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RESEARCH ARTICLE

Using Growth and Ionic Contents of Wheat Seedlings as Rapid Screening Tool for Salt Tolerance

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Abstract

High germination percentage with vigorous early growth is preferred for harvesting good wheat stand under saline soils. Therefore, an attempt for rapid screening of wheat genotypes for salt tolerance was made in this study. Eleven wheat genotypes including salt tolerant check Kiran-95were subjected to salinity (120 and 160 mMNaCl) along with non-saline control. Results showed a gradual decrease in seed germination and restricted seedling growth in tested wheat genotypes in response to increasing NaCl concentration in nutrient solution. Among the genotypes, NIA-AS-14-6 and NIA-AS-14-7 exhibited more sensitivity towards the salt stress at the germination stage but NIA-AS-14-6 performed quite satisfactorily later on at the seedling stage. Wheat genotypes NIA-AS-14-2, NIA-AS-14-4, NIA-AS-14-5, NIA-AS-14-10, and Kiran-95 showed better performance in term of root-shoot length, plant biomasses (fresh and dry), K^+:Na^+ ratio with least Na^+ content, and high accumulation of K^+ at higher levels of NaCl stress. On the basis of overall results, the categorization of genotypes was carried out as sensitive, moderately tolerant, and tolerant. Wheat genotypes NIA-AS-14-2, NIA-AS-14-4, NIA-AS-14-5, NIA-AS-14-10, and Kiran-95 grouped as tolerant, moderately salt tolerant group comprised of NIA-AS-14-1, NIA-AS-14-3, NIA-AS-14-6, and NIA-AS-14-8, whereas, NIA-AS-14-7 and NIA-AS-14-9 were found sensitive to salt stress. Principal component analysis revealed that components I and II contributed 70 and 16.5%, respectively. All growth parameters are associated with each other except RDW. In addition to growth traits, low Na^+ and improved K^+ content with better K^+:Na^+ ratio may be used for screening of salt tolerance in wheat as potential physiological criteria.

Key words : Screening, germination, salinity, Na/K ratio, wheat

Introduction

Wheat (*TriticumaestivumL.*) is the main staple food for Asia as well as for more than one-third of the world's population and contributes more calories and protein to the world diet than any other cereal (Shiraziet al. 2001). Wheat is a leading cereal crop in Pakistan, which is cultivated all over the country. Wheat contributes 9.9% to the value added in agriculture and 2% to the GDP of Pakistan which is ranked among the top wheat-producing countries of the world (Anonymous 2015).

Among the abiotic stresses, soil salinity is most important affecting seed germination, crop growth, and productivity (Sairamet al. 2002). Salinity influenced the crop stand establishment which has significant importance and is the key factor limiting crop production under saline regimes (Wahid et al. 2010). It has been well-documented that excessive amounts of soluble salts in soil restrained or delayed seed germination by avoiding the seed from water uptake which also affects further seedling growth in many crops (Almansouri et al.2001; Munns 2005). Salt stress is responsible for the disturbance of plant metabolism as leaf growth rate reduced due to the osmotic effect of salt around the roots; thus, the growth of the root is generally less affected than that of leaf growth (Munns and Tester 2008). Salinity induced a change in the signal transduction originating from the root which alters the hormonal balance of the plant and ultimately influences root and shoot growth (Lerner et al.1994).

Under saline conditions, high Na^+ concentration inhibits the uptake of K^+ ions which results in ionic imbalance; the significant decrease in K^+/Na^+ ratio restricted vegetative growth and economic productivity in wheat (Mahboob et al. 2016). In plant tissues, the ratio of K^+/Na^+ has been exploited

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as an indicator of sodium toxicity, since it is presumed that activity of K^+ is vital for some enzymes (Gao, et al. 2016). The Na^+ and K^+ concentration showed a negative relationship in roots and leaves which revealed that better salt tolerance in plants is linked with a highly efficient system for selectivity of K^+ over Na^+ uptake (Tester and Davenport 2003). The varying degrees of salt tolerance can be determined through the observation of root and shoot growth.

The varietal differences in response to salinity (Turki et al. 2012) are most likely related by evolving ion transport properties and mechanism of cellular compartmentation (Munns 1988). Hence, a compatible strategy is essential to tackle soil salinization by understanding the impact of salinity on plant growth and to evolve salt-tolerant species (Rengasamy 2006). Selection of salt tolerant wheat genotypes may be a feasible and economical approach for utilization of salt-affected areas. Therefore, this study was carried out with the aim of examining differences in salt tolerance among advanced wheat lines based on plant growth and ionic contents.

Materials and Methods

Planting material and experimental details

Seeds of different wheat genotypes were obtained from Plant Breeding and Genetic Division, Nuclear Institute of Agriculture (NIA), Tando Jam, Pakistan. Wheat advance lines with their names and pedigree details have been summarized in Table 1.

