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Original scientific article

GENETIC VARIABILITY, HERITABILITY AND INTERRELATIONSHIP IN SALT-TOLERANT LINES OF T. AMAN RICE

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Twenty salt-tolerant breeding lines of T. Aman rice were studied under field conditions at the experimental farm of the Department of Genetics and Plant Breeding, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh. The experiment was conducted following Randomized Complete Block Design (RCBD) with three replications to estimate the genetic variations in yield and yield-related traits, and their interrelationship and to assess the direct and indirect effects of different yield-related traits on grain yield for the selection of high-yielding T. Aman rice. Twelve characters viz., days to flowering, days to maturity, plant height (cm), tillers per hill, panicles per hill, flag leaf length (cm), panicle length (cm), panicle weight (g), filled grains per panicle, spikelet fertility percentage, 100-grain weight (g) and grain yield per m^2 (kg) were studied. The genotypes differed significantly for all the traits studied indicating the wide range of variations existed across the genotypes. The analysis of variance of all characters studied was highly significant that revealed a wide range of variability among the newly developed 20 salt-tolerant genotypes of T. Aman rice. The genotypes BU1, BU4, BU6, BU7, and BU14 had high grain yields and could be directly selected as high-yielding varieties. Based on all genetic parameters, all the traits could significantly improve the grain yield of salt-tolerant lines of T. Aman rice. The correlation coefficient revealed that the genotype selected based on days to flowering, days to maturity, plant height (cm), panicles per hill, flag leaf length (cm), panicle weight (g), filled grains per panicle, and spikelet fertility (%) and 100-grain weight directly would significantly contribute to grain yield of 20 salt-tolerant genotypes of T. Aman rice. However, considering the genotypic correlations and path coefficients, direct selection on the basis of panicles per hill, panicle

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weight, plant height, flag leaf length, filled grains per panicle, spikelet fertility (%), days to flowering, and days to maturity would significantly improve the grain yield of salt-tolerant T. Aman rice genotypes.

Key words: Grain yield, mean performance, path coefficient, salt-tolerant rice, yield-related traits

Abbreviations

CV = coefficient of variation, LSD = Least significant difference, SE = Standard error, SD = standard deviation, σ^2g = genotypic variance, σ^2p = phenotypic variance, GCV = genotypic coefficient of variation, PCV = phenotypic coefficient of variation, h^2_b = heritability in broad sense, GA = genetic advance, GAPM = genetic advance in percent of mean

INTRODUCTION

Rice is a staple food for more than 3.5 billion people around the world, particularly in Asia, Latin America, and parts of Africa. Bangladesh is an agro-based and predominately rice-based country. Bangladesh earns about 13.35% of its GDP from agriculture (ECONOMIC REVIEW, 2020). Rice provides 75% of the calories and 55% of the protein in the average daily diet of the people in our country**.** Therefore, rice is not only the staple food but also "rice is life" in the Bangladesh context.

Across the various abiotic factors, salinity and drought are the most serious abiotic factors which impede growth, and development through osmotic and oxidative stresses as well as hinder crop production (SARKER and OBA, 2018a-e; 2019a; 2020a; SARKER *et al*., 2018). It was estimated that about 20% (45 million ha) of irrigated land, producing one-third of the world's food, is salt-affected (SHRIVASTAVA and KUMAR, 2015). The coastal region covers almost 29,000 km^2 or about 20% of Bangladesh. Furthermore, the coastal areas of Bangladesh cover more than 30% of the net cultivable lands. Agricultural land use in these areas is very poor, which is roughly 50% of the country's average (SRDI, 2019). In Bangladesh, rice production may reduce by 10% by 2050 for salinity (ANONYMOUS, 2008).

In Bangladesh rice is grown in three seasons, termed Aus, Aman, and Boro. Among these seasons, T. Aman plays a vital role in total rice production in our country. It occupied the highest area (48.92 % of total rice cropped area) coverage (BBS, 2020). It is suited to different AEZ in the coastal area. More attention has to be given to the improvement of rice varieties to increase rice production to meet up the increasing need. Thus, improvement in the yield of T. Aman rice varieties could contribute more effectively compared to the Aus and Boro varieties owing to larger coverage of cultivation areas. For the designing of an effective breeding program to develop high-yielding T. Aman rice varieties variability, heritability, and interrelationship (correlation and path coefficient) analysis are much more important.

