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Identification of Drought Tolerance Indices of Wheat (*Triticum aestivum l.)* Genotypes Under Water Deficit Conditions

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Abstract

Now a days drought stress is one of the major abiotic factors to limiting access to high yield by restricting growth and development of wheat crop in arid and semi-arid areas. For the isolation of consequences of drought tolerance on morpho-physiological characters and experiment was conducted on ten bread wheat (Triticum aestivum l.) genotypes during the season of 2017-2018. Thus the experiment was laid out in split plot design with three replication consisting of two treatments (i.e. normal and water deficit) conditions. The variance among the treatment and genotypes were significant at 1% and 5% for all the characters however, treatment × genotypes had also meaningful association with majority of the characters except spike length and spikelets per spike. For the maximum performance of wheat genotypes under water limited conditions selection indices is a best tool to evaluate the genotypes best for water deficit conditions therefore, eight selection indices yield index, yield stability index, stress tolerance index, sensitivity drought tolerance, stress susceptibility index, tolerance index, mean productivity and geometric mean productivity were calculated for grains yield per plant and harvest index. From these indices it was concluded that Bhittai and NIA Sunder were the best genotypes under both conditions, SKD-1, Sassui and NIA Amber displayed better performance under optimum availability of water, Hamal and Kiran-95 were water stress tolerant while the NIA Sunder, Khirman and Marvi were the susceptible ones. Correlation of indices has also been worked out. For better understanding of association between the indices correlation among the indices were also calculated.

Keywords: Drought tolerance; Bread wheat; Means performance; Correlation; Selection indices; PCA analysis

Introduction

Bread wheat (Triticum aestivum l.) belongs to the family Poaceae, tribe triticeae originating in South West Asia [1]. Wheat production has annually increased around 2% globally until 2013 to acquire the future demands of imposed population and prosperity growth [2]. It ranks first among all the cereals, about 30% contributing of all cereal food globally that makes available almost 20% of overall food calories directly or indirectly for the human body [3]. Pakistan ranks 6th in the world where it is used as a basic staple food item [4]. Wheat is extreme among grain crops, mainly due to the reason that grains occupy protein with unique chemical and physical properties [5]. experiencing food scarcities and its role in world trade. Besides staple food for human beings, wheat straw also serves as good source of feed for animals [6]. Sustainable increase in production is demand of present situation of increasing food and feed demands and requires breeders to explore germ plasm to select stable high yielding cultivars [7]. Yield is a quantitative trait and extremely affected by atmosphere.

Stress is classified into two categories biotic and abiotic and these are the major cause of numerous variations of regular physiological activities of most of the crops [8]. Drought is one of the common and globally extensive and constantly increasing environmental phenomenon encountered by wheat crop, sometimes shortage of water for long period results in huge reduction in total wheat production [9].

Wheat is mostly cultivated in rain-fed conditions in semi-arid areas, where a huge number of instabilities occurring are in the amount and regularity of rainfall events from several years and among sites within years [10]. Scarcity of water is one of the major problems for most of the growers over previous decades and several distinct applications have been familiarized into the limelight. The comparative crop performance of different varieties under water limited and desirable conditions are one of the common initial points for the isolation of suitable genotypes for unpredictable rain-fed environments [11]. Therefore, wheat production and its sustainability are largely influenced by drought stress which results in reduced crop yield [12].

Drought tolerance is a polygenic character with minimum heritability it has a maximum level of genotype by environment (G × E) interaction and traits such as phenology and plant height can confound plant responses to it [13]. Therefore, a number of researchers have advised selection in normal conditions [14,15], some of researchers also advised selection in the target stress conditions [16] whereas, several researchers have preferred the mid-way and believe in selection under both normal and water stress conditions [17,18,19]. To estimate the response of plant genotypes under water deficit, various selection indices are advised. Drought tolerant indices describing the relationship of yield in normal and water stress conditions have been widely used [20]. Those indices may be based on water stress tolerance or water sensitivity of varieties. Yield Index (YI) was suggested by Gauzzi et al. [21] is a yield, base measurement which evaluate the stability of cultivars in the both stress and non- stress conditions. The genotypes with high values of this index will be suitable for drought stress condition. Yield Stability Index (YSI) was computed by Bouslama et al. [22]. This factor was calculated for a given genotype using grain yield under stress condition to its grain yield under non-stress environments. The genotypes possessing high YSI are expected to have greater yield under stress and low minimum yield under non-stress conditions [23]. Fernandez evaluated new advanced index stress tolerance index, STI which is used to differentiate the yield performance among the non-stress (Yp) and stress (Ys), since drought stress vary in severity in the field environment around years [24]. Sensitive Drought Index (SDI) was introduced by Frashadfar et al. [25]. The genotypes with lower values of SDI are more desirable under stress environments. Stress Susceptibility Index (SSI) which was introduced by Fischer and Maurer in 1978 to identify stress susceptible genotypes, Tolerance Index (TOL) was identify by Rosielle and Hamblin in 1981 in order to prevent high tolerant genotypes in both non stress and stress environments. Mean Productivity (MP) is the calculation of mean performance of genotypes in both conditions

[26] and Geometric Mean Performance (GMP) was proposed by Ramirez et al. maximum values of this index are more desirable as stated by many breeders. Therefore, an experiment is purposed in order to isolate the wheat genotypes for drought tolerance and to study relationships among different drought tolerance indices in stress conditions.

Materials and Methods

Ten bread wheat genotypes (Triticum aestivum l.) were selected for the study of drought tolerance under normal and water deficit conditions. An experiment was carried-out as a field study in department of the plant breeding and genetics, Sindh agriculture university Tandojam during the year 2017-2018. The trail was laid out under split plot design with two treatments (i.e. normal and water deficit) conditions with three repeats. Observations were taken from ten randomly tagged plants from each repeats. Following observations data were recorded days to 90% maturity, plant height, tillers per plant, spike length, spikelets per spike, grains per spike, seed index, grain yield per plant, biological yield and harvest index. Data from the experiment was subjected to analysis of variance according to procedures outlined by Gomez et al. [27]. Pearson's Correlation coefficient was calculated among selection indices. Eight selection indices were calculated *viz*.,

1. (YI) Yield Index=Ys/ Yp
2. (YSI) Yield Stability Index=Ys/Yp
3. (STI) Stress Tolerance Index=[(Yp) ×(Ys)]/(Ȳp)2
4. (SDI) Sensitivity Drought Tolerance=(Yp-Ys)/Yp
5. (MP) Mean Productivity=(Yp+Ys)/2
6. (TOL) Tolerance Index=Yp-Ys
7. (GMP) Geometric Mean Productivity=(Yp* Ys)
8. (STI) Stress Susceptibility Index=[(1-(Ys/Yp)]/SI=1- (Ys/Ȳp)

The genotypes used in experiment are given as under:

Genotypes=10

V1=SKD1

V2=Hamal

V3=Bhitai

V4=NIA sunder

V5=Sassui

V6=Marvi

V7=NIA amber

V8=Khirmin

V9=Kiran-95

V10=NIA

sarang

Data were collected from 10 randomly selected indexes of plants from each plot and in each replication for the following traits.

