Journal of Soil Salinity and Water Quality 6(1), 21-27, 2014

Grouping of Advanced Rice Breeding Lines Based on Grain Yield and Na:K Ratio under Alkaline Conditions

Y.P. Singh*[1], Dhananjaya Singh[1] and S.L. Krishnamurthy[2]

[1]*Central Soil Salinity Research Institute, Regional Research Station, Lucknow- 226 005, Uttar Pradesh, India*
[2]*Central Soil Salinity Research Institute, Karnal-1320 01, Haryana, India*

Abstract

A field experiment was conducted to monitor the performance of rice genotypes for alkalinity tolerance and assess their yield potential under alkaline condition. Forty seven rice genotypes received under International Rice Soil Stress Tolerance Screening Nursery Trial (IRSSTN) from International Rice Research Institute (IRRI) were evaluated for yield and physiological traits. On basis of the grain yield and Na: K ratio, the rice genotypes were grouped in four categories viz. highly tolerant, tolerant, susceptible and highly susceptible**.** The rice genotypes from the high salt tolerant and moderate salt tolerant groups reported lower values for the Na accumulation and Na: K ratio and higher values for grain yield over the susceptible and highly susceptible genotypes. The lowest sodium accumulation and sodium and potassium ratio and highest grain yield was recorded in rice genotype IR74095-AC 64 as compared to the checks (tolerant and susceptible). The rice genotype IR 74095-AC 64 is considered potentially tolerant to alkaline stress and could be used for further breeding programme

Key words: Rice genotypes, Salt stress tolerance, Physiological traits, Na: K ratio

Introduction

Salt is a key constraint among the abiotic stresses which affect the physiological processes of plants and it is the most important factor which severely affects crop growth and development, as well as productivity, especially in rice crops. The adverse effects of three major hazards associated with salt stress are; osmotic (water) stress arising from more negative osmotic potential (higher osmotic pressure) of the root zone, specific ion toxicity, excess of exchangeable sodium which lead to soil swelling and dispersion causing water infiltration, aeration and root penetration problem and nutritional imbalance (Munns and Tester, 2008; Patade et *al.,* 2008). Selection of highly salt tolerant genotypes within a species can be expected to provide useful material in comparisons with the salt sensitive ones. Even the yield of most tolerant traditional varieties reduced to one third. It is intrinsic to a screening procedure that the phenotype should be adequately reflecting the potential of the genotype; and salt tolerance has been treated as a single factor which could include a genetically linked group of factors. The salt tolerance in non- halophytes is the product of several independent factors. Two important factors play key role. Firstly, the salt resistance in rice can be increased beyond the present phenotypic range because there is no reason to expect that, in the absence of selection process, current varieties have evolved the optimal combination of characters for salt resistance. Secondly, such characters will commonly be cryptic, i.e. the genotype for one may not on its own influence the phenotype sufficiently for that phenotype to be selected in a screening process. This study was undertaken to examine the salt tolerance potential in rice genotypes on the basis of ionic accumulation, Na: K ratio and grain yield.

*Corresponding author

Material and Methods

The experiment was conducted under sodic soil (pH 9.6-9.7) condition at Central Soil Salinity Research Institute, Regional Research Station, Research Farm, Shivri, Lucknow-Uttar Pradesh. The site is geographically located at 26^0 47'N latitude and 80^0 46'E longitude and 120 m altitude. Forty seven rice advance breeding lines developed by International Rice Research Institute (IRRI) were evaluated under International Rice Soil Stress Tolerance Screening Nursery Trial (IRSSTN). The nursery of these rice genotypes was raised under normal soil and 30 days old seedlings were transplanted during *kharif* 2011 in the field having soil pH 9.6-9.7. Three times replicated trial was conducted in randomized block design. Two to three seedlings $hill^{-1}$ were transplanted at a spacing of 20 cm × 15 cm. The recommended dose of fertilizers for sodic soils *viz.,* 150 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1}, 40 kg K ha^{-1} and 25kg zinc were applied uniformly to all the genotypes. Half dose of nitrogen through urea and diammonium phosphate, full dose of P_2O_5 through diammonium phosphate and full dose of zinc through

