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MORPHOLOGICAL AND PHYSIOLOGICAL CRITERIA FOR DROUGHT TOLERANCE AT SEEDLING STAGE IN WHEAT

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ABSTRACT

The current research work was conducted to identify drought tolerant wheat genotypes after passing through screening criteria at seedling stage in wheat. Fifty wheat genotypes were studied for Emergence percentage, Emergence Index, Emergence rate Index, Energy of emergence and Relative Cell Injury (RCI) under normal and drought conditions. The data regarding germination traits and relative cell injury exposed significant differences among genotypes (P>0.01). Out of 50 genotypes, eight were termed as drought tolerant, ten moderately drought tolerant and thirty two drought susceptible. Among drought tolerant group, Chakwal-50 was the most drought tolerant genotype followed by 6302 and Chakwal-86. Whereas in drought susceptible group, Lasani-08 was the most susceptible genotype followed by Faisalabad-08 and Sehar-06. Strongest correlation was observed between emergence index and emergence percentage. RCI had negative association with germination traits.

Key words: Morph-physiological parameters, PEG-6000, correlation, wheat, drought tolerance

INTRODUCTION

Wheat (*Triticum aestivum* L.) is amongst the leading cereal crops used as food and about twenty percent of the required protein and dietary calories for human beings, are acquired from wheat worldwide (Kugler *et al.*, 2013). Wheat productivity is decreasing gradually and progressively due to the adverse effects of abiotic stresses (drought, extreme temperature, cold and salinity). But drought alone being the most devastating stress, decreases the overall yield as compared to any other type of stress. Water stress tends to impair the plant growth and development and slow down the optimum productivity (Farooq *et al.*, 2011a; Ahmadizadeh *et al*., 2013).

Globally water deficit has become the most critical problem due to the reasons of its detrimental effects on plant growth and performance, among the existing various environmental stresses (Janmohammadi, 2008). High temperature with low humidity leads to scarcity of water, which is major restricting factor, for plant better performance and enhancement of wheat production (Turhan, 1997; Hirt and Shinozaki, 2004).

Germination is among the critical stages of plant, which is badly disturbed by low soil moisture. But the plants which could tolerate scarcity of water appear as stable plants (Jajarmi, 2009). Various researchers had reviewed the inauspicious effects of drought on germination and seedling development in crops such as wheat (Dhanda *et al*., 2004; Almaghrabi, 2012), barley, corn and canola (Gharoobi *et al*., 2012).

Soil moisture unreachability is among the prime causes of low germination in various crop seeds (Mohammad *et al.*, 2002). Germination rate and percentage are reduced by water deficit (Delachiave and de Pinho, 2003). But in drought conditions the plants that make efficient use of water can guarantee higher crop production (Dodd and Donovan, 1999).

According to statistical data, drought is affecting more than 99 million hectare area across the developing nations and more than 60 million hectares across the developed parts of the world (Rajaram, 2000). In Pakistan, about 15 million hectares of land are affected by this environmental stress caused by the short supply of water (Mujtaba and Alam, 2002). Yield losses ranging from 17 to 70% are attributed to the drought stress (Nouri-Ganbalani *et al*., 2009). It has been proved that the crop losses due to water shortage are greater than any other type of biotic or abiotic stress across the globe (Kramer, 1983).

Effect of drought at cellular level is indicated as physiological and biochemical disorders like electrolyte leakage through cell membrane. This leakage will be minimized in cells with a stable membrane. Thus, stability of cell membrane in the presence of stresses like drought or high temperature may indirectly indicate the ability of plant to withstand periods of stress. Cell membrane thermostability (CMT) also expressed as relative cell injury percentage (RCI%) in terms of electrolyte leakage, is an efficient physiological criterion (Sullivan, 1972) which has been frequently used by lot of researchers for screening of drought and heat tolerant genotypes in different crops like wheat (Saadalla *et al*., 1990; Tahir and Singh,1993; Ibrahim and Quick,2001;

Farooq *et al*., 2011b) rice (Farooq *et al*., 2009) and cotton (Azeem *et al*., 2008; Ali and Awan, 2009).