1. Days to 90% maturity: Physically observed at the time when the plants were 90% mature, the dates were recorded from sowing time.
2. Plant height (cm): The height of tagged plants from soil surface to the top of the plant was measured in the centimeters, when the plants get fully matured and the color of the plants turn to yellowish.
3. Tillers plant-1: The total number of tillers per plant is counted at the time of maturity. For these character total fertile tillers per plant in each replication is counted.
4. Spike length (cm): The main spikes from the five sampled plants were measured and averaged to represent the spike length in cm.
5. Spikelets spike-1: Spikelets of the tagged plants were counted and averaged after the harvesting.
6. Grains spike-1: The total numbers of seeds in main spike were counted and data were recorded as grains spike.
7. Grain yield plant-1 (g): After harvesting, each plant was threshed separately by hand and grains were weighed on electronic digital balance and yield plant-1 was recorded in grams.
8. Seed index (1000-grain wt. g): Thousand seeds were counted at random and weighed in grams with the help of electronic digital balance in laboratory.
9. Biological yield plant-1: The tagged plants harvested at the maturity and single plant was weighed on electronic balance in laboratory.
10. Harvest index (%): Harvest index (%) was calculated according to following formula.

Results and Discussion

Analysis of variance for various morpho-physiological characters of bread wheat

From the outcome results of ANOVA it is stated that water deficit conditions can cause significant impact on all the morpho-physiological traits observed. According to Table 1, most of the data based on field parameters were significant. Treatment and genotypes interaction showed meaningful differences for almost majority of the traits however, treatment × genotypes interaction were also displayed meaningful differences for most of the traits except spike length and spikelets per spike. The significant of treatment × genotype interaction results in when genotypes performed variably under the stress treatments. Naimat et al. [28] reported that Analysis of variance revealed significant differences among genotypes for majority of traits and Neeru et al. [29] also reported significant genotypic differences were observed for all the traits in both environments (Table 1).

These relationships are utilized by many wheat breeders to isolate the best performing genotypes based on one or more reliable drought tolerant indicators. The results are discussed character wise as under.

To better understand the reduction of yield and yield contributing traits under water stress conditions a graph (Figure 1) is given below. According to bar chart the first square of graphs showing the performance of yield and other morpho-physiological traits under normal conditions. Second square of graphs showing the performance of traits mentioned above in water stress conditions however, the third square of graphs showing the reduction observed between non-stress and water stress conditions (Figure 1).

Table 1: *Mean squares form or pho-physiological characters of ten bread wheat genotypes. **,*: significant at 1% and 5% probability level respectively, ns: Non-significant.*

Yield trait	Replication	Treatment	Error	Genotypes	T x G	Error
	D.F.=2	(T)	(a)	(G)	D.F.=9	(b)
		D.F.=1	D.F.=2	D.F.=9		D.F.=36
Days to 90% maturity	3.65	1008.65**	0.35	62.30**	12.93**	0.91
Plant height	0.91	1123.20**	0.25	201.18**	25.86**	1.97
Tillers per plant	1.76	50.41**	0.24	8.24**	4.21**	0.72
Spike length	1.7	10.43*	0.64	11.62**	0.95ns	0.48
Spikelets per spike	7.84	86.40ns	8.24	16.84**	3.45ns	1.24
Grains per spike	0.65	1422.04**	1.8	161.11**	59.97**	3.41
Seed index	0.28	337.20**	0.62	91.12**	3.84**	1.08
Grain yield plant	1.14	152.22**	0.61	9.26**	3.06**	0.74
Biological yield	0.66	443.90**	2.46	30.62**	15.08**	0.94
Harvest index	1.1	73.97**	0.1	8.60**	3.48**	1.12

Mean performance of various morpho-physiological traits

Days to 90% maturity: Days to 90% maturity, ranged from genotypes 133.67 to 121.67 under non-stress condition, while in water stress condition it ranged from 124.33 to 122.00 (Table 2). The minimum reduction due to water stress was noted in Bhittai (-3.00) followed by Kiran-95 (-4.67) and SKD-1 (-6.67) respectively. The maximum

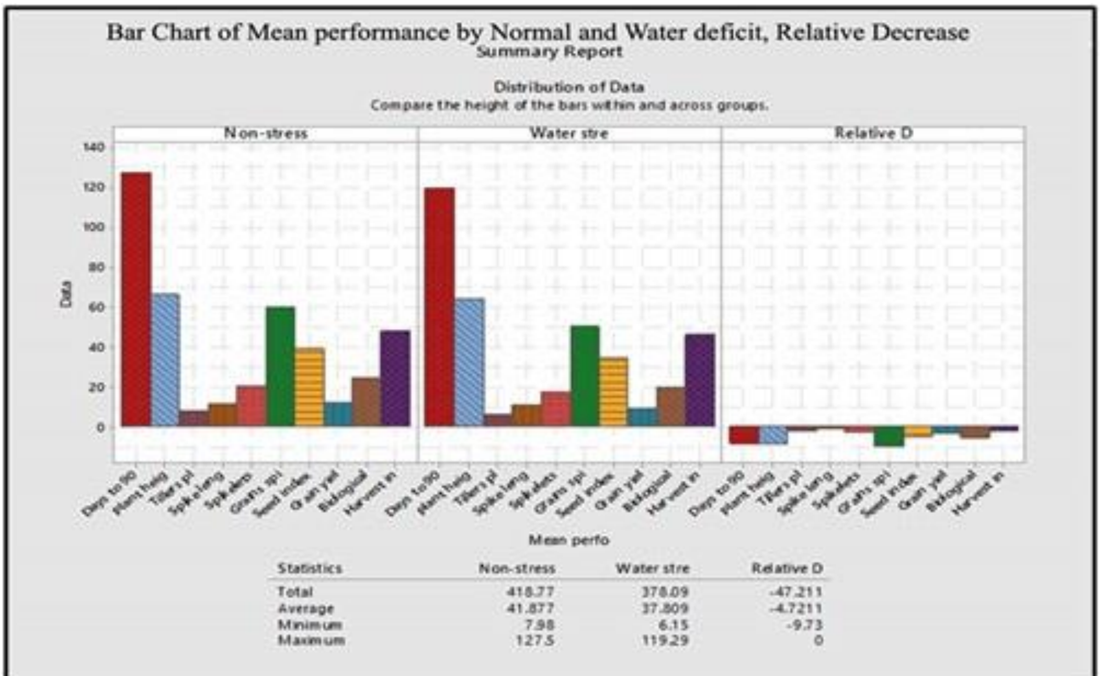

Figure 1: Average performance under non-stress and water stress with average reduction of ten bread wheat genotypes in a graphical form.

reduction was measured in NIA Sunder (-12.67) followed by NIA Amber (-10.67) and NIA Sarang (-10.67).

