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Original Article

Screening Drought-Tolerant Genotypes in Chickpea using Stress Tolerance Score (STS) Method

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ABSTRACT

Objective: In order to study genetic variation and effect of drought stress on grain yield and some morphological traits in chickpea, an experiment was conducted on 64 genotypes during 2013-2014 cropping season at deputy of Kermanshah Sararood Dry Land Agricultural Research Institute, located on the western part of Iran. **Methods:** The experimental design was a randomized lattice design with tow replications under two complementary irrigation and dryland conditions. Six drought tolerance indices including stress tolerance index (STI), geometric mean productivity (GMP), mean productivity index (MP), stress susceptibility index (SSI), tolerance index (TOL), harmonic mean productivity (HMP), were calculated and adjusted based on grain yield under drought (Ys) and irrigated conditions (Yp). **Results:** Results of ANOVA under two complementary irrigation and dryland conditions revealed significant differences among genotypes for YLD, NPMP and NSPP. In dryland condition all of tolerance indices except SSI*TOL have significant negative correlation with SSI index and the rest of indices except TOL*YS, HMP*TOL and YI*TOL show positive correlation. The first two components explained 95.8% of total variation between the data. Based on biplot the genotypes 40 and 63 were superior genotypes under both stress and non-stress conditions. These genotypes had stable performance in the circumstances of low sensitivity to drought stress. Genotypes 29, 55, 56, 57, 45 and 16 had a relatively low yield and they are sensitive to drought stress. In conclusion, this study showed that the effect of drought stress on grain yield was varied which suggested genetic variability for drought tolerance in this materials. Therefore, breeders can select better genotypes based on indices and a combination of different methods of selection.

1.INTRODUCTION

Chickpea (*Cicer arietinum* L.)is a self-pollinated diploid (2n = 2x = 16) annual legume with a genome size of ~738 Mbp (Arumuganathan and Earle, 1991). World population is increasing apace and important percentage of the needed food for this growing population is depended on agricultural production(Cai *et al.*, 2011). Chickpea, the third most important cultivated grain legume in the world after soybean and beans (FAOSTAT

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2009). Among grain legumes, chickpea is rich in nutritional compositions and does not contain significant quantities of any specific major anti-nutritional factors. On an average, chickpea seed contains 23% of highly digestible protein, 64% crude fiber, 6% soluble sugar and 3% ash. The mineral component is high in phosphorous (343mg/100g), calcium (186mg/100g,) magnesium (141mg/100g), iron (7mg/100g) and zinc (3mg/100g) (Nayak, 2010).

In the natural environments, plants often grow under various stresses which are threats for plants and inhibiting them from reaching to their full genetic potential and limit the crops productivity worldwide (Krishania *et al.*, 2013). Moreover, these stresses may threat the stability of agricultural industry (Mahajan and Tuteja, 2005). Current estimates indicate that 25% of the world's agricultural land is now affected by drought stress (Li *et al.*, 2011).So, one of the main purposes of all nations is reducing these damages simultaneity with the increasing food demands (Mahajan and Tuteja, 2005).

Drought, cold and salinity are the most important among the other stresses which adversely affect plant growth and productivity (Cai *et al.*, 2011).Drought is a major limiting factor for agricultural production in most parts of the world (Yu and Setter, 2003).In semiarid regions such as Iran, where rainfall is erratic and low, water deficit becomes the most important limitation to crop production. Therefore, improvement for drought tolerance has become a major aim for breeders in these areas (Pouresmaeil *et al.*, 2012).

Despite the general definition of drought tolerance in native plant species, it is defined in terms of productivity in crop species(Passioura, 1983).Therefore, grain yield and its components remain as the major selection criteria for improved adaptation to a stress environment. Evaluation of genotypes for either high yield potential or stableperformance under different water stress treatments is a starting point in selection for drought tolerance(Ahmad *et al.*, 2003; Pouresmaeil *et al.*, 2012).Sojka *et al.* (1981) defined drought tolerance as the ability to minimize yield loss in the absence of soil water availability.

