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Genetic-environment interaction and genetic advance of superior wheat mutants by Francis and Kannenberg's method

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Abstract

Increasing salinity, in the coastal area, is one of the major reasons of reducing wheat production. It is necessary to develop high yielding salt tolerant genotypes for sustainable yield of wheat in these areas. In our previous study, 37 lines were selected based on Francis and Kannenberg (1978) method following mean and standard deviation (SD) constructed in scattered plot diagram. In the present study, these selected lines along with 'Prodip' were grown in two different conditions: one is non-saline condition (BINA, Mymensingh) and another is saline condition (BINA, Satkhira). These wheat genotypes were evaluated to select the best performing lines which are stable in both the environment for their yield attributes. In RCBD trail with 3 replications, it was revealed that there were variations for plant height, flag leaf duration, spike length, spikelets per spike, 100-grain weight, number of tiller and yield per plant. Plant height, spikelets per spike and yield per plant showed higher heritability, higher phenotypic coefficient of variation and genetic advance. However, spike length, number of tiller and flag leaf duration showed medium heritability. Genotype-environment interaction and stability analysis showed variation for plant height, flag leaf duration, 100 grain weight and yield per plant and the line L-61-18, L-879-2, L-879-22, L-880-7, L-880-18 and L-880-43 were the most potential and stable genotypes in both saline and non-saline environments for yield. Higher selection score was obtained from L-880-38 followed by L-879-34 and L-880-36 and lower selection score was obtained from L-880-34 respectively. Importance should be given on plant height, spike length, spikelet per spike and yield per plant for selection of salt tolerant wheat line in future wheat research programme.

Key words: Mutants, wheat, yield contributing characters, saline tolerant, Prodip

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Introduction

Wheat (*Triticum aestivum*), widely cultivated cereal grain, is the second most important winter crops in Bangladesh. After maize, it is also the second most produced cereal crop in the world. Although the global production of wheat is in increasing trend (FAO, 2018/19), in Bangladesh, it is in decreasing trend after 1997 (BBS, 2018). From 2016, the yearly total production is below 5 lakh metric ton (BBS, 2018).Last 45 years data revealed that the yield rate of wheat in Bangladesh is increasing. However, the area of production is decreasing continuously since 1999/2000 (BBS, 2018). One of the reasons of this scenario of wheat production in Bangladesh is the increasing of soil salinity.

Many soil salinity problems have been reported in large irrigation schemes in many countries in Central Asia, where more than 16 Mha of irrigated land are now salinized (FAO, 2010). It is one of the major obstacles to decrease in wheat production on millions of hectares of land in arid and coastal areas in the tropics and sub-tropics. In principle, elevated salinity in soils results mainly from two sources such as natural and man-made. Salinity in arid and semiarid areas is mainly caused by natural factors viz; low precipitation, high level of evaporation and existence of saline parent rock. On a global scale, nearly 40% of the earth's land surface is potentially endangered by salinity problems of which approximately 19% of the world's agricultural land is subjected to salt stress (FAO, 1996).

Out of 2.85 million hectares of coastal and offshore land of Bangladesh about one million hectare of arable land across around 64 upazillas in 13 coastal and offshore districts are adversely affected by varying degrees of salinity (Karim *et al*., 1990) and remains fallow during the dry months. This is the target area for which salt tolerant varieties are needed. The intrusion of sea water during tidal flood and tidal bores along the rivers and estuaries in the coastal belt is the main cause of this salinization. Those soils have highly saline, shallow underground water table and subsequent evaporation of water from the soil increases salinity during the dry season. Salinity also moves into inland areas as well as ground water level due to drainage deterioration of the flood plain of the Ganges and greater use of sea water for shrimp culture. In principle, the loss of agricultural land resulting from increasing salinity could be reversed either by soil desalinization or by the use of salt tolerant varieties (Yeo and Flowers 1986).

Moreover, various morphological and physiological characters contribute to the grain yield. These yield contributing characters are related to each other showing a complex chain of relationship with yield. The effectiveness of increasing yield in a crop depends upon the genetic variation of the yield related traits (morphological and physiological). These characters are to some extent influenced by the growing environment for their potential expression. The magnitude of variability and more particularly its genetic components are clearly the most important aspect of the genetic constitution of the breeding materials. In this study, we have aimed to estimate heritability, genetic advance and selection index of 37 superior lines, selected from our previous study, based on morphological characters, for screening the superior mutant lines for salt effected land areas.

Materials and Methods

Experimental site and season**:** The experiment was carried out at two different places:

Place 1: BINA at Mymensingh (non-saline land): The soil of this experimental area is a medium high land belonging to the Old Brahmaputra Floodplain Agro-ecological Zone-9 (UNDP and FAO 1988). The texture of the soil is silty loam having pH 6.7, low in organic matter and fertility level.

