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Adaptive response of *oryza sativa* (L.) To salinity stress

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Abstract

Salinity is one of the major obstacles in enhancing rice production in growing areas in India. Salinity decreases germination percentage, speed of germination and led to reduction in shoot and root length and dry weight in all varieties of rice and the magnitude of reduction increased with increasing salinity stress. Therefore, development of salt tolerance varieties has been considered as one of strategies to increase rice production in saline prone areas. In this present study, adaptive response of *Oryzae sativa* L. to salinity stress was investigated. Seedlings of *Oryza sativa* showed significant reduction in different growth parameters studied i.e. seed germination, length of radicle and plumule, vigour index, fresh and dry weight of *Oryza sativa* seedlings with 100 mM NaCl concentration. The inhibitory effect of salinity stress was proportional to the exposure period and salt concentration. Maximum reduction in seed germination was observed with 100 mM NaCl solution at 72 h. Different concentrations of NaCl adversely affected the chlorophyll and protein contents in the seedlings of *Oryza sativa* in comparison to control. It has been observed that chlorophyll pigment in rice is very sensitive to salt stress. The depletion of biochemical constituents such as chlorophyll and protein contents under the influence of higher concentration of NaCl might cause inhibition in germination and growth characteristics of rice. The exogenous application of L-proline significantly decreased the effects of NaCl. Hence, it can be recommended that seeds of rice should be sown in the fields free from salt toxicity otherwise it will adversely affect the crop productivity.

Keywords: salinity stress, adaptive response, *oryza sativa*, proline, chlorophyll, sugar, protein

1. Introduction

Salt stress in soil or water is one of the major stresses especially in arid and semi-arid regions and can severely limit plant growth and productivity. The deleterious effects of salinity on plant growth are associated with: (1) low osmotic potential of soil solution (water stress), (2) nutritional imbalance, (3) specific ion effect (salt stress) or (4) a combination of these factors. The ability of plants to tolerate salts is determined by multiple biochemical pathways that facilitate retention and/or acquisition of water, protect chloroplast functions and maintain ion homeostasis. Essential pathways include those that lead to synthesis of osmotically active metabolites, specific proteins and certain free radical enzymes to control ion and water flux and support scavenging of oxygen radicals.

Salinity is one of the major obstacles in enhancing rice production in growing areas in India. Salinity decreases final germination percentage, speed of germination and led to reduction in shoot and root length and dry weight in all varieties and the magnitude of reduction increased with increasing salinity stress. Therefore, development of salt tolerance varieties has been considered as one of strategies to increase rice production in saline prone areas or irrigation with mixed water at the end of water rivers.

Rice is a major crop which provides one-third of the total carbohydrate for the world's population, especially in Asian countries. It is the stable food for more than 3 billion people and provides 50 to 80% daily calorie intake [4]. The major limitation in rice crop production is abiotic stress caused by salinity, drought, extreme temperature, submergence, and ultraviolet irradiation. In this present study, the adaptive response of *Oryza sativa* L. to salinity stress was investigated in detail.

2. Materials and Methods

The seeds of *Oryza sativa* L.Co.51 collected from Tamil nadu Agricultural University, Coimbatore were used in this present study. Certified, healthy and uniform seeds of rice were stored in sterilized polythene bags to avoid contamination. Seed germination bioassay was used to test the effect of salt (NaCl) stress on the Oryza sativa seeds under laboratory conditions. The seeds were allowed to germinate in 20 cm diameter petridishes with a tight - fitting lid for 3 days. Five moistened seedlings were then potted in a plastic pot containing soil: sand: peat mixture (1: 1: 2 v/v) and kept under 70% relative humidity at 25±10 °C with a 12 h photoperiod following a guideline of [3]. The seedlings were watered daily with 100 ml half - strength Hoagland nutrient solution and allowed to grow for 10 days. Then, seedlings were separated into seven groups according to the treatment as follows: 0 (control), 25mM, 50 mM, 75mM, 100mM and 150 mM NaCl. Control seedlings were watered with 25 ml distilled water whereas for NaCl treatment, seedlings were irrigated daily with 25 ml of different concentrations of NaCl solution for 72 hours. After 72-h, the following growth parameters were tested: Germination percentage, Seedling length, Vigour index, Biomass and Moisture %.

2.1 Physiological characteristics
Estimation of chloroplast pigments [1], protein [6] and proline [2] contents of leaves, stem and root were carried out at different time intervals by following standard protocols.

3. Results and Discussion
In India and especially in coastal rice fields of Tamil Nadu State soil salinity is a major stress that reduces the rice productivity to a great extent [5]. Salinity is detrimental to the various processes of crops such as seed germination, seedling growth and vigour, vegetative growth, flowering and fruit set and ultimately it causes diminished economic yield and also quality of produce [7]. In response, plants have developed a number of mechanisms to counteract high salt stress such as mineral ions homeostasis and accumulation of compatible solutes such as proline. Therefore, screening for salt-stress tolerant genotypes of rice crop will help in ensuring future crop production. In this present study, the effect of salinity on germination, seedling growth, biomass production and physiological characteristics of rice seedlings were investigated and the results are given in Table 1.

Table 1: Effect of NaCl stress on the growth parameters of *Oryza sativa.* The Data are mean values of three different experiments.

