DROUGHT TOLERANCE INDICES OF SELECTED LANDRACES AND BREAD WHEAT (*TRITICUM AESTIVUM* L.) GENOTYPES DERIVED FROM SYNTHETIC WHEATS

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Abstract. The present study was performed to determine performance of selected four synthetic derived bread wheat genotypes, four bread wheat landraces and four modern wheat genotypes under rain-fed and supplemented irrigation experiments based on randomized complete block design with four replications at GAP International Agricultural Research and Training Center, Diyarbakır, Turkey in 2013-2014 and 2014-2015 growing seasons. According to results of pairwise correlation and biplot analysis, significant and positive correlation was observed between grain yield in stress condition (Ys) and stress tolerant index (STI), geometric mean productivity (GMP), mean productivity (MP), harmonic productivity (HM), yield stability index (YSI), yield index (YI), drought resistance index (DI) and stress non-stress production index (SNPI) indicating these indices can be used as parameters for evaluating drought tolerant genotypes. Negative correlation between grain yield in stress (Ys) with SSI and no correlation with TOL indicated that these indices should be used in severe drought conditions for screening genotypes. Number seed in spike (NSS), plant height (PH) and thousand kernel weight (TKW) correlated with grain yield in stress conditions (Ys) according to biplot analysis, also genotypes with lower reduction relating to these traits had higher yield in stress conditions. According to results SEN-DER genotypes G7, G10, landrace group genotype G11 (Sorık) were determined as the most tolerant genotypes to be used to improve drought tolerant varieties, while modern wheat genotypes G4 (Ceyhan-99) and G2 (Tekin) were high productive in irrigation conditions and low productive in rain-fed conditions.
Keywords: *abiotic stress, grain yield, spad, grain number, Triticum aestivum* L, *correlation, biplot*

Introduction

Wheat (*Triticum aestivum* L.) is the main human consumption that provides food for 35 % of world population (Nouri et al., 2011). Increasing world's population expected to hit ~9 billion by 2050. It is expected that wheat's demand will increase by 40% by the year 2030 (Dixon et al., 2008). It would aggravate the environmental impacts by intensifying the water and land conflicts. Thus, a congruent effort for mounting consumptive needs with environmental protection seems obligatory (Koh-Banerjee et al., 2004).

Environmental stresses are the major constraints to the world food production. Although, wheat is probably the only cereal crop that can survive large range of temperature, altitudes and water availability ranges (Reynolds and Rebetzke, 2011), its production fluctuates from year to year and from location to location due to unpredicted climatic conditions. Therefore, improvement of wheat production under drought has become a primary objective of breeding programs around the globe particularly in arid and semi-arid regions. Food security in present and future will rely on the improved resistance to drought and high yielding cultivars (Ogbonnaya et al., 2008).

Traits that related to drought genetic resistance is very limited because of lack of genetic variability in modern wheat cultivars. Due to land limitations, the enhancement of wheat production must come from higher absolute yields by increasing efforts in

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plant breeding along with biotechnological tools and expanded genetic diversity (Rajaram, 2001). For example in the past 20 years CIMMYT (International Maize and Wheat Improvement Center) have created synthetic hybrid wheats (SHW) to incorporate novel resistance genes/traits for biotic and abiotic stress in modern wheat cultivars (Ogbonnaya et al., 2008). This exiting new resource is created by artificially crossing durum wheat (*Triticum turgidum*; 2n=4x=28 AABB) with *Aegilops tauschii* (2n=2x=14 DD). Also, researcher have screened landrace to determine drought tolerant traits. Wheat landraces have a good adaption in drought stress condition but their yield potential under favorable conditions is limited because of lodging sensitivity, and low nitrogen use efficiency, thus their using in Turkey National Wheat programs has been neglected (Akçura, 2001b).

Wheat production of 65-70% in Turkey depends on rainfall conditions, where drought stress occurs most often, thus improving and determination of drought tolerant wheat genotypes is very important. Determination of drought tolerant genotypes in breeding programs is also very complicate since the lack of drought tolerant indicators. Genotypes have been evaluated in dry and normal conditions to estimate drought resistance level of genotypes. Mathematical relationship based on grain yield loss between favorable and stress conditions provide several selection indices to determine drought resistance difference between genotypes. These indices measure productivity of genotypes under dry condition that are indicator for drought tolerance and used in investigations such as TOL (Tolerance), SSI (Stress susceptibility index), MP (Mean productivity) and STI (Stress tolerant index).

