolerant genotypes and higher in susceptible genotypes. Other moderately tolerant (ADT 53) and moderately susceptible (ASD 16) and susceptible (ADT 37) genotypes recorded higher Na\(^+\)/K\(^+\) ratio than Pokkali and had lower than IR 64.

3.6 Osmotic Potential

Osmotic potential (Ψs) of all genotypes were increased in saline treatments as compared to control (Table 8). Tolerant genotypes recorded higher osmotic potential than susceptible genotypes. Highest osmotic potential was observed in tolerant check Pokkali -1.64 MPa, -2.74 MPa and -3.08 MPa (Control, 75 and 100 mM NaCl respectively) and TRY 3; -1.50 MPa, -2.63 MPa and -2.92 MPa (Control, 75 and 100 mM NaCl respectively). Lowest osmotic potential was observed in susceptible check IR 64 -1.12 MPa, -1.73 MPa and -1.92 MPa (Control, 75 and 100 mM NaCl respectively). Reduction percentage was higher in IR 64 about -55.38 and -72.42 (75 and 100 mM NaCl) and the reduction percentage was lower in tolerant genotypes namely; Pokkali, TRY 3 and CO 43.

3.7 Electrolyte Leakage

Electrolyte leakage is a measure of membrane stability index and membrane permeability is based on amount of ion leakage. The electrolyte leakage was increased with increasing salinity (Fig. 8). Tolerant genotypes had lower electrolyte leakage about 11%, 13.1%, and 17.8% (Control, 75 and 100 mM NaCl respectively) in Pokkali; TRY 3 about 12.4%, 14.5% and 23.2% (Control, 75 and 100 mM NaCl respectively) and CO 43; 13.1%, 15.1% and 26.2% (Control, 75 and 100 mM NaCl respectively). Maximum electrolyte leakage was observed in IR 64; 26.7%, 30.3%, and 33.9% (Control, 75 and 100 mM NaCl respectively). Other moderately tolerant (ADT 53) and moderately susceptible (ASD 16) and susceptible (ADT 37) genotypes had higher leakage than Pokkali and lower than IR 64.

4. DISCUSSION

4.1 Shoot and Root Length

Pokkali had higher shoot length 50 cm, 44.5 cm, 44 cm and 44 cm (0, 4, 6, and 12 dS/m respectively) and root length 21.67 cm, 19.33 cm, 19.33 cm and 17.33 (0, 4, 6, and 12 dS/m respectively) [22] these values coincidence with present results, it shows that pokkali is highly tolerant; root and shoot length is reduced under salinity than control. Similar decreasing trend in
shoot and root length was also reported by [23]. This negative trend in shoot length under salinity is due to reduced water uptake and cell division was reported by [24]. Possible causes of reduced root length under salinity are reduced cell size and rate of cell production, similar result was found by [25].

4.2 Fresh and Dry Weight

The data on fresh and dry weight of the seedlings had decreasing trend with increasing salinity. Imposition of 0, 60, 100 and 150 mol m\(^{-3}\) NaCl stress results in reduced fresh and dry weight of the seedling and the reduction was higher in salt sensitive genotype and lower in tolerant genotype [26]. This negative effect of salinity on fresh and dry weight was also strong agreement with results of [27]. The possible reasons of reduced weight of the rice seedling under salinity are due to inhibition of growth at early seedling stage by salinity, similar result was reported by [28,29]. Application of 150 mM NaCl stress causes significant reduction in dry weight of seedling in rice; these findings are in confirmation with the present results [29]. Increasing concentration of salinity reduced the fresh and dry weight of the rice seedling [30].

4.3 Leaf Drying Score and Root Shoot Ratio

Under salt stress the genotypes showed high difference from score 1 (Highly tolerant) to score 9 (Highly susceptible) based on SES give by IRRI (2003). Tolerant genotypes had lower score 1 and sensitive genotypes had higher score 9 under salinity [30,31]; these results on leaf drying score was confirmation with the above results. In [32] study, they observed greater variation between different rice genotypes in SES from 3(Tolerant) to 9 (Highly susceptible). Higher variation in SES occurred between rice genotypes under salinity tolerance [33]. Application of 7 and 12 EC stress showed greater variation (From highly tolerant to highly susceptible) in SES of 25 rice genotypes [34]. The data on root shoot ratio had negative trend with increasing salinity and tolerant genotypes recorded higher ratio than susceptible genotypes. Application salt stress on rice genotypes significantly reduces the root shoot ratio [35]. This negative trend in root shoot ratio is due to reduced dry weight of the seedling and survival percentage under salinity.

