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VARIABILITY ANALYSIS AND CHARACTER ASSOCIATION FOR SODICITY TOLERANCE IN $F_{2:3}$ BIPARENTAL POPULATION OF RICE UNDER SODIC CONDITION

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Abstract

The present investigation was under taken with the objectives to estimate genetic variability for sodicity related traits and its association with grain yield in $F_{2:3}$ segregating population under slightly sodic condition.. The experiment was conducted at the Agricultural Research Farm of Banaras Hindu University, Varanasi (U. P.), India during *kharif*, 2018. Analysis of variance revealed significant differences for the traits studied indicating the existence of high genetic variability among the lines. Estimates of phenotypic coefficients of variation (PCV) were higher than genotypic coefficient of variation (GCV) for all the characters studied, indicating considerable effect of environment. Tolerant parent CSR 43 performed better than sensitive parent Pusa 44 for all the traits studied under sodic stress. CSR 43 and the $F_{2:3}$ lines which showed tolerance response, recorded low shoot Na^+ concentration and $Na^+ : K^+$ ratio, high shoot K^+ concentration, total chlorophyll content and all together respond to gain higher yield than susceptible lines. Heritability was highest among the traits studied for total chlorophyll content. Selection for shoot Na^+ concentration, $Na^+ : K^+$ ratio and shoot K^+ concentration, total chlorophyll content will support the breeder in any breeding program for further improvement of the traits under sodic condition as these traits showed significant association with grain yield per plant in favorable negative and positive direction, respectively. The present investigation was under taken with the objectives to estimate genetic variability for sodicity related traits and its association with grain yield in $F_{2:3}$ segregating population under slightly sodic condition.. The experiment was conducted at the Agricultural Research Farm of Banaras Hindu University, Varanasi (U. P.), India during *kharif*, 2018. Analysis of variance revealed significant differences for the traits studied indicating the existence of high genetic variability among the lines. Estimates of phenotypic coefficients of variation (PCV) were higher than genotypic coefficient of variation (GCV) for all the characters studied, indicating considerable effect of environment. Tolerant parent CSR 43 performed better than sensitive parent Pusa 44 for all the traits studied under sodic stress. CSR 43 and the $F_{2:3}$ lines which showed tolerance response, recorded low shoot Na^+ concentration and $Na^+ : K^+$ ratio, high shoot K^+ concentration, total chlorophyll content and all together respond to gain higher yield than susceptible lines. Heritability was highest among the traits studied for total chlorophyll content. Selection for shoot Na^+ concentration, $Na^+ : K^+$ ratio and shoot K^+ concentration, total chlorophyll content will support the breeder in any breeding program for further improvement of the traits under sodic condition as these traits showed significant association with grain yield per plant in favorable negative and positive direction, respectively.

Key words: Sodic stress, rice (*Oryza sativa* L.), biparental mapping population, variability parameter, correlation, shoot Na^+ and shoot K^+ concentration.

Introduction

Rice is exceptionally sensitive to salinity and sodicity at early seedling stage. It is estimated that 20% of all cultivated land and nearly half of irrigated land is affected by salt, greatly reducing the yield of crops to well below their genetic potential (Tripathi *et al.*, 2018; Gao *et al.*, 2007; Ismail *et al.*, 2007). There are limited evidence at present that remediation of saline soils to enhance crop yield stability (Tester and Devenport, 2003). Genetic variability is a measure of the tendency of individual genotypes in a population to vary from one another. Variability is different from genetic diversity, which is the amount of variation seen in a particular population. The variability of a trait describes how much that trait tends

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to vary in response to environmental and genetic influence (Tripathi *et al.*, 2018). Heritability is the proportion of observed differences on a trait among individuals of a population that are due to genetic differences.