Variability plays a vital role in the selection of superior genotypes in crop improvement programs (SARKER *et al*., 2014; 2015a-b). The knowledge about genetic variability can help to know if these variations are heritable or non-heritable. The magnitude of variation due to a heritable component is very important because it would be a guide for the selection of parents for crop improvement (SARKER *et al*., 2016; KARIM *et al*., 2007; 2014; GANAPATI *et al*., 2014). There are a lot of quantitative and qualitative studies were observed for the evaluation of variabilities such as agronomic traits (HASAN *et al*., 2020; BISWAS *et al*., 2006), grain yield (HASAN-UD-

DAULA and SARKER, 2020), proximate compositions (SARKER and OBA, 2019b-c), minerals (SARKER and OBA, 2020b-c), pigments (SARKER and OBA, 2019d; 2020d; 2021), vitamins (CHAKRABARTY *et al*., 2018), phenolics (SARKER *et al*., 2020a), flavonoids content (SARKER and OBA, 2020e-g) and antioxidant activity (SARKER *et al*., 2020b-c). Heritability estimates provide authentic information about a particular genetic attribute that will be transmitted to successive generations and constitute an efficient guide for breeders in the choice of parents for crop improvement programs**.** Thus, the estimation of heritability along with genetic advance conjointly is more reliable and helpful in predicting the gain under selection than heritability alone**.**

Grain yield is a complex trait**,** controlled by many genes as well as environmentally influenced and determined by the magnitude and nature of their genetic variability **(**AZAM *et al*., 2013; TALUKDER *et al*., 2011, 2015)**.** In addition, grain yield is related to other traits such as plant types, growth duration and yield components **(**ALI *et al*., 2014; SIDDIQUE *et al*., 2009)**.** These traits are also correlated among themselves. The associations among different traits can be evaluated by correlation analysis (SARKER and MIAN, 2004) which helps to identify which characters are influenced much by yield. Path coefficient analysis is a statistical technique of partitioning the correlation coefficients into their direct and indirect effects so that the contribution of each trait to yield could be estimated. It is used in plant breeding programs to determine the nature of the relationships between yield and yield components that are useful as selection criteria to improve crop yield. Such as, grain yield has been influenced by the high direct positive effects of many characters as reported by SARKER and MIAN (2003).

Therefore, with this backdrop, the present investigation was undertaken with the following objectives. i) To estimate the extent of genetic variability, heritability, and genetic advance among the 20 salt-tolerant lines of T. Aman rice. ii) To find out the interrelationship of yield and yield attributing traits through simple correlation coefficients. iii) To assess the direct and indirect contribution of each character on grain yield through path-coefficient analysis for selection of high-yielding salt-tolerant lines of T. Aman rice.

MATERIALS AND METHODS

The experimental site, materials, and design

This study was conducted at the Genetics and Plant Breeding research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur. The geographical location of the experimental site was 24°23′ N - 90°08′ E latitude with an elevation of 8.4 m from the sea level. The soil was slightly acidic (pH 6.4) and low in organic matter (0.87%), total N (0.09%), and exchangeable K (0.13 cmol/kg)**.** Twenty salt-tolerant T. Aman lines (BU1 to BU20) collected from the Department of Genetics and Plant Breeding were evaluated for grain yield and its related agronomic traits. The experiment was executed in a randomized complete block design with three replications. The field was divided into three blocks, each block was subdivided into 20 plots where genotypes were randomly assigned. The plot size was 5 m × 1 m, row to row, and plant to plant distances were 20 cm. Urea, triple superphosphate (TSP), murate of potash (MP), and Gypsum were applied @ 150-100-70-60 kg/ha, respectively. Total TSP, MP, and Gypsum were applied in final land preparation but urea was applied in three installments, at 15, 30 and 45 days after transplanting (DAT), as recommended by BRRI (BRRI, 2014). Standard intercultural practices were followed during the cropping period for proper growth and development of the plants. Harvesting was done depending upon the maturity of different genotypes. The date of harvesting was confined when 90% of the grain attained a golden yellow color.

Collection of data

Different quantitative characters such as days to flowering and maturity were recorded on visual observations. Plant height (cm) was taken from ten randomly selected plants in each experimental unit and the length was measured from the base of the plant to the tip of the panicle. In addition, tillers per hill, panicles per hill, flag leaf length (cm), panicle length (cm), panicle weight (g), filled grains per panicle, spikelet fertility percentage, 100-grains weight (g) were measured from ten randomly selected samples. Grain yield was recorded and expressed as kg/m^2.

Statistical analysis

The raw data were compiled by taking the means of all the plants taken for each treatment and replication for different traits. Statistix 8 software was used to analyze the data for analysis of variance (ANOVA) (RASHAD and SARKER, 2020). Genotypic and phenotypic coefficients of variation were calculated by the formula suggested by RAI *et al*. (2013). Broad sense heritability was estimated following the formula described by HASAN *et al*. (2012a, b). The expected genetic advance for different characters under selection was estimated using the formula of RAHMAN *et al*. (2007a, b). Genetic advance in the percentage of mean was calculated from the formula given by AZAM *et al*. (2014). The genotypic and phenotypic correlation coefficients were calculated in all possible combinations through the formula suggested by SARKER and MIAN (2003). Correlation coefficients were further partitioned into components of direct and indirect effects by path coefficient analysis (SARKER *et al*., 2001).

