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Evaluation of genotypes of rice (*Oryza sativa* L.) for their seedling stage tolerance to costal salinity

Shubhangi Maraskole, SV Sawardekar, AK Singh, BD Waghmode, AV Mane and MC Kasture

Abstract
An experiment was conducted in collaboration with the school of water stress management, ICAR-NIASM, Malegaon, Baramati during 2021-2022 to evaluate the rice (*Oryza sativa* L.) genotypes. 20 rice genotypes were collected from R.A.R.S., Karjat and K.L.R.S., Panvel, including checks. Plants were treated with salt had electrical conductivity of 6 dSm^{-1} and 9 dSm^{-1}, respectively, with control (3 dSm^{-1}) (Coastal saline soil with no additional salts) during seedling stage. On the basis of visual salt injury symptoms, SES (Standard evaluation score) and STI (Salt tolerance index) were estimated at 6 dSm^{-1} and 9 dSm^{-1}. Among 20 rice genotypes, based on visual salt injury symptoms, SR 3-9, Kala rata, CST 7-1, Damodar, CSR 36, Panvel 1 and Panvel 3 scored 1, suggesting a high degree of tolerance at 6 dSm^{-1} and genotypes SR 3-9, Kala rata and CST 7-1 observed a highly tolerance at 9 dSm^{-1}. However, among the 20 genotypes, the maximum value of salt tolerance index was observed in Kala rata followed by CST 7-1, SR 3-9 and Damodar at both 6 dSm^{-1} and 9 dSm^{-1} as compared to check as popular cultivars such as FL478 and Karjat 4. This work reveals the potential of rice genotypes to resist coastal salinity up to 9 dSm^{-1}. The genotypes showed the best performance under saline conditions and can help to identify relevant genes essential to develop salt-tolerant varieties.

Keywords: Rice, genotypes, salt, salinity, tolerance

Introduction
Oryza sativa L. (2n=24), known as rice, a self-pollinated plant and a model species for monocots and cereals belonging to the family Gramineae or Poaceae, which has 22 wild species and just two cultivated varieties (Vaughan *et al.*, 2003) [28]. Rice is grown throughout in humid tropical and subtropical climates (Blair *et al.*, 2002) [7]. India ranks second in rice production, followed by China. In India, rice occupied 45.76 million hectares area with an annual production of 124.36 MT, and 2.72 tons/ha productivity (Anonymous, 2021) [4]. Konkan has a rice-dominating area of about 0.387 million ha with annual production of 1.031 MT, and the average productivity of the Konkan is about 2.66 t/ha milled rice (Anonymous, 2021) [5].

In India, about 6.73 million hectares of land affected by salinity, and by 2050, that number is anticipated to rise to 16.2 million hectares (CSSRI Vision-2050, 2019; Singh, 2018) [9, 26]. More than 127000 ha of saline soil have been found in Maharashtra state. Out of these, 70,000-hectare land is classified as coastal salinity and 57000 ha land is classified as inland salinity. The coastal saline soils are fertile, but their productivity is limited due to the inundation of tidal brackish water and submergence during the rainy season (Sawardekar *et al.*, 2003) [24].

Natural disasters caused by climate change, biotic and abiotic stresses represent a severe problem to the world's 60 per cent population's food security and economic development. Singh *et al.*, in 2004 [27] estimated that the ultimatum for rice in 2025 will be 140 MT. Contrarily, the abiotic stress of soil salinity is the subject of this study since it contributes significantly to the decline in global rice output. Nevertheless, many Asian countries, where rice nursery frequently have to establish in soils already tainted with salt, consider the increase of salt tolerance as a breeding priority.

It may be necessary to test genotypes for salt tolerance when plant are at seedlings stage because there is a significant time savings (Ali *et al.*, 2014) [2] and help to develop salt tolerant with high-yielding cultivars. This study looked into the screening salinity tolerance of rice based on visual salt injury symptoms. This work reveals the potential of genotypes to resist salinity up to 9 dSm^{-1}, respectively.

Materials and Methods

Plant growth environment and plant materials

The experiment was conducted with 20 rice genotypes collected from the R.A.R.S., Karjat and K. L. R. S., Panvel of the coastal area, including checks as well-known salt-tolerant and salt-sensitive varieties undertaken in collaboration with the ICAR-NIASM, Malegaon, Baramati, 413115 during 2021-2022. The soil used in the experiment was coastal saline soil from the Konkan coast (Panvel). For the establishment of seedlings, pre-germinated seeds were sowed to plastic pots with normal soil medium for the seedling establishment for 15 days outside a greenhouse in open-air (natural) conditions. Only three uniform seedlings were transferred and kept in each pot containing 3.5 kg coastal saline soil from the Konkan coastal area with EC 3 dSm^{-1} as a growth media. Plants were treated by salt stress had electrical conductivity of 6 and 9 dS/m, with control (C) (Coastal saline soil with no additional salts) 21 days after emergence. Experimental design set up with saline and without saline conditions in a Factorial Completely Randomized Design (FCRD) in 3 replication.

