Evaluation of Salinity Tolerant Wheat (*Triticum aestivum* L.) Genotypes through Multivariate Analysis of Agronomic Traits

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ABSTRACT

Background: Wheat (*Triticum aestivum* L.) is the second major global cereals mostly grown in winter season which led wheat plants to suffer with salinity stress. Twenty to thirty per cent of the arable land of the world is present in the saline area. Therefore, it is necessary to develop salinity tolerant wheat varieties to meet the future food demand.

Methods: A field experiment was carried out during November 2018 to March 2019 to observe the effect of salinity on yield and other desired plant characters and finally screening of wheat genotypes for salinity tolerance. The experiment was laid out in a complete randomized design containing three treatments with three replications. The treatments were three levels of salinity such as control, 8 dS m^{-1} and 15 dS m^{-1}. Multivariate and principal components analysis was executed to evaluate yield and other plant characters.

Result: The results of the experiment revealed that different plant characters showed wide range of variation under different salinity levels. Biplot analysis considering PC1 and PC2 revealed that grain yield was positively correlated with grain spike^{-1}, spike length, thousand seed weight and total tiller plant^{-1}. Correlation study also revealed that total tiller plant^{-1}, spikelet spike^{-1}, grain spike^{-1} and thousand seed weight showed significant and positive relation with grain yield plant^{-1}. On the basis of yield reduction per cent and yield the genotypes G12 (2.51 g), G16 (2.49 g) and G4 (2.19 g) were found suitable for 15 dS m^{-1} salinity.

Key words: Biplot, Salinity level, Variability, Wheat genotypes, Yield.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the second major global cereals with a global annual production of 756.40 million metric tons from 240 million hectares of land, in 2016-2017 (USDA, 2019). It delivers 20 per cent of the total energy requirement in human food (Shahzad *et al.,* 2013). Human survival in developing countries is directly influence by the wheat production and productivity (Shahzad *et al.,* 2013). The world population is increasing vary quickly and may reach 7.2 to 9.6 billion by the year 2050 and 16.5 billion by the end of the century (UNFPA, 2017), while the crop production is decreasing rapidly due to negative impact of various environmental stresses (Reddy *et al.,* 2017). So, it is now very important to develop stress-tolerant crop varieties to cope with this upcoming problem of food security. To assure food security in the world, crop production should be increased by 50% by 2025. For that reason, the saline-prone area must be brought under intensive crop cultivation.

Wheat is mostly grown in winter season which led wheat plants to suffer with salinity stress. Salinity is a prominent abiotic stress that limits the growth and productivity of crops (Yadav *et al*., 2021). Primarily salinity executes an osmotic stress on plants and secondarily ion toxicity stress. Excess soil salinity may badly affect plant growth either through osmotic inhibition of water uptake by roots or specific ion effects. Specific ion effects may cause direct toxicity or alternatively, the insolubility or competitive absorption of ions may affect plant nutritional balances (Silva *et al.,* 2008). Darwish *et al.* (2009) stated that salinity stress causes serious damage of cellular and physiological processes including photosynthesis, nutrient uptake, water absorption, root growth, spikelet formation, fertilization of florets and cellular metabolism, which lead to yield reduction.

Twenty to thirty per cent of the arable land of the globe is present in the coastal area. Wheat is a cool loving cereal crop mainly cultivated in the winter season. The problem of salinity is severe during the winter dry season due to influx

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of salts from the around to the surface through capillary movement. Due to salinity problem the average crop yield is very low in the saline region. At present the total production of wheat in Bangladesh is about 1.3 million metric tons from 332274 ha of land (BBS, 2020) which is not sufficient as required. Due to lack of salinity tolerant wheat variety the acreage and production of wheat in saline area is very low. In order to increase cropping intensity of saline area and to increase food grain production in country, wheat could be fitted in the cropping pattern. So, it is necessary to develop salinity tolerant wheat varieties to meet the future food demand.

Therefore, with a view to expand the cultivation and to sustain the yield of wheat in the saline prone area, the present research was implemented to evaluate agronomic traits of wheat as screening criteria against salinity and finally selection of wheat genotypes for salinity tolerance.

MATERIALS AND METHODS

The experiment was carried out in the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh, during November 2018 to March 2019. The soil used in the plastic pot was silty clay. Plants were grown in punctured plastic pots. The pots of the same replication were placed inside a single bucket serving as water baths.