Grain yield is a polygenetically controlled character with complex in inheritance (Selvaraj *et al.*, 2011. It is influenced by number of component characters like Na^+ and K^+ concentration, $Na^+ : K^+$ ratio, total chlorophyll content etc., and environment either directly or indirectly. Salt tolerance is related to exclusion of Na^+ ion and distribution of almost uniform concentration of this ion in all leaves (Haq *et al.*, 2009). Maintenance of a low Na^+: K^+ ratio in cells is essential for plants tolerance to salt stress (Maathuis and Amtmann, 1999). One of the most notable effects of salt stress is the alteration of photosynthetic pigment biosynthesis (Maxwell and Johnson, 2000). The decrease in chlorophyll content under salt stress is a commonly reported phenomenon and in various studies and the chlorophyll concentration is used as a sensitive indicator of the cellular metabolic state (Chutipaijit *et al.*, 2011). Hence, selection for one component traits may simultaneously affect grain yield in a favorable direction. Therefore, identifying the characters, which are favourably related to grain yield becomes highly essential (Rangare and Krupakar, 2012). The knowledge on association among different traits with yield and interrelationship is essential to improve the selection efficiency. The strategies for mitigating salinity problems in crop production include genetic improvement of salinity tolerance in current cultivars (Epstein *et al.*, 1980). Therefore, the need for genetic improvement of salt tolerance is great and is expected to increase dramatically in near future. Keeping this objective in view, the present study was conducted with the view of to find out genetic variability and to observe any influence on correlations among plant attributes under sodic environment.

Materials and Methods

Experimental Site

Experiment was carried out in *kharif* 2018, at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Soil samples were collected randomly from different part of experimental fields, pre-transplanting and post harvesting. Collected soil samples were mixed in equal proportion and subjected to analysis by pH and EC meter. pH, pre transplanting and post harvesting was recorded as 8.2 and 8.1, respectively while the EC recorded was 1.28 dS/m. Based on above readings the experimental site was categorized as slightly sodic.

Experimental Material

A set of 298 $F_{2:3}$ families derived from the cross PUSA 44 (Sodicity sensitive variety) × CSR 43 (Sodicity tolerant variety), following single seed descent method, was transplanted on 31 July, 2018 @10 plants per family along with parents as check, in alpha lettice design with two replications maintaining a spacing of 15 × 20 cm plant to plant and row to row, respectively, under sodic condition.

Traits Observed

Visual scoring of sodicity stress among the 298 families of $F_{2:3}$ poulation along with the parents were carried out following IRRI's Standard Evaluation Score (SES) to categories their response against the sodic stress. Mean data on sodicity stress score (SSS), shoot Na^+ concentration (SNa), shoot K^+ concentration (SK), Na^+: K^+ ratio (NaKR), total chlorophyll content (TCC) and grain yield per plant (GYPP; g) were recorded on five plants from each replication respectively. Na^+ and K^+ concentration in shoot were analysed using flame photometer and total chlorophyll content using spade meter. Data were subjected to statistical analysis.

Statistical Analysis

Analysis of Variance (ANOVA) were performed using the PROC GLM procedure by SAS v9.2. Various genetic parameters such as genetic and phenotypic variance, genetic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) were worked out as per Burton and De-Vane (1953). GCV and PCV values were classified as per classification suggested by Sivasubramanian and Menon (1973), accordingly traits having <10 %= low; 10-20% = Moderate; >20 % = high.

Broad sense heritability (h^2), genetic advance (GA) were computed by using the formula given by Allard (1960). Heritability estimates were classified following the classification suggested by Johnson *et al.* (1955).

Table 1: Analysis of Variance (ANOVA) for five sodicity related traits along with grain yield of $F_{2:3}$ population under slightly sodic condition.

Source of variation	d.f.	SSS	SNa	SK	NaKR	TCC	GYPP
Treatment	299	2.19**	0.83**	0.84**	0.48**	13.52**	59.62**
Replication	1	22.42	44.46	3.68	10.64	330.82	1221.56
Block(Rep)	38	1.23	0.89	0.83	0.47	2.67	53.48
Error	261	1.14	0.45	0.44	0.27	3.76	30.33

** Significant at 1% level of significance., d.f. = degree of freedom

(SSS) sodicity stress score, (SNa) shoot Na^+ concentration; (SK) shoot K^+ concentration; (NaKR) Na^+: K^+ ratio; (TCC) total chlorophyll content and (GYPP) grain yield per plant.

