International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 11, No. 2, p. 60-67, 2017

RESEARCH PAPER

OPEN ACCESS

Growth and yield response of wheat genotypes to salinity at different growth stages

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Article published on August 30, 2017

Key words: Wheat, Grain yield, Growth stage, Salinity

Abstract

Growth and yield response of wheat genotypes to salinity were studied at Regional Agricultural Research Station, Rahmatpur, Barisal to find out the performance of the genotypes at three growth stages with different salinity levels and to assess the relationship of growth and yield with three growth stages. This experiment performed in a three-factor experiment comprising six genotypes, five doses of salinity (control, 4, 8, 12, 16 dS/m) and three growth stages: vegetative, heading and pod filling . Results revealed that genotype, salinity level and growth stages exhibited highly significant variation for yield and its components. Control was the most appropriate environment in attaining higher yield followed by 4 and 8dS/m salinity level. Tolerance of wheat increased after heading 60stages and salt sensitivity of wheat is more in heading stages which is identical with vegetative stage. Grain yields were greatly decreased with salinity increase and the decreases differed depending upon the tolerance of genotype. The yield reduction was observed in G33, a tolerant genotype was 33 % at 16 dS/m and in G45, a susceptible genotype was 106%. Vegetative and heading stages were the most affected stage than grain-filling stage when treated with NaCl salinity.

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Introduction

On a global scale, nearly 40% of the earth's land surface is potentially endangered by salinity problems (Orcutt and Nilsen, 61000). In the coastal and southeastern districts of Bangladesh 3 million hectares of land are affected by salinity with EC values ranging from 4 to 16 dS/m (Rahman *et al.*, 2012; Zaman and Bakri, 2003). Amount of saline affected area is increasing continuously due to the effect of sea level rise, coastal subsidence, increased tidal effect and continuous reduction of river flow, particularly during dry period (Uddin *et al.*, 2017).

Sensitive growth stage differs among the crops, among cultivars of the same crop and even different growth stages in a same cultivar (Blume, 1985). According to Mass (1986) crops such as barley, corn, cowpea, rice sorghum and wheat are most sensitive during early seedling growth and then become increasingly tolerant during later stages of growth and development. Several studies have shown that exposure of a plant to salinity at early seedling stage shows a greater yield loss than that exposure at latter part of growth (Gill, 1990 and Pasternak *et al.*, 1979). Tolerance observed at the early vegetative stage is of great importance. Because it has been emphasized by many workers that the assessment of salt tolerance at vegetative stage of a plant species is of considerable value in determining the ultimate tolerance of the species (Ashraf and Mc Neilly, 1987, Ashraf *et al.*, 1990; Aslam*et al.*, 1993; Ashraf, 1994 and Aziz *et al.*, 2005). Aziz *et al.* (2006) evaluated salt tolerance in mungbean plant at different growth stages. They concluded that vegetative stage was being more sensitive than flowering and pod-filling stages. The salt tolerance in mungbean was in order of vegetative stage >flowering stage> pod filling stage. Aslam *et al.* (1993) found that rice is very tolerant at germination and tillering stage of its growth but is very sensitive at 1-2 leaf and flowering stages. Ripening appears to be little affected by salinity (Akbar and Ponnamperuma, 1982; Jones and Stenhouse, 1983; Mass and Hoffman, 1977). The experiment was done to find out the performance of the genotypes at three growth stages with different salinity levels and to assess the relationship of growth and yield with three growth stages of wheat.

Materials and methods

Experimental site

The experiment was conducted at the Experimental Farm of the Regional Agricultural Research Station, Rahmatpur, Barisal which lies at the 22º 42″ North latitude and 90º 23″ East longitude at an elevation of 4 meter above the sea level. It belongs to the Non-calcareous Grey Floodplain Soils (Non saline, Ganges Tidal Alluvium) under AEZ 13 (BARI, 2015).

Salinity development

The genotypes (Table 1) were grown in pot culture under semi-controlled environment (inside plastic green house) and natural light during the season of 2009-2010. The materials were evaluated under five doses of salinity (control, 4, 8, 12, 16 dS/m) and three growth stages: vegetative, heading and pod filling following a randomized complete block with three replications. Salt solution was prepared artificially by dissolving calculated amount of commercially available NaCl with tap water. The pots were irrigated with 40, 80, 120 and 160 mMNaCl solutions (EC = 4, 8, 12, 16 dS/m, respectively) at vegetative, heading and grain-filling stages. Plants in control were irrigated with tap water (EC =0.8 dS/m). The salt solution was applied with an increment of 40 mM at every alternate day till the respective concentrations were attained to protect the plants from osmotic shock. Treatment solution was applied in excess so that extra solution dripped out from the bottoms of the pots. Treatments at vegetative stage began 12 days after sowing. Salinization at the heading stage was began when first floral buds appeared. For pod filling stage, the treatment solution was applied when maximum grain were in developing stage. Treatments at each stage were continued for 10 days, after which the pots were flushed with tap water to leach out the accumulated salt and the plants were irrigated with tap water until maturity (Aziz *et al.*, 2005, 06).

