**Original Research Article**

**Selection Criteria and Genetic Variability Studies in Salinity Tolerant Rice Genotypes**

**ABSTRACT:** The analysis of variance revealed significant genotypic difference for all the traits studied indicating that a large amount of variability present in germplasm and there is a scope for selecting promising genotypes to develop salinity tolerant rice varieties. The values of genotypic and phenotypic coefficients of variation (GCV and PCV) were moderate for Total no. of tillers/plant, No. of effective tillers/plant and spikelet fertility (%), grain length (mm) and grain breadth; low for days to 50% flowering. Selection for these traits would offer better scope for genotypes A close difference between phenotypic and genotypic coefficient of variation revealed that there was a little influence of environment on the expression of the character studied. Selection for these traits would offer better scope for development of these traits. High heritability coupled with high genetic advance as percent of mean was observed for all the traits except for plant height and reproductive stage salinity stage scoring indicating the preponderance of additive type of gene action for the expression of this characters and selection may be effective for improving this character. The study of simple correlation in the present investigation suggested that selection of plants with more number of productive tillers per plant, panicle length, number of grains per panicle and test weight which had significant positive association with yield. Present study revealed that there was good amount of genetic variability in the traits number of effective tillers per plant, panicle length, grains/panicle and test weight, selection would be more effective for developing these traits.

 **Keywords:** Rice, GCV, PCV, Heritability, Genetic advance as percent of mean

**INTRODUCTION**

Abiotic stressors that impact plant metabolism and lower plant development and output include drought, floods, heat, oxidative stress, low temperatures, water scarcity, excessive salinity, and metal toxicity (Razzaque *et al*., 2017). Salinity is the second most destructive abiotic danger to rice production, behind drought, which affects around 1 billion hectares of land worldwide (Kakar *et al*., 2019). Worldwide, 50% of irrigated land and 20% of Earth's surface area are salinised (Malumpong *et al*., 2019). Over 90% of the world's rice is produced in Asia, specifically in South and Southeast Asia, which contains 21.5 million hectares of salt-affected land, of which 9.5 million are alkaline/sodic and 12 million are saline (Mohammadi *et al*., 2013). Sodic and saline soils are the two categories of salt-affected soils. High concentrations of carbonate and bicarbonate anions, as well as an excess of sodium ions on swap sites, are characteristics of sodic soils. High pH (8.2 to 10.8) is typically linked to these. Conversely, saline 1 soils have increased electrical conductivity (>4 dS/m) due to their dominant chloride and sulphate anions and abundant sodium (Ali *et al*., 2013). Coastal salinity and inland salinity, primarily sodicity, are concerning on the rise in irrigation commands among the many salinity situations. These factors include poor irrigation water with high salt levels, water table depletion, flooding from seawater, excessive use of chemical fertilizers, and inadequate drainage (Kakar *et al*., 2019).

Among cereal crops, rice is the most susceptible to salt, exhibiting a variety of responses at different phases of development. The reproductive stage is critical because it ultimately decides grain yield, yet numerous studies have shown that rice is resistant to salinity during the germination, tillering, and maturity stages but becomes extremely vulnerable during the seedling and reproductive stages (Zhang *et al*., 2020). However, because it affects crop establishment, the significance of the seedling stage cannot be overlooked (Mondal *et al*., 2019). Unfortunately, rice plants are susceptible to salt stress while they are seedlings, and high salt levels typically cause osmotic stress and ion toxicity in rice plants.

Particularly during the pollination and fertilization phases, the reproductive stage is extremely susceptible to salinity. Salinisation during the blooming stage has an impact on pollen germination and spikelet development, which eventually lowers the number of filled grains or panicles and raises the number of unfilled grains, which lowers spikelet fertility. Additionally, salinity decreases 1000 grain weight and panicle length, which lowers productivity (Sen *et al*., 2017). Grain yield is significantly reduced by salinity during the reproductive stage compared to the vegetative stage (Mondal *et al*., 2019).