The aim of present study was to (i) investigate drought tolerant of synthetic *hexzaploid* wheat, landraces and modern bread wheat genotypes under rain-fed conditions of Southeast Anatolian Region of Turkey, (ii) determine the efficiency of tolerance indices to grouped bread wheat genotypes into sensitive and tolerant (iii) investigate of relationships between tolerance indices and also relation between investigated traits and grain yield.

Material and Methods

Four modern bread wheat genotypes that largely grown in southeast of Turkey, four bread wheat derived from synthetic hexzaploid wheat and four bread wheat landrace were chosen for study based on their yield performance in regional yield trials. The origin and status of genotypes are given (*Table 1*). Experiments were conducted at GAP International Agriculture and Training Center, Diyarbakır province under supplemented irrigation and rain-fed conditions during both 2013-2014 and 2014-2015 growing seasons. The experimental station of GAP International Agricultural Research and Training Center is located 37º55'36" N 40º13'49" E at 640 m above sea level. According to soil analysis, the soil of experimental area was clay-loam, pH of 8.1, content of organic matter 1.75%, ECe of 1.98 dSm^{-1}, $CaCO_3$ of 15.1 g kg^{-1} and suitable P for plant 18.86 kg ha^{-1}. Climatic condition of Diyarbakır province is characterized by a semi-arid climate (humid winters and dry summers). Rainfall distribution is fluctuate in Diyarbakır province and most of precipitation occurs between November and May, and precipitation of long term is 455 mm. Annual rainfall were 365 and 445 mm during 2013-2014 and 2014-2015 growing seasons respectively in Diyarbakır. Genotypes were planted by a sowing-machine into 4 replication with randomized complete block design (RCBD) experiments. Plots were 6 rows, 5 meters long, and spaced 20 cm. Plots were

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seeded 200 kg ha^{-1} and fertilized with 60 kg ha^{-1} Urea and 120 $kgha^{-1}$ DAP fertilizers. Herbicide, Topic-15 WG at 33 g a.i. ha^{-1} were used for weeds control in all experiments. 110 mm water were applied for irrigated plots at tillering (55 mm) and booting stages (55 mm).

Grain yield (GY) explained as ton per hectare (t ha^{-1}), and the other traits number of spike m^{-2} (NS), number of grains spike (NSS) plant height (PH), days to heading (HD), thousand kernel weight (TKW), protein content (PRT), and spad values (SPAD-chlorophyll content) were recorded.

For drought tolerance indices below formulas were used as follow:

Stress susceptibility index (Fernandez, 1992) = SSI= (1-(Ys/Yp))/SI (Eq.1)

Stress tolerance index (Fernandez, 1992) = STI= (Yp*Ys)/ $\bar{Y}p^2$ (Eq.2)

Tolerance (Hossain et al., 1990) = TOL=Yp-Ys (Eq.3)

Geometric mean productivity (Fernandez, 1992) = GMP = $\sqrt{(Yp * Ys)}$ (Eq.4)

Mean Productivity (Rosielle and Hambline, 1981) = MP=(Yp+Ys)/2 (Eq.5)

Harmonic Mean (Chakherchaman et al., 2009) = HM=2*(Yp*Ys)/(Yp+Ys) (Eq.6)

Yield stability index (Bouslama and Schapaugh, 1984) = YSI= Ys/Yp (Eq.7)

Yield index (Gavuzzi et al., 1997) = YI = Ys/ $\bar{Y}s$ (Eq.8)

Drought resistance index (Lan, 1998) = DI = Ys x(Ys/Yp)/ $\bar{Y}s$ (Eq.9)

Abiotic tolerance index (Moosavi et al., 2008) = ATI= [(Yp-Ys)/($\bar{Y}p$/ $\bar{Y}s$)] x [$\sqrt{Yp * Ys}$] (Eq.10)

Stress susceptibility percentage index (Moosavi et al., 2008) = SSPI = [Yp-Ys/2($\bar{Y}p$)] x 100 (Eq.11)

Stress non-stress production index (Moosavi et al, 2008) = SNPI = $\sqrt{(Yp + Ys)/(Yp - Ys)}$] x [$\sqrt{Yp \text{ x } Ys \text{ x } Ys}$] (Eq.12)

Where, Yp is the yield under non-stress; Ys the yield under stress condition; $\bar{Y}p$ is the mean yield of all genotypes; $\bar{Y}s$ is the mean yield of all genotypes; and

SI = 1-($\bar{Y}s$/$\bar{Y}p$) (Eq.13)

Combined analysis of variance based on Random Complete Block Design (RCBD), correlation and biplot analyses were carried out using GenStat 12th (Genstat, 2009). Comparison of the means were calculated by LSD test ($p< 0.01$ and $p< 0.05$).