Plant height (cm): The results presented in Table 2a revealed that among the cultivars Khirman, NIA Amber and NIA Sarang expressed maximum undesirable plant height as (88.00, 85.13 and 82.00cm) under non-stress conditions, whereas SKD-1 (66.20cm) and Kiran-95 showed minimum height in non-stress conditions (Table 2a).

Tillers plant-1: In non-stress, the range of tillers plant-1 was counted as
5.43 to 10.33 tillers while in stress the tillers was 4.07 to 8.27. According to mean values, water shortage caused -1.83 tillers deduction in tillers plant-1. Among the genotypes, maximum of 10.33, 10.33 and 9.07 tillers plant-1 were given by Bhittai, NIA Sunder and Sassui in non- stress respectively (Table 2b).

Spike length (cm): Analysis of the data presented in Table 2b indicated that spike length was measured as 10.23 to 14.38 cm in normal irrigation condition while in stress condition it was noted as 8.49 to
14.11 cm. Thus average decline of -0.83 was recorded.

Spikelets spike-1: In non-stress, the average spikelets spike-1 was

Table 2a: *Mean performance for the days to 90% maturity and plant height of wheat genotypes grown under normal and water deficit condition.*

Genotypes	Days to 90% maturity			Plant height (cm)		
	Non-stress	Water stress	R.D*	Non-stress	Water stress	R.D*
SKD-1	121.67	115	-6.67	66.2	64.13	-2.07
Hamal	126	116.67	-9.33	76.07	71.47	-4.6
Bhittai	122	119	-3	85.73	69.67	-16.06
NIA Sunder	129	116.33	-12.67	78	64.67	-13.33
Sassui	126.33	119	-7.33	77.4	68	-9.4
Marvi	133.67	124.33	-9.34	81.93	74.87	-7.06
NIA Amber	131.67	121	-10.67	85.13	73.67	-11.46
Khirmin	129.67	122	-7.67	88	82	-6
Kiran-95	124	119.33	-4.67	73.13	64.6	-8.53
NIA Sarang	131	120.33	-10.67	82	74	-8
Mean	127.5	119.29	-8.2	66.2	64.13	-8.651
LSD (5%) (T)	0.65	0.55	P-value	P-value	P-value	P-value
LSD (5%) (G)	1.11	1.64	P-value	P-value	P-value	P-value
LSD (5%) (T x G)	1.57	2.32	P-value	P-value	P-value	P-value

Table 2b: *Mean performance for the tillers plant-1 and spike length of wheat genotypes grown under normal and water deficit condition.*

Genotypes	Tillers plant-1			Spike length (cm)		
	Non-stress	Water stress	R.D*	Non-stress	Water stress	R.D*
SKD-1	7.67	8.27	0.6	11.28	9.81	-1.47
Hamal	7.67	5.67	-2	10.23	9.81	-0.42
Bhittai	9.07	5.87	-3.2	12.33	11.45	-0.88
NIA Sunder	10.33	8.2	-2.13	10.59	11.25	0.66
Sassui	10.33	5.4	-4.93	12.92	11.75	-1.17
Marvi	5.53	6	0.47	14.38	14.11	-0.27
NIA Amber	7.73	7	-0.73	10.47	8.49	-1.98
Khirmin	7.4	4.73	-2.67	11	10.45	-0.55
Kiran-95	6.47	4.07	-2.4	11.94	10.14	-1.8
NIA Sarang	7.67	6.33	-1.34	10.29	9.81	-0.48
Mean	7.98	6.15	-1.83	11.54	10.7	-0.83
LSD (5%) (T)	0.54	0.89				
LSD (5%) (G)	0.99	0.81				
LSD (5%) (T x G)	1.4	1.14				

20.01 whereas under water deficit conditions was 17.61, according to mean values the water deficit conditions caused -2.40 decline in terms of spikelets spike-1 (Table 2c).

Grains spike-1: In normal conditions, the range of grains spike-1 was counted as 51 to 66.73 seeds while underwater deficit 44.40 to 64.73 grains spike-1. According to mean values water shortage caused -9.73 seeds reduction in grain spike-1 (Table 2c).

Table 2c: *Mean performance for spikelets spike-1 and grains spike of wheat genotypes grown under non-stress and water stress conditions.*

Genotypes	Spikelets spike-1			Grains spike-1		
	Non-stress	Water stress	R.D*	Non-stress	Water stress	R.D*
SKD-1	18.07	15.93	-2.14	58.27	47.33	-10.94
Hamal	19	17.8	-1.2	65.4	59	-6.4
Bhittai	22.87	21.27	-1.6	65.47	64.73	-0.74
NIA Sunder	17.07	17	-0.07	51	46.67	-4.33
Sassui	20.73	17.93	-2.8	57.27	52	-5.27
Marvi	20.47	19.4	-1.07	66.73	45	-21.73
NIA Amber	20.2	15.4	-4.8	55.87	49	-6.87
Khirmin	21.27	18.87	-2.4	66	50	-16
Kiran-95	19.2	14.73	-4.47	54.73	44.4	-10.33
NIA Sarang	21.27	17.8	-3.47	64	49.23	-14.77
Mean	20.01	17.61	-2.4	60.47	50.73	-9.73
LSD (5%) (T)	3.19	1.488				
LSD (5%) (G)	1.3	2.16				
LSD (5%) (T x G)	1.85	3.05				

Seed index: Under non-stress, the mean value of seed index was 39.31 g whereas under water deficit condition the mean value was 34.57 g, thus on an average water stress caused -4.74 g reduction in terms of thousand grain weight (Table2d).

Grain yield plant-1 (g): Grain yield per plant is the ultimate results of all physiological and agronomist responses of varieties to drought stress conditions. The average reduction occurred by -3.18 g due to water stress (Table 2d).

Table 2d: *Mean performance for seed index and grains yield plant-1 of wheat genotypes grown under non-stress and water stress at anthesis.*

Genotypes	*Seed index (g)*			*Grain yield plant-1 (g)*		
	Non-stress	*Water stress*	*R.D**	*Non-stress*	*Water stress*	*R.D**
SKD-1	36.49	35.01	-1.48	11.82	10.33	-1.49
Hamal	33.97	30.08	-3.89	10.06	7.74	-2.32
Bhittai	36.4	32.01	-4.39	14.15	11.82	-2.33
NIA Sunder	41.72	36.07	-5.65	13.98	9.33	-4.65
Sassui	41.65	36.33	-5.32	12.14	10.01	-2.13
Marvi	46.73	41	-5.73	13.08	7	-6.08
NIA Amber	38	30.59	-7.41	11.03	9	-2.03
Khirmin	37.76	34.31	-3.45	12.29	8.14	-4.15
Kiran-95	35.59	31	-4.59	11.18	7.67	-3.51
NIA Sarang	44.84	39.33	-5.51	13.49	10.33	-3.16
Mean	39.31	34.57	-4.74	12.32	9.13	-3.18
LSD (5%) (T)	0.87	0.87				
LSD (5%) (G)	1.21	1.01				
LSD (5%) (T x G)	1.72	1.43				

Biological yield plant-1 (g): It is an important trait if biological yield is high in water stress condition that is most desirable character according the results presented in Table 2e. The maximum biological yield under non-stress condition were given by genotypes Bhittai, NIA Sunder and Marvi (31.00, 28.25 and 28.03 g) whereas under water stress conditions cultivars (23.05, 22.00 and 21.34 g) SKD-1, Bhittai and NIA Sarang gave high biological yield as it desired in breeding perspective (Table 2e).

