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Proceeding Paper

Phenotypic Evaluation of Recombinant Inbred Lines for Sodicity Tolerance at Reproductive Stage in Rice †

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Abstract: Salt stress is the most widespread soil problem in rice-growing countries, and it causes significant reductions in rice production worldwide. Identifying QTLs for sodicity tolerance at the reproductive stage is crucial to enhance the grain yield in sodic stress ecology. From this perspective, we developed recombinant inbred lines (RILs) from MTU 1001/Kalarata. A set of 176 recombinant inbred lines (RILs) was evaluated, along with the tolerant parent Kalarata and the sensitive parent MTU 1001, in a controlled microplot with a sodicity of pH ~ 9.5 at ICAR - Central Soil Salinity Research Institute (CSSRI), Karnal. The lines RIL34 (13.1 g/plant), RIL83 (12.7 g/plant), RIL40 (11 g/plant), RIL41 (10.2 g/plant), and RIL124 (10.1 g/plant) were top yielders. The yield-contributing traits, namely, plant height (cm), panicle length (cm), total tiller, productive tiller, biological weight (g/plant), and spikelet fertility (%), were highly affected in sodic stress conditions. The tolerant lines RIL34, RIL83, RIL40, RIL41, and RIL124 could be used for breeding programs and further studies to dissect the molecular and physiological mechanisms of reproductive stage sodic stress tolerance in rice.

Keywords: sodicity tolerance; RILs; rice; reproductive stage

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1. Introduction

Rice is a diploid (2n = 2x = 24) cereal crop, which serves as a primary staple food for more than 3.5 billion people in the world, and it is cultivated in more than 114 countries. In developing countries, an exploding population with urbanization and a decrease in cultivable lands are threatening food security. Therefore, achieving food security is of global concern. To meet the food demand, we must increase global rice production by at least 70% to feed the projected number of 9.6 billion people by 2050 [1]; however, at that time, India will have a population size of around 162 million, which will require about 136 mt of rice [2]. Recently, the agricultural sector has been facing various emerging problems of biotic and abiotic stresses. Abiotic stresses, such as drought, temperature, and salinity, seriously affect rice yield to a great extent. Among these, salt stress (both salinity and alkalinity) is the most predominant soil problem in rice-cultivating countries in the world, and it is a serious threat to increasing rice production worldwide [3]. Salt-affected soil has been reported in more than 100 countries, and it is estimated that, out of around one billion hectares of land worldwide, around 580 mha is facing the problem of alkalinity [4]. In India, the total salt-affected area has been estimated to be 6.73 million hectares, of which 2.97 million hectares is saline, whereas 3.77 million hectares is affected by alkaline soils. Rice is a salt-sensitive crop, and exposure to salt stress has serious negative effects on its vegetative growth and grain yield. The effects of salt stress on the morphological, physiological, and biochemical traits of rice have been reported. Salt stress has been found to significantly reduce grain yield by affecting tillering, spikelet filling, plant height, biomass production, and 1000 grain weight [5–7]. Therefore, the development of salt tolerance during the reproductive stage is the only option left for the efficient management of salt-affected soils. Alkalinity tolerance in rice is a complex trait that makes the screening of phenotypes under field conditions very difficult. Furthermore, to improve alkalinity tolerance in rice, it is very important to find sufficient genetic variation and to formulate suitable screening techniques that are reliable and able to identify alkaline-tolerant genotypes [8]. Grain yield is a complex trait, and it is influenced by various genetic and environmental factors. To improve grain yield, an evaluation of breeding lines is the most important step to select the superior genotype. From this perspective, the present investigation was carried out to evaluate an RIL population and to study the association between grain yield and important yield-contributing traits in rice under alkaline conditions.

2. Materials and Methods

A population of 176 recombinant inbred lines (RILs, F_7 generation) derived from a cross between MTU1001 (alkaline sensitive) and Kalarata (alkaline tolerant) was evaluated for alkalinity tolerance at the reproductive stage in alkaline soil microplots (6 × 3 m) at a facility at ICAR-CSSRI, Karnal. A complete set of the RIL population, along with parents, was raised in normal field conditions in a nursery with the recommended package of practices. Thirty-day-old seedlings were transplanted into alkaline microplots (pH ~ 9.5) in a randomized complete block design with two replications. Before transplanting plant material, pH2 of microplots was measured by dissolving one part of soil in two parts of distilled water. Each genotype was planted in a single row of 3.0 m length following a row x plant spacing of 20 × 15 cm. One month after transplanting, at the maximum tillering stage, alkaline stress was imposed by irrigating alkaline water created using sodium bicarbonate. Subsequently, the pH of the microplots was recorded weekly and maintained at around pH~9.5 throughout the cropping season up to maturity. Morphological data were recorded as per the standard evaluation system of rice [9]. The data were recorded from 5 randomly labeled plants from each RIL, parent, and check. Morphological characteristics were days to 50% flowering, salt injury score, plant height (cm), panicle length (cm), total tillers per plant, productive tiller per plant, spikelet fertility (%), 1000 grain weight (g), biomass/plant (g), grain yield/plant (g), and harvest index (%). The salt injury score was recorded based on visual symptoms following the IRRI-modified standard evaluation system (SES) for rice, with a score of "1" meaning highly tolerant and a score of "9" meaning highly sensitive [9]. The phenotypic data were used to estimate ANOVA, histograms, and correlations among yield-contributing traits. All the analyses and diagrammatic visualization of data were carried out using the variability package of R program.

