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Effect of different salt stresses on agro-morphological traits and utilisation of salt stress indices for reproductive stage salt tolerance in rice

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ABSTRACT

Salinity is known to reduce rice yield in ecosystems prone to salt stress. Seasonal variations in rainfall and temperature require development of rice varieties with differential salinity tolerance. Evaluation of breeding lines under varying salinity levels will help to identify appropriate genotypes for similar salt affected areas. A set of 34 genetically and geographically diverse, representative rice genotypes was evaluated in non-stress moderate sodic (pH ∼ 9.5), high sodic (pH ∼ 9.9) and high saline (EC ∼ 10 dS/m) stress environments with three replications in controlled micro-plots/lysimeters for two wet seasons of 2011 and 2012. The stress intensity (SI) for grain yield under moderate sodic, high sodic and high saline environments as compared to non-stress was 0.28, 0.77 and 0.56, respectively. Compared to the non-stress, the per cent grain yield reduction under moderate sodicity ranged from 7 (IR78806-B-B-16-1-2-2-AJY1) to 76% (Pusa 44), while under high sodicity and high salinity, it ranged from 44 (CSR 27) to 97% (PR 120) and 28 (CSR-RIL-50) to 91% (Pusa 44) respectively. Amongst the genotypes evaluated, highest stress tolerance indices (STI) were noticed in genotype CSR 36 (2.17, 1.27 and 1.15 in moderate sodicity, high sodicity and high salinity, respectively), whereas the lowest STI was recorded in genotype NDR 359 (0.27 and 0.05 in moderate sodicity, high sodicity) and TR-2000-008 (0.18 in high salinity). Similarly, genotype CSR 36 registered the highest geometric mean productivity (GMP) and mean productivity (MP) in all stress conditions. The biplot analysis of grain yield showed that the stress tolerance attributes MP, GMP, STI and grain yield favored salt tolerant genotypes CSR 23, CSR 27, CSR 36, CSR-RIL-197, HKR 127 and IR60997-16-2-3-2-2R. The sensitive genotypes PR 113, PR 114, PR 118, PR 120, Pusa 44, TR-2000-008 and VSR 156 were favored by other indices TOL and SSI. Thus, a combination of salt stress indices helps in selection of stable rice genotypes for reproductive stage salt tolerance. Selection based on salt stress indices coupled with trait correlation resulted in the identification of high yielding reproductive stage salt tolerant genotypes viz. CSR 36, CSR 23, CSR 27 and CSR-RIL-197.

1. Introduction

Rice is the most important cereal crop with the highest contribution to the global food requirements. Worldwide, the annual production of rice is around 675 million tones that accounts for about 27 per cent of total food grain production (FAO, 2013). An ever increasing human population has further magnified the need for additional rice, especially in Asian countries. Therefore, improving rice productivity is crucial for food security, economic development and sustainable agriculture. Higher rates of population growth and the transfer of highly productive cultivable lands for industrial and residential purposes have necessitated rice cultivation under less productive ecologies such as saline, sodic, drought and flood prone areas. Approximately, 900 million hectares of soil are affected by salinity which includes both sodic and saline soils (OECD/FAO, 2012). Salt stress causes detrimental effects on crop yield by altering plant metabolism, including reduced water potential, ion imbalances and toxicity; sometimes leading to total crop failure. There are two types of salt affected soils namely, sodic and saline soils (Sharma et al., 2004). Sodic soils are characterized by an excess of sodium ions on exchange sites and high concentrations of carbonate and bicarbonate anions. These are generally associated with high pH (8.2 up to 10.8). On the other hand, saline soils possess excessive sodium but with dominant anions of chloride and

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sulphate resulting in higher electrical conductivity (> 4 dS/m). Rice is one of the few crops that can thrive on salt-affected soils because of its ability to grow well in standing water that can help leach salts from topsoil and is, therefore, recommended as an entry crop for desalinization of salt affected lands (Tyagi, 1998; Singh et al., 2010). It has also been reported, however, that the capacity of the rice plant to survive harsh saline environments at the vegetative stage is not actually correlated with its reproductive-stage tolerance (Singh et al., 2010). Salinity has in fact independent effects at these two critical stages, that is, tolerance at the seedling stage is not necessarily associated with tolerance at the reproductive stage, and vice versa. The reproductive stage seems to be more relevant for grain yield because it is within this stage that fertilization and formation of the seed occurs. It has long been recognized that salinity can cause sterility in rice, particularly if imposed during pollen development and fertilization (Jenks et al., 2007); hence, high-yielding salt-tolerant rice varieties must possess reproductive-stage tolerance. However, in view of genotypic variation, there is an urgent need to develop varieties that can withstand initially high levels of salts besides maintaining optimum yield under moderate salinity. A high level of intra-specific variation in rice for tolerance to salt stress has been reported and harnessed in the form of development and dissemination of salt tolerant varieties in various countries including India (Singh et al., 2010).