Before the start of the experiment, healthy seeds of uniform size and identical color were selected and surface sterilized with 3% solution (v/v) of sodium hypochlorite for 10 min. After that, seeds rinsed thoroughly with distilled water and air-dried at room temperature (25°C). The experiment was conducted under completely randomized design (CRD) in growth chamber (Vindon, England) at Plant Physiology Lab, Nuclear Institute of Agriculture, Tandojam, Pakistan. Wheat genotypes were subjected to three levels of salinity based on NaCl salt (0, 120, and 160 mM). Hoagland solution (1/4th strength) was used as growth medium and salt stress was applied through nutrient solution. Day and night lengths were kept at 14/10 h, with 25 and 20°C temperatures, respectively. Relative humidity was maintained at 60%.

Final germination percentage and growth attributes

Final germination percentage (GP) was calculated according to the International Seed Testing Association (ISTA) method.

Ten days after sowing, plant samples were collected to record the data. A sample of five plants from each treatment was selected to measure the growth attributes. Plant height, root and shoot length was computed with the help of measuring rod. After that, fresh biomass of selected plants was determined by weighing the plants with an electrical weighing balance (AND-3000; Japan).

Determination of ionic content

Sodium and potassium contents were measured according to Ansari and Flowers (1986). The oven-dried leaf material was ground to form a powder. A tissue sample of 0.1 g was extracted in 0.2 m*M* acetic acid (CH_3COOH) by subjecting it to pre-heated water bath at 95°C for 60 min. The Na and K contents were determined in extracted solution by using flame photometer (PFP-7, Jenway Ltd).

Baseline for classification of salt tolerant wheat genotypes

The tested wheat genotypes were assorted by forming three groups named as salt tolerant, moderately tolerant, and salt sensitive primarily based on their roots and shoots fresh as well as dry weight at different levels of salinity (Murillo et al. 2001). The percent of control (values in parenthesis) observed at 120 and 160 mM NaCl were averaged and exploited for the categorization as given below.

On fresh weight basis of root and shoot the wheat genotypes showed average values ≥ 50% were categorized as tolerant group, those exhibiting values 40-49.9% are classified as moderately tolerant, whereas genotypes having values lower than 40% of average values (% of control) at two levels of NaCl stress were placed in the salt-sensitive class.

Table 1. Pedigree details of wheat genotypes used in this study.

S. #	Genotypes / varieties	Pedigree
1	NIA-AS-14-1	(TJ-83 x VASCO) x INQILAB-91
2	NIA-AS-14-2	(TJ-83 x4085/3) x INQILAB -91
3	NIA-AS-14-3	TJ-83 x4085/3
4	NIA-AS-14-4	SUNCO x TJ-83
5	NIA-AS-14-5	CIMMYT-6055 x AS- 2002
6	NIA-AS-14-6	TD-1 x D-108
7	NIA-AS-14-7	CIMMYT -6007 x TD-1
8	NIA-AS-14-8	CIMMYT -6009 x TD-1
9	NIA-AS-14-9	SD-88 x AS-2002
10	NIA-AS-14-10	No.B3 mot x TD-1
11	Kiran-95	WL 711 x Crow 'S'

On the basis of root and shoot dry weight, the genotypes expressed average values (percent of control) ≥ 70, 60-69.9, and < 60% under different saline regimes were grouped as tolerant, moderately tolerant, and sensitive, respectively. Likewise scale was used to classified wheat genotypes relying root and shoot length.

Statistical analysis

The graphical presentation of data and computation of standard errors for comparison of treatments were done using Microsoft Excel (Microsoft Corporation, Los Angeles, CA, USA).The correlation of different growth attributes of wheat genotypes was evaluated through Principal Component Analysis (PCA).

Results

High levels of NaCl stress influenced the final germination percentage in tested wheat genotypes but at variable rate (Fig. 1). Maximum germination percentage was noted for Kiran-95 under control as well as at both levels of salt stress and followed by NIA-AS-14-3 and NIA-AS-14-9. On other hand, increasing salt stress (120 and 160 mM NaCl) adversely affected seed germination in wheat genotype NIA-AS-14-6 and NIA-AS-14-7 that resulted in low emergence percentage.

Our results showed that growth attributes, i.e. root and shoot length, root fresh and dry weight, shoot fresh and dry weight were reduced with increasing level of NaCl stress (Tables 2, 3 and 4). Under moderate salt stress (120 mM of NaCl), the effects of salt stress were less prominent than the higher salinity (160 mM NaCl). Genotypes were classified in salt tolerance groups according to selection criteria based on shoot and root fresh weight (Table 2). The average decrease in shoot fresh weight due to the application of 120 and 160 mM NaCl was 36.5 and 62.1%, respectively, as compared to control plants. Wheat genotypes NIA-AS-14-5, NIA-AS-14-2, and NIA-AS-14-10 were least affected by increasing salinity and resulted in maximum shoot fresh weight by expressing highest values of percent of control 64, 60.7, and 53.8%, respectively. All these genotypes along with NIA-AS-14-4 and NIA-AS-14-8 were categorized as salt tolerant. However, NIA-AS-14-7 failed to produce better shoot fresh weight having minimum average value (38.9%) percent of control and placed in the salt-sensitive group. In response to 160 mM NaCl, the decrease in RFW ranged from 0.22 to 1.05 g among the tested genotypes (Table 2). However, NIA-AS-14-2 had exhibited maximum tolerance by maintaining highest RFW under both salinity levels and showed greater mean value 72.7% of control. Wheat genotypes NIA-AS-14-4, 5, 6, 10 and Kiran-95 were categorized as moderately salt tolerant. The most sensitive genotype was NIA-AS-14-1 who revealed maximum average reduction (52.1%) followed by NIA-AS-14-9, 3, 8 and NIA-AS-14-7.