Table 1. Soil characteristics of the experimental field

S. No.	Property	
1.	pH	9.7
2.	ECe (dS m^{-1})	1.33
3.	CEC (meq100^{-1} g soil)	7.9
4.	ESP (meq100^{-1} g soil)	50
5.	Organic matter (%)	0.12
6.	Available nitrogen (kg ha^{-1})	178
7.	Available phosphorus (kg ha^{-1})	6
8.	Available potassium (kg ha^{-1})	160

zinc sulphate were applied as basal and remaining half dose of N was applied in two equal splits at 30 and 60 days of transplanting. The physical and chemical properties of the soils of the experimental field are given in Table 1. The flag leaf sample was collected from each genotype for analysis of ionic accumulation. Required amounts of 300 mM glacial acetic acid were subsequently added to the same solution to make final concentrations 100 mM. The tissue was re-extracted for 2 h at 90 °C for the determination of Na^+ and K^+ content of leaves as described in Yeo and Flowers (1983). The ionic concentrations of flag leaves was determined following wet digestion method using flame spectrophotometer as described by Sharma *et al.* (2011). Ion concentrations were calculated as m mol g^{-1} fresh weight in case of leave sample. This Na: K ratio which is balanced between Na and K in shoot is also a valid criterion in measuring salt stresses. Grouping of genotypes was done on the basis of Na: K ratio and grain yield which are good indicators for tolerance to salt stress (Gregorio *et al.*, 1997). Based on modified standard evaluation score (SES) of visual salt injury at vegetative stage as given in Table 2, the genotypes were grouped in to four categories viz.

Highly salt tolerant: The first group consist of rice genotypes which gave maximum yield and having tolerant potential to a salt stress.

Tolerant: The second group consist of the rice genotypes which are moderately salt tolerant.

Susceptible: The third group consist of rice genotypes which are low yielding and susceptible to salt stress.

Highly susceptible: The fourth group consist of rice genotypes which are very low yielding and highly susceptible to salt stress.

Results and discussion

Evaluation of salt stress symptoms at vegetative and reproductive stage

Salt toxicity of rice genotypes were monitored based on salt injury symptoms. This scoring discriminates the highly susceptible to highly tolerant genotype. Scoring was conducted at vegetative and reproductive stage. the first group representing highly tolerant genotypes namely, IR 10T107, IR 74095-AC 64,IR 71895-3R-60-3-1, IR 73571-3B-14-2, IR 74099-AC7, IR 72046-B-R-8-3-1-2, IR 72579-B-2R-1-3-2, IR 10T 105, IR 10T 108, IR 10T 101, IR 10T 110, IR 10T 103, POKKALI (ACC 108921), NONA BOKRA, IR 66946-3R-178-1-1 (FL 478), CSR 28 and CSR 36 was recorded the salt injury score 3, 2, 3, 3, 4, 4, 2, 3, 4, 3, 4, 4, 2, 3, 2, 2 and 3 respectively (Table 3).The second group categorized as tolerant consist of genotypes namely, IR 74095-AC 45, IR 07 T101, IR 59418-7B-21-3, IR 68144-2B-2-2-3-3, IR 58427-5B-15, IR 68144-2B-2-2-3-2, IR 77674-3B-8-2-2-14-4-AJY1, IR 71829-3R-89-1-1, IR 72593-B-13-3-3-1, IR 72593-B-18-2-2-2, IR 72593-B-3-2-3-3, IR 76397-2B-6-1-1-1-1, IR 77674-3B-8-2-2-14-4-AJY 2, IR 10T 109 and AGAMI MI reported 5, 6, 4, 3, 3, 5, 6, 5, 6, 6, 4, 4, 5, 4 and 6 salt injury score respectively. The third group i.e. sensitive consist of genotypes namely, IR 77674-3B-8-2-2-12-5-AJY 2, TCCP 266-1-3B-10-2-1, IR 77674-3B-8-2-2-13-4-AJY 2, IR 10T 102, IR 10T 115, IR 55179-3B-11-3, AT 401, IR 45427-2B-2-2B-1-1 and A 69-1 had found the salt injury score 7, 7, 5, 7, 5, 5, 7, 6 and 7 respectively.The fourth group categorized as highly sensitive consist of rice genotypes namely, IR 07T 113, IR 70870-B-P-2-2, IR 77674-3B-8-2-2-8-3-AJY 4, IR 77674-3B-8-2-2-14-1-AJY 5, IR 29 and IR 28 had salt injury score 7, 8, 7, 8, 8, and 8 respectively (Table 3). The results of present findings are in accordance with the reports given by Babu *et al* (2014) and Krishnamurthy *et al.* (2014).