Polyethylene glycol (PEG-6000) is a chemical used to induce artificial desiccation, being commonly utilized in laboratory conditions for screening drought tolerant genotypes at early growth stage (seedlings). Earlier studies disclosed that polyethylene glycol can be applied to change the osmotic potential of nutrient solution and as a result create plant water scarcity in a moderately controlled manner (Money, 1989; Shanahan *et al*., 1990). Using this technique the present study was planned to screen 50 wheat varieties/lines for drought tolerance using germination related parameters and relative cell injury at seedling stage. Relative cell injury (RCI) and germination related traits (emergence, emergence rate, emergence rate index, energy of emergence, etc.) are important criteria for study of drought tolerance at early stage of growth in wheat**.** Electrolyte leakage estimation test provides the information about level of drought stress. The test determined the degree of cell membrane damage caused by stress based on assessment of electrolyte leakage from the cell.

Information pertaining to correlation allows possibility of indirect choice of selection for several traits, this inter-relationship offers valuable information to the researchers in recognizing parameters that have very little or no value in selection in plant breeding programs. Keeping in view the importance of drought in the existing global scenario, current research project was made to identify drought tolerant genotypes after passing through screening criteria at seedling stage in wheat.

MATERIALS AND METHODS

The studies were conducted in the wire house at University of Agriculture, Faisalabad, Pakistan during crop season 2008-2009. Fifty diverse genotypes, collected from different sources (local and exotic) were utilized. Two experiments (one under normal and second under drought conditions) were conducted using a triplicated complete randomized design. The sterilized seeds (soaked in 5% sodium hypochloride solution for 5 minutes and washed with distilled water for several times) were sown @ two seeds (at 2 cm depth) per polythene bag filled with measured quantity of sand. After germination one healthy seedling was maintained in each bag. Each genotype treatment consisted of ten bags per replication. For the experiment under controled condition, no stress was levied but for the experiment under drought condition, artificial desiccation was induced by using Poly ethylene (PEG-6000) 7.5% solution following methods as described by Shanahan *et al.,* (1990).

For determining Relative Cell Injury (RCI), Leaf discs from flag leaves of ten randomly selected plants were collected with steel punch (10 mm inner diameter) at fourth leaf stage to study the electrolyte leakage from leaves by conductivity meter. Samples were collected in paired sets from both sides of leaf midrib. One set was collected from normal experiment (control) and other from drought experiment (PEG-treated). Samples were rinsed thrice with de-ionized water to get rid of surface contamination and then samples from control were submerged in 17ml de-ionized water in test tubes (control) and samples from drought experiment were exposed to 17ml polyethylene glycol (PEG-6000) 30 % solution in test tubes. These test tubes were covered tightly.

Control samples were kept at room temperature (25°C) and drought samples were treated at (49°C) in water bath (MEMMERT-WB 1, Germany) for one hour. After the treatment periods, readings of both control (normal) and (drought) samples were recorded by using conductivity meter (Model No. JENWAY-4510 Sr. No-02370 Barlow World Scientific Limited, UK) after keeping the test tubes over night. Next day both control and drought test tubes were placed in autoclave (Model No. HVA-85 HRAYAMA Manufacturing Company, Japan) at 120°C and 0.10 Mpa for a period of 10 minutes to kill tissues completely and facilitate leakage of electrolyte from samples. Both set of samples were cooled down at room temperature (25°C). Then second conductometric reading (at 25°C) from both set of samples was recorded after autoclaving by using the conductivity meter. Then the RCI was computed following Sullivan (1972).

$$\text{RCI (\%)} = 1 - \frac{1-(T1/T2)}{1-(L1/L2)} \times 100$$

Where,

RCI = Relative Cell Injury

T_1= conductivity reading at 49°C

T_2= conductivity reading at 120°C for 10 minutes.

C_1= conductivity reading at room temperature.

C_2=conductivity reading at room temperature after autoclave at 120°C for 10 minutes.

