Effect of Different Levels of Salinity on Morpho-Physiological Traits of Rice (*Oryza sativa* L.) Varieties Relation with Grain Yield

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Abstract: ***A pot experiment was conducted at the Net House of Department of Crop Physiology at Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad during Kharif season in year 2011-12 and 2012-13 to investigate the effect of different levels of salinity on morphological and physiological traits of rice associated with salinity tolerance. Four rice variety viz. Pokkali, Narendra Ushar Dhan 3, IR 28 and IR 29 were grown in various salinity levels i.e. normal soil, EC 6.0 and 10.0 dSm^{-1} three seedling of 21 days old were transplanted. Results indicated that morpho-physiological characters such as plant height, number of tillers, dry biomass, chlorophyll, carbohydrate, catalase activity, seed yield per plant, and mineral ions in shoots, such as potassium and calcium were decreased with gradual increasing of salinity levels, whereas, sodium content in shoot was increased with increased respective salinity level in rice varieties. The lowest values of them were observed at EC 10.0 dSm^{-1}. Generally rice varieties having the ability to exclude Na^{+} from shoot were found salt tolerant in respect of grain yield and in susceptible varieties vice-versa. Among the varieties, the yield loss due to salinity was less in Pokkali and Narendra Ushar Dhan 3 than in the IR 28 and IR 29. Pokkali and Narendra Ushar Dhan 3 had a greater tolerance to salinity than IR 28 and IR 29.***

Keywords: Salinity, morphological traits, physiological traits, mineral ions, grain yield and rice

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important staple food crops in the world. In Asia, more than two billion people are getting 60-70% of their energy requirement from rice and its derived products. In India, rice occupies an area of 44 million hectares with an average production of 90 million tonnes with productivity of 2.0 tonnes/ha. Demand for rice is growing every year and it is estimated that in 2025 AD the requirement would be 140 million tonnes. To sustain present food self-sufficiency and to meet future food requirements, India has to increase its rice productivity by 3% per annum [21]. Rice has been cultivated as a major crop for 11,500 years, and it currently sustains nearly one-half of the world population [25], and the native is in tropical and subtropical of South East Asia and Africa. Rice is the principal source of food for more than one third of the world's population.

Salinity decreased the agricultural productivity seriously. As reclamation of saline soils is laborious and almost impossible, development or selection of salt tolerant crop species is one of the possible means for extension of the crop area. Generally, salinity affects the growth of the rice plant at all stages of its life cycle. But it is more pronounced on reproductive stage than on vegetative stage consequently decreased the grain yield [3]. Rice is moderately susceptible to salinity, since most rice plants are severely injured at an EC 8-10 dSm^{-1}. Study on the response of rice to salinity stress may be helpful in identifying physiological features potential salinity tolerance such as active osmotic adjustment in cells sap, accumulation of toxic Na^{+} and Cl^{-} ions in the older parts of the plant, higher photosynthetic efficiency of the young leaves, escaping ability to uptake Na^{+} and Cl^{-} etc. Sultana *et al.*,[5] showed that the Na^{+} concentrations of leaf is increased, while Ca^{++} and K^{+} concentrations of leaf is decreased with increas of salinity. It is generally recognized that K^{+} uptake by the plant and deposition in both growing and non-growing tissues is reduced by salinization. Many studies conducted with reasonable Na: Ca ratios in the solutions have suggested that Ca^{+2} uptakes, translocation and distribution may be critically affected by salinization. Salt tolerant cultivars had lower Na and higher K content [24].

2. Materials and Method

Pot experiment was conducted during Kharif 2011 and 2012 at the Department of Crop Physiology, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) under normal soil and saline condition with EC 6.0 and 10.0 dSm^{-1}. The soil was sandy loam in nature with having pH 8.7, organic carbon 0.22%, EC 3.6 dSm^{-1} and ESP 71 % concentration in soil solution. Three soil salinity levels (*i.e.* Normal, EC 6.0 and 10.0 dSm^{-1}) and variety namely, Pokkali, Narendra Ushar Dhan 3, IR 28 and IR 29 were taken in the experimentation. The experiment was laid down in CRD factorial with three replications.

Soil was collected from normal and saline fields. Soil was mashed and sieved to get it well pulverized. Both types of soils were sprayed on separate polythene sheets and major nitrogen, phosphorus and potassium @ 120:60:60 kg/ha were added through urea, single super phosphate and muriate of potash in the soils before filling pots. The remaining half of the nitrogen was applied in two equal splits at tillering and panicle initiation stage. Earthen pots of uniform size (25 x 20 cm) were used for the experiment and each pot was filled with 8 kg of dry soil and irrigated with 2 liters of water to maintain proper moisture for sowing.

