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Screening of Wheat (Triticum aestivum L.) Genotypes for Salt Tolerance on the Basis of Physiochemical Characteristics and Bio-Physiological Parameters and Indices

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Abstract. *Salt stress is a major threat for growth and development of wheat crop. Screening technique for salinity tolerance is an effective tool to identify tolerant cultivar and high yielding wheat genotypes. Present study was carried out to screen twenty wheat genotypes under laboratory terms utilizing various growth and physiological indices like plant fresh weight stress indices (PFSI), plant height stress tolerance index (PHSI), shoot length stress tolerance index (SLSI), germination stress tolerance index (GSI), plant dry weight stress indices (PDSI), root length stress tolerance index (RLSI), relative water content (RWC). Multivariate techniques like cluster analysis and correlation were used to analyze the variance between wheat genotypes. The correlations analysis indicated significant among different physiological indices like GSI, SLSI, RLSI, PFSI, PDSI and RWC. On the basis of cluster analysis 20 wheat genotypes were classified into three clusters: first cluster included (The genotype WL-711 was the premier scorer followed by Nifa Bathoor, ARRI-II and Millat-11) presents sufficient salt tolerating degree, on the other hand, cluster-2 is comprised of wheat genotypes (Inqilab-91, NIAB-09, Punjab-96, Sehar-2006, Tatara, AS-2002, SA-75, Lasani-09, FSD-08 and Galaxy-13) with medium level of salt tolerance and cluster-3 included genotypes (LU-26-S, Fakhar e Sarhad, Bakhtawar, Punjab-11, Barsat and Kohistan-97) did not perform upto the mark and have lower level of salt tolerance. Correlation analysis among different screening techniques indicated that physiological indices exhibited highly significant and positive correlations among GSI, PHSI, SLSI, PDSI, PFSI, and RWC while non-significant correlation existed among PDSI and RLSI. The correlation between PFSI and RWC was significant. Significant correlations between cluster analysis and different indices also proved that salt tolerant wheat genotypes screened.*

Keywords: *Wheat, salt tolerance, correlation analysis, screening*

1.Introduction

Salinity is one of the important environmental factors that cause soil degradation, limit distribution and productivity of major crops in many regions of the world [1-3]. About 6.3 million hectares out of the 80.0 million hectares or 197.0 million acres (total geographical area of Pakistan) is salt-affected. It includes 0.45 million hectares in Punjab, 0.94 million hectares in Sindh and 0.5 million hectares in NWFP [4]. Plant germination and early seedling growth is mostly limited due to salinity [5]. Firstly,

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accumulation of excess amount of salt in the root affects emergence which results in prohibition of growth and development of plants and wheat crop as well [6]. Out of world's total cereal production Wheat (*Triticum aestivum* L.) constitutes up to 29 -30% and is the third most grown staple food crop of the world population after maize and rice [7-9].

In Pakistan, wheat ranks first as basic food crop and occupies central position in its agriculture based economy as it shares 13.1% value in agriculture and 2.8 % to gross domestic production of the country [10]. Pakistan is the 6th largest wheat producer because it contributes about 3.58% of the world wheat production from 4.21% of the world's wheat growing area. Wheat is commonly classified as a moderately salt tolerant crop as it threshold about 50 % yield loss at 15 dSm^{-1} and zero yield loss at 7 dSm^{-1} [11-12]. In wheat (hexaploid), the 4D chromosome from *Aegilops squarrosa* (wild grass) is responsible to tolerate salinity and discriminate K^+ / Na^+ translocation [13]. Evaluating wheat germplasm is necessary to resolve and find genotypes which are tolerant to ionic stress and possess high yield [14]. Different genotypes have been analyzed on basis of physiological indices at germination and early seedling variation in many crop plants [15]. It may leads to recognize varieties which are salt tolerant and are considered as economical exploit variety in future to cultivate it on salt-affected lands. Current study plans to figure out the NaCl stress of 20 wheat genotypes along with surveying the variability of their genotypic response to salt stress. The objectives of our study to evaluate the worth of several stress indices for identification of genotypes with better performance at different levels of salt stress.