The data were also collected for emergence percentage, emergence index, emergence rate index and energy of emergence under both conditions and were analyzed using analysis of variance (Steel *et al*., 1997) to determine significant differences among genotypes. Comparison of means was conducted based on Duncan's Multiple Range test (Duncan, 1955). Genotypes were grouped as drought tolerant, moderately drought tolerant and drought susceptible (Farooq *et al*., 2011a; Farooq *et al.,* 2011b). Correlation among seedling traits was also determined following Pearson (1920).

RESULTS

Analysis of variance revealed significant differences among genotypes for all the traits under study

in normal as well as water stress conditions (Table 1) indicating presence of sufficient variability. Coefficient of variability for traits under study ranged from 1.62 to 5.18% and 1.68 to 6.25% under normal and drought conditions, respectively. Table 2 depicted that emergence percentage, emergence index, emergence rate index, energy of emergence and relative cell injury means ranged from 62.21 to 100.00, 4.18 to 8.84, 0.067 to 0.089, 28.32 to 69. 82 and 21.29 to 79.08 under normal and 51.32 to 98.79, 2.40 to 8.008, 0.046 to 0.081, 27.45 to 58.84 and 28.55 to 94.88 under drought condition, respectively. All seedling traits showed a decrease ranging from 11.33 to 27.02 % except RCI which presented an increase of 18.98%.

Table 1. Analysis of variance for five seedling traits in wheat under normal and drought (PEG- treated) conditions.

Traits	Genotypes (Mean squares)		Error (Mean Squares)		Over all mean		CV%	
	Normal	Drought	Normal	Drought	Normal	Drought	Normal	Drought
Emergence % age	625.001**	491.799**	1.644	1.434	79.131	71.079	1.62	1.68
Emergence Index	4.375**	4.445**	0.094	0.077	6.064	4.774	5.06	5.80
Emergence rate Index	0.000077**	0.00017**	0.000016	0.000017	0.076	0.067	5.18	6.25
Energy of emergence	290.502**	262.861**	0.823	0.962	45.752	37.468	1.98	2.62
Relative cell injury	625.001**	846.704**	3.957	2.966	51.707	63.820	3.85	2.70

** = $P \leq 0.01$

Table 2. Range of means and percentage change in seedling traits of fifty wheat genotypes under normal and drought (PEG-treated) conditions.

Traits	Range of means		Percentage Increase (+) or decrease (-) over normal
	Normal	Drought	
Emergence % age	62.21 - 100.00	51.32 - 98.79	-11.33
Emergence Index	4.18 - 8.4	2.40 - 8.008	-27.02
Emergence rate Index	0.067 - 0.089	0.046 - 0.081	-13.43
Energy of emergence	28.32 - 69.82	27.45 - 58.84	-22.11
Relative cell injury	21.29 - 79.08	28.55 - 94.88	+18.98

Emergence percentage (EP): Overall results revealed that emergence percentage was reduced under drought conditions as compared to that under normal conditions. Under normal condition genotype 6302 displayed maximum emergence (100.00%) followed by Lasani-08 and Faisalabad-08 with values of 99.90% and 99.83%, respectively, (Table 3). Minimum value of 62.21% was attained by line-9438. Whereas, under drought, Chakwal-86 exposed maximum value (98.79%) and followed by line-6302 and Chakwal-50 (98.53 and 97.79%), respectively. Lowest emergence percentage (51.32%) was displayed by Lasani-08 and Perwaz-94 followed by Sehar-06 and Faisalabad-08 (51.72 and 52.23%, respectively).

Emergence index (EI): Highest emergence index (8.84) was recorded for Chakwal-86 followed by Chakwal-50, 6302, Lasani-08, Sehar-06 and Faisalabad-08 (8.34, 8.15, 8.21, 8.11 and 8.10, respectively). While minimum (4.18) was recorded for Perwaz-94 (Table 3). Under drought conditions, the genotype 6302 displayed maximum emergence index (8.01) followed by Chakwal-50 and Chakwal-86 (7.72 and 7.50, respectively). Minimum value (2.40) was noted for Faisalabad-08 followed by Sehar-06 (2.64) and Lasani-08 (3.06).