On exposure to salinity, dry mass of shoot and root considerably reduced at variable rate among all the tested genotypes. Shoot dry weight ranged 0.18 to 0.267 g and 0.063 to 0.2 g at 120 and 160 mM NaCl, respectively, while root dry weight varied from 0.06 to 0.1 at 120 mM NaCl and 0.031 to 0.83 g at 160 mM NaCl. On the basis of shoot dry weight (Table 3), the most tolerant genotype was NIA-AS-14-5 followed by NIA-AS-14-2, Kiran-95, and NIA-AS-14-4, respectively, and placed in tolerant group. Moderately tolerant class included NIA-AS-14-3, NIA-AS-14-6, NIA-AS-14-10, NIA-AS-14-9, NIA-AS-14-8, and NIA-AS-14-1 in descending order of salt tolerance. Wheat genotype NIA-AS-14-7 was most sensitive line regarding shoot dry weight that has an

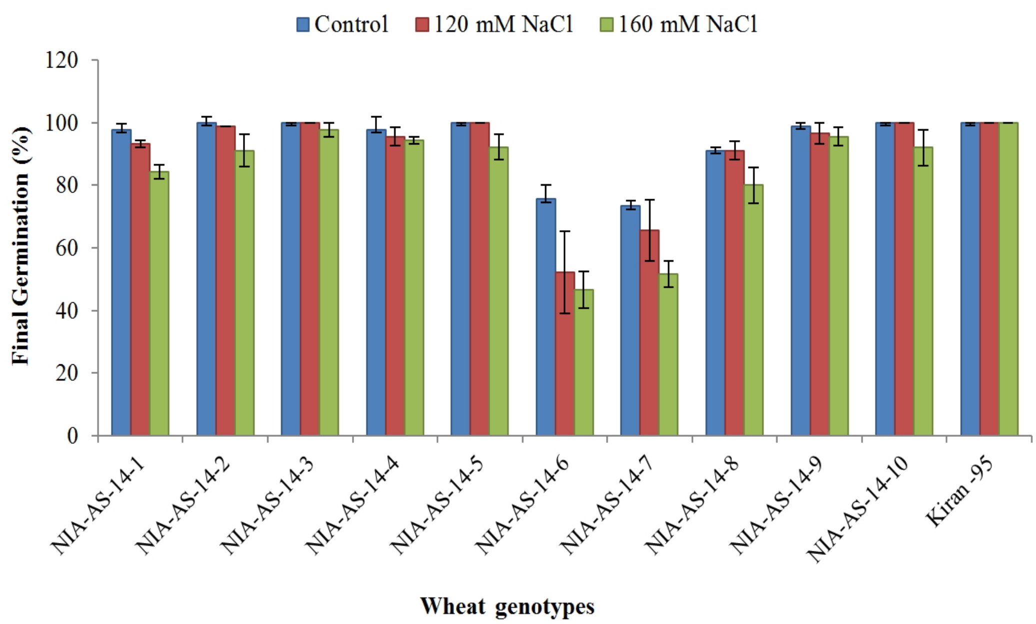

Fig. 1. Impact of salinity on germination percentage ± S.E. in different wheat genotypes.

Table 2. Root and shoot fresh weight of wheat advance lines influenced by NaCl stress at early seedling stage.