based on yield loss under drought conditions in comparison to optimal conditions, different drought indices were defined that have been used for screening drought tolerant genotypes(Mitra, 2001). These selection indices were determined based on the mathematical relationship between yields in stress and non-stress conditions to differentiate drought tolerant genotypes from susceptible ones(Clarke *et al.*, 1984; Huang, 2000).Therefore, plants are divided into the four groups based on STI index: (1) – genotypes that express uniform superiority in rain-fed and irrigated conditions (group A), (2) - genotypes which perform favorably only in non-stress conditions (group B), (3) - genotypes which yield relatively higher only in stress conditions (group C) and (4) - genotypes which perform poorly in non-irrigated and irrigated conditions (group D)(Fernandez, 1992; Ghasemi and Farshadfar, 2015). The geometric mean productivity (GMP) is often as a relative performance, since drought stress can be variable in severity fields in over years(Ramirez-Vallejo and Kelly, 1998). Tolerance index (TOL) and mean productivity (MP)(Rosielle and Hamblin, 1981), stress susceptibility index (SSI)(Fischer and Maurer, 1978) and Harmonic Mean Productivity (HMP) (Fernandez, 1992)are other indices for evaluation of genotypes in drought conditions.

2.MATERIALS AND METHODS

2.1.Plants materials

Sixty fourchickpea genotypes listed in Table 1 were studied during 2013-2014 cropping season at deputy of Kermanshah Sararood Dry Land Agricultural Research Institute, located on the western part of Iran (Latitude 34º 19' north and longitude 47º 17' east, altitude 1351 m above the sea level) with deep soils of clay-loam texture. The average annual precipitation is estimated to 455 mm. The precipitation at the cropping season of the experiment was ???? mm. The experimental design was a randomized lattice design with tow replications under two complementary irrigation and dryland conditions. Sowing was done at three row plots, 3 m length, and 0.30 m row spacing. Complementary irrigation was imposed at heading and grain filling stages by 30 mm irrigation.

Five plants were randomly selected from each plot to measure the number of pods per plant (PPP), the number of seed per pod (SPP), biological yield (BY) and Grain yield (GY). After removing the border effect, the whole plot was harvested to calculate the grain yield (g. h^{-1}).

Table 1.
List of the plant materials

ENT.NO	Var	Origion	LAST.Ent.No	Var	rigion
1	X98TH75K1-83	adapt-cw-90	33	X03TH152-88 K6	AYT4C.W-92
2	FLIP98-55C	adapt-cw-90	34	X03TH153-88 K2	AYT4C.W-92
3	SAR79J78K3-86	adapt-cw-90	35	X03TH153-88 K3	AYT4C.W-92
4	SAR79J18K1-86	adapt-cw-90	36	FLIP 99-66 C	Iran
5	SAR79J15K3-86	adapt-cw-90	37	ILC482 C	Iran
6	SAR79J610K1-86	adapt-cw-90	38	Hashem	Iran
7	SAR79J78K5-85	adapt-cw-90	39	Arman	Iran
8	SAR79J87K1-85	adapt-cw-90	40	Azad	Iran
9	SAR79J38K8-85	adapt-cw-90	41	Bivanij	Iran
10	SAR79J710K2-85	adapt-cw-90	42	ICCV 10304	Maragheh-Iran
11	FLIP03-110C	adapt-cw-90	43	ICCV 10305	Maragheh-Iran
12	SAR79J18K1-86	ON FARM-C-W-92	44	ICCV 10306	Maragheh-Iran
13	SAR79J15K3-86	ON FARM-C-W-92	45	ICCV 10308	Maragheh-Iran
14	SAR79J78K5-85	ON FARM-C-W-92	46	ICCV 10310	Maragheh-Iran
15	SAR80J21K13	ON FARM-C-W-92	47	ICCV 10312	Maragheh-Iran
16	SAR79J610K1-86	ON FARM-C-W-91	48	ICCV 10314	Maragheh-Iran
17	SAR79J710K2-85	ON FARM-C-W-91	49	ICCV 10315	Maragheh-Iran
18	SAR80J61K2-87	ON FARM-C-W-91	50	ICCV 10316	Maragheh-Iran
19	SAR80J57K1-87	ON FARM-C-W-91	51	ICCV 10318	Maragheh-Iran
20	SAR79J78K3-86	ON FARM-C-W-90	52	KAK-2	Maragheh-Iran
21	SAR79J87K1-85	ON FARM-C-W-90	53	FLIP 03-27 C	Iran
22	SAR80J78K2-87	ADAPT-C2-W-91-93	54	FLIP 05-67 C	Iran
23	SAR80J21K1-87	ADAPT-C2-W-91-93	55	FLIP 06-64 C	Iran
24	SEL S.P.L.K1-87	ADAPT-C2-W-91-93	56	FLIP 06-65 C	Iran
25	SEL S.P.L.K12-87	AYT4C.W-92	57	FLIP 06-86 C	Iran
26	SEL S.P.L.K23-87	AYT4C.W-92	58	FLIP 06-102 C	Iran
27	SEL S.P.L.K19-87	AYT4C.W-92	59	FLIP 06-142 C	Iran
28	FLIP05-143C	AYT4C.W-92	60	FLIP 07-12 C	Iran
29	SAR80J109K12-87	AYT4C.W-92	61	FLIP 07-35 C	Iran
30	SAR80J61K2-87	AYT4C.W-92	62	FLIP 08-35 C	Iran
31	SAR80J61K6-87	AYT4C.W-92	63	FLIP 08-42 C	Iran
32	SAR80J61K10-87	AYT4C.W-92	64	ILC 3279	Iran