**MATERIALS AND METHOD**

Reproductive stage salinity screening was conducted at Agricultural Research Station, Kampasagar. The 72 genotypes were screened for salinity tolerance as per protocol of Pani *et al.* (2013) with certain modifications. The scoring was given below as per SES of IRRI (1997).The experimental design adopted was Alpha lattice design. The crop was raised under irrigated conditions during *kharif* 2023-2024. Nursery was raised in normal condition and all recommended package of practices were adopted to raise a healthy nursery. The twenty five days old seedlings were transplanted in the main field with spacing of 20×15 cm and soil salinity recorded at 30 DAS was 4.3 dSm-1,. Peizometer was installed in field to measure soil salinity at different growth stages. A total of 72 germplasm including 4 checks were transplanted in continuous three rows of 4 m row length at spacing of 20 cm between rows and 15 cm between plants within the row. Cultural practices like weeding, irrigation and necessary crop protection practices were followed to maintain good crop.

Data on days to 50% flowering, plant height (cm), total number of tillers plant-1, number of effective tillers plant-1,panicle length (cm),number of filled grains panicle-1, grain yield plant-1 (g), spikelet fertility (%),test weight, grain length(mm),grain breadth(mm), grain L/B ratio (mm) and reproductive stage salinity scoring were recorded based on 5 plants per genotype. The details of the observations recorded and methodology followed is presented here under character wise.

Estimates of phenotypic and genotypic coefficients of variation according to Burton & De Vane (1952), heritability estimates in broad sense according to Lush (1940) and genetic advance as per suggested by Johanson *et al.* (1955) and correlation coefficient according to Robinson *et al.* (1951) were calculated following standard statistical procedures.

**RESULTS AND DISCUSSION**

Analysis of variance was carried out as per standard procedure by Patterson and Williams, 1956. The range, mean, variability estimates *i.e.* genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, genetic advance and genetic advance as percentage of mean were estimated for yield, its components presented in table 1. The analysis of variance revealed significant genotypic difference for all the traits studied indicating that a large amount of variability was present in the material under salinity condition.

 Variability of a character is measured by its coefficient of variation. The genotypic and phenotypic coefficients of variation are classified (low: less than 10%, moderate: 10-20% and high: more than 20%) as suggested by Sivasubramanian and Madhava Menon (1973). Heritability estimates are categorized (low: less than 30%, moderate: 30-60% and high: more than 60%) as recommended by Johnson *et al*. (1955). The range of genetic advance as percent of mean is classified (low: less than 10%, moderate: 10-20% and high: more than 20%) as suggested by Johnson *et al.* (1955).

**Table 1: Estimates of variability and genetic parameters of fourteen yield traits in rice genotypes under salinity condition.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Character** | **Range** | **Mean** + **SE** | **Mean sum of squares** | **GCV (%)** | **PCV (%)** | **Heritability (bs) (%)** | **Genetic advance** | **Genetic advance as % of mean** |
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| --- |
| Days to 50% flowering |

 | 85 - 124 | 103.42 + 1.3 | 100.26 | 6.72 | 6.96 | 93.43 | 13.85 | 8.39 |
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| --- |
| Plant height (cm) |

 | 53.3 - 125 | 77.16+ 1.59 | 528.2 | 20.95 | 21.26 | 98.10 | 32.99 | 42.76 |
| Total no. of tillers/plant | 4 - 17.67 | 12.20 + 0.58 | 8.83 | 16.72 | 17.70 | 89.18 | 3.96 | 32.53 |
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| --- |
| No. of effective tillers/plant |

 | 5 - 14 | 9.63 + 0.57 | 5.29 | 15.82 | 17.90 | 78.05 | 2.77 | 28.79 |
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| --- |
| Panicle length (cm) |

 | 14 - 26.4 | 20.29+ 0.44 | 14.33 | 13.01 | 13.36 | 94.83 | 5.29 | 26.11 |
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| --- |
| No. of filled grains/panicle |

 | 10 - 191 | 108.43 + 5.75 | 2126.07 | 29.59 | 30.53 | 93.96 | 64.08 | 59.10 |
| Spikelet fertility (%) | 20.6 - 91.93 | 64.98 + 3.21 | 330.26 | 19.14 | 20.38 | 88.22 | 24.07 | 37.04 |
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| --- |
| Test weight (g) |

 | 9.12 - 26.98 | 17.15+ 0.68 | 33.26 | 23.49 | 24.10 | 94.58 | 8.05 | 46.97 |
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| --- |
| Single plant yield (g/plant) |

