CHAPTER IV

Discussion

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Rice varieties differed in their capacity to tolerate salinity during seedling stage. At low salinity of EC 5 m mhos/cm there was no effect on any of the varieties but beyond EC10 m mhos/cm there was a considerable inhibition of the shoot dry matter accumulation of ten days old seedlings to varying degrees. Ten days old seedlings in their dry matter accumulation of shoot at EC 15 m mhos/cm salinity level indicated wide varietal difference in their resistance capacity viz. AU1, Co36 and CSC1 were more susceptible, and CSC2 and IR20 were less susceptible.

Among five varieties tested for their tolerance to 100 mM NaCl upto 30 days after initial salinization, the shoot and root length were highly inhibited in TKM4 and less inhibited in Co43. The Co43 also accumulated fresh and dry matter of shoot and root compared to others at 30 days of salinization. CSC1, CSC2 and TKM4 were proved to be more sensitive than Co43 as their dry matter content of shoot and root at the end of salinization during the seedling stage was much reduced. The seedlings of 30-37 days were the most sensitive when compared to their other developmental stages (Flowers and Yeo, 1981; Rathert, 1983b). Kaddah and Fakahry (1961) too reported the rice to be sensitive to salinity in their early stages of growth.

Longer periods of NaCl treatment brought about decrease in the length and dry weight of shoot and root systems of TKM4 and CSC1 because Na^+ had accumulated in excess without any sparing effect upon K^+. The shoots of all the varieties exhibited a higher content of Na^+ and Cl^- than the roots indicating probably a free translocation of Na^+ and Cl^- from roots to shoots (Marschner and Schafarczyk, 1967). The additional accumulation of Na^+ in the shoots might enhance turgor pressure and therefore modified cell size (fresh weight and dry weight) and growth rates. In comparison with other varieties, the TKM9 and Co43 accumulated high levels of Na^+ and exhibited less inhibition of shoot and root length and their dry weight. A direct correlation between massive salt accumulation at low salinities and an increase in osmotic pressure, fresh weight and dry weight yields was found in the extremely salt resistant <u>Suaeda</u> <u>monoica</u> (Storey and Wyn Jones, 1979). When susceptible varieties were exposed to longer periods of salt treatment, the net 'loss' of K^+ probably compensated by the influx of Na^+ as a sparing effect which might on the other hand lead to Na^+ toxicity.

But in less susceptible varieties like CSC2 the influx of K^+ from saline root environment could help in better dry weight accumulation. In contrast to CSC2, sometimes in susceptible varieties additional K^+ unavailability for osmotic adjustment resulted and the lowered shoot length, root length, dry weights and growth rates might be the consequence. Storey and Wyn Jones (1978) found that in Spartina, a Gramineae member, the decline in K^+ was balanced by the accumulation of Na^+.

Interestingly, the CSC2 accumulated a large concentration of K^+ than the Na^+ under stress condition. Probably this variety excluded the Na^+ toxicity by raising the K^+ levels as evidenced in rice and sorghum (Hegde and Joshi, 1974; Pathmanabhan and Rao, 1976). Marschner (1971) commented that the ability of plants to replace K^+ by Na^+ and growth stimulation by Na^+ largely reflected the order of salt resistance in agronomic crops. It would appear from our results and other studies (Greenway, 1973) that avoidance of salt accumulation and maintenance of K^+ level in the growing shoots and roots was of fundamental importance in conferring resistance among rice varieties. The selectivity of K^+ over Na^+ by the roots of CSC2 might represent as a minimum requirement for cytoplasmic K^+ and an important adaptation to survive in the saline environment. It had been observed that in the Na^+ and K^+

interactions of glycophytes roots and of some halophytes, Na^+ might increase rather than decrease the K^+ content of roots (Storey and Wyn Jones, 1979).