Methods

Standard Evaluation Score (SES)

According to conventional IRRI (Gregorio *et al*., 1997) [31] system shown in Table 1, the modified standard evaluation score (SES) was recorded each day from 3-6 DAT.

Table 1: Modified Standard Evaluation Score (SES)

Score	Observations	Tolerance levels
1	Normal growth, no leaf symptoms	HT
3	Nearly normal growth, but leaf tips of few leaves whitish and rolled.	T
5	Growth severely retarded, most leaves rolled, only a few are elongating.	MT
7	Complete cessation of growth, most leaves dry some plants dying	S
9	Almost all plants dead or dying	HS

[HT- Highly tolerant, T- Tolerant, MT- Moderately tolerant, S- Susceptible, HS- Highly Susceptible]

Salt Tolerance Index (STI)

At the end of experiment, the dry weight of plant samples' was recorded to estimate the salt tolerance index (%).
The given standard formula calculates it:

STI (%) = 100 × (Total D.W. Salt stress /Total D.W. control) (Ashraf *et al*., 2006) [6],
[Where, DW-Dry weight]

Results

Standard Evaluation Score (SES)

Visual symptoms across all the genotypes showed differential salt tolerance and sensitivity when subjected to 6 dSm^{-1} and 9 dSm^{-1} of salt stress for eight days at the seedling stage. The genotypes showed morphological variations after 2 days of stress implication. By allocating SES 8 DAS imposition to each genotype, the tolerance level of the genotypes was calculated based on the evident salt-induced damage (Fig. 1).

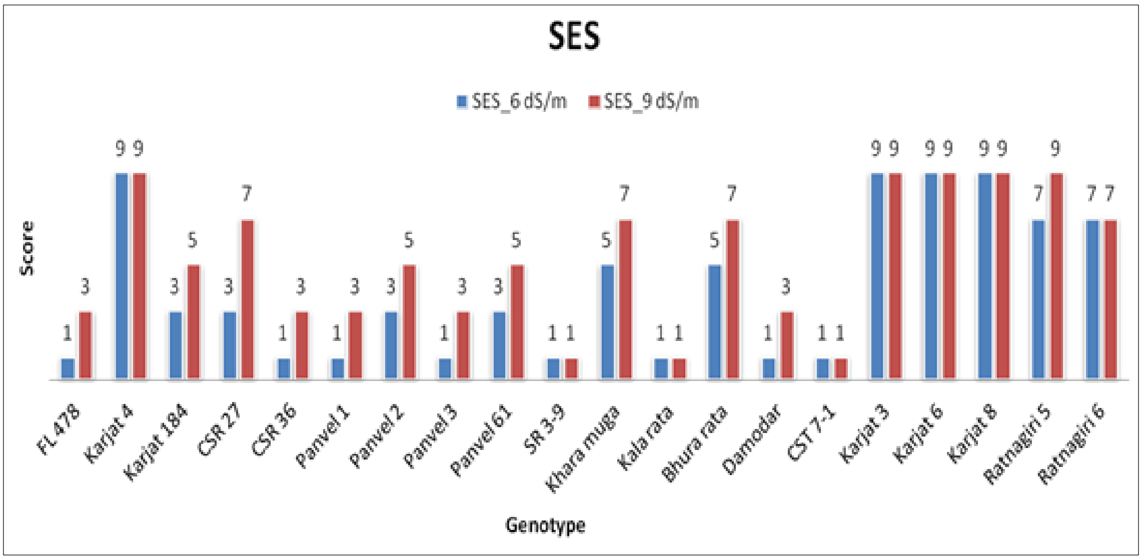

Fig 1: Effect of salt stress on standard evaluation score (SES) of rice genotypes

After imposition of salt of 6 dSm^{-1}, SR 3-9, Kala rata, CST 7-1, Damodar, CSR 36, Panvel 1 and Panvel 3 scored 1, indicates high degree of tolerance in these genotypes. In contrast, Karjat 3, Karjat 4, Karjat 6 and Karjat 8 was highly susceptible genotype which scored 9 and Karjat 184, CSR 27, Panvel 2 and Panvel 61 had scored 3, referring a tolerance in these genotypes, Khara muga and Bhura rata had a score of 5, intimating a moderately tolerant genotype and Ratnagiri 6 and Ratnagiri 5 had scored 7, hinting a susceptible genotype (Fig. 1).