4.4 Na, K Content and Na\(^+\)/K\(^+\) Ratio

In rice, several authors have shown that Na-K selectivity of plant roots functions to minimize the entry of Na\(^+\) into plants and maintain effective K\(^+\) uptake together with the mechanism of low salt transport to expanding leaves is very important mechanism directly correlated with salt tolerance [36]. Results on sodium ion content had positive effect under salinity; tolerant genotypes had lower sodium content than susceptible genotypes. These results are in confirmation with earlier findings of [37] in rice [38] in wheat. Similar decreasing trend in sodium content was also observed by [24]. Lower sodium content is the best indicator of salt tolerance mechanism [39]. [40] observed that application of 0, 4, 8, 12 EC salt stress increases the sodium content; among the eight genotypes used in this study pokkali had very low sodium content 0.51%, 0.75%, 1.38% and 2.87% (0, 4, 8 and 12 EC respectively) and higher accumulation was absorbed in IR 20. Salt tolerance mechanism is depending on sodium exclusion and uptake of potassium ion, so only the tolerant genotypes had lower sodium content [41].

Rice salt tolerance mechanism is depending on high potassium accumulation; tolerant genotypes recorded high potassium content than susceptible genotypes [41]. Data on potassium content of present study had negative effect with increasing salinity; tolerant genotypes recorded higher potassium content. Application of salinity under hydroponic condition to 36 rice genotypes reduced the potassium content; the reduction percentage was higher in salt sensitive genotypes and reduction was lower in salt tolerant genotypes [24]. Imposition of 0, 60, 100 and 150 mol m\(^{-3}\) NaCl stress results in reduced potassium content of the rice seedling and the reduction was higher in salt sensitive genotype and lower in tolerant genotype, 150 mol m\(^{-3}\) NaCl causes severe reduction in potassium ion accumulation; these results analogous with present study [26]. Application of 0, 4, 8, 12 EC salt stress decreases the potassium content; among the eight genotypes used in that study pokkali had very high sodium content and lower accumulation was absorbed in susceptible cultivar IR 20 [40].

Na\(^+\)/K\(^+\) ratio of the present study was increased with increasing amount of salinity; tolerant genotypes had lower ratio than the susceptible genotypes. Application of salt stress at early seedling stage increases the Na\(^+\)/K\(^+\) ratio and
tolerant genotype Pokkali had minimum Na\(^+\)/K\(^+\) ratio than other genotype [42]. Important salt tolerance mechanism in rice is reduced uptake of Na\(^+\) and more uptake of K\(^+\) to maintain a lower Na\(^+\)/K\(^+\) ratio which disturbs the ion homeostasis [41]. Imposition of salt stress under hydroponic condition to 36 rice genotypes increased the Na\(^+\)/K\(^+\) ratio; ratio was higher in tolerant genotypes, due to higher uptake of potassium [24]. Application of 100 mM NaCl stress significantly increased the Na\(^+\)/K\(^+\) ratio of rice seedlings [43]. Maintenance of lower Na\(^+\)/K\(^+\) ratio is important to balance nutrients and plant growth; similar results were found by [44].

4.5 Osmotic Potential

Result of the present study showed that two different type of salinity increases the osmotic potential; tolerant genotypes had higher osmotic potential than susceptible genotypes. The possible reasons for higher osmotic potential are more accumulation of proline, total sugar and Potassium ion content [45]. Salt induced osmotic stress leads to physiological drought, causes many disorders and injuries in plant [46]. Ion accumulation also causes change in osmotic potential of plant; to prevent such osmotic imbalance and restrict the entry of sodium and chloride ions into plants [47], [48] Observed that application of salt stress increased the osmotic potential and it depends on particular genotype efficiency to accumulate high compatible solute; that leads to more potassium ion accumulation in tolerant cultivars. Different type of solutes accumulates in cytosol to maintain a lower osmotic potential for maintenance of cell turgor and water potential leads to improved growth [49].