Emergence rate index (ERI): The highest value (0.089) of ERIwas observed for Chakwal-86 under normal condition (Table 3) followed by genotypes 9191 (0.086), Chakwal-50 (0.084), Faisalabad-08 (0.081) and Lasani-08 (0.079). Lowest ERI (0.067) was recorded for the genotypes Line-9452 and Perwaz-94. Under drought condition, the genotype 6302 had maximum ERI (0.081) followed by Chakwal-50 and Chakwal-86 (0.079 and 0.076, respectively). Minimum ERI (0.046) was observed for Faisalabad-08 followed by Sehar-06 and Lasani-08 (0.051 and 0.052, respectively).

Energy of emergence (EOE): The energy of emergence decreased significantly under PEG induced drought condition in all genotypes (Table 3). Faisalabad-08 had highest EOE (69.82) under normal condition followed by Sehar-06 (60.77), 6302 (60.32), Chakwal-86 (59.90), and Chakwal-50 (59.71). The lowest EOE (28.32) was recorded in the genotype 6238. Under drought condition, highest EOE (58.84) was observed for the genotype 6302 followed by Chakwal-86 (58.11) and Chakwal-50 (57.90). Minimum EOE (27.45) was recorded for the

genotype 6238 followed by Sehar-06 (27.86) Faisalabd-08 (28.35) and Lasani-08 (28.44).

Relative cell injury (RCI): RCI ranged from 21.29-79.08 % under normal condition. The genotype 6302 had minimum RCI (21.29%) followed by Chakwal-50 (25.82%) and Chakwal-86 (29.86%), while Uqab-2000 had maximum RCI (79.08%) followed by Lasani-08 (75.67%), Faisalabad-08 (74.83%) and Sehar-06 (73.32%). Comparison of the genotypes under drought (PEG treated) condition depicted that range of RCI was 28.55-94.88% The genotype Chakwal-50 had minimum RCI (28.55%) followed by the genotype 6302 and Chakwal-86 (28.62% and 31.72%, respectively). These genotypes also showed lower RCI (21.29%, 25.82% and 29.86%, respectively) under normal conditions (Table 4). The genotype Lasani-08 showed maximum RCI (94.88%) followed by Faisalabad-08 (92.74%) and Sehar-06 (90.38) under drought condition. These genotypes also showed high RCI under control condition.

On the basis of RCI under PEG induced drought, fifty genotypes were divided into three groups viz., drought tolerant (28.55 to 43.91%), moderately drought tolerant (44.94 to 60.82%) and drought susceptible (63.14 to 94.88%).

Duncan multiple's range test helped to divide genotypes into homogenous groups under normal and drought condition. The data indicated that under normal conditions, 23 genotypes had less than 50% RCI and 27 genotypes had more than 50% RCI. Similarly, under drought, 12 genotypes showed less than 50% RCI while 38 genotypes had more than 50% RCI (Table 4).

Correlation: Positive and highly significant relationship was observed among all seedling traits (emergence percentage, emergence index, emergence rate index and energy of emergence) under both normal and drought conditions (Table 5). However, RCI displayed negative and highly significant association with emergence percentage, emergence index and energy of emergence both under normal and drought condition. The correlation of RCI with emergence rate index was also negative but was non-significant under normal and highly significant under drought conditions.

Table 3. Comparison of genotypic means for four seedling traits under normal and drought condition.