2.Materials and methods

2.1. Experimental design

This experiment was conducted in lab/greenhouse to determine the salt tolerance in 20 genotype of wheat and 0, 80 and 120 mM NaCl were applied, different physiological indices were used as screening tool. The whole experimentation was operated at NIAB, Plant Stress Physiology Lab, Faisalabad, Pakistan. Twenty local wheat genotypes seeds were used for this study. Healthy seeds of 20 wheat genotypes were surface sterilized by using 3% sodium hypochlorite solution for 5 min and washed it for 3 times with distilled water. 10 seeds of each genotype of wheat were grown up in Petri plates moistened with above-mentioned solutions of salinity consisting double layered filter papers. Experiment was carried out in a Growth Chamber (Sanyo-Gallenkamp, UK) running at 28±2^{o}C. Germination percentage was recorded when the radical was of 2mm in length. After one week of germination, roots and shoots were separated, washed with distilled water and blotted with filter paper.

2.2. Seed material

The seeds of twenty local wheat (*Triticum aestivum*L.) genotypes/lines (NIAB-09, LU-26, Bakhtawar, Kohistan-97, Tatara, Punjab-96, SA-75, NifaBathoor, AS-2002, Fakhar E Sarhad, WL-711, Barsat, Punjab-11, Inqlab-91, Millat-11, ARRI-11, Sehar-06, Galaxy-13, FSD-08 and Lasani -09) were used for conducting the studies. The seed of said cultivars were obtained from research institute NIAB, Jhang road, Faisalabad, Pakistan.

2.3. Physiological indices

Following physiological indices were calculated by using following formulae [16]:

- Germination stress tolerance index (GSI) was calculated by

$$\mathbf{GSI} = \frac{(PI\ of\ stressed\ seeds)}{PI\ of\ control\ seeds)} \times 100$$

- Promptness index (PI) was calculated by

$$\mathbf{PI} = nd1\ (1.00) + nd2\ (0.75) + nd3\ (0.50) + nd4\ (0.25)$$

- Plant height stress tolerance index (PHSI)

$$\textbf{PHSI} = \frac{(Plant\ height\ of\ stressed\ plants)}{(Plant\ height\ of\ control\ plants)} \times 100$$

After 14 days of experiment, shoot and root length and fresh weight were calculated. Sample was dried in oven at 70°C and noted the dry weight of sample.

- Root length stress tolerance index (RLSI)
  RLSI = (Root length of stressed plants / Root length of control plants) x100

- Shoot length stress tolerance index (SLSI)
  SLSI = (Shoot length of stressed plants / Shoot length of control plants) x100

- Plant fresh biomass stress tolerance index (PFSI)
  PFSI= (Plant fresh weight of stressed plants / Plant fresh weight of control plants) x 100

- Plant dry biomass stress tolerance index (PDSI)
  PDSI = (Plant dry weight of stressed plants / Plant dry weight of control plants) x 100

- Relative water content (RWC)

The formula given by [17] can be used to calculate relative water contents

RWC = (fresh weight-dry weight) / (turgid weight-dry weight)]*100

Soil Properties

Texture of soil and physiochemical parameters (pH, EC and ion contents) are given in Table 1. Characteristics i.e. physiochemical and texture of soil were determined by using methods of [18-19]. Total N was measured by Kjeldhal method [20]. Sodium and potassium in plant digests sample was analyzed using flame photometer (PFP 7, Jenway). Calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined according to the method proposed by Hand Book-60 by Salinity Laboratory Staff US, 1954 [21]. The ground plant material (1 g) was taken and heated with 15 mL distilled water in tubes and was placed in oven at 50°C for 6 h. The extract was filtered and estimation of chloride by using chloride meter (Corning- 920, Germany).

Table 1. Soil properties of pot experiment

Characteristics of soil	**Pot Experiment (NIAB, Faisalabad)**
Physical	
Soil texture	Sandy clay loam
Saturation percentage (%)	35.5
Chemical	
EC_e	0.71–0.96 dS/m
Soil pH_s	7.1
Organic matter	0.31 %
Ca+Mg	2.70 meq/L
CO_3 (meq/L)	NIL
HCO_3	3.23 meq/L
Cl^-	2.4 meq/L
Total N	0.071 %
soluble K^+	28.0 mg/kg
Available P	8.54 mg/kg

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2.4. Statistical analysis

The obtained data was subjected to analysis of variance and Least Significant Difference (LSD) test at 5% probability level was used to compare the significant means [22]. Comparison of results was statistically analyzed by using the software program statistic 8.1. Minitab-16 was used to describe coefficient of variation analysis and cluster analysis.