4.6 Electrolyte Leakage

Electrolyte leakage is a measure of relative membrane permeability in leaves; this membrane permeability is based on amount ion leakage. Electrolyte leakage of the present study had increasing trend with increasing salinity; tolerant genotypes had lower leakage than the sensitive genotypes. The possible causes of lower electrolyte leakage in salt tolerant genotypes are reflects the extent of ROS induced lipid peroxidation [50]. These findings are in confirmation with results of [51,52]. Electrolyte leakage was used as an effective screening tool for salinity stress [53]. [51] Observed that application of 150 mM NaCl stress significantly increased the leakage.

5. CONCLUSION

Eight rice genotypes were hydroponically screened in two saline levels (75, 100 mM NaCl stress) and control conditions. There is difference observed between all eight rice genotypes. In this study, the rice genotypes Pokkali, TRY 3, CO 43 perform as tolerant; CO 51, ADT 53, ASD 16 perform as moderately tolerant; ADT 37 is susceptible and IR 64 is highly susceptible based on visual score, seedling growth and physiological traits. By using these rice genotypes in breeding programme an improved ideotype of rice having lower Na\(^+\)/K\(^+\) ratio, lower electrolyte leakage and osmotic potential will be selected. This genotype possessing salt tolerance character will help in boosting up rice production in salt-affected soils. Therefore, a genotype exhibiting relative salt tolerance for all the plant attributes may be ideal one.