3. Results and Discussion

Analysis of variance (ANOVA) was carried out for all morphological parameters, and it was found that the genotypic mean sum of square was highly significant, indicating variation within genotypes. There were prominent differences in the responses of rice plants to alkaline stress at the reproductive stage. The alkaline injury score was recorded after forty days of stress, and it was found that 67, 73, 30, and 12 genotypes exhibited tolerant, moderate tolerant, sensitive, and highly sensitive reactions with salt injury scores of 3, 5, 7, and 9, respectively, in response to stress (Figure 1). Sensitive RILs scoring 9 died without producing any grain yield. The classification was carried out based on their phenotypic performances in all measurements, including plant height, panicle length, tiller number, and biological surveys, of which the alkaline injury score and survivability were conclusive parameters. Grain yield per plant (g) was the trait most affected by alkalinity. The reductions in plant growth, and grain yield and its contributing traits that take place under alkaline stress occur through osmotic effects, which reduce a plant's ability to absorb water and cause reduced growth [10,11].

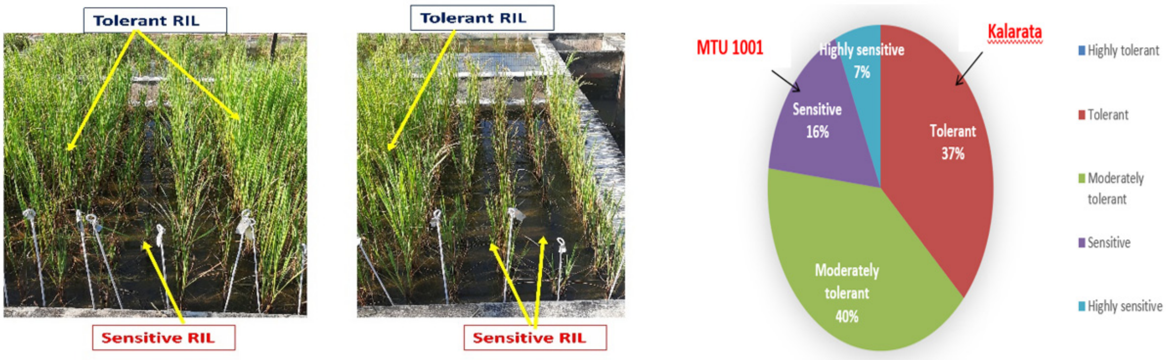

Figure 1. Response of RIL population in alkaline stress conditions.

At the reproductive stage, RIL 19 (145.5 cm) had the highest plant height, and the lowest value was found in RIL 165 (31.43 cm); the plant height ranged from 31.43 to 145.5 cm. The highest panicle length was recorded in RIL 32 (26.6 cm), while no panicle was produced by highly sensitive RILs. The total number of tillers was recorded to be the highest in RIL 170 (11) and the lowest in RIL 9 (2) however, the highest productive tillers per plant was observed in RIL 170 (10), and no productive tillers were found in RIL 132, RIL 162, RIL 163, RIL164, RIL 165, or RIL 169. The highest spikelet fertility (%) was observed in RIL 68 (95.57%), while the lowest spikelet fertility (%) was observed in RIL 161 (8.51). The maximum biomass per plant (g) was observed in RIL 57 (34.5 g), while the minimum biomass was observed in RIL 162 (3.33 g). The range of grain yield per plant (g/plant) was 0 in RILs with salt injury score 9 to 13.1 g for RIL 34 in alkaline stress. The lines RIL34 (13.1 g/plant), RIL83 (12.7 g/plant), RIL40 (11 g/plant), RIL41 (10.2 g/plant), and RIL124 (10.1 g/plant) showed the significantly highest grain yields amongst all the RILs evaluated in alkaline stress conditions. The top yielding recombinant inbred lines showed the highest biomass production, spikelet fertility, test weight, and productive tillers. The RILs recorded with the highest performance under sodic stress are the most likely to perform well in saline stress as reported by [7].

These results are in agreement with the findings of [10,12] in rice. Histograms of the distribution of frequency of the most affected traits, i.e., spikelet fertility (%) and grain yield per plant (g), are depicted in Figure 2.