 | 5.5 - 29.23 | 17.59 + 0.84 | 56.21 | 29.76 | 30.52 | 95.03 | 10.51 | 59.76 |
| Reproductive stage salinity scoring | 3-9 | 5.6 + 0.78 | 2.45 | 13.97 | 24.28 | 23.11 | 0.92 | 9.56 |
| Grain length (mm) | 4.2 - 9.7 | 5.86 + 0.18 | 1.204 | 12.83 | 13.62 | 88.78 | 1.46 | 24.9 |
| Grain breadth(mm) | 1.01 - 2.23 | 1.62 + 0.04 | 0.129 | 15.54 | 16.01 | 94.20 | 0.5 | 31.06 |
| Grain L/B ratio(mm) | 2.29 - 6.51 | 3.84 + 0.126 | 1.699 | 23.75 | 24..20 | 96.28 | 1.84 | 48.01 |
| Seedling mortality (%) | 20.51-95 | 36.7 + 3.06 | 536.02 | 39.93 | 42.22 | 89.43 | 30.99 | 77.8 |

The results on genetic variability revealed that phenotypic coefficient of variation were higher than genotypic coefficient of variation. The difference between PCV and GCV was minimum for all the characters studied. The apparent variation is not only due to influence of genotype but also due to environment. A close difference between phenotypic and genotypic coefficient of variation revealed that there was a little influence of environment on the expression of the character studied. The values of genotypic and phenotypic coefficients of variation (GCV and PCV) were moderate for Total no. of tillers/plant, No. of effective tillers/plant and spikelet fertility (%),Grain length (mm) and grain breadth; low for days to 50% flowering. Selection for these traits would offer better scope for genotypes under study and there is a need for creation of variability either by hybridization or mutation followed by selection. Spikelet fertility ranged from 20.6% to 91.93%, with a mean of 64.98%. The moderate GCV (19.14%) and PCV (20.38%) suggest some environmental influence, but the high heritability (88%) indicates that most variation is genetic. The genetic advance of 24.07% (37.04% of the mean) means breeders can significantly improve fertility through selection.

Single plant yield varied from 5.5 g to 29.23 g, with a mean of 17.59 g. The high GCV (29.76%) and PCV (30.52%) indicate significant variability, but the very high heritability (95%) confirms that yield is strongly influenced by genetics. The genetic advance of 10.51 g (59.76% of the mean) suggests excellent potential for yield improvement through breeding. Salinity tolerance at the reproductive stage was scored from 3 to 9, with a mean of 5.6. The moderate GCV (13.97%) and high PCV (24.28%) indicate that environmental factors play a major role. The low heritability (33.11%) suggests limited genetic control, making this trait harder to improve through breeding alone. Seedling mortality under stress conditions ranged from 20.51% to 95%, with a mean of 36.7%. The very high GCV (39.93%) and PCV (42.22%) indicate extreme variability, but the high heritability (89.43%) suggests that genetics play a major role. The large genetic advance (30.99%, 77.8% of the mean) indicates strong potential for breeding stress-tolerant varieties.

Most traits, especially yield-related ones (plant height, panicle length, grains per panicle, test weight, and single plant yield), exhibit high heritability and genetic advance, indicating that they can be efficiently increased by breeding. Traits like reproductive stage salinity tolerance have low heritability, indicating that improving them may require additional strategies beyond pure genetic selection. Overall, this data helps breeders prioritize traits for crop improvement programs. The trait Days to 50% flowering has high heritability (93.43) c with low genetic advance (8.39) indicates non additive gene action and selection for this trait may not be rewarding.

High heritability (broad sense) estimates (>60%) were observed for all the traits except reproductive stage salinity screening *viz*., days to 50% flowering (93.43%), plant height (98.10),total number of tillers per plant(89.18), number of effective tillers per plant (78.05), panicle length (94.83), number of filled grains per panicle (93.96), sigle plant yield(95.03), test weight (94.58),spikelet fertility percentage(88.22),),grain length(88.78),grain breadth(94.20),grain L/B ratio(96.28) and seedling mortality percentage(89.43) except reproductive stage salinity sscore (23.11). Since the estimates of heritability alone sometimes misleads interpretation hence estimates of genetic advance as percent of mean is used for better prediction of characters under study. The values of genetic advance as percent of mean were high for the traits under studied except for plant height and reproductive stage salinity scoring. Reproductive stage salinity score has low heritability (23.11) coupled with low genetic advance (9.56) indicating that this trait is highly influenced by environmental effects and selection would be ineffective.