The experiment was laid out in a completely randomized design (CRD) with three treatments and three replications. The treatments were control (0.0 dS m^{-1}), 8 dS m^{-1} and 15 dS m^{-1}. Twenty one genotypes were used in this experiment. Before treatment imposition the pots were irrigated with tap water until 25 days of sowing. Then the saline water collected from the sea was diluted for the respective salinity treatments. To protect the plant from osmotic shock the treatment were exposed to 2.5 dS m^{-1} salinity for 5 days before exposing the plants with the respective salinity. Then the plants were irrigated with control, 5 and 12 dS m^{-1} respectively for 7 days. Finally the plants were irrigated with control, 8 and 15 dS m^{-1} respectively.

Urea, triple super phosphate (TSP), Muriate of Potash (MoP) and gypsum were applied at the rates of 150-175, 135-150, 100-110 and 110-125 kg ha^{-1}, respectively. Total amount of TSP, MOP, gypsum and half of urea was applied at the time of final pot preparation. Second split of urea was applied at 22 days after first application. Intercultural practices were done as and when necessary. Crops were harvested when the flag leaf and spikes turned yellow. The data such as plant height, tiller per plant, spike length, spikelet per spike, grains per spike, thousand seed weight, grain yield per plant and biomass per plant were recorded from each plant of three treatments and three replications. The collected data were analyzed using the program SPSS 16.

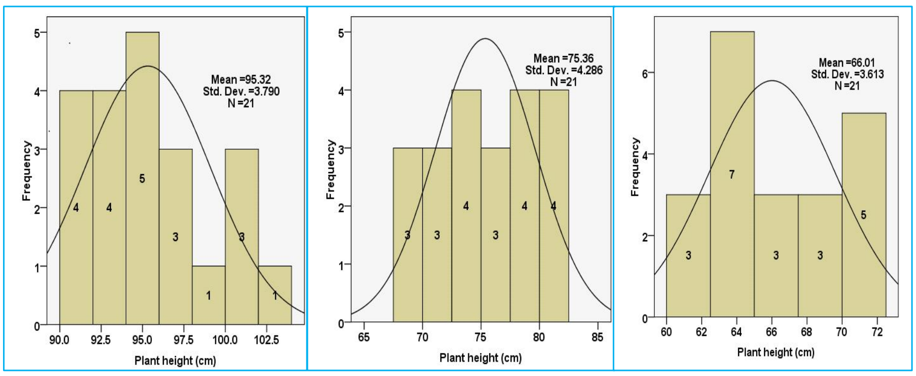
RESULTS AND DISCUSSION

Plant height

At control, plant height of seventeen genotypes ranged from 90 cm to 100.0 cm and four genotypes showed plant height more than 100.0 cm (Fig 1a). At 8 dS m^{-1} salinity, plant height of seventeen genotypes ranged from 67.0 cm to 80.0 cm and four genotypes showed plant height more than 80 cm (Fig 1b). At 15 dS m^{-1} salinity, plant height of sixteen genotypes ranged from 60.0 cm to 70.0 cm and five genotypes showed plant height more than 70.0 cm (Fig 1c). These results show that plant height was decreased due to salinity. Salinity markedly decreases the photosynthetic rate, reduces transportation of compatible nutrients, arrested cell division, which ultimately restricted the shoot growth rate (Ouhaddach *et al*., 2018; Kalhoro *et al.,* 2016). On the other hand, decrease in plant height, also due to the adverse effect of salinity on enzyme activity which subsequently affects the synthesis of protein and decrease the level of carbohydrates and growth hormones, which can lead inhibition of crop growth (Mazher *et al.,* 2007).

Total tiller plant^{-1}

At control, total tiller plant^{-1} of sixteen genotypes ranged from 2.0 to 3.0 and five genotypes showed more than 3 tiller plant^{-1} (Fig 2a). At 8 dS m^{-1} salinity, tiller plant^{-1} of twenty genotypes ranged from 1.3 to 2.0 and only one genotype showed tiller plant^{-1} more than 2.0 (Fig 2b). At 15 dS m^{-1} salinity, tiller plant^{-1} of sixteen genotypes ranged from 0.5 to 1.0 and five genotypes showed tiller plant^{-1} more than 1.0 (Fig 2c). These results show that tiller number significantly decreased with



(a) (b) (c)

Fig 1: Frequency distribution of plant height of wheat genotypes under (a) control, (b) 8 dS m^{-1} salinity and (c) 15 dS m^{-1} salinity.

the increase of salinity. Table 1 shows that at 15 dS m^{-1} salinity tiller $plant^{-1}$ has a positive and significant correlation with grain yield. Under salinity the reduction of tillers $plant^{-1}$ might be due to absorption of excessive salts by the plants, which affects the plant growth by decreasing the photosynthesis (Kalhoro *et al.,* 2016).