RESULT AND DISCUSSION

The analysis of variance for 12 grain yield and yield-related quantitative traits in the present set of 20 salt-tolerant rice genotypes is presented in Table 1. It was evident from the analysis of variance that the genotypic differences were highly significant for all the traits under study. A wide range of variations across the salt-tolerant T. Aman genotypes indicates the existence of variability among them. Similarly, significant variability and diversity for various characters in a different set of genotypes were also reported which is corroborative of the present study (NATH *et al*., 2008; BISWAS *et al*., 2014 in maize; SARKER *et al*., 2017; 2018a-c in amaranth**).**

Mean performance

The mean performance of 20 salt-tolerant genotypes of T. Aman rice for yield and yield-related traits is shown in Table 2. The study showed that days to flowering for the genotypes ranged from 95.34 to 115.56 days with a mean value of 107.92 days. The longest period for flowering was observed in BU18 which was statistically related to BU11, BU12, BU16, and BU17. The genotype BU1 had the minimum days for flowering which was closely related to BU2. The study showed that days to maturity for the genotypes ranged from 121.03 to 152.00 days with a mean value of 135.15 days. The minimum days to maturity were found in genotype BU1 which was statistically similar to BU2. The maximum days to maturity were found in genotype BU18 which was followed by BU14, BU15, BU16, and BU20. It indicated that BU1 and BU2 could be considered for selection as short-duration early varieties.

Table 1. Analysis of variance (ANOVA) of 12 grain yield and yield-related traits in 20 salt-tolerant advance lines of T. Aman rice

Sl. No.	Characters	Mean Square		
		Replication	Genotypes	Error
	Degree of freedom	2	19	38
1.	Days to flowering	0.150	55.701**	0.501
2.	Days to maturity	0.001	88.332**	0.719
3.	Plant height (cm)	1.667	937.316**	0.737
4.	Tillers per hill	2.217	2.010**	0.620
5.	Panicles per hill	5.717	1.624**	0.418
6.	Flag leaf length (cm)	0.795	63.909**	0.798
7.	Panicle length (cm)	0.580	4.715**	0.453
8.	Panicle weight (g)	0.001	1.151**	0.014
9.	Filled grains per panicle	0.817	1,426.276**	1.150
10.	Spikelet fertility (%)	0.650	142.746**	0.878
11.	100-grain weight (g)	0.004	0.270**	0.004
12.	Grain yield per m^2 (kg)	0.001	0.048**	0.000

** = 1% level of significance

Genotypes differed in plant height that ranging from 113.83 to 173.00 (cm) with a mean value of 137.33 (cm). Across the genotypes, the mean value BU10 was the tallest (173.00 cm), which was statistically different from other genotypes except for BU1 while, the shortest genotype was BU2 (113.63 cm), which was followed by BU8, BU12, and BU18. Tillers per hill ranged from 7.06 to 11.60 per hill with a mean value of 9.25. Out of 20 genotypes, the maximum tillers per hill (11.60) were observed in BU3 which was followed by BU2, BU17, and BU18. The minimum tillers per hill (7. 06) were recorded in BU15 which is followed by BU12 and BU20. Panicles per hill of rice is a major determinant for panicle production and as a result, it affects total yield. The genotypes, which produced a higher number of panicles per plant showed higher grain yield in rice (DUTTA *et al*., 2013). The genotypes with more tillers showed a better productive tiller per plant. Significant variations in the number of panicles per hill ranging from 6.33 to 11.40 were observed with a mean value of 8.84 among the genotypes under this study. The highest number (11.40) of panicles per hill was produced by BU3 and the lowest was produced by BU15 and followed by BU12 and BU20. Out of 20 genotypes, eight showed above-average mean performance.

Flag leaf length varied significantly in different genotypes with a range of 24.92 to 40.35 cm with a mean value of 32.20 cm in this study. The maximum mean flag leaf length was found in the genotype BU1 which was statistically similar to BU4, BU15, BU10 and BU17 and the minimum number of flag leaf length (24.92) was recorded in BU12 which is statistically similar to BU5. The maximum panicle length (30.36) was recorded in BU17 followed by BU11 and BU15. The minimum panicle length (24.38) was recorded in BU18 which is followed by BU6. It was observed that genotypes showing longer plant height had also shown long panicles and vice versa. This might be described due to the positive association between plant height and panicle length. Out of 20 genotypes, ten showed above-average mean performance. Panicle weight ranged from 3.16 to 5.87 g with an overall mean of 4.13 g. The highest panicle weight was recorded from the genotype BU15 and it was found statistically closer to the genotypes BU6 and BU20. The lowest panicle weight was computed in the genotype BU19 and it was found statistically similar to the genotype BU18. Out of 20 genotypes, nine showed above-average mean performance.