Similarly, after imposition of salt stress of 9 dSm^{-1}, SR 3-9, Kala rata and CST 7-1 score 1, implies a highly tolerance, whereas Karjat 3, Karjat 4, Karjat 6, Karjat 8 and Ratnagiri 5 was highly susceptible with a score of 9 and Damodar, CSR 36, Panvel 1 and Panvel 3 scored 3, inferring a tolerant in these genotypes, Karjat 184, Panvel 2 and Panvel 61 had scored 5, indicating a moderately tolerant genotype and CSR 27, Khara muga, Bhura rata and Ratnagiri 6 scored 7, insinuating a susceptible genotype (Fig. 1).

Salt Tolerance Index (STI) (%)

Salt tolerance index (STI) differed significantly among the genotypes under salt stress. At 6 dSm^{-1}, the Maximum salt tolerance index was notice in Kala rata (94.08%), followed by CST 7-1, SR 3-9, and Damodar having values 88.78%, 83.41% and 77.59%, however; these genotypes were significantly superior over salt tolerant check FL 478 (69.10%). The minimum value for the salt tolerance index was observed in Karjat 6 (44.27%) (Fig. 2).

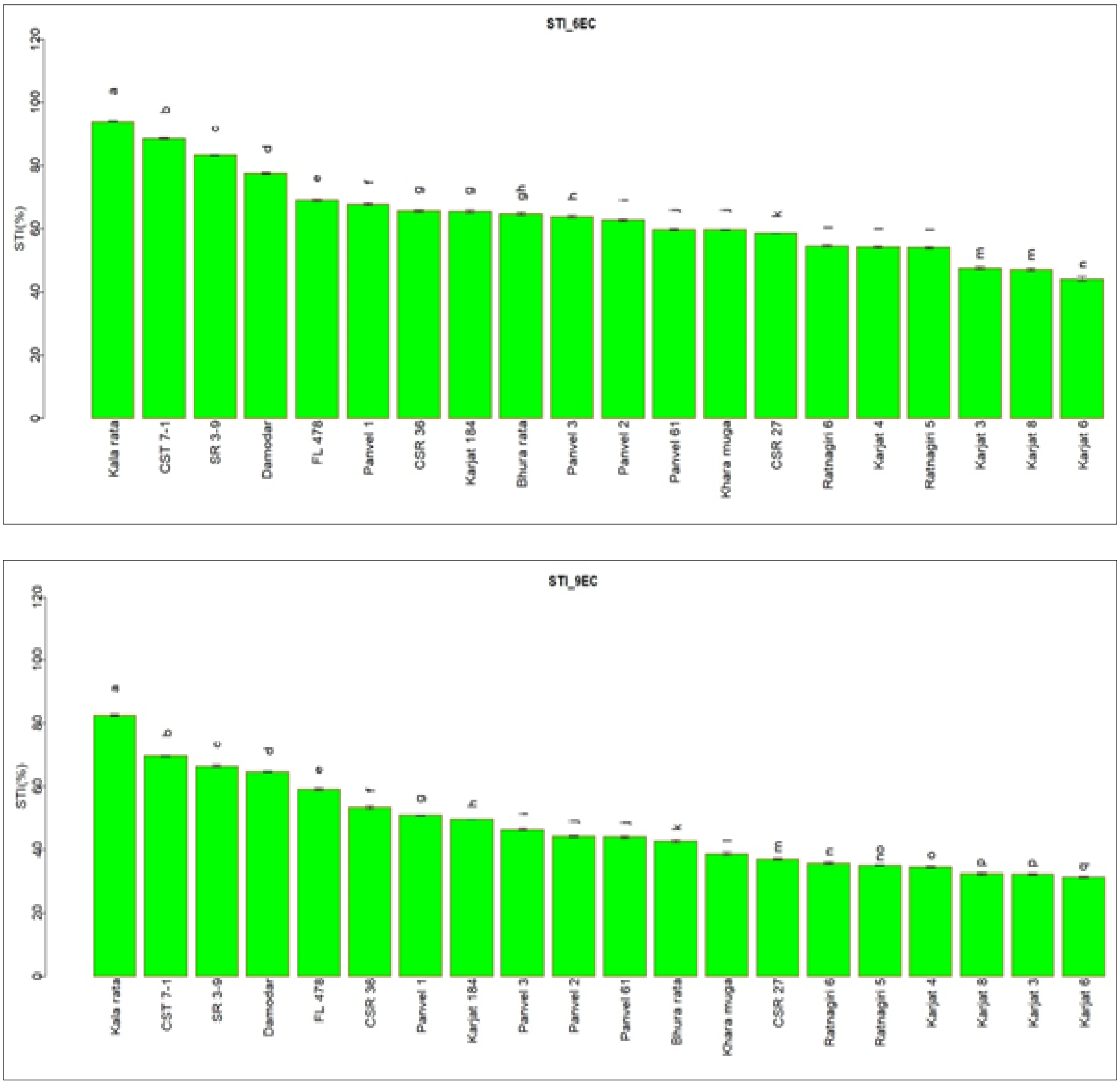

Fig 2: Effect of salt stress on salt tolerance index (STI) (%) of rice genotypes

Similarly, at 9 dSm^{-1} salt tolerance index (STI) also varied significantly among the genotypes. However, the highest salt tolerance index was noted in Kala rata (82.67%), followed by CST 7-1, SR 3-9 and Damodar having values of 69.79%, 66.56% and 64.70%; however, these genotypes were significantly superior over salt tolerant check FL 478 (59.30%). However, Karjat 6 (31.38%) had a minimum salt tolerance index (Fig. 2).

Discussion

Standard Evaluation Score (SES)

The modified standard evaluating score of the salt injury method developed by IRRI (Gregorio *et al*. 1997) [31] was used in present study for screening 20 rice genotypes, including two check cultivars for comparison at the seedling stage, revealing differences in salinity tolerance at two different treatments. Genotypes were tested to salinity at the seedling stage. However, at 6 dSm^{-1}, eight genotypes showed high tolerance; four were tolerant, two were moderately tolerant, two were susceptible, and four were very sensitive. At 9 dSm^{-1}, three genotypes showed high tolerance; five were tolerant, three showed moderately-tolerant, four were susceptible, and five were very sensitive. Same results were studied in rice by Islam and Karim (2010) [12]; Kanawapee *et al*. (2012) [14]; Pani *et al*. (2013) [19]; Rubel *et al*. (2014) [21]; Chunthaburee *et al*. (2016) [8]; Aliyu *et al*. (2016) [3]; Safitria *et al*. (2017) [22]; Samaco *et al*. (2018) [23]; Yichie *et al*. (2018) [30]; Aala Jr. and Gregorio (2019) [1]. Sensitivity to salinity was clearly observed from the damage to plants. The approximation of a standardized evaluating score in screening cultivars also shown previously by Sexcion *et al*. (2009) [25]. Islam *et al*. (2007) [13] also noted variation during screening from tolerant to highly susceptible lines using modified SES of standard IRRI protocol.

Salt Tolerance Index (STI) (%)

These STI figures imply vast difference in salt tolerance of rice genotypes. The STI reported for potential yield under non-stress environments and yield under-stress territories. The STI found to be effective selection indices in the present research work. Our result stated that the salt tolerance index decreased with increased salt stress imposition. Similar results were obtained by Islam and Karim (2010) [12]; Vibhuti *et al*. (2015) [29]; Krishnamurthy *et al*. (2016) [17]; Kargbo *et al*. (2019) [15]; Rasel *et al*. (2021) [20] in rice and also reported by Goudarzi and Pakniyat (2008) [10], Khatun *et al*. (2013) [16] in wheat. Salt tolerance index parameter has used to identify genotypes and substantial ability to withstand salinity (Munns and James 2003) [18]. The perception of the STI examine indigenous landraces at the morpho-biochemical basis (Ali *et al*., 2014) [2], indicating the value of landraces as probable sources for de-novo genes inferring tolerance to them as being observed in the study.

Conclusion

Understanding this mechanisms of salt tolerance and their assessment is much more well defined by screening the genotypes with different salinity levels at the seedling stage's morphological (SES, STI) basis, as undertaken in the present research. Based on visual salt injury symptoms, among 20 rice genotypes SR 3-9, Kala rata, CST 7-1, Damodar, CSR 36, Panvel 1 and Panvel 3 scored 1, indicating a high degree of tolerance at 6 dSm^{-1} and genotypes SR 3-9, Kala rata and CST 7-1 got a score of 1, referring a high tolerance at 9 dSm^{-1}. However, among the 20 genotypes, at 6 dSm^{-1}, the maximum value of salt tolerance index was noted in Kala rata, followed by CST 7-1, SR 3-9, and Damodar and at 9 dSm^{-1}, the maximum salt tolerance index (STI) value was noted in Kala rata followed by CST 7-1, SR 3-9 and Damodar. This work reveals the potential of rice genotypes to resist coastal salinity up to 9 dSm^{-1}. This can help to identify relevant genes essential to develop salt-tolerant varieties.

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