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Table 1. *Wheat genotypes with their code, cross and origin*

Genotypes	Code	Status	Cross	Origin
Asure	G1	Landrace	-	
Tekin	G2	Cultivar	Wbll1*2/Tukuru	Turkey-CIMMYT
Sagitario	G3	Cultivar	-	ITALY
Ceyhan-99	G4	Cultivar	Bjy/Coc (Cimmyt)	Turkey-CIMMYT
Karakılçık	G5	Landrace	-	Turkey-CIMMYT
Karacadağ-98	G6	Cultivar	Rrv/Ww.15/3/Bj/2Bon //4/Nac	Turkey-CIMMYT
Vorobey	G7	Cultivar (SEN-DER)	Croc_1/Ae. squarrosa (224)//Opata/3/Pastor	CIMMYT
Sokoll	G8	Line (SEN-DER)	Pastor x Altar 84/Aegılops Squarrosa (Taus)//Opata	CIMMYT
SEN-DER 2.	G9	Line (SEN-DER)	Altar 84/Ae.Squarrosa (219)//2*Seri/4/Pfau/Bow// Vee#9/3/Ducula	CIMMYT
SEN-DER 3.	G10	Line (SEN-DER)	Croc_1/Ae.Squarrosa(205)// Kauz/3/Pastor	CIMMYT
Sorık	G11	Landrace	-	Turkey
Bejireş	G12	Landrace	-	Turkey

Results

Evaluation of Grain Yield and Investigated Traits

According to combined ANOVA analysis of Ys, Yp and drought tolerance indices, there were highly significant differences ($p<0.01$or $p<0.05$) among environments, genotypes, and GE interaction for grain yield and investigated another all traits (*Table 2*). These results indicating presence of consideration variability in irrigated and rain-fed conditions for investigated traits such as grain yield (GY), thousand kernel weight (TKW), plant height (PH), number of spike in square meter (NS), number seed in spike (NSS). Also, drought stress caused decreasing of GY, TKW, PH, NS and NSS values (*Table 4*). Mean grain over two year yield in stress condition ranged from 3.46 to 5.50 t ha^{-1} and from 4.56 to 6.80 t ha^{-1} in irrigated conditions (*Table 3*). The mean grain yield was decreased by 30% in stress condition compare to non-stress condition over two years (*Table 3*). These results provide also possibility of select genotypes under both stress and non-stress conditions for high yield potential and drought tolerance. According to mean yield of two years for irrigation condition, G7 (SEN-DER), G4 and G10 (SEN-DER) showed best performances with 6.83; 6.80 and 6.74 t ha^{-1} respectively (*Table 3*). For mean yield in rainfall condition the highest yield were given by synthetic derived bread wheat genotypes G10, G7 and G 8 with 5.50; 4.98 and 4.76 t ha^{-1} respectively. These results indicated that genotypes derived from synthetic wheat genotypes G7 and G10 had high yield potential also tolerant against to water limited conditions.

According to average of two years, plant height was reduced 13.8 cm (12.1%) compare to irrigated condition (*Table 4*). The less plant height reduction is indirect indicator of tolerance for drought (Mursalova et al., 2015). Plant height were positively correlated with grain yield in rain-fed condition ($r = 0.67^*$) and grain yield in irrigated condition ($r = 0.50$ns) (*Table 7*). Genotypes originated from synthetic wheats G7 and G10 showed low plant height reduction and also their yield were highest (*Table 4*). Average of heading days were 119 days in irrigation condition and 116 stress condition. Correlation between grain yield and heading days in water limited condition and irrigation conditions was

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negative, which means that earliness provide tolerance against to drought or provide escape from drought stress effect. Mean number spike m^{-2} was 541 in irrigation condition and 422 in rainfall condition over two years, also positive correlation was determined between NS and grain yield in both irrigation (r= 67**) and rainfall condition (r= 0.66) (*Table 7*). The mean of TKW were 36.6 g in irrigated and 31.4 g in rainfall conditions, and 14.1% reduction was recorded for TKW compare to irrigated condition. Mean of the number seed in spike that contribute grain yield were 33.2 seed/spike in irrigated and 29.8 seed/spike in rain-fed conditions, also positive and significant was determined among NSS and grain yield in irrigated (r= 0.81**) and rain-fed conditions (r= 0.54*) (*Table 7*).