Place 2: BINA at Satkhira (saline land): The soil of this experimental area is medium low land belonging to the Ganges Tidal Floodplain Agro-ecological Zone-13 (UNDP and FAO, 1988). The texture of the soil is loam having pH range from 6.2-8.4. Satkhira lies about 1.5 to 11.8 meters above the mean sea level. The CEC of the soil range from 14.2-25.2 m.e.%. The organic matter level in Satkhira soil is 1.8-2.2% with N content 0.9 to 0.3%. During the monsoon, salinity level usually remains 8-12dS/m. About 146 thousand hectares of land in Satkhira are saline. Two types of saline soil are found: (i) saline calcareous and non-calcareous soil, and (ii) saline acid sulphate soil.

Plant material**:** Thirty-seven wheat mutants were used as experimental material, selected by Francis and Kannenberg's method based on high yield in non-saline land. The variety 'Prodip' was used as control genotype, collected from wheat research programme, Plant Breeding Division, Bangladesh Institute of Nuclear Agriculture (BINA).

Experimental design and plant growth conditions**:** The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The plot size was 6m × 2.5m. The distance regarding block to block was 1m, plot to plot was 75cm, line to line was 20cm and plant to plant within rows was 5 cm. The seeds were sown on 1st December 2011 in continuous rows keeping the row-to-row distance of 30 cm. Finally, plants in a row were kept at a distance of about 5cm. Thinning was done after 10 days of sowing. Two times weeding was done, oneafter 10 days of sowing seeds and the other after irrigation. In raising the experimental crop, one irrigation was applied. Other intercultural operations were done as and whenever necessary. The plants were harvested at full maturity. Harvesting was done on 24 March 2012.

***Statistical analysis*:** Pooled analysis of variance for genotype-environment interaction was performed by the Plant Breeding Statistical Program (PLABSTAT, Version 2N) using the following model:

$Y_{ijk} = \mu+g_i +e_j + r_{ik}+ge_{ij} + \varepsilon_{ijk}$……………………Eq. 1

Where,

Y_{ijk} = observation of genotype i in environment j in replication k,
μ = general mean,
g_i = effect of genotype i,
e_j = effect of environment j,
r_{ik} = effect of replication k in the environment j,
ge_{ij} = genotype x environment interaction of genotype i with j,
ε_{ijk} = residual error of genotype i in environment j in replication k.

Analysis of variance was performed using the plant breeding statistical program (PLBSTAT, Version 2N) with the following model:

$y_{ij} = g_i + r_j + \varepsilon_{ij}$……………………………………Eq. 2

Where,

y_{ij} = observation of genotype i in replication j
g_i = effects of genotype i
r_j = effects of replication j,
ε_{ij} = the residual error of genotype i in replicate j.

The replicates were considered as random variable. Multiple mean comparisons were made with Fisher's least significant difference (LSD) procedure using Stat Graphics Plus (Statistical Graphics Crop. Rockville, USA).

***Estimation of heritability*:** Heritability in broad sense (h^2_b) was estimated according to the formula suggested by Johanson *et al.* (1955) and Hanson *et al*. (1956).

***Estimation of genetic advance*:** Genetic advance (GA) was estimated according to the following formula-

Genetic advance (GA) = $h^2 \sqrt{\delta^2_p}$. i………………Eq. 3

Here,

h^2=heritability
δ^2_p=standard deviation
i=standardized selection differential

***Estimation of selection index*:** Selection indices were constructed using the methods developed by Smith (1936) based on the discriminate function of Fisher (1936).

Results and Discussion

***Pooled analysis of variance*:** It was observed that genotypic effects were highly significant for plant height, spike length and spikelet per spike indicating presence of variation among genotypes for these characters (Table 1). The environment was also showed highly significant difference for plant height and spike length whereas number of tiller and yield per plant were non-significant for different genotypes. The genotypes were not significantly different for spike length and 100 grain weight. In case of genotype environment interaction, it was found that G×E interaction was highly significant for plant height, flag leaf duration spike length, spikelet per spike and 100-grain weight.

***Analysis of environmental effect on the performance of the genotypes*:** Plant height, spike length, number of tiller and yield per plant had the highest value in environment-1 and in environment -2 spikelets per spike, flag leaf duration, 100-grain weight had highest value (Table 2). In environment -2, plant height and spike length had significantly lower values than environment-1. The remainder traits including spikelets per spike, number of tillers, 100-grain weight and yield per plant did not differ significantly between the two environments: saline and non-saline.

Table 1. Analysis of variance for seven plant characters in a G×E interaction study with 38 wheat genotypes (37 mutants and 'Prodip').

Item	Plant height (cm)	Flag leaf duration (Days)	Spike length (cm)	No. of Spikelets/ spike	No. of tiller	100 grain weight (g)	Yield/ plant (g)
Genotypes	71.6559**	9.8355	4.26**	17.5865**	6.5624	0.6497	19.27
Environment	7885.669**	5.6842	113.9429**	1.7544	3.4386	0.392	15.1591
Replication	7.5806	0.9518	13.2865	2.5833	1.8289	0.3043	3.6253
G-E	28.0961**	8.0896**	1.7118**	6.2769**	6.2494**	0.8906**	14.8624**

Table 2. Summary mean and LSD value of different plant characters of 38 wheat genotypes in two environments.