2.2.Drought indices

Drought indices were calculated using the following formulas:

1) $$SSI = \frac{1-(Ys/Yp)}{1-(\bar{Y}s/\bar{Y}p)}$$ (Fischer and Maurer, 1978)

2) TOL = Yp – Ys (Rosielle and Hamblin, 1981)

3) MP = (Ys+Yp)/2 (Rosielle and Hamblin,

1981)

4) $\mathrm{GMP}=\sqrt{(\mathrm{Ys}\times\mathrm{Yp})}$ (Fernandez, 1992)

5) $STI = \frac{(Yp)(Ys)}{(\bar{Y}p)^2}$ (Fernandez, 1992)

6) HARM= [2(Ys× Yp)]/(Ys+Yp) (Schneider *et al.*, 1997)

Where "Ys" is the yield of genotype under stress, "Yp" is the yield of genotype under irrigated conditions, " $\overline{\mathrm{Y}}\mathrm{s}$ " and " $\overline{\mathrm{Y}}\mathrm{p}$ " are the mean yields of all genotypes under stressed and non-stressed conditions, respectively, and "1- ($\overline{\mathrm{Y}}\mathrm{s}$ / $\overline{\mathrm{Y}}\mathrm{p}$)" is the stress intensity.

2.3.Statistical software

Analysis of variance was carried out using SAS ver.9.1 software. Duncan multiple range test (DMRT) was used for the mean comparisons. Pearson correlation among indices and cluster analysis for genotypes were performed by SPSS ver.22. Principal component analysis (PCA) and biplot diagram were carried out by and Stat graphics ver.16.1.11.

3.RESULTS AND DISCUSSION

Results of ANOVA under two complementary irrigation and dryland conditions (Table 2 and 3) revealed significant differences among genotypes for YLD, NPMP and NSPP which indicating the presence of genotypic variability, different responses of genotypes and possible selection genotypes for breeding programs. NP trait was not significant two complementary irrigation and dryland conditions.

Table 2.

Analysis of variance for component yield characteristics of chickpea genotypes under complementary irrigation condition.

S.O.V.	MS				
	df.	NP	YLD	NPMP	NSPP
Replication	1	15.82	873.62	0.125	0.0488
Adjusted Block/Reps	14	228.36	2318175	185.39	50.47
Unadjusted Treatment	63	213.39	301991	335.15	107.64
Adjusted Treatment	63	191.72^{ns}	301992*	335.15**	107.64**
Error Effective	49	119.42	150478	116.38	33.42
RCBD Intrablock	63	143.63	168566	131.71	37.21
Efficiency of Lattice over RCBD	-	108.67	103.91	104.53	103.56
CV%	-	28.92	37.26	38.21	38.58

^{ns}, * and **: Non significant, significant at the 5% and 1% probability levels, respectively.

Table 3.
Analysis of variance for component yield characteristics of chickpea genotypes under dryland condition.

S.O.V.	MS				
	df.	NP	YLD	NPMP	NSPP
Replication	1	4.5	55395	0.125	NSPP
Adjusted Block/Reps	14	73.34	36115	185.39	0.0488
Unadjusted Treatment	63	154.23	61500	335.15	50.47
Adjusted Treatment	63	154.23^{ns}	61503^{*}	335.15^{**}	107.64^{**}
Error Effective	49	136.95	46777	116.38	37.21
RCBD Intrablock	63	122.82	44408	131.71	33.42
Efficiency of Lattice over RCBD	-	89.67	94.93	104.53	37.21
CV%	-	20.85	60.95	38.21	103.56

^{ns}, * and **: Non significant, significant at the 5% and 1% probability levels, respectively.

