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Significance of standard evaluation score to assess salinity tolerance in rice

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Abstract
Soil salinity is one of the major abiotic stress that has hampered global rice production. In such instances, the identification and improvement of salt-tolerant rice varieties is a prerequisite. Conventional phenotyping of rice still has equal importance in the modern mechanized era, and the standard evaluation system is one of them. Two rice genotypes from the Konkan region, Panvel-1 (salt-tolerant) and Karjat-4 (salt-sensitive) were grown under controlled conditions in coastal saline soil with an EC of 3 dS/m. Additional NaCl was added to achieve 6 and 9 dS/m. The aim of the study was to apply a standard evaluation system for the determination of salt injuries in rice at the reproductive stage. Simultaneously the survival percentage of the plant was also noted. The results revealed that the application of salt stress has a severer impact on the survival % of the plants and had the maximum salt injury score. Between the two genotypes, Panvel-1 was less affected and had the minimum salt injury score than Karjat-4. Through this investigation, it validated that the standard evaluation system is one of the important parameters that can be employed to identify salt tolerance levels in different genotypes.

Keywords: Rice, coastal salinity, salt injury score, survival %, phenotyping

1. Introduction
Over one-third of the world's population depends on rice (*Oryza sativa*), a crop that is produced and consumed to a large extent throughout Asia (www.indiastat.com). Salinity is one type of abiotic stress that affects over 6% of the world's agricultural land, or nearly 1 billion ha (Kakar *et al*., 2019) [2]. Most of the fertile land in the coastal region and along inland saline tracks becomes barren as a result of salt deposition. The best strategy to deal with an unproductive environment will be to adapt crops to salt stress, although improving screening and phenotyping techniques is vital. Salt stress impairs plant development, photosynthetic capacity, and partial sterility, which drastically reduces biomass and production (Pardo, 2010; Todaka *et al*., 2012) [4, 8] and, in certain situations, even results in plant death.
The fundamental strategies used by crop plants to overcome salt stress involve the adaptation of diverse physiological, biochemical, and molecular systems to exclude excess Na+ ions. To better understand the physiological changes that occur throughout the development of rice varieties grown on salt-affected coastal soils, evaluation, and comparison of the growth and physiological features of rice genotypes are thought to be relevant. The goal of the current study was to determine how two well-known Konkan rice varieties with different salt tolerance levels would respond to using a standard evaluation system during panicle initiation under salinity stress. The data collected might be used to compare the field performance of different rice genotypes and identify physiological traits that could be used as valid criteria for the breeding and selection of salt-tolerant rice.

2. Material and Methods
The present investigation was conducted at ICAR – National Institute of Abiotic Stress Management, Malegaon. For the pot experiment, two rice genotypes Panvel-1 (Salt-Tolerant) and Karjat-4 (Salt-Intolerant) were grown in coastal saline soil. The experiment was conducted in a controlled environment in a factorial randomized block design (Factor A-Genotypes and Factor B-Salinity treatments) with four replications.

2.1 Imposition of salt stress
For the experiments, three salt concentrations-3 dS/m (Actual EC of soil, without salt stress), 6 dS/m (moderate), and 9 dS/m (high) were employed. Salt stress was applied by watering pure

NaCl into the soil at the panicle initiation stage. Control plants were also maintained at 3 dS/m for comparison (in the absence of NaCl application).

2.2 Standard Evaluation Score
Plants were scored for visual salt injury score (SIS) of 1–9 based on a modified standard evaluation score (SES) (Table 1) given by Gregorio *et al*. (1997) [1].

Table 1: Standard Evaluation Score

Score	Observation	Tolerance
1	Normal growth, no leaf symptoms	Very tolerant
3	Nearly normal growth, but leaf tips or few leaves whitish and rolled	Tolerant
5	Growth severely retarded; most leaves rolled; 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	Very susceptible

2.3 Survival percentage
The survival percentage was calculated at the end of the experiment as the number of survived plants over the total number of treated plants per pot.

2.4 Statistical analysis
Statistical analysis of the data obtained during the course of the investigation was carried out by using the standard statistical analysis method of analysis of variance by Panse and Sukhatme 1987 [3].

3. Results
3.1 Salt injury score
After 20 days, salt tolerance in the plants was evaluated by phenotyping according to the standard evaluation system. At varying salt concentrations, a considerable difference in the scoring for salt stress injury was seen (Fig. 1). With a score of 2.5, the distribution of salt injury scores was normal under control conditions. The salt injury score was 5 at moderate salt stress. While high salt stress showed a mean score of 7.4 and represented the highest frequency among treatments.

Both genotypes scored significantly different salt stress injuries. Karjat-4 (6.40) had the highest score, followed by Panvel-1 (3.53).

No significant interaction was observed between salt stress and genotypes for salt injury score.

