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Original article

Tolerance diversity in Kabuli chickpea local germplasm under terminal drought

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Extended abstract

Introduction

Chickpea is mainly grown in the west and north west of Iran in dryland conditions, and in most areas, it is planted as post rainy season crop from March to late May. Due to irregular, untimely and insufficient rainfall in cultivated areas, this plant is usually suffering from drought during flowering and pod filling stages, which are the most susceptible stages of chickpea growth. Utilization of local genetic diversity that are useful sources of adaptation gene to environmental changes is a starting point and a functional approach to overcome this problem. Assuming the local chickpea accession conserved in National Plant Gene Bank of Iran (NPGBI) have appropriate diversity for terminal drought tolerance, a research was conducted with the aim of identify drought tolerant accessions and determining their yield potential under dryland condition.

Materials and methods

Seventy Kabuli chickpea landraces were identified as tolerant accessions in different previous projects were done in NPGBI entered to this study. The experiment was held in Sanandaj and Karaj research station both in two different treatments. Control and drought treatments, through cutting off irrigation at flowering stage till maturity, in Karaj and dryland and complementary irrigation treatments, using two additional irrigations during flowering and pod filling, in Sanandaj station. The accessions were planted in the second half of March in augmented design, during 2016-17 growing season. Different agronomical traits were recorded, quantitative drought tolerance and susceptibility indices, were calculated and based of them accessions were grouped using the principle component and cluster analysis.

Results and discussion

Based on the results, a significant decrease in day to maturity, flowering period, canopy height and width, plant weight, pods number and weight per plant, seeds number per plant, plant yield, biomass, yield and harvest index were observed in drought stress conditions. There was considerable variation in yield and yield components, biomass and harvest index, among understudied landraces. Seed

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production increased by 9.7 and 1.3 times under irrigation treatment in Karaj and Sanandaj, respectively.

Principal component analysis across tolerant and susceptible indices and considering eigen values greater than or equal to 1.0 showed that in both locations, two components together accounted for 92.32 and 99.33 percent of variation. The first component contributed most of the variability 52.18% in Karaj and 83.62% in Sanandaj was explained by variation in HM, STI, GMP and MP indices. The second component was explained by the diversity among genotypes for TOL and SSI indices. Hence, accession number KC.215172, KC.215286, KC215369 and KC.216010 in Sanandaj station and accession number KC.215286, KC.215727, KC215442, KC.215443, and KC.216023 in Karaj with higher amount of GMP and STI indices and lower amount of TOL and SSI were among more drought tolerance accessions.

Cluster analysis based on evaluated traits and calculated drought tolerance and susceptibility indices, were divided accessions in to 3 clusters in Karaj. The cluster number three that TOl and SSI indices and the percentage of unfilled pods had lower values than the total average and plant weight, seed and pod number per plant, seed and pod weight per plant, biomass, yield, harvest index and STI and GMP indices have higher values than the average was called drought tolerant cluster. Accessions number KC.215727, KC.215442, KC.215710, KC.216023 were this cluster member. The cluster number 4 that had high yield potential and high STI and GMP indices and including 24 accessions was drought tolerant cluster in Sanandaj. Accession number KC215369 was in this group.

Conclusions

Although it is possible to increase the yield of chickpea by changing the planting season from traditional spring planting to winter, but farmers still prefer spring planting. Therefore, it is necessary to produce suitable high-yielding cultivars for both seasons, because in this way, farmers have the opportunity to choose suitable cultivars for spring or winter planting, depending on their local environmental or climatic conditions. The mismatch between grouping of tolerant genetic accessions in two experimental locations was due to the lack of similarity of stress intensities between two locations. The intensity of stress was 0.89 in Karaj and 0.24 in Sanandaj and this issue affects the reaction of the accessions. Genotype × environment interaction is the most important challenge in breeding program. Therefore, description of interaction effects and finding out appropriate genotypes with specific or common adaptation for target environments is the most important aim for multi-year and multi-location assessments. Summarizing the results of both sites demonstrated accessions number KC.215286, KC.215442 and KC.215443 were superior genotypes at both locations.

Totally, this study revealed the existence of desirable diversity in terms of agronomic traits and stress tolerance among local accessions of chickpea and highlighted the importance of paying attention to these accessions for advanced and complementary research to identify potentials of these valuable heritage.