	Shoot fresh weight/Five plants (g)					Root fresh weight/ Five plants (g)				
Genotypes	Control	120 mM	160 mM	Mean*	Group	Control	120 mM	160 mM	Mean*	Group
NIA-AS-14-1	2.103	1.420 (67.5)	0.490 (23.3)	45.2	MT	1.112	0.711 (63.9)	0.221 (19.8)	41.9	S
NIA-AS-14-2	2.787	1.933 (69.4)	1.450 (52.0)	60.7	T	1.421	1.123 (78.8)	0.944 (66.2)	72.7	T
NIA-AS-14-3	3.030	1.987 (65.6)	0.893 (29.5)	48.3	MT	2.001	1.214 (60.5)	0.573 (28.4)	44.7	S
NIA-AS-14-4	2.993	1.860 (62.1)	1.123 (37.5)	50.0	T	1.610	1.031 (63.9)	0.732 (45.3)	54.8	MT
NIA-AS-14-5	2.470	1.690 (68.4)	1.500 (60.7)	64.0	T	1.630	1.116 (68.1)	1.015 (61.9)	65.4	MT
NIA-AS-14-6	2.261	1.623 (71.8)	0.600 (26.5)	47.8	MT	1.652	1.231 (74.5)	0.636 (38.1)	56.5	MT
NIA-AS-14-7	2.714	1.405 (51.8)	0.682 (25.1)	38.9	S	1.525	0.913 (59.8)	0.493 (32.2)	46.1	S
NIA-AS-14-8	2.682	1.704 (63.5)	0.962 (35.9)	50.0	T	1.943	1.139 (58.7)	0.609 (31.4)	45.0	S
NIA-AS-14-9	3.048	1.844 (60.5)	1.209 (39.7)	46.7	MT	2.021	1.081 (53.4)	0.691 (34.1)	43.8	S
NIA-AS-14-10	2.635	1.682 (63.8)	1.148 (43.6)	53.8	T	1.674	1.129 (67.6)	0.777 (46.7)	56.9	MT
Kiran-95	2.860	1.610 (56.3)	1.140 (39.9)	48.1	MT	1.196	0.843 (70.5)	0.647 (53.7)	62.3	MT

( ) = Per cent of control, T= Tolerant, MT= moderately tolerant, S= Sensitive *= Mean per cent of control of both salt treatments

Table 3. Root and Shoot dry weight of wheat advance lines influenced by NaCl stress at early seedling stage.

	Shoot Dry Weight/Five plants (g)					Root Dry weight/Five plants (g)				
Genotypes	Control	120 mM	160 mM	Mean*	Group	Control	120 mM	160 mM	Mean *	Group
NIA-AS-14-1	0.200	0.180 (90.0)	0.063 (30.0)	60.00	MT	0.067	0.060 (89.5)	0.031 (46.2)	67.9	MT
NIA-AS-14-2	0.223	0.198 86.3)	0.185 (81.3)	83.86	T	0.095	0.091 (95.7)	0.061 (64.2)	80.0	T
NIA-AS-14-3	0.283	0.260 (92.8)	0.127 (44.7)	69.64	MT	0.130	0.101 (77.6)	0.068 (52.3)	65.0	MT
NIA-AS-14-4	0.293	0.267 (93.1)	0.143 (48.2)	70.69	T	0.107	0.098 (91.6)	0.071 (66.3)	79.0	T
NIA-AS-14-5	0.243	0.223 (91.6)	0.200 (79.1)	85.42	T	0.113	0.092 (81.4)	0.083 (73.4)	77.4	T
NIA-AS-14-6	0.238	0.204 (86.9)	0.111 (47.8)	67.39	MT	0.110	0.071 (64.5)	0.047 (42.7)	53.6	S
NIA-AS-14-7	0.280	0.180 (64.2)	0.098 (35.7)	50.00	S	0.121	0.078 (64.4)	0.049 (40.4)	52.5	S
NIA-AS-14-8	0.289	0.207 (75.0)	0.135 (50.0)	62.50	MT	0.117	0.081 (69.3)	0.062 (52.9)	61.1	MT
NIA-AS-14-9	0.306	0.224 (73.3)	0.167 (56.6)	65.00	MT	0.139	0.082 (58.9)	0.063 (45.3)	52.2	S
NIA-AS-14-10	0.264	0.203 (73.0)	0.164 (61.5)	67.31	MT	0.111	0.079 (71.1)	0.065 (58.5)	64.9	MT
Kiran-95	0.256	0.202 (82.0)	0.160 (64.0)	73.00	T	0.077	0.076 (98.7)	0.060 (77.9)	88.3	T

( ) = Per cent of control, T= Tolerant, MT= moderately tolerant, S= Sensitive *= Mean per cent of control of both salt treatments

average of 50% of control. On other hand, for root dry weight the maximum mean percent of control (88.3%) was observed in Kiran-95 succeeded by 80, 79, and 77.4% in NIA-AS-14-2, 4, and 5, respectively, assigned as salt tolerant genotypes. Among the medium tolerant genotypes NIA-AS-14-1 was best performing which are followed by NIA-AS-14-3, 10, and 8 whereas, salt-stressed plants of NIA-AS-14-9, 7, and 6 showed minimum values for root dry weight and revealed maximum average reduction by 47.8, 47.5, and 46.4 respectively, thus categorized as sensitive.

