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Screening commonly cultivated rice cultivars in Sri Lanka with special reference to Jaffna for salt tolerance at seedling stage under hydroponics

L. Pradheeban[1]*, S.P. Nissanka[2], L.D.B. Suriyagoda[2]

[1]*Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka*

[2]*Department of Crop Science, University of Peradeniya, Sri Lanka*

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Abstract

To screen rice cultivars cultivated in Sri Lanka for salt tolerance at seedling stage, factorial experiment was conducted in a completely randomized design with five replicates. Twenty two rice cultivars were tested against five salt levels (0, 4, 8, 12 and, 24 dSm^{-1}). Using shoot, root parameters and its percentage reduction with salt levels and sodium to potassium ratio, grouping of rice cultivars and their significances were tested by using cluster analysis. Four groups were identified as; highly tolerant, tolerant, susceptible and very susceptible. ANOVA and correlation analysis were performed to check the significant differences among cultivars with in clusters and correlation between tested variables, respectively. Values of all tested variables decreased with increasing salt levels in all tested cultivars except for sodium to potassium ratio in shoots. Percentage reduction increased with increasing salt levels for shoot height, shoot dry weight, root length, root dry weight and root surface area and showed significant differences among the cultivars at salt level of 24 dSm^{-1}. Both osmotic and toxic effect reduced shoot and root growth by inhibiting the water absorption by roots and caused leaf death, respectively. Among the cultivated rice cultivars, based on shoot and root parameters and sodium to potassium ratio in shoots, Pachaperumal, Periavellai, At 303, Adakari, Bg 406 and CO 10 categorized as highly tolerant group while Bg 250, At 353, At 362, Modaikarupan, H4, Bg 304 and Morungan were grouped as tolerant. Also Bg 352 and At 308 found susceptible and Bg 360 seems very susceptible.

* **Corresponding Author:** L. Pradheeban ✉ loha_p@yahoo.com

Introduction

Soil salinity is one of the main problems of world agriculture**.** Crop productivity is seriously affected by soil salinity throughout the world. It is estimated that 2% of the rain-fed agriculture area (32 million ha) is affected by salinity (FAO, 2008).

Salt tolerance is known as the ability of the plant to survive and to complete its growth cycle under saline conditions (Seydi, 2003). Among abiotic stress, salinity stress is complex because of variation in sensitivity at various stages in the life cycle of plant. Salt stress not only affects the plant morphological attributes, but also disturbs the plant metabolic activities. Several strategies have been developed to reduce the impacts of salinity by using tolerant cultivars and adopting different management strategies. Screening of rice cultivars could be done at different growth stages. However, tolerance to salinity varies accordance to stage of growth, adaptation characteristics of plant and species (Akbari *et al.*, 2007).

Several studies indicated that rice is tolerant during germination, becomes very sensitive during early seedling stage (2-3 leaf stage), tolerance during vegetative growth stage sensitive during pollination and fertilization and become increasingly more tolerant at maturity (IRRI, 1967; Heenan *et al.*, 1988; Lutts *et al.*, 1995). The development of salt tolerant cultivars has been considered as one of the strategies to increase rice production under saline conditions. Screening of rice cultivars in germination and seedling stage is easier because of short time requirement.

Screening for salt tolerance in the field is difficult as soil salinity is dynamic i.e. the high variability of spatial and temporal variation of salt concentration in soil. Growing plants in hydroponics can avoid most of such variability. Plants absorb all essential elements through their roots since the macro and micronutrients are dissolved in water (David, 2004). Screening under controlled condition has the benefit of reduced environment effects and the hydroponic system is free of difficulties associated with soil related stress factors.

In Sri Lanka, salinity is one of the major constraints limiting the expansion of cultivated areas and diminishing the productivity of rice lands. It is gradually spreading in the rice lands of Sri Lanka, both in the coastal regions and inlands (Sirisena and Herath, 2009). In Sri Lanka, saline soils occur mostly in major irrigated inland areas of the dry zone and coastal areas. In the dry zone, salinity is largely the result of insufficient drainage facilities (Jeganathan and Adamplan, 1980; Balasooriya, 1987). Recent research indicates that about 100,000 hectares of paddy lands in Sri Lanka are affected by high salt conditions or salinity (UNDP, 2012). Salinity levels are particularly severe in areas where evaporation exceeds precipitation.