Mean comparison of studied traits in complementary irrigation and dryland conditions for 64 chickpea genotypes show in Table 4 and Table 5. According of Table 4 (complementary irrigation condition), the highest and lowest value of NP (65.82 and 23.5 for genotypes 60 and 43), YLD (2945 and 599 for genotypes 58 and 12), NPMP (54.5 and 12.75 for genotypes 37 and 17) and NSPP (97 and 23 for genotypes 37 and 38) were observed, respectively. In dryland condition following results were observed (Table 5): the maximum value of NP, YLD, NPMP and NSPP were 74.5, 1445.5, 26 and 74 for genotypes 54, 48, 39 and 41 and theirs minimum value were 23.5, 112, 6.5 and 15.5 for genotypes 45, 45, 57 and 55(57), respectively.

Tabel 4.
Mean comparison of studied traits in complementary irrigation condition for 64 chickpea genotypes.

gen	NP	YLD	NPMP	NSPP	gen	NP	YLD	NPMP	NSPP
1	39.8304	1281.8	16.75	32.5	34	59.1491	1130.15	23.25	53.5
2	40.5274	683.95	31.5	52	35	59.4932	808.7	16.25	32
3	40.938	1034.55	30	56.5	36	50.4952	868.75	23.25	36.5
4	48.2683	1390.4	13.25	25.5	37	55.6398	2019.95	54.5	97
5	42.5064	1060.6	30.75	62	38	57.8509	1292.25	23	37.5
6	56.0987	1333.15	29.25	57.5	39	52.7663	1648.4	22	38.5
7	35.7317	813.2	13.5	27.5	40	53.9106	2029.7	29.25	47
8	44.9863	1121.9	18.25	35.5	41	45.7341	1087.6	16.5	30
9	29.6789	1610.45	28	53	42	44.6305	1728	31.75	43.5

10	45.1652	1280.85	15.75	31.5	43	23.5	778.9	21.5	38.5
11	64.6604	1106.55	33.75	65	44	54.6583	1214.5	15.5	30
12	25.5548	595.5	16.75	34.5	45	36.0411	1267.5	27.75	46
13	46.3876	1451.85	22.5	44	46	55.1974	1178.5	15	27.5
14	44.803	1607.1	24	43	47	45.5093	1122	17.5	27.5
15	33.3485	738.9	13	25.5	48	33.9795	1123	16	28.5
16	52.6994	1474.4	26.25	45	49	46.5298	1259.85	15.75	25.5
17	58.6628	981.55	12.75	23	50	36.7337	1007.5	29	49
18	35.6193	1080.8	26	45.5	51	44.3167	738.35	16.5	32.5
19	46.7961	1238.95	21	37	52	48.3006	1250	15.75	31.5
20	42.0943	1060.7	18	35.5	53	52.3578	1165.7	18.5	31.5
21	41.8211	1380.6	29.25	60	54	61.367	1228	18.5	33.5
22	41.1285	1026	21.5	37	55	58.7889	1596.5	15.5	29
23	45.4907	1204.5	15.25	25	56	57.8002	1407.5	25	42
24	40.3328	1192.6	20.75	37.5	57	62.3533	1367	16.5	28
25	46.197	1312.9	27.75	40	58	51.9267	2945	34.75	59.5
26	50.6309	1429.75	18.75	36.5	59	58.9565	1249.95	26.75	55
27	61.6882	1428.2	22.5	40	60	65.8235	1871.5	24.25	36.5
28	48.1285	1334.55	22.25	44.5	61	51.5894	1833	20.25	35.5
29	56.8074	2011.45	13.5	30.5	62	40.5298	1486	14	25
30	33.8372	1321.3	23.25	42	63	64.11	2041.5	13	24
31	46.7869	1160.75	14.25	35.5	64	33.1696	975.5	30.75	56.5
32	52.3759	1289	28.5	49.5	LSD 1%	30.8	1030.36	15.36	28.65
33	48.7087	1224.8	20	31.5	LSD 5%	23.09	755.19	11.55	21.56

Tabel 5.
Mean comparison of studied traits in complementary dryland condition for 64 chickpea genotypes.