Observation recorded

The data on plant height (cm), days to heading, days to maturity, number of spikes/plant, number of grains/spike, 1000-grain weight (g) and grain yield/plant were recorded.

Table 1. List of wheat entries with pedigree used in the experiment.

Sl. No.	Genotype code #	Variety/Line/Pedigree	Source
1	G11	Shatabdi	Wheat
2	G15	JUN/PRL	Research
3	G22	Chirya-3	Centre,
4	G33	AKR/BALAKA//FAN/PVN	BARI,
5	G40	KRL 1-4	Joydebpur,
6	G45	RAWAL87//BUC/BJY	Gazipur

Data analysis

The collected data were analyzed statistically following Gomez and Gomez (1984) using MSTAT-C statistical pakage. The LSD test were done to compare treatment superiority, where necessary

Results and discussion

Combined analysis of variance

The combined analysis of variance for all characters under study is shown in Table 2. It exhibits that genotypic effects were highly significant (P<0.01) for all characters under study indicating the presence of variation among the genotypes for these characters. The salinity levels also highly significantly influenced yield per plant and yield contributing characters under study at 01% level of probability. Genotype x salinity level interaction was highly significant (P<0.01) for days to heading, plant height and yield per plant. Growth stages were highly significant (P<0.01) for all characters under study. Only 1000-grain weight showed highly significant among the genotype (P<0.01) for genotypes x growth interaction. Salinity level x growth stage interaction showed highly significant (P<0.01) for days to maturity, number of grains per spike, 1000-grain weight and yield per plant. A significant variation was found for days to heading and plant height in genotypes x salinity level x growth stage interaction. Dhayal and Sastry (2003) reported a significant genotype x environment interaction for various characters in wheat.

Table 2. Combined analysis of variance (MS) for different economic characters of selected wheat genotypes to salinity in three growth stages.

Items	df	Days to heading	Days to maturity	Plant height (cm)	Spikes/ plant (no.)	Grains/ plant (no.)	1000-grain weight (g)	Grain yield (g/plant)
Replication	2	2.88	14.85	54.34	0.79	93.81	34.46	9.86**
Genotype	5	167.13**	22.27**	693.9**	17.5**	386.2**	1387**	48.12**
Salinity level	4	62.57**	30.97**	220.1**	9.50**	565.6**	290**	96.13**
Gen. X Sal. level	20	13.83**	6.84	57.89**	1.12	40.96	21.05	6.17**
Growth stage	2	58.13**	29.62**	227.4**	5.61**	484.0**	979**	37.09**
Gen. X Growth stage	10	8.85	4.40	24.58	0.75	32.23	51.6**	2.48
Sal. X Growth stage	8	3.63	16.57**	49.12*	1.48	65.97**	76.1**	6.41**
Gen. X Sal. X G. stage	40	12.53**	3.28	27.37*	0.61	18.39	18.00	1.87
Error	178	5.68	3.64	16.97	0.89	27.41	16.03	2.02

* and ** indicate significant at 5% and 1% level of probability, respectively.

Response of six wheat genotypes to salinity at three growth stages

The mean performance of six wheat genotypes evaluated for yield and yield contributing characters to salinity over three growth stages are presented in Table 3. The earliest maturity was found from the genotype G45 while the latest maturity was obtained from G22 and G40. The tallest plant (85 cm) was produced by G22 and the shortest plant (74 cm) was the genotype G33. Again, the genotype G22 and G33 produced the highest number of spikes per plant and the lowest was found from G15 and G45. The maximum number of grains per spike (35.31) was observed from G40 while, the minimum (<29) from G15, G45and G11. G_{33} was the bold sized grain (50.09 g/1000 grain) while the G15 and G45 bore the smallest seed. G22, G33 and G40 yielded the highest (> 6.0g/plant) followed by G11 (5.5g/plant), G45 (4.9 g/plant), while G15 produced the lowest (4.5g/plant).