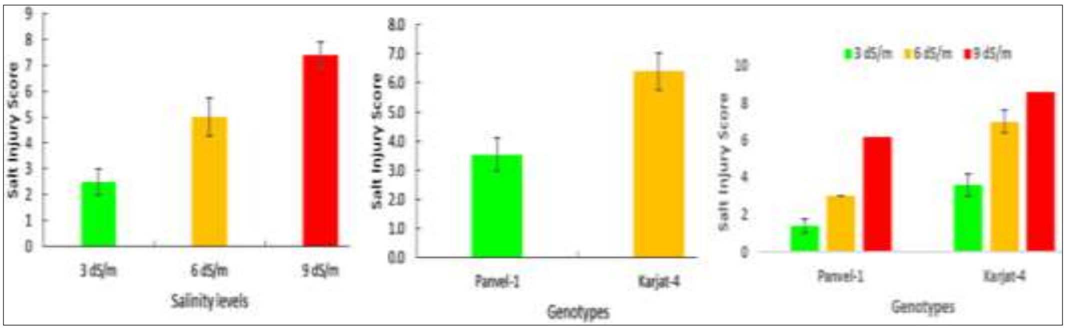

Fig 1: Salt injury score of rice genotype under salt stress

3.2 Survival percentage
The survival percentage was recorded at the end of the experiment. The plant survival at the panicle initiation stage significantly varied from 4 to 100% depending on the exposure to salinity stress (Fig. 2). Under control conditions little or no effect of saline soil (3 dS/m) was found on plant survival. At moderate stress of salt, 90% of plants survived with some salinity symptoms. The impact was greater when plants experienced high salt stress. The survival percentage was merely 4% in 9 dS/m.

A significant variation was obtained in the percentage of survival of the two genotypes. The maximum number of plants of Panvel-1 survived (69.3%) followed by Karjat-4 (60%).

There was a significant interaction effect observed between salt stress and genotypes on the survival percentage of plants. Panvel-1 showed 100% survival at the control and moderate stress, whereas it survived poorly at 9 dS/m (8%). Without salt treatment, Karjat-4 maintained its survival rate but at 6 dS/m it dropped to 88%, and at high salt stress, not a single plant was able to survive.

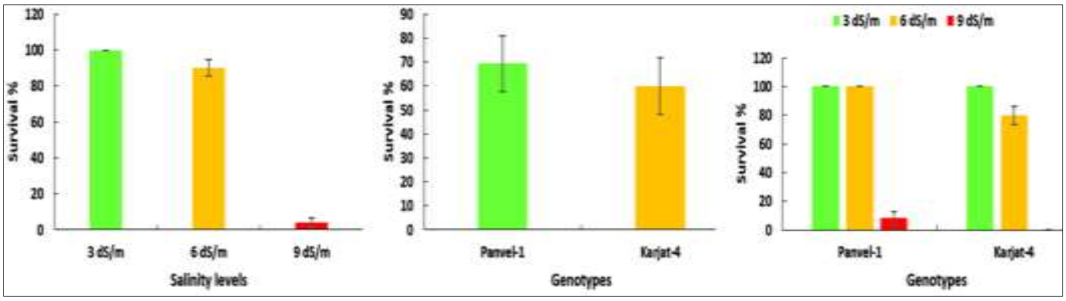

Fig 2: Survival percentage of rice genotype under salt stress

4. Discussion

Several symptoms of salt injury like yellowing of leaves, rolling and tip whitening, drying of leaves, and reduction of shoot growth and stem thickness, and in some cases, death of plants were detected within 6-7 days of salt stress at 3, 6, and 9 dS/m. The initial sign was a reduction in the shoot (leaf) area, prior to all the others. Salinity suppresses the growth of leaves in the plants and eventually completes the cessation of growth and premature senescence of leaves. Overall, the plant growth was suppressed under salinity stress, with a maximum score of 9 at high salt stress and with minimum survival %. On the other hand, all plants in the control condition survived with normal growth over the salinized condition having a score of 1.

Salt-tolerant genotype was distinguished from the sensitive one when grown in salinized conditions. The salt-tolerant Panvel-1 showed minor symptoms of salt injury than Karjat-4. However, Karjat-4 has some minor symptoms of salt stress, like leaf yellowing and tip burning even at 3 dS/m during the panicle initiation. Many studies have been carried out where salt injury score and survival percentage were used as the metric to scrutinize the genotypic responses under salt stress (Thu *et al*., 2017; Prusty *et al*., 2018; Site *et al*., 2021) [7, 5, 6]

5. Conclusion

Salt stress exhibited the injury symptoms on plants which led to maximum scoring than the control, however, the tolerant genotype (Panvel-1) had a minimum salt injury score than the sensitive Karjat-4. During high salt stress, the injury score was maximum; in contrast, the survival % was dropped in salt stress condition and Karjat-4 had more loss. The study concluded that a standard evaluation system that has been given for the determination of salt stress injuries is a significant parameter of salt stress phenotyping. Furthermore, survival % has evidenced the effect of salt stress on rice genotypes. SIS validated that Panvel-1 is the salt-tolerant rice cultivar however Karjat-4 is salt sensitive.

6. Abbreviations

DAT- Days after treatment, EC- Electrical conductivity, SIS- salt injury score

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