Table 2. *Mean squares of investigated traits of 12 wheat genotypes*

Source	DF	GY	TKW	NS	NGS	HD	PH	Spad	Prt
Stress conditions									
Year (Yr)	1	52.2**	682**	111657**	392**	1743**	938**	155.0**	119.3**
Rep (Yr)	6	1.3	1.3	228.2	0.85	0.73	31.30	10.3	0.97
Genotype (Gen)	11	3.0**	64.7**	11857.7**	40.4**	57.96**	250**	29.5*	3.92**
Yr*Gen	11	1.4**	29.7**	1054.1	13.7**	12.51**	221**	8.1	4.40**
Error	66	2.0	0.96	645.2	1.7	0.26	18.9	15.3	0.32
R2 (%)		0.84	0.96	0.86	0.9	0.99	0.83	0.39	0.91
CV (%)		13.4	3.1	0.6	4.3	0.5	4.30	10.7	4.7
Non-stress cond.									
Year (Yr)	1	73.5**	882**	79063**	121.5	18.64**	551	221.4*	0.18ns
Rep (Yr)	6	0.23	1.06	1797 ns	0.97	0.34	8.2	14.5	1.05
Genotype (Gen)	11	4.37**	60.1**	20447**	49.7**	61.5**	56**	32.0	1.38**
Yr*Gen	11	1.23**	6.1**	4039**	12.3**	7.6**	27**	6.7	0.76**
Error	66	1.56	0.86	838.2	1.29	0.42	7.97	17.9	0.15
R2 (%)		0.92	0.96	0.87	0.91	0.98	0.75	0.4	0.75
CV (%)		6.9	2.5	5.5	3.4	0.6	2.5	9.9	3.3

** : significant at level 0.05, **: significant at level 0.01, GY: Grain yield, NS: Number spike, NGS: Number grain in spike, TKW: Thousand kernel weight, HD: Heading days, PH: Plant height, Spad: Chrolophil content, Prt: Protein content*

Drought Tolerance Indices

According to drought indices that used for discriminating of genotypes (*Table 5*); G7, G8, G10 and G11 were determined as a candidate drought tolerant genotypes with their small values of SSI, TOL, ATI, SSPI and high values of STI, GMP, MP, HM, YSI, YI, DI, SNPI. Also, G5 seem to be drought tolerant according to YSI results, but its yield performance in both irrigated and rainfall conditions was lower than other genotypes. For TOL G3, G4, G6 and G9 were highly sensitive genotypes. Although G1 and G5 seem to be tolerant genotypes according to TOL, ATI and SSPI values, but their productivity under irrigation conditions were limited. G1, G5, G9 and G12 were also determined as a drought sensitive genotypes for GMP, MP, HM and YI. G4 had one of highest grain yield in irrigated condition but it's yield in rainfall was limited. According to stress susceptible index (SSI) G1 (Aşure; landrace) and G11 (Sorık; landrace) were drought resistance but they did not give high yield performance in stress condition, because of their limited yield potential.

Correlation analysis between grain yield under two conditions and drought tolerant indices (*Table 6*) indicated that grain yield in non-stress conditions were correlated with

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Ys (r = 0.72**), SSI (r = 0.26ns), STI (0.89**), TOL (r = 0.58*), GMP (r = 0.91**), MP (0.94**), HM (r = 0.88**), YI (r =0.72**) ATI (0.80**) and SSPI (0.59*). Also, high and significant correlation were determined between grain yield in stress conditions (Ys) and SSI (r = - 0.48*), STI (r = 0.95**), GMP (r = 0.94**), MP (r = 0.91), HM (r = 0.96**), YSI (r = 0.50**), YI (r = 0.97**), DI (r = 0.93**) and SNPI (r = 0.95**).

Table 3. *Grain yield (t ha^{-1}) of wheat genotypes in both conditions and reduction of yield*

Genotypes	Season of 2013-2014			Season of 2014-2015			Average of Two Years		
	SIR	NIR	R%	SIR	NIR	R%	SIR	NIR	R%
G1	3.70	2.32	37	5.88	4.60	22	4.79	3.46	28
G2	5.45	3.75	31	7.30	4.98	32	6.38	4.37	32
G3	5.89	3.35	43	6.90	4.49	35	6.39	3.92	39
G4	6.49	3.69	43	7.11	4.41	38	6.80	4.05	40
G5	3.09	2.01	35	6.03	5.13	15	4.56	3.57	22
G6	5.56	3.60	35	6.75	4.47	34	6.16	4.03	34
G7	6.39	4.87	24	7.27	5.09	30	6.83	4.98	27
G8	5.35	3.99	25	7.52	5.54	26	6.43	4.77	26
G9	4.51	2.61	42	7.62	5.12	33	6.07	3.86	36
G10	5.89	4.74	19	7.59	6.25	18	6.74	5.50	18
G11	4.98	3.61	28	6.96	5.39	22	5.97	4.50	25
G12	4.94	3.39	32	6.33	4.17	34	5.64	3.78	33
Mean	5.19 A	3.49 B	33	6.94 A	4.97 B	28	6.06 A	4.23 B	30
Lsd	0.48**	0.52**		0.70**	1.03**		0.56**	0.42**	