Harvest index (%): It is a desirable tool for increasing the productivity of wheat is to spilt yield into biomass at maturity and Harvest Index (HI). In present study, mean values of (HI) was dropped by -2.21% because of water deficit conditions, however this reduction was smaller in some of the cultivars such as Kiran-95 (-0.52%), Sassui (-1.31%) and Khirmin (-1.88%) while sharper reductions occurred in NIA Amber (-4.92%), SKD-1 (-4.02%) and Hamal (-2.77%) as presented in Table 2e.

Table 2e: *Mean performance for biological yield plant-1 and harvest index of wheat genotypes grown under non-stress and water stress conditions.*

Genotypes	*Biological yield (g)*			*Harvest index (%)*		
	Non-stress	*Water stress*	*R.D**	*Non-stress*	*Water stress*	*R.D**
SKD-1	24.52	23.05	-1.47	49.7	45.68	-4.02
Hamal	20.8	17.06	-3.74	48.16	45.39	-2.77
Bhittai	31	22	-9	47.2	47.47	0.27
NIA Sunder	28.25	21	-7.25	46.87	44.48	-2.39
Sassui	25.07	21	-4.07	50.26	48.95	-1.31
Marvi	28.03	17	-11.03	46.96	44.48	-2.48
NIA Amber	22.19	17.33	-4.86	50.31	45.39	-4.92
Khirmin	25.66	18	-7.66	47.05	45.17	-1.88
Kiran-95	22.66	19	-3.66	48.08	47.56	-0.52
NIA Sarang	23	21.34	-1.66	48.73	46.56	-2.17
Mean	25.11	19.67	-5.44	48.33	46.11	-2.21
LSD (5%) (T)	1.74	0.35				
LSD (5%) (G)	1.13	1.24				
LSD (5%) (T x G)	1.6	1.75				

Drought indices: Descriptive statistics of drought tolerance indices innon-stress and water deficit conditions are presented in (Table 3a). In normal conditions highlighted as “Yp” maximum grain yield plant-1 observed in genotypes Bhittai, NIA Sunder and Marviwhile the genotypes Hamal, NIA Amber and Kiran-95 had the minimum grains yield per plant. However, under water stress “Ys” maximum grain yield per plant exhibited by genotypes Bhittai, SKD-1 and NIA Sarang while genotypes such as Marvi, Hamal and Kiran-95 showed minimum performance under water stress conditions, Aktaş concluded that GMP, MP and STI values are convenient traits to select high yielding wheat cultivars under both stress and non-stress conditions whereas RDY, TOL and SSI values are better indices to define tolerance levels [30].

Stress susceptible index: Stress Susceptible Index (SSI) was introduced by Fischer et al. [17] according to them genotypes with low values SSI<1 indicated the tolerance to water stress conditions. Genotypes such as SKD-1, Bhittai and Sassui showed minimum values of SSI index therefore, ranked as 1 to 3 however cultivars Marvi, Kiran-95 and NIA Sunder exhibited maximum values under both conditions and ranked as 10 to 8. Therefore the first group of genotypes is more suitable. Singh et al. found SSI values are better indices to define tolerance levels [31].

Tolerance index: Tolerance Index (TOL) is coined by Rossielle et al. It is commonly used to differentiate of yield performance of genotypes in water deficit and normal conditions. Genotypes possessing minimum values of this index are mainly suitable. SKD-1, NIA Amber and Sassui have the minimum values therefore these genotypes were ranked as 1 to 3. Genotypes Marvi, NIA Sunder and Khirman were susceptible and showed maximum values of tolerance index and were categorized as 10 to 8 [26].

Mean productivity: Mean Productivity (MP) is recommended by Rossielle et al. [26]. According to them this index is used to calculate the average between normal and water stress conditions. Genotypes having higher percentage under this index are commonly more desirable therefore, from Table 3a data, it is estimated that Bhittai (12.98), NIA Sarang (11.91) and NIA Sunder (11.65) showed higher average values and ranked from 1 to 3. Hamal (8.90), Kiran-95 (9.42) and NIA Amber (10.01) were undesirable due to lower values of index. Mevlut et al. described in general, similar ranks for the genotypes were observed by GMP and MP parameters as well as STI, which suggests that these three parameters are equal for screening drought tolerant genotypes (Table 3a) [32].

Geometric mean productivity: Geometric Mean Productivity (GMP) was proposed by Ramirez et al. Maximum values of this index are more desirable as stated by the many breeders [25]. According to the results presented in Table 3b genotypes Bhittai (12.93), NIA Sarang (11.8) and NIA Sunder (11.42) exhibited maximum yield under both conditions and ranked as a 1 to 3. While genotypes Hamal (8.82), Kiran-95 (9.26) and Marvi (9.56) showed minimum performance therefore the rank from 10 to 8 were given to these genotypes.

Yield index: (YI) Yield Index was introduced by Gauzzi et al. is a yield, base measurement that is used to isolate the permanence of cultivars under normal and water deficit environments [21]. Cultivars that result in maximum values of this index are thought to be majorly desirable under stress conditions. Genotypes Bhittai (0.26), SKD-1 (0.23) and NIA Sarang (0.23) showed the highest values of YI in Table 3b thus, these cultivars can be declared as desirable under waters deficit and normal conditions.

Yield stability index: Bouslama et al. worked out on (YSI) Yield Stability Index which is used to calculate the performance of cultivars under water deficit and normal conditions [22]. The genotypes with higher values of YSI are more suitable cultivar sunder water deficit and normal environments. The cultivar SKD-1 (0.87), Bhittai (0.83) and Sassui (0.82) were showed high values, thus ranked as 1 to 3 respectively and considered as stable verities in normal and water deficit conditions (Table 3b).