Jaffna is situated in northern part of Sri Lanka and belongs to the agro ecological region of DL3. Total paddy land available for the cultivation is 12,000 ha. Out of which nearly 66.6% is being cultivated and 16.6 % of paddy land is being identified as marginal due to high NaCl concentration (Rajadurai, 2003). Salt concentrations in paddy lands of Jaffna fluctuate in the soil profile during dry and wet seasons. From preliminary study, it is in the range of 6 to 8 dSm^{-1} during dry and 2 to 4 dsm^{-1} in wet season in top soil of different salt affected areas. Identification of salt tolerant cultivars which are suitable to Jaffna climatic and soil conditions is essential to make salinity affected unproductive lands to productive. In Jaffna, the impacts of NaCl salt development on soil quality and crop performances especially for paddy are largely unexploited. Selection of rice cultivars which are tolerant to salt is an important requirement to Jaffna to maintain sustainable yield in salt affected areas. Therefore, a study was conducted in poly-tunnel to screen and identify salinity tolerant rice cultivars for Sri Lanka mainly to Jaffna from traditional, old improved and new improved cultivars which are commonly cultivated in Jaffna at seedling stage based on growth of seedlings under hydroponics with different salt concentrations.

Materials and methods

Seeds of twenty two rice cultivars; seventeen cultivars representing commonly cultivated cultivars in Jaffna including new improved, old improved, traditional or local, two check cultivars (Pokkali and At 354), two cultivars commonly grown in other parts of Sri Lanka (Bg 400-1 and Bg 450) and one recently released salt tolerant variety (Bg 369) were used (Table 1). The experiment was conducted in completely randomized design with five replicates as a two factor factorial with factors cultivar and salinity. Five NaCl salt concentrations were used with the electrical conductivity (EC) of 0, 4, 8, 12 and 24 dSm^{-1}. Sodium chloride solution was used to represent different levels of salinity. Distilled water was used as the control.

Table 1. Selected rice cultivars and their types.

Type	Cultivars
New improved	Bg 250, At 303, At 353, At 362, At 308, Bg 352, Bg 360, Bg 406, Bg 304,Bg 359, Bg 369,Bg 400-1, Bg 450
Old improved	H4
Traditional/Local	Modaikarupan, Periavellai, Morungan, Pachaperumal
Check variety	Pokkali , At 354
Other	CO 10, Adakari

Stock solution was prepared based on the methods adapted from Yoshida *et al*., (1976). Sterilized seeds were placed in Petri dishes with moistened filter papers and incubated for 48 h to germinate (IRRI, 1997). Two pre-germinated seeds were planted per hole on the Styrofoam seedling float. Each replicate consisted of 10 such holes. The radicle was inserted through the nylon mesh. During this process, damage caused to radicle was not being visible. Any damage to the radicle will be destroyed the main salt tolerance mechanism of rice. Therefore, seedlings were allowed 3 days to repair any root damage. Then seedlings were allowed to grow under normal nutrient solution up to 14 days (IRRI, 1997). After well establishment of seedlings, nutrient solution was salinized by adding NaCl while stirring up to the desired EC. Distilled water was used in making up Yoshida solution as local tap water may result in precipitation of minerals and will alter mineral concentrations that may affect salt sensitivity. Due to evaporation and transpiration there was loss of solution volume and pH get changed. Every two days the volume was brought back to the level of touching the netting in the Styrofoam seedling float and the pH adjusted to 5 by adding 1% HCl or 5 % NaCl. Solution was changed by lifting off the Styrofoam seedling float and placing them temporarily onto empty basin and pouring the hydroponics solutions back into a big container where the bulked solution is pH adjusted for the whole experiment in one step. Once adjusted, the solution was re-distributed into the test containers and the seedling platform returned. These operations also helped to aerate the hydroponics solution. The solutions were renewed every 8 days. Sampling was done at 5, 10 and 15days after initial salinization.

Measurements

Shoot height, shoot dry weight, root length, root dry weight, root surface area, root to shoot ratio sodium concentration, potassium concentration and sodium potassium ratio were measured.

Data analysis

Cluster Analysis and MANOVA

To prepare the dendogram shoot height, shoot dry weight, root length, root dry weight, root surface area, root shoot ratio and sodium potassium ratio were considered. Cluster analysis was done in SAS 9.1 version using the Proc CLUSTER procedure.

Multivariate analysis of variance (MANOVA) was used to determine whether different clusters identified through cluster analysis were significantly different or not using the test statistic, Wilks' Lambda.

Analysis of variance (ANOVA)

To check the difference among cultivars within each cluster for shoot height, shoot dry weight, root length, root dry weight, root surface area, root shoot ratio; an analysis of variance was performed using Proc GLM procedure followed by the LSMEANS procedure for mean separation. All the significances were expressed at α=0.05.

Correlation analysis

The correlation analysis between variables shoot height, shoot dry weight, root length, root dry weight, root surface area, shoot root ratio was done at EC level of 24 dSm^{-1}.

Results and discussion

Clustering was done at a standardized distance of 0.6 in the dendogram for shoot height, shoot dry weight, root length, root dry weight, root surface area, root shoot ratio and sodium potassium ratio. Four distinct clusters were identified as follows (Fig. 1). Variety Pokkali (check variety) grouped together into the first cluster (highly tolerant).