Thus the genotypes G40, G33 and G22 were the most suitable across all salinity levels and under three growth stages. This observation agrees with the results of Aziz *et al.* (2006) in mungbean.

Table 3. Mean values of important plant characters of wheat genotypes (values averaged over five salinity levels and three growth stages).

Genotype	Days to heading	Days to maturity	Plant height (cm)	Spikes/ plant (no.)	Grains/ plant (no.)	1000-grain weight (g)	Grain yield (g/plant)
G11	63.09 a	99.42 ab	82.82 b	4.92 b	27.74 c	45.92 b	5.49 b
G15	59.91 c	99.13 ab	81.84 bc	4.32 c	29.04 c	39.81 c	4.50 c
G22	63.80 a	99.93 a	74.02 e	5.48 a	33.54 ab	34.73 d	6.61 a
G33	61.09 b	98.82 b	80.87 c	5.69 a	32.61 b	50.09 a	6.88 a
G40	59.56 c	99.69 a	85.24 a	5.03 b	35.31 a	45.81 b	6.78 a
G45	59.22 c	97.98 c	78.20 d	4.10 c	29.77 c	39.96 c	4.90bc

Within column values followed by same letter (s) did not differ significantly at $p<0.05$ by DMRT.

Response of NaCl salinity on wheat genotypes

The average salinity levels, summarized over genotypes (Table 4) showed that all the characters studied except days to heading had the highest value in control A decreasing trend of yield and other characters studied except days to heading were observed when increase in salinity. Days to heading was ranked the highest in 16 dS/m salinity. The highest yield (8.18 g/plant) was found in control followed by 4 dS/m (5.67 g/plant) and 8 dS/m (5.39 g/plant). The yield in 4 dS/m and 8 dS/m were identical. The genotypes yielded 5.27 g/plant in 12 dS/m. 16 dS/m scored 3rd position in yield per plant (4.8 g), which is statistically similar to 12/dS/m salinity level. Increasing salinity significantly reduced mean grain yield per plant observed Ashraf and Mc Neilly (1988).

Table 4. Mean values of important plant characters of wheat grown at five salinity levels (values averaged over six genotypes and three growth stages).

Salinity level	Days to heading	Days to maturity	Plant height (cm)	Spikes/ plant (no.)	Grains/ plant (no.)	1000-grain weight (g)	Grain yield (g/plant)
Control	59.33 c	100.44 a	84.04 a	5.58 a	36.60 a	46.31 a	8.18 a
4 dS/m	61.13 b	99.30 b	79.35 b	4.60 c	32.35 b	43.15 b	5.67 b
8 dS/m	61.32 ab	98.57 b	79.32 b	4.54 c	29.08 c	41.74 b	5.39 b
12 dS/m	61.56 ab	98.65 b	79.48 b	4.85 bc	29.43 c	42.40 b	5.27 bc
16 dS/m	62.22 a	99.00 b	80.32 b	5.05 b	29.22 c	40.01 c	4.80 c

Within column values followed by same letter (s) did not differ significantly at $p<0.05$ by DMRT.

Response of growth stages on wheat genotypes

The average effect of growth stages, summarized over genotypes are shown in Table 5. The results revealed that all characters including yield per plant studied had the highest value in grain filling stage. The maximum days to heading and maturity were observed in vegetative and grain filling stages (≥ 61 and 99 days, respectively). The genotypes in heading stage had required 60 days to heading and 98 days to maturity. The tallest genotypes (82 cm) and the highest number of spikes per plant (5.2) were found in grain filling which were statistically different with other two stages. The highest number of spikes per plant (5.21) and grains per spike (33.05) were observed in grain filling stage while, the lowest in vegetative and heading stage. The number of spikes and grains in these stages were statistically similar. The bold sized grain (45.45 g/1000 grain) was obtained in grain filling stage followed by vegetative (43.66 g/1000 grain) and heading stage (39.6 g/1000 grain). Grain filling stage produced the highest yield (6.51 g/plant). While, vegetative and heading stage yielded identical lowest yield. Aziz *et al.* (2006) observed that the grain yield of mungbean treated with salinity at pod/filling stage was the least affected.

Table 5. Mean values of important plant characters of wheat in three growth stages (values averaged over six genotypes and five salinity levels).