Items	Plant height (cm)	Flag leaf duration	Spike length (cm)	Spikelets/ spike	No. of tiller	100 grain weight (g)	Yield/plant (g)
Environment-1	94.27	100.09	12.04	18.19	9.02	4.18	12.68
Environment-2	82.51	100.4	10.63	18.37	8.77	4.26	12.16
Mean	88.39	100.25	11.33	18.28	8.89	4.22	12.42
LSD 0.05	1.5	0.85	0.41	0.67	0.62	0.25	1.19

***Analysis of mean performance of the genotypes*:** The mean performances of 37 wheat mutant genotypes with standard check variety 'Prodip' over saline and non-saline environments were evaluated for seven characters presented in (Table 3). From the tabular results it was observed that the mutant L- 880-5 was significantly tallthan the others. In contrast, l- 879-33 was the shortest plant which did not differ significantly with l-61- 28, l-879-1, l-880-26 and l-880-27. The check variety, 'Prodip' had intermediate height between these two groups. Flag leaf duration was longest in L-880-11 that did not differ significantly with the check variety, 'Prodip'and L-880-18 had shorter flag leaf duration which was not significantly different from L-880-13. Spike length was longest in L-61-18 that did not differ significantly with the check variety and l-61-15. L-61-35 had the shortest spike length. L-61-7 and L-885- 10 had the highest spikelet per spike and L-880-36 had the lowest spikelet per spike. L-880-14 had the highest number of tillers which was not significantly different from L-879-11 and L-880-18 had lowest number of tillers per plant which was not significantly different from L-879-1. Hundred grain weights was highest in L-885-10 that did not differ significantly with L-879-1 and L-880-27 and L-880-5 was the lowest 100 grain weight. L-880-43 had the highest yield per plant and L-880-27 had the lowest yield per plant. Plant height fluctuates in both the environments and mostly reduced in environment-2.

***Genotype-environment (G-E) interaction and stability*:** It was found that differences exist among genotypes for plant height, spikelets per spike, number of tiller and yield per plant in both saline and non-saline environment.

Table 3. Mean performances of 37 wheat mutant genotypes and standard check variety 'Prodip' for yield and yield contributing characters averaged over two environments.