Cluster 1 - Highly tolerant to salt (HT).
Cluster 2 – Tolerant to salt (T).
Cluster 3 - Sensitive to salt (S).
Cluster 4- Very sensitive to salt (VS).

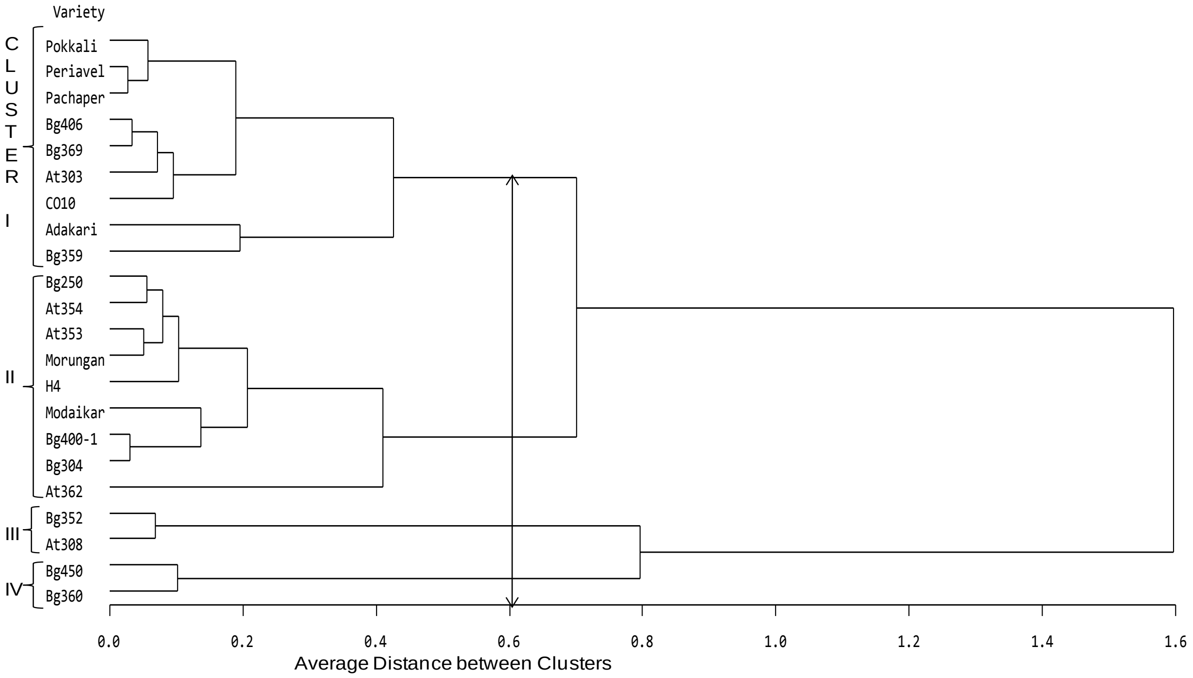

Fig.1. Dendogram of rice cultivars at EC level of 24 dSm^{-1}.

Based on the clustering, cultivars were grouped under four different clusters (Table 2).

Table 2. Cultivars grouped under different clusters.

Cluster	Cultivars
1(HT)	Pokkali, Periavellai, Pachchaperumal, Bg 406, Bg 369, CO 10, At 303, Adakari,Bg 359.
2 (T)	Bg 250, At 354, At 353, Morungan, H4, Modaikarupan, Bg 400-1, Bg 304, At 362.
3 (S)	Bg 352, At 308
4 (VS)	Bg 450, Bg 360

Root dry weight

Root dry weight of all tested cultivars decreased with increasing salt levels (Fig. 2). There were significant differences in root dry weight between cultivars and EC levels. Pachaperumal and Adakari, representing cultivars from Jaffna and in highly tolerant cluster, showed 69 % and 71% reduction in root dry weight. Bg 250, Modaikarupan and At 353 in tolerant cluster showed 71 %, 72 % and 61 % reduction in root dry weight. At 308 and Bg 352 showed 69 % and 67 % reduction and Bg 360 showed 86 % reduction in root dry weight. Salt sensitive cultivars showed higher % reduction in root dry weight compared to tolerant cultivars.