<30% = Low; 31-60% = Medium; >60% = High

Likewise, for genetics advance following classification was used:

<10% = Low; 10- 20% = Moderate; >20% = High

Correlation analysis was performed using the software packages ADEL-R and META-R developed by CIMMYT, Mexico. Following scales were used for categorization based values of correlation coefficient given by Searle, 1965

>0.65 = Very strong; 0.50 to 0.64 = moderately storng; 0.30 to .49 = moderately weak; <0.30 = very weak.

Results and Discussion

Analysis of variation and genetic parameters

It is revealed from the analysis of variance that all 298 $F_{2:3}$ lines along with parents were highly significant at (P<0.01) for all the traits under study (Table 1) suggesting the presence of considerable amount of variability under sodic condition among the lines. Presence of significant variance for a trait will be useful for a breeder in selection and further improvement of the trait. Similar results were also reported by Tripathi *et al.*, (2018); Gopikannan and Ganesh (2013) and Fiyaz *et al.*, (2011).

Mean performance

Data on mean values revealed that tolerant parent CSR 43 performed better than susceptible parent Pusa 44 for all six traits studied. Based on visual sodicity score CSR 43 scored '1' showed high tolerance while, Pusa 44 scored 5, showed moderate tolerant under slightly sodic soil. Meanwhile, 298 $F_{2:3}$ population showed a population mean of 3.77 and categorized under classes presented in table 2. It is clear from the data that all the tolerant parent absorbed less sodium as compared to susceptible parent. CSR 43 recorded low 1.63 mg g^{-1} Na^+ concentration but high 4.32 mg g^{-1} K^+ concentration along with low Na^+: K^+ ratio (0.38) while, Pusa 44 recorded high 2.49 mg g^{-1} Na^+ concentration but low 2.21 mg g^{-1} K^+ concentration in shoot and had high Na^+ : K^+ ratio (1.15) suggested better regulation of tolerant parent over the distribution and accumulation of Na taken up by the plant and kept delicate plant part relatively free of Na, besides had an assured K supply even under higher pH. While, the sensitive parent Pusa 44 was unable to prevent either the accumulation of Na^+ or depletion of K^+. High total chlorophyll content was recorded for tolerant parent CSR 43 (30.71%) in comparison Pusa 44 (29.91%). CSR 43 showed high grain yield per plant (33.74g) while Pusa 44 recorded low 28.09g grain yield per plant. Enhanced uptake of sodium and decreased uptake of potassium and calcium under salinity stress have been also reported by Tripathi *et al.* (2018); Srivastava and Velu (2000). The mean value of 298 $F_{2:3}$ families recorded 2.83 mg g^{-1}, 3.08 mg g^{-1}, 1.09, 38.7% and 23.96 g, for shoot Na^+ concentration, shoot K^+ concentration, Na^+ : K^+ ratio, total chlorophyll content and grain yield per plant, respectively. For total chlorophyll content the population mean of 298 $F_{2:3}$ families fall out of the range of parents suggesting the existence of appearance of transgressive segregation for the traits contributing towards the sodicity tolerance is controlled by polygenes and also suggests that both the parents, PUSA 44 and CSR 43, possess many genes. Earlier reports of Xiao *et al*., (1996); De Vicente and Tanksley (1993) confirmed the appearance of transgressive segregation in $F_{2:3}$ segregating population.

In the present study phenotypic coefficient of variation (PCV) were higher than genotypic coefficient of variation (GCV) for all the six traits studied revealed that apparent variation is not only due to genotypes but also due to the influence of environment and, the interaction of both. The difference between genotypic and phenotypic co-efficient of variation was quite high indicating a considerable effect of environment on the expression of these traits. Selection based on GCV and PCV will not be effective for increasing tolerance and further yield improvement. Na^+ : K^+ ratio showed highest genotypic as well as phenotypic coefficients of variation, among all the six traits studied indicated that there is a scope of selection and improvement of the trait for sodicity tolerance (Table 3). Lowest GCV and PCV for total chlorophyll content indicated that the breeders should go for other source of higher variability for the trait to make further improvement. Likewise, remaining four traits shoot Na^+ concentration, shoot K^+ concentration sodicity stress score and grain yield per plant showed moderate

Table 2: Sodicity Stress Score based on SES, IRRI among the 298 $F_{2:3}$ along with parents.