3.Results and discussions

GSI (Germination stress tolerance index) with significant variations ($p \leq 0.05$) unveiled that salinity decreased the seed germination of all wheat genotypes (Table 2). The values of GSI recorded at 80 and 120mM NaCl were 81.12 and 76.04% respectively and reduced with the increase in salinity owing to the significant variation among all salinity treatments (Table 2). At 80 mM NaCl level Kohistan-97 exhibited less GSI (71.15%) values while WL-711 (92.75%) and NifaBathoor (90.32%) wheat genotypes exhibited maximum. At 120 mM NaCl salinity level, WL-711 recorded 81.16% GSI, while it was (67.31%) in Kohistan-97. Overall ranking for GSI have shown that Kohistan-97 was at 20th position whereas WL-711 was at 1st, Barsat covers 2nd and NifaBathoor was found at 3rd position. Salinity significantly minimized plant height of different wheat cultivars which directly influenced the plant height stress tolerance indices. PHSI significantly declined with increase in salt stress levels (84.55 and 71.24% respectively at 80 and 120 mM NaCl. Variations between all the salinity treatments were significant (Table 3). All wheat cultivars responded differently at 80mM NaCl treatment. The maximum PHSI (91.16%) was observed in WL-711 closely followed by Lasani-09 (90.88%) while the minimum PHSI was exhibited by Kohistan-97 (59.37%). At 120mM NaCl treatment, WL-711 (83.14%) and NifaBathoor (80.56%) maintained the maximum PHSI closely followed by LU-26 (78.46%) while the lowest PHSI was observed (47.17%) again in Kohistan -97. The overall ranking and genotypic means for PHSI indicated that WL-711 positioned at first, NifaBathoor at second and Barsat at third position whereas Kohistan-97 at 20th positions. Salinity influenced the shoot length stress tolerance index (SLSI) by reducing shoot length of all wheat genotypes. SLSI significantly decreased with the increase in salinity level (83.99 and 71.97% respectively at 80 and 120 mM NaCl) (Table 4). The maximum SLSI (92.76%) was observed in WL-711 closely followed by Bakhtawar (90.86%) while the minimum SLSI was exhibited by Galaxy-13 (66.75%). At 120mM NaCl treatment, WL-711 (85.78%) maintained the maximum SLSI and lowest SLSI was seen again in Galaxy-13 (53.63%). Genotypic mean clearly indicated that WL-711 gained at first, NifaBathoor was found at second, Barsat was at third rank and Galaxy-13 is at 20th positions. Root length stress tolerance index (RLSI) of each wheat genotypes was affected by salinity stress (71.34% and 85.18 under 80 and 120 mM NaCl, respectively) (Table 5). RLSI gave significant variations between all salinity levels. The lowest value (50.9%) for RLSI was observed in Kohistan-97at 80 mM NaCl treatment, while maximum was exhibited by WL-711 (91.93%) and FSD-08 (91.62%) closely followed by Lasani-09 (90.87%). The highest RLSI value (81.02%) was given by WL-711 and the lowest value (38.93%) was recorded by Kohistan-97 under 120 mM NaCl salinity stress. On the basis of RLSI genotypic means, WL-711 was ranked first and FSD-08 as 2nd while Kohistan-97 was ranked as 20th. Plant fresh weight significantly reduced under different salinity levels which ultimate influenced plant fresh weight stress tolerance index. PFSI was recorded as 81.79 and 73.92% under 80 mM and 120mM NaCl levels respectively (Table 5). Kohistan-97 and Galaxy-13 exhibited minimum performance for PFSI values (66.76 and 67.98%, respectively) while NifaBathoor and Sehar-2006 maintained similar PFSI (92.4%) at 80mM NaCl level. Under 120mM NaCl, WL-711(87.63%) possessed the highest PFSI while Kohistan-97 (54.7%) and Galaxy-13 (51.3%) exhibited the minimum PFSI. NifaBathoor and WL-711 scored maximum points for PFSI and was ranked at 1st and 2nd while Galaxy-13 was at 20th position in whole genotypic means evaluation. Salt stress influenced plant dry weight stress tolerance index (PDSI) and it gradually decreased with increase in salinity levels as 74.44 and 62.02% PDSI values under levels of 80 and 120 mM NaCl respectively (Table 5). At 80mM NaCl level, PDSI top most value was seen in WL-711 (90.2%) while minimum PDSI was observed in Inqlab-91 (49.2%). Maximum PDSI value was recorded for WL-711 (82.71%)