Heritability alone fails to indicate the response to selection and a character having high heritability may not necessary give high genetic advance. Therefore heritability should be always considered along with genetic advance as percent of mean to arrive at a more reliable conclusion. High heritability coupled with high genetic advance as percent of mean was observed for all the traits except for plant height and reproductive stage salinity stage scoring indicating the preponderance of additive type of gene action for the expression of this characters and selection may be effective for improving this character.

The efficiency of selection for yield mainly depends on the direction and magnitude of association between yield and its component characters and also among themselves. Character association provides information on the nature and extent of association between pairs of metric traits and helps in selection for the improvement of the character. The knowledge regarding relative contribution of individual traits to yield may be accomplished by correlation studies. Further, the component characters of yield exhibit different associations among themselves and also with yield. Unfavorable associations between the desired attributes under selection may limit genetic advance. Therefore, knowledge on the magnitude of association between the yield and its attributing characters is essential for planning sound breeding programme.

In the present investigation, simple correlation studies were estimated for yield and its components. Estimates of simple correlation coefficients for yield traits under salinity condition are presented in (table 2).

**Table 2: Estimates of simple correlation coefficients for yield traits under salinity condition.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Trait** | **DFF** | **PH** | **TL** | **PT** | **PL** | **FG** | **SFP** | **TW** | **SPY** | **GL** | **GB** | **L/B ratio** | **SES** | **SM%** |
| **DFF** | **1** | -0.209 | -0.111 | -0.233 \* | 0.034 | 0.012  | -0.0227  | -0.0614  | 0.03  | 0.1263  | -0.0063  | 0.0385  | 0.1374  | -0.102  |
| **PH** |  | **1** | 0.215  | 0.1537  | 0.67 \*\* | 0.39 \*\* | 0.2385 \* | 0.0119  | 0.293 \* | -0.1053  | 0.21  | -0.236 \* | -0.1985  | -0.243 \* |
| **TL** |  |  | **1** | 0.94 \*\* | 0.2005  | 0.55 \*\* | 0.41 \*\* | 0.049  | 0.484 \*\* | 0.1663  | 0.105 | -0.107  | -0.482 \*\* | -0.481 \*\* |
| **PT** |  |  |  | **1** | 0.114  | 0.4272 \*\* | 0.379 \*\* | 0.192  | 0.459 \*\* | 0.1187  | -0.031  | -0.027  | -0.3762 \*\* | -0.444 \*\* |
| **PL** |  |  |  |  | **1** | 0.3544 \*\* | 0.306 \*\* | -0.071  | 0.303 \*\* | 0.1295  | 0.172  | -0.036  | -0.1079  | -0.251 \* |
| **FG** |  |  |  |  |  | **1** | 0.792 \*\* | 0.199  | 0.89 \*\* | 0.0694  | 0.190  | -0.165 | -0.4233 \*\* | -0.849 \*\* |
| **SFP** |  |  |  |  |  |  | **1** | 0.072  | 0.72 \*\* | 0.2135  | 0.061  | 0.002  | -0.4234 \*\* | -0.72 \*\* |
| **TW** |  |  |  |  |  |  |  | **1** | 0.431 \*\* | -0.071  | 0.027  | -0.087  | -0.0124 NS | -0.435 \*\* |
| **SPY** |  |  |  |  |  |  |  |  | **1** | 0.056  | 0.196  | -0.136  | -0.2632 \* | -0.930 \*\* |
| **GL** |  |  |  |  |  |  |  |  |  | **1** | -0.2614 \* | 0.757 \*\* | -0.1455  | -0.083  |
| **GB** |  |  |  |  |  |  |  |  |  |  | **1** | -0.769 \*\* | 0.0821  | -0.084  |
| **L/B ratio** |  |  |  |  |  |  |  |  |  |  |  | **1** | -0.0015  | 0.063  |
| **SES** |  |  |  |  |  |  |  |  |  |  |  |  | **1** | 0.257 \* |
| **SM%** |  |  |  |  |  |  |  |  |  |  |  |  |  | **1** |