*SIR: Supplemented irrigated, NIR: Non-irrigated, * : significant at level 0.05, **: significant at level 0.01, R: Reduction*

Evaluation of investigated traits and drought indices by GGE biplot analysis

The GGE biplot for ten drought tolerance indices of twelve bread wheat genotypes showed that PC1 explained 59.86% and PC2 explained 39.90% of the total variation (*Fig. 1*). According to results YI, YSI, DI and SNPI were highly correlated with yield in rainfall conditions (Ys), while yield in both irrigation and rain-fed conditions were correlated with GMP, HM, MP and STI. Abiotic stress index (ATI), TOL, SSPI and SSI had a negative correlation with Ys, hence they can be discarded for determining drought tolerance genotypes. The GGE biplot for observed traits of twelve bread wheat genotypes in rain-fed conditions, 38.62% of variation explained by PC1 and 25.79 % by PC2 (*Fig. 2*). The total variation in irrigated conditions was 60.56% that of 37.96 % explained by PC1 and 22.66% by PC2. Examined traits were divided into three groups in both rain-fed and irrigated conditions, which means that traits in the same group correlated each other. According to relationship between traits in rain-fed condition grain yield (Ys), NSS, PH, TKW were similar and included in first group, NS, PRTC and SPAD were strongly correlated each other and included the second group and HD included third group. In irrigation condition, grain yield (Yp), NSS, PH and TKW strongly correlated traits that included in first group, PRTC, NS included second group and HD and SPAD included third group (*Fig. 3*). Plant height (PH), number seed in spike (NSS) and thousand kernel weight (TKW) were correlated with grain yield in both conditions. Heading days (HD) correlated as the negatively with grain yield in both conditions.

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Table 4. Investigated traits of genotypes (averaged over 2 years)

Genotypes	TKW			NS			NGS			HD			PH			SPAD			PRT	
	SIR	NIR	%R	SIR	NIR	%R	SIR	NIR	%R	SIR	NIR	%R	SIR	NIR	%R	SIR	NIR	%R	SIR	NIR
G1	39.3	34.7	11.8	489	416	15	28.5	24.3	14.9	117.0	113.8	2.8	114.4	101.3	11.5	40.7	36.4	10.6	12.4	12.9
G2	36.2	30.0	17.2	535	435	19	35.1	32.0	8.9	114.3	111.8	2.2	113.1	104.4	7.7	42.1	39.2	6.9	12.3	12.9
G3	37.9	33.3	12.1	543	397	27	33.3	30.3	9.0	116.6	114.4	1.9	113.8	96.9	14.8	43.9	38.4	12.5	12.5	12.7
G4	36.5	31.8	12.8	533	380	29	38.1	33.0	13.4	118.4	114.8	3.1	110.6	98.8	10.7	39.8	34.5	13.5	12.1	12.3
G5	32.8	29.5	10.0	448	366	18	30.1	28.9	4.1	121.1	118.6	2.1	105.6	89.4	15.4	43.3	36.5	15.7	12.6	12.1
G6	31.2	26.8	14.2	625	475	24	34.1	28.9	15.4	117.3	114.8	2.1	116.3	103.1	11.3	43.8	39.9	8.9	12.9	13.6
G7	36.7	31.3	14.6	628	471	25	34.5	30.1	12.7	118.0	115.0	2.5	118.1	106.9	9.5	39.9	34.9	12.5	12.9	12.8
G8	36.3	31.3	13.8	564	462	18	34.0	30.4	10.5	122.5	120.1	1.9	112.5	99.4	11.7	44.1	37.6	14.9	12.1	12.4
G9	35.5	26.8	24.6	570	432	24	31.4	29.0	7.6	122.1	119.4	2.3	112.5	93.8	16.7	45.3	35.0	22.7	12.4	12.7
G10	41.8	35.6	14.8	544	467	14	33.0	31.1	5.9	115.4	112.6	2.4	116.9	109.4	6.4	43.9	38.4	12.6	12.3	12.3
G11	37.0	34.3	7.4	476	401	16	34.1	31.6	7.3	116.6	114.3	2.0	112.5	96.3	14.4	43.2	34.3	20.5	12.0	12.2
G12	37.6	31.6	16.0	536	368	31	32.0	28.6	10.5	121.6	117.5	3.4	109.4	100.6	8.0	46.1	36.1	21.7	12.3	12.2
Mean	36.6 A	31.4 B	14.1	541 A	422B	22	33.2A	29.9B	10.0	118A	116 B	2.4	113 A	100 B	11.5	43 A	36.8B	14.4	12.4	12.6
Lsd	0.92**	0.98**		28.9**	25.4**		1.1**	1.3**		0.64**	0.56**		2.8**	4.4**		4.2**	3.9**		0.4**	0.3**