Genotypes	Plant height (cm)	Flag leaf duration (days)	Spike length (cm)	Spikelets/spike	No. of tiller	100 grain weight (g)	Yield/plant (g)
L-885-10	89.18g-k	99.67h-l	11.37c-h	21.33ab	9.333b-g	4.798a	10.99i-n
L-61-7	87.82j-m	100g-k	11.52c-h	21.5a	9.5b-f	4.278a-g	11.95f-m
L-61-12	88.6h-l	99.17j-l	10.78e-i	20.5a-e	9.667b-e	4.332a-g	12.71e-j
L-61-15	87.28k-n	101.3c-f	13.17ab	20b-g	8.333e-i	4.275a-g	11.54g-m
L-61-18	88.31i-l	98.83kl	14.03a	20b-g	8.167f-j	4.34a-g	11.59g-m
L-61-28	84.25o-r	100.5d-i	12.42bc	19.5c-i	9b-h	3.973c-g	11.73g-m
L-61-33	87.27k-n	101.7cd	11.52c-h	19.17e-i	8.333e-i	4.03b-g	9.218no
L-61-34	89.62f-j	99.83g-k	11.39c-h	20.33a-f	7.667h-k	4.418a-f	11.9f-m
L-61-35	92.7cd	99.67h-l	10.17i	18.67g-k	6.833jk	4.43a-f	10.96j-n
L-61-37	94.03bc	98.83kl	10.75e-i	18.67g-k	8.333e-i	4.512a-e	12.16f-l
L-879-1	84.29o-r	101.8bc	10.52g-i	19.33d-i	6.667k	4.877a	12.22f-l
L-879-2	87.25k-n	101c-g	11.2d-i	15.83pq	9b-h	4.243a-g	11.53g-m
L-879-4	87.55j-n	100.8c-h	10.6f-i	19.5c-i	9.167b-g	4.73ab	10.9j-n
L-879-5	85.42n-p	101.5c-e	11.56c-h	16pq	9.333b-g	4.682a-c	13.74c-f
L-879-11	84.53o-q	98.5lm	11.03d-i	20.83a-c	10.33ab	3.833e-g	12.57f-j
L-879-22	85.8m-o	100.2f-j	10.8e-i	17m-p	9.5b-f	4.31a-g	15.4bc
L-879-32	88.48i-l	99.67h-l	10.82e-i	17.67j-n	9.333b-g	4.232a-g	13.22d-g
L-879-33	82.28r	100.5d-i	11.63c-f	18.5h-l	10a-d	3.983c-g	12.89e-i
L-879-34	89.27g-k	100.7c-i	11.45c-h	18.17i-m	9.5b-f	3.765fg	12.54f-j
L-880-1	92.9cd	101.8bc	10.7e-i	17m-p	8.333e-i	4.44a-f	12f-m
L-880-5	98.02a	100.8c-h	11.05d-i	19.67c-h	10.17a-c	3.635g	10.33l-o
L-880-7	86.89l-n	99.5i-l	10.92e-i	17m-p	9.333b-g	4.218a-g	13.1d-h
L-880-10	87.92j-m	100.2f-j	11.2d-i	18.33h-m	9.333b-g	3.958c-g	12.28f-k
L-880-11	87.68j-m	103.3a	11.52c-h	17m-p	9.833b-d	4.043b-g	12.68f-j
L-880-13	85.92m-o	97.33mn	11.2d-i	16.17o-q	8.833c-h	4.41a-f	10.46k-o
L-880-14	92.27c-e	100.3e-j	12.05cd	17.5k-o	11.33a	3.767fg	10.2m-o
L-880-15	85.35n-p	100.5d-i	11.25d-i	16.17o-q	9b-h	3.73fg	11.82g-m
L-880-17	88.24i-l	100.7c-i	10.62e-i	15.83pq	9.167b-g	4.273a-g	11.27h-m
L-880-18	88.27i-l	97.17n	11.07d-i	17.5k-o	6.667k	3.972c-g	12.62f-j
L-880-19	91.28d-g	100.7c-i	11.37c-h	17m-p	8g-k	4.652a-d	13.16d-h
L-880-20	91.85c-f	99.67h-l	10.79e-i	16.5n-o	8.167f-j	4.16a-g	15.3bc
L-880-26	83.53p-r	99.5i-l	11.6c-g	20.67a-d	9.5b-f	3.9e-g	14.85b-d
L-880-27	82.57qr	100.3e-j	11.7c-e	18.33h-m	9b-h	4.785a	8.638o
L-880-34	87.54j-n	100.8c-h	10.7e-i	19f-j	9.333b-g	3.723fg	13.31d-g
L-880-36	90.37e-i	98.83kl	11.02d-i	15q	8g-k	4.023b-g	12.24f-l
L-880-38	90.79d-h	99.83g-k	10.49hi	17m-p	7i-k	3.933d-g	14.62b-e
L-880-43	88.37i-l	100.8c-h	10.79e-i	19.33d-i	8.667d-h	4.39a-f	17.44a
Prodip	95.27b	103ab	13.89a	17.17l-p	10.33ab	4.273a-g	15.83ab
Mean	88.39	100.25	11.33	18.28	8.89	4.22	12.42
Min	73.6	95	8.6	14	4	2.58	5.44
Max	109	105	16	25	14	6.35	20.5
LSD (0.05)	6.2	3.33	1.53	2.93	2.92	1.1	4.51

Variation was low in case of flag leaf duration, spike length and 100-grain weight (Table 4).

In case of plant height in non-saline environment maximum value was found in L- 880-5 (107.07cm) and minimum value in L-880-27 (85.17cm) whereas in saline environment, 'Prodip' had maximum plant height and L-879-22 had minimum value. Variation was prominent for the characters plant height, spikelets per spike, number of tiller and yield per plant.

Table. 4. Analysis of mean for genotype-environment interaction on yield and yield contributing characters of 37 wheat mutants including 'Prodip'.

