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Genetic Variation and Agronomic Evaluation of Chickpea Cultivars for Grain Yield and Its Components Under Irrigated and Rainfed Growing Conditions

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ABSTRACT-Water deficit is an important factor limiting crop growth all over the world. In order to evaluate genetic variation, heritability and the interrelationship between agronomic traits, twenty chickpea genotypes were cultivated in two separated randomized complete block experiments with three replications under normal irrigated and rainfed conditions. The experiments were carried out at the Agricultural Research Station of Razi University, Kermanshah, Iran, in the 2004-2005 growing season. Under normal conditions, plants were irrigated at stem elongation, pod appearance and pod filling stages. In rainfed conditions, no irrigation treatment was applied. The results revealed that the genotypes S95274 under irrigated and X95TH69 in rainfed conditions had the highest number of pods per plants (NPP), number of seeds per plant (NSP) and grain yield. The genotypes X96TH54 and X95TH69 produced relatively high grain yield compared to other genotypes in both conditions. The highest genotypic and phenotypic coefficients of variation in irrigated (32.61% and 34.67%, respectively) and in rainfed conditions (47.88% and 49.39%, respectively) and also the highest estimation of heritability in both conditions (88% and 93%, respectively) belonged to grain yield. In rainfed growing conditions, the correlations between grain yield and its components were significantly positive while in irrigated conditions grain yield showed significant correlation with NPP (r=0.50) and NSP (r=0.49). According to the results of path analysis, the highest direct (0.99 and 0.73 in irrigated and rainfed conditions, respectively) and indirect effects (0.89 in irrigated and 0.71 in rainfed experiments) on grain yield belonged to NSP and NPP respectively. Based on cluster analysis method, genotypes were classified into three and four groups in irrigated and rainfed conditions, respectively. It can be concluded that the NPP and NSP traits could be used as selection criteria for grain yield improvement in both conditions in chickpea breeding programs.

Keywords: Chickpea, Genetic variation, Heritability, Rainfed conditions

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the second most important legume crop grown in central and west Asia, south Europe, Ethiopia, north Africa, the Americas and Australia (Singh and Ocampo, 1997**)** and is used to feed both humans and livestock

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(Talebi *et al*., 2008). Its grain is a major source of protein in the human diet. This annual legume also contributes to sustainable agriculture through nitrogen fixation and diversification of agricultural production systems (Gan *et al*., 2006). Due to a low content of sodium and fat, chickpea can be used in gluten-free, diabetic, low salt, low calorie, low cholesterol and high fiber diets (Khalil *et al*., 2007). Moreover, the grain is useful in controlling the cholesterol level of the human body (Geervani, 1991).

Water deficit is one of the main challenges facing semiarid and arid climatic regions for obtaining economic yield in crop plants (Gunes *et al.,* 2008). It has been estimated that about one-third of the world arable land suffers from an inadequate water supply **(**Kramer, 1980**).** Although chickpea is mainly cultivated as a rainfed crop, water stress often influences both productivity and stability of grain yield. The erratic weather of winter followed by spring rainfall in Mediterranean regions, usually results in a relatively low and decreased chickpea grain yield (Lopez-Bellido *et al*., 2004)**.** Therefore, in breeding for higher yielding cultivars breeders need to consider characterization of stress, identification of genetic variation and availability of simple screening methods (Srinivasan *et al*., 1998). In addition, genetic improvements for adaptation to drought, submergence and nutrient toxicities are of important targets in breeding for high grain yield cultivars of chickpea under drought stress (Mackill *et al*., 1999; Johansen *et al*., 1994).

The evaluation of interactions between genotypic and environmental factors is necessary in breeding programs. On the other hand, the effect of environmental factors on grain yield is not inheritable (Gular *et al*., 2001). Estimation of genetic variation and its contribution to phenotypic variance and the heritability of the traits are of importance to achieve significant genetic improvement in chickpea production using different genotypes (Arshad *et al*., 2004).