The nitrogen metabolism of salinized rice seedlings was considerably changed depending upon the varietal tolerance. Accumulation of free amino acid and proline in shoots, a typical response of osmotically stressed plants, on the other hand, showed the importance of that effect (Abdul-Kadir, 1982; Wyn Jones and Storey, 1978; Stewart and Lee, 1974). In TKM4, CSC1 and CSC2 the proline concentration increased with increasing amount of Na^+ in all the days of salinization. Voetberg and Stewart (1984) commented that the proline concentration were directly proportional to Na^+ concentration and each increase of Na^+ concentration was balanced by an increase in proline concentration equal to about 4% of the raise in Na^+. Weimberg et al.(1982) reported an increase in proline equal to about 5% of the increase in $Na^+ + K^+$ for leaves from salt stressed sorghum plants. Invariably, the CSC2 had a high proline concentration. Moreover, this variety maintained a high level of K^+ than the Na^+ and earlier reports concluded that high K^+ levels would enhance the proline accumulation (Udayakumar et al., 1976; Mukherjee, 1974). Comparatively, the TKM9 and Co43 accumulated large concentration of proline than the others and exhibited less inibition of vegetative growth. Ball (1975) indicated the proline accumulation in rice when exposed to salinity and he suggested that proline served as a source of energy for growth and survival in rice.

It had, therefore, been suggested by Stewart and Lee (1974) that proline functioned for intracellular osmotic adjustment under saline conditions. Many other investigators found an accumulation of proline accounting for 30-70% of the free amino acids in plants when exposed to salt stress (Chu et al., 1976b). Salinity affected the protein-bound-proline adversely under prolonged salinity in all the varieties tested, indicating the break down of proline from its protein. On the contrary, Palfi and Juhasz (1968) observed that the accumulated proline could conceivably have arisen from the synthesis or partly from the breakdown of proline rich protein during salt stress and they critically commented that the accumulated proline in the free amino acid pool might be mainly due to the increased level of synthesis rather than the breakdown.

Salinization brought about an increase in the levels of total and soluble protein in both shoots and roots of all the varieties with a parallel decrease in the insoluble protein during seedling stage. Salinity decreased the protein synthesis and increased its hydrolysis as observed in grape leaves (Saakyan and Petrosyan, 1964) and in bean leaves (Nieman, 1965). However, protein break down and turnover was delayed by salinity in Vigna sinensis (Prisco and Vieira, 1976). On the other hand, salinity increased protein content in wheat seeds (Singh and Vijayakumar, 1974) and in particular acid proteins in pea roots (Rakova et al., 1969). Salt treatment increased the total nitrogen in both shoots and roots of TKM4 and TKM9, whereas it decreased in other varieties during seedling stage. There was an increase in total nitrogen content of desert fodder plants (Add-El-Rahman et al., 1974) and in rice (Shimose, 1957, 1968), but the observation on wheat reported a decrease in total nitrogen, (Abdul Kadir and Paulsen, 1982).

Among the five varieties studied during seedling stage, Co43 could tolerate saline treatment better than others. CSC1 exhibited less sodium content and high level of soluble and total protein. TKM4 and TKM9 significantly increased the total nitrogen to salinity. This may be a physiological adaptation of these varieties for survival under saline stress.

Effect of salinity on preflowering vegetative growth was of varying magnitude among the nine varieties tried. AU1, Co43 and CSC1 during the six weeks of salinization indicated comparatively less reduction in growth than the varieties Co36, CSC2, GR3, IR20 and TKM4. The differences among the varieties of rice in growth parameters was used to screen varieties for saline tolerance by Janardhan and Murthy (1972). Other rice varieties used in earlier experiments considerably differed in their vegetative growth to salinity (Malek _et al._, 1961; Venkateswarlu _et al._, 1972; Giriraj _et al._, 1976).

The production of tillers was greatly affected by exposure to salinity. Varieties AU1, Co43 and TKM9 showed less reduction of tiller number. The TKM4 and IR20 were highly susceptible in the production of tiller number. The height of tillers was not much affected in the AU1, Co43, CSC1 and CSC2. Salinity brought about a high reduction in the dry weight of tillers in TKM4, Co36, GR3 and IR20, and low reduction in AU1, CSC1, CSC2 and Co43. In general AU1 and Co43 seemed to have a better tiller growth in response to salinity. Salinity significantly affected the vegetative growth of rice varieties such as the number of tillers, height of tillers and weight of tillers in varying degrees (Agarwal _et al._, 1964; Datta, 1972; Ehrler, 1960; Farah and Anter, 1978; Javed and Khan, 1975; Kaddah and Fakahry, 1961; Paricha, _et al._, 1975; Shimose, 1958 and 1963).