Field screening under natural salinity and sodicity stresses is important for identifying tolerant germplasm. However, soil heterogeneity and inherent spatial variability for salt concentration under natural conditions often hamper the true expression of genotypes. To avoid this constraint, use of specially designed microplots/lysimeters which simulate natural conditions is very crucial for reliable screening. The present study perhaps for the first time endeavored to study the simultaneous performance of a representative set of rice genotypes under precisely controlled non-stress, saline and sodic conditions. Different kinds of tolerance indices have been employed by different workers. Five kinds of stress indices viz., stress tolerance index (STI), stress susceptibility index (SSI), stress tolerance (TOL), mean productivity (MP) and geometric mean productivity (GMP) were employed for judging the relative tolerance to sodicity as well as salinity. The stress tolerance index (STI) can be used as selection criterion which identifies genotypes with high yield and stress tolerance potentials (Fernandez, 1993). The STI considers yield capacity under non-stress as well as stress environments. The stress susceptibility index (SSI) relies on identifying only those genotypes which show minimum reduction under stress compared to non-stress (Fischer and Maurer, 1978). Thus, the SSI favors stress tolerant genotypes but with low yield potential and often fails to identify genotypes with both high yield and stress tolerance potentials. The stress tolerance (TOL) has been defined by Rosielle and Hamblin (1981) as the difference in yield between stress and irrigated environments and mean productivity (MP) as the average yield of genotypes under stress and non-stress conditions. The geometric mean productivity (GMP) is often used by breeders interested in relative performance, since salt stress can vary in severity across field environments (Ramirez and Kelly, 1998). The present study was planned and undertaken to know the effects of salinity as well as sodicity stress on grain yield and its component traits in a representative set of rice genotypes and to understand the association between different stress

Table 1
List of 34 rice genotypes and their pedigree/origin.

Sl. No.	Designation	Pedigree	Geographical location	Status of genotypes[a]
G1	BCW 56	Unknown	IIRR India	Parental line
G2	CSR 10	M40-431-24-114/Jaya	CSSRI India	STV
G3	CSR 13	CSR1/Bas. 370//CSR 5	CSSRI India	STV
G4	CSR 23	IR64//IR4630-22-2-5-1-3/IR9764-45-2-2	CSSRI India	STV
G5	CSR 27	NONA BOKRA/IR5657-33-2	CSSRI India	STV
G6	CSR 36	CSR13/Panvel 2//IR 36	CSSRI India	STV
G7	CSR-RIL-169	CSR 27/MI 48	CSSRI India	RIL
G8	CSR-RIL-170	CSR 27/MI 48	CSSRI India	RIL
G9	CSR-RIL-192	CSR 27/MI 48	CSSRI India	RIL
G10	CSR-RIL-197	CSR 27/MI 48	CSSRI India	RIL
G11	CSR-RIL-50	CSR 27/MI 48	CSSRI India	RIL
G12	CSR-RIL-75	CSR 27/MI 48	CSSRI India	RIL
G13	HKR 120	PTB-33/4/IR-3403-267-1	HAU India	HVY
G14	HKR 127	PAU 21-93-1/HKR 120	HAU India	HVY
G15	HKR 46	Released variety from Kaul	HAU India	HVY
G16	HKR 47	12193-1/HKR-120	HAU India	HVY
G17	IR60997-16-2-3-2-2R	IR50972-39-3-3/IR72	IRRI Philippines	Salt tolerant
G18	IR77674-3B-8-1-3-13-2-AJY2	IR 71730-51-2/NSIC RC 106	IRRI Philippines	Salt tolerant
G19	IR77674-3B-8-2-2-13-4-AJY2	IR 71730-51-2/NSIC RC 106	IRRI Philippines	Salt tolerant
G20	IR77674-3B-8-2-2-14-2-AJY3	IR 71730-51-2/NSIC RC 106	IRRI Philippines	Salt tolerant
G21	IR77674-3B-8-2-2-14-2-AJY4	IR 71730-51-2/NSIC RC 106	IRRI Philippines	Salt tolerant
G22	IR78806-B-B-16-1-2-2-AJY1	PSB RC 86/IR 64	IRRI Philippines	Salt tolerant
G23	MI 48	Pelita//H4//H501	India	Sensitive line
G24	NDR-359	BG-90-2-4/08677	NDUAT, India	HVY
G25	PAU 201	PR103/PAU1126	PAU India	HVY
G26	PR 113	IR8//RP2151-173-18/IR8*4	PAU India	HVY
G27	PR 114	TN1/Patong32//PR106*4///IR8	PAU India	HVY
G28	PR 115	RP2151-173-1-8/PR103*3	PAU India	HVY
G29	PR 116	PR108///TN1/Patong32//PR106*4///PR108	PAU India	HVY
G30	PR 118	Pusa44/PR110//Pusa44*3	PAU India	HVY
G31	PR 120	PAU 1196-14-2-5-1-3/SR817-255	PAU India	HVY
G32	Pusa 44	IARI-5901-2/IR8	IARI India	HVY
G33	TR-2000-008	TS29/ASD16	Tichy, India	HVY
G34	VSR 156	Sensitive check	VPKAS,India	Sensitive line

IRRI—International Rice Research Institute, IIRR—Indian Institute of Rice Research, CSSRI—Central Soil Salinity Research Institute, TNAU—Tamil Nadu Agricultural University, NDUAT—Narendra Dev University of Agriculture & Technology, PAU—Punjab Agricultural University, IARI—Indian Agricultural Research Institute, HAU—Haryana Agricultural University, VPKAS—Vivekananda Parvatiya Krishi Anusandhan Sansthan.

[a] STV: Salt tolerant variety, RIL: Recombinant inbred line, HYV: High yielding variety.

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