Table 3a: *Drought tolerance indices based on grain yield per plant under normal and water stress conditions.*

S.No	Genotypes	Yp	Rank	Ys	Rank	SSI	Rank	MP	Rank	TOL	Rank	STI	Rank
1	SKD-1	11.82	7	10.33	2	0.51	1	11.07	5	1.49	1	0.06	1
2	Hamal	10.06	10	7.74	9	0.93	5	8.9	10	2.32	4	0.03	5
3	Bhittai	14.15	1	11.82	1	0.66	2	12.98	1	2.33	5	0.08	2
4	NIA Sunder	13.98	2	9.33	5	1.34	8	11.65	3	4.65	9	0.06	8
5	Sassui	12.14	6	10.01	4	0.71	3	11.07	4	2.13	3	0.06	3
6	Marvi	13.08	4	7	10	1.88	10	10.04	8	6.08	10	0.04	10
7	NIA Amber	11.03	9	9	6	0.74	4	10.01	6	2.03	2	0.05	4
8	Khirman	12.29	5	8.14	7	1.37	9	10.21	7	4.15	8	0.05	9
9	Kiran-95	11.18	8	7.67	8	1.27	7	9.42	9	3.51	7	0.04	7
10	NIA Sarang	13.49	3	10.33	3	0.95	6	11.91	2	3.16	6	0.07	6

Stress susceptible index: Fernandez suggested the Stress Tolerance Index (STI) which is referred as a basic useful tool for determining higher yields and stress tolerance potential of genotypes [19]. The cultivars with high STI value will be tolerant to drought stress. The genotypes Bhittai (0.08), NIA Sarang (0.07) and NIA Sunder (0.06) can be considered as drought tolerant due to high STI value whereas Hamal (0.03), Kiran-95 (0.04) and Marvi (0.046) were susceptible to drought due to their lower values of STI as shown in Table 3b. Pireivatlou observed that STI is reliable for selecting high yielding cultivars in optimum as well as in non-optimum water conditions [33].

Table 3b: *Drought tolerance indices based on grain yield per plant under normal and water stress conditions.*

S.No	Genotypes	GMP	Rank	YI	Rank	YSI	Rank	SDI	Rank
1	SKD-1	11.05	4	0.23	2	0.87	1	0.12	1
2	Hamal	8.82	10	0.17	8	0.761	5	0.234	5
3	Bhittai	12.93	1	0.26	1	0.83	2	0.16	2
4	NIA Sunder	11.42	3	0.2	5	0.663	8	0.33	9
5	Sassui	11.02	5	0.22	4	0.82	3	0.17	3
6	Marvi	9.56	8	0.15	9	0.53	10	0.46	10
7	NIA Amber	9.96	7	0.2	6	0.81	4	0.18	4
8	Khirman	10	6	0.18	7	0.665	9	0.33	8
9	Kiran-95	9.26	9	0.172	10	0.68	7	0.31	7
10	NIA Sarang	11.8	2	0.231	3	0.768	6	0.238	6

Sensitive drought tolerance: Sensitive Drought Tolerance Index (SDI) was given by Frashadfar et al. [25]. Varieties resultings in minimum values of SDI are more suitable under stressed environment. Genotypes SKD-1 (0.12), Bhittai (0.16) and Sassui (0.17) showed minimum values of SDI therefore, these genotypes considered as more desirable. However, Marvi, NIA Sunder and Khirman displayed maximum values of SDI therefore; these genotypes are not desirable for drought conditions Table 3b.

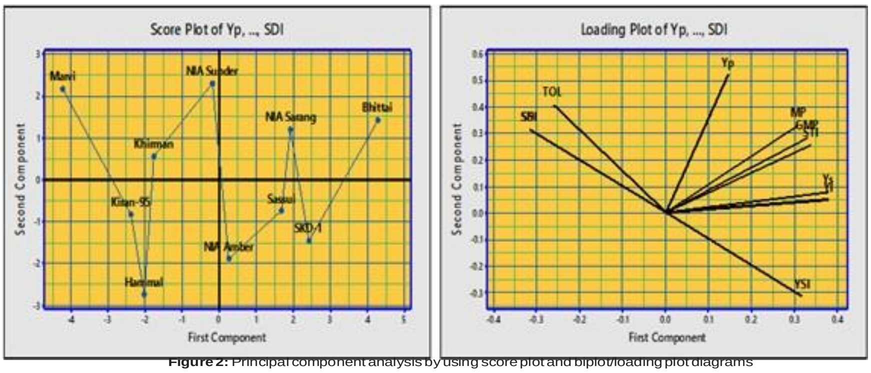

Figure 2: Principal component analysis by using score plot and biplot/loading plot diagrams of various indices.

(PCA) Principal Component Analysis for various selection indices

PCA is a method of identification and isolation of genotypes which is commonly used to differentiation of drought resistance and susceptible genotypes from a grouped data, hence (PCA, Principal Component Analysis) was carried out. From the results obtained genotypes Bhittai and NIA Sarang belongs to group 'A' (Figure 2) due to higher PCA1 and higher PCA2 therefore these genotypes are suitable for both of the conditions. Other genotypes such as SKD-1, Sassui and NIA Amber with high PCA1 but lower PCA2 are considered as drought tolerant in optimum water condition and considered as in 'B' category. Higher PCA2 and lower PCA1 describe those genotypes which are suitable to stress environments and the genotypes Hamal and Kiran-95 fall in 'C' category. Still a fourth group mentioned as 'D' with low PCA1 and PCA2 identified those genotypes performed poor in non-stress and in water stress environments therefore, genotypes NIA Sunder, Khirman and Marvi fall in the 'D' category.

According to the numerical values of indices, a three dimension diagram (Figures 3 and 4) was drawn for grain yield under both environments so as to differentiate genotypes of A, B, C and D groups. Genotypes such as Bhittai, and NIA Sarang were recognized as high performing cultivars under both water deficit and normal situations, clearly shown in the 3-D. Bhittai and NIA Sarang are clearly shown in line plot with green and purple colour and angle of these varieties are above from all the other varieties (Figure 4). It can be assumed that these two varieties performed better under both conditions.

Correlation among drought tolerant indices

Correlation analysis among grain yield per plant under all conditions and drought tolerant indices were performed. Yp (yield in normal conditions) had positive and significant association with Ys, MP, TOL, STI, GMP and YI (r=0.50**, 0.85**, 0.41**, 0.74**, 0.79** and 0.45**). However, indices such as SSI (0.20ns) had non-significant but positive association. YSI and SDI exhibited negative and non-significant association (-0.19ns and -0.19ns) with Yp results are presented in Table 4a. Ys (yield in stress) exhibited positive and significant association with MP, STI, GMP, YI and YSI (r=0.88**, 0.93**, 0.92**, 0.99** and 0.74**). While Ys had negative but significant association with SSI, TOL and SDI (r=-0.74**, -0.57 and 0.74**). Correlation coefficient among indices were also performed and presented in Table 4a. The results showed SSI had significant association with TOL and SDI (r=0.97** and 0.99**). While indices that showed negative but significant association with SSI are MP, STI, GMP, YI and YSI (r=- 0.34*, -0.47**, -0.43**, -0.77** and -0.99**). MP displayed positive and significant association with indices STI, GMP, YI and YSI (r=0.97**, 0.99**, 0.85** and0.34*). Whereas negative but significant relationship with SDI (r=-0.34*). Only TOL showed negative and non-significant association with MP (r-0.12ns). TOL had negative but significant relationship with YI, YSI and SDI (r=-0.62**, -0.97** and -0.97**). However TOL was non-significant and negative correlated with STI and GMP (r=-0.27 ns and -0.22ns). STI had significant relationship with indices such as GMP, YI and YSI (r = 0.98**, 0.92** and 0.43**), whereas negative but significant association with SDI index (r=-

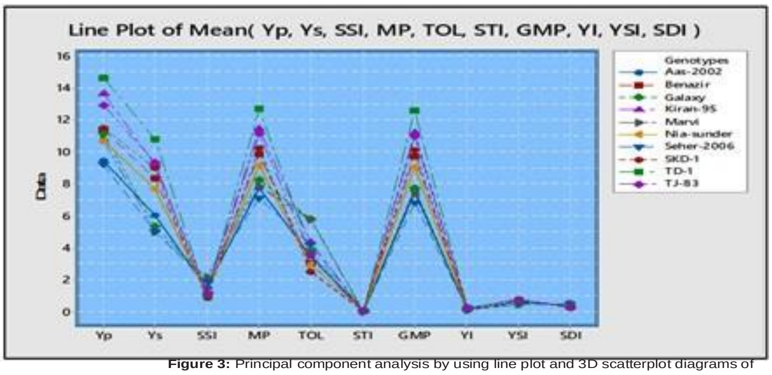

Figure 3: Principal component analysis by using line plot and 3D scatterplot diagrams of various indices.