\* Significant at p< 0.05; \*\*Significant at p<0.01 (DFF-Days to 50% flowering; PH-Plant height; TL- Total tillers per plant; PT-Productive tillers per plant; Pl-Panicle length; FG- No. of filled grains per panicle; SFP-Spikelet fertility percentage; TW-Test weight; SPY-Single plant yield per plant; GL-Grain length; GB- grain breadth; SES-Reproductive stage salinity score; SM- Seedling mortality (%).

The genotypic correlation of days to 50% flowering was positive but non-significant with RES (0.1374 NS), GL (0.1263 NS), L/B Ratio (0.0385 NS), PL (0.0346 NS), SPY (0.03 NS), and FG (0.0124 NS). Plant height was positive and significant correlated with panicle length and grain yield. Similar results were observed for panicle length (Ramesh *et al.,* (2018) and grain yield per plant by Tiwari *et al.* (2016), Sanju *et al.,* (2019), Ramesh et al.(2018), Reddy *et al.,* (2018b). A significant negative correlation was observed with PT (-0.233 \*). Productive tillers per plant was significantly and positively correlated with TL (0.9455 \*\*), SPY (0.4593 \*\*), FG (0.4272 \*\*), and SFP (0.3799 \*\*). Kumar *et al.,* (2017) also noted that higher tillering potential positively affects yield under abiotic stress. Similar findings were reported by Hakim *et al.,* (2013) and Hossen *et al.,* (2017)., who observed strong positive associations between productive tillers and other yield components while screening rice varieties under saline conditions at multiple electrical conductivity levels (4, 8, and 12 dSm⁻¹). It also had positive, though non-significant, correlations with TW, PH, GL, and PL. Filled grains per panicle was significantly and positively associated with SPY (0.8907 \*\*), SFP (0.7923 \*\*), TL (0.5571 \*\*), PT (0.4272 \*\*), PH (0.3995 \*\*), and PL (0.3544\*\*). It also had non-significant positive correlations with TW, GB, GL, and DFF. On the other hand, FG had significant negative correlations with SM% (-0.8496 \*\*) and RES (-0.4233 \*\*), and a non-significant negative correlation with L/B Ratio. SFP displayed significant positive correlations with FG (0.7923 \*\*), SPY (0.7223 \*\*), TL (0.4114 \*\*), PT (0.3799 \*\*), PL (0.3064 \*\*), and PH (0.2385 \*).

Reproductive stage salinity score (RES) was significantly and positively correlated with SM% (0.2571\*), and had non-significant positive correlations with DFF and GB. Significant negative associations were found with TL (-0.482 \*\*), SFP (-0.4234 \*\*), FG (-0.4233 \*\*), PT (-0.3762 \*\*), and SPY (-0.2632 \*), while PH, GL, PL, TW, and L/B Ratio had non-significant negative correlations. The present investigation revealed that SM% (Seedling Mortality Percentage) had a positive and significant correlation with RES (0.2571 \*), indicating that genotypes with higher resistance scores tend to exhibit increased seedling mortality. Additionally, a positive but non-significant correlation was observed with L/B Ratio (0.0635 NS). In contrast, SM% showed strong and significant negative correlations with several important agronomic traits, including SPY (-0.9304 \*\*), FG (-0.8496 \*\*), SFP (-0.722 \*\*), TL (-0.4818 \*\*), PT (-0.4446 \*\*), TW (-0.4359 \*\*), PL (-0.2511 \*), and PH (-0.2435 \*), suggesting that increased seedling mortality adversely affects yield components and plant growth traits. Furthermore, negative but non-significant associations were found with DFF (-0.1022 NS), GB (-0.0849 NS), and GL (-0.0835 NS), indicating weak or inconsistent relationships with these traits.

The study of simple correlation in the present investigation suggested that selection of plants with more number of productive tillers per plant, panicle length, number of grains per panicle and test weight which had significant positive association with yield may be taken in to account in rice breeding program for yield improvement to develop salinity tolerant rice varieties.

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