Spike length

At control, spike length of twenty genotypes ranged from 9.0 cm to 12 cm and one genotype showed spike length more than 12.5 cm (Fig 3a). At 8 dS m^{-1} salinity, spike length of twenty genotypes ranged from 8.0 cm and 12.0 cm and only one genotype showed spike length more than 12.0 cm (Fig 3b). At 15 dS m^{-1} salinity, spike length of fourteen genotypes ranged from 5.0 cm to 10.0 cm and seven genotypes showed spike length more than 10.0 cm (Fig 3c). Significant decrease in spike length of wheat genotypes was observed with increasing salinity levels. Salt in plants reduces growth by causing premature senescence of plant parts and hence reduced supply of assimilates to growing

Table 1: Correlation coefficient of eight plant characters of twenty one wheat genotypes under 15 dS m^{-1} salinity.

Traits	PTH	TTP	SKL	SPS	GPS	TSW	GYP
PH	1						
TP	-.505*	1					
SL	0.000	0.383	1				
SS	-0.060	0.619**	0.867**	1			
GS	0.166	0.434*	0.392	.635**	1		
TSW	0.144	-0.086	-0.222	-0.032	0.172	1	
GYP	0.280	0.447*	-0.073	0.598*	0.496*	0.518*	1

*Correlation is significant at the 0.05 level.

**Correlation is significant at the 0.01 level.

Note: PTH= Plant height (cm), TTP= Total tiller $plant^{-1}$, SKL= Spike length, SPS= Spikelet $spike^{-1}$, GPS= Grain $spike^{-1}$ TSW= Thousand seed weight (g), GYP= Grain yield $plant^{-1}$ (g).

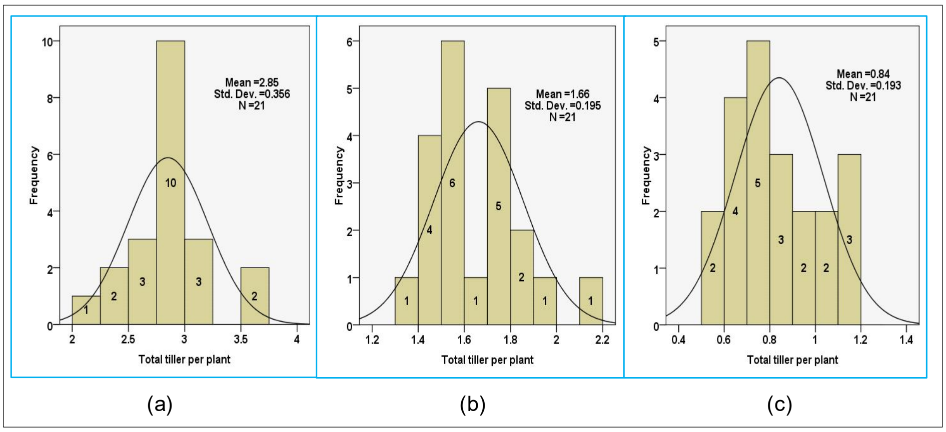


Fig 2: Frequency distribution of total tiller $plant^{-1}$ of wheat genotypes under (a) control, (b) 8 dS m^{-1} salinity and (c) 15 dS m^{-1} salinity.