while Kohistan-97 (40.04%) demonstrates poor PDSI at 120mM NaCl level. The whole genotypic scoring for PDSI indicates that WL-711 ranked as first, at second it was Barsat while Kohistan-97and Inqlab-91 were at 19th and 20th positions respectively. Salt stress significantly reduced relative water contents in all wheat cultivars (Table 5) and it gradually decreased as salt stress level increased (82.01and 78.99% under 80 and 120 mM NaCl levels, respectively). At 80mM NaCl level, maximum RWC (92.15%) was observed in WL-711 while minimum RWC (67.61%) was recorded in Kohistan-97. Maximum RWC (90.69%) was recorded for WL-711 while Kohistan-97 (62.21%) and Galaxy-13 (68.24%) demonstrates poor RWC at 120mM NaCl level. On premise of genotypic mean for RWC, WL-711 was ranked as first, NifaBathoor as second and Barsat as third while Kohistan-97 was at 20th position. Valid correlations among RLSI, PDSI, SLSI and GSI were calculated by analysis of correlation. Significant and positive correlations were also obtained between GSI, RLSI, SLSI, PFSI and PDSI (Table 6). Results marked as those genotypes were salinity tolerant which high SDSI, SFSI, RDSI, SLSI, and GSI. In present study, wheat genotypes were completely spilt into three clusters based ondendogram (cluster correlation)complete linkage correlation coefficient distance (Figure 1).Cluster-2 consisted of wheat genotypes (NIAB-09, Punjab-96, Sehar-2006, Inqilab-91, Tatara, AS-2002, SA-75, Lasani-09, FSD-08 and Galaxy-13) with moderate salt tolerance capacity and first cluster included (WL-711, NifaBathoor, ARRI-II, Millat-11) exhibited adequate degree of salt tolerance, and genotypes based on cluster-3 (LU-26-S, Fakhar e Sarhad, Bakhtawar, Punjab-11, Barsat and Kohistan-97) did not perform up to the mark and have lower level of salt tolerance. Finding of present study suggest that exploitation of genetic variability for different morphophysiological markers would be beneficial for wheat cultivar development under salt stress. Findings of present study showed that physiological indices can explain some of the mechanisms representing tolerance to salt stress. Aim of wheat breeders is to produce salt tolerant wheat genotypes through technique of screening whereas screened genotypes show versatile performances on different environmental stresses. The conventional fact depict by the tolerance level at seedling stages reflects the tolerance at initial stages such as in wheat and maize [23], sorghum [24] and cotton [25]. Many factors such as condition at the time of harvesting and temperature effect germination. Hence, germination cannot be a good criterion to find out salt tolerance potential of many crop plants [24]. For salt stress, many genotypes are screened on basis of survival of seedlings. Salt stress decreases all physiological indices under salt stress conditions and it also harm cell membrane of seedling which leads to ion homeostasis disturbance [15]. Salt stress decreases all physiological indices under salt stress conditions and affects negatively to growth of radical and plumule. It also harms cell membrane of seedling which leads to ion homeostasis disturbance [26]. Plant fresh and dry weight also decreased under salt stress which ultimately effects PFSI and PDSI [27-28]. Ashraf et al. [1] recorded reduction in absorption of water due to osmotic effects under salinity which lead to adverse results on cell differentiation and division [29-30]. In seedlings, water scarcity results in poor biosynthesis of hormones and plant growth hormones [31]. It is evident that results of present study show that physiological indices like GSI, PHSI, SLSI, RLSI, RWC, PFSI and PDSI were able to utilize to screen germplasm of wheat for salt tolerance. WL-711 genotype was the main scorer for physiological indices followed by NifaBathoor, ARRI-II and Millat-11exhibited adequate degree of salt tolerance which gathered them in 1 cluster dendogram (Figure 1) whereas, cluster-2 consisted of wheat genotypes (Inqilab-91, NIAB-09, Punjab-96, Sehar-2006, Tatara, AS-2002, SA-75, Lasani-09, FSD-08 and Galaxy-13) with medium level of salt tolerance. While wheat genotypes LU-26-S, Fakhar e Sarhad, Bakhtawar, Punjab-11, Barsat and Kohistan-97 did not perform up to the mark and joined them in the cluster 3rd (Figure 1) and mentioned as sensitive. Cluster analysis were used by different researchers to categorized various wheat cultivars on the basis of different characteristics and classified the cultivars within different group based on similarities among them. The closest cultivars were classifies in one group. In current research work, cluster analysis also supported the findings and split the twenty cultivars into three clusters. These results are in accordance with the findings of [16] and [15]. Screening of crop germplasm for stress tolerance by cluster analysis was emphasized in literature [32-34]. These selected genotypes could be used in further breeding programs for salt tolerance.