Genotypes	Environments	Plant height (cm)	Flag leaf duration (days)	Spike length (cm)	Spikelets/ spike	No. of tiller	100 grain weight (g)	Yield/plant (g)
L-885-10	Env-1	96.07	98.33	12.15	23	8	4.68	9.26
	Env-2	82.3	101	10.6	19.67	10.67	4.92	12.72
L-61-7	Env-1	91.87	99.33	12.37	20.67	11	4.07	11.32
	Env-2	83.78	100.67	10.67	22.33	8	4.49	12.59
L-61-12	Env-1	92.4	99.67	12.33	21	10.33	4.39	12.22
	Env-2	84.8	98.67	9.23	20	9	4.28	13.19
L-61-15	Env-1	91.33	100.67	14	19	9	3.82	10.86
	Env-2	83.23	102	12.33	21	7.67	4.73	12.23
L-61-18	Env-1	93.4	98.67	13.03	19.33	9.33	5.1	11.68
	Env-2	83.23	99	15.03	20.67	7	3.58	11.5
L-61-28	Env-1	91.33	101.67	12.6	19.33	10.67	3.73	10.59
	Env-2	77.17	99.33	12.23	19.67	7.33	4.22	12.86
L-61-33	Env-1	91.93	102.33	12.8	18	6.67	4.15	6.07
	Env-2	82.6	101	10.23	20.33	10	3.91	12.37
L-61-34	Env-1	94.93	99.67	11.23	19.67	6.33	4.82	12.16
	Env-2	84.3	100	11.54	21	9	4.01	11.64
L-61-35	Env-1	97.07	100	10.77	20.33	8.33	4.06	10.51
	Env-2	88.33	99.33	9.57	17	5.33	4.8	11.42
L-61-37	Env-1	99.73	98.33	11.23	18.67	8	5.09	12.75
	Env-2	88.33	99.33	10.26	18.67	8.67	3.93	11.57
L-879-1	Env-1	85.53	102.33	10.8	20.33	5.67	5.38	12.4
	Env-2	83.05	101.33	10.23	18.33	7.67	4.37	12.03
L-879-2	Env-1	96.27	100.33	12.2	16.67	9	4.03	13.63
	Env-2	78.23	101.67	10.2	15	9	4.45	9.43
L-879-4	Env-1	96.6	103.67	11.07	19.33	9.67	5.12	10.44
	Env-2	78.5	98	10.13	19.67	8.67	4.34	11.37
L-879-5	Env-1	90.13	101.67	12.05	16.33	8.67	4.47	16.13
	Env-2	80.7	101.33	11.07	15.67	10	4.89	11.36
L-879-11	Env-1	93.27	98.33	11.4	21.33	9.33	3.88	11.02
	Env-2	75.8	98.67	10.67	20.33	11.33	3.79	14.13
L-879-22	Env-1	96.4	99	11.63	17.33	9.33	4.1	19.59
	Env-2	75.2	101.33	9.97	16.67	9.67	4.52	11.21
L-879-32	Env-1	94	99.67	11.77	17	9.33	3.61	14.85
	Env-2	82.97	99.67	9.87	18.33	9.33	4.86	11.59

L-879-33	Env-1	89	100.67	12.92	19.33	9.67	3.59	13.36
	Env-2	75.55	100.33	10.33	17.67	10.33	4.38	12.41
L-879-34	Env-1	95.6	97.33	12.27	17.67	9.33	3.84	13.16
	Env-2	82.93	104	10.63	18.67	9.67	3.69	11.93
L-880-1	Env-1	98.73	103.33	11.8	16.33	9.33	4.95	12.03
	Env-2	87.07	100.33	9.6	17.67	7.33	3.93	11.96
L-880-5	Env-1	107.07	101.33	11.63	18.33	11.33	3.56	10.67
	Env-2	88.97	100.33	10.47	21	9	3.71	9.99
L-880-7	Env-1	94.07	98.33	11.9	16	12.33	4.44	13.05
	Env-2	79.72	100.67	9.93	18	6.33	4	13.14
L-880-10	Env-1	93.97	100.67	11.99	20.33	8.67	3.65	12.97
	Env-2	81.87	99.67	10.41	16.33	10	4.26	11.59
L-880-11	Env-1	96.07	104	13.1	17	9.67	3.75	14.33
	Env-2	79.3	102.67	9.94	17	10	4.34	11.04
L-880-13	Env-1	95.87	96	12.04	16.67	9.67	3.99	9.48
	Env-2	75.97	98.67	10.37	15.67	8	4.83	11.45
L-880-14	Env-1	99.33	101.67	13.27	18.67	11.33	3.88	7.76
	Env-2	85.2	99	10.83	16.33	11.33	3.66	12.64
L-880-15	Env-1	91.53	101.67	11.67	17	9	3.32	11.68
	Env-2	79.17	99.33	10.83	15.33	9	4.14	11.95
L-880-17	Env-1	94.68	100.33	12.2	17	8.67	3.79	11.88
	Env-2	81.8	101	9.03	14.67	9.67	4.75	10.66
L-880-18	Env-1	92	96	11.9	16	6.33	4.12	13.6
	Env-2	84.53	98.33	10.24	19	7	3.83	11.63
L-880-19	Env-1	96.13	100	11.9	14.67	7.67	5.03	14.4
	Env-2	86.43	101.33	10.84	19.33	8.33	4.28	11.91
L-880-20	Env-1	95.47	98.67	11.77	17.33	7.33	3.73	18.21
	Env-2	88.23	100.67	9.8	15.67	9	4.59	12.39
L-880-26	Env-1	88.73	98	12.13	20.33	9.67	4.4	16.09
	Env-2	78.33	101	11.08	21	9.33	3.4	13.62
L-880-27	Env-1	85.17	99	11.97	17	8.67	4.58	9.42
	Env-2	79.97	101.67	11.43	19.67	9.33	4.99	7.86
L-880-34	Env-1	93.2	101.67	11.63	18.67	9.67	3.84	11.57
	Env-2	81.88	100	9.77	19.33	9	3.61	15.05
L-880-36	Env-1	97.03	97.33	11.54	14.33	9.67	3.37	10.1
	Env-2	83.7	100.33	10.5	15.67	6.33	4.68	14.37
L-880-38	Env-1	95.22	100.67	11.32	16.33	8.33	3.75	17.4
	Env-2	86.37	99	9.67	17.67	5.67	4.11	11.84
L-880-43	Env-1	94.57	99	11.9	19.67	8.67	4.98	16.93
	Env-2	82.17	102.67	9.69	19	8.67	3.8	17.95
Prodip	Env-1	96.73	104	13.25	15.33	9	3.68	18.13
	Env-2	93.8	102	14.53	19	11.67	4.87	13.53
LSD (0.05)		6.2	3.33	1.53	2.93	2.92	1.1	4.51