** : significant at level 0.05, **: significant at level 0.01, TKW: Thousand kernel weight, NS: Number spike, NGS: Number grain in spike, HD: Heading days, PH: Plant height, Spad: Crolofil content, Prt: Protein content*

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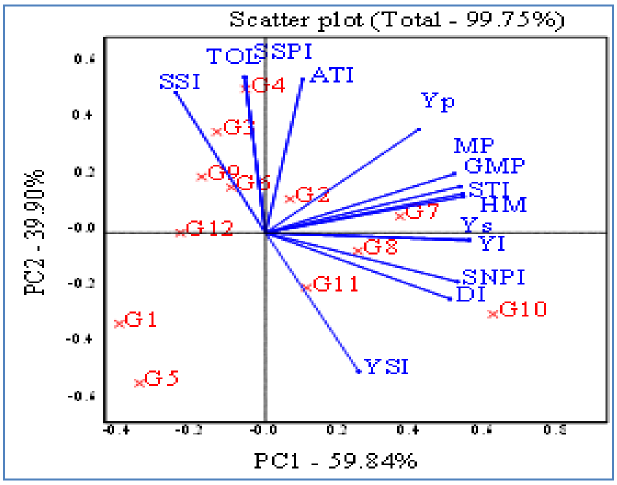

Figure 1. *Biplot based on first two principal component axes (PC1 and PC2).*

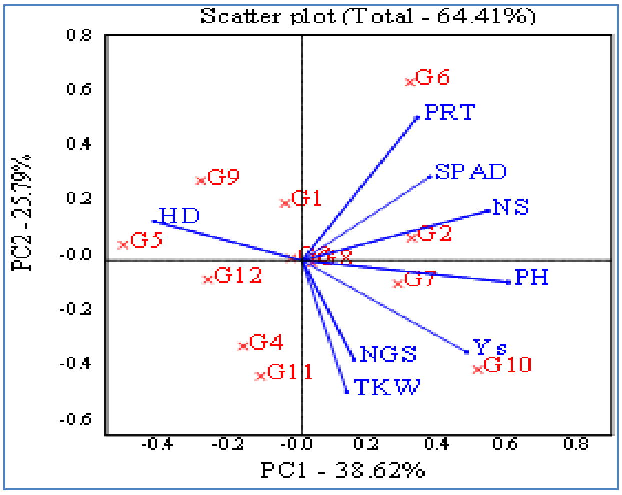

Figure 2. *Biplot based on first two principal component axes (PC1 and 2) for traits of genotypes in rain-fed conditions.*

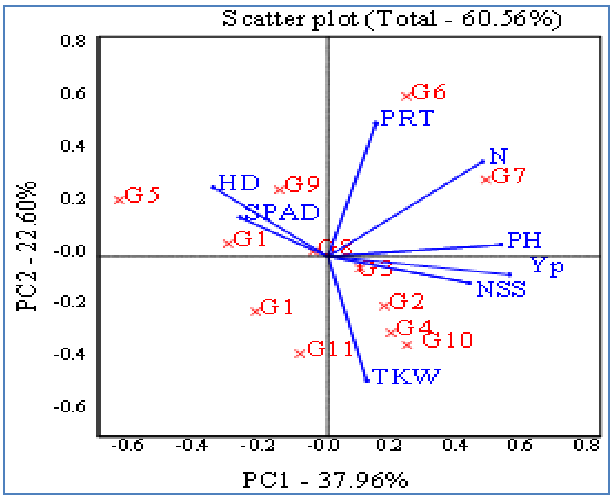

Figure 3. *Biplot based on first two principal component axes (PC1 and 2) for traits of genotypes in irrigated conditions.*

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Table 5. *Drought indices of 12 wheat genotypes (averaged over 2 years)*