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Table 2. Impact of salinity levels on different physiological indices (GSI, PHSI, SLSI) of wheat genotypes

	Germination stress tolerance indices GSI (%)					Plant height stress tolerance indices PHSI (%)					Shoot length Stress tolerance indices SLSI (%)				
	Salinity treatments (NaCl in mM)						Salinity treatments (NaCl in mM)					Salinity treatments (NaCl in mM)			
Genotypes	80mM	120mM	Means		80mM	Ranking	120mM	Means		80mM	Ranking	120mM	Means		Ranking
NIAB-09	75	73.21	74.11	HI	17	86.65	72.62	80	CDEF	11	85.8	77.18	81.5	ABCDEF	9
LU-26	85.25	78.69	81.97	BCDE	6	87.06	78.46	83	ABC	4	89.7	78.62	84.14	ABCD	5
Inqlab-91	73.68	68.42	71.05	IJ	18	85.84	75.71	81	BCDE	8	84.1	79.98	82.04	ABCDEF	8
Sehar 2006	84.21	78.95	81.58	BCDE	7	87.62	73.05	80	BCDEF	9	88.2	71.87	80.05	BCDEFG	10
Bakhtawar	81.48	77.78	79.63	CDEFG	10	59.37	47.17	53	I	20	68.3	55.87	62.1	IJ	19
Kohistan-97	71.15	67.31	69.23	J	20	83.22	70.6	77	DEFG	13	90.9	80.28	85.57	ABC	4
Tatara	77.19	73.68	75.44	GH	16	82.85	69.04	76	EFG	15	78.8	67.03	72.93	GH	16
Punjab-96	82	78	80	BCDEF	9	85.81	74.35	80	BCDEF	10	87.3	80.58	83.96	ABCD	6
SA-75	78.57	75	76.79	FGH	14	85.33	72.48	79	CDEFG	12	84.8	70.22	77.5	DEFG	13
NifaBathoo r	90.32	77.42	83.87	ABC	3	89.58	80.56	85	AB	2	90.6	83.08	86.86	AB	2
AS 2002	83.02	77.36	80.19	BCDEF	8	87.31	75.51	81	BCD	7	85.5	70.65	78.06	CDEFG	12
Fakhar E Sarhad	80	76.36	78.18	DEFGH	12	83.12	68.23	76	EFG	16	78.9	58.91	68.88	HI	17
WL-711	92.75	81.16	86.96	A	1	91.96	83.14	88	A	1	92.8	85.78	89.27	A	1
Barsat	88.33	80	84.17	AB	2	87.71	77.81	83	ABC	3	89	82.34	85.68	ABC	3
Punjab-11	77.78	74.07	75.93	FGH	15	83.18	64.48	74	G	18	76.2	61.05	68.63	HI	18
FSD-08	84.21	80.7	82.46	BCD	4	86.92	77.05	82	BCD	6	83.1	76.23	79.68	BCDEFG	11
Millat-11	78.95	77.19	78.07	EFGH	13	84.36	66.06	75	FG	17	80.3	69.01	74.67	FGH	15
ARRI-11	80.39	78.43	79.41	DEFG	11	87.41	66.2	77	DEFG	14	88.9	61.8	75.36	EFGH	14
Galaxy-13	73.21	67.86	70.54	IJ	19	74.89	57.83	66	H	19	66.8	53.63	60.19	J	20
Lasani-09	84.91	79.25	82.08	BCDE	5	90.88	74.53	83	ABC	5	90	75.29	82.67	ABCDE	7
Means	81.12	76.04				84.55	71.24				84	71.97			