***Keywords*:** *Cicer arietinum*, Drought stress, Genetic diversity, Kabuli type, Tolerance indices

Table 1. The number of studied Kabuli chickpea genotypes and their code in NPGBI

*Plot No.	Genotype code	Plot No.	Genotype code	Plot No.	Genotype code	Plot No.	Genotype code
1	KC.215123	25	KC.215166	54	KC.215928	78	KC215911
2	KC.215168	26	KC.215202	55	KC.215960	79	KC215107
3	KC.215172	27	KC.215581	56	KC.216022	80	KC215840
4	KC.215181	28	KC.216090	57	KC.215976	81	KC215383
5	KC.215187	29	KC.215668	58	KC.215996	82	KC215440
6	KC.215221	30	KC.215683	59	KC.216010	83	KC215442
7	KC.215239	31	KC.215684	60	KC.216015	84	KC215443
8	KC.215247	37	KC.215287	61	KC.215238	85	KC216223
9	KC.215263	38	KC.215290	67	KC.215291	91	KC.216086
10	KC.215720	44	KC.215704	68	KC.215567	92	KC.216051
11	KC.215274	45	KC.215718	69	KC.215703	93	KC215191
12	KC.215281	46	KC.216133	70	KC.215710	94	KC.216023
13	KC.215286	47	KC.216100	71	KC.215727	95	ILC6266
14	KC.215315	48	KC.216098	72	KC.215729	101	Arman
20	KC.215353	49	KC.216075	73	KC.215730	102	Azad
21	KC.215362	50	KC.216073	74	KC.215789	103	Samin
22	KC.215369	51	KC.215851	75	KC.215299	104	Hashem
23	KC.215833	52	KC.215895	76	KC.215688	105	KC.215283
24	KC.216169	53	KC.215905	77	KC215712		

*The plot numbers of repeated controls in different blocks has been excluded from the table.

Table 2. Climatical parameters during different months of chickpea growth period in two research stations of Karaj and Sanandaj in 2016-17

	Karaj				Sanandaj			
Growth period months	**Mean Tem.**	**Min Tem.**	**Max Tem.**	**Precipitation**	**Mean Tem.**	**Min Tem.**	**Max Tem.**	**Precipitation**
	----------°C----------			mm	----------°C----------			mm
Feb- March	11.3	0.1	22.2	24.6	9.1	-2.6	20.2	59.9
March- April	14.8	0.5	31.6	51.6	12.6	-2	28.8	43.4
April- May	21.3	8.2	35.1	12.6	17.9	6	33	22.9
May- June	25.6	10.3	39.1	0	24.8	9.2	38.4	0.2
June- July	27.6	14.9	40.7	0	28.8	13.6	41.8	0

Table 3. Analysis of variance for evaluated traits in 5 chickpea check lines under control treatment in Karaj

S.O.V	df	Harvest index	Grain yield	Biomass	Seed weight Plant^{-1}	Seed No. Plant^{-1}	%Single seed pods	Pod weight Plant^{-1}
Block	4	49.18*	1183.94*	4897.6**	11.34**	101.83**	616^{ns}	18.78**
Genotype	4	168.14**	6657.03**	13501 ^{ns}	10.22 ^{ns}	447.77**	4766**	27.51*
Error	16	15.52	15.52	280.13	2724.35	4.69	35.04	203.5
CV%		*9.3*	*17.8*	*21.81*	*26.93*	*16.68*	*24.1*	*26.26*

Table 3. Continued

S.O.V	df	Pod No. Plant^{-1}	Plant weight	Branch number	Fist pod height from ground	Canopy width	Canopy height
Block	4	122.39*	22.87*	0.23 ^{ns}	12.84 ^{ns}	67.07 ^{ns}	28.92 ^{ns}
Genotype	4	207.76**	109.29**	0.06 ^{ns}	42.44**	45.1 ^{ns}	101.51**
Error	16	9.02	38.74	20.55	0.16	7.33	20.51
CV%		*17.67*	*24.66*	*12.17*	*13.72*	*11.49*	*14.09*

*, **, ns: Significant at 5% and 1% probability levels and non-significant, respectively

Table 4. Statistical parameters of evaluated traits in Kabuli chickpea landraces under control and terminal drought stress treatments in Karaj