Score	Observation	Reaction*	No. of Lines BHU
1	Normal growth, no symptom	Highly tolerant	56
3	Nearly normal growth but leaf tips or few leaves whitish and rolled	Tolerant	162
5	Growth severely retarded most leaves rolled, only few leaves elongating	Moderately tolerant	73
7	Complete cessation of growth, most leaves dry, some plants die	Susceptible	9
9	Almost all plants die	Highly susceptible	0

GCV and high PCV, respectively suggested that these traits could be improved by the vigorous selection. Results were in confirmation with the findings of Maurya *et al.,* (2018); Tripathi *et al.,* (2018) and Khatun *et al.,* (2015).

Heritability and Genetic advance

Heritability plays a predictive role in selection procedures as it gives information on transmission of characters. In broad sense heritability is the relative magnitude of genotypic and phenotypic variances for the traits studied. This gives an idea of the total variation ascribable to genotypic effects, which are exploitable portion of variation (Sanghera *et al.,* 2013). From table 3 it was revealed that heritability in broad sense was highest among the traits studied but moderate for total chlorophyll content (56.41%), suggesting that it may not be useful for improvement of total chlorophyll content because, heritability is based on total genetic variation which includes both, fixable and non- fixable variances meanwhile, also suggested the presence of a high component of heritable portion of variation which plays an important role in deciding the suitability and strategy for selection of this particular trait. Lowest heritability was recorded for Na^+ : K^+ ratio (26.31%) indicating that, direct selection for this trait will not be effective due to masking effect of the environment on the genotype. Low heritability was recorded for the remaining traits.

Table 3: Genetic variability parameters for five sodicity related traits along with grain yield under slightly sodic condition.

Para-meters	SSS	SNa	SK	NaKR	TCC	GYPP
Pusa 44	5	2.49	2.21	1.15	29.91	28.09
CSR 43	1	1.63	4.32	0.38	30.71	33.74
Range Min	1	1.35	1.56	0.30	29.91	9.28
Max	7	4.68	4.59	2.79	44.57	45.77
Mean	3.77	2.83	3.08	1.09	38.71	23.96
V_g	0.52	0.19	0.2	0.1	4.88	14.65
GCV	19.19	15.38	14.47	28.92	5.71	15.97
V_p	1.67	0.65	0.65	0.38	8.65	44.98
PCV	34.23	28.38	26.05	56.05	7.59	27.98
h^2	31.13	29.38	30.76	26.31	56.41	32.56
(%)	(L)	(L)	(L)	(L)	(M)	(L)
GA	0.83	0.48	0.51	0.33	3.42	4.49
GA%	22.17	17.18	16.55	30.73	8.83	18.77

*Alphabets in the parenthesis indicates: H = High; M = Moderate ; L = Low

**Vg = Genotypic variance, Vp = Phenotypic variance, GCV = Genotypic coefficient of variation, PCV = Phenotypic coefficient of variation, h^2 = Heritability (Broad sense), GA = Genetic advance.

Table 4: Genotypic and Phenotypic correlation coefficients among five sodicity related traits along with grain yield under slightly sodic condition.

Traits	SSS	SNa	SK	NaKR	TCC	GYPP
SSS	1	1.00*	-1.00*	1.00*	-0.36*	-1.00*
SNa	0.93*	1	-0.95*	0.97*	-0.44*	-1.00*
SK	-0.89*	-0.97*	1	-0.96*	0.38*	0.92*
NaK^R	0.90*	0.96*	-0.95*	1	-0.45*	-0.97*
TCC	-0.20*	-0.22*	0.21*	-0.22*	1	0.45*
GYPP	-0.92*	-0.97*	0.93*	-0.91*	0.24*	1

*Significance at 5% level of significance.
Below diagonally- Phenotypic correlation coefficient.
Above diagonally- Genotypic correlation coefficient.
(SSS) sodicity stress score, (SNa) shoot Na^+ concentration; (SK) shoot K^+ concentration; (NaKR) Na^+: K^+ ratio; (TCC) total chlorophyll content and (GYPP) grain yield per plant.