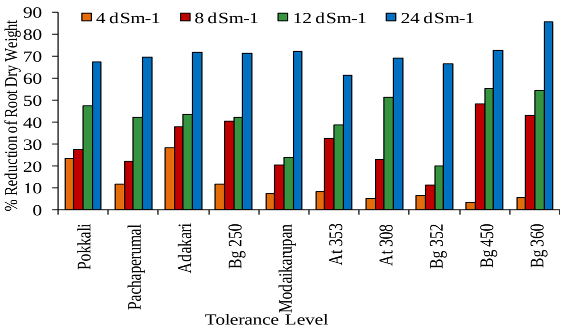

Fig. 2. Percentage reduction of root dry weights of selected rice cultivars with control under each cluster at EC levels of 4, 8, 12 and 24 dSm^{-1}

There was a significant difference between clusters for root dry weight in control and EC level of 24 dSm-1 (Fig. 3).

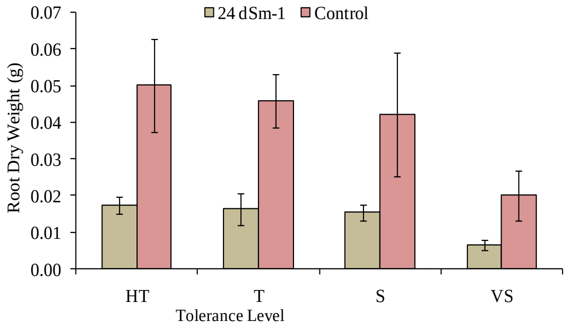

Fig. 3. Root dry weight per plant of each cluster at control and 24 dSm^{-1}.

Root length

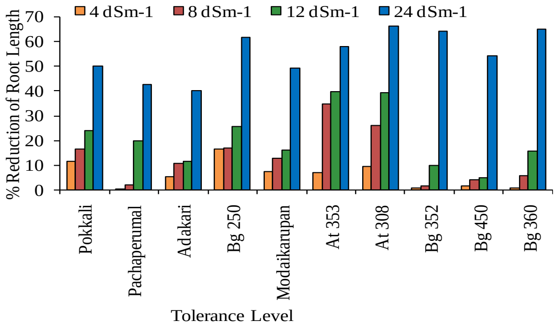

Fig. 4. Percentage reduction of root length of selected rice cultivars with control under each cluster at EC levels of 4, 8,12 and 24 dSm^{-1}.

Root length of tested cultivars decreased with increasing salt levels. There was a significant difference between cultivars at EC levels of 24 dSm^{-1}. Higher tolerant cultivars had higher root length compared to very sensitive cultivars (Fig. 4). Within cultivated cultivars in Jaffna, Pachaperumal and Adakari showed 43 % and 40 % reduction in root length in highly tolerant cluster, Bg 250, Modaikarupan and At 353 showed 62 %, 49 % and 58 % reduction in tolerant cluster, At 308 and Bg 352 showed (66 %) and 64 % reduction in sensitive cluster and Bg 360 showed 65% reduction in root length in very sensitive cluster respectively. The percentage reduction in root length was higher in sensitive cultivars compared to tolerant cultivars. Lee *et al.*, (2003) also showed that a marked growth reduction was reported in earlier in sensitive cultivars of japonica and indica rice seedlings exposed to salinity stress. Similar results were obtained by Rahman *et al.,* (2001).

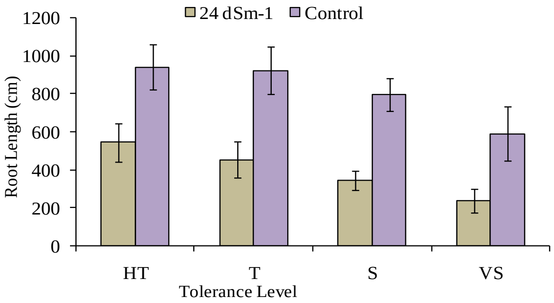

Fig. 5. Root length per plant of each cluster at control and 24 dSm^{-1}.

There was a significant difference between clusters for root length in control and EC level of 24 dSm-1 (Fig. 5).

Shoot dry weight

Shoot dry weight of tested cultivars decreased with increasing salt levels. There was a significant difference in shoot dry weight between cultivars and at EC levels of 24 dSm^{-1} (Fig. 6). Among the cultivated cultivars in Jaffna, Pachaperumal, Adakari in highly tolerant cluster showed 52 % and 65 % reduction in shoot dry weight, Bg 250, Modaikarupan and At 353 in tolerant cluster showed 61 %, 62 % and 53 % reduction, At 308 and Bg 352 in sensitive cluster showed 76 % reduction and Bg 360 showed 94 % reduction in shoot dry weight respectively compared to control (i.e. 0 dSm^{-1}).This could be due to high salinity decreasing water uptake, cell division and enlargement of roots, leading to reduced growth of shoots (reduced leaf area and leaf size) by inhibiting translocation to shoot. Volkmar *et al.*, (1998) stated that higher levels of salts can produce decreased water uptake in plants. Ali *et al.,* (2004) noticed the reduction in leaf area under saline conditions in rice due to decreased water uptake, toxicity of sodium and chloride in the shoot cell as well as reduced photosynthesis. Munns (2003) concluded that the reduction in dry weight of the plants might be attributed to the inhibition of hydrolysis of reserved foods and their translocation to the growing shoots.