	Control				Terminal drought stress			
Traits	**Min.**	**Max**	**Mean**	**Rang**	**Min.**	**Max**	**Mean**	**Rang**
Days to 50% flowering	64	79	71.81	15	63	81	68.99	18
Days to maturity	91	113	104.79	22	72	96	89.06	24
Canopy height (cm)	21.4	40.65	31.33	19.25	18.8	33.8	27.42	15
Canopy width (cm)	25.75	60.4	47.17	34.65	14	33.4	24.78	19.4
Fist pod height (cm)	12.6	25.8	19.13	13.2	11.4	28.8	19.39	17.4
Branch number	2.33	5.33	3.5	3	1.33	5	3.02	3.67
Plant weight (g)	3.46	54.18	21.45	50.72	1.86	7.75	4.12	5.89
Pod No. Plant^{-1}	6.33	106.67	44.64	100.33	0	17.33	5.75	17.33
Pod weight Plant^{-1} (g)	0.33	59.04	14.87	58.71	0.02	5.09	0.97	5.07
Unfilled pod%	0.84	73.68	11.38	72.84	0	100	31.75	100
%Twinge seed pods	0	100	33.65	100	0	71.43	8.19	71.43
Seed No. Plant^{-1}	1.67	130.33	50.27	128.67	0	18	4.55	18
Seed weight Plant^{-1} (g)	0.11	29.62	10.38	29.52	0	2.23	0.62	2.23
Biomass (g. m^{-2})	83.58	684.38	295.12	600.79	21.70	409.33	83.71	387.63
Grain yield (g. m^{-2})	8.5	291.62	104.99	283.12	0	148.67	12.22	148.67
Harvest index	10.41	83.54	41.12	73.12	0	52.45	13.89	52.45

Table 5. Statistical parameters of evaluated traits in Kabuli chickpea landraces under rainfed and complementary irrigation treatments in Sanandaj

	Complementary irrigation				Rainfed planting			
Traits	**Mean**	**Min.**	**Max**	**Rang**	**Mean**	**Min.**	**Max**	**Rang**
Days to 50% flowering	39.64	37	42	5	38.26	38	40	2
Days to maturity	105.3	104	112	8	100.15	99	103	4
Canopy height (cm)	29.09	22	37	15	27.07	23	31	8
Number of seed per pod	1.076	1	2	1	1.06	1	2	1
Pod No. Plant^{-1}	9.29	2	19	17	6.93	1	16	15
100Seed weight	11.96	9.8	17.1	7.3	9.97	5.1	14	8.9
Grain yield (g. m^{-2})	30.28	20.83	59.16	38.33	23.04	20.33	41.33	21

Table 6. Eigen value, percent of variance and cumulative percentage of component extracted from PCA analysis of drought tolerance indices in Karaj and Sanandaj

	Karaj		Sanandaj	
	Principal component (PC)		Principal component (PC)	
	PC1	PC2	PC1	PC2
Eigen value	4.17	3.21	6.69	1.257
%Proportional Variance	52.18	40.14	83.62	15.7
% Cumulative Variance	52.18	90.26	83.62	99.32
Geometric Mean of Productivity (GMP)	0.47	-0.13	0.38	-0.12
Harmonic Mean (HARM)	0.38	-0.34	0.38	-0.19
Mean Productivity (MP)	0.38	0.34	0.39	-0.05
Stress Susceptibility Index (SSI)	0.00	0.44	0.30	0.55
Stress Tolerance Index (STI)	0.47	-0.13	0.38	-0.18
Stress Tolerance (TOL)	0.26	0.46	0.33	0.45
Yield in control condition (Yp)	0.32	0.41	0.38	0.16
Yield in stress condition (Ys)	0.33	-0.40	0.27	-0.63

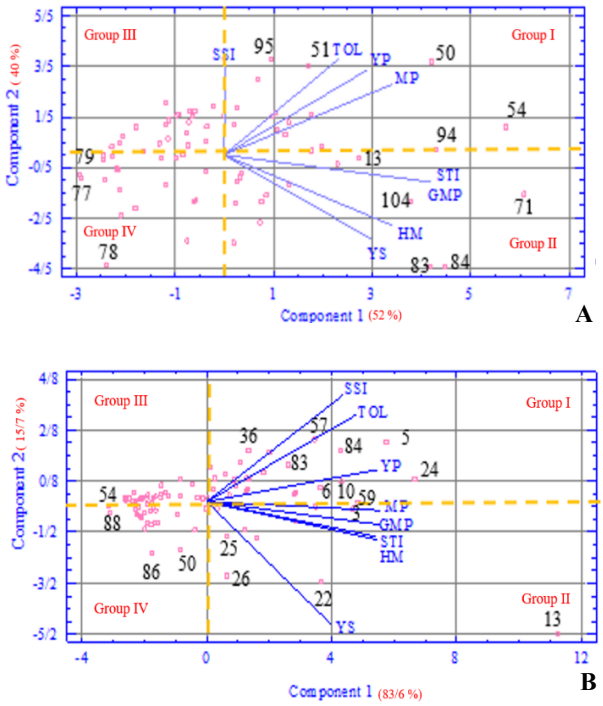

Fig. 1. Biplot display of two principal components of drought tolerance indices in chickpea genotypes under drought stress treatment in Karaj (A) and Sanandaj (B).