Table 2. Mean performance of 20 salt-tolerant advance lines of T. Aman rice for grain yield and yield-related traits

Advance lines	DF	DM	Plant height (cm)	Tillers per hill	Panicles per hill	Flag leaf length (cm)	Panicle length (cm)	Panicle weight (g)	Filled grains per panicle (g)	Spikelet fertility (%)	100-grain weight (g)	Grain yield/m^2 (kg)
BU1	95.34	121.03	170.37	9.63	9.27	40.35	27.78	4.47	142.33	88.57	2.94	0.97
BU2	99.00	122.66	113.63	9.77	8.90	30.73	27.30	3.49	133.00	78.59	2.38	0.70
BU3	103.21	124.00	124.90	11.60	11.40	30.99	25.90	3.49	87.33	61.88	3.08	0.77
BU4	106.42	128.00	166.43	8.93	8.63	37.83	28.31	4.61	175.33	89.27	2.35	0.89
BU5	101.61	125.67	129.90	9.10	8.70	26.82	27.89	4.09	118.33	76.77	2.85	0.74
BU6	111.67	131.00	154.50	9.43	9.23	28.69	25.18	4.62	153.00	83.14	2.79	0.98
BU7	105.67	134.00	139.50	9.50	8.90	27.32	25.49	4.26	160.00	82.73	2.73	0.97
BU8	102.33	133.24	117.67	9.57	9.23	27.13	27.53	4.32	151.00	73.09	2.41	0.84
BU9	107.35	134.00	131.50	9.40	9.03	31.47	26.78	4.28	133.33	80.85	2.74	0.82
BU10	111.76	140.00	173.00	9.33	8.67	39.47	25.70	4.38	123.33	78.81	3.12	0.84
BU11	112.60	141.05	139.93	8.73	8.50	34.05	28.52	3.84	161.33	91.66	2.41	0.83
BU12	115.00	139.00	118.37	7.67	7.37	24.92	25.82	4.28	120.33	72.99	2.94	0.65
BU13	110.59	137.00	126.63	9.17	8.97	31.97	26.93	3.83	161.00	83.14	2.19	0.79
BU14	108.21	142.77	124.80	9.70	9.40	29.00	26.19	3.83	170.67	77.95	2.31	0.92
BU15	110.09	143.00	135.83	7.06	6.33	37.57	28.50	5.87	151.33	73.89	3.06	0.74
BU16	113.43	143.56	126.63	8.63	8.37	33.30	26.87	4.05	142.00	81.06	2.78	0.82
BU17	113.18	135.00	158.53	10.46	9.87	39.67	30.36	3.65	106.00	76.24	3.11	0.82
BU18	115.56	152.00	113.83	9.83	9.30	28.13	24.38	3.24	97.33	80.19	2.55	0.57
BU19	105.33	130.00	134.87	9.30	8.87	31.91	27.82	3.16	88.67	49.26	3.03	0.60
BU20	110.00	145.81	145.67	8.07	7.83	32.73	28.40	4.74	146.00	74.19	2.70	0.77
Grand Mean	107.92	135.15	137.33	9.25	8.84	32.20	27.08	4.13	136.08	77.72	2.72	0.80
LSD	1.91	2.94	6.37	0.41	0.42	1.64	0.53	0.22	9.42	3.58	0.10	0.05
SE (±)	0.72	1.104	2.39	0.15	0.16	0.62	0.20	0.08	3.54	1.34	0.04	0.01
SD	5.56	8.55	18.54	1.19	1.21	4.76	1.54	0.65	27.40	10.41	0.30	0.14
CV (%)	1.34	2.24	2.70	7.57	7.41	4.85	2.65	7.03	7.35	6.97	3.49	10.68

DF = Days to flowering, DM = Days to maturity, LSD = Least significant difference, SE = Standard error, SD = standard deviation, SE= standard error, CV = Coefficient of variation

In this study, the maximum number of filled grains per panicle was observed in genotype BU4 which was statistically related to BU11 and BU14 while the minimum number of filled grains per panicle was observed in genotype BU3 which was statistically similar to BU19. Those values ranged from 87.33 to 175.33 with a mean value of 136.08. Out of 20 genotypes, eleven showed above-average mean performance. YUAN, *et al.* (2005) studied the variation in the yield components of 75 high-quality rice cultivars. Among the yield components, the greatest variation was recorded for the number of filled grains per panicle in Indica rice. HAIRMANSIS *et al*. (2010) also reported variation in the number of filled grains per panicle in respect of yield. BU4, BU11, and BU14 could be selected for higher yield potentials as the greater number of filled grains per panicle are one of the major criteria for contributing to higher grain yield potential.