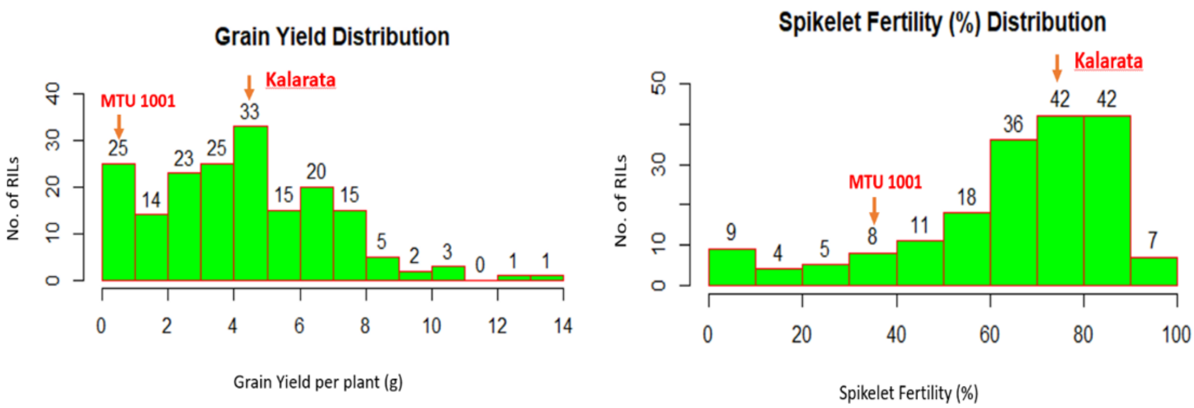

Figure 2. Histograms of distribution of RIL population for grain yield per plant (g) and spikelet fertility (%).

A positive correlation between two traits permits simultaneous improvement in both the traits while confining selection to any one of the associated traits [10]. Grain yield per plant showed a significant positive association with days to 50% flowering (0.24), plant height (0.73), panicle length (0.64), total tillers per plant (0.36), productive tillers per plant

(0.63), test weight (0.6), spikelet fertility (0.7), biological yield per plant (0.87), and harvest index (0.75), while it showed a significant negative correlation with the alkaline injury score (0.84) (Figure 3). Similar findings were previously reported by [10,13].

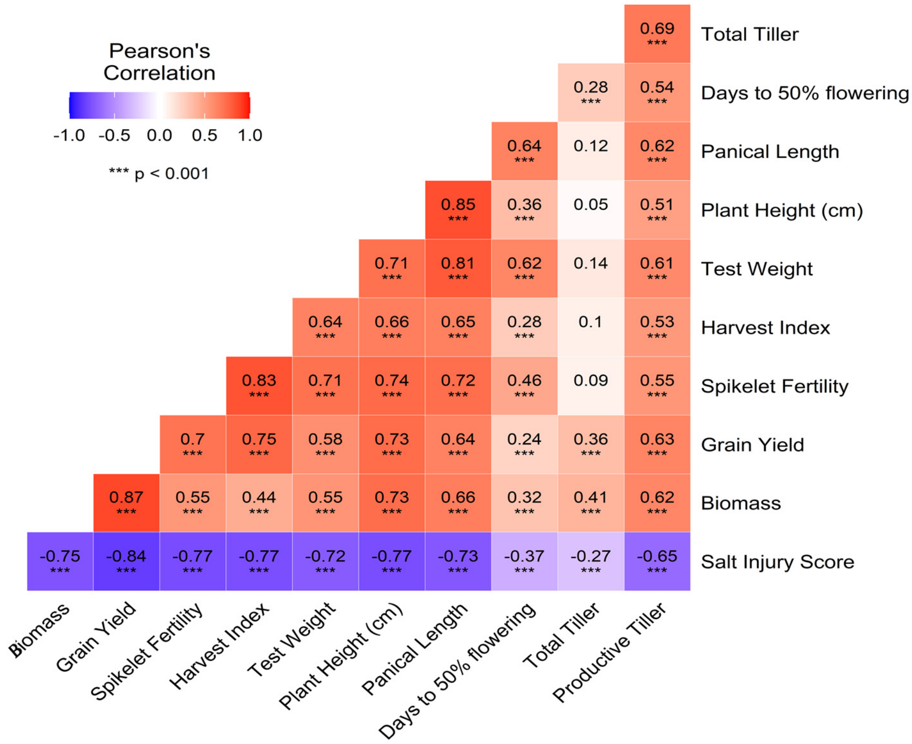

Figure 3. Correlations among morphological traits under alkaline conditions.

4. Conclusions

In this study, positive correlations were found between grain yield and its contributing traits, which may be useful as selection criteria for the improvement of grain yield in alkaline stress conditions. The tolerant lines RIL34, RIL83, RIL40, RIL41, and RIL124 could be used for breeding programs and further studies of the molecular and physiological mechanisms of sodic stress tolerance in rice at the reproductive stage. The findings of this study may help to simplify the breeding of salinity tolerance in rice in order to adapt to climate change.

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