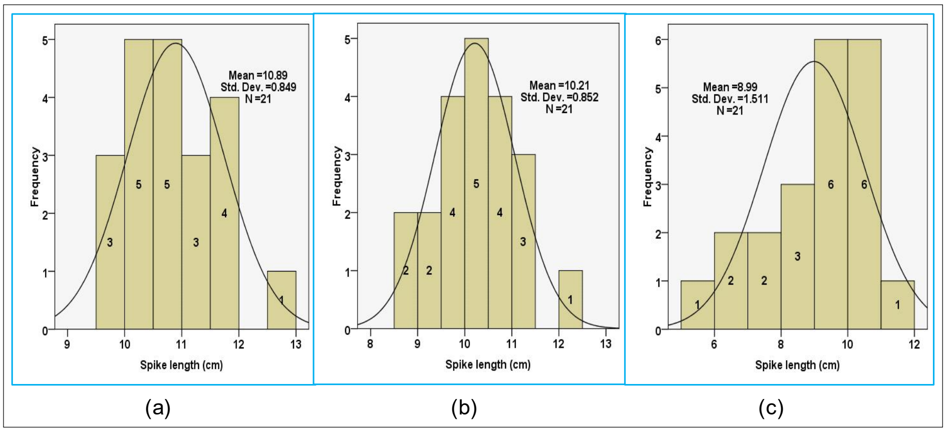


Fig 3: Frequency distribution of spike length of wheat genotypes under (a) control, (b) 8 dS m^{-1} salinity and (c) 15 dS m^{-1} salinity.

regions ultimately reduce the length of spike. Many researchers also found that salinity reduces the spike length of wheat (Kalhoro *et al*., 2016; Chamekh *et al.,* 2014).

Spikelet spike^{-1}

At control, spikelet spike^{-1} of nineteen genotypes ranged from 14.0 to 20.0 and only two genotypes showed more than 20.0 (Fig 4a). At 8 dS m^{-1} salinity, eleven genotypes showed 13.0 to 18.0 spikelet spike^{-1} and ten genotypes showed 18.0 to 20.0 spikelet spike^{-1} (Fig 4b). At 15 dS m^{-1} salinity, seventeen genotypes showed 8.0 to 18.0 spikelet spike^{-1} and four genotypes showed more than 18.0 spikelet spike^{-1} (Fig 4c). These results show that spikelet spike^{-1} decreased due to salinity. Table 1 shows that spikelet spike^{-1} has a significant correlation with grain yield plant^{-1} at 15 dS m^{-1} salinity. Mans and Rawson (2004) found that salinity suppressed the reproductive development of wheat, which ultimately reduced the spikelet formation as well as spikelet number. Asgari *et al.* (2012) stated that root zone salinity influence the reduction of spikelet spike^{-1}.

Grains spike^{-1}

At control, nineteen genotypes showed 32.5 to 45.0 grains spike^{-1} and two genotypes showed more than 45.0 grains spike^{-1} (Fig 5a). At 8 dS m^{-1} salinity, 19 genotypes showed 30 to 40 grains spike^{-1} and two genotypes showed more than 40 grains spike^{-1} (Fig 5b). At 15 dS m^{-1} salinity, fourteen genotypes showed 22 to 30 grains spike^{-1} and seven genotypes showed more than 30 grains spike^{-1} (Fig 5c). This parameter showed a reduction with increase of salinity. Table 1 shows that grain spike^{-1} has a positive and significant correlation with grain yield plant^{-1} at 15 dS m^{-1} salinity. Salinity reduces the floret viability and decreases the grains number spike^{-1} of wheat. Salinity shortens the spikelet development stage, which resulted in less number of spikelet spike^{-1}, thus reducing the number of grains spike^{-1} (Chamekh *et al*., 2014).

Thousand seed weight

At control, 1000-seed weight of seventeen genotypes ranged from 38.0 to 48.0 g and rest four genotypes showed more than 48.0 g (Fig 6a). At 8 dS m^{-1} salinity, 1000-seed weight of seventeen genotypes ranged from 20.0 to 35.0 g and rest four genotypes showed more than 35.0 g (Fig 6b). At 15 dS m^{-1} salinity, 1000-seed weight of eighteen genotypes ranged from 16.0 to 28.0 g and rest three genotypes showed more than 28.0 g (Fig 6c). Increase in salinity decreased thousand seeds weight of wheat genotypes. Table 1 shows