The mean values of spikelet fertility rate among the genotypes ranged from 49.26 to 91.66 % and with an overall mean of 77.72%. The highest spikelet fertility (91.66%) was found in BU11 which was followed by BU1 and BU4. The lowest (49.26%) in BU19 is followed by BU3. The maximum value of 100 grains weight (3.12 g) was observed in genotype BU10 which was statistically similar to BU3, BU15, and BU17 while the minimum value of 100-grain weight (2.19 g) was observed in genotype BU13 which was followed by BU2, BU4, BU8 BU11 and BU14. Out of 20 genotypes, eleven showed above-average mean performance. Yield is the most excellent trait and all the research work and objectives are dependent on yield. In this study, the grain yield of genotypes ranged from 0.57 to 0.98 kg per meter square with an overall mean of 0.80 kg/m^2. Higher grain yield per m^2 (0.98 kg) was harvested from BU6, which was statistically related to BU1, BU7, and the minimum number of yields was recorded (0.57) in BU18 which was followed by BU12 and BU19. Out of 20 genotypes, eleven genotypes i.e., BU1, BU4, BU6, BU7, BU8, BU9, BU10, BU11, BU14, BU16, and BU17 were out-yielded along with most of the yield-related traits over their corresponding grand means. The selection of these genotypes would be useful for yield aspects. However, the genotypes BU1, BU4, BU6, BU7, and BU14 had high grain yields and could be directly selected as high-yielding varieties.

Variability, heritability, and genetic advance

Genotypic variances (σ^2g), phenotypic variances (σ^2p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in a broad sense (h^2_b), genetic advance (GA), and genetic advance in percent of the mean, (GAPM) for all the grain yield and yield contributing characters are shown in Table 3. All the traits except for filled grain per panicle, plant height, and spikelet fertility% had close differences in genotypic and phenotypic variances which indicated a preponderance of additive gene effects for these traits i.e., less environmental influence in the expression of these traits or the major portion of the phenotypic variance was the genetic and greater scope of improvement of salt-tolerant T. Aman rice through selection. In the present investigation, phenotypic coefficients of variation were very close to the genotypic coefficient of variation for all the characters indicating the little influence of the environmental factors on these traits. This narrow difference in these values indicated the presence of preponderance additive gene actions in the phenotypic expression of the characters (BAGATI *et al.*, 2016; BHATT *et al.*, 2016) also observed similar findings. The genotypic and phenotypic coefficients of variation were high for filled grains per panicle, grain yield per m^{2,} and panicle weight, indicating the presence of a wide range of variability for the traits and a greater scope of selection for the improvement of salt-tolerant T. Aman rice genotypes. Plant height, tillers per hill, panicles per hill, flag leaf length, spikelet sterility (%), and 100-grains weight showed moderate genotypic and phenotypic coefficients of variation**.** These traits might also be considered for the improvement of salt-tolerant T. Aman rice genotypes. These results are in agreement with the results of the rice report by PATEL *et al*. (2018). The lowest PCV and GCV values were recorded for days to flowering, days to maturity, and panicle length. Similar results were reported by PANIGRAHI *et al*. (2018). Filled grain per panicle and plant height exhibited the highest value of heritability (86.91% and 96.11%). All the traits had a high to moderate value of heritability. Estimates of heritability along with genetic advances are more useful in predicting the value of selection than heritability alone. High to a moderate value of heritability coupled with high to moderate genetic advance as percent of mean were observed for all the traits that revealed the preponderance of additive gene effects and direct selection based on these traits could be performed for the improvement of salt-tolerant T. Aman rice genotypes. The present study corroborated the results reported by SUBBAIAH *et al.* (2011); RAHMAN *et al.* (2014); BISNE *et al.* (2009); ULLAH *et al.* (2011).

Table 3. Estimates of genetic parameters for grain yield and yield-related traits

Characters	σ^2p	σ^2g	PCV	GCV	h^2_b	GA	GAPM
Days to flowering	31.95	29.95	5.24	5.06	93.44	10.88	10.08
Days to maturity	75.60	66.43	6.43	6.03	87.88	15.74	11.65
Plant height (cm)	353.05	339.30	13.68	13.41	96.11	37.20	27.09
Tillers per hill	1.58	0.79	12.12	9.46	60.97	1.41	15.22
Panicles per hill	1.26	0.84	12.72	10.34	66.08	1.53	17.32
Flag leaf length (cm)	23.49	21.04	15.05	14.25	89.60	8.94	27.78
Panicle length (cm)	2.41	1.89	5.73	5.08	78.58	2.51	9.28
Panicle weight (g)	0.43	0.35	15.94	14.39	81.54	1.11	26.77
Filled grains per panicle	764.38	664.29	20.32	18.94	86.91	49.49	36.37
Spikelet fertility (%)	108.67	79.33	13.41	11.46	73.00	15.68	20.17
100-grain weight (g)	0.09	0.09	11.18	10.91	95.29	0.60	21.95
Grain yield per m^2 (kg)	0.02	0.01	16.81	13.02	61.98	0.17	21.77

σ^2p = Phenotypic variance, σ^2g = Genotypic variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, h^2_b = % heritability in broad sense, GA = Genetic advance, GAPM = Genetic advance in percent of mean

Correlation analysis

Correlation coefficient analysis has been used by breeders to reveal a positive relationship between yield and other traits that enhance yield in rice genotypes. Grain yield, being a quantitative trait, is a complex character of any crop. Various morphological and physiological plant traits contribute to yield. These yield-contributing components are interrelated with each other showing a complex chain of relationships and are highly influenced by the environmental conditions (PRASAD *et al*., 2001). The breeding strategy in rice mainly depends upon the degree of associated traits as well.