Genotypes	Emergence % age		Emergence index		Emergence rate index		Energy of emergence (%)	
	Normal	Drought	Normal	Drought	Normal	Drought	Normal	Drought
2862	70.53	68.56	5.36	4.57	0.076	0.067	40.46	30.12
6206	95.11	94.22	6.78	6.30	0.071	0.067	52.22	51.26
6237	89.94	72.77	6.75	4.76	0.075	0.065	40.25	35.73
6238	68.25	68.00	4.84	5.18	0.071	0.075	28.32	27.45
6253	66.91	66.34	4.54	4.47	0.068	0.067	36.42	31.32
6284	70.61	67.34	5.68	4.41	0.080	0.066	40.32	31.12
6301	77.93	75.47	5.61	5.22	0.072	0.069	41.23	29.78
6302	100.00	98.53	8.15	8.01	0.081	0.081	60.32	58.84
6309	70.64	67.78	4.78	4.08	0.068	0.060	35.68	28.99
6312	73.01	72.88	5.15	4.61	0.070	0.063	35.45	31.53
6314	86.13	74.54	6.48	5.24	0.075	0.070	56.43	40.44
6316	79.44	55.73	6.08	3.43	0.076	0.062	40.44	32.82
6317	90.56	82.92	6.56	5.79	0.072	0.070	55.71	51.52
8186	70.89	65.11	5.32	4.38	0.075	0.067	39.52	30.12
8188	72.94	70.12	5.41	4.38	0.074	0.063	45.34	34.10
8191	85.44	71.11	6.71	4.97	0.079	0.070	51.29	31.72
9021	96.76	95.07	6.93	5.79	0.072	0.061	54.64	50.80
9189	68.20	65.88	4.76	4.50	0.070	0.068	38.32	29.17
9191	65.33	60.07	5.59	3.50	0.086	0.058	43.33	35.12
9193	67.77	60.34	5.17	4.39	0.076	0.073	55.11	52.13
9194	71.00	68.97	5.28	4.72	0.074	0.068	40.70	32.41
9244	96.54	75.12	7.65	4.67	0.079	0.062	48.67	41.32
9247	70.78	69.52	5.42	4.55	0.077	0.065	41.28	38.15
9381	70.33	66.32	5.43	4.53	0.077	0.068	38.35	29.94
9438	62.21	61.28	4.19	3.42	0.067	0.056	38.47	31.92
9444	90.33	74.91	6.92	5.71	0.077	0.073	52.23	43.91
9452	79.74	69.00	5.33	3.74	0.067	0.054	40.63	35.41
9476	75.23	64.22	5.46	3.46	0.073	0.054	35.43	30.18
AS-02	63.24	62.80	4.32	3.68	0.068	0.059	32.59	29.12
Aas	95.24	92.12	7.50	6.59	0.079	0.072	48.42	39.92
Chakwal-50	99.53	97.79	8.34	7.72	0.084	0.079	59.71	57.90
Chakwal-86	99.45	98.79	8.84	7.50	0.089	0.076	59.90	58.11
Chakwal-97	81.24	73.71	6.41	5.27	0.079	0.072	58.42	44.11

Faisalabad-08	99.83	52.23	8.10	2.40	0.081	0.046	69.82	28.35
Fareed-06	80.12	70.41	6.41	4.32	0.080	0.061	54.50	45.19
GA-02	64.56	60.98	5.25	4.51	0.081	0.074	38.11	32.65
Kohinoor-83	69.38	65.77	5.45	5.45	0.079	0.075	46.25	31.68
Lasani-08	99.90	51.32	8.21	3.06	0.082	0.052	61.38	28.44
Lu-26	99.35	96.33	7.68	6.53	0.077	0.068	59.31	55.71
Manthar-03	68.55	66.32	5.33	4.94	0.078	0.075	38.68	35.44
Meraj-08	83.25	73.23	6.71	5.13	0.081	0.070	49.52	41.93
Nesser	96.51	94.25	7.57	6.71	0.078	0.075	58.44	55.54
Pak81	70.01	69.81	5.33	4.53	0.076	0.065	48.58	41.47
PBW	72.35	70.11	5.77	3.82	0.080	0.065	34.45	32.49
Perwaz-94	62.33	51.32	4.18	3.55	0.067	0.069	35.41	31.72
Punjab-81	68.91	66.91	5.58	5.07	0.081	0.075	36.72	30.12
Sehar-06	99.61	51.72	8.11	2.64	0.081	0.051	60.77	27.86
Shalimar-88	69.20	65.99	5.31	4.37	0.077	0.066	38.43	31.47
Ufaq-02	65.58	64.04	5.11	4.50	0.078	0.070	37.32	35.39
Uqab-00	65.87	55.50	5.36	3.78	0.081	0.068	34.31	31.29
SE	1.05	0.98	0.25	0.23	0.003	0.003	0.74	0.80

Table 5. Simple correlation of seedling traits of wheat under normal and drought (PEG-treated) conditions