Ionic accumulation

The ionic accumulation (Na, K and Na: K ratio) in flag leaves of salt tolerant rice genotypes was significantly different. In first group (highly salt tolerant), the rice genotype namely, IR 74095-AC 64 recorded lower Na accumulation (3.28 mg g^{-1}) and lower the Na: K ratio (0.10) in flag leaves (Table 4). This shows that it was not affected by salt stress as compared to other genotypes.

Table 2. Modified standard evaluation score (SES) of visual salt injury at vegetative stage.

Score	Observation	Tolerance
1	Normal growth, no leaf symptoms	Highly tolerant
3	Nearly normal growth, but tips or few leaves whitish/burn and rolled	Tolerant
5	Growth severely retarded; most leaves roll; only a few are elongating	Moderately tolerant
7	Complete cessation of growth; most leaves dry; some plants dying	Susceptible
9	Almost all plants dead or dying	Highly Susceptible

Table 3. Salt injury score of 47 genotypes of rice.

Genotype	Origin	Stress injury score at vegetative stage	Stress injury score at reproductive stage	Grade
IR 10T107	IRRI	3	4	Highly tolerant
IR 74095-AC 64	IRRI	2	2	Highly tolerant
IR 71895-3R-60-3-1	IRRI	3	3	Highly tolerant
IR 73571-3B-14-2	IRRI	3	4	Highly tolerant
IR 74099-AC7	IRRI	4	5	Highly tolerant
IR 72046-B-R-8-3-1-2	IRRI	4	5	Highly tolerant
IR 72579-B-2R-1-3-2	IRRI	2	3	Highly tolerant
IR 10T 105	IRRI	3	4	Moderately tolerant
IR 10T 108	IRRI	4	5	Highly tolerant
IR 10T 101	IRRI	3	4	Moderately tolerant
IR 10T 110	IRRI	4	5	Highly tolerant
IR 10T 103	IRRI	4	5	Moderately tolerant
POKKALI (ACC 108921)	Sri Lanka	2	4	highly tolerant
NONA BOKRA	India	3	5	highly tolerant
IR 66946-3R-178-1-1 (FL 478)	IRRI	2	4	highly tolerant
CSR 28	India	2	4	highly tolerant
LOCAL CHECK (CSR 36)	India	3	4	Moderately tolerant
IR 74095-AC 45	IRRI	5	6	Moderately tolerant
IR 07 T101	IRRI	6	6	Tolerant
IR 59418-7B-21-3	IRRI	4	5	Moderately tolerant
IR 68144-2B-2-2-3-3	IRRI	3	5	Tolerant
IR 58427-5B-15	IRRI	3	5	Tolerant
IR 68144-2B-2-2-3-2	IRRI	5	5	Tolerant
IR 77674-3B-8-2-2-14-4-AJY 1	IRRI	6	7	Tolerant
IR 71829-3R-89-1-1	IRRI	5	6	Tolerant
IR 72593-B-13-3-3-1	IRRI	6	7	Tolerant
IR 72593-B-18-2-2-2	IRRI	6	7	Tolerant
IR 72593-B-3-2-3-3	IRRI	4	5	Tolerant
IR 76397-2B-6-1-1-1-1	IRRI	4	5	Tolerant
IR 77674-3B-8-2-2-14-4-AJY 2	IRRI	5	6	Tolerant
IR 10T 109	IRRI	4	5	Tolerant
AGAMI MI	Egypt	6	6	Tolerant
IR 77674-3B-8-2-2-12-5-AJY 2	IRRI	7	8	Susceptible
TCCP 266-1-3B-10-2-1	IRRI	7	8	Susceptible
IR 77674-3B-8-2-2-13-4-AJY 2	IRRI	5	6	Susceptible
IR 10T 102	IRRI	7	8	Susceptible
IR 10T 115	IRRI	5	7	Susceptible
IR 55179-3B-11-3	IRRI	5	7	Susceptible
AT 401	Sri Lanka	7	7	Susceptible
IR 45427-2B-2-2B-1-1	IRRI	6	8	Susceptible
A 69-1	Sri Lanka	7	8	Susceptible
IR 07T 113	IRRI	7	8	Highly Susceptible
IR 70870-B-P-2-2	IRRI	8	9	Highly Susceptible
IR 77674-3B-8-2-2-8-3-AJY 4	India	7	8	Highly Susceptible
IR 77674-3B-8-2-2-14-1-AJY 5	IRRI	8	9	Highly Susceptible
IR 29	IRRI	8	9	Highly Susceptible
IR 28	IRRI	8	9	Highly Susceptible