Yeo and Flower (1983) noticed a strong negative relationship between shoot sodium level and varietal survival in rice varieties. Janardhan and Murthy (1970) screened rice varieties for saline tolerance based on the survival of the plants and leaf injury. Maskima *et al.* (1979) noticed that the rice varieties which showed low morality, produced high grain yield than the variety that had a high morality. In the present study it could be concluded that high sodium uptake brought about the least survival rate in CSC2 and TKM4. The relationship between the sodium uptake and varietal survival strongly inferred that the most significant aspect of rice salt sensitivity was due to the excessive entry of ions. The data demonstrated the predictive value of sodium uptake for varietal survival in saline conditions and consequently, implied the prominence of excessive ion entry in saline sensitivity in these species.

Varieties AU1 and CSC1 were susceptible during early seedling stage, but found to tolerate salinity in the later stages of growth, but CSC2 and IR20 were more resistant during seedling stage and became susceptible to salinity in the later stages of growth. Someone reported that rice varieties could tolerate salinity during germination stage but became susceptible in the subsequent growth stages (Anonymous, 1967). Castor varieties also differed in their capacity to tolerate salinity. It was observed that they were susceptible during seedling stage, but showed tolerance in the later stages of growth (Abdel-Rahman *et al.*,1975).

Survival capacity of the varieties were of the following order Co43 > AU1 = GR3 = IR20 > Co36 > TKM9 > TKM4 > CSC2.

The inorganic constituents of shoot system of preflowering vegetative growth stage indicated that the Co36, CSC2 and IR20 accumulated a high level of Na^+ and Cl^- and low level of K^+, Ca^{2+} and Mg^{2+} concentrations when compared to the control. Excessive accumulation of Na^+ and Cl^- with parallel decrease in K^+, Ca^{2+} and Mg^{2+} levels by the susceptible varieties was also observed in wheat by Poonia et al., (1972). Increased Na^+ and Cl^- levels with increasing K^+, Ca^+ and Mg^{2+} levels were observed in AU1, Co43 and CSC1. These results were consistent with the earlier observations in rice (Hegde and Joshi, 1974; Paricha et al., 1975; Palfi, 1965) and sorghum (Pathamanabhan and Rao, 1976). Comparing all the nine varieties, AU1 had been found to accumulate a less amount of sodium throughout the study period. These results and also those reported by Greenway (1962a) in *Hordeum*, Syed and Swaify (1973) in sugarcane, Bowling and Ansari (1971) in sunflower roots and Hegde and Joshi (1974), Parich et al., (1975)& Giriraj et al. (1976) in rice consistently indicated that salt tolerant plants accumulated less sodium in their tissues. The ability of a plant to maintain higher concentration of K^+ and lower concentration of Na^+ was one of the factors in determining the salt tolerance of the plant. The capacity of rice variety to withstand salinity was also attributed to its ability to maintain a high level of potassium in its system (Hegde and Joshi, 1974).

Sodium chloride treatment increased the free amino acid level in all the varieties during the preflowering vegetative growth period and varieties AU1, Co43, and CSC1 accumulated the maximum of 1 to 3 fold over the control. Palfi et al. (1974) observed differential accumulation of proline in 27 species under water stress. Some species were found to accumulate high proline than others. Stewart and Lee (1974) suggested that the capacity of species to accumulate proline was correlated with salt tolerance and acted as an intracellular osmoticum. Genotypic differences in the accumulation of proline under stress was also observed in sorghum (Sinha and Rajgopal, 1975; Blum and Adelina Ebercon, 1976). Hence, accumulation of proline could also be used as a criterion for the assessment of varieties for saline stress conditions.

Salinity markedly affected the nucleic acid content of shoots during later growth stages. Varieties AU1, Co43, CSC1 and IR20 showed low rate of decrease over the control (i.e. 10 to 25 per cent) in the RNA content, but there was a distinct increase in the DNA content only in the first three varieties. The increased DNA content was in conformation with the findings of Kabanov and Ermakov (1969) in pea, and Tsenov _et al._ (1973) in tomato. Alternatively, salinization decreased the synthesis of RNA and DNA in okra , spongegourd (Maliwal and Paliwal, 1972a), bean (Nieman, 1965) and tomato (Tal, 1977).