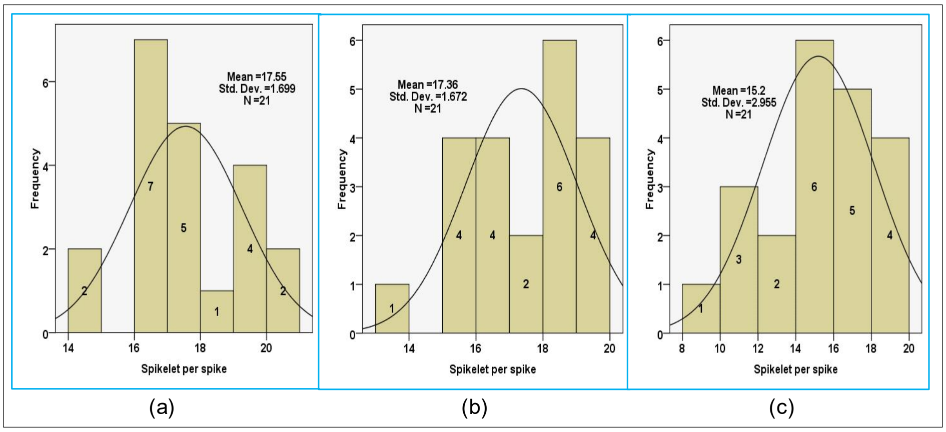


Fig 4: Frequency distribution of spikelet spike^{-1} of wheat genotypes under (a) control, (b) 8 dS m^{-1} salinity and (c) 15 dS m^{-1} salinity.

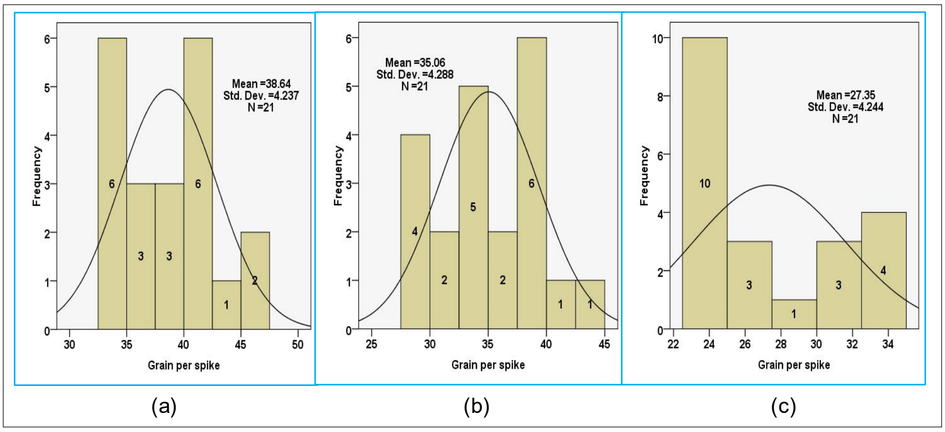


Fig 5: Frequency distribution of grain spike^{-1} of wheat genotypes under (a) control, (b) 8 dS m^{-1} salinity and (c) 15 dS m^{-1} salinity.

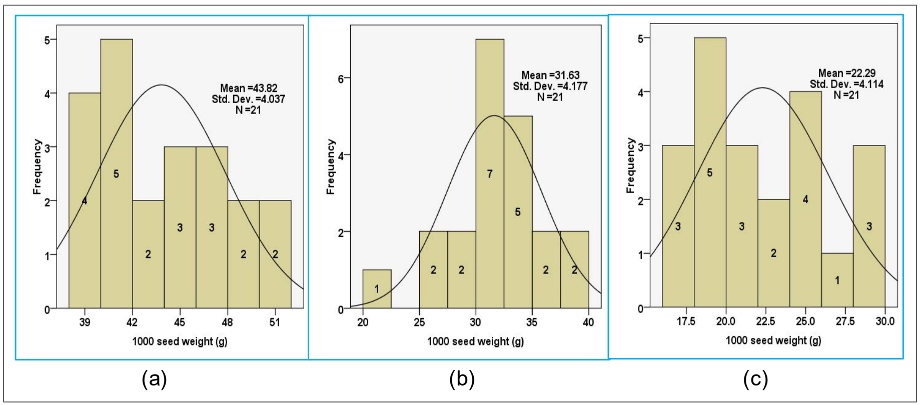


Fig 6: Frequency distribution of 1000 seed weight of wheat genotypes under (a) control, (b) 8 dS m^{-1} salinity and (c) 15 dS m^{-1} salinity.