Table 4. Rice genotypes based on grain yield, Na, K content (mg g^{-1} dry weight) and Na^+/ K^+ ratio in the flag leaves at flowering stage

Designation	Grain Yield (kg/ha)	Na	K	Na: K ratio
Highly salt tolerant				
IR 10T107	3680.56	5.86	43.60	0.13
IR 74095-AC 64	3905.56	3.28	31.75	0.10
IR 71895-3R-60-3-1	3541.67	3.26	25.55	0.13
IR 73571-3B-14-2	3250.00	3.97	25.18	0.16
IR 74099-AC7	3388.89	2.74	20.80	0.13
IR 72046-B-R-8-3-1-2	3472.22	3.96	25.55	0.15
IR 72579-B-2R-1-3-2	3736.11	3.26	28.43	0.11
IR 10T 105	3611.11	2.87	22.73	0.13
IR 10T 108	3611.11	3.83	21.13	0.18
IR 10T 101	3638.89	3.63	22.30	0.16
IR 10T 110	3638.89	3.53	20.96	0.17
IR 10T 103	3472.22	3.97	27.18	0.15
POKKALI (ACC 108921)	2644.44	3.78	29.78	0.13
NONA BOKRA	2597.22	4.14	36.24	0.11
IR 66946-3R-178-1-1 (FL 478)	3150.00	4.08	35.45	0.12
CSR 28	3172.22	5.68	39.23	0.14
LOCAL CHECK (CSR 36)	3730.56	4.22	35.10	0.12
Tolerant				
IR 74095-AC 45	2888.89	15.36	41.13	0.37
IR 07 T101	2569.44	13.15	29.48	0.45
IR 59418-7B-21-3	2666.67	5.47	17.48	0.31
IR 68144-2B-2-2-3-3	2847.22	5.86	28.45	0.21
IR 58427-5B-15	2986.11	6.26	31.83	0.20
IR 68144-2B-2-2-3-2	3027.78	9.92	36.60	0.27
IR 77674-3B-8-2-2-14-4-AJY 1	2555.56	10.07	23.48	0.43
IR 71829-3R-89-1-1	3041.67	8.07	27.18	0.30
IR 72593-B-13-3-3-1	2638.89	11.23	28.48	0.39
IR 72593-B-18-2-2-2	2527.78	18.99	40.48	0.47
IR 72593-B-3-2-3-3	2916.67	6.16	19.33	0.32
IR 76397-2B-6-1-1-1-1	3027.78	5.16	18.33	0.28
IR 77674-3B-8-2-2-14-4-AJY 2	2638.89	12.39	30.48	0.41
IR 10T 109	2500.00	13.91	45.48	0.31
AGAMI MI	2638.89	15.31	35.48	0.43
Susceptible				
IR 77674-3B-8-2-2-12-5-AJY 2	2083.33	18.49	31.13	0.59
TCCP 266-1-3B-10-2-1	2055.56	19.46	28.93	0.67
IR 77674-3B-8-2-2-13-4-AJY 2	2208.33	10.54	29.68	0.36
IR 10T 102	2152.78	18.56	22.13	0.84
IR 10T 115	2430.56	12.76	22.75	0.56
IR 55179-3B-11-3	2083.33	15.66	33.78	0.46
AT 401	2236.11	17.56	26.13	0.67
IR 45427-2B-2-2B-1-1	2416.67	15.84	21.50	0.74
A 69-1	2347.22	14.01	24.35	0.58
Highly susceptible				
IR 07T 113	1805.56	22.10	20.25	1.09
IR 70870-B-P-2-2	1597.22	22.12	20.68	1.07
IR 77674-3B-8-2-2-8-3-AJY 4	1944.44	21.86	24.13	0.91
IR 77674-3B-8-2-2-14-1-AJY 5	1805.56	22.37	19.13	1.17
IR 29	1166.67	25.29	21.10	1.20
IR 28	1527.78	20.29	18.10	1.12
SE	1009.41	10.71	8.93	0.39
LSD (p= 0.05)	2146.57	21.56	17.97	0.78