Sodium chloride adversely affected the protein level in the leaves of all the varieties during the later stages of growth. Generally, soluble protein was found to increase in all the varieties. Constant increase of insoluble protein and total protein was noticed in AU1, Co43 and CSC1 only. Salinity decreased the protein synthesis and increased its hydrolysis as observed in grape leaves (Saakyan and Petrosyan, 1964) and in bean leaves (Nieman, 1965). However, protein break down and turnover was delayed by salinity in _Vigna._ (Prisco and Vieira, 1976). On the other hand, salinity increased protein content in wheat seeds (Singh and Vijayakumar, 1974) and particularly acid proteins in pea roots (Rakova _et al._,1969). There was a marked increase of total nitrogen content in AU1, Co43, and CSC1 while it decreased in other varieties at the end of salinization. There was an increase in total nitrogen content in desert fodder plants (Add-El-Rahman _et al._, 1974) and in rice (Shimose,1957, 1958), but the observation on wheat reported a decrease (Abdul Kadir-Paulsen, 1982).

From the above studies it was clear that the AU1, Co43 and CSC1 exhibited increased levels of DNA, proline, insoluble and total protein and total nitrogen. These might be some types of speculative mechanisms of these varieties for saline environment.

Salinization altered the carbohydrate levels in all the varieties during the later vegetative growth stage. Generally, the reduction in the starch content was noticed in all the varieties. The reduced carbohydrate utilization as a result of salt stress might possibly initiate feed-back effects where photosynthesis was diminished (Hall and Milthorpe, 1978), which could contribute to reduce starch content during increased stress. Salinization resulted in accelerated accumulation of reducing, non-reducing,& total soluble sugars and total carbohydrate in AU1, Co43 and CSC1, whereas it decelerated these group of compounds in other varieties. The genotypically high sugar content with possible consequences to the carbohydrate metabolism acted evidently as an additional mechanism to prevent salt injury (Rathert, 1982). A restricted utilization of carbohydrate under salinity could possibly result in the lack of energy for growth (Rathert, 1983a). Rathert et al. (1981) reported that the low carbohydrate content might be the result of a stimulation of the respiration rate and/or a decrease in the photosynthetic activity accompanied by reduced growth rates under high salinity stress. These carbohydrate changes were regulated by the absorbed ions, mainly K^+ and Cl^- directly or indirectly via synthetases and degradative enzymes in cooperation with the genotypic different carbohydrate metabolsim (Rathert, 1982). The increased carbohydrates caused by salt stress had been reported for barley (Munns et al., 1982), cotton (Rathert, 1983a) and soyabean (Rathert and Doering, 1983; Rathert, 1985).

Possible interactions of varietal difference in ion regulation and carbohydrate metabolism might indicate a competition for energy between saline adaptation and growth (Rathert, 1985). Besides the possible differences in ion regulation, varietal differences in the genetic fixation of carbohydrate pattern could be an effective tolerance mechanism. Accelerated carbohydrate accumulation via soluble sugars in AU1, Co43 and CSC1 could be an effective mechanism for salt tolerance in rice.

Salinity decreased the ascorbic acid content in cabbage and radish (Kim, 1958). However, cultivars of rice exhibited differential effects as a response to salinity. The rice cultivars could be differentiated into four groups on the basis of their reaction to salinity; primarily, cultivars that accumulate considerable endogenous ascorbic acid content irrespective of the ionic concentration around their root like Co43, CSC1 and GR3; secondly, cultivars that reacted with accumulation of ascorbic acid to the initial salinization but indicated not much difference with the control later, like Co36; thirdly, the varieties indicating and initial accumulation and as the EC value of the soil increased indicated a decrease in the endogenous ascorbic acid content like TKM4 & TKM9; and finally, the varieties like AU1 indicated a reduced accumulation at low levels of salinity but as the salinity became severe accumulated more of ascorbic acid. Gupta and Parmil Kaur (1970a) commenting upon the relationship between salt tolerance and ascorbic acid content in pea concluded that the variety rich in ascorbic acid content was more salt tolerant than the variety with low level of ascorbic acid content or greater variation. Probably our results too pointed to the same conclusion as in pea.

Titrable acid number was increased in all the varieties at all the growth periods after salinization. Sometimes in AU1, Co43 and CSC1 the increase was 2 to 4 fold. Salinity increased the titrable acid number in Bryophyllum (Karmarkar and Joshi, 1969), Saccharum (Nimbalkar, 1973) and Phaseolus (Khot, 1978). In the present experiment by taking nine varieties of the same crop differing in their response to salinity, it has been possible to conclude that the leaf ascorbic acid levels and titrable acid number of the shoot system could possibly play a great role in salt tolerance capacity of rice varieties and accordingly the varieties AU1, Co43 and CSC1 were more efficient to maintain high levels of endogenous ascorbic acid and considerable increase in their titrable acid number in response to NaCl treatment.