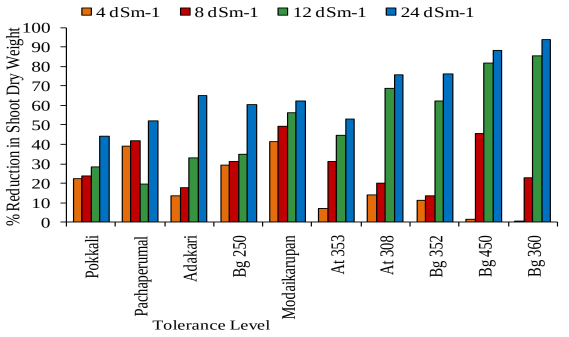

Fig.6. Percentage reduction of shoot dry weight of selected rice cultivars with control under each cluster at EC levels of 4, 8, 12 and 24 dSm^{-1}.

There was a significant difference between clusters for shoot dry weight in control and EC level of 24 dSm-1 (Fig. 7).

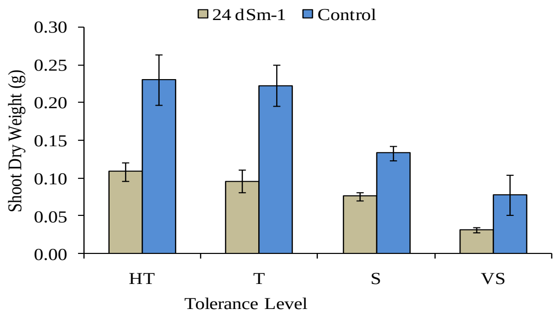

Fig. 7. Shoot dry weight per plant of each cluster at control and 24 dSm^{-1}.

Shoot height

Shoot height decreased with increasing salt concentrations in all tested cultivars (Fig. 8). The percentage reduction in shoot height was highest in very sensitive cultivars compared to tolerant cultivars. Within the cultivated cultivars in Jaffna, Pachaperumal and Adakari in highly tolerant cluster had 32 % and 34 % reduction in shoot height, Bg 250 (35 %), Modaikarupan (24 %) and At 353 (26 %) in tolerant cluster had 35 %, 24 % and 26 % reduction in shoot height, At 308 and Bg 352 in sensitive cluster had 34 % and 24 % and Bg 360 in very sensitive cluster had 45% reduction in shoot height respectively compared to control (i.e. 0 dSm^{-1}).

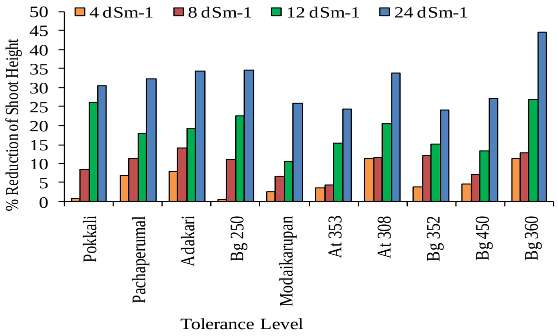

Fig. 8. Percentage reduction of shoot heights of selected rice cultivars with control under each cluster at EC levels of 4, 8, 12 and 24 dSm^{-1}.

There was a significant difference in shoot heights between treatments and cultivars. (Fig. 9)

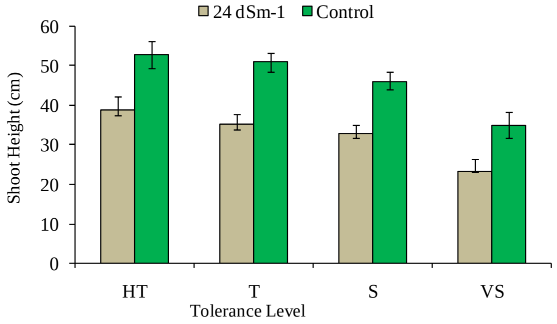

Fig. 9. Shoot height per plant of each cluster at control and 24 dSm^{-1}.

Root surface area

Root surface area decreased with increasing salinity levels in all cultivars and showed a significant difference between cultivars and salt levels (Fig. 10). The percentage reduction in root surface area was higher in susceptible cultivars compared to tolerant cultivars. Within the cultivated cultivars in Jaffna, Pachaperumal and Adakari in highly tolerant cluster had root surface area reduction of 54 % and 57 % respectively. Bg 250 Modaikarupan and At 353 showed 56 %, 60 % and 49 % reduction in root surface area of tolerant cluster. At 308 and Bg 352 showed percentage reduction of 61 % and 65 % in sensitive cluster and Bg 360 showed 65 % in very sensitive cluster respectively compared to control.