The correlation coefficients of 12 grain yield and yield-related traits in salt-tolerant T. Aman rice genotypes are presented in Table 4. The genotypic correlation coefficients were a little higher but close to the phenotypic correlation coefficients demonstrating that the observed relationships among the various traits were due to prominent additive gene actions. In a few cases, the phenotypic correlation coefficient was slightly higher suggesting that both environmental and genotypic correlation in these cases act in the same direction and finally maximize their expression at the phenotypic level.

Table 4. Coefficient of genotypic (r_g) and phenotypic (r_p) correlation among grain yield and different yield-related traits in 20 salt-tolerant advance lines of T. Aman rice

Characters		Days to maturity	Plant height (cm)	Tillers /hill	Panicles/ hill	Flag leaf length (cm)	Panicle length (cm)	Panicle weight (g)	Filled grains/ panicle	Spikelet fertility %	100-Grain weight (g)	Grain yield per m^2 (kg)
Days to flowering	r_g	0.830**	-0.055	-0.392**	-0.346**	-0.037	-0.175	0.039	-0.018	0.097	0.048	-0.268*
	r_p	0.792**	-0.033	-0.259*	-0.233	-0.032	-0.165	0.030	-0.009	0.071	0.041	-0.163
Days to maturity	r_g		-0.206	-0.494**	-0.466**	-0.082	-0.184	0.124	0.115	0.119	-0.122	-0.286*
	r_p		-0.194	-0.359**	-0.351**	-0.067	-0.202	0.096	0.107	0.078	-0.129	-0.208
Plant height (cm)	r_g			-0.013	-0.010	0.765**	0.312*	0.383**	0.198	0.346**	0.352**	0.619**
	r_p			0.009	-0.002	0.731**	0.285*	0.362**	0.191	0.290*	0.341**	0.616**
Tillers/hill	r_g				0.989**	-0.043	-0.261*	-0.798**	-0.459**	-0.214	0.023	0.038
	r_p				0.969**	0.017	-0.081	-0.473**	-0.331**	-0.068	0.018	0.292*
Panicles/hill	r_g					-0.080	-0.264*	-0.766**	-0.391**	-0.193	-0.029	0.324*
	r_p					-0.040	-0.103	-0.492**	-0.302*	-0.051	-0.025	0.316*
Flag leaf length (cm)	r_g						0.559**	0.273*	0.075	0.253	0.302*	0.268*
	r_p						0.527**	0.277*	0.072	0.180	0.286*	0.222
Panicle length (g)	r_g							0.143	0.088	-0.034	0.070	-0.051
	r_p							0.245	0.134	0.040	0.068	0.116
Panicle weight (g)	r_g								0.546**	0.289*	0.181	0.382**
	r_p								0.511**	0.302*	0.152	0.386**
Filled grains /panicle	r_g									0.706**	-0.643**	0.681**
	r_p									0.640**	-0.590**	0.638**
Spikelet fertility (%)	r_g										-0.493**	0.582**
	r_p										-0.409**	0.542**
100-grains weight (g)	r_g											-0.153
	r_p											-0.087

r_p = phenotypic correlation coefficient, r_g = genotypic correlation coefficient, ** 1% level of significance, * 5% level of significance

Grain yield had significant positive interrelationship with plant height (0.619^{**}, 0.616^{**}), panicles per hill (0.324^{*}, 0.316*), panicle weight (0.382^{**}, 0.386^{**}), filled grains per panicle (0.681^{**}, 0.638^{**}) and spikelet fertility (0.582^{**}, 0.542^{**}) at both genotypic and phenotypic levels, respectively. There was a positive association of grain yield with flag leaf length only at the genotypic level and tillers per hill only at the phenotypic level. On the other hand, it had a significant negative association with days to flowering (-0.268*) and days to maturity (-0.286*) only at the genotypic level. The correlation coefficient revealed that the genotype selected based on fewer days to flowering, fewer days to maturity, more flag leaf length (cm), plant height (cm), tillers per hill, panicles per hill, panicle weight, filled grains per panicle and spikelet fertility (%) would significantly improve the grain yield of salt-tolerant T. Aman rice. We found very similar findings that corroborated with the results of KIANI and NEMATZADEH (2012); AKINWALE *et al.* (2011); SADEGHI (2011); SINGH *et al.* (2013). PRASAD *et al.* (2001) showed that a number of effective tillers per plant have significant and positive interaction with yield.