Analysis of correlation between grain yield and its components is a prerequisite to plan a meaningful breeding program (Ahmad and Saleem, 2003; Nemati *et al*., 2009). Islam *et al.* (1984) reported a high and positive correlation between grain yield and pod number per plant and also the number of secondary branches per plant in chickpea. Furthermore, these traits were suggested to be used as selection criteria in chickpea breeding programs. A selection index based on high pods, high primary branches and low secondary branch number is likely to improve chickpea grain yield (Khan *et al*., 1989; Bakhsh *et al*., 1993).

Using a hierarchical clustering method, Bakhsh *et al.* (1993) classified 39 chickpea genotypes into different groups that were evaluated in water stress conditions. Talebi *et al.* (2008) evaluated 36 chickpea genotypes using agronomic and RAPD markers and identified three clusters, one of which included 28 genotypes with an average flowering time, pod number and grain yield per plant, while the second cluster of genotypes was early flowering with small number of pods and low grain yield.

Due to the importance of drought and its effects on chickpea performance, the present study was conducted to evaluate the genetic diversity and interrelationships of agronomic traits of 20 chickpea genotypes in irrigated and rainfed conditions and to introduce tolerate cultivars for breeding programs of the crop.

MATERIALS AND METHODS

This study was conducted at the Agricultural Research Station of Razi University, Kermanshah, Iran (47.3 ^{0}E and 34.23 ^{0}N) in the 2004-2005 growing season. Twenty genotypes including native and imported cultivars were cultivated in two separated

randomized complete block designs with three replications under irrigated and rainfed conditions. The genotypes (Table 1) were obtained from the chickpea breeding programs of Sararuod Institute of Rainfed Research, Kermanshah, Iran. Each experimental plot consisted of four one-meter long rows spacing 25 cm. Weeds were pulled out manually and no fertilizer was applied for either conditions. Under the irrigated condition, plants were irrigated at stem elongation, pod appearance and pod filling stages. In rainfed condition no irrigation treatment was applied. Number of pods per plant (NPP), number of seeds per pod (NSP), 100 seeds weight (100SW) (g) and grain weight per plant (GWP) were measured using five randomly selected plants in each plot. Grain yield (g/m^2) was measured for the whole plot.

Phenotypic (CVp) and genotypic (CVg) coefficients of variation and heritability (h^2) of the traits were calculated using the following formulas (Falconer and Mackay, 1996):

$$Cv_p = \frac{\sqrt{Vp}}{m} \times 100,\ Cv_g = \frac{\sqrt{Vg}}{m} \times 100,\ h^2 = \frac{Vg}{Vp} \times 100 \quad Vg = \frac{MSc - MSe}{r}$$

Where, V_P, V_g, μ, MSc, MSe and r are phenotypic variance, genotypic variance, mean of the traits, expected mean squares of cultivars, expected mean squares of error and number of replications, respectively.

Table 1. Chickpea genotypes studied under irrigated and rainfed conditions

Number	Genotype name	Number	Genotype name
1	**Arman**	**11**	**Flip-82-150c**
2	**X96TH41K4**	**12**	**Flip-00-40c**
3	**Flip-00-63**	**13**	**S95274**
4	**Bivanich**	**14**	**S95181**
5	**Flip-82-115**	**15**	**X96TH46**
6	**Hashem**	**16**	**X95TH69**
7	**X96TH54**	**17**	**S95346**
8	**X94TH154**	**18**	**X95TH**
9	**IIe482**	**19**	**S96085**
10	**Flip-82-150c**	**20**	**Flip-82-245**

Analysis of variances (ANOVA) was performed using SAS software. Comparison of means was conducted using least significant difference (LSD) test. Cluster analysis based on average distance method (Johnson and Wicheren, 1996) was used to classify genotypes based on the value of the traits in both conditions (SAS 9.1, SAS Institute). Genotypic correlation coefficients among agronomic traits for both conditions were calculated based on expected mean squares and covariance analysis. In order to determine direct and indirect effects of the measured traits on grain yield in both conditions, path coefficients analysis (Dewey and Lu, 1959) was conducted using PATH2 software.