The same results are reported by Bajwa (1982) in rice. The second group of rice genotypes ranges Na accumulation from 5.16-18.99 mg g^{-1} and Na: K ratio from 0.20-0.47 in flag leaves. In this group, the genotype namely, IR 58427-5B-15 recorded lower Na accumulation (6.26 mg g^{-1}) and lower the Na: K ratio (0.20) in flag leaves. The genotypes in this group were not affected due salt stress as compared to other genotypes. The third group (susceptible) of genotypes ranges Na accumulation from 10.54-19.46 and Na: K ratio from 0.36-0.84. In this group genotype namely, IR 77674-3B-8-2-2-13-4-AJY 2 recorded lowest (10.54 mg g^{-1}) ionic accumulation of Na and lowest the Na: K ratio (0.36). The fourth group representing highly sensitive group of genotypes ranges 21.86 - 25.29 mg g^{-1} Na and 0.91-1.20 Na: K ratio. In this group genotypes namely, IR 66946-3R-178-1-1 recorded higher Na accumulation (25.29 mg g^{-1}) and higher Na: K ratio (1.20) in flag leaves causing a significant decline the grain yield. Genotypes belong to this category were highly affected by salt stress as compared to other genotypes. This indicates that rice genotype was highly susceptible to sodicity during maturity stage because of accumulation of higher Na and higher Na: K ratio in flag leaves. This is in accordance with finding of Islam and Salam (1997), Islam *et al*. (1998), Hakim *et al*. (2005), Sen *et al*. (2004) and Ali *et al.* (2013).

Grain yield

Classification of salt tolerant potential of rice genotypes on the basis of average grain yield and Na: K ratio is given in Fig 1. The rice genotypes IR 74095-AC 64, IR 72579-B-2R-1-3-2, CSR 36, IR 10T107, IR 71895-3R-60-3-1, IR 74099-AC7, IR 10T 105, IR 72046-B-R-8-3-1-2, IR 10T 103, IR 73571-3B-14-2, IR 10T 101, IR 10T 110, POKKALI (ACC 108921), NONA BOKRA, IR 66946-3R-178-1-1 (FL 478), CSR 28 and IR 10T 108 grouped as highly salt tolerant recorded higher grain yield and lower accumulation of Na and lower Na: K ratio in flag leaves (Table 4). They have not affected by salt stress at pH 9.7 however, other genotypes severely affected at this level of sodicity. This indicates that they are not sensitive to salt stress during the maturity stage of the crop growth. The results of present findings are in accordance with the reports given by Afria and Narnolia (1999) and Gonzales and Ramirez (1998). Grain yield reduction of rice genotypes due to salt stress is also reported by Linghe *et al.* (2000) and Gain *et al.* (2004) and Krishnamurthy *et al.* (2013).

The genotypes namely, IR 74095-AC 45 , IR 07 T101, IR 59418-7B-21-3, IR 68144-2B-2-2-3-3, IR 58427-5B-15, IR 68144-2B-2-2-3-2, IR 77674-3B-8-2-2-14-4-AJY 1, IR 71829-3R-89-1-1, IR 72593-B-13-3-3-1, IR 72593-B-18-2-2-2, IR 72593-B-3-2-3-3, IR 76397-2B-6-1-1-1-1, IR77674-3B-8-2-2-14-4-AJY2, IR 10T 109 and AGAMI MI grouped as tolerant recorded lower grain yield as compared to genotypes grouped under highly tolerant. The accumulation of Na and Na: K in flag leaf was comparatively higher in these genotypes.

The genotypes namely, IR 77674-3B-8-2-2-12-5-AJY 2, TCCP 266-1-3B-10-2-1, IR 77674-3B-8-2-2-13-4-AJY 2, IR 10T 102, IR 10T 115, IR 55179-3B-11-3, AT 401, IR 45427-2B-2-2B-1-1 and A 69-1 categorized as susceptible have produced significantly lower yield than the genotypes stands under highly tolerant and tolerant categories. The accumulation of Na and Na: K in flag leaf was also higher in these genotypes.