The total clorophyll content were determined according to the method described [6], and expressed as mg g^{-1} fresh weight. The total soluble sugar were determined according to the method described by [26], and expressed as mg g^{-1} dry weight. Catalase activity (unit g^{-1} Fresh weight) was assayed by calorimetrically method given in analytical biochemistry [19].

3. Results and Discussion

The results indicate that the plant height decreased both tolarent and susceptible varieties of rice in saline to normal soil at the all growth stages. The effects of EC 10.0 dSm^{-1} was more pronounced and registered heavy reduction in plant height as compared to EC 6.0 dSm^{-1} in tolerant and susceptible varieties. The minimum reduction in plant height were found in Pokkali followed by Narendra Usar Dhan 3 under treatment EC 6.0 and 10.0 dSm^{-1} however, the magnitude of reduction in plant height were observed in susceptible variety IR 28 and IR 29. Result shows that the effect of salinity on plant elongation of different varieties. Bhowmik *et al.*,[9] also observed differences in plant height probably results slow growth caused by osmotic stress imposed by a high concentration of salts rooting zone. The reduction of rice height in proportion to increases salinity is due to the effect of osmotic stress in reduction of water and nutrient absorption including nitrogen which is necessary for plant height.

The number of tillers per plant is also an important yield parameter, because it determines the grain bearing panicles. Salinity caused a significant reduction in the number of tillers per plant as compared to IR 28 and IR 29, however, the minimum tillers was observed Pokkali followed by Narendra Usar Dhan 3. The decrease in tillering capacity might be due to the toxic effect of salt on plant growth. The development of more tillers in tolerant varieties may be a mechanism of salt tolerance by dilatation of salt in plants [7].

Table 1: Effect of different EC level of different growth and biochemical parameters of rice varieties

S. No.	Variety	Plant Height (cm) at maturity	No. of Tiller $plant^{-1}$	Dry biomass $plant^{-1}$	Total Chlorophyll (mg g^{-1} dry wt) at maturity	Total carbohydrate (mg g^{-1} dry wt) at maturity	Catalase activity (unit g^{-1} fr. wt.) in leaves at maturity
1	Pokkali	131.13	4.91	30.36	10.67	191.58	421.73
2	Narendra Ushar Dhan 3	68.93	4.82	18.95	10.07	161.67	384.9
3	IR 28	63.50	3.83	16.61	8.69	144.32	345.03
4	IR 29	68.35	4.12	18.81	8.87	120.74	313.06
1	Normal	100.54	5.66	24.82	11.7	132.7	312.58
2	EC 6.0	84.02	4.55	21.81	9.68	155.0	377.44
3	EC 10.0	64.37	3.05	16.92	7.35	176.1	408.53
Sem±		V= 1.83 T=1.58 VXT= 3.16	V= 0.15 T=0.13 VXT=0.26	V= 7.38 T=6.39 VXT=12.78	V= 0.47 T=0.41 VXT=0.81	V= 5.79 T=5.01 VXT=10.02	V= 7.38 T=6.39 VXT=12.78
CD at 5%		V= 5.36 T=4.64 VXT=NS	V= 0.44 T=0.38 VXT=NS	**V= 7.38 T=6.39 VXT=12.79**	V= 1.37 T=1.19 VXT=NS	V= 16.99 T=14.72 VXT=NS	V= 21.66 T=18.76 VXT=NS

The detrimental response of salinity on growth and yield of crops might be mediated through their effects on metabolism of the plants in the present investigation; salts stress alters various metabolic aspects in rice varieties which induced total chlorophyll content, nitrate reductase and proline content in leaves of rice. All varieties had lower total chlorophyll in leaves under saline soil than normal soil. The maximum reduction was observed in susceptible varieties IR 28 and IR 29; however, tolerant varieties Pokkali and Narendra Usar Dhan 3 had less reduction. The reduction in chlorophyll content under salinity might be due to the loosened binding between chlorophyll and chloroplast protein [2]. The reduction in chlorophyll depends on the varietal tolerance to salinity.

The total soluble carbohydrate in shoot decrease significantly under salinity condition in all the rice varieties at all the growth stages, however, highest total soluble carbohydrate was observed in Pokkali and Narendra Usar Dhan 3. IR 28 and IR 29 showed comparatively less carbohydrate content. Reduction in soluble carbohydrate under salinity may due to reduced hydrolysis of reserve polysaccharides or rapid utilization of total soluble sugars. Decrease in sugar content under salt stress has been also reported by a number of workers [16] and [4] .