RESULTS

Results of combined analysis of variance for irrigated and rainfed conditions revealed highly significant differences among genotypes for all the traits. Combined analysis of variance indicated significant cultivar × experiment interaction for all parameters (Table 2). Therefore, analyses of variance and mean comparisons were conducted for both normal and irrigated conditions separately (Tables 3 and 4). Genotypes S95274, S95274, X96TH46, S96085 and S95274 showed the highest

values for NPP, NSP, GWP, 100SW and grain yield under normal irrigated conditions, respectively. In rainfed conditions, genotypes X95TH69 and Bivanich showed greater values for these traits. For the traits NPP, NSP, GWP, 100SW and grain yield, genotypes X96TH41K4, X96TH41K4, X94TH154, Flip-82-150c and Hashem showed the lowest values in rainfed condition respectively.

Table 2. Combined analysis of variance for grain yield and its components in chickpea cultivars evaluated under irrigated and rainfed conditions

		Mean squares				
Source	**DF**	**NPP**	**NSP**	**GWP**	**100SW**	**GY**
Experiment (E)	**1**	**3453.13****	**4047.71****	**213.81****	**159.92****	**545318.59****
Error [block (E)]	**4**	**36.47**	**27.62**	**2.70**	**6.08**	**3123.79**
Cultivar (C)	**19**	**88.95****	**77.05****	**5.79****	**36.67****	**7747.18****
C × E	**19**	**101.87****	**105.90****	**6.24****	**18.18****	**8384.61****
Residual	**76**	**14.73**	**17.38**	**1.37**	**6.93**	**856.59**
CV%		**23.82**	**24.98**	**25.47**	**9.24**	**23.15**

NPP: number of pods per plant, NSP: number of seeds per pod, GWP: grain weight per plant, 100SW: weight of 100 seeds, GY: grain yield, DF: degree of freedom,
****, * = Significant at 1 and 5% probability levels, respectively**

Table 3. Results of ANOVA and mean comparisons in 20 Chickpea genotypes under irrigated conditions

Genotype	**NPP**	**NSP**	**GWP**	**100SW**	**GY (g/m^2)**
Arman	**23.08^{c-f}**	**21.67^{c-h}**	**5.84^{b-h}**	**28.20^{c-f}**	**140.50^{g-j}**
X96TH41K4	**19.17^{d-h}**	**20.83^{d-h}**	**6.37a^{b-f}**	**26.67^{d-f}**	**185.80^{c-h}**
Flip-00-63	**23.50^{c-f}**	**23.33^{b-g}**	**5.99^{b-g}**	**30.25^{a-e}**	**225.44^{b-d}**
Bivanich	**18.25^{e-i}**	**17.58^{f-i}**	**5.42^{d-h}**	**30.90^{a-d}**	**242.80^{b-c}**
Flip-82-115	**17.16^{f-i}**	**18.48^{e-i}**	**4.99^{e-h}**	**25.07^{f}**	**327.00^{a}**
Hashem	**26.58^{b-c}**	**29.17^{a-c}**	**8.08^{ab}**	**29.45^{c-f}**	**226.50^{b-d}**
X96TH54	**21.33^{c-g}**	**21.83^{c-h}**	**5.39^{d-h}**	**34.36^{ab}**	**196.70^{b-g}**
X94TH154	**23.67^{c-f}**	**25.08^{b-f}**	**5.10^{e-h}**	**28.80^{c-f}**	**157.69^{e-h}**
IIe482	**22.28^{c-g}**	**26.11^{b-e}**	**7.87^{a-c}**	**31. 70^{a-c}**	**149.62^{f-i}**
Flip-99-26c	**17.83^{f-i}**	**19.67^{e-i}**	**5.39^{d-h}**	**31.26^{a-d}**	**147.90^{f-j}**
Flip-82-150c	**12.75^{h-i}**	**14.67^{h-i}**	**4.40^{f-h}**	**26.88^{d-f}**	**173.90^{d-h}**
Flip-00-40c	**11.50^{i}**	**11.83^{i}**	**3.63^{h}**	**27.51 $^{c-f}$**	**83.36^{j}**
S95274	**38.08^{a}**	**37.23^{a}**	**7.23^{a-e}**	**29.92^{b-e}**	**344.90^{a}**
S95181	**31.33^{a-b}**	**29.33^{a-c}**	**8.59^{a}**	**31.27^{a-d}**	**207.10^{b-f}**
X96TH46	**15.58^{g-i}**	**15.92^{g-i}**	**5.70^{c-h}**	**30.88^{a-d}**	**89.30^{i-j}**
X95TH69	**26.17^{b-d}**	**28.42^{b-d}**	**7.77^{abc}**	**28.80^{c-f}**	**178.70^{c-h}**
S95346	**15.25^{g-i}**	**15.92^{g-i}**	**3.95^{gh}**	**26.16^{e-f}**	**128.16^{h-j}**
X95TH	**25.42^{b-e}**	**25.83^{b-e}**	**5.64^{c-h}**	**29.39^{c-f}**	**252.06^{b}**
S96085	**27.25^{b-c}**	**30.08^{b-c}**	**7.60^{a-d}**	**34.97^{a}**	**196.30^{b-g}**
Flip-82-245	**13.33^{h-i}**	**17.00^{f-i}**	**3.62^{h}**	**30.20^{b-e}**	**222.90^{b-e}**
			Mean squares		
Source	**DF**	**NPP**	**NSP**	**GWP**	**100SW**	**GY(g/m^2)**
Replication	**2**	**33.14**	**37.18**	**4.39**	**3.83**	**6204.50**
Genotype	**19**	**133.44****	**122.61****	**6.79****	**19.20***	**13547.47****
Error	**38**	**20.09**	**24.52**	**1.99**	**8.131**	**1559.73**
CV%		**20.87**	**22.01**	**23.84**	**9.62**	**20.37**