			Drought Indices											
Code	Yp	Ys	SSI	STI	TOL	GMP	MP	HM	YSI	YI	DI	ATI	SSPI	SNPI
G1	4.79	3.46	0.92	0.45	1.33	4.07	4.1	4.02	0.72	0.82	10.6	3.0	11.0	18.8
G2	6.38	4.37	1.04	0.76	2.01	5.28	5.4	5.18	0.68	1.03	12.7	5.8	16.6	25.5
G3	6.39	3.92	1.28	0.68	2.48	5.00	5.2	4.86	0.61	0.93	10.2	6.8	20.4	20.2
G4	6.80	4.05	1.34	0.75	2.75	5.25	5.4	5.08	0.60	0.96	10.2	7.9	22.7	21.0
G5	4.56	3.57	0.72	0.44	0.99	4.03	4.1	4.00	0.78	0.84	11.8	2.2	8.2	21.8
G6	6.16	4.03	1.14	0.68	2.12	4.98	5.1	4.88	0.66	0.95	11.2	5.8	17.5	21.9
G7	6.83	4.98	0.90	0.92	1.85	5.83	5.9	5.76	0.73	1.18	15.4	5.9	15.3	32.9
G8	6.43	4.77	0.86	0.83	1.67	5.54	5.6	5.48	0.74	1.13	14.9	5.0	13.7	31.3
G9	6.07	3.86	1.20	0.64	2.20	4.84	5.0	4.72	0.64	0.91	10.4	5.8	18.2	20.2
G10	6.74	5.50	0.61	1.01	1.24	6.09	6.1	6.05	0.82	1.30	19.0	4.1	10.3	44.8
G11	5.97	4.50	0.82	0.73	1.47	5.18	5.2	5.13	0.75	1.06	14.4	4.2	12.1	29.3
G12	5.64	3.78	1.09	0.58	1.86	4.61	4.7	4.52	0.67	0.89	10.7	4.7	15.3	20.2

Table 6. *Correlation between drought tolerance indices and grain yield in both conditions based on mean of 2 years*

	Ys	SSI	STI	TOL	GMP	MP	HM	YSI	YI	DI	ATI	SSPI	SNPI
Yp	0.72**	0.26	0.89**	0.58*	0.91**	0.94**	0.88**	-0.24	0.72**	0.39	0.80**	0.59*	0.49*
Ys	1	-0.48	0.95**	-0.15	0.94**	0.91**	0.96**	0.50*	0.97**	0.93**	0.14	-0.15	0.95**

**: Significant at level 0.05, **: Significant at level 0.01, Yp: Yield in irrigated cond., Ys: Yield in non-irrigated conditions*

Table 7. *Correlation between investigated traits and grain yield in irrigated (Yp) and non-irrigated (Ys) based on mean of 2 years*

	Ys	NS	PH	HD	TKW	NGS	SPAD	PRT
Yp	0.72**	0.67**	0.45ns	-0.28ns	0.22 ns	0.81**	-0.15ns	-0.16ns
Ys		0.66**	0.67**	-0.27ns	0.33ns	0.54*	-0.08ns	-0.10ns

**: Significant at level 0.05, **: Significant at level 0.01, ns: Non significant, NS: Number spike, NGS: Number grain in spike, TKW: Thousand kernel weight, HD: Heading days, PH: Plant height, Spad: Crolofil content, Prt: Protein content, Yp: Yield in irrigated cond., Ys: Yield in non-irrigated conditions*

Discussion

Wheat breeder have been evaluating wheat genotypes in irrigated and rainfall conditions to discriminate genotypes regarding to level of drought tolerance with many drought indices. Fernandez (1992) reported that genotypes can be divided in to four group according to their yield in stress and non-stress conditions: genotypes that have high yield under both stress and non-stress (group A), genotypes with high yield response in non-stress (group B), or stress condition (group C) and the last genotypes with low yield performance in both conditions (group D). Three synthetic derived genotypes (G7, G8 and G10) and landrace G11 (Sorık) were the most productive in both conditions, thus, these genotypes stayed into group A. It was reported that wheat genotypes derived from

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synthetic wheat originated from CIMMYT were superior genotypes than modern bread wheat genotypes in mega environments yield trials regarding to grain yield and quality traits (Lage et al., 1998). Also, SEN-DER bread wheat genotypes have novel genes/traits related to biotic and abiotic stress, such as drought stress and rust diseases (Mujeeb-Kazi et al., 2008**)**. In study performed at Mexico reported that synthetic derived wheat lines showed 26% more grain yield than parental hexzaploid wheat under drought stress (Lopes and Reynolds, 2011). Landrace genotypes G1 (Aşure), G5 (Karakılçık) and G9 (SEN-DER) can be defined as group D genotypes, because of their poor yield performance in both conditions. Modern wheat genotypes (G2, G3, G4, G6) were defined as Group B, since their high yield performance in irrigation condition and poor yield in rainfall condition. Two landrace genotypes G1 (Aşure), G5 (Karakılçık) showed poor performance in both irrigated and rainfall conditions, while the other two landrace genotypes G11 (Sorık) and G12 (Bejireş) had a appreciate grain yield in both conditions. Aynehband et al. (2011) indicated that modern bread wheat genotypes are more adapted to favorable conditions, while landrace have poor yield in favorable conditions because of their lodging problem and lower response to nitrogen, even their yield under drought stress is appreciate On the other hand, wheat genotypes which carry dwarf genes provide lodging resistance, high nitrogen efficiency and more grain yield in the last decades (Mursalova et al., 2015).