Rice varieties exhibited a variability in chlorophyll breakdown by NaCl treatment. The lowest reduction of about 10 to 23 per cent in the chlorophyll content of third leaf was noticed in AU1, Co43, and CSC1 at six weeks after initial salinization when the soil ESP level was comparatively more, whereas these varieties increased the chlorophyll a and chlorophyll b content upto four weeks by sodium chloride treatment. A likely negative correlation existed between the shoot sodium content and pigment level in these cultivars. It could also be concluded that the AU1, Co43 and CSC1 exhibited more resistance and showed less amount of sodium uptake and less reduction of chlorophyll in comparison with other varieties. By comparing different varieties too, one could draw an overall negative relationship between the chlorophyll and sodium concentrations, demonstrating that as the sodium ion concentration increased, the chlorophyll pigments levels declined (Dostanova, 1966; Sivtsev, 1973).

Salinity decreased the chlorophyll content in radish, cabbage, lettuce (Kim, 1958), beet, spinach (Nieman, 1962), tomato, celery, vines (Siegel and Bjarsch, 1962) and some glycophytes ((Prokrovskaya, 1958). Yeo and Flowers (1983) assessed the toxicity of sodium on the chlorophyll content in a number of rice varieties. The sodium and chlorophyll data were interpreted as showing that the varieties tested differed in the shoot sodium concentration which brought about a given degree of chlorophyll loss and consequently, the leaf tissue of some varieties were more resistant to salt ions than the leaf tissue of others.

Sodium chloride treatment increased the peroxidase, polyphenolase and ascorbic acid oxidase in all the varieties in varying degrees. These results are in conformity with the earlier observations in rice (Aleshin et al., 1971), cotton, maize lucerne (Azisbekova, 1964) and in other plants (Strogonov, et al., 1956). Varieties Co43, GR3 and AU1 inspite their stimulated ascorbic acid oxidase level under salinization, they could maintain their ascorbic acid level. The activity of other oxidases i.e., peroxidase and polyphenol oxidase had been taken by the plant physiologists as indicators of healthy growth, a decrease in the activity indicating a reduced growth. But alternatively, a stimulated growth could also be correlated with inhibited growth as IAA oxidase had been considered to be an isozyme of peroxidase and thereby brought about a decreased endogenous IAA level that affects growth (Halevy, 1963). Salinity promoted the amylase, invertase and phosphorylase activity in all the varieties as noticed in wheat (El-Fouly and Jung, 1970), barley (Dzhanibekova, 1972) potato, beans and spinach (Latzko, 1954). The change in amylase activity has been positively correlated with the accumulation of starch and sucrose in the leaves of cotton sensitive to salinity (Rathert, 1982). While comparing the reduction in starch in the order of Co36 = GR3 > TKM4 = CSC2 > IR20 > TKM9 > AU1 > CSC1 > Co43 with the increase amylase activity TKM4 > Co36 > IR20 > TKM9 > CSC2 > AU1 > GR3 > Co43 = CSC1, varieties Co36 and TKM4 could be correlated with decreased starch content and stimulated amylase activity and in AU1, Co43 and CSC1, the vice versa. Similar comparison between the degree of stimulation in the invertase activity with the rate decrease in the non-reducing sugar or the rate of increase in the reducing sugar over the control was evident only in AU1 and not in other varieties.