ACKNOWLEDGEMENTS

I would like to thank my chairman Dr. V. Ravichandran, Associate professor, Department of Crop Physiology, TNAU, Coimbatore for his kind support and guidance to conduct the experiment. I thank my Advisory committee members, department faculties for their support during experimental period.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. Food and agriculture data. Food and Agriculture Organization, Statistics Division (FAOSTAT), Italy; 2012.
2. Chao DY, Gao JP, Lin HX. Understanding abiotic stress tolerance mechanisms: Recent studies on stress response in rice. J. Integrative Plant Bio. 2007;49(6):742-750.
3. Food and Agriculture Organization. Report of salt affected agriculture; 2010. Available:http://www.fao.org/ag/againfo/agll/sps/sh/
4. Aref F, Rad HE. Physiological characterization of rice under salinity stress during vegetative and reproductive stages. Indian J. Sci. Technol. 2012;5:2578-2586.
5. Ashraf M, Ali Q. Relative membrane permeability and activities of some...
antioxidant enzymes as the key determinants of salt tolerance in canola (Brassica napus L.). Environmental and Experimental Botany. 2008;63:266–273.
6. Arzani A. Improving salinity tolerance in crop plants: A biotechnological view. In vitro Cell Dev. Biol. Plant. 2008;44:373-383.
7. Munns R, Tester M. Mechanisms of salinity tolerance. Annual Review of Plant Biology. 2008;59(1):651–681.
8. Jamil M, Rha ES. Pak. Response of transgenic rice at germination and early seedling growth under salt stress. J. Biol. Sci. 2007;10(23):4303-4306.
9. Chen HJ, Chen JY, Wang SJ. Molecular regulation of starch accumulation in rice seedling leaves in response to salt stress. Acta Physiol. Planta. 2008;30(2):135-142.
10. Zeng L, Shannon MC, Lesch SM. Timing of salinity stress affects rice growth and yield components. Agricultural Water Management. 2001;48(3):191–206.
11. Hosseini SJ, Tahmasebei S, Pirdasti H. Analysis of tolerance indices in some rice (Oryza sativa L.) genotypes at salt stress condition. International Research Journal of Applied and Basic Sciences. 2012;3(1):1–10.
12. Safitri H, Sapta Purwokob B, Saraswati Dewic I, Wahyuning Ardieb S. Salinity tolerance of several rice genotypes at seedling stage. Indonesian Journal of Agricultural Science. 2017;18(2):63-68.
13. Kumari R, Kumar P, Sharma VK, Kumar H. Evaluation of salinity tolerance of rice varieties through in vitro seed germination and seedling growth. Int. J. Curr. Microbiol. App. Sci. 2018;7:2648-2659.
14. Yoshida S, Forno DA, Cock JK, Gomez KA. Laboratory manual for physiological studies of rice. IRRI, Los Banos, Philippines. 1976;61-61.
15. Gregorio GB, Senadhira D, Mendoza RD. Screening rice for salinity tolerance. IRRI. International Rice Research Institute, Manila. 1997;22:1-30.
16. Rasool S, Ahmad A, Siddiqi TO, Ahmad P. Changes in growth, lipid peroxidation and some key antioxidant enzymes in chickpea genotypes under salt stress. Acta Physiol Plant. 2013;35:1039–1050.
17. IRRI. Standard evaluation system for rice. Los Banos. International Rice Research Institute, Philippines; 2003.
18. Patman MG. Ion uptake by plant roots. Encyclopedia of Plant Physiology. 1976;2:95–128.
19. Wu MT, Wallner S. Heat stress responses in cultured cells. Plant Physiology. 1983;72:817-820.
20. Chandra Babu R, Sajullah Pathan M, Blum A, Henry TN. Comparison of measurement methods of osmotic adjustment in rice cultivars. Crop Science. 1999;39:150-158.
21. Gomez KA, Gomez AA. Statistical procedure for agricultural research. Wiley Inter-Science Publications (New York). 2010:253-259.
22. Kargbo SS, Showemimo FA, Porbeni JBO, Akintokun PO. Response of rice genotypes to salinity under hydroponic conditions. Agro-Science. 2019;18(3):11-18.
23. Hakim MA, Abdul SJ, Hanafi MM, Selamat A, Mohd Razl I, Rezaul Kariim SM. Studies on seed germination and growth in weed species of rice field under salinity stress. J. Environ. Bio. 2011;32:529-536.
24. Anyomi WE, Ashalley R, Kofi Abaka AN, Blay ET, Ofori K. Hydroponic screening of rice seedlings for salinity tolerance. Research Journal’s of Journal of Agriculture. 2018;5(6):1-15.
25. Azaizeh H, Gunse B, Steudle E. Effects of NaCl and CaCl$_2$ on water transport across root cells of maize (Zea mays L.) seedlings. Plant Physiol. 1992;99:886-894.
26. Iqbal M, Akhtar J, Anwar-Uri-Haq M, Nasim M, Saeed A, Naveed M. Variation in growth and ion uptake in rice cultivars under NaCl stress in hydroponics. Pakistan Journal of Agricultural Sciences. 2007;44(3):393–405.
27. Amirjani MR. Effect of NaCl on some physiological parameters of rice. Eur. J. Biol Sci. 2010;3:6-16.
28. Munns R. Comparative physiology of salt and water stress. Plant, Cell & Environment. 2002;25(2):239–250.
29. Jamil M, Bashir S, Anwar S, Bibi S, Bangash A, Ullah F, Rha ES. Effect of salinity on physiological and biochemical characteristics of different varieties of rice. Pakistan Journal of Botani. 2012;44:7–13.
30. Chunthaburee S, Dongsansuk A, Sanitchon J, Pattanagul W, Theerakulpisut P. Physiological and biochemical parameters for evaluation and clustering of rice cultivars differing in salt tolerance at seedling stage. Saudi Journal of Biological Science. 2016;23(4):467–477.
31. Haq TU, Akhtar J, Nawaz S, Ahmad R. Morpho-physiological response of rice (Oryza sativa L.) varieties to salinity stress. Pak. J. Bot. 2009;41:2943-295.

32. Islam MM, Karim MK. Evaluation of rice (Oryza sativa L.) genotypes at germination and early seedling stage for their tolerance to salinity. The Agriculturists. 2011;8(2):57-65.

33. Bhowmik K, Titov S, Islam MM, Siddika A, Sultana S, Haque MDS. Phenotypic and genotypic screening of rice genotypes at seedling stage for salt tolerance. African Journal of Biotechnology. 2009;8(23):6490-6494.

34. Eti I, Rasel MD, Hassan L, Ferdausi A. Morphological based screening and genetic diversity analysis of the local rice (Oryza sativa L.) landraces at the seedling stage for salinity tolerance. Journal of Bioscience and Agricultural Research. 2018;18(01):1496-1511.

35. Beakal T, Hussein M, Alemayehu A. The effect of salinity on germination, vegetative and final growth stage of different rice (Oryza sativa L.) genotypes. Journal of Animal & Plant Sciences. 2016;29(3):4651-4664.