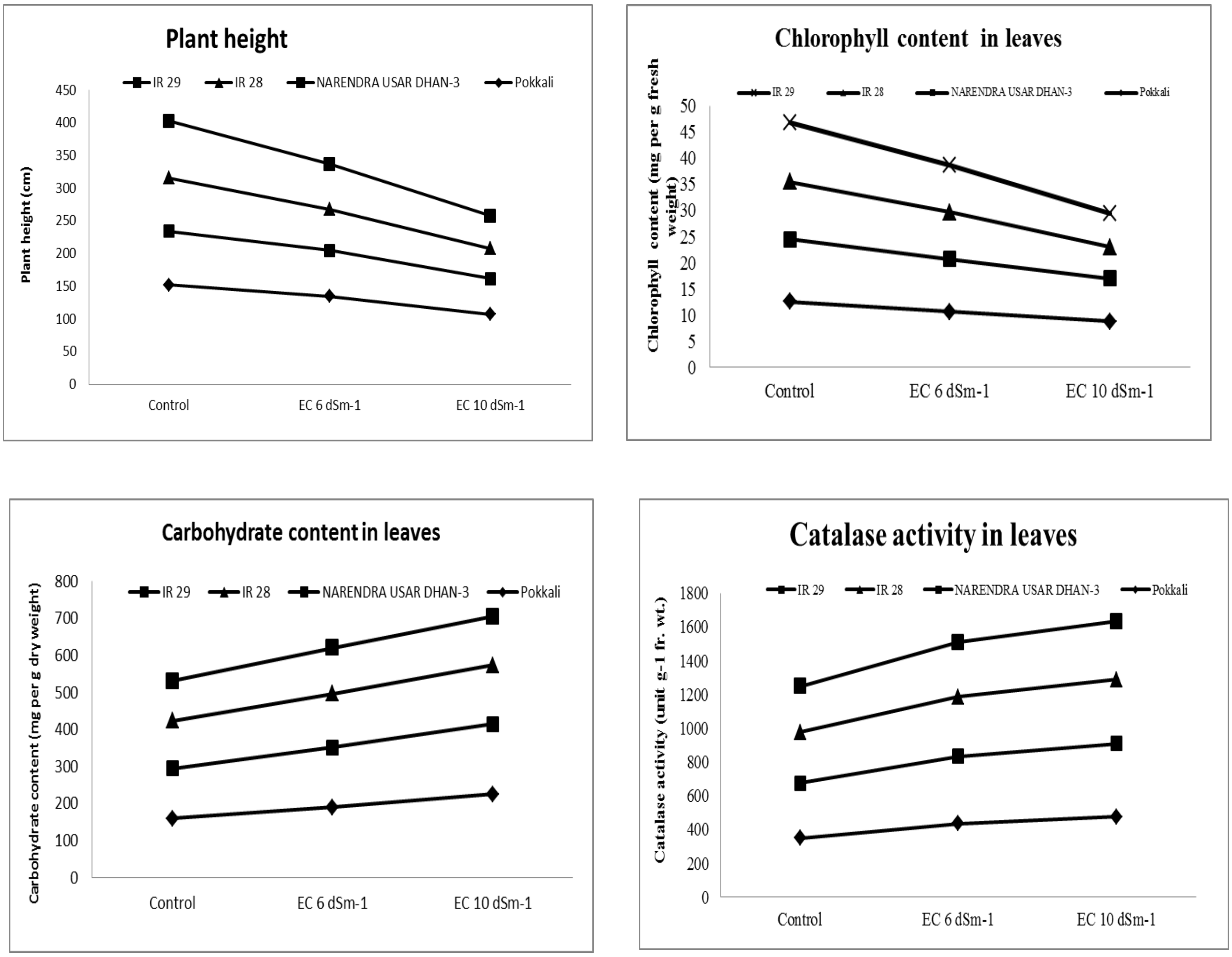

Figure 1: Effect of different EC level of height, chlorophyll, carbohydrate and catalase activity of rice varieties

Under the saline condition, reduction in biomass production is a common feature in crop plants. In this study; salinity caused a significant reduction in shoot dry weight of all the varieties compared with normal condition. Among varieties, the lowest reduction in biomass was found in Pokkali followed by Narendra Usar Dhan 3 indicating their tolerance to salinity, whereas, the most sensitive genotypes are IR 28 and IR 29, which showed a higher reduction in plant biomass. Under both the treatment, *i.e*. E.C. 6.0 and E.C. 10.0, the minimum reduction was observed by Pokkali followed by Narendra Usar Dhan 3 respectively in comparison to control. While the maximum reduction was observed by IR 28 respectively in comparison to control. Under salinity stress, plant cell turgor pressure decrease and stomatal closure took place, resulting in a decrease in photosynthesis [10]. Another cause of growth inhibition under NaCl stress could be an imbalance in uptake of mineral nutrients due to competition with Na^+ [9].