gen	NP	YLD	NPMP	NSPP	gen	NP	YLD	NPMP	NSPP
1	NP	YLD	17	50	34	51	363.9	23	39.5
2	52.5	342.95	18.2	47	35	61.5	342.95	9.7	29
3	52.5	439.95	18.15	51	36	49.5	309.35	18.2	39
4	48	272.1	14.5	41.5	37	46	457.4	21	60.5
5	59	285.25	11.65	32	38	46	339.75	19.5	51
6	39.5	393.7	12.15	36	39	63.5	449.05	26	58.5
7	54	312.45	10	30.5	40	52.5	404.95	20	50.5
8	52.5	320.7	13.85	40	41	51.5	397.95	25.2	74
9	55.5	311	14.35	40.5	42	42	411.5	15.35	45
10	59	325.1	20	58	43	57	308.55	12	37
11	51	333.7	7.65	23	44	49	318.5	9.5	28
12	50.5	179.75	11.85	33.5	45	23.5	112	11.85	35
13	51	173.25	15.8	54.5	46	62	148.5	12.35	33.5
14	47.5	291.55	14.85	44	47	47	380	10.5	33.5
15	62	261.45	19.5	52.5	48	48.5	1445.5	13	40
16	50	264.65	13.35	36.5	49	37.5	277.25	14.15	41
17	40.5	198.2	14.35	38	50	56.5	312	16.5	46

18	57	340.8	21.35	58	51	40	238.55	12.7	37
19	67.5	460.6	16.15	46.5	52	53.5	515.5	11.15	35
20	47.5	263.75	19.5	58	53	55	393.25	9.3	27
21	43	267.4	19.8	57.5	54	74.5	423	12.5	36
22	47	270.3	11.85	33	55	65.5	150.5	6.5	19
23	46	254.7	12.5	35.5	56	62	164.5	6.65	17
24	54	275.65	18	52	57	50	129	6.5	15.5
25	53	423.9	15.35	44	58	52.5	470	17.15	43
26	50	502.7	16.5	46	59	60	488.75	17.85	50.5
27	57.5	457.2	12.85	38	60	60.5	408	11.85	35.5
28	65.5	492.05	14.65	44	61	49.5	314	15.5	48.5
29	69	191.05	16.35	48	62	49.5	430.9	17.85	44
30	63.5	323.55	11.5	33	63	43.5	625	15	45.5
31	62	195.7	14.8	41.5	64	61.5	340.5	15.35	44.5
32	70	222.7	14.65	42.5	LSD 1%	32.08	547.47	13.817	32.64
33	48	267.65	12.3	25.5	LSD 5%	23.39	432.93	10.395	24.56

For better evaluation of 64 chickpea genotypes for drought tolerance, nine selection indices, including STI, TOL, SSI, MP, GMP, HMP, YI, K_1STI and K_2STI were used. Tolerance indices were calculated on the basis of grain yield. The greater the TOL value, the larger yield reduction under drought stress conditions and the higher drought sensitivity. A selection based on minimum yield reduction under stress conditions in comparison with nonstress conditions (TOL) failed to identify the most tolerant genotypes (Farshadfar *et al.*, 2014). Rosielle and Hamblin (1981) reported that selection based on the tolerance index often leads to selecting cultivars which have low yields under nonstress conditions. The greater SSI and TOL values, the greater sensitivity to stress, thus a smaller value of these indices is favored. According to correlation between indices (Table 5), all of selection indices with performance in both condition have significant correlation with together. so, it can be stated that these mentioned indices are the best indices for identify superior genotypes (Golabadi *et al.*, 2006). All of tolerance indices except YI*YP, SSI*STI, HMP*TOL and YI*TOL show significant positive correlation and all of these indices except SSI*TOL and SSI*YP have significant negative correlation with SSI index in complementary irrigation condition. In dryland condition all of tolerance indices except SSI*TOL have significant negative correlation with SSI index and the rest of indices except TOL*YS, HMP*TOL and YI*TOL show positive correlation (Table 6). Farshadfar *et al.* (2014) report SSI index have negative and significant correlation in the stress condition and TOL index with performance in the rain-fed have the significant and positive correlation. HMP index with the GMP and STI indices had a significant and positive correlation. Ghasemi and Farshadfar (2015) perform the same work and confirm these results.

Table 6.

Simple correlation coefficients between tolerance and susceptibility indices of chickpea genotypes under complementary irrigation condition.