36. Munns R, Tester M. Mechanisms of salinity tolerance. Annual Review of Plant Biology. 2008;59(1):651–681.

37. Aslam M, Qureshi RH, Ahmad N, Kluwer Acad. Mechanisms of salinity tolerance in rice (Oryza sativa L.). In: Lieth, H., Massoum, A. A. Towards Rational Use of High Salinity Tolerant, Plants Publ. 1993;2:135-138.

38. Nawaz S, Qureshi RH, Aslam M, Akhtar J, Parveen S. Comparative performance of different wheat varieties under salinity and water logging. II. Ionic relations. Pak. J. Bio. Sci. 1998;1(12):357-359.

39. El-Hendawy SE, Hu Y, Schmidhalter U. Growth, ion content, gas exchange and water relations of wheat genotypes differing in salt tolerances. Aust. J. Agric. Res. 2005a;56:123-134.

40. Hakim MA, Juraimi AS, Hanafi MM. The effect of salinity on growth, ion accumulation and yield of rice varieties. J. Anim. Plant Sci. 2014;24:874–885.

41. Gregorio GB, Senadhira D. Genetic analysis of salinity tolerance in rice (Oryza sativa). Theor Appl Genet. 1993;86:333-338.

42. Singh MP, Singh DK, Rai M. Assessment of growth, physiological and biochemical parameters and activities of antioxidative enzymes in salinity tolerant and sensitive basmati rice varieties. Journal of Agronomy and Crop Science. 2007;193:398-412.

43. Chachar NA, Chachar SD, Chachar QI, Keerio MI, Shereen A, Chachar MH. Screening for salt tolerant rice (Oryza sativa L.) genotypes at early seedling stage. Journal of Agricultural Technology. 2014;10(1):265-275.

44. Wu Y, Hu Y, Xu G. Interactive effects of potassium and sodium on root growth and expression of K/Na transporter genes in rice. Journal of Plant Growth Regulation. 2009;57:271–280.

45. Nasir Ahmed S, Ravichandran VK, Tamil Selvan N, Sankaran VM, Sathiyaavelu A, Giridharan S. Performance of sugarcane varieties in problem soils. Proceedings of Sugarcane Technologist Association. 1999:61:47-49.

46. Romero-Aranda R, Soria T, Cuartero J. Tomato plant-water uptake and plant-water relationships under saline growth conditions. Plant Science. 2001;160:265–272.

47. Tavakkoli E, Fatehi F, Coventry H, Rengasamy P, McDonald GK. A comparison of hydroponic and soil-based screening methods to identify salt tolerance in the field in barley. Journal of Experimental Botany. 2012;63(10):3853–3868.

48. Lutts S, Kinet JM, Bou harmont J. Effects of salt stress on growth, mineral nutrition and proline accumulation in relation to osmotic adjustment in rice (Oryza sativa L.) cultivars differing in salinity resistance. Plant Growth Regulation. 1996;19:201-218.

49. Rhodes D, Samaras Y. Cellular and molecular physiology of cell volume regulation. Boca Raton., CRC Press. 1994:347-367.

50. Sairam RK, Rao KV, Srivastava GC. Differential response of wheat genotypes to long term salinity stress relation to oxidative stress, antioxidant activity and osmolyte concentration. Plant Science. 2002;163:1037–1046.

51. Ashraf M, Ali Q. Relative membrane permeability and activities of some antioxidant enzymes as the key determinants of salt tolerance in canola (Brassica napus L.). Environmental and Experimental Botany. 2008;63:266–273.
52. Mahmoudi H, Kaddour R, Huang J, Nasri N, Olfa B, M’Rah S, Hannoufa A, Lachaal M, Ouerghi Z. Varied tolerance to NaCl salinity is related to biochemical changes in two contrasting lettuce genotypes. Acta Physiologiae Plantarum. 2011;33:1613–1622.

53. Kukreja S, Nandwal AS, Kumar N, Sharma SK, Unvi V, Sharma PK. Plant water status, H$_2$O$_2$ scavenging enzymes, ethylene evolution and membrane integrity of *Cicer arietinum* roots as affected by salinity. Biol. Plantar. 2005;49:305-308.

© 2020 Lakshmi et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/58640