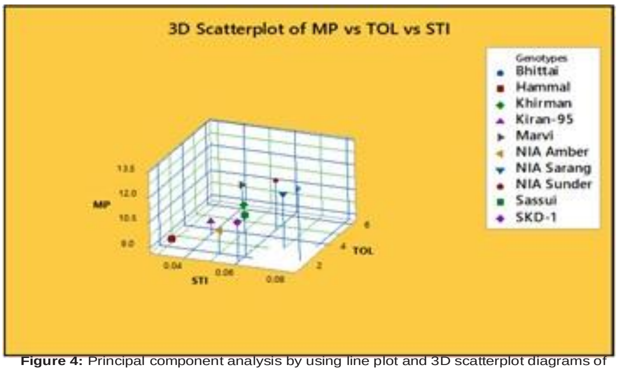

Figure 4: Principal component analysis by using line plot and 3D scatterplot diagrams of various indices.

0.43**). GMP had positive and significant association with YI and YSI (r=0.90** and 0.43**) while negative but significant relationship with SDI index (r=-0.43**). YI showed significant relationship with YSI (r=0.77**) and negative association with SDI (r = -0.77**). YSI had negative but significant association with (SDI r=-0.99**). Frashadfar et al. observed related result while conducting multivariate analysis. They also obtained 66% and 34% variability accounted PCA1 and PCA2 respectively (Table 4a) [34-40].

Cluster/combined correlation coefficient for quantitative traits

Days to 90% maturity: The coefficient of correlation between days to 90% maturity and other characters are highlighted in Table 4b from these results it is stated that days of 90% maturity had positive and significant association with plant height (0.76**), spike length (0.31*), spikelets per spike (0.47**), grains per spike (0.47**), seed index (0.69**), grain yield per plant (0.50**), biological yield (0.43*) and harvest index (0.38**) whereas days to 90% maturity showed non-

Table 4a: *Correlation coefficient between yield and drought tolerance/resistance indices.*

Indices	*Yp*	*Ys*	*SSI*	*MP*	*TOL*	*STI*	*GMP*	*YI*	*YSI*
Ys	*0.50***	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*
SSI	*0.20ns*	*-0.74***	*-*	*-*	*-*	*-*	*-*	*-*	*-*
MP	*0.85***	*0.88***	*-0.34**	*-*	*-*	*-*	*-*	*-*	*-*
TOL	*0.41***	*-0.57***	*0.97***	*-0.12ns*	*-*	*-*	*-*	*-*	*-*
STI	*0.74***	*0.93***	*-0.47***	*0.97***	*-0.27ns*	*-*	*-*	*-*	*-*
GMP	*0.79***	*0.92***	*-0.43***	*0.99***	*-0.22ns*	*0.98***	*-*	*-*	*-*
YI	*0.45***	*0.99***	*-0.77***	*0.85***	*-0.62***	*0.92***	*0.90***	*-*	*-*
YSI	*-0.19ns*	*0.74***	*-0.99***	*0.34**	*-0.97***	*0.48***	*0.43***	*0.77***	*-*
SDI	*-0.19ns*	*-0.74***	*0.99***	*-0.34**	*0.97***	*-0.48***	*-0.43***	*-0.77***	*-0.99***

significant association with tillers plant-1 (0.21ns). Singh et al. were examined similar results they suggested if the correlation coefficient in a casual factor and their effect is almost identical to its direct effect, then the correlation describes the accurate relationship and direct selection through this trait will be effective [31].

Plant height: The coefficient of correlation of plant height and other traits are presented in Table 4b. According to results plant height showed positive and significant association with spikelets per spike (0.63**), grains per spike (0.53**), seed index (0.45*), grain yield per plant (0.45*) and biological yield (0.40*). However plant height displayed non-significantly correlation with tillers per plant (0.22ns), spike length (0.19ns) and harvest index as (0.15ns). Golparvar et al. stated that plant height had non-significant correlation with spike length and harvest index in terms of water stress and non-stress conditions [41].

Table 4b: *Combined correlation coefficient (r) between yield and other traits of wheat genotypes under non-stress and water stress conditions. **,*: significant at 1% and 5% probability level respectively, ns: Non-significant.*

Characters	*Days to 90% maturity*	*Plant height*	*Tillers plant-1*	*Spike length*	*Spikelets spike-1*	*Grains spike-1*	*Seed index*	*Grain yield plant-1*	*Biological yield*
Plant height	*0.76***								
Tillers plant-1	*0.21ns*	*0.22ns*							
Spike length	*0.31**	*0.19ns*	*0.06ns*						
Spikelets spike-1	*0.47***	*0.63***	*0.22ns*	*0.51***					
Grains spike-1	*0.47***	*0.53***	*0.16ns*	*0.22ns*	*0.69**				
Seed index	*0.69***	*0.45**	*0.32**	*0.52***	*0.39**	*0.21ns*			
Grain yield plant-1	*0.50***	*0.45**	*0.60***	*0.22*	*0.50**	*0.59***	*0.52***		
Biological yield	*0.43**	*0.40**	*0.54***	*0.34**	*0.43**	*0.50***	*0.51***	*0.87***	
Harvest index	*0.38**	*0.15ns*	*0.21ns*	*0.04ns*	*0.26ns*	*0.35**	*0.20ns*	*0.41**	*0.33**

Tillers per plant: The coefficient of correlation of tillers per plant with other traits is presented in Table 4b. The significant association of tillers per plant was observed with seed index (0.32*), grain yield per plant (0.60**) and biological yield (0.54**). While tillers per plant exhibited non-significantly correlated with spike length (0.064ns), spikletes per spike (0.22ns), grains per spike (0.16ns) and harvest index (0.21ns). Khan et al. were presented similar results that tillers plant-1 was negatively correlated with almost all the traits except seed index, grain yield and biological yield under both the conditions water stress and non-stress conditions. Furthermore the trait tillers palnt-1 negatively correlated with spike length, spikeletes spike-1 and grains spike-1 [42].