	YP	STI	TOL	SSI	MP	GMP	HMP	YI
YP	1							
STI	0.631**	1						
TOL	0.904**	0.247*	1					
SSI	0.369**	-0.445**	0.722**	1				
MP	0.920**	0.876**	0.664**	-0.015	1			
GMP	0.652**	0.982**	0.279*	-0.399**	0.884**	1		
HMP	0.352**	0.922**	-0.062	-0.651**	0.671**	0.938**	1	
YI	-0.369**	0.446**	-0.722**	-1.000**	0.015	0.399**	0.651**	1

Table 7.

Simple correlation coefficients between tolerance and susceptibility indices of chickpea genotypes under dryland condition.

	YS	STI	TOL	SSI	MP	GMP	HMP	YI
YS	1							
STI	0.826**	1						
TOL	-0.318*	0.247*	1					
SSI	-0.857**	-0.445**	0.722**	1				
MP	0.497**	0.876**	0.664**	-0.015	1			
GMP	0.799**	0.982**	0.279*	-0.399**	0.884**	1		
HMP	0.924**	0.922**	-0.062	-0.651**	0.671**	0.938**	1	
YI	0.857**	0.446**	-0.722**	-1.000**	0.015	0.399**	0.651**	1

To employ all indices simultaneously, multivariate statistics such as principal components analysis was performed. The first two components explained 95.8% of total variation between the data (Tabel 7). Thus, a biplot was drawn based on the first two factors (Fig. 1). The first component (PC1), expressed 68.85% of total variation and had a high positive relationship with STI, TOL, MP, GMP, HMP, YI, K_1STI and K_2STI and a negative coefficient with SSI (Table 7). Therefore, the first component was named as drought tolerance. The higher scores for PC1 were in accordance with the higher rank of drought tolerance, whereas low scores for PC1 showed drought-sensitive genotypes (Table 7). The second component (PC2) accounted for 26.95% of total variation and had positive correlation with STI, MP, GMP K1STI tolerance indices (Table 7). This component was able to distinguish low-yielding genotypes under stress conditions with high SSI and TOL values.

Table 8.

Principle component analysis for different drought resistance indices and grain yield under stress and non-stress conditions.

PC	% of variance	STI	TOL	SSI	MP	GMP	HAM	YI	K_1STI	K_2STI
Component 1	68.85	0.400	0.170	-0.092	0.350	0.397	0.373	0.343	0.359	0.370
Component 2	26.95	0.021	-0.574	-0.611	0.295	0.002	-0.213	-0.327	0.213	-0.106

3.1. Biplot method for drought indices

Regarding the principal components analysis, results for the indices and biplot were displayed based on the first two factors. The associations among different drought tolerance indices are displayed in a biplot of PCA_1 and PCA_2 (Fig 1). The PCA_1 and PCA_2 axes which explain 95.8% of total variation, mainly distinguish the indices in different groups. Fernandez (1992) classified plants according to their performance in stress and non-stress environments in four groups: genotypes with good performance in both environments (Group A); genotypes with good performance only in non-stress environments (Group B) or genotypes with good performance in stress environments (Group C); and genotypes with weak performance in both environments (Group D). The higher scores for PC1 and lower scores for PC2 (part A from Fig. 1) were in accordance with the higher rank of drought tolerance. Based on Figure 1 the genotypes 40 and 63 were superior genotypes under both stress and non-stress conditions. These genotypes had stable performance in the circumstances of low sensitivity to drought stress. Genotypes 29, 55, 56, 57, 45 and 16 had a relatively low yield and they are sensitive to drought stress.

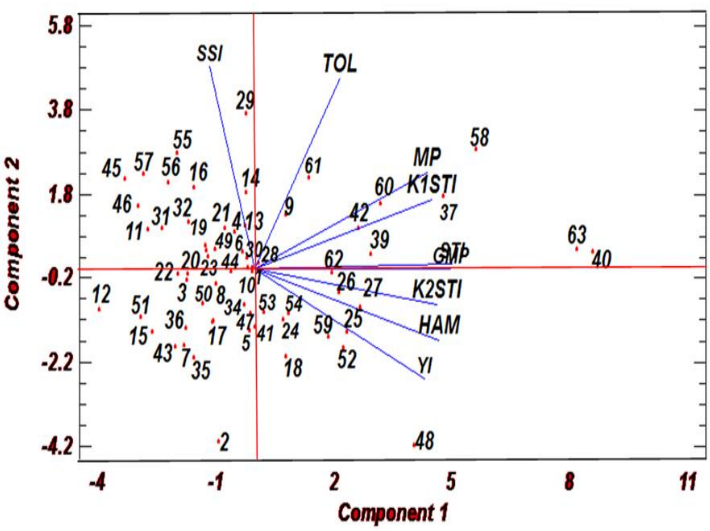

Fig. 1. Biplot based on first and second components of drought tolerance indices for 64 chickpea genotypes.