Note: Means sharing in same row and column having similar letter did not differ significantly (p>0.05)

Table 3. Impact of salinity levels on different physiological indices (RLSI, PFSI, PDSI) of wheat genotypes

Genotypes	Root length stress tolerance indices RLSI (%)					Plant fresh weight stress tolerance indices PFSI (%)					Plant dry weight stress tolerance indices PDSI (%)				
	Salinity treatments (NaCl in mM)					Salinity treatments (NaCl in mM)					Salinity treatments (NaCl in mM)				
	80mM	120mM	Means		Ranking	80mM	120mM	Means		Ranki ng	80mM	120mM	Means		Ranki ng
NIAB-09	87.69	68.85	78.27	BCD	15	84.19	76.86	80.53	CDE	9	55.32	40.42	47.87	H	18
LU-26	84.85	78.68	81.77	ABCD	8	82.4	78.03	80.22	CDE	10	84.34	73.63	78.99	ABC	4
Inqlab-91	87.4	71.87	79.64	ABCD	12	81.83	71.36	76.6	DEF	13	49.2	39.69	44.45	H	20
Sehar 2006	87.8	74.74	81.27	ABCD	9	92.4	82.69	87.55	AB	3	77.31	58.4	67.86	EFG	13
Bakhtawar	50.9	38.93	44.92	G	20	66.76	54.7	60.73	H	19	59.82	40.06	49.94	H	17
Kohistan-97	76.09	61.52	68.81	F	19	80.7	76.59	78.65	CDEF	12	82.92	68.66	75.79	BCDE	6
Tatara	87.23	71.78	79.51	BCD	13	83.22	78	80.61	CDE	8	68.54	54.97	61.76	G	16
Punjab-96	84.72	69.76	77.24	CD	16	82.15	80.07	81.11	CD	5	73.78	59.38	66.58	G	14
SA-75	86.01	74.76	80.39	ABCD	10	81.35	67.86	74.61	EFG	15	75.33	64.47	69.9	EF	12
NifaBathoor	88.66	78.3	83.48	ABC	5	92.4	86.45	89.43	A	2	81.37	75.32	78.35	ABCD	5
AS 2002	89.13	79.92	84.53	AB	4	87.25	71.83	79.54	CDEF	11	66.68	56.91	61.8	G	15
Fakhar E Sarhad	86.99	77	82	ABCD	7	85.25	80.49	82.87	BC	4	74.04	71.34	72.69	CDEF	8
WL-711	91.93	81.02	86.48	A	1	91.92	87.63	89.78	A	1	90.2	80.66	85.43	A	1
Barsat	86.62	73.51	80.07	ABCD	11	84.1	77.23	80.67	CDE	7	87.3	82.71	85.01	A	2
Punjab-11	90.72	78.76	84.74	AB	3	76.43	70.45	73.44	FG	17	77.65	65.22	71.44	CDEF	10
FSD-08	91.62	77.96	84.79	AB	2	83.91	77.88	80.9	CD	6	80.44	63.93	72.19	CDEF	9
Millat-11	88.43	63.95	76.19	DE	17	78.62	69.23	73.93	FG	16	82.96	68.43	75.7	BCDE	7
ARRI-11	86.14	70.59	78.37	BCD	14	75.01	65.51	70.26	G	18	88.68	73.88	81.28	AB	3
Galaxy-13	79.98	61.1	70.54	EF	18	67.98	51.3	59.64	H	20	53.77	40.04	46.91	H	19
Lasani-09	90.87	73.84	82.36	ABCD	6	77.86	74.28	76.07	DEFG	14	79.23	62.23	70.73	DEF	11
Means	85.19	71.34				81.79	73.92				74.44	62.02			