Days to flowering exhibited a highly significant and positive correlation only with days to maturity and suggested that the increase in days to flowering subsequently increased the days to maturity. It showed a negative and significant correlation between tillers per hill and panicles per hill. Days to maturity exhibited a highly significant and negative correlation with tillers per hill and panicles per hill. It revealed that early flowering and growth duration rice confirm more tillers per hill and panicles per hill. Plant height exhibited a highly significant and positive correlation with flag leaf length, panicle length, panicle weight, spikelet fertility (%), and 100-grain weight. It indicated that taller plant height ensured more flag leaf length, panicle length, panicle weight, spikelet fertility (%), and 100-grain weight. Tillers per hill exhibited a highly significant and positive correlation with the number of panicles per hill suggesting that more tillering ability also ensured more panicles per hill. It had a significant and negative correlation with panicle length, panicle weight, and filled grains per panicle. Panicles per hill exhibited highly significant and negative interactions with panicle length, panicle weight, and filled grains per panicle. Flag leaf length showed a highly significant and positive correlation with panicle length and panicle weight which signified positive associations across the traits. Panicle weight showed a significant and positive correlation with filled grains per panicle and spikelet fertility (%). Filled grains per panicle showed highly significant and positive interaction with spikelet fertility (%) and significant and negative interaction with 100-grain weight. Spikelet fertility (%) showed a highly significant and negative interaction with 100-grain weight.

Path analysis

Path coefficient analysis is used in plant breeding programs to determine the nature of the relationships between yield and yield components that are useful as selection criteria to improve crop yield. The goal of the path analysis is to accept descriptions of the correlation between the traits, based on a model of cause and effect relationship and to estimate the importance of the affecting traits on a specific trait. In correlation studies, with the increasing number of variables, the indirect association becomes intricate and important. In such a situation, path coefficient analysis is useful to find out direct and indirect causes of associations. Path coefficient analysis at the genotypic level permits a critical examination of specific factors acting to produce a given correlation and measures the relative importance of each factor. Grain yield per m^2 was considered as a resultant (dependent) variable where, days to flowering, days to maturity, plant height (cm), tillers per hill, panicles per hill, flag leaf length (cm), panicle length (cm), panicle weight (g), filled grain per panicle, spikelet fertility (%), 100-grain weight (g), were causal (independent) variables. Assessment of direct and indirect effects of path co-efficient analysis for 12 traits of salt-tolerant T. Aman rice is presented in Table 5. The result of a path analysis revealed that panicles per hill (1.119), panicle weight (0.900), plant height (0.882), flag leaf length (0.581), filled grains per panicle (0.566), spikelet fertility (%) (0.416) have high positive direct effects along with significant genotypic correlations on grain yield per m^2. Similar results were reported by PANIGRAHI *et al*. (2018) for filled grains per panicle. Again, moderate negative direct effects were observed for days to maturity (-0.188) and days to flowering (-0.109). The present study revealed that direct selection based on panicles per hill, panicle weight, plant height, flag leaf length, filled grains per panicle, spikelet fertility (%), days to flowering and days to maturity would significantly improve the grain yield of salt-tolerant T. Aman rice genotypes. The residual effect permits accurate explanation about the pattern of interaction of other possible components of yield which was not included in the investigation on the dependent variables. The residual effect was 0.138, denoted that contribution of component characters on grain yield per m^2 was 86.2% by the 12 traits studied in path analysis, the rest of 13.8% was the contribution of other factors which were not included in the study on the dependent variable.

Table 5. Partitioning of genotypic correlation into direct (bold phase) and indirect effects of grain yield-related traits in 20 salt-tolerant advance lines of T. Aman rice