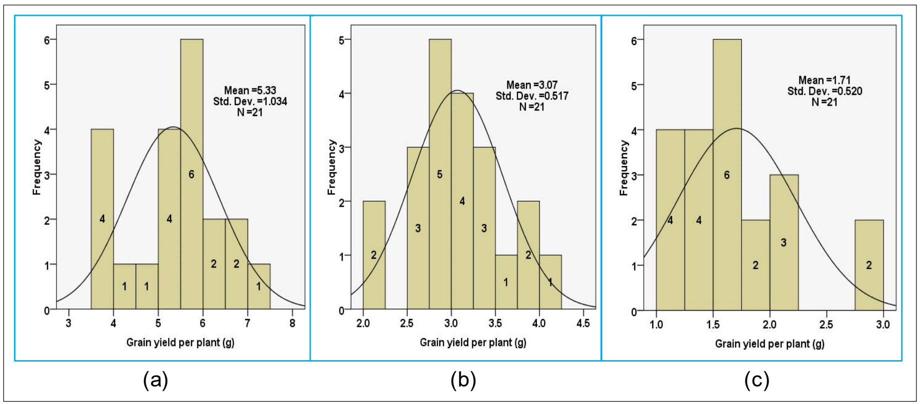


Fig 7: Frequency distribution of grain yield plant^{-1} of wheat genotypes under (a) control, (b) 8 dS m^{-1} salinity and (c) 15 dS m^{-1} salinity.

that 1000-seed weight has a positive and significant correlation with grain yield plant^{-1} at 15 dS m^{-1} salinity. Salt reduces the maturation and grain filling period of cereal crops. Therefore, reduction of grain weight at higher salinity might be due to the result of shortened grain filling period. Several researchers have observed that salinity reduced 1000 grain weight (Kalhoro *et al.,* 2016).

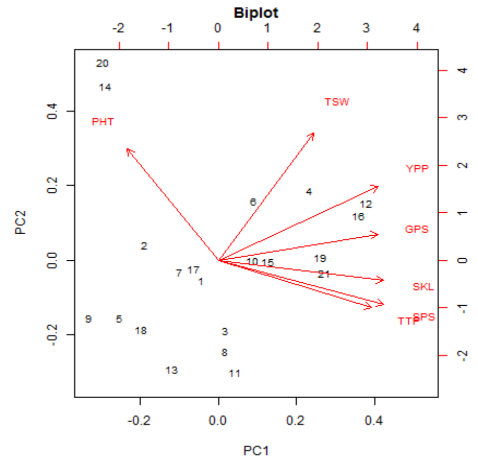
Grain yield plant^{-1}

At control, grain yield plant^{-1} of six genotypes ranged from 3.5 to 5.0 g, fourteen genotypes showed 5.0 to 7.0 g and one genotype showed grain yield plant^{-1} more than 7.0 g (Fig 7a). At 8 dS m^{-1} salinity, grain yield plant^{-1} of twenty genotypes ranged from 2.0 to 4.0 g and only one genotype showed more than 4.0 g (Fig 7b). At 15 dS m^{-1} salinity, grain yield plant^{-1} of nineteen genotypes ranged from 1.0 to 2.0 g and only two genotypes showed grain yield plant^{-1} more than 2.5 g (Fig 7c). Grain yield of wheat genotypes significantly decreased with increasing salinity levels. On the basis of yield and yield reduction per cent genotypes G4 (4.02 g), G12 (3.98 g), G16 (3.95 g) and G6 (3.85 g) were found suitable for 8 dS m^{-1} salinity and genotypes G12 (2.51 g), G16 (2.49 g) and G4 (2.19 g) were found suitable for 15 dS m^{-1} salinity (Table 2). It has been reported that reduction of grain yield due to salinity compare to control condition is used as an indicator of tolerance to salinity stress

Table 2: Grain yield and yield reduction (%) of wheat genotypes under different salinity level.