Our results based on correlation analysis indicated that selection based on indices (STI, GMP, MP, HM, YSI and YI) may increase yield in both conditions and using DI and SNPI as parameters may contribute yield increasing in drought stress conditions. Similar results reported by Mohammadi et al. (2011) indicated that GMP, MP and STI were suitable drought indices to identify RILs producing high yield in stress and non-stress conditions. Also, it was found significant and high correlations between HM, YI, GMP in investigation related to exotic wheat genotypes (Anvar et al., 2011). TOL correlated positively with Yp and negatively with Ys which means that selection based on TOL will increase grain yield for irrigated conditions. Similar results concluded with investigation on landraces and modern wheat genotypes in Central Anatolia conditions, Turkey (Akçura et al., 2011a). Farshadfar et al. (2012) observed non-significant correlations between TOL, SSI, SSPI and yield in stress conditions; and high and significant correlation between DI and Ys.

Biplot analysis were also used to identify relation between drought tolerant indices and grain yield in both conditions (*Fig. 1*). For drought tolerance indices, 59.84% of variation explained by PC1 correlated with GMP, HM, MP, Yp, Ys, YSI, YI, DI and SNPI (*Fig. 1*). The PC2 explained 39.90% of total variation and highly correlated with TOL, SSI and SSPI (*Fig. 1*). Genotypes with high PCA1 and low PCA2 are more productive under stress and non-stress conditions (Gauch, 2006). Thus, SEN-DER genotypes G7, G8 and G10, and also modern wheat genotype G2 (Tekin) are superior genotypes with their high PC1 and low PC2 for both irrigated and rain-fed conditions (*Fig. 1*). According to biplot analysis, YI, YSI, DI and SNPI were highly correlated with grain yield in rainfall conditions (Ys), these result suggested that selection based on these indices will provide increasing grain yield in stress conditions, while grain yield in both irrigation and rain-fed conditions were correlated with GMP, HM, MP and STI, which means that selection based on these indices will resulted increasing grain yield in both conditions. TOL and SSI positively correlated with Yp (grain yield in irrigated condition) and negatively with Ys (grain yield in rainfed condition). Biplot

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analyse were discriminated that G7, G8, G10 and G11 as the most drought tolerance genotypes.

Correlation between investigated traits in both irrigated and rain-fed conditions and grain yield was displayed by biplot (*Fig. 2 and Fig. 3*). Total variations in rain-fed conditions (64.41 %) was more than irrigated conditions (60.56 %), which means that genotypes showed more variable reactions in stress conditions. According to results of biplot grain yield in both conditions were strongly correlated with plant height (PH), numbers seed in spike (NSS) and thousand kernel weight (TKW), these results indicated that using traits related to grain yield in stress conditions can contribute to improving and determining of drought tolerance genotypes in breeding programs. Similar results reported by Jatav and Kandalkar (2014) claim that genotypes with lower plant height, thousand kernel weight and number seed in spike reduction in stress conditions are more productive and tolerant against to drought. It was reported that the reason low yield in stress condition was due to reduction in number seed in spike and number of the spike in square meter (Akçura et al., 2011a). SEN-DER., wheat genotypes G10 and G7 also modern wheat genotype G2 (Tekin) were most productive in rain-fed conditions according to biplot results (*Fig. 2*). Biplot results (*Fig. 3*), also indicated that grain yield in irrigated conditions were correlated with numbers seed in spike (NSS) and thousand kernel weight (TKW). According to results obtained from biplot indicated that modern wheat genotype G4 (Ceyhan-99) and genotype G10 (SEN-DER) were most productive, in irrigated conditions (*Fig. 3*). Aktaş (2014) reported that Ceyhan-99 cultivar is largely cultivated in Turkey and more adaptable for favorable conditions.

Conclusion

According to pairwaise correlation, biplot analysis YI, YSI, DI and SNPI drought indices can be used as parameter in breeding programs to increase grain yield in stress conditions and GMP, HM, MP and STI in both stress and non-stress conditions. Also, it was concluded that genotypes derived from synthetic wheats valuable germplasm because of high performance of SEN-DER., genotypes G10 and G7. Also, results indicated that plant height, number seed in spikes and number spikes in square meter is important traits that can be used criterions to improving drought tolerant genotypes.

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