Spike length: The coefficient of correlation of spike length with other traits is displayed in Table 4b. From the results it is stated that spike length significantly correlated with seed index (0.52**), grain yield per plant (0.22**) and biological yield (0.34*). Whereas spike length showed non-significant correlation with spikelets per spike (0.51ns), grain per spike (0.22ns) and harvest index (0.04ns). Seher et al. evaluated bread wheat genotypes of diversified origin under water stress conditions [43]. Thirteen wheat genotypes exhibited promising performance and accordingly they were selected for further multiplication. Correlation studies indicated that grains spike-1, seed index and grain yield plant-1 had straight association with length of spike under drought conditions.

Spikelets spike: The coefficient of correlation of spikelets per spike with other traits is presented in Table 4b. It is stated that spikelets per spike showed significantly correlation for grains per spike (0.69*), seed index (0.39*), grain yield per plant (0.50*) and biological yield (0.43*). However, spikelets per spike displayed non-significant association with harvest index (0.26ns). Yildirim investigated the response of six wheat cultivars in irrigated and rainfed conditions in relation to grain yields. The study also focused on position weight variation so that better understanding is developed to know how seed index influenced by the position of spikelets spike-1 under irrigated and rainfed condition to grain relative understanding about the drought resistance in wheat plant [44].

Grains per spike: The coefficient of correlation of grain spike-1 with other traits is presented in Table 4b. Significant association of grains per spike was observed with grain yield per plant (0.59**), biological yield (0.50**) and harvest index (0.35*) while grains spike-1 demonstrated non-significant association with seed index (0.21ns) (Table 4b).

Seed index: The coefficient of correlation of seed index with other traits is displayed in Table 4b. This table showed that seed index exhibited significant relationship with grain yield per plant (0.52**) and biological yield (0.51**) whereas, non-significant association of seed index was observed with harvest index (0.20ns). Shamsi et al. also presented that the most important yield component grains per spike were significantly correlated with 1000 grain weight, biological yield and harvest index [45].

Grain yield per plant: The coefficient of correlation of grain yield per plant with rest of the traits is presented in Table 4b. Significant association of grain yield per plant with biological yield (0.87**) and harvest index (0.41*) was shown. Cheema et al. also described significant positive phenotypic and genotypic association between grain yield plant-1 and the yield components, such as harvest index and biological yield [46].

Biological yield per plant: The coefficient of correlation of biological yield with other traits is presented in Table 4b. From the results biological yield showed significantly correlation with harvest index (0.33*). Golparvar et al. stated that plant height had non-significant correlation with spike length and harvest index in terms of water stress and non-stress conditions [41,47-53].

Conclusion

According to all results obtained from the field of experiment following results can be made.

Water stress caused substantial decline on all morpho-physiological characters like days to 90% maturity, plant height, tillers per plant, spike length, spikelets per spike, grains per spike, seed index, grain yield per plant, biological yield and harvest index and all varieties also differed significantly for most of the characters studied. The genotypes responded variably over the treatments as indicated by treatment × genotypes interactions.

According to results from drought tolerance indices based on grain yield per plant and harvest index, the genotypes were grouped in four categories. Where genotype like Bhittai and NIA Sarang recorded good performance therefore fall in "A" category and genotypes like SKD-1, Sassui and NIA Amber have very close relationship to all three indices therefore considered as drought tolerant under optimum water conditions and lies under group "B" genotypes. Among all the indices calculated, grain yield in Yp as well as in Ys was significantly and positively associated with most of the indices. According to principal component analysis, PC As axes on first dimension (Figures 1 and 2) YI, Ys, STI and Yp somehow, bearing close relationship, hence placed in group-1. Whereas indices YSI and SDI have no close relationship shown in (Figures 1 and 2) therefore, they fall in group-2 from PCA analysis it is concluded that YI and STI indices are more suitable for all environments. PCA from 3-D and line plot (Figures 3 and 4) showed that genotypes Bhittai and NIA Sarang performs better and belongs to group "A". Therefore, these two genotypes can be further used as parent for perfection and advancement of drought tolerance in most of the genotypes. This could be done using a pool of well characterized drought tolerant and a contrasting set of drought susceptible genotypes. The current study also deduced that the material evaluated contain useful genetic diversity for drought tolerance.

References

1. Mergoum M, Singh PK, Pena RJ, Lozano-del R (2009) Triticale: A "new" crop with old challenges. Cereals pp: 267-287.

2. Anonymous (2015) Development of chromosome-specific BAC resources for genomics of bread wheat. Cytogenet Genome Res 129: 211-23.

3. Lal R, Humberto BC (2007). Impacts of long-term wheat straw management on soil hydraulic properties under no-tillage. Soil Sci Society of Amer J 71:2136-2201.

4. Rahman Z, Praveen N, Iqbal M, Younis M, Nawaz S, et al. (2012) Rust resistance evaluation of advanced wheat (Triticum aestivum l.) Genotypes using pcr-based DNA markers. Pak J Bot 46: 251-257.

5. Ali N, Muhammad I, Shaheena Y, Iftikhar A, Armghan S, et al. (2013) Genetic variation at loci controlling quality traits in spring wheat. Pak J Agri Sci 50: 637-647.

6. Sarwar N, Maqsood M, Mubeen K, Shehzad M, Bhullar MS, et al. (2010) Effect of different levels of irrigation on yield and yield components of wheat cultivars. Pak J Agri Sci 47: 371-734.

7. Zameer M, Mahmood S, Mushtaq Z, Tabasum B, Ali Q (2015). Detection of bacterial load in drinking water samples by 16s rRNAribotyping and RAPD analysis. Adv Life Sci 2: 135- 141.

8. Khalili M, Aboughadareh AP, Naghavi MR (2013) Assessment of drought tolerance in barley: Integrated selection criterion and drought tolerance indices. Environ and Exp Bio 14: 33-4.

9. Nezhad AA, Prodhan Z, Faruq G (2013) Drought Tolerance in Wheat. The Sci World J 13:1-12.

10. Kirigwi FM, Ginkel MV, Trethowan R, Sears RG, Rajaram S, et al. (2007) Markers associated with a QTL for grain yield in wheat under drought. J Mol Breed 20:401-413.

11. Mohammadi R, Sadeghzadeh ED, Mohammad A, Ahmed A (2011) Evaluation of durum wheat experimental lines under different climate and water regime conditions of Iran. Crop Pasture Sci 62: 137-151.

12. Trethowam RM, Van M, Ginkel S, Rajaram S (2005) Progress in breeding wheat for yield and adaptation in global drought affect environments. Crop Sci 42:1441-1446.

13. Fleury D, Jefferies S, Kuchel H, Langridge P (2010) Genetic and genomic tools to improve drought tolerance in wheat. J Exp Bot 16: 3211-3222.

14. Richards RA (1996). Defining selection criteria to improve yield under drought. Plant Grow Reg 20:157-166.

15. Bonjean AP, Angus WJ (2001) The world wheat book: A history of wheat breeding. 2nd ed. Lavoisier Pub Paris.

16. Ceccarelli S, Grando S (1991) Environment of selection and type of germplasm in barley breeding for low-yielding conditions. Euphytica 57: 207-219.

