Correlation studies in seedling and reproductive stage salinity tolerance in rice (Oryza sativa L.) under salinity

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DOI: https://doi.org/10.22271/chemi.2021.v9.i1ad.11538

Abstract
Salinity is a major abiotic stress limiting rice productivity worldwide. The present study had 234 F$_2$ population of a salt-tolerant donor Indra (MTU 1061) in the genetic background of Sri Druthi (MTU 1121) to elucidate the genetic basis of seedling and reproductive stage salinity tolerance. The F$_2$ population were evaluated under salt stress at seedling stage (EC 6 & 12 dSm$^{-1}$) and reproductive stage (EC 6 & 12 dSm$^{-1}$). At seedling stage, salt injury score had positive significant correlation with shoot Na$^+$ concentration and Na/K ratio while it was negative & significant with K$^+$ concentration, shoot length, root length and shoot dry weight. This indicated that homeostasis between Na$^+$ and K$^+$, plays a key role in the seedling stage tolerance to salt stress. In reproductive stage grain yield per plant play pivotal role for salinity tolerance comparative to remaining parameters such as number of spikelets, filled spikelets and unfilled spikelets. Results showed positive significant correlation of grain yield with days to flowering, number of total grains and productive tillers while it was negative significant with panicle length. The results of this study confirmed that salinity tolerance at the seedling and reproductive stages are independent to each other.

Keywords: Rice, salinity tolerance, seedling stage, reproductive stage, f$_2$ population, correlation

Introduction
Enormous environmental changes have brought negative impact on food crops in the world. Among these environmental factors, salinity is known to inhibit plant growth and ultimately cause crop yield loss. Salinity affecting approximately 1 billion ha of land globally. This equals more than 6% of the world’s total farming area and nearly 20% of the globally irrigated area (Kakar et al., 2019) $^{[8]}$. As the most important staple food in Asia, a significant portion of rice crops are grown along the coastal areas where rice paddy fields suffer various degrees of salinity (Naveed et al., 2018) $^{[15]}$.

In general, salinity imposes both osmotic and ionic stresses on plant. The gradient between the soil and root cells due to high salt content reduces the absorption capacity resulting in water deficit in the plant system. At the same time, the altered proportion of Na$^+$/$K^+$ and high Cl$^-$ concentration impedes the normal physiological activity of the plant. Further, high level of salinity can upset the nutrient balance in the plant or interfere with the uptake of some nutrients (Venkata Ramana Rao et al., 2018) $^{[19]}$.

Rice is tolerant during germination, becomes very sensitive during early seedling stage (2-3 leaf stage, when 2-3 leaves appeared), and it gains tolerance during vegetative growth stage, becomes sensitive during pollination and fertilization, and then becomes increasingly more tolerant at maturity (Mondal et al., 2016) $^{[13]}$. 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, suggesting that they are regulated by different processes and genes (Krishnamurthy et al., 2016) $^{[9]}$. Hence, pyramiding of contributing traits at both stages is needed for developing resilient salt-tolerant cultivars (Mohammadi et al., 2014) $^{[12]}$.

The overall goal of the present study was to screen 234 F$_2$ population to develop tolerance to salt stress at the seedling and reproductive stage using salt tolerant rice cultivar Indra (MTU
Results and Discussion

Correlation among different tolerance traits at Seedling Stage: The correlation coefficient matrix (Table 1) revealed salt injury score (SIS) had significant and positive association with shoot Na⁺ concentration (0.576**), NaK ratio (0.860**) while it had negative significant correlation with K⁺ concentration (-0.574**), shoot length (-0.670**), root length (-0.584**) and shoot dry weight (-0.598**). This results were in accordance with Venkata Ramana Rao et al. (2018) [19] who evaluated 112 ILs of Nona Bokra / Cheniere at the seedling stage. Positive and significant correlation was observed between shoot Na⁺ concentration and shoot K⁺ concentration (0.195**) and NaK ratio (0.634**) whereas it was negative and significant between shoot length (-0.425**), root length (-0.410**) and shoot dry weight (-0.309**). This results were in contrary with Batayeva et al. (2018) [2] who screened 27 accessions under salinity stress (EC @ 12 dSm⁻¹) at the seedling stage. The shoot K⁺ concentration showed positive association with shoot length (0.437**), root length (0.321**), shoot dry weight (0.389**) and negative significant correlation with NaK ratio (-0.601**). The results were in confirmation with Venkata Ramana Rao et al. (2017 & 2018) [18, 19] and Naveed et al. (2018) [15]. The correlation between Na⁺ and K⁺ in shoot confirms that the tolerance to salt stress is governed by the homeostasis between Na⁺ and K⁺ rather than the concentration perse. The NaK ratio
recorded negative and significant association with shoot length (-0.696**), root length (-0.586**), shoot dry weight (-0.546**). These results are in agreement with Teresa et al. (2015) [16] and Ahmadi et al. (2011) [11]. The association between shoot length and root length (0.704**), shoot length and shoot dry weight (0.657**) were positive and significant. Similar findings were reported by Venkata Ramana Rao et al. (2018) [19] and Bizimana et al. (2017) [1]. The root length was positively correlated with shoot dry weight (0.438**).