Growth stage	Days to heading	Days to maturity	Plant height (cm)	Spikes/ plant (no.)	Grains/ plant (no.)	1000-grain weight (g)	Grain yield (g/plant)
Vegetative	61.87 a	99.47 a	79.51 b	4.76 b	31.26 b	43.66 b	5.75 b
Heading	60.27 b	98.33 b	79.66 b	4.79 b	28.70 b	39.06 c	5.22 b
Grain filling	61.20 a	99.58 a	82.33 a	5.21 a	33.05 a	45.45 a	6.51 a

Within column values followed by same letter (s) did not differ significantly at p<0.05 by DMRT.

A number of investigators reported various effect of salinity applied at different growth stages (Gill, 1990, Aziz *et al.* 2006, Islam *et al.* 2008). The results indicated that salt tolerance enhanced at grain filling stage. Vegetative and flowering stage were the most sensitive in salinity and then became increasing tolerant during later stages of growth and development. Gill, (1990). Pasternak *et al.* (1979) found in their study that exposure of a plant to salinity at early stage shows a greater yield loss than that of exposure at later part of growth. Aziz *et al.* (2006) exhibited that vegetative stage was the more sensitive stage of mungbean than flowering and pod filling stages.

Genotype and salinity level interaction

Genotype and salinity level interaction was presented in Table 6. The Table shows that days to heading, plant height and grain yield were statistically significant among the genotypes.

The maximum days to heading was obtained from G22 in 12 dS/m salinity while minimum from G15 in control. Again, the tallest (91 cm) and shortest (71 cm) plant were produced by G11 in control and G22 in 4 and 8 dS/m salinity level, respectively. The highest yield (10.18 g/plant) was found in G22, a moderately tolerant genotype under control condition followed by G11 (9.53 g/plant), a moderately tolerant genotype under control condition. The lowest yield (3.27 g/plant) was found in G15, a susceptible genotype under 16 dS/m salinity level. Grain yields were greatly decreased with salinity increase and the decreases differed depending upon the tolerance of genotype (Aziz *et al.* 2006). There were small differences among the tolerant genotypes (G33 and G40) for grain yield per plant with increase salinity. The yield reduction of G33 and G40 in 16 dS/m salinity were 33% and 29%, respectively. While, 69% and 106% reduction of yield were found from the susceptible genotypes (G15 and G45, respectively) in 16 dS/m salinity.

Table 6. Mean values of important economic characters of selected wheat genotypes as influenced by salinity levels.

Genotype code no.	Salinity level	Days to heading	Days to maturity	Plant height (cm)	Spikes/ plant (no.)	Grains/ spike (no.)	1000-grain weight (g)	Grain yield (g/plant)
G11	Control	61.78	102.22	91.44	5.59	34.78	47.93	9.53
	4 dS/m	62.56	99.44	82.78	4.89	26.91	46.10	5.43
	8 dS/m	63.33	98.22	79.78	4.50	23.13	46.10	4.32
	12 dS/m	63.67	98.22	78.11	4.44	26.72	45.40	3.90
	16 dS/m	64.11	99.00	82.00	5.17	27.17	44.08	4.26
G15	Control	56.78	99.78	82.89	4.50	37.62	44.39	5.52
	4 dS/m	59.89	99.11	82.22	4.17	30.22	41.54	4.33
	8 dS/m	60.44	100.11	82.22	3.94	26.58	39.98	5.25
	12 dS/m	60.00	98.44	81.44	4.50	24.24	38.52	4.15
	16 dS/m	62.44	99.11	80.44	4.50	26.54	34.63	3.27
G22	Control	61.33	101.89	79.56	6.44	39.46	39.46	10.18
	4 dS/m	64.00	100.56	70.89	5.06	36.81	35.11	6.77
	8 dS/m	65.22	99.00	70.89	5.00	28.95	31.19	5.40
	12 dS/m	65.89	98.67	73.11	5.33	31.26	34.58	5.62
	16 dS/m	62.56	99.56	75.67	5.56	31.22	33.29	5.08