Acid phosphatase activity was found to increase by salinity in all the varieties as supported by El-Fouly and Jung (1970) and El-Fouly (1972) in wheat, and Dzhanibekova (1972) in barley. Membrane-bound ATPase activity was stimulated by saline treatment in all the varieties and the increased level of Na and K ions support the increased activity of membrane-bound ATPase. Salinity promoted the ATPase activity in the cotylendons of *Phaseolus vulgaris* (Lai and Thompson, 1972) and in the leaves of *Avicennia nitida* (Kylin and Gee, 1970). Invariably, the activities of the nitrate reductase, glutamate oxalocetate transaminase (GOT) and glutamate pyruvate transaminase (GPT) were increased in AU1, Co43 and CSC1 but it was inhibited in others by saline treatment. Nitrate reductase activity was decreased in many plants due to saline root medium (Heimer, 1973; Abdul-Kadir and Paulsen, 1982). Salinity tremendously increased the protease activity in CSC2 and to a less extent in other varieties. Sodium chloride decreases the protein synthesis and increases its hydrolysis in pea roots (Klyshev and Rakova, 1964) and in grape leaves (Saakyan and Petrosyan, 1964). Prisco and Vieira (1976) reported contrary to this a delayed protein breakdown and turnover by the sodium chloride treatment in *Vigna sinensis*.

The stimulation of dehydrogenases in all the varieties indicated the stimulation of the tricarboxylic acid cycle and thereby respiration to salinity. The dehydrogenase activity in the tricarboxylic acid cycle was stimulated in barley, sunflower and tomato (Zhukovskaya and Lyakhova, 1969). Contrary to this, a direct correlation between salt tolerance and total dehydrogenases was evidenced in pea (Gupta and Parmil Kaur, 1970b).

From the above studies it is suggested that the variation in the response of enzymes activities to salinity could be one of the several possible indicators for salt tolerance of rice varieties under saline conditions. However, care has to be taken for possible artifact of the isolated functional proteins in the cell free system. Different species were known to regulate the ionic environment of the cytoplasm to protect the enzymes within the different compartments.

Sodium chloride treatment delayed the flowering in all the varieties except GR3 which showed ten days early flowering. The delay in the flowering was less pronounced in AU1, Co43 and CSC1 than the others. Reduction in the panicle length, number of panicle per plant, number of spikelets per panicle, number of filled grain per panicle and dry weight of filled grain per panicle was quite less in AU1, Co43 and CSC1 than the other varieties tested. Increased number of unfilled grains per panicle was found in Co36, CSC2, IR20, TKM4 and TKM9 in response to sodium chloride treatment. Reduction in the net grain yield per plant was between 41 and 50 per cent in Co43, CSC1 and AU1, which was comparatively less than the other varieties. The highest reduction of grain yield per plant upto 95 per cent over the control was recorded in TKM4 and CSC2. However, weight of 100 grains was not much affected in AU1, Co36, Co43 and GR3 while it was adversly affected in CSC2, TKM4 and TKM9 to saline treatment.

The highest grain yield reduction in TKM4 and CSC2 could be due to decrease in the number of panicle per plant, increase in the number of unfilled grain per panicle and decrease the number of filled grain per panicle as observed earlier (Balasubramanian and Rao, 1977). Several investigators screened rice varieties for salinity tolerance based on their differences in their yield parameters (Malek et al., 1961; Venkateswarlu et al., 1972; Giriraj et al., 1976; Janardhan and Murthy, 1972). Murthy and Narasinga Rao (1965) reported that the reduction in the grain yield was attributed by the reduction in the number of fertile tillers, grain number per panicle and an increased percentage of sterile spikelets. Murthy and Narasinga Rao (1965, 1967) investigated that salinity increased spikelets sterility and decreased the number of ear bearing tillers per plant, number of grain per panicle, 1000 grain weight and grain yield of rice varieties. Fifty per cent reduction in grain yield in salt susceptible varieties was observed at a salinity level of EC 8 m mhos/cm compared to a salt tolerant variety, which showed a higher tolerance (Giriraj et al., 1976).

Varieties AU1, Co43 and CSC1 showed less reduction of straw weight than the other varieties to saline treatment. The highest reduction was exhibited with reference to straw weight in Co36, CSC2, IR20, TKM4 and TKM9. Varietal differences in the reduction of straw yield was noticed in rice (Farah and Anter, 1978; Javed and Khan, 1975; Pajanissamy and Dhanapalamosi, 1973). Comparing the final yield of the rice varieties, AU1, Co43 and CSC1 indicated better resistance capacity than the other varieties tested.