In each column, genotypes with at least one different letter are significantly different.
CV: coefficient of variation, NPP: number of pods per plant, NSP: number of seeds per pod, GWP: grain weight per plant, 100SW: weight of 100 seeds, GY: grain yield, DF: degree of freedom.
****, * = significantly different at 1 and 5% probability levels, respectively**

Table 4. Results of ANOVA and mean comparisons in 20 chickpea genotypes under rainfed conditions

Genotype	NPP	NSP	GWP	100SW	GY (g/m^2)
Arman	14.50^{a-d}	16.92^{a}	3.79^{b-e}	22.39^{h-i}	75.51^{c-e}
X96TH41K4	2.55^{k}	2.50^{h}	1.04^{i}	26.27^{c-h}	14.72^{k-l}
Flip-00-63	8.67^{f-j}	8.75^{de-g}	3.05^{d-g}	28.44^{c-f}	34.11^{i-k}
Bivanich	17.42^{a-b}	17.08^{a}	4.68^{a-c}	32.67^{a-b}	94.23^{b-c}
Flip-82-115	11.50^{c-h}	11.33^{b-f}	3.11^{d-g}	25.19^{e-h}	71.46^{d-f}
Hashem	8.00^{g-j}	6.67^{e-h}	1.76^{g-i}	25.99^{d-h}	12.25^{l}
X96TH54	14.17^{a-e}	14.25^{a-c}	4.75^{a-b}	30.15^{a-c}	106.57^{a-b}
X94TH154	4.50^{i-k}	3.92^{g-h}	0.91^{i}	25.38^{e-h}	20.40^{j-l}
IIe482	13.00^{b-g}	13.08^{a-d}	3.18^{d-g}	23.79^{g-h}	64.52^{d-g}
Flip-99-26c	8.75^{f-j}	8.83^{d-g}	3.47^{b-e}	33.44^{a}	83.00^{c-d}
Flip-82-150c	10.17^{d-i}	11.58^{b-e}	4.34^{a-d}	19.25^{h}	46.53^{g-i}
Flip-00-40c	6.25^{ijk}	7.17^{e-h}	2.00^{f-i}	29.83^{a-d}	62.72^{d-g}
S95274	6.67^{h-k}	6.08^{f-h}	2.68^{e-h}	24.94^{f-h}	38.84^{h-j}
S95181	5.92^{i-k}	6.33^{e-h}	1.6^{1h-i}	26.75^{c-g}	24.77^{j-l}
X96TH46	15.25^{a-c}	15.83^{a-b}	4.86^{a-b}	25.37^{e-h}	55.05^{e-h}
X95TH69	18.10^{a}	17.10^{a}	5.60^{a}	28.88^{b-f}	118.06^{a}
S95346	9.30^{e-j}	9.67^{c-f}	2.69^{e-h}	29.67^{a-d}	52.09^{f-i}
X95TH	13.50^{a-f}	12.92^{a-d}	4.05^{b-e}	29.07^{b-e}	70.50^{d-f}
S96085	15.25^{a-c}	14.67^{a-c}	4.31^{a-d}	28.96^{b-f}	67.30^{d-f}
Flip-82-245	11.50^{c-h}	13.00^{a-d}	3.29^{c-f}	30.04^{a-c}	67.60^{d-f}