Traits selection should be based on high heritability, coupled with high genetic advance, for successful crop improvement programmes (Shah *et al.,* 2017). It was clearly evident from table 3 that none of the traits showed high genetic advance under slightly sodic soil while, it was recorded low for all the traits studied in a range of 0.33 % – 4.49 % suggesting governance by non-additive genes thus heterosis breeding may be useful for the traits. Moderate heritability with low genetic advance was observed for total chlorophyll content indicated the existence of non additive gene action. Further, moderate heritability is probably being exhibited due to favorable influence of environment rather than genotype. Selection for these traits may not be effective, therefore. Similar observations were also obtained by Shah *et al.,* (2017) and Singh *et al.,* (2012). For the remaining traits *i.e.* shoot Na^+ concentration, shoot K^+ concentration, Na^+ : K^+ ratio, sodicity stress score and grain yield per plant low heritability and low genetics advance suggested that the characters are highly influenced by environmental effect and selection may be ineffective.

Character association

Studies on association of sodicity related traits with grain yield per plant furnished in table 4, revealed that genotypic correlation was higher than phenotypic correlation indicated a strong association of these traits (except shoot K^+ concentration) with grain yield per plant genetically and, the phenotypic value is lessened by the significant interaction of environment. Similar findings were reported by Shah *et al.,* (2017); Pallavi *et al.,* (2017) and Sudharani *et al.,* (2013). Shoot K^+ concentration had higher phenotypic correlation than genotypic correlation for the association with grain yield indicating that, apparent association of these traits is not only due to genes but, also on an account of favourable influence of environment.

From Table 4 it was indicated that shoot K^+ concentration had significantly positive and very strong correlation (0.92* and 0.93*) with grain yield per plant at both genotypic and phenotypic level, respectively suggested that the increasing value of K^+ concentration in shoot lead provide better tolerance and increases yield under sodic stress. Hossain *et al.,* (2015) observed the similar association in their study. Total chlorophyll content had significantly positive correlation with grain yield but it moderately weak (0.45*) and very weak (0.24*) genotypically and phenotypically, respectively. Gopikannan and Ganesh (2013) reported the similar finding for total chlorophyll content. Shoot Na+ concentration and Na^+ : K^+ ratio had very strong and significantly negative association with grain yield at both genotypic (~-1.00*, -0.97*) and phenotypic (-0.97*, -0.91*) level, respectively suggests that pri-ority should be given to these traits while making selection for yield improvement. Significant negative correlation recorded for shoot Na^+ concentration and Na^+ : K^+ ratio were in close conformity with the results of Hossain *et al.,* (2015); Gopikannan and Ganesh (2013); Hussein *et al.,* (2007); Arunroj *et al.,* (2004) and Mishra *et al.,* (1994).

Conclusion

Results of present investigation indicated existence of wide range of genetic variability was found among 298 $F_{2:3}$ lines for the studied traits suggesting that, there is ample scope for further improvement through selection of these traits. Tolerant parent CSR 43 performed better than sensitive parent Pusa 44 for all the traits studied under sodic stress. CSR 43 and the $F_{2:3}$ lines which showed tolerance response, recorded low shoot Na^+ concentration and Na^+ : K^+ ratio, high shoot K^+ concentration, total chlorophyll content and all together respond to gain higher yield than susceptible lines. Highest PCV and GCV was observed for Na^+ : K^+ ratio while lowest for total chlorophyll content. Likewise, remaining four traits shoot Na^+ concentration, shoot K^+ concentration sodicity stress score and grain yield per plant showed moderate GCV and high PCV, respectively. Heritability was highest among the traits studied for total chlorophyll content while, none of the traits showed high genetic advance under slightly sodic soil. Direct yield improvement under sodicity stress condition is difficult hence, yield improvement in sodic environment could be achieved by identifying secondary sodicity related traits which can contribute towards higher yield by achieving tolerance and, selecting for these traits in a breeding programme. Thus, selection on the following sodicity related traits *viz.,* shoot Na^+ concentration, Na^+ : K^+ ratio and shoot K+ concentration, total chlorophyll content will support the breeder in any breeding program for further improvement of the traits under sodic condition as these traits showed significant association with grain yield per plant in favorable negative and positive direction, respectively.

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