Note: Means sharing in same row and column having similar letter did not differ significantly (p>0.05)

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Table 4. Impact of salinity stress on relative water content (RWC) of different wheat cultivars

Genotype	Salinity treatments (NaCl in mM)				Ranking
	80mM	120Mm	Means		
	RWC (%)				
NIAB-09	76.82	72.38	74.60	LM	17
LU-26	88.00	86.53	87.27	CD	4
Inqlab-91	75.29	71.04	73.17	M	18
Sehar 2006	85.71	82.84	84.27	EF	7
Kohistan-97	67.61	62.21	64.91	O	20
Bakhtawar	83.30	80.79	82.04	GH	10
Tatara	77.75	74.22	75.98	JKL	15
Punjab-96	83.70	80.79	82.24	GH	9
SA-75	79.22	75.16	77.19	JK	14
Nifa Bathoor	90.74	89.55	90.14	AB	2
AS 2002	84.53	82.47	83.50	FG	8
Fakhar E Sarhad	81.19	77.95	79.57	I	12
WL-711	92.15	90.69	91.42	A	1
Barsat	89.37	87.57	88.47	BC	3
Punjab-11	77.61	73.60	75.60	KL	16
FSD-08	86.90	84.76	85.83	DE	5
Millat-11	78.82	76.26	77.54	J	13
ARRI-11	82.74	79.38	81.06	HI	11
Galaxy-13	73.22	68.24	70.73	N	19
Lasani-09	85.55	83.33	84.44	EF	6
Means	82.01	78.99			

Note: Means sharing in same row and column having similar letter differed non-significantly at $p>0.05$

Table 5. Overall screening score of wheat cultivars on the basis of growth and physiological indices

Varieties	GSI	PHSI	SLSI	RLSI	PFSI	PDSI	RWC	Scores	Ranking
NIAB-09	7.41	7.96	8.15	7.83	8.05	4.79	7.46	51.65	17
LU-26	8.20	8.28	8.41	8.18	8.02	7.90	8.73	57.71	4
Inqlab-91	7.11	8.08	8.20	7.96	7.66	4.45	7.32	50.77	18
Sehar 2006	8.16	8.03	8.01	8.13	8.76	6.79	8.43	56.29	6
Bakhtawar	7.96	7.69	8.56	6.88	7.87	7.58	8.20	54.74	10
Kohistan-97	6.92	5.33	6.21	4.49	6.07	4.99	6.49	40.51	20
Tatara	7.54	7.59	7.29	7.95	8.06	6.18	7.60	52.22	16
Punjab-96	8.00	8.01	8.40	7.72	8.11	6.66	8.22	55.12	9
SA-75	7.68	7.89	7.75	8.04	7.46	6.99	7.72	53.53	13
NifaBathoor	8.39	8.51	8.69	8.35	8.94	7.83	9.01	59.72	2
AS 2002	8.02	8.14	7.81	8.45	8.74	6.18	8.35	55.69	8
Fakhar E Sarhad	7.82	7.57	6.89	8.20	8.29	7.27	7.96	53.99	12
WL-711	8.70	8.75	8.93	8.62	8.98	8.54	9.14	61.66	1
Barsat	8.42	8.28	8.57	8.01	8.07	8.50	8.85	58.68	3
Punjab-11	7.59	7.38	6.86	8.47	7.36	7.14	7.56	52.38	15
FSD-08	8.25	8.20	7.97	8.43	8.09	7.22	8.58	56.73	5
Millat-11	7.81	7.52	7.47	7.62	7.39	7.57	7.75	53.13	14
ARRI-11	7.94	7.68	7.54	7.84	7.03	8.13	8.11	54.26	11
Galaxy-13	7.05	6.64	6.02	7.05	5.96	4.69	7.07	44.49	19
Lasani-09	8.21	8.27	8.27	8.24	7.61	7.07	8.44	56.11	7

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Table 6. Correlation among screening techniques