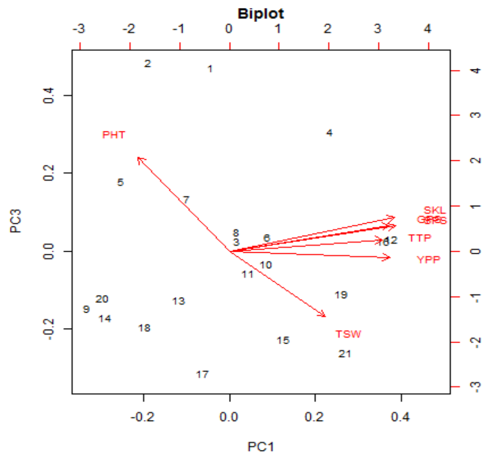
Genotype	Grain yield (g/plant)			% Yield reduction	
no	control	8 dS m^{-1}	15 dS m^{-1}	8 dS m^{-1}	15 dS m^{-1}
G1	5.76	3.43	1.44	40.45	75.00
G2	4.37	2.97	1.33	32.04	69.57
G3	5.28	2.76	1.70	47.73	67.80
G4	6.62	4.02	2.19	39.27	66.92
G5	5.18	3.43	1.00	33.78	80.69
G6	5.69	3.85	1.96	32.34	65.55
G7	3.9	3.06	1.63	21.54	58.21
G8	6.06	2.7	1.49	55.45	75.41
G9	3.56	2.15	1.11	39.61	68.82
G10	5.74	3.55	1.87	38.15	67.42
G11	5.73	2.75	1.56	52.01	72.77
G12	6.48	3.98	2.51	38.58	61.27
G13	6.23	3.55	1.06	43.02	82.99
G14	3.53	3.19	1.47	9.63	58.36
G15	6.8	3.54	1.97	47.94	71.03
G16	5.96	3.95	2.49	33.72	58.22
G17	4.61	2.1	1.53	54.45	66.81
G18	5.7	2.57	1.25	54.91	78.07
G19	5.54	3.62	2.09	34.66	62.27
G20	6.9	3.7	1.69	46.38	75.51
G21	5.4	3.76	1.99	30.37	63.15

Averages from three independent experiments are shown.



Position of wheat genotypes from the selected germplasm pools along first two axes obtained from PCA, where PH= Plant height (cm), TTP= Total tiller plant^{-1}, SKL= Spike length, SPS= Spikelet spike^{-1}, GPS= Grain spike^{-1}, TSW= Thousand seed weight (g), YPP= Grain yield plant^{-1} (g).

Fig 8: Principal components analysis (PCA) ordination graph between PC1 and PC2.



Position of wheat genotypes from the selected germplasm pools along first and third axes obtained from PCA.

Fig 9: Principal components analysis (PCA) ordination graph between PC1 and PC3.

(Chamekh *et al.,* 2014). Yield reduction was occurred by the accumulated reduction obtained from all yield components such as number of spikelet, grain number and grain weight in response to higher salinity. Darwish *et al.* (2009) stated that salinity causes serious damage of cellular and physiological processes including photosynthesis, nutrient uptake, water absorption, root growth, spikelet formation, fertilization of florets and cellular metabolism, which lead to yield reduction. Table 1 shows that spikelet spike^{-1}, grain spike^{-1} and 1000-seed weight has a positive and significant correlation with grain yield plant^{-1} at 15 dS m^{-1} salinity. Asgari *et al.* (2011) found a reduction in seeds spike^{-1} of salt stressed wheat and suggested that increases in number of seeds spike^{-1} lead to higher grain yield. Growth reduction under salinity is the result of water deficit or ion imbalances which ultimately reduces the yield of crops.

Biplot analysis

PC1 and PC2 biplot graph clearly indicated that grain yield plant^{-1} showed more acute angle with grain spike^{-1}, spike length, thousand seed weight and total tiller plant^{-1}, whereas grain yield plant^{-1} showed obtuse angle with plant height (Fig 8). In Fig 9, grain yield plant^{-1} showed strong correlation with total tiller plant^{-1}, grain spike^{-1}, spike length, spikelet spike^{-1}, thousand seed weight and negative correlation with plant height and straw plant^{-1}.

CONCLUSION

Wheat (*Triticum aestivum* L.) is one of the most important leading cereal crops in the world. At control, the genotype G20 showed highest yield plant^{-1} (6.90 g) followed by G15 (6.80 g), G4 (6.62 g) and G12 (6.48 g). However, at 8 dS m^{-1} salinity, the genotype G4 showed highest yield plant^{-1} (4.02 g) followed by G12 (3.98 g) and G16 (3.95 g) and at 15 dS m^{-1} salinity, the genotype G12 showed the highest yield plant^{-1} (2.51 g) followed by G16 (2.49 g) and G4 (2.19 g). On the basis of yield and yield contributing factors the genotypes G4, G12 and G16 might be considered as the genotypes having potentiality for developing saline tolerant variety at 8 dS m^{-1} and 15 dS m^{-1} salinity.

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