Genotype code no.	Salinity level	Days to heading	Days to maturity	Plant height (cm)	Spikes/ plant (no.)	Grains/ spike (no.)	1000-grain weight (g)	Grain yield (g/plant)
	Control	61.89	100.44	80.33	7.00	36.66	52.89	8.65
	4 dS/m	60.44	98.67	80.33	5.17	33.21	50.92	6.40
	8 dS/m	60.56	98.11	81.78	5.28	31.17	49.83	6.28
G33	12 dS/m	59.89	99.11	82.44	5.22	30.64	50.17	6.55
	16 dS/m	62.67	97.78	78.44	5.78	31.39	46.67	6.50
	Control	56.67	99.00	86.89	5.06	35.62	47.57	8.00
	4 dS/m	59.44	100.33	83.22	4.33	36.97	44.96	6.19
	8 dS/m	59.89	99.33	83.33	4.89	35.93	44.16	6.60
G40	12 dS/m	60.00	99.78	86.44	5.50	35.54	47.01	6.94
	16 dS/m	61.78	100.00	86.33	5.39	32.48	45.37	6.18
	Control	57.56	99.33	83.11	4.89	35.43	45.62	7.19
	4 dS/m	60.44	97.67	76.67	4.00	29.99	40.26	4.87
	8 dS/m	58.44	96.67	76.89	3.61	28.72	39.18	4.50
G45	12 dS/m	59.89	97.67	75.33	4.11	28.17	38.72	4.45
	16 dS/m	59.78	98.56	79.00	3.89	26.51	36.04	3.49
LSD (0.05)		1.28	ns	3.83	ns	ns	ns	1.32

ns = non-significant.

Salinity level and growth stage interaction

Salinity level and growth stage interaction is exhibited in Table 7. The results reveals that days to maturity, number of grains per spike, grain weight and yield were statistically significant among the genotypes. The latest matured genotypes were found in vegetative stage under 4 dS/m salinity level while, the earliest matured genotypes in heading stage at 8 dS/m salinity level. The highest number of grains per spike (≈ 36) was noticed from vegetative, heading and grain filling stage under control and vegetative and grain filling stage under 4 dS/m level of salinity. The lowest number of grains per spike (≈ 26) was observed from heading stage at 4, 8, 12 and 16 dS/m salinity. The bold sized grain (47 g/1000 grain) was obtained in grain filling stage at 12 dS/m while, heading stage at 16 dS/m salinity had the smallest seed (34 g/1000 grain). Vegetative, heading and grain filling stage at control produced the highest yield (≈ 8 g/plant). Heading stage at 16 dS/m salinity gave the lowest yield (4 g/plant).

Table 7. Summary mean of important of selected wheat genotypes to NaCl salinity under three growth stages.

Salinity level	Growth stage	Days to heading	Days to maturity	Plant height (cm)	Spikes/ plant (no.)	Grains/ plant (no.)	1000-grain weight (g)	Grain yield (g/plant)
	Vegetative	59.89	100.67	84.44	5.60	36.94	46.41	8.65
Control	Heading	59.11	100.39	83.33	5.61	36.53	46.14	8.09
	Grain filling	59.00	100.28	83.83	5.52	36.32	46.38	7.80
	Vegetative	62.39	101.22	80.00	4.64	35.08	43.70	5.90
4 dS/m	Heading	59.89	98.06	78.33	4.53	26.38	40.16	4.55
	Grain filling	61.11	98.61	79.72	4.64	35.59	45.59	6.55
	Vegetative	62.33	98.83	77.89	4.42	29.90	42.27	4.75
8 dS/m	Heading	60.11	97.67	77.44	4.11	26.38	37.58	4.84
	Grain filling	61.50	99.22	82.61	5.08	30.97	45.36	6.58
	Vegetative	61.83	98.28	77.89	4.64	29.47	43.40	4.97
12 dS/m	Heading	60.89	98.17	78.67	4.64	27.66	37.14	4.74
	Grain filling	61.94	99.50	81.89	5.28	31.17	46.66	6.09
	Vegetative	62.89	98.33	77.33	4.53	29.89	42.51	4.97
16 dS/m	Heading	61.33	98.39	80.00	5.08	26.54	34.27	3.91
	Grain filling	62.44	100.28	83.66	5.53	31.22	43.26	5.51
LSD (0.05)		ns	1.26	ns	ns	3.44	2.63	0.94

ns = non-significant.

Conclusion

G40, G33 and G22 were the most tolerant genotypes across all salinity levels and under three growth stages. Control was the most appropriate environment in attaining higher yield followed by 4 and 8dS/m salinity level. Tolerance of wheat increased after heading stages and salt sensitivity of wheat is more in heading stages which is identical with vegetative stage. Grain yields were greatly decreased with salinity increase and the decreases differed depending upon the tolerance of genotype. The yield reduction was in G33, a tolerant genotype was 33% at 16 dS/m and in G45, a susceptible genotype was 106%. Vegetative and heading stages were the most affected stage than grain-filling stage when treated with NaCl salinity.

Acknowledgment

The authors would like to thank to Professor Dr. M. A. Newaz, Department of Genetics and Plant Breeding, Bangladesh Agricultural University, Mymensingh for his guidance to carry out the research work.

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