		Mean squares				
Source	DF	NPP	NSP	GWP	100SW	GY (g/m^2)
Replication	2	39.81	18.06	1.00	8.33	43.07
Genotype	19	57.38**	60.34**	5.24**	35.64**	2584.33**
Error	38	9.38	10.24	0.74	5.72	153.45
CV%		28.50	29.39	26.41	8.75	20.99

In each column, genotypes with at least one different letter are significantly different ,
**, * = significant at 1 and 5% probability levels, respectively
CV: coefficient of variation, NPP: number of pods per plant, NSP: number of seeds per pod, GWP: grain weight per plant, 100SW: weight of 100 seeds, GY: grain yield. DF: degree of freedom

Traits Interrelationships

Almost all genotypic correlations showed higher magnitude than phenotypic correlations (Table 5). Under irrigated conditions, genotypic correlations between NPP and NSP and also grain yield and 100SW were lower than their corresponding phenotypic correlation coefficients. High and positive correlations between NPP and NSP (r_p=0.97** and r_g=0.98** in normal irrigated; r_p=0.98** and r_g=0.97** in rainfed condition), NPP and GWP (r_p=0.80** and r_g=0.76** in normal irrigated; r_p=0.92** and r_g=0.92** in rainfed condition) and also NSP and GWP (r_p=0.83** and r_g=0.77 ** in normal irrigated; r_p=0.92** and r_g=0.91** in rainfed condition) were found. Although the correlation coefficients between grain yield and other traits under rainfed conditions were significantly positive, under the irrigated condition, significant correlations were only found between grain yield and NPP as well as grain yield and NSP. The traits NPP and NSP showed the highest correlations under both conditions (r=0.98** in irrigated and r=0.97** in rainfed conditions). Although under irrigated condition, the correlation coefficient between grain yield and 100SW (r_p= 0.03, r_g= -0.03) was the lowest, this correlation was significant (r_p =0.42*, r_g =0.43*) under rainfed conditions.

Table 5. Phenotypic and genotypic correlation coefficients among agronomic traits for irrigated (under diagonal) and rainfed (above diagonal) conditions

Traits		NPP	NSP	GWP	100SW	GY
NPP	R_p	1	0.97**	0.92**	0.16	0.80**
	R_g	1	0.98**	0.92**	0.16	0.81**
NSP	R_p	0.98**	1	0.91**	0.10	0.80**
	R_g	0.97**	1	0.92**	0.10	0.81**
GWP	R_p	0.76**	0.77**	1	0.14	0.81**
	R_g	0.80**	0.83**	1	0.15	0.82**
100SW	R_p	0.16	0.16	0.24	1	0.42*
	R_g	0.38	0.41*	0.43*	1	0.43*
GY	R_p	0.50**	0.49**	0.29	0.03	1
	R_g	0.51**	0.51**	0.23	-0.03	1

R_p: Phenotypic correlation coefficient, R_g: Genotypic correlation coefficient.
NPP: number of pods per plant, NSP: number of seeds per pod, GWP: grain weight per plant, 100SW: weight of 100 seeds, GY: grain yield.
****, * = Significant at 1 and 5% probability levels, respectively**