Table 1: Pearson Correlation of morph physiological traits in F_{2:3} lines under salt stress (EC = 12 dSm^{-1}) at seedling stage

| SIS | Na^{+} | K^{+} | NaK | SHL | RTL | DWT |
|-----|--------|-------|-----|-----|-----|-----|
| SIS | 1      |       |     |     |     |     |
| Na^{+} | 0.576** | 1     |     |     |     |     |
| K^{+} | -0.574** | 0.195** | 1   |     |     |     |
| NaK | 0.860** | 0.634** | -0.601** | 1 |     |     |
| SHL | -0.670** | -0.425** | 0.437** | -0.696** | 1 |     |
| RTL | -0.584** | -0.410** | 0.321** | -0.586** | 0.704** | 1 |
| DWT | -0.598** | -0.309** | 0.389** | -0.546** | 0.657** | 0.438** | 1 |

** Significant at 0.05 (two tail)

Correlation among different traits at Reproductive stage:
The Pearson correlation coefficients (Table 2) revealed that the plant height showed negative correlation with panicle length (-0.070) and productive tillers per plant (-0.022). Days to flowering had positive significant association with number of filled grains per panicle (0.414**), number of total grains per panicle (0.600**), spikelet fertility (0.486**), grain yield per plant (0.412**) and productive tillers per plant (0.593**) while it was negative significant with panicle length (-0.582**). Similarly Tiwari et al. (2016) [17] also reported the findings which are in accordance with present study. Panicle length recorded negative and significant association with number of total grains per panicle (-0.442**), spikelet fertility (-0.222**), grain yield per plant (-0.434**) and productive tillers per plant (-0.511**). These results were in contrary with the findings of Hakim et al. (2013) [5] who screened five rice varieties under different salinity levels at reproductive stage. The number of filled grains panicle^{-1} had significant and positive correlation with number of total grains per panicle (0.325**), spikelet fertility (0.412**) and productive tillers per plant (0.306**). The results were in confirmation with Hakim et al. (2013) [5], Hossen et al. (2017) [6] and Mondal et al. (2019) [14]. The number of total grains per panicle was positively correlation with spikelet fertility (0.622**), grain yield per plant (0.777**) and productive tillers per plant (0.832**). The findings are in conformity with the reports of Mohammadi et al. (2013) [11]. The spikelet fertility is positive and significantly associated with productive tillers plant^{-1} (0.478**). Similar findings were reported by Mondal et al. (2019) [14] who evaluated 92 F_{2} progenies of NSIC Rc222 / BRRI dhan 47 at reproductive stage under different salinity stress (EC @ 6, 8 &10 dSm^{-1}). The grain yield per plant had positive significant association with productive tillers per plant (0.692**). These results are in conformity with the findings of Mondal et al. (2019) [14], Krishnamurthy et al. (2016) [9] and contrary with Mansuri et al. (2012) [10].

Table 2: Pearson Correlation matrix of yield components of F_{2:3} population under salt stress (EC @ 12 dSm^{-1}) at the reproductive stage

| Plant height (PHT) | Days to flowering | Panicle length | Number of filled grains panicle^{-1} | Number of total grains panicle^{-1} | Spikelet fertility (%) | Grain yield/panicle (g) | Productive tillers plant^{-1} |
|-------------------|------------------|----------------|-------------------------------------|-------------------------------------|------------------------|-------------------------|-------------------------------|
| DFL               | 0.036            | 1              |                                     |                                     |                        |                         |                               |
| FNL               | -0.070           | -0.582**       | 1                                   |                                     |                        |                         |                               |
| NFG/Pn            | -0.009           | 0.414**        | -0.070                              |                                     | 1                      |                         |                               |
| NTG/Pn            | 0.030            | 0.606**        | -0.442**                            | 0.325**                             | 1                      |                         |                               |
| SPF (g)           | 0.002            | 0.486**        | -0.222**                            | 0.412**                             | 0.622**                | 1                      |                               |
| GY/PI (g)         | 0.054            | 0.417**        | -0.434**                            | 0.094                               | 0.777**                | 0.032                   | 1                            |
| PT/PI             | -0.022           | 0.593**        | -0.511**                            | 0.306**                             | 0.832**                | 0.478**                 | 0.692**                      |

**Correlation is significant at the 0.01 level (2-tailed).

Conclusion
We observed that at seedling stage, the F_{2:3} lines had high Na^{+} and high K^{+} concentration in the shoot suggesting that homeostasis between Na^{+} and K^{+} plays a key role in the seedling stage tolerance to salt stress. In reproductive stage grain yield per plant play pivotal role for salinity tolerance comparative to remaining parameters such as number of spikelets, filled spikelets and unfilled spikelets. It can be concluded from the study that tolerance at the seedling stage is not necessarily associated with tolerance at the reproductive stage and vice versa.

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