REFERENCES

Ahmad, R., Qadir, S., Ahmad, N. and Shah, K. (2003). Yield potential and stability of nine wheat varieties under water stress conditions. Int. J. Agric. Biol, 5: 7-9.

Arumuganathan, K. and Earle, E. (1991). Nuclear DNA content of some important plant species. Plant molecular biology reporter, 9: 208-218.

Cai, H., Tian, S., Liu, C. and Dong, H. (2011). Identification of a MYB3R gene involved in drought, salt and cold stress in wheat (Triticum aestivum L.). Gene, 485: 146-152.

Clarke, J. M., Townley-Smith, F., McCaig, T. N. and Green, D. G. (1984). Growth analysis of spring wheat cultivars of varying drought resistance. Crop Science, 24: 537-541.

Farshadfar, E., Sheibanirad, A. and Soltanian, M. (2014). Screening landraces of bread wheat genotypes for drought tolerance in the field and laboratory. International Journal of Farming and Allied Sciences, 3: 304-311.

Fernandez, G. C. (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.

Fischer, R. and Maurer, R. (1978). Drought resistance in spring wheat cultivars. I. Grain yield responses. Crop and Pasture Science, 29: 897-912.

Ghasemi, M. and Farshadfar, E. (2015). Screening drought tolerant genotypes in wheat using multivariate and stress tolerance score methods. International Journal of Biosciences (IJB), 6: 326-333.

Golabadi, M., Arzani, A. and Maibody, S. M. (2006). Assessment of drought tolerance in segregating populations in durum wheat. Afr J Agric Res, 1: 162-171.

Huang, B. (2000). Role of root morphological and physiological characteristics in drought resistance of plants. Plant–environment interactions. Marcel Dekker Inc., New York: 39-64.

Krishania, S., Dwivedi, P. and Agarwal, K. (2013). Strategies of adaptation and injury exhibited by plants under a variety of external conditions: a short review. Comunicata Scientiae, 4: 103-110.

Li, P., Chen, J. and Wu, P. (2011). Agronomic characteristics and grain yield of 30 spring wheat genotypes under drought stress and nonstress conditions. Agronomy Journal, 103: 1619-1628.

Mahajan, S. and Tuteja, N. (2005). Cold, salinity and drought stresses: an overview. Archives of biochemistry and biophysics, 444: 139-158.

Mitra, J. (2001). Genetics and genetic improvement of drought resistance in crop plants. CURRENT SCIENCE-BANGALORE-, 80: 758-763.

Nayak, S. (2010). Identification of QTLS and Genes for Drought Tolerance Using Linkage Mapping and Association Mapping Approaches in Chickpea (Cicer arietinum), Osmania University, Hyderabad, India.

Passioura, J. (1983). Roots and drought resistance. Agricultural water management, 7: 265-280.

Pouresmaeil, M., Khavari-Nejad, R., Mozafari, M., Najafi, F., Moradi, F. and Akbari, M. (2012). Identification of drought tolerance in chickpea (Cicer arietinum L.) landraces. Crop Breeding Journal, 2: 101-110.

Ramirez-Vallejo, P. and Kelly, J. D. (1998). Traits related to drought resistance in common bean. Euphytica, 99: 127-136.

Rosielle, A. and Hamblin, J. (1981). Theoretical aspects of selection for yield in stress and non-stress environment. Crop Science, 21: 943-946.

Schneider, K. A., Rosales-Serna, R., Ibarra-Perez, F., Cazares-Enriquez, B., Acosta-Gallegos, J. A., Ramirez-Vallejo, P., Wassimi, N. and Kelly, J. D. (1997). Improving common bean performance under drought stress. Crop Science, 37: 43-50.

Sojka, R., Stolzy, L. and Fischer, R. (1981). Seasonal drought response of selected wheat cultivars. Agronomy Journal, 73: 838-845.

Yu, L.-X. and Setter, T. L. (2003). Comparative transcriptional profiling of placenta and endosperm in developing maize kernels in response to water deficit. Plant Physiology, 131: 568-582.