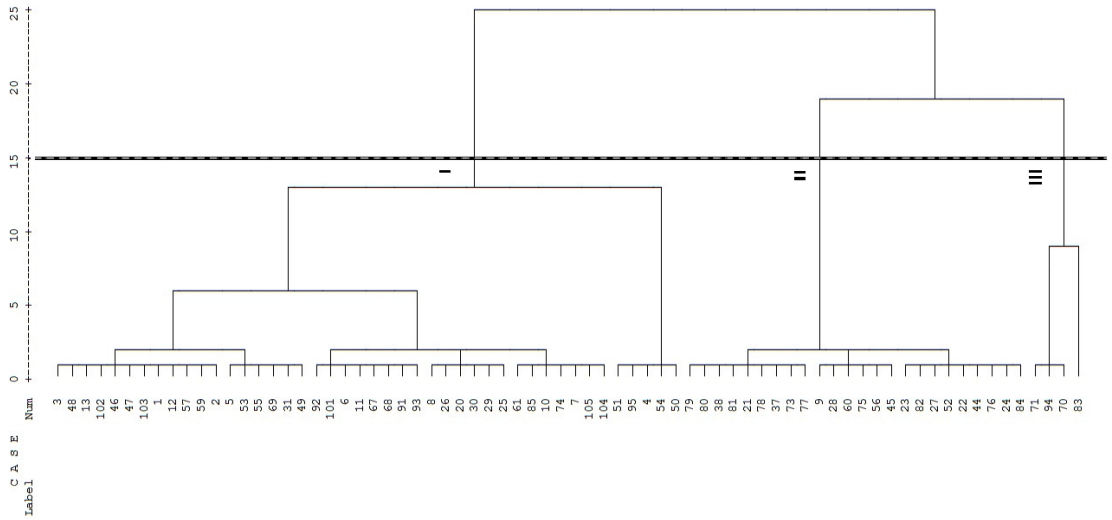

Fig. 2. The dendrogram for chickpea accessions grouping based on agronomical traits under drought stress condition in Karaj and drought tolerance indices

Table 7. Mean of measured quantitative traits and drought tolerance indices in center of clusters developed by K-means cluster analysis in Karaj

Character	Cluster No. 1	2	3	Mean
Days to 50% flowering	68.9	68.55	71.5	69.65
Flowering duration	83.4	82.2	85	83.53
Canopy height (cm)	27	27.65	26.5	27.05
Canopy width (cm)	34.28	225	23.5	24.26
Fist pod height from ground (cm)	18.46	19.81	16.5	18.26
Plant weight (g)	4.29	3.89	5.2	4.46
Pod No. Plant^{-1}	5.72	5.39	9.5	6.87
Pod weight Plant^{-1} (g)	0.95	0.96	1.76	1.22
Unfilled pod%	32.31	30.23	10	24.18
Seed No. Plant^{-1}	4.47	4.41	10.34	6.41
Seed weight Plant^{-1} (g)	0.62	0.6	1.28	0.83
Biomass (g. m$^{-2)}$	79.58	69.91	373.72	174.4
Grain yeild (g. m$^{-2)}$	11.46	8.96	83.67	34.7
Harvest index	14.42	13.21	20.92	16.18
Stress Tolerance Index (STI)	0.13	0.07	58.23	0.17
Geometric Mean of Productivity (GMP)	34.87	23.49	58.23	38.86
Stress Tolerance (TOL)	49.91	151.52	-1.16	66.76
Stress Susceptibility Index (SSI)	0.84	1.06	-1.8	0.04

Table 8. Mean of yield and drought tolerance indices in center of clusters developed by K-means cluster analysis in Sanandaj

	Cluster Number			
	1	**2**	**3**	**4**
Yield in supplementary irrigation (Yp)	84.08	78.11	151	115.78
Yield in rainfed condition (Ys)	66.08	66.76	71	73.28
Mean Productivity (MP)	66.08	72.31	94.91	94.35
Stress Tolerance (TOL)	75.08	11.41	92.78	42.58
Geometric Mean of Productivity (GMP)	74.36	71.98	103.36	91.73
Stress Susceptibility Index (SSI)	0.829	0.580	2.201	1.518
Stress Tolerance Index (STI)	0.676	0.631	1.300	1.027
Harmonic Mean (HARM)	73.66	71.65	96.35	89.20