Techniques	GSI	PDSI	PFSI	PHSI	RLSI	RWC
PDSI	0.8551**					
PFSI	0.7475**	0.4916*				
PHSI	0.7748**	0.5190*	0.8234**			
RLSI	0.6126*	0.4386ns	0.6784**	0.8737**		
RWC	0.9783**	0.7912*	0.7809**	0.8421*	0.6686*	
SLSI	0.7394**	0.4930*	0.7709**	0.8579**	0.5124*	0.7901**

GSI = Germination stress tolerance index; PHSI = Plant height stress tolerance index; SLSI = Shoot length stress tolerance index; RLSI = Root length stress tolerance index; PFSI = Plant fresh weight stress tolerance index; PDSI = Plant dry weight stress tolerance index; RWC = Relative water content

* = Significant ($p<0.05$); **= Significant ($p<0.01$); ns= non-significant ($p>0.05$)

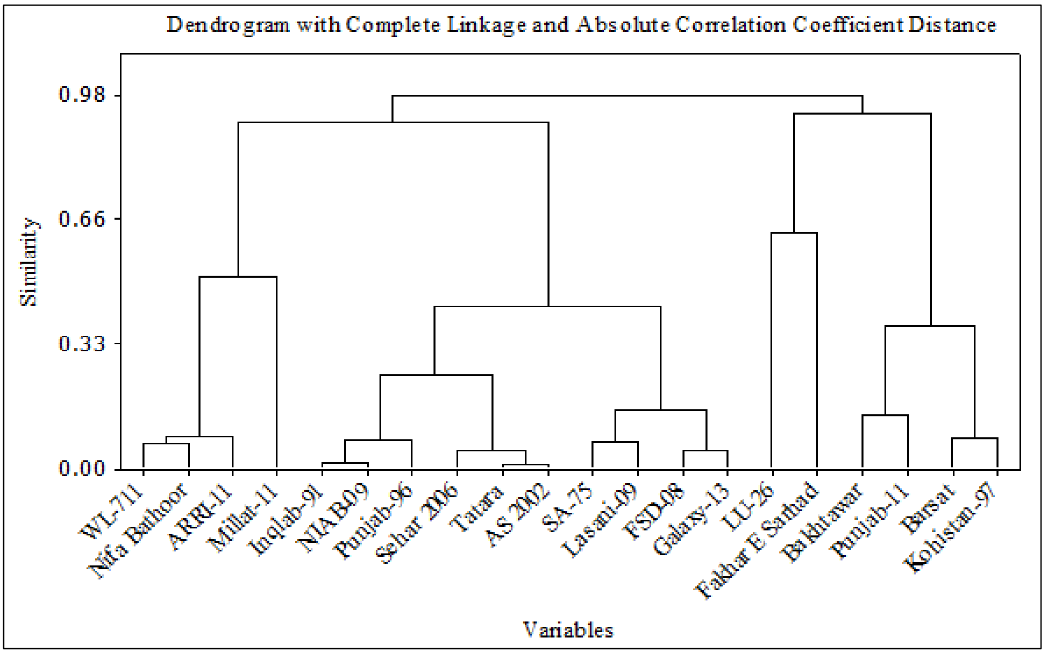

Figure 1. Dandogram from cluster analysis based on physiological indices as a screening tool for salt tolerance in different wheat genotypes. Clusters detail; Cluster: 1 WL-711, NifaBathoor, ARRI-II, Millat-11; Cluster 2: Inqilab-91, NIAB-09, Punjab-96, Sehar-2006, Tatara, AS-2002, SA-75, Lasani-09, FSD-08 and Galaxy-13; Cluster 3: LU-26-S, Fakhar e Sarhad, Bakhtawar, Punjab-11, Barsat and Kohistan-97

4.Conclusions

From the results of this study, it was concluded that different wheat genotypes can be screened on the basis of physiological indices for salt tolerance. Significant correlations between cluster analysis and different indices also proved that salt tolerant wheat genotypes screened. Cultivation of these salt tolerant wheat genotypes can be recommended under salt stress conditions and to acquire high yield production. It is further recommended for cultivations of salt tolerant wheat genotypes on normal soil as well on salt affected soil.

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