Con. of NaCl (mM)	Seed Germination (%)	Seedling Growth (mm)		Radicle Length (cm)	Plumule Length (cm)	Vigour Index	Fresh wt (g)	Dry wt (g)	Moisture (%)
		Shoot length	Root Length						
0	97	1	0	4.7	5.8	1023.2	0.62	0.16	74.1
25	82	33	74	4.2	5.2	770.9	0.54	0.14	74.0
50	79	32	69	3.9	4.4	657.8	0.52	0.14	73.0
75	64	26	56	3.2	3.5	429.7	0.49	0.13	73.4
100	52	21	49	2.8	2.7	286.4	0.39	0.12	69.2
125	48	20	47	1.5	2.6	197.1	0.22	0.10	54.5
150	37	11	16	1.0	2.2	118.4	0.12	0.08	33.3

From Table 1, it may be inferred that increasing concentration of NaCl decreases the germination percentage significantly. Seed germination is one of the most important phases in the life cycle of plant and is highly responsive to existing environment. Higher seed germination and vigour index was observed in control in comparison to the treatment. Seedlings of *Oryza sativa* showed significant reduction in different growth parameters studied i.e. seed germination, length of radicle and plumule, vigour index, fresh and dry weight of *Oryza sativa* seedlings with 100 mM NaCl concentration. The inhibitory effect of salinity stress was proportional to the exposure period and salt concentration. The rate of inhibition of germination and growth parameters of *Oryza sativa* was in order: 100 mM > 50 mM. Maximum reduction in seed germination was observed with 100 mM NaCl solution at 72 h. Rice seedlings exhibited higher vigour index in control whereas significant reduction in vigour index was observed with 100 mM NaCl solution.

Chlorophyll and Protein content
Chlorophyll *a*, chlorophyll *b* and total carotenoids of leaves of *Oryzasativa* cultured in different concentrations of NaCl was estimated and the results are given in Table 2.

Table 2: Chlorophyll *a*, chlorophyll *b* and total carotenoids of *Oryza sativa* cultured in different concentrations of NaCl. The Data are mean values of three different experiments.

Con of NaCl (mM)	Chl *a* (µg/gfw)	Chl *b* (µg/gfw)	Total chlorophyll (µg/gf w)	Anthocyanin (µg/gfw)	Total Protein (µg/gfw)
0	911	343	1254	105	994
25	612	212	824	122	950
50	575	208	783	157	675
75	484	198	682	187	525
100	465	135	600	200	450
125	446	122	568	202	220
150	412	118	530	247	190

It is evident from the Data (Table 2), anthocyanin content was increased steadily with increasing concentrations of NaCl. Salt-tolerant genotypes showed the high percentages of proline and anthocyanin more than in the salt-sensitive genotypes. In addition, anthocyanin content in salt-tolerant genotypes was accumulated greatly and higher than those in salt sensitive genotypes under salt treatments. The highest rate of increase in anthocyanin accumulation was demonstrated in salt-stressed seedlings while the lowest rate was represented non-stressed seedlings. Salt-tolerant seedlings treated with NaCl had a greater increase in the percentage of accumulated anthocyanins than salt-sensitive seedlings when compared with the control. The results accord with many reports of increased levels of flavonoid and anthocyanins during abiotic stress, including salinity, in various plant species [9, 10].

Different concentrations of NaCl adversely affected the chlorophyll and protein contents in the seedlings of *Oryza sativa* in comparison to control. Seedlings of rice exhibited 1.3 mg/g total chlorophyll content in control while 0.78 mg/g and 0.60 mg/g total chlorophyll content was observed in 50 mM and 100 mM NaCl solution at 72 h (Table 2). The amount of chlorophyll was decreased in different treatments and maximum reduction was observed in 100 mM NaCl solution at 72 h. It has been observed that chlorophyll pigment in rice is very sensitive to salt stress. The reduction in the amount of chlorophyll might be due to inhibition in synthesis of enzymes, proteins and cofactors required for synthesis of chlorophyll or excessive breakdown of chlorophyll under the influence of NaCl stress.

Table 3: The effect of salinity on proline content of 5- day old rice seedlings. The Data are mean values of three different experiments.

Con of NaCl (mM)	Proline content(µg/gdw)		
	Shoot	Root	Leaf
0	58	49	118
25	75	79	144
50	130	118	193
75	134	144	366
100	221	366	421
125	415	393	444
150	422	395	478

It is interesting to note from the Data, that when salt concentration increases the endogenous proline content was also increased as a protective mechanism under proline salinity [5]. NaCl is positively involved in proline biosynthesis. The exogenous application of L-proline significantly decreased the effects of NaCl (Table 4). The root and shoot lengths were increased under salinity stress with increasing concentrations of proline.

Table 4: Effect of application of exogenous L – proline on seedlings growth of rice under NaCl stress. The concentration of NaCl was 100 mM. The Data are mean values of three different experiments.

Proline (mM)	Shoot length (mm)		Root length(mm)	
	5 – day	10 – day	5 –day	10 –day
1	38	52	95	125
2	28	36	42	61
3	28	38	51	66
4	28	39	56	67
5	29	39	58	69
6	31	42	61	74
7	31	44	64	75

4. Conclusion

The change in physiological processes inhibited and delayed the seed germination and growth characteristics of *Oryza sativa* under the influence of NaCl. Seeds of *Oryza sativa* were sensitive to salt stress. Hence, it can be recommended that seeds of rice should be sown in the fields free from salt toxicity otherwise it will adversely affect the crop productivity. This study provides information on biochemical parameters, which are used as stress indicators at the cellular level. The overproduction of osmoprotectants, increasing expression of antioxidant enzymes helps the plant to withstand the environmental stress.

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