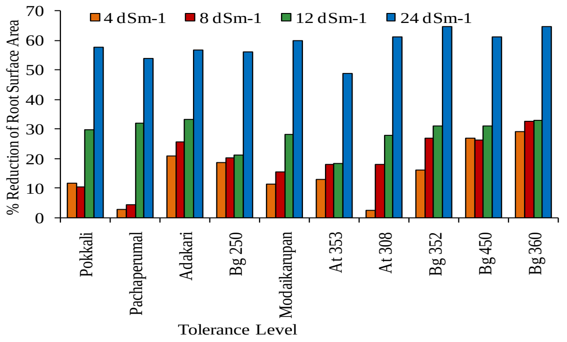

Fig. 10. Percentage reduction of root surface area of selected rice cultivars with control under each cluster at EC levels of 4, 8, 12 and 24 dSm^{-1}.

There was a significant difference between clusters for root surface area in control and EC level of 24 dSm-1 (Fig.11).

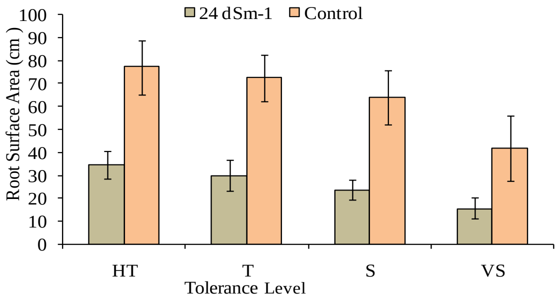

Fig. 11. Root surface area per plant of each cluster at control and 24 dSm^{-1}.

In overall, root dry weight, root length, shoot dry weight, shoot height and root surface area decreased with increasing salt concentrations in all tested cultivars. The results clearly showed that increases in salinity decreased growth of rice plants. However, rice cultivars differ in their sensitivity or tolerance to salts. This percentage reduction was higher in very sensitive and sensitive cultivars compared to tolerant cultivars. Growth reduction of roots and shoots was observed in plants due to osmotic and toxic effect (Soledad *et al.,* 2012). It was generally observed in plants quickly after exposed to salinity stress. This response is due to the osmotic changes outside the root causing changes in cell-water relations (osmotic effect). Osmotic effects of salts on plants are a result of lowering of the soil water potential due to increasing solute concentration in the root zone. At very low soil water potentials, this condition interferes with the plant's ability to extract water from the soil and maintain turgor (Soledad *et al.,* 2012). Due to salt, cell elongation and cell division are reduced, it leads to lower rates of leaf and root growth. Salt accumulation in leaves caused premature senescence, reducing the supply of assimilates to the growing regions and thus decreasing plant growth (Munns *et al.,* 1995). Salt stress affects all the major processes such as growth, water relations, photosynthesis and mineral uptake. Salinity induced a rapid reduction in root growth (Neumann, 1995); shoot growth decreases proportionally more than root growth, causing an increase in the root / shoot ratio.

Reduction in dry weight was higher in shoots compared to roots. Plants regulate water transport under salinity stress because a sufficient amount of water is indispensable for the cells to maintain their growth and vital cellular functions such as photosynthesis and metabolisms. Reductions in cell division and elongation translate into slower leaf appearance and size. Final leaf size depends on both cell division and cell elongation of rice plant. These results were supported by many research studies. Läuchli and Epstein, (1990) also stated that reduction in shoot growth due to salinity is commonly expressed by a reduced leaf area and stunted shoots. These results are in agreement with Ahmed *et al.,* (2012) that the seedling growth was drastically decreased at higher salinity level and the impact was remarkable on shoot compared to the root growth. Jamil *et al.,* (2006) found a direct relationship between reduced shoot and root length with increased salt concentration in the growth medium and they suggested that the shoot and root length are important indicators of salt stress tolerance because the root is in direct contact with the growth medium and absorbs water and other components of the media, making them available to the rest of the plant. Therefore, shoot and root length is an indicator of plant response to salinity. Roy *et al.,* (2002) stated that with increase of salinity, reduction of root length, shoot length, dry weight of root and shoot was observed. Govinda Raju and Balakrishnan (2002) stated that effect of salinity was more in susceptible cultivars than resistant cultivars and the observation are in agreement with the present findings. Growth of aerial organ was inhibited under salt by the decrease of root growth (Cramer *et al.,* 1989; Yeo *et al.,* 1991; Rengel, 1992). According to Levigneron *et al.,* (1995), the increase of soil salinity is translated by an immediate reduction of shoot growth in plants.Ion accumulations in the cytosol (mainly K^+) and in the vacuole (Na^+, especially in salt tolerant cultivars/species) are also found to be important for the osmotic adjustment of plant cells (Gorham *et al.,* 1985).