'Prodip' and L-880-11 had higher flag leaf duration in non-saline environment and L-880-13 had lower flag leaf duration. In case of saline and non-saline environment flag leaf duration ranged from 104 to 98 days and higher flag leaf duration was obtained from L-879-34, and L-880-43 and lower flag leaf duration was obtained 98 days for L-879-4. Spike length was showed variation. Thus, L-61-15 and L-61-18 had the higher and lower, respectively, spike length in Environment-1. L-61-18 and L- 880-17 had the maximum and minimum spike length. L-885-10 and L-61-7 had higher spikelets per spike in non-saline and saline environment, whereas L-880-36 and L-880-17 had lowest spikelets per spike in non-saline and saline environment. Plant character, number of tillers per plant was found more variable. L-880-7 and 'Prodip' had maximum number of tillers in non-saline and saline environment. In both environment 5.67 is the minimum number of tillers. In case of 100-grain weight, L-879-1 had maximum value and L-880-15 had the lowest in non-saline environment. In saline environment, L-885-10andL-880-26hadhigher and lower 100 grain weight. L-879-22 and L-880-43 had higher grain yield per plant in non-saline environment and saline environment L-61-33 and L-880-27 had lower value. Yield per plant for the wheat genotype was found highly fluctuated in both environments. Fluctuation was found for the lines L-879-22, L-61-33, L-880-10, L- 880-27, L-880-36 and 'Prodip'. More or less same yield per plant in both environments was found for the lines L-61-12, L-61-18, L-61-34, L-61-35, L-61-37, L-879-4, L-879-33, L-880-1, L-880-5, L-880-18 and L-880-43.

***Variability, heritability and genetic advance for yield and yield contributing characters*:** Phenotypic and genotypic co-efficient of variation, heritability and genetic advance for yield and yield contributing characters for 38 wheat genotypes (37 mutants and 'Prodip') are presented in the (Table 5). Estimates of heritability in broad sense indicates that plant height, flag leaf duration, spikelets per spike, were highly heritable. Number of tillers, spike length and yield per plant showed medium heritability and 100-grain weight showed low heritability. High heritability for plant height, number of tillers per plant, spike length, grain yield per plant and low heritability for number of spikelets per spike was also observed by Khan *et al*. (2005).

Table 5. Genetic parameters of selected genotypes for yield and yield contributing characters.

Characters	Phenotypic coefficient of variation (PCV%)	Genotypic co- efficient of variation (GCV%)	Heritability (%)	Genetic advance (GA)
Plant height (cm)	71.66	67.74	94.59	13.3
Flag leaf duration	9.84	8.6	88.6	4.28
Spike length (cm)	4.26	3.35	79.59	2.26
Spikelet per spike	17.59	16.02	91.01	6.1
No. of tiller	6.56	5.02	76.37	2.61
100 grain weight	0.65	0.24	37.86	0.2
Yield per plant (g)	19.26	16.4	85.41	5.58

It was observed that the character plant height showed the highest phenotypic co-efficient of variation. This was followed by the characters yield per plant, spikelets per spike and flag leaf duration. All these characters had more than 15% phenotypic co-efficient of variation. These characters exhibited also considerable amount of genotypic co-efficient of variation. The characters 100-grain weight and spike length exhibited minimum phenotypic and genotypic co-efficient of variation. Flag leaf duration, spike length, spikelets per spike and number of tillers showed little differences between phenotypic and genotypic co-efficient of variation, which suggests the expression of this character was less influenced by the environment. Plant height, 100-grain weight and yield per plant showed many differences between phenotypic and genotypic coefficients of variation indicating that these characters were influenced by the environment.

The results of the present study supported by the findings of Mukherjee *et al.* (2008) in bread wheat, who studied phenotypic and genotypic coefficients of variation and reported maximum coefficients of variation of spikes per plant. Sidharthan and Malik (2007) studied phenotypic and genotypic coefficients of variation and reported maximum coefficients of variation for grain yield per plant in bread wheat. Bergale *et al.* (2001) conducted an experiment with 50 bread wheat genotypes and observed that the genotypic and phenotypic coefficients of variation were high for spikes per plant, 100-grain weight and grain yield per plant. High genotypic coefficients of variation for spikes per plant and grain yield per plant were reported by Kumar and Mishra (2004) in 30 diverse bread wheat cultivars. The results of the present study indicate that the characters plant height, 100- grain weight and yield per plant had more variation and selection for these characters would give good response.