Traits	Condition	EP	EI	ERI	EOE	RCI
EP	N	1.00				
	D	1.00				
EI	N	0.95**	1.00			
	D	0.92**	1.00			
ERI	N	0.37**	0.63**	1.00		
	D	0.50**	0.77**	1.00		
EOE	N	0.82**	0.84**	0.47**	1.00	
	D	0.81**	0.78**	0.46**	1.00	
RCI	N	-0.30*	-0.36*	-0.24NS	-0.41**	1.00
	D	-0.51**	-0.60**	-0.52**	-0.41**	1.00

EP=Emergence percentage, EI=Emergence index, ERI= Emergence rate index, EOE=Energy of emergence RCI=Relative cell injury, N=Normal and D=Drought.; *= $P \leq 0.05$, **= $P \leq 0.01$

Table 4. Comparison of genotypic means for Relative Cell Injury (RCI %) using Duncan's multiple range test under normal and drought (PEG-treated) conditions

Accession No.	Genotype	Normal (Control)		Drought (PEG-Treated)		
		Mean	Homogenous Group	Mean	Homogenous group	Remarks*
1	Uqab-00	79.08	a	88.15	c	DS
2	Lasani-08	75.67	b	94.88	a	DS
3	Faisalabad-08	74.83	bc	92.74	ab	DS
4	Sehar-06	73.32	bc	90.38	bc	DS
5	Pak-81	71.91	cd	88.98	c	DS
6	6312	69.04	de	82.99	d	DS
7	GA-02	68.88	de	77.97	ef	DS
8	PBW	67.00	ef	78.04	e	DS
9	9021	66.82	ef	78.88	e	DS
10	9476	65.14	fg	75.22	fg	DS
11	Punjab-81	63.08	gh	70.11	ij	DS
12	6206	62.99	gh	67.01	kl	DS
13	Kohinoor-83	62.15	ghi	66.10	klm	DS
14	6301	62.09	ghi	74.09	gh	DS
15	9244	62.08	ghi	68.08	jk	DS

Accession No.	Genotype	Normal (Control)		Drought (PEG-Treated)		
		Mean	Homogenous Group	Mean	Homogenous group	Remarks*
16	6253	61.13	hij	85.11	d	DS
17	Fareed-06	60.89	hij	64.99	lmn	DS
18	6317	59.86	hij	63.93	mn	DS
19	6238	59.11	ij	63.14	no	DS
20	Mearj-08	58.98	ij	68.02	jk	DS
21	8188	58.95	ij	70.01	ij	DS
22	6237	58.86	j	60.82	o	MDT
23	9247	58.26	j	67.22	kl	DS
24	9452	52.28	k	72.37	hi	DS
25	Lu-26	51.86	k	54.90	pq	MDT
26	Shalimar-88	51.83	k	64.94	lmn	DS
27	Manthar-03	50.93	k	71.96	hi	DS
28	Perwaz-94	47.19	l	79.15	e	DS
29	9193	46.26	lm	68.39	jk	DS
30	Nesser	45.84	lm	54.84	pqr	MDT
31	Ass	44.78	lmn	53.79	qr	MDT
32	AS-02	43.31	mno	68.29	jk	DS
33	Ufaq-02	43.15	mno	75.23	fg	DS
34	Chakwal-97	41.88	nop	43.90	uv	DT
35	9194	41.21	op	57.16	p	MDT
36	8191	41.11	op	52.07	rs	MDT
37	9189	40.94	op	46.90	t	MDT
38	9444	40.83	op	44.94	tuv	MDT
39	2862	40.69	op	49.82	s	MDT
40	6316	39.85	pq	45.94	tu	MDT
41	9438	37.30	qr	63.35	mno	DS
42	6284	37.12	qrs	70.18	ij	DS
43	9191	35.38	rst	64.44	lmn	DS
44	9381	34.20	rst	38.26	w	DT
45	6309	34.08	rst	39.16	w	DT
46	6314	34.03	st	43.05	v	DT
47	8186	32.21	tu	42.17	v	DT
48	Chakwal-86	29.86	U	31.72	x	DT
49	Chakwal-50	25.82	V	28.55	y	DT
50	6302	21.29	W	28.62	y	DT
SE		1.62		1.41		

*DT= Drought tolerant, MDT= Moderately drought tolerant and DS= Drought susceptible

DISCUSSION

Water stress is a major limiting factor in wheat crop production in arid and semiarid regions of the world. It inhibits plant growth and development severely and ultimately causes decline in yield. The response of PEG induced drought was evident in this study where germination/seedling traits were declined drastically.