Out of the 11wheat genotypes, six showed more than 30% reduction in their shoot length; however, NIA-AS-14-2, NIA-AS-14-4, NIA-AS-14-5, and NIA-AS-14-10 performed better at both 120 and 160 mM NaCl and ranked as tolerant genotypes (Table 4). Minimum values for shoot length (45.26 and 52.78% of control) was observed in NIA-AS-14-7 and NIA-AS-14-8, respectively, and placed in the salt-sensitive group while based on the shoot length genotypes NIA-AS-3, 6, 9, and Kiran-95were categorized as moderately tolerant. Nevertheless, wheat genotypes NIA-AS-14-5 showed the highest value (82.11% of control) for root length followed by NIA-AS-14-7, NIA-AS-14-10, and NIA-AS-14-6 at 120 mM as well as 160 mM NaCl which indicate their ability to tolerate salinity. Moderately tolerant group comprised of genotypes Kiran-95, NIA-AS-14-2, NIA-AS-14-3, and NIA-AS-14-4 in descending order of salt tolerance. The minimum value (41.17%) of percent of control for root length was observed in genotypes NIA-AS-14-1 followed by NIA-AS-14-8 and NIA-AS-14-9 and categorized as salt sensitive.

Data presented in Fig. 2 indicates that the Na^+ content of leaf significantly enhanced in all wheat genotypes with increasing salinity but varied substantially. The Na^+ content ranged from 1.65 to 1.93% and 1.65 to 1.93% under 120 and 160 mM NaCl, respectively. Maximum leaf Na^+ was accumulated in NIA-AS-14-7 at both salinity levels with highest relative increase by 5.61-and 6.13-fold correspondingly.

Table 4. Root and shoot length of wheat advance lines influenced by NaCl stress at early seedling stage

	Shoot length (cm)					Root length (cm)				
Genotypes	Control	120 mM	160 mM	Mean*	Group	Control	120 mM	160 mM	Mean*	Group
NIA-AS-14-1	15.76	14.26 (90.5)	5.14 (32.6)	61.57	MT	12.68	8.69 (68.5)	1.75 (13.8)	41.17	S
NIA-AS-14-2	16.69	14.34 (85.9)	11.2 (67.5)	76.76	T	13.99	10.1 (72.4)	6.12 (43.7)	58.12	MT
NIA-AS-14-3	17.36	15.96 (91.9)	5.76 (33.1)	62.56	MT	14.03	10.9 (78.4)	4.44 (31.7)	55.11	MT
NIA-AS-14-4	18.74	16.28 (86.9)	10.1 (53.7)	70.35	T	13.57	11.1 (82.5)	3.72 (27.5)	55.00	MT
NIA-AS-14-5	15.18	13.35 (87.9)	11.5 (76.2)	82.11	T	9.52	9.07 (95.3)	7.55 (79.3)	87.38	T
NIA-AS-14-6	16.36	13.54 (82.7)	7.42 (45.3)	64.07	MT	9.05	8.10 (89.6)	4.70 (52)	70.82	T
NIA-AS-14-7	15.78	9.39 (59.5)	4.89 (31.0)	45.26	S	6.28	6.32 (100)	3.88 (61.8)	81.35	T
NIA-AS-14-8	16.07	11.42 (71.1)	5.53 (34.4)	52.78	S	12.62	8.23 (65.2)	3.49 (27.6)	46.47	S
NIA-AS-14-9	15.33	14.46 (94.3)	8.90 (58)	76.23	MT	10.66	7.44 (69.8)	3.93 (36.8)	53.36	S
NIA-AS-14-10	17.60	15.09 (85.7)	10.4 (59.1)	72.45	T	10.82	9.82 (90.7)	5.93 (54.8)	72.78	T
Kiran-95	18.46	15.21 (82.4)	12.9 (70.1)	76.31	MT	12.04	8.07 (67)	6.18 (51.3)	59.23	MT

( ) = Per cent of control, T= Tolerant, MT= moderately tolerant, S= Sensitive *= Mean per cent of control of both salt treatments

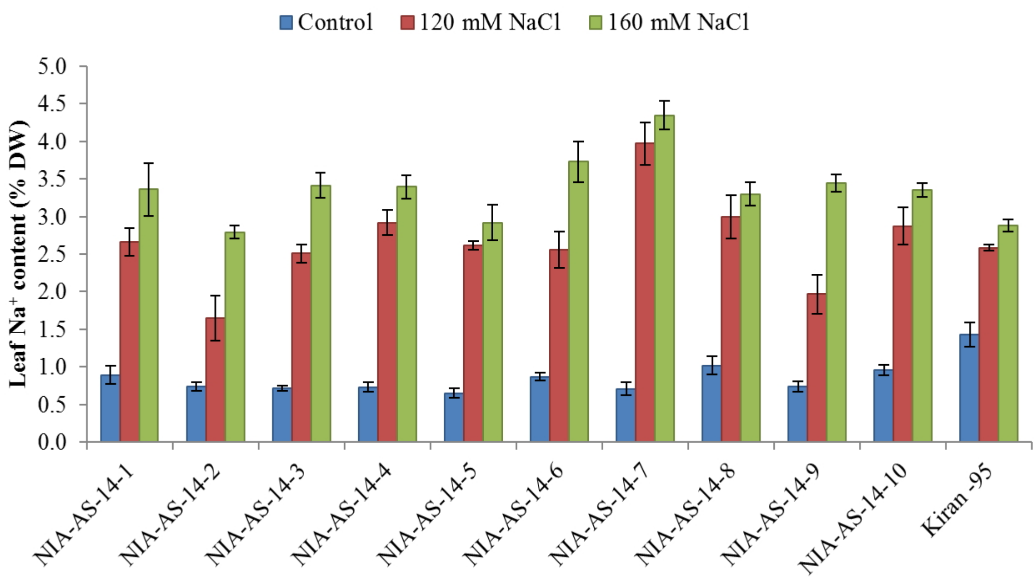

Fig. 2. Impact of salinity on leaf sodium content ± S.E. in different wheat genotypes.