Analysis of genetic advance (Figure 1) showed that the characters; plant height, spikelets per spike and yield per plant had more than 30% expected genetic advance which could be considered for good selection. The characters; spike length, number of tillers, flag leaf duration and 100 grain weight had minimum genetic advanced. Plant height, spikelets per spike and yield per plant recorded high heritability coupled with high genetic advance suggesting that this character was predominantly controlled by additive gene effects. Therefore, direct selection for these characters in early generation would give effective response.

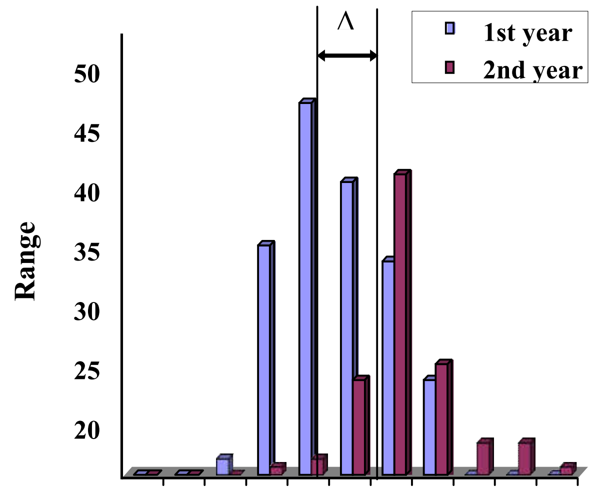

Figure 1. Graphical presentation of genetic advance among the wheat lines between two years. ΔG: genetic advance.

Sidharthan and Malik (2007) stated that high heritability accompanied by high genetic advance in percentage of mean for number of grains per spike, 100-grain weight and grain yield per plant in spring wheat. Khan et al. (2005) estimated high heritability accompanied with high genetic advance in percentage of mean for grain yield per plant. They obtained medium heritability in bread wheat and reported high heritability for 100-grain weight. They also reported moderate broad sense heritability coupled with low genetic advance for spikes per plant. Gupta et al. (2004) reported moderate heritability coupled with low genetic advance in percentage of mean for spikelets per spike and high heritability with high genetic advance in percentage of mean for grain yield per plant in bread wheat. A character with high phenotypic coefficients of variation and high heritability generally gives high genetic advance. Therefore, selection should aim at those characters which exhibited high heritability, high phenotypic coefficient of variation and high genetic advance.

***Selection index*:** Selection index is a method of artificial selection in which several useful traits are selected simultaneously. Selection index was constructed to select genotypes among 37 lines and the variety 'Prodip'of wheat in order to recommendation for further selection model in further generation considering yield per plant. Genotype L-880-38 possessed the highest selection score index and ranked as the best followed by the genotypes L-879-34, L-880-36 and L-880-11 (Table 6) with 215.38, 211.29 and 209.73 respectively. The genotype L-880-34 was worst having the lowest selection score followed by L-880-20, L-880-10 and L-880-15. The expected genetic gain (ΔG) was 18.90 at 5% selection intensity.

In summary, plant height was higher in non-saline environment than saline environment. L-880-5 was the tallest plant and L-879-33 was the most dwarf. L- 880-14 had the highest number of tiller and L-880-18 had the lowest among the 37 genotypes. Number of tillers was higher in non-saline environment than saline environment. L-61-7 showed higher spikelets per spike followed by L-885-10. In env-2 genotypes produced higher spikelets per spike and 100 grain weight. L-885-10, L-879-1 and L-880-27 had heaviest seed and L-880-5 had smallest seed. Grain yield showed highest value in env-1 and L-880-43 yielded highest whereas L-880-27 yielded lowest. Thus env-1 (Mymensingh location) was better than env-2 (Satkhira location) for the genotypes and the genotypes L-880-11, L-880-36, L-61- 37, L-879-34, , L-61-12, L-61-18 and L-880-38 were most suitable for cultivation across all the environments under study while other genotypes varied in their performance. Among the characters plant height, flag leaf duration and spike length were highly heritable over both environments. Spike length, number of tiller and yield per plant showed medium heritability and 100 grain weight showed low heritability. The wheat line L-880-11 had longer flag leaf duration followed by 'Prodip', L-879- 34, L-880-43 and L-880-11, L-880-13 had shorter

Table 6. Selection score, rank and expected genetic gain of 38 (37 mutants and 'Prodip') genotypes of wheat considering yield character.