Salinity treatment increased the K^+, Ca^{2+} and Mg^{2+} levels with increasing concentration of Na^+ and Cl^- in the straw and filled and unfilled grains of AU1, Co43 and CSC1 when compared to their respective controls. The above observation was reported earlier (Krishnamurthy et al., 1986). On the contrary, salinity decreased the K^+, Ca^{2+} and Mg^{2+} levels with increasing level of Na^+ and Cl^- in the straw and filled and unfilled grains of Co36, CSC2, GR3, IR20, TKM4 and TKM9 as compared to the control. AU1, Co43, GR3 and TKM9 accumulated less sodium in the straw than the other varieties. Co43 had less ability to accumulate high levels of sodium and chloride in the both filled and unfilled grains. Comparatively, IR20 and TKM4 had high concentration of sodium in their filled and unfilled grains in response to salinity.

Organic constituents of the grains obtained from saline exposed plants were analysed in all the varieties. Reducing, non-reducing and total soluble sugar contents were decreased in all the varieties except AU1, Co43 and CSC1 which had maintained increased levels of sugars due to saline exposure overtheir control. Starch and total carbohydrate levels of grains were found to decrease in all the varieties to saline treatment and this reduction was less in AU1, Co43 and CSC1, and more in CSC2 and TKM4 as compared to their controls. Generally amino acid content of the grains improved in all the varieties except Co36 and Co43 when exposed to salinity. Total nitrogen and total protein content were found to decline in the grains of all the varieties to salinization. Co43, CSC1 and AU1 showed lower reduction in the total nitrogen and total protein than the other varieties.

While studying the germination performance of the grains obtained from saline exposed plants AU1, Co43 and CSC1 exhibited low reduction in the rate and final emergence, shoot and root length, and fresh and dry weight of shoot and root than the other varieties tested with their respective controls. High reduction of dry matter content of shoot and root was recorded in TKM4 and CSC2 than the others. In a nutshell rice varieties AU1, Co43 and CSC1 were more resistant in terms of their grain storage efficiency and further generation establishment of their grain due to saline treatment.

Rice is considered to be a salt sensitive crop (John *et al.*,1977; Flowers and Yeo, 1981). However, considerable variability for salinity resistance among rice varieties is also apparent (Datta, 1972; Yeo and Flowers, 1982). In the present study an attempt has been made to assess the rice varieties for their nature of resistance to salinity using the criteria, based on the decreased and/or increased percentage (when compared to the control) of growth, physiological (at the final week of salt treatment) and final yield parameters totally amounting to 85 (Table 37) which helped in seggregating the varieties into three groups viz., resistance, moderately resistance and sensitive (Table 38). The criteria taken for the assessment of varieties were varied with parameters. The minimum and maximum percentage increase and/or decrease were equally divided into three parts. Less reduction of growth and yield parameters upto 33.3 per cent in the total range of all the varieties was considered as resistance and the group falling between 33.4 to 66.6 per cent was considered as moderately resistance and the range (66.7 to 100) was considered as sensitive and presented in Table 38. Similarly, the characteristics were also classified (Table 38). Taking into consideration the 85 characters it can be concluded that the varieties AU1, Co43 and CSC1 are resistant to salinity, Co36, CSC2,

Table 37 : Assessment of rice varieties for their nature of resistance to NaCl salinity using growth, physiological (during sixth week of salinization) and yield parameters (Percentage of increase and/or decrease over the control)

Serial number of parameters	Growth and metabolic characteristic	Criteria taken for assessment of varieties	
		Resistance	Sensitive
I	II	III	IV
	Growth		
	Vegetative		
1	Height of shoot system	low reduction	high reduction
2	Fresh weight of shoot system		
3	Dry weight of shoot system		
4	Number of tiller		
5	Height of tiller		
6	Fresh weight of tiller		
7	Dry weight of tiller		
8	Total leaf area		
9	Percentage of survival to salinity	high per cent survival	low per cent survival
	Reproductive		
10	Length of panicle	low reduction	high reduction
11	Number of panicle		
12	Number of spikelets		
13	Number of filled grain		
14	Fresh weight of filled grain		

contd...

Table 37 (contd.)

I	II	III	IV
15	Dry weight of filled grain		
16	Net grain yield		
17	100 grain weight		
18	Straw yield		
19	Biological yield		
20	Harvest index		
21	Number of unfilled grain	low increase	high increase
22	Fresh weight of unfilled grain		
23	Dry weight of unfilled grain		
	Germination performance of harvested seeds		
24	Percentage of germination at 10th day	low reduction	high reduction
25	Length of shoot		
26	Fresh weight of shoot		
27	Dry weight of shoot		
28	Length of root		
29	Fresh weight of root		
30	Dry weight of root		
	Inorganic constituents shoot system		
31	Sodium	low increase	high increase
32	Chloride		

Table 37 (contd.)