The second much slower effect was the result of salt accumulation in leaves. This salt toxicity can result in the death of leaves and reduce the total photosynthetic leaf area. Salt accumulation leading to salt toxicity in the plants, primarily in the older leaves (i.e. salt-specific effect). As a result, there is a reduction in the supply of photosynthate to the plant, affecting the overall carbon balance necessary to sustain growth (Munns, 2002).

Root to shoot ratio

Root shoot ratio of rice seedling decrease with increasing salinity level for all tested cultivars. There was a significant difference between treatments and cultivars at EC level of 24 dSm^{-1}. Higher tolerant cultivars had lower root to shoot ratio and very sensitive cultivars had higher root to shoot ratio (Fig. 12). Even though root length decreased with increased salt level, sensitive cultivars produced more roots compared to shoots in each salt concentration to absorb water and nutrient for their survival under stress condition and had higher root to shoot ratio compared to tolerant cultivars. Among the cultivated cultivars in Jaffna, Pachaperumal and Adakari in highly tolerant cluster showed root to shoot ratio of 0.13 and 0.18 respectively and Bg 360 showed root to shoot ratio of 0.22at EC level of 24 dSm^{-1}.

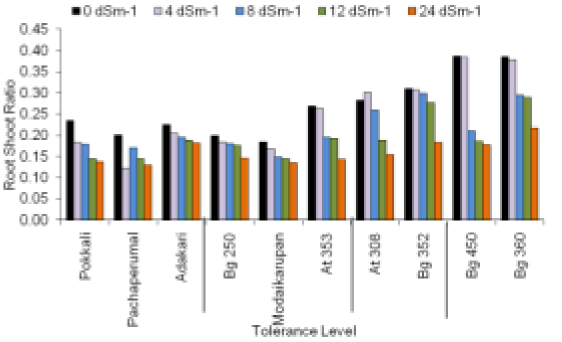

Fig. 12. Root to shoot ratio of selected rice cultivars under each cluster at EC levels of 0, 4, 8, 12 and 24 dSm^{-1}.

This result was supported by many research studies. Hanson and Hitz (1982) noted that the discriminatory effect of salinity stress on root to shoot growth and reduction of root to shoot ratio are known for a long time. Gilbert *et al.,* (1997) showed that effect on root to shoot growth is due to altered carbon allocation, chloroplast metabolism, photosynthetic rate etc. and modification of carbohydrate metabolism, partitioning and transport. High dry wt. associated with high root to shoot ratio under stress may be considered important for salt tolerance as the inhibitory effect on these growth attributes were more pronounced in susceptible than resistant cultivars of the same crop (Alian *et al.,* 2000).

Sodium to potassium ratio

Sodium potassium ratio of rice seedling increased with increasing salt levels of all tested cultivars. Sensitive cultivars showed higher sodium to potassium ratio (Na/K ratio) compared to tolerant cultivars (Fig. 15). Within the cultivated cultivars in Jaffna, Pachaperumal and Adakari in highly tolerant groups showed Na/K ratio of 6.17 and 6.83 respectively. Bg 360 in very sensitive group showed Na/K ratio of 13.71.

The typical mechanism of salinity tolerance in rice is the Na exclusion or uptake reduction or uptake more Na and stores it in the shoots as harmless form and absorption of K increased to maintain a good Na to K balance in the shoot. The shoots of more tolerant cultivars had lower amount of Na^+ but higher amount of K^+ compared to sensitive cultivars. With increasing salinity, the concentration of Na^+ in shoots in all cultivars was dramatically increased and K^+ decreased at EC levels of 24 dSm^{-1} (Fig. 13, 14 & 15).

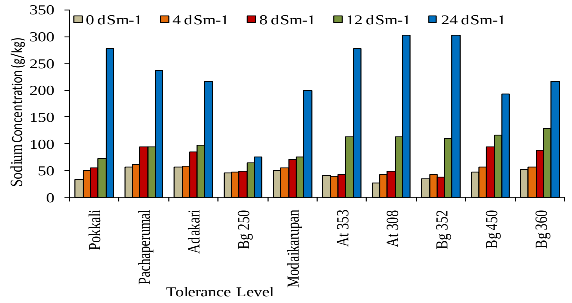

Fig. 13. Sodium concentration of selected rice cultivars under each cluster at EC levels of 0, 4, 8, 12 and 24 dSm^{-1}.