The results of the path analysis are presented in Table 6. Among the traits studied, NSP showed the largest direct effect on grain yield in irrigated (0.99) and rainfed (0.73) conditions while the direct effect of NPP was the lowest (0.14 in irrigated and -0.32 in rainfed experiments). In addition, the direct effects of GWP and 100SW were positive under rainfed conditions while the corresponding ones were negative in the irrigated experiment (Table 6). Based on estimated indirect effects of the traits, traits NPP (0.89 and 0.71 for irrigated and rainfed conditions, respectively) and GWP (0.77 and 0.67) revealed the greatest positive contribution on grain yield through NSP. In the rainfed experiment, trait 100SW had no considerable indirect effect on grain yield through NPP, NSP and GWP.

Table 6. Path coefficients for direct (on diagonal) and indirect effects of the traits on grain yield

Traits	Experiment	NPP	NSP	GWP	100SW	Correlation with grain yield
NPP	Irrigated	0.14	0.89	-0.44	-0.08	0.51
	Rainfed	-0.32	0.71	0.36	0.05	0.81
NSP	Irrigated	0.14	0.99	-0.46	-0.09	0.51
	Rainfed	-0.32	0.73	0.36	0.03	0.81
GWP	Irrigated	0.12	0.77	-0.55	-0.10	0.23
	Rainfed	-0.30	0.67	0.39	0.05	0.82
100SW	Irrigated	0.05	0.38	-0.24	-0.23	-0.03
	Rainfed	-0.05	0.07	0.06	0.35	0.43

NPP: number of pods per plant, NSP: number of seeds per pod, GWP: grain weight per plant, 100SW: weight of 100 seeds

Heritability, Genotypic and Phenotypic Coefficients of Variation

Genotypic and phenotypic coefficients of variation and heritability of traits for normal irrigated and rainfed conditions are presented in Table 7. The highest genotypic and phenotypic coefficients of variation for both conditions were obtained for grain yield (CV_g=32.61% and CV_p=34.67% under irrigated conditions;

CV_g=47.88% and CV_p=49.39% under rainfed conditions) while the lowest ones were observed for 100SW (CV_g=8.08% and CV_p=9.84%; CV_g=11.56% and CV_p=12.62% under irrigated and rainfed conditions, respectively). Coefficients of variation for all traits in the rainfed condition were higher than corresponding ones in the irrigated condition. The highest heritability in both conditions was estimated for grain yield (h^2=88.49% and 93.98% under irrigated and rainfed conditions, respectively). The lowest estimated heritability in irrigated conditions was for 100SW (h^2=67.45%) while under rainfed conditions the lowest belonged to NSP (h^2= 83.04%).

Table 7. Phenotypic and genotypic coefficients of variation and heritability of the traits in irrigated and rainfed conditions

Traits	Experiment	Mean	Rang	V_g	V_p	CV_g (%)	CV_p (%)	h^2 (%)
NPP	Irrigated	21.48	10.00 - 41.25	37.78	44.48	28.62	31.05	84.94
	Rainfed	10.74	2.00 - 25.75	16.00	19.13	37.24	40.72	83.63
NSP	Irrigated	22.50	11.25 - 40.50	32.70	40.87	25.41	28.41	80.04
	Rainfed	10.88	1.75 - 22.25	16.70	20.11	37.55	41.22	83.04
GWP	Irrigated	5.93	2.89 - 10.33	1.60	2.26	21.32	25.82	70.58
	Rainfed	3.260	0.76 - 6.29	1.50	1.75	37.57	40.58	85.71
100SW	Irrigated	29.63	22.26 - 38.34	5.74	8.51	8.08	9.84	67.45
	Rainfed	27.32	18.09- 34.28	9.97	11.88	11.56	12.62	83.92
Grain yield	Irrigated	193.83	63.53 - 372.0	3995.91	4515.82	32.61	34.67	88.49
	Rainfed	59.01	10.57- 130.66	798.29	849.44	47.88	49.39	93.98