Characters	DF	DM	Plant height (cm)	Tillers per hill	Panicles per hill	Flag leaf length (cm)	Panicle length (cm)	Panicle weight (g)	Filled grains per panicle	Spikelet fertility (%)	100-grain weight (g)	Grain yield per m^2 (kg)
DF	**-0.109**	0.217	-0.012	0.159	-0.539	-0.037	-0.003	0.050	-0.003	0.079	-0.005	-0.268*
DM	-0.080	**-0.188**	0.295	0.123	-0.590	0.061	0.001	-0.019	0.027	-0.057	-0.005	-0.286*
Plant height (cm)	0.002	-0.063	**0.882**	0.048	-0.048	-0.461	0.010	0.327	-0.074	0.166	-0.162	0.619**
Tillers per hill	0.061	-0.129	-0.149	**-0.282**	1.001	0.116	-0.004	-0.666	0.306	-0.251	-0.093	0.038
Panicle per hill	0.052	-0.155	-0.038	-0.254	**1.119**	0.026	-0.002	-0.395	0.162	-0.143	-0.084	0.324*
Flag leaf length cm)	-0.014	-0.030	0.211	0.055	-0.083	**0.581**	-0.597	0.252	-0.039	0.166	-0.146	0.268*
Panicle length (cm)	0.010	0.012	0.300	0.035	-0.078	-0.221	**0.030**	0.094	-0.029	0.041	-0.086	-0.051
Panicle weight (g)	-0.006	-0.006	0.321	0.209	-0.491	-0.167	0.003	**0.900**	-0.287	0.172	-0.086	0.382**
Filled grains per panicle	-0.001	-0.017	-0.456	0.189	-0.398	-0.051	0.002	0.144	**0.566**	0.269	0.269	0.681**
Spikelet fertility (%)	-0.021	-0.040	0.352	0.170	-0.384	-0.238	0.003	0.372	-0.294	**0.416**	0.172	0.582**
100-grain weight (g)	-0.001	0.003	0.307	-0.057	0.201	-0.187	0.006	0.166	0.263	-0.153	**-0.466**	-0.153

Residual effect 0.138

CONCLUSION

The analysis of variance of all characters studied was highly significant that revealed a wide range of variability among 20 newly developed salt-tolerant genotypes of T. Aman. rice. The genotypes BU1, BU4, BU6, BU7, and BU14 had high grain yields and could be directly selected as high-yielding varieties. The genetic parameters revealed that selection based on all traits could significantly improve the grain yield. The correlation coefficient revealed that genotype could be directly selected based on days to flowering, days to maturity, plant height (cm), panicles per hill, flag leaf length (cm), panicle weight (g), filled grains per panicle, and spikelet fertility (%)

and 100-grain weight for the improvement of grain yield of salt-tolerant T. Aman rice genotypes. However, considering the genotypic correlations and path coefficients, direct selection on the basis of panicles per hill, panicle weight, plant height, flag leaf length, filled grains per panicle, spikelet fertility (%), days to flowering, and days to maturity would significantly improve the grain yield of salt-tolerant T. Aman rice genotypes.

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GENETIČKA VARIJABILNOST, HERITABILNOST I MEĐUSOBNI ODNOSI KOD LINIJA PIRINČA TOLERANTNIH NA SO-T. AMAN

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Izvod

Dvadeset linija pirinča T. Aman otpornih na so proučavano je u poljskim uslovima na eksperimentalnoj farmi Odeljenja za genetiku i oplemenjivanje biljaka, Bangabandhu Sheikh Mujibur Rahman poljoprivrednog univerziteta, Bangladeš. Eksperiment je sproveden prema randomiziranom kompletnom blok dizajnu (RCBD) sa tri ponavljanja da bi se procenile genetičke varijacije u prinosu i osobinama povezanih sa prinosom, njihov međusobni odnos i direktni i indirektni efekti različitih osobina povezanih sa prinosom na prinos zrna značajnih za selekciju na visok prinos T. Aman. Dvanaest osobina, broj dana do cvetanja, broj dana do zrelosti, visina biljke (cm), broj biljaka po kućici, dužina lista zastavičara (cm), dužina klasa (cm), težina klasa (g), broj zrna po klasu, procenat fertilnih klasića, masa 100 zrna (g) i prinos zrna po m2 (kg). Genotipovi su se značajno razlikovali za sve proučavane osobine što je ukazalo na širok raspon varijabilnosti među njima. Analiza varijanse svih proučavanih osobina bila je veoma značajna i otkrila je širok spektar varijabilnosti između novorazvijenih 20 genotipova pirinča T. Aman otpornih na so. Genotipovi BU1, BU4, BU6, BU7 i BU14 sa visokim prinosom zrna mogli su se direktno odabrati kao visokoprinosne sorte. Na osnovu svih genetičkih parametara, sve osobine bi mogle značajno da poboljšaju prinos zrna linija pirinča T. Aman, tolerantnih na so. Koeficijent korelacije je otkrio da je genotip odabran na osnovu broja dana do cvetanja, broja dana do zrelosti, visine biljke (cm), broja klasova po kućici, dužine lista zastavičara (cm), težine klasa (g), zrna po klasu i plodnosti klasića (%) i težine 100 zrna direktno, značajno doprineo prinosu zrna 20 genotipova T. Aman pirinča otpornih na so. Međutim, s obzirom na genotičke korelacije i koeficijente puta, direktna selekcija na osnovu broja klasova po kućici, težine klasa, visine biljke, dužine lista zastavičara, zrna po klasu, plodnosti klasića (%), broju dana do cvetanja i broju dana do zrelosti bi značajno poboljšala prinos zrna genotipova pirinča T. Aman otpornih na so.

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