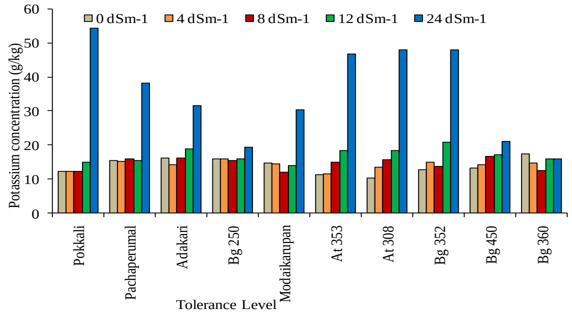

Fig. 14. Potassium concentration of selected rice cultivars under each cluster at EC levels of 0, 4, 8, 12 and 24 dSm^{-1}.

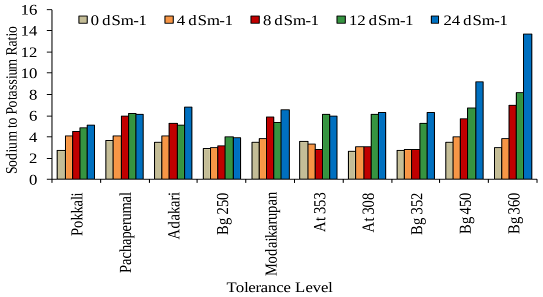

Fig. 15. Sodium to potassium concentration of selected cultivars under each cluster at EC levels of 0, 4, 8, 12 and 24 dSm^{-1}.

Most authors agree on the effects of sodium on the plant and the importance of control mechanisms for sodium uptake in salt-resistant plants, little emphasis has been put on root selectivity for potassium over sodium (Asch *et al.*, 1997a; Flowers and Yeo, 1986). The ability of plants to discriminate between Na and K can be determined by an index, the Na/ K ratio (Flowers, 2004). Qadar (1988) reported that the potassium status of the rice shoot can be used as an index for salt tolerance. Na to K ratio could then be a good parameter in quantifying the degree of salinity tolerance for genetic and molecular studies by screening (IRRI, 2006). There were strong relationships between Na and K concentration and the Na/K ratio in the shoots with the level of salt tolerance. The results indicated that the Na/K ratio in shoots is strongly related with the degree of salt tolerance. Under salt stress the highest value of K/Na ratio was recorded sensitive cultivars compared to tolerant cultivars. This could be due to the difference in Na and K up take by cultivars with increasing salt levels. The Na/K ratio shows relative decrease in K content compared to Na content in the genotypes along the salinity gradient (Mass and Poss, 1989) and higher salinity disturbs Na/K ratio in the plant which impairs the protein metabolism of the plants. Osmotic adjustments by means of solute accumulations inside the cell are essential to reduce the cellular osmotic potential against an osmotic gradient between root cells and outside saline solution, which eventually restore the water uptake into roots during salinity stress (Greenway and Munns,1980). Ion accumulations in the cytosol (mainly K^+) and in the vacuole (Na^+, especially in salt tolerant cultivars/species) are also found to be important for the osmotic adjustment of plant cells (Gorham *et al.*, 1985). Tester and Davenport (2003) indicate that many plants can tolerate salt stress by excluding Nafrom the stem, or at least from the leaves, and maintaining high levels of K. Chen *et al.*, (2005) reported that sodium concentration of root and shoot increased and K/Na ratio was decreased under salinity stress. Increase of sodium uptake and reduction of sodium iterance to vacuole cause increase of sodium concentration in apoplast.

Munns *et al.,* (1982) assessed the contribution of osmotic effects of salinity relative to its ionic effects and concluded that inhibitory effects on growth were mostly due to osmotic and not ion specific effects. There is evidence for a relation between potassium and sodium uptake by the rice plant and performance under salinity (Qadar, 1988; Rajarathinam *et al.*, 1988; Pandey and Srivastava, 1991; Bohra and Dörffling, 1993). The study stated that rice dry-matter production under salinity is positively correlated with shoot potassium concentration and negatively with sodium concentration in later growth stages (Dutt and Bal, 1985; Heenan *et al.*, 1988).

Conclusion

The results clearly showed that increases in salinity decreased growth of rice plants. However, rice cultivars differ in their sensitivity or tolerance to salts. This percentage reduction was higher in very sensitive and sensitive cultivars compared to tolerant cultivars. Among the cultivated rice cultivars in Jaffna at seedling stage, Pachaperumal, Periavellai, At 303, Adakari, Bg 406 and CO 10 had higher shoot height, shoot dry weight, root length, root dry weight, root surface area and lower root to shoot ratio and sodium to potassium ratio in shoots and categorized in to highly tolerant group. Cultivars Bg 250, At 353, At 362, Modaikarupan, H4, Bg 304 and Morungan were in tolerant group. Cultivars Bg 352 and At 308 were under susceptible group due to lower shoot height, shoot dry weight, root length, root dry weight, root surface area and higher root to shoot ratio and sodium to potassium ratio compared to tolerant cultivars. Variety Bg 360 was in the very susceptible group.

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