17. Fischer R, Maurer R (1978) Drought resistance in spring wheat cultivars. I grain yield responses. Aus J Agric Res 29: 897-912.

18. Clarke MJ, Ronald DM, Townley-Smith F (1992) Evaluation of methods for quantification of drought tolerance in wheat. J Crop Sci 32: 21-35.

19. Fernandez GCJ (1992) Effective selection criteria for assessing plant stress tolerance. Proceedings of the international symposium on adaptation of vegetables and other food crops in temperature and water stress. pp: 257-270.

20. Golabadi M, Arzani A, Mohammadi SAMM (2008). Effects of late season water stress on yield and morphophysiological traits in durum wheat F3. J Agric Res 6: 418-405.

21. Gauzzi PF, Rizza F, Palumbo M, Campanile RG, Ricciardi GL, et al. (1997) Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Can J Plant Sci 77: 523-531.

22. Bouslama M, Schapaugh WT (1984) Stress tolerance in soybeans. I evaluation of three screening techniques for heat and drought tolerance. Crop Sci 24:933-937.

23. Mohammadi-joo S, Mirasi A, Saeidi-aboeshaghi R, Amiri M (2015) Evaluation of bread wheat (Triticum aestivum l.) genotypes based on resistance indices under field conditions. Int J Biosci 6: 331- 337.

24. Ramirez-Vallejo P, Kelly JD (1997) Improving common bean performance under drought stress. Crop Sci 37:43-50.

25. Frashadfar E, Javadinia J (2011) Evaluation of chickpea (Cicerarietinum L.) genotypes for drought tolerance. Seed Plant Improvement J 27: 517-537.

26. Rosielle AA, Hamblin J (1981). Theoretical aspects of selection for yield in stress and non-stress environments. Crop Sci 21: 943-946.

27. Gomez KA, Gomez AA (1984). Statistical procedures for agricultural research. John wiley and sons, NewYork Res Edi 2 pp: 670-680.

28. Naimat U, Ullah H, Afridi K, Alam M, Jadoon SA, et al. (2018) Genetic variability, heritability and correlation analysis among morphological and yield traits in wheat advanced lines. Bio Diver Conserv 11: 166-177.

29. Neeru, Panwar IS, Singh V (2017) Genetic parameters of variability and path analysis in wheat under timely and late sown conditions. Int J Curr Microbiol App Sci 6:1914-1923.

30. Aktaş H (2016) Drought tolerance indices of selected landraces and bread wheat (Triticum aestivum l.) genotypes derived from synthetic wheat. Appl Ecol Environ Res 14: 177-189.

31. Singh RK, Chaudhary BD (1979). Biometrical methods in quantitative genetic analysis. pp:80-101.

32. Mevlut A, Sait C (2011) Evaluation of drought tolerance indices for selection of Turkish oat (Avena sativa L.) landraces under various environmental conditions. Žemdirbystė Agriculture 98: 157-166.

33. Pireivatlou MJ (2014) Selection for drought tolerance in bread genotypes with drought tolerance and susceptibility indices. J Appl Environ Biol Sci 4:128-133.

34. Frashadfar E, Sukta M (2002) Repeatability of drought tolerance indices in chickpea genotypes over stress and non-stress environments. Acta Agro Hung 61:123-137.

35. Akram M (2011) Growth and yield components of wheat under water stress of different growth stages. Bangladesh J Agril 36: 455-468.

36. Amiri R, Sohbat B, Saeid JH (2013) Effect of terminal drought stress on grain yield and some morphological traits in 80 bread wheat genotypes. Int J Agric Crop Sci 5: 1145-1153.

37. Betran FJ, Ribaut JM, Beck D, Gonzaledeleon de L (2003). Genetic diversity, specific combining ability, and heterosis in tropical maize under stress and nonstress environments. Crop Sci 43: 797 806.

38. El-Hafid R, Smith D, Karrou M, Samir K (1998) Physiological responses of spring durum wheat cultivars to early-seasons drought in a mediterranean environment. Ann Bot 81:363-370.

39. Jatoi MA, Baloch MJ, Kumbhar MB, Keerio MI (2012) Heritability and correlation studies of morpho-physiological traits for drought tolerance in spring wheat. Pak J Agri Agril Engg Vet Sci 28: 100-114.

40. Jatoi WA, Baloch MJ, Kumbhar MB, Khan NU, Keerio MI (2011) Effect of water stress on physiological and yield parameters at anthesis stage in elite spring wheat cultivars. Sarhad J Agri 27: 59-65.

41. Golparvar AR, Abdollah GP, Hamid M (2006) Genetic control of some physiological attributes in wheat under drought stress

conditions. Pak J Bio Sci 9: 1442-1446.

42. Khan AJ, Azam F, Ali A (2010) Relationship of morphological traits and grain yield in recombinant inbred wheat lines grown under drought conditions. Pak J Bot 42:259-267.

43. Seher M, Ghulam S, Awais R, Alvina G (2015) Performance of diverse wheat genetic stocks under moisture and stress conditions. Pak J Bot 47:21-26.

44. Yildirim M, Bilge B (2013) Heat and drought resistances criteria in spring bread wheat: Drought resistance parameters. Sci Res Essays 5: 1742-1745.

45. Shamsi K, Noor-mohammadi M, Haghparast G, Kobraee A, Rasekhi SB (2011) Differential agronomic responses of bread wheat cultivars to drought stress in the west of Iran. Afric J Bio 10: 2708- 2715.

46. Cheema ZA, Khichi AH, Khaliq A (2005). Feasibility of reducing herbicide dose in combination with sorgaab for weed control in transplanted fine wheat (Triticum aestivum l.). Int J Agric Biol 7: 892–894.

47. Kumar S, Kumari J, Bansal R, Kuri BR, Upadhyay D, et al. (2018) Multi-environmental evaluation of wheat genotypes for drought tolerance. Ind J Genet 78:26-35.

48. Motzo R, Giunta F (1996) Relationships between grain filling parameters, fertility, earlines and grain protein of durum wheat in a mediterranean environment. Field Crops Res 47:129-142.

49. Parba ML, Cairns JE, Babu RC, Laffite HR (2009). Identification of physiological traits underlying cultivar differences in drought tolerance in rice and wheat. K Agron Crop Sci 195: 30-46.

50. Pearson K (1880) International statistical. Establishment of mathematical statistics 77: 3-29.

51. Plaut Z, Butow BJ, Blumenthal CS (2004) Transport of dry matter into developing wheat kernels and its contribution to grain yield under post-anthesis water deficit and evaluated temperature. Field Crops Res 86: 185-198.

52. Rana L, Hirak B, Krishnendu R, Sukamal S (2017) System of Wheat Intensification (SWI) a new approach for increasing wheat yield in small holder farming system. K App Nat Sci 9: 1453-1464.

53. Zaman E, Abdul KM, Nasimul BM, Nurunnaher A (2017) Growth and yield performance of selected wheat varieties under water deficit conditions. Bangladesh J Sci Res 29: 163-172.

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