Whereas, NIA-AS-14-2 showed minimum content of Na^+ (1.65%) which is statistically at par with NIA-AS-14-9 (1.96%) exposed to 120 mM NaCl. On the other hand, salt-tolerant genotypes NIA-AS-14-2, Kiran-95, and NIA-AS-14-5 maintained a lower Na^+ content (2.79, 2.88, and 2.92%, respectively) at the highest level of stress (160 mMNaCl). Salt-tolerant genotype Kiran-95 revealed a minimum increase in leaf Na^+ by1.81- and 2.02-fold respectively under rising salinity. All the tested genotypes showed differential behavior regarding K^+ content in response to salt stress and most of the genotypes resulted in a significant reduction in leaf K^+ compared with their respective control (Fig. 3). Among the genotypes, the maximum reduction in shoot K^+ content was recorded in NIA-AS-14-7 under all stress levels with respect to the non-saline control. Under 120 mM NaCl stress, NIA-AS-14-9 showed the highest K^+ content (3.29%) which is statistically at par with NIA-AS-14-10 (3.25%) and Kiran-95 (3.24%). While leaf K^+ of NIA-AS-14-2 and NIA-AS-14-4 enhanced in response to high salinity (160 mM NaCl), however, NIA-AS-4 illustrated higher K^+ content (2.96%) at 160 mM NaCl followed by Kiran-95 (2.62%) and NIA-AS-14-2 (2.56%). The K^+/Na^+ ratio in wheat genotypes were markedly affected when subjected to salinity. A reduction in K^+/Na^+ ratio was observed in all the tested wheat genotypes under saline stress (Fig. 4) and minimum values for Na^+/K^+ ratio (0.498, 0.268) were noted for NIA-AS-14-7 at both salinity levels. At 120 mM NaCl stress, the greater Na^+/K^+ ratio was revealed by NIA-AS-14-9 followed by NIA-AS-14-2 and Kiran-95,whereas in the case of high salt stress (160 mM NaCl) NIA-AS-14-2 expressed highest Na^+/K^+ ratio with lower

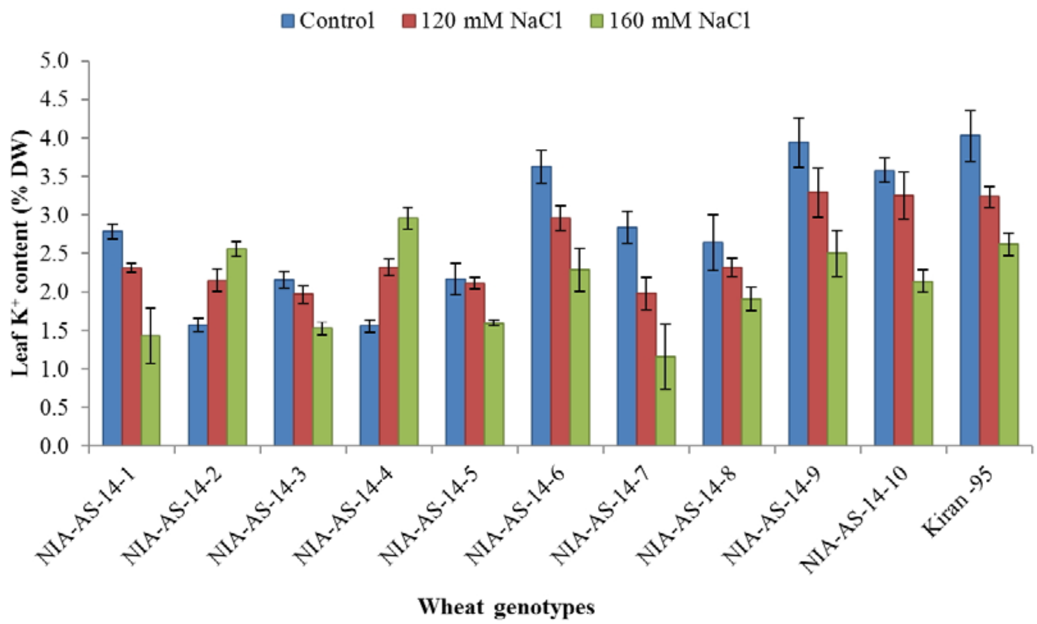

Fig. 3. Influence of salinity on leaf potassium content ± S.E. in different wheat genotypes.