Sl No.	Genotypes	Selection score/ selection index	Rank	Expected genetic gain
1	L-885-10	208.55	6	18.90
2	L-61-7	204.34	24	
3	L-61-12	208.2	9	
4	L-61-15	206.26	15	
5	L-61-18	205.84	16	
6	L-61-28	202.75	27	
7	L-61-33	202.43	30	
8	L-61-34	206.38	14	
9	L-61-35	205.3	21	
10	L-61-37	209.29	5	
11	L-879-1	200.75	33	
12	L-879-2	202.07	31	
13	L-879-4	205.35	20	
14	L-879-5	204.06	25	
15	L-879-11	205.83	17	
16	L-879-22	202.45	29	
17	L-879-32	207.18	12	
18	L-879-33	208.54	7	
19	L-879-34	215.38	2	
20	L-880-1	203.51	26	
21	L-880-5	205.28	22	
22	L-880-7	207.36	11	
23	L-880-10	197.93	36	
24	L-880-11	209.73	4	
25	L-880-13	199.99	34	
26	L-880-14	202.49	28	
27	L-880-15	199.35	35	
28	L-880-17	207.46	10	
29	L-880-18	208.27	8	
30	L-880-19	205.59	18	
31	L-880-20	197.45	37	
32	L-880-26	206.43	13	
33	L-880-27	201.74	32	
34	L-880-34	195.62	38	
35	L-880-36	211.29	3	
36	L-880-38	219.7	1	
37	L-880-43	204.56	23	
38	Prodip	205.44	19	

flag leaf duration. Plant height, spikelets per spike and yield per plant showed higher phenotypic coefficient of variation and higher genetic advance.

Among the genotypes L-880-38 possessed the highest selection score index and ranked as the based followed by the genotypes L-879-34, L-880-36, L-880-11 and L-61-36 respectively. The genotype L-880-34 was the worst having the lowest selection score followed by L-880-20 and L-880-10. The expected genetic gain (ΔG) was 18.90 at 5% selection intensity i.e. highest scoring genotypes from these 38 wheat genotypes might be recommended for further selection for better yield.

In conclusion, genotypes, environment and their interaction influenced plant height, flag leaf duration, spike length, 100-grain weight and yield per plant. Considering overall performance of the genotypes over environments, selected saline tolerant lines could be performed in satisfactory level up to 12dSm-1 of salt concentration. Therefore, these selected lines could be cultivated in the farmer's field of saline zone after multiplication of the seeds in future wheat extensive programme of the country.

References

BBS (2018). 45 years Agriculture Statistics of Major Crops (Aus, Amon, Boro, Jute, Potato and Wheat) Bangladesh Bureau of Statistics (BBS) Statistics and Informatics Division (SID).

Bergale SB, Mridull AS, Holkai KN, Ruwali, Prasad SVS (2001). Genetic variability, diversity and association of quantitative traits with grain yield in bread wheat (*Triticum aestivum* L.). Madras Agric. J, 88(7/9), 457-461.

FAO (1996). Control of water pollution from agriculture. Irrigation and drainage paper 55. Rome. (http://www.fao.org/docrep/W2598E/W2598E00.htm).

FAO (2010). AQUASTAT Data base (www.fao.org/nr/water/aquastat/main/index.stm).

FAO (2018/19). http://www.fao.org/worldfoodsituation/csdb/en/.

Gupta RS, Singh RP, Tiwari DK (2004). Analysis of path coefficient for yield and its related characters in bread wheat (*Triticum aestivum* L. EmThell). Adv. Pl. Sci. 17(1), 299-302.

Hanson CH, Robinson HF, Comstock RE (1956). Biometrical studies in yield in segregating populations of Korean lespediza. Agron. J., 48, 214-318.

Johnson HW, Robinson HF, Comstock LE (1955). Genotypic and Phenotypic correlation in soybean and their implications in selection. Agron. J., 47, 177-483.

Karim Z, Hussain SG, Ahmed M (1990). Salinity problems and crop intensification in the coastal regions of Bangladesh. Bangladesh Agricultural Research Council.

Khan MQ, Awan SI, Mughal M (2005). Estimation of genetic parameters in spring wheat genotypes under rainfed conditions. Indus Journal of Biological Sciences, 2 (3), 367-370.

Kumar PY, Mishra CN (2004). Genetic variability in wheat (*Triticum aestivum* L.). Biodiversity and sustainable utilization of biological resources, Scientific Publishers, India. 144.

Mukherjee S, Gupta S, Maji A, Gupta S, Bhowmik N (2008). Character association and path coefficient analysis of wheat (*Triticum aestivum* L.) genotypes under late sown condition. Env. and Ecol. 26(4C): 2218-2220.

Fisher RA (1936). The use of multiple measurements in taxonomic problems. Annals of Eugenics, 7, 179-188.

Sidharthan B, Malik SK and Breeding P (2007). Variability studies in wheat. Internat. J. Agric. Sci., 3 (1), 142-144.

Smith HF (1936). A discriminant function for plant selection. Ann Eugn. 7. 240-250.

United Nations Development Programme, Food and Agriculture Organization (1988). Land resources data base. Technical Report 3, II.

Yeo AR, Flowers TJ (1986). Salinity resistance in rice (*Oryza sativa* L.) and a pyramiding approach to breeding varieties for saline soils. Australian Journal of Plant Physiology, 13, 161-173.