The genotypes namely, IR 07T 113, IR 70870-B-P-2-2, IR 77674-3B-8-2-2-8-3-AJY 4, IR 77674-3B-8-2-2-14-1-AJY 5, IR 29, and IR 28 found highly susceptible and produced lowest grain yield. They were severely affected by salt stress as compared to other genotypes. Trend of Na: K ratio in the flag leaf showed that, as to increase grain yield, the accumulation of Na: K ratio was decreased. The correlations between grain yield and Na: K ratio of rice genotypes s given in Fig. 2. This indicates the sensitivity to salt stress during maturity stage in rice. This is in accordance with the findings of Powar and

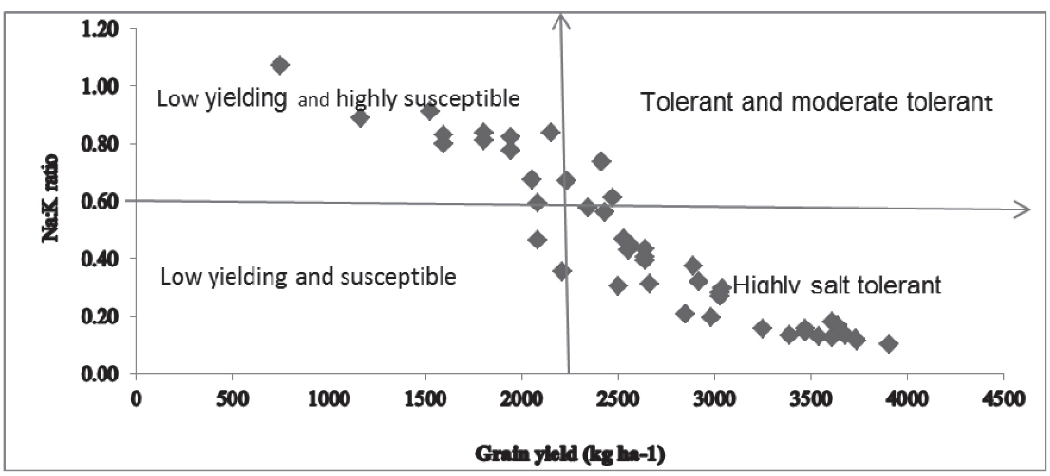

Fig.1. Classification of salt tolerant potential of rice genotypes on the basis of average grain yield and Na: K ratio

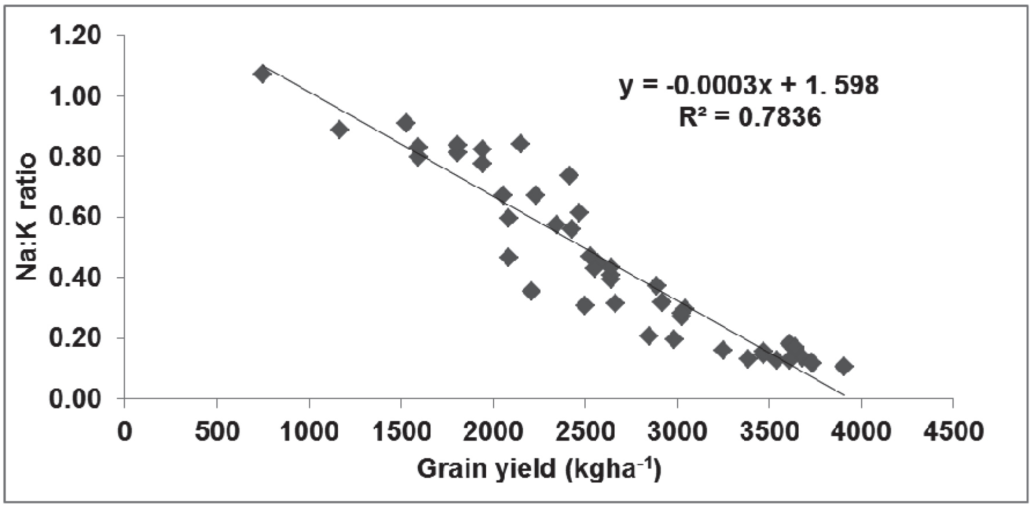

Fig. 2. Correlations between Grain Yield and Na: K ratio of rice genotypes of salt tolerance

Mehta (1997) who reported that grain and straw yields decreased with increasing salt stress and similar finding is reported by (Quadar, 1991 and Surekha *et al*., 2008).

Conclusions

Based upon the grouping of rice genotypes for sodicity tolerance and yield, the rice genotypes from highly salt tolerant group recorded a lower value for the Na: K ratio higher grain yield. The lowest Na: K ratio and higher grain yield was recorded by rice genotype namely, IR 74095-AC 64 as compared with and others in high yield and tolerant genotypes. This rice genotypes IR 74095-AC 64 could be used in further breeding programme to enhance the productivity of salt affected soils.

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Received: December, 2013; Accepted: April, 2014