16-18 February 2026

9th National and 1st International Conference of Plant Physiology

University of Guilan, Rasht, Guilan, Iran

Evaluation of Rice Genotypes (*Oryza sativa* L.) for Salinity Tolerance Using Stress Tolerance Indices

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Abstract

Salinity is one of the most important constraints limiting rice growth and yield, and the selection of salt-tolerant genotypes is essential for cultivation in saline regions. In this study, 83 rice lines along with four check cultivars (two salt-tolerant and two salt-sensitive) were grown under normal and saline conditions in Guilan province. The experiment was conducted as a randomized complete block design with three replications in 2024, and the yield of genotypes in each environment were evaluated. Salinity tolerance indices including Stress Tolerance Index (STI), Geometric Mean Productivity (GMP), Harmonic Mean (HM), Stress Susceptibility Index (SSI), Tolerance (TOL), and Mean Productivity (MP) were calculated to assess the ability of the lines to maintain yield under salinity stress. Data analysis showed that STI, GMP, and HM were highly correlated with each other and can be considered effective criteria for identifying salt-tolerant genotypes. Evaluation of superior lines revealed that genotypes 72 and 8 exhibited both the lowest percentage of yield reduction and the highest values of STI, GMP, and HM, making them the best candidates for breeding programs and cultivation in saline areas. The results emphasize that the simultaneous use of multiple tolerance indices along with yield reduction percentage is an appropriate approach for screening salt-tolerant genotypes and can be effectively applied in rice breeding programs.

Introduction

Salinity is one of the most important environmental stresses in agriculture, particularly in rice production, which can significantly reduce both yield and crop quality. Considering the increasing area of saline soils in Iran and many other countries worldwide, the identification and utilization of salt-tolerant genotypes is essential as a sustainable and economical strategy to maintain agricultural production (Sackey *et al.*, 2025; Zarbafi *et al.*, 2025).

One effective strategy to combat salinity is the selection and introduction of tolerant genotypes through yield evaluation under stress conditions and the use of stress tolerance indices. These indices enable researchers to identify genotypes capable of maintaining satisfactory performance under saline conditions and provide more precise criteria for breeding programs (Bleih *et al.*, 2022).

Despite the importance of these indices, few studies in Iran have simultaneously examined multiple salinity tolerance indices in rice experimental lines. Therefore, there is a need for a comprehensive evaluation of experimental lines using various indices and a comparison of their yield under both normal and saline conditions. This study aimed to evaluate 83 rice experimental lines along with four control varieties under normal and saline environments and to identify tolerant lines using salinity tolerance indices. The results of this study can assist in the selection of resistant genotypes, guide breeding programs in saline areas, and provide insights for improving rice yield under adverse conditions.

Materials and methods

This study included 83 rice experimental lines along with four control varieties (comprising two salt-sensitive and two salt-tolerant varieties), which were evaluated across three environments: one normal environment (Rasht) and two saline environments (Chaf and Talesh) in Guilan province. The experiment was conducted as a randomized complete block design with three replications in each environment, and agronomic management was carried out according to standard rice cultivation practices. Grain yield for each genotype was measured under both normal and saline conditions, and the percentage of yield reduction for each genotype was calculated.

Salinity tolerance indices, including SSI, TOL, MP, GMP, STI, and HM, were calculated for each genotype based on grain yield under normal and saline environments. The correlations between tolerance indices were calculated using Pearson's method, and heatmaps were generated to illustrate variations in yield reduction percentage and the relationships among the indices. Salt-tolerant genotypes were selected based on low yield reduction and high values of STI, GMP, and HM indices. Data analysis, heatmap visualization, and calculation of the correlation matrix among the indices were conducted using R version 4.3.2.

Results and discussion

Evaluation of the percentage of yield reduction under saline conditions revealed that the studied lines exhibited different responses to salinity stress (Figure 1). Some genotypes showed minimal yield reduction, whereas others experienced substantial decreases in yield. These differences reflect variability in the ability of genotypes to maintain yield under saline conditions and highlight the importance of using stress tolerance indices to identify superior genotypes.

Pearson correlation analysis among salinity tolerance indices revealed that STI, GMP, MP, and HM were highly and positively correlated with each other (r = 0.98–0.99), indicating that these indices provide similar information regarding the tolerance capacity of genotypes under salinity stress (Figure 2). This finding suggests that these four indices can be used synergistically for the identification of salt-tolerant genotypes. In contrast, SSI and TOL showed a strong positive correlation with each other (r = 0.91) but exhibited negative correlations with STI, GMP, MP, and HM. This pattern indicates that SSI and TOL primarily reflect genotype sensitivity to salinity stress rather than true tolerance, meaning that genotypes with higher yield reduction rates (more sensitive) display higher SSI and TOL values, whereas more tolerant genotypes show higher values for STI, GMP, MP, and HM. These results are consistent with findings reported in recent studies on the application of multiple indices for evaluating tolerance to environmental stresses (Sai Prasanna *et al.*, 2025; Mubushar *et al.*, 2022).

Figure 1- Heatmap of yield reduction percentage of 87 rice genotypes in two saline environments relative to the normal environment.

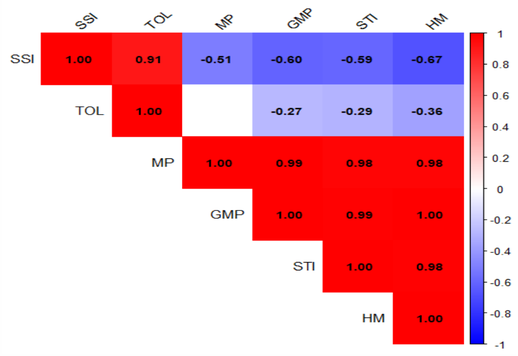

Figure 2- Heatmap of Pearson correlation coefficients among salinity tolerance indices in 87 rice genotypes.

Evaluation of the experimental lines showed that genotype 5 had the lowest percentage of yield reduction, while genotype 65 exhibited the highest values for STI, GMP, and HM indices. These findings indicate that selecting salt-tolerant genotypes based solely on a single numerical index or yield reduction percentage may not be sufficient. Further examination of the top 10 genotypes revealed that genotypes 72 and 8 simultaneously showed the lowest yield reduction and the highest values of STI, GMP, and HM, making them superior candidates for identifying salt-tolerant genotypes. Genotypes that maintain high yield performance while also exhibiting high tolerance index values represent reliable and resilient options for rice breeding programs in saline regions. Moreover, the observed differences among genotypes based on these two criteria are consistent with the correlation analysis, as STI, GMP, and HM showed strong intercorrelations and can be effectively used as complementary criteria for identifying salt-tolerant genotypes.

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