Vg = genetic variation, Vp = phenotypic variation, CVg = genotypic coefficient of variation, CVp = phenotypic coefficient of variation, h^2= heritability, NPP: number of pods per plant, NSP: number of seeds per pod, GWP: grain weight per plant, 100SW: weight of 100 seeds

Cluster Analysis

According to cluster analysis of chickpea genotypes based on grain yield and its components (Figures 1 and 2), genotypes were classified into three groups in irrigated and four groups in rainfed conditions. Under irrigated conditions, seven (Arman, X94TH154, IIe482, Flip-99-26c, Flip-00-40c, X96TH46 and S95346), eleven (X96TH41K4, Bivanich, Hashem, X96TH54, Flip-82-150c, S95274, S95181, X95TH69, X95TH, S96085and Flip-82-245) and two (Flip-82-115 and S95274) genotypes were classified in the first, second and third group, respectively. In rainfed conditions, genotypes Arman, Bivanich, Flip-82-115, IIe482, Flip-99-26c, Flip-00-40c, X95TH, S96085 and Flip-82-245 were allocated to the first group while in the second, third and fourth groups there were two (X96TH54 and X96TH46), four (X96TH41K4, Hashem, X94TH154 and S95181) and five (Flip-00-63, Flip-82-150c, S95274, X96TH46 and S95346) genotypes, respectively. The highest distance or dissimilarity between genotypes in the irrigated condition for grain yield and its components was between genotypes S95274 and Arman, and the highest similarity was shown for genotypes IIe482 and Flip-99-26c. In the rainfed condition, the

highest distance, however, was observed for genotypes Arman and S95346, and the highest similarity was obtained for genotypes X95TH and Flip-82-245.

Under irrigated condition, the highest NPP, NSP and grain yield belonged to the third group while the lowest were observed in group one (Table 8). For the traits GWP and 100SW, the second group showed the highest values, but the lowest values for GWP and 100SW belonged to the first and third groups, respectively. In rainfed conditions, the highest mean values of all traits were obtained for group 2 while the lowest ones except 100SW belonged to the third group of genotypes.

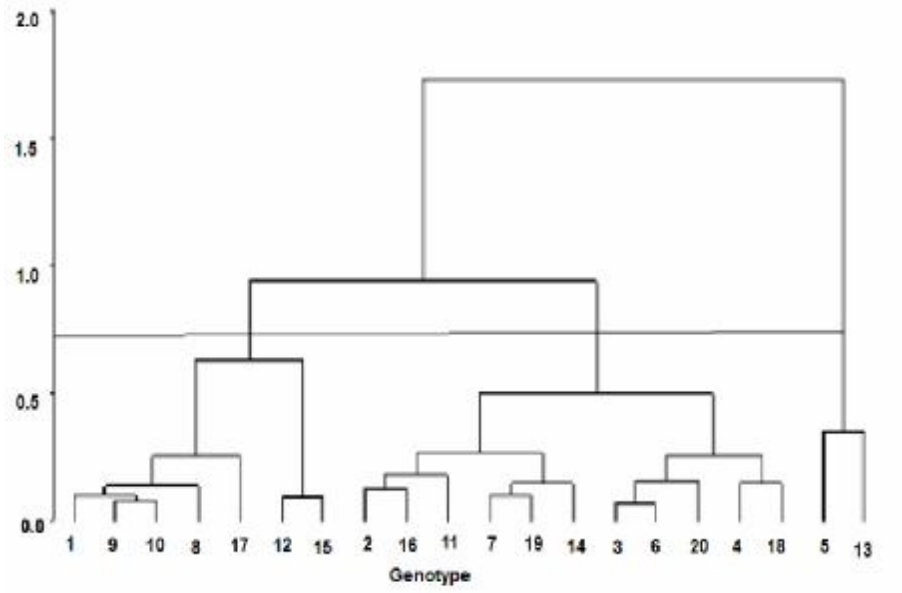

Fig. 1. Tree dendrogram of 20 chickpea genotypes under irrigated condition (digits refer to name of genotypes explained in Table 1)

