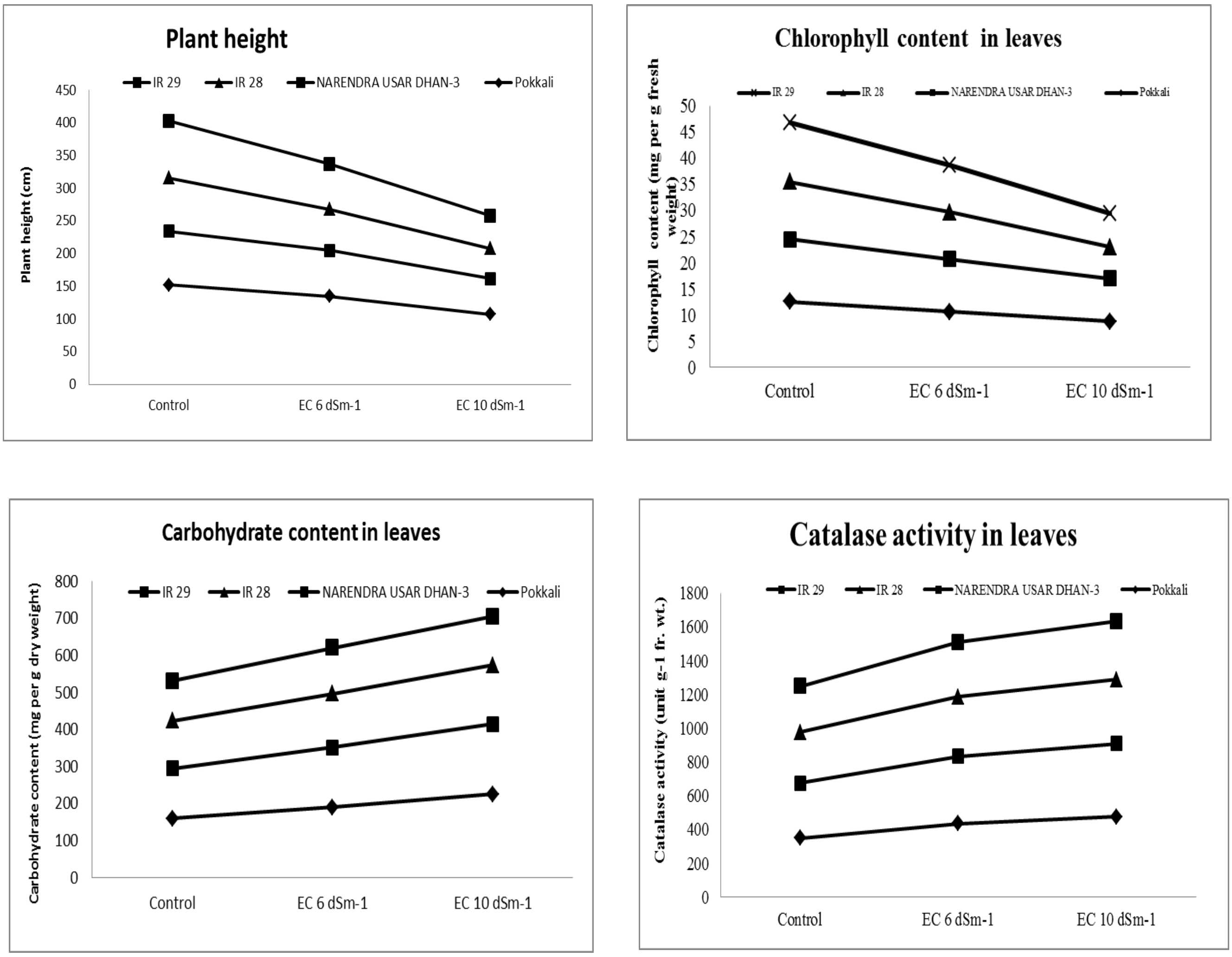

Figure 1: Effect of different EC level of height, chlorophyll, carbohydrate and catalase activity of rice varieties

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.

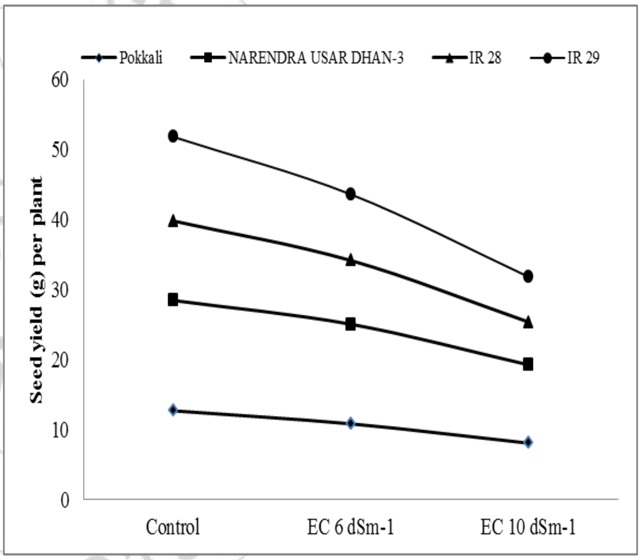

Figure 2: Effect of different levels of salinity on grain yield plant^{-1} of rice variety

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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