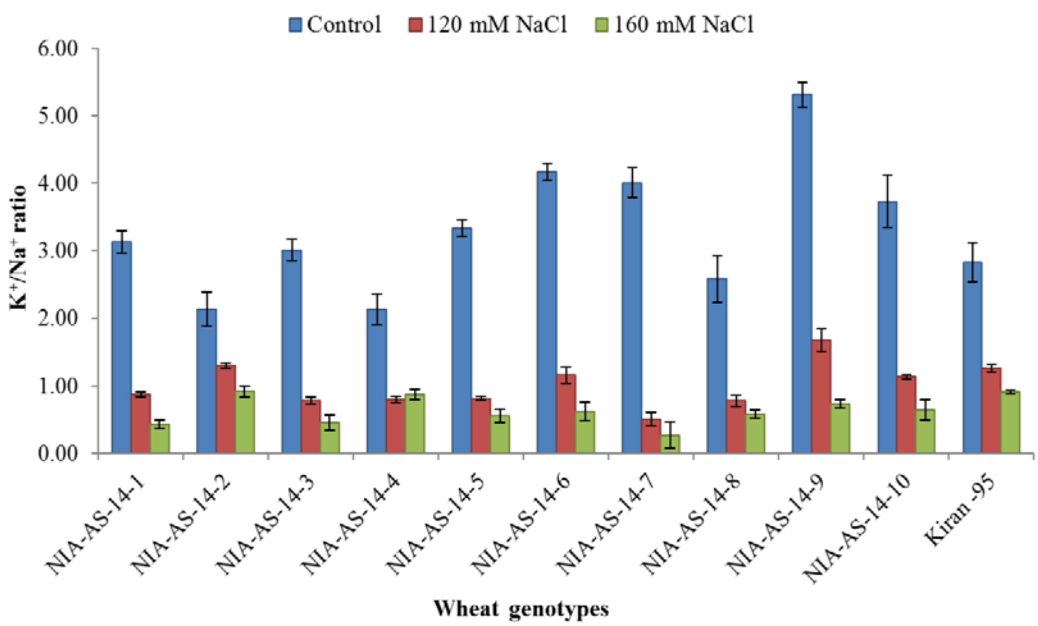

Fig. 4. Influence of salinity on leaf potassium content ± S.E. in different wheat genotypes.

relative decrease (57.04%) followed byKiran-95 (0.909%).

Principle component analysis (Fig. 5) investigated all growth attributes and permitted two principle components to be identified. It is revealed that component 1 and component 2 contributed 70 and 16.5%, respectively. All growth attributes are positively correlated with component 1. While in the case of component 2, RDW and SDW are positively correlated and the rest are negatively correlated. All growth parameters are associated with each other except RDW.

Based on overall growth attributes, NIA-AS-14-2, NIA-AS-14-4, NIA-AS-14-5, and Kiran-95 were categorized as tolerant genotypes whereas wheat genotypes NIA-AS-14-1, 3, 6, and 10 performed moderately. On other hand, NIA-AS-14-7 and NIA-AS-14-9 failed to cope with saline stress resulting in poor growth and were placed in the salt-sensitive group.

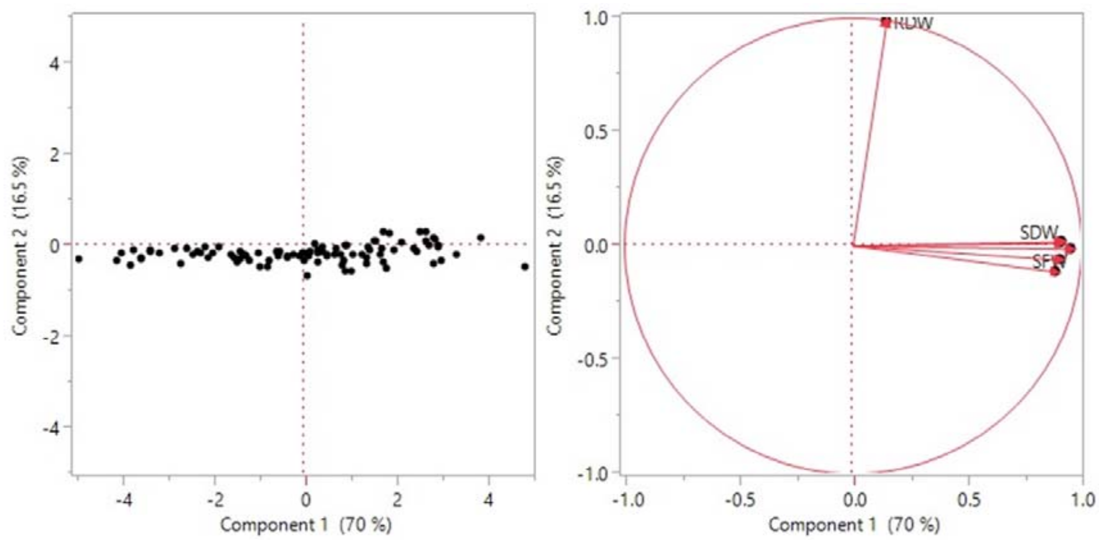

Fig. 5. Principal component analysis for different parameters of some wheat genotypes.