The activity of catalase in rice leaves increased under saline condition. However, the magnitude of increase in above enzymes was higher in tolerant varieties than susceptible one. Reactive oxygen species (ROS) are regarded as the main source of damage to the cell of abiotic stress, such as superoxide anion (O_2^-), hydrogen peroxide (H_2O_2) and the hydroxyl anion (OH^-) particularly synthesized in the chloroplast and mitochondria [12]. Plant processes a number of antioxidant enzyme like SOD, APX, and CAT to protect against the damaging effect of ROS [27]. Several factors associated with salinity stress can lead to an increase in reactive oxygen species (Apel and Hirt, 2004). Free radical scavenging systems such as SOD can be a critical component of salinity tolerance because of their protection of chloroplast function under high salinity (Orcutt and Nisen, 2000). Antioxidant enzyme plays a significant role in plants to protect them against the damaging effect to ROS generated during salinity stress [27]. SOD catalyses, the dismutation of superoxide to H_2O_2, which is detoxified by catalase and/ or peroxidase to water and oxygen. The minimum reduction catalase was observed by IR 29, where, as maximum reduction was observed by Pokkali respectively. Similar results have also been reported by [11 1].

Salinity enhanced the sodium content with concomitant decrease in calcium content in rice shoot. Tolerant varieties had less sodium and more calcium content in under saline soil, while, susceptible varieties, IR 28 and IR 29 showed high Na content with low Ca. The ESP of salinity, soil is high which causes increased uptake of sodium by plants. The sodium ions have a competitive effect with the absorption of calcium as results decrease their uptake. Enhanced uptake of sodium and decreased uptake of potassium and calcium under salt stress have been also reported by several researchers [22, 18]. An increased absorption of potassium and calcium is needed to maintain good Na-Ca balance for the growth of the plant in saline soil.

Table 2: Effect of different EC level of different ion and yield attributes parameters of rice varieties

S. No.	Variety	Na content in leaves	K content in leaves	Ca content in leaves	Na:Ca Ratio	No. of panicle /plant	Grain yield (g) plant^{-1}
1	Pokkali	4.97	33.97	3.38	1.60	3.76	10.51
2	Narendra Ushar Dhan 3	4.36	32.72	3.34	1.41	3.75	13.72
3	IR 28	3.49	30.16	2.67	1.50	3.41	8.86
4	IR 29	3.42	30.47	2.75	74.41	3.4	9.3
1	Normal	0.99	38.27	3.58	0.28	4.07	12.95
2	EC 6.0	3.49	30.42	2.98	1.16	3.66	10.9
3	EC 10.0	7.69	26.8	2.55	57.75	3.02	7.95
Sem ±		V= 0.05 T=0.04 VXT= 0.23	V= 0.84 T= 0.72 VXT= 1.45	V= 0.04 T=0.03 VXT= 0.06	V= 1.83 T=1.58 VXT= 3.16	V= 0.09 T=0.23 VXT= 0.16	V= 0.24 T=0.21 VXT= 0.41
CD at 5%		V= 0.13 T=0.06 VXT=0.23	V=2.46 T=2.13 VXT=NS	V= 0.10 T=0.09 VXT=0.18	V= 5.36 T=4.64 VXT=NS	V= 0.27 T=0.23 VXT=NS	V= 0.69 T=0.60 VXT=NS

Calcium is essential for the maintenance of cell membrane integrity. Calcium plays an important role in the synthesis of new walls in cell, particularly the middle lamellae that separate newly divided cells (Taiz and Zeiger, 2006). The rice membrane was damaged and enhanced permeability due to displacement of Ca2+ and increasing Na+ from the binding sites of phospholipids of membranes. In the present study, calcium ion decreased with the increase in salinity levels. Calcium influx increased in the shoot and decreased in the root with the increase in salinity levels (Table 2). Na^+ specific damage is associated with accumulation of Na^+ in leaf tissues and results in necrosis of older leaves. Deficiency of other nutrients in the soil is due to the high concentration of Na^+ that interacts with other environmental factors, which exacerbate the problem [14]. Besides, high Na^+ hampers the uptake of other nutrients, thus the uptake of water, growth limiting nutrients.