Higher the emergence percentage, emergence index and energy of emergence and lower mean emergence time, earlier and rapid was the germination. Decrease in emergence percentage under water deficit conditions is reported to be as a result of occurrence of certain metabolically disorders (Ayaz *et al*., 2000). It is obvious that reduction of emergence percentage and other parameters is related to decrease of water absorption into the wheat seeds at turgescence and seed imbibition stages (Hadas, 1977).

Effect of drought was also evident as increase in Relative Cell Injury percentage as compared to the controlled condition. Cell Membrane Thermostability (CMT), also evinced as relative cell injury percentage (RCI %) in terms of electrolyte leakage, is an efficient physiological criterion while studying drought tolerance (Sullivan, 1972; Saadalla *et al*., 1990; Farooq *et al*., 2011b)

The genotypes with least injury to cell membrane possessed tolerance to drought. Cell

membrane stability may be considered as the vital criterion for selection at early stage being the regulatory factor of most membrane related biochemical pathways of metabolism. Its usefulness as a selection criterion at early stages has also been highlighted by (Farooq *et al*., 2009). Studies with respect to relative cell injury percentage revealed that genotypes with less injury to plasma membrane are tolerant and genotypes with more injury to cell membrane (excessive leakage of electrolytes from the cell) were drought susceptible (Renu *et al*., 2004; Ali *et al*., 2013).

Drought tolerant cultivars maintained their cell membrane stability and integrity against water stress. Stability of membrane is also important for growth and development of wheat plant as it tolerate water deficit condition. As drought stress damages the plasma membrane structure and function. Electrolyte leakage extent increases steadily with the increase in drought stress. Change in cell membrane thermostability (CMT) also results due to worst environmental conditions such as water stress and high temperature etc. These stresses may affect the cell membrane to disturb ion exchange and causing imbalance which ultimately alter turgor pressure resulting cell membrane damage rendering plants to be susceptible. Effects of such change in cell membrane in response to environmental stresses were also highlighted (Gollojeh and Ranjbar, 2012). It became evident from the study that cell membrane integrity of drought tolerant genotypes was stable in comparison with drought susceptible genotypes.

On the basis of median values under stress conditions out of 50 genotypes, 8 were termed as drought tolerance, 10 as moderately drought tolerant and 32 as drought susceptible genotypes. Similar grouping was done by researchers (Farooq *et al*., 2011a; Farooq *et al.*, 2011b). Keeping in view the above results and discussion, three genotype viz., Chakwal-50, 6302 and Chakwal-86 were termed as drought tolerant which may be used in further breeding programmes for developing drought tolerant varieties for rainfed areas. In contrast, the genotypes Faisalabad-08, Lasani-08 and Sehar-06 showed higher relative cell injury and also lower other germination traits and were termed as drought susceptible genotypes.

Information regarding the association of morpho-physiological parameters may further assist to formulate the tactics for indirect selection. Positive and significant association under both planting conditions was observed amongst all the seedling traits except RCI which exposed negative and significant correlation with them. Strongest correlation was noticed among emergence index and emergence percentage both under normal as well as drought stress conditions. This showed that increase in any germination trait may enhance the other germination parameters. Similar results were also reported by researchers (Noorka *et al*., 2007). But on the contrary it was observed that this enhancement in germination had also negative effects on RCI. More RCI possessed by any genotype had adverse effects on germination under both environmental conditions. Tolerant genotypes had lower RCI and higher germination and vice versa. The positive relationship of electrolyte leakage with drought was also reported (Ahmadizadeh, 2013; Hossein *et al*., 2012; Ali *et al*., 2013).

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