I	II	III	IV
33	Potassium	increase	decrease
34	Calcium		
35	Magnesium		
	Straw		
36	Sodium	low increase	high increase
37	Chloride		
38	Potassium	increase	decrease
39	Calcium		
40	Magnesium		
	Filled grain		
41	Sodium	low increase	high increase
42	Chloride		
43	Potassium	increase	decrease
44	Calcium		
45	Magnesium		
	Unfilled grain		
46	Sodium	low increase	high increase
47	Chloride		
48	Potassium	increase	decrease
49	Calcium		
50	Magnesium		

Table 37 (contd.)

I	II	III	IV
	Organic constituents		
	Shoot portion		
51	Free amino acids	high magnitude of increase	low magnitude of increase
52	Free proline		
53	Titrable acid number		
54	Soluble protein	high magnitude of increase	low magnitude of increase and/or low magnitude of decrease
55	Insoluble protein		
56	Total protein		
57	Total nitrogen	increase	decrease
58	Ascorbic acid	high magnitude of increase	low magnitude of increase and/or high magnitude of decrease
59	Reducing sugar		
60	Total soluble sugar		
61	Chlorophyll a	low reduction	high reduction
62	Chlorophyll b		
63	Starch		

Table 37 (contd.)

I	II	III	IV
	<u>Enzymes</u>		
64	Nitrate reductase	increase	decrease
65	GOT		
66	GPT		
67	Membrane-bound ATPase	high increase	low increase
68	Peroxidase	low increase	high increase
69	Ascorbic acid oxidase		
70	Polyphenolase		
71	Amylase		
72	Invertase		
73	Phospharylase		
74	Phosphatase		
75	Protease		
76	α-Ketoglutaric dehydrogenase		
77	Succinic dehydrogenase		
78	Pyruvic dehydrogenase		
	<u>Harvested grain analysis</u>		
79	Reducing sugar	high magnitude of increase	low magnitude of increase and/or high magnitude of decrease
80	Total soluble sugar		
81	Amino acids		

Table 37 (contd.)

I	II	III	IV
82	Starch	low reduction	high reduction
83	Total carbohydrate		
84	Total protein		
85	Total nitrogen		

IR20 and TKM4 are sensitive to sodium chloride treatment and GR3 and TKM9 are moderately resistant having a tendency to be sensitive (Table 38). There is no detailed information regarding the assessment of rice varieties to salinity resistance on the basis of physiological parameters. However, attempts have been made to classify on the basis of endogenous proline and ascorbic acid levels (Palfi _et_ _al_., 1974; Sinha and Rajgopal, 1975; Blum and Adelina Ebercon, 1976; Gupta and Parmil Kaur, 1970a). In other reports, the assessment of varieties of rice to salinity tolerance using the growth and yield (Malek _et_ _al_., 1961; Venkateswarlu _et_ _al_., 1972; Giriraj _et_ _al_., 1976; Janardhan and Murthy, 1972). seems more meaningful in the judging of different cultivars of rice to saline tolerance. While testing cultivars under stress at most importance has to be given for grain and to a much lesser extent to straw yield. Considering only net grain yield (Parameter 16) GR3 seggregates under the group resistance but falls under moderatly resistance if the straw yield alone is considered (Parameter 18). Besides TKM4 also gets seggregated as moderatly resistance regarding straw yield though its grain yield was reduced by 93 per cent. This clearly indicates, while selecting a cultivar against stress, that the grain yield has to be investigated before arriving at a defenite conclusion. Besides the cumulative study indicates GR3 to be moderatly resistant with a tendency to be susceptible. On the contrary, the yield decrease in GR3 was only 57 per cent as against 50 per cent in AU1 which documents resistance characteristic in all the characters tested. Though the classification based on proline and ascorbic acid is supported by the yield data except in the case of GR3, the other data proves that considering one or two physiological characters in judging saline tolerance can lead to erroneous conclusion. So, cautious approach has to be employed while selecting the indicators for resistance or sensitivity. We could conclude from the present study among the nine varieties screened AU1, Co43 and CSC1 proved to have better resistance characters to salinity of EC 7.95 m mhos/cm with 13 ESP level.