Ionic ratios are very important to determine the relative toxicities that could provide relative biological processes rates under specific ionic antagonisms [23, 17]. Relative proportions are also important in plant nutrition. The ratio of Na^+/K^+, and Ca^{2+}/Na^+ in shoot of rice plant showed an indication of the nutritional status under salt environment. Pardo *et al.* [28] observed that the Na^+/K^+ plays a role for growth of plants, since metabolism is adversely affected by low Na+/K+ ratios under salt condition. Na^+/K^+ ratio impressively increased in the root under salt stress (Fig.4). K+ and Ca^{2+} uptake significantly influenced in wheat and increased Na^+/K^+ and Na^+/Ca^{2+} ratios as well as reduced the growth and yield [12, 9]. Salt sensitive varieties expressed more nutritional imbalance while the salt tolerant varieties were able to maintain balance among the nutrients in the tissues whereas, the sensitive varieties showed lacking such type of mechanisms and thus suffered nutritional imbalance.In present study, the leaf K:Na ratio, showed differences in the wheat cultivars used and those having higher leaf.

Yield components recorded under both salinity conditions relative to normal soil showed a significant reduction in the number of panicles plant^{-1} and grain yield plant^{-1} of all varieties. The magnitude reduction in all above traits was less in tolerant varieties, Pokkali and Narendra Usar Dhan 3, whereas, susceptible IR 28 and IR 29 had higher reduction.

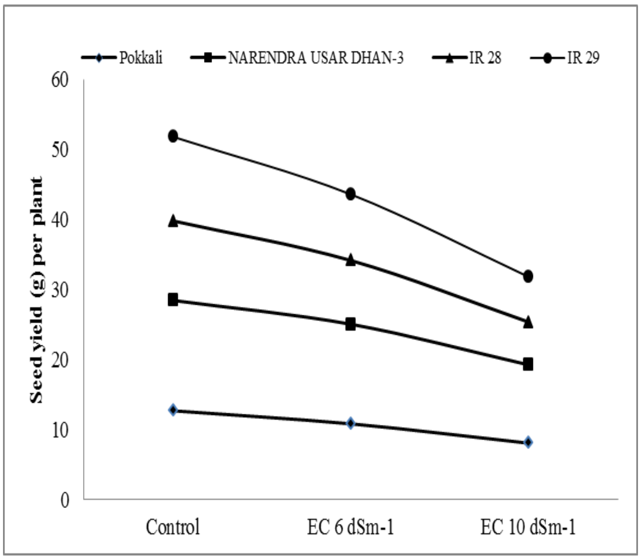

Figure 2: Effect of different levels of salinity on grain yield plant^{-1} of rice variety

Yield is a summation of all metabolic processes and growth events during the life cycle of a crop plant and any abiotic or biotic stress during their growth and development influence potential productivity of crop yield. Plants grown under saline soil have chlorotic leaves which reduce their capacity to fix CO_2 as a result total biomass is affected. The total biomass is an important character to maintain the grain yield. In the present study, the reduction in biomass under salinity was more in susceptible variety IR 28 and IR 29 and these varieties also exhibited higher grain yield reduced and vice-versa was true for tolerant Pokkali and Narendra Usar Dhan 3. The magnitude of salt induced yield losses could not be attributed to single factor. Different physiological, biochemical factors at different stages of rice plants may be involved. One factor may be the overall control mechanism (before flowering) of sodium uptake through root and its subsequent distribution in different vegetative and floral parts, especially in leaves where it causes leaf mortality thereby reduces transportation of total assimilates to the growing region [13].

4. Conclusion

Salinity significantly reduced plant height, dry biomass, tillers number, membrane stability index and relative water content in the rice varieties at all the growth stages. Moreover, tolerant varieties, Pokkali and Narendra Ushar Dhan 3 showed less decrease under salinity in above traits, however, sensitive varieties, IR 28 and IR 29 exhibited higher reduction.

Salinity significantly reduced the total chlorophyll and marked increase in carbohydrate and activity of antioxidant enzymes like catalase. Tolerant verities showed higher total chlorophyll as compared to susceptible varieties. However, magnitude of increment of carbohydrate and catalase activity was more in tolerant varieties as compared to susceptible varieties.

Sodium content in leaves increased significantly with a concomitant decrease in potassium and calcium content in saline soil. The tolerant varieties Pokkali and Narendra Ushar Dhan 3 showed comparatively more sodium accumulation than susceptible varieties with the increment of salinity.

Number of panicles plant^{-1} and grain yield plant^{-1} all varieties declined under saline soil as compared to normal soil. Extent of decrease in all above traits was comparatively less in Pokkali and Narendra Ushar Dhan 3 than IR 28 and IR 29.

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