Discussion

Impaired seed germination is a major factor limiting the establishment of seedling under salinity (Wahid et al. 2010). Increasing salt stress had adversely affected seed germination in wheat genotypes NIA-AS-14-6 and NIA-AS-14-7 resulting in low germination count (Fig, 1). Likewise, inhibitory effect of salinity on final germination percentage crops including wheat has been reported earlier (Datta et al. 2009; Zafar et al. 2015). Seeds failure to germinate at high salt stress might be due to embryo damage by Na^+/Cl^- ions (Khajeh-Hosseini et al. 2003), inability of seed to imbibe water (Saboora and Kiarostami 2006) or exosmosis (Rahman et al.2008) and oxidative stress induced by salinity (Amor et al.2005).

The suppressing effects of NaCl stress on plant growth and biomass production are well known (Ma et al. 2013). Our results clearly indicate that considerable variations were observed for all seedling growth attributes among salinity levels as well as wheat genotypes. However, the adverse effects of increasing NaCl concentration recorded a gradual reduction in seedling growth in all tested genotypes (Tables 1, 2, and 3). Similar outcomes were also reported in wheat by various researchers (Gurmani et al. 2014; Hussain et al. 2013; Mahboob et al. 2016) who reported that seedling biomass in terms of fresh and dry weight was reduced gradually with increasing NaCl concentration. However, the variability for salt tolerance was existed among the observed genotypes. In comparison with control, maximum reduction in shoot and root fresh weight was observed in salt-sensitive genotype NIA-AS-14-7 followed by AS-14-9 with increase in salinity levels which strengthen the findings of Gurmani et al. (2014) who claimed greater decline in plant (shoot & root) dry biomass in salt-sensitive genotypes than salt-tolerant. The reason for low shoot and root length, their fresh and dry masses may be due to increase in osmotic potential by increasing salts, which results in dehydration, ionic imbalance in transpiring leaves that caused decrease in meristem activity and cell elongation, consequently inhibit the growth of wheat plant (Huang et al.2006; Munns 2005; Zhu 2001). However, it was observed that wheat genotypes produced high plant biomass at the seedling stage confirming better salt tolerance on maturity (Ahmadi and Ardekani, 2006). So the vigorous seedling establishment is a significantly important step in the life cycle of various crops.

Salinity tolerance in glycophytes like wheat is well known to be associated with Na^+ exclusion and the capacity to retain Na^+ in leaf tissue (Poustini and Siosemardeh 2004). The data of the present study revealed that genotypic variations exist in different wheat genotypes regarding Na^+ and K^+ uptake. Therefore, salt-stressed plants illustrated a gradual increase in leaf Na^+ content and decrease in K^+ as compared to control plants but varied significantly (Figs. 2, 3, and 4). Many researchers have reported that salt-tolerant wheat genotypes maintained lower content of leaf Na^+, higher level of leaf K^+, and greater K^+ to Na^+ ratio under saline environments than salt-sensitive genotypes (Bilkis et al. 2016; Khan et al.2014; Mahboob et at. 2016). The net buildup of sodium (Na^+) in plant cells might be because of the equilibrium between influx via ion channels and efflux through a probable Na^+/H^+ antiporter (Tester and Davenport 2003). The differential behavior of wheat genotypes was noted for K^+ content under salt stress and NIA-AS-14-2 and NIA-AS-14-4 showed an increase in leaf K^+ content with increasing levels of salinity (Fig. 3).Accordingly, the response of wheat was also reported by Cuin et al. (2008) who explained that an increase in K^+ concentration at the whole tissue level is largely a reflection of the behavior of K^+ within the vacuole, therefore masking the degree of changes in cytosolic K^+ activity. In monocots like wheat, salinity tolerance is associated with the ability of plant to exclude Na^+ and maintain high K^+/Na^+ in shoot tissue (Poustini and Siosemardeh 2004; Tester and Davenport 2003).

Conclusion

From the results, it can be concluded that the rising level of NaCl concentration in the solution caused a gradual decrease in seed germination and inhibit the growth of early seedlings at a variable rate in evaluating wheat genotypes. However, NIA-AS-14-6 and NIA-AS-14-7 showed more sensitivity regarding germination but NIA-AS-14-6 performed quite satisfactorily at the seedling stage. On the basis of the overall results, the genotypes NIA-AS-14-2, NIA-AS-14-4, NIA-AS-14-5, NIA-AS-14-10, and Kiran-95 were grouped as tolerant, moderately salt tolerant group comprised of NIA-AS-14-1, NIA-AS-14-3, NIA-AS-14-6, and NIA-AS-14-8; whereas, NIA-AS-14-7 and NIA-AS-14-9 were found sensitive to salt stress. Besides the growth parameters, low Na^+ uptake and better K^+ concentration with improved K^+:Na^+ ratio may be used as potential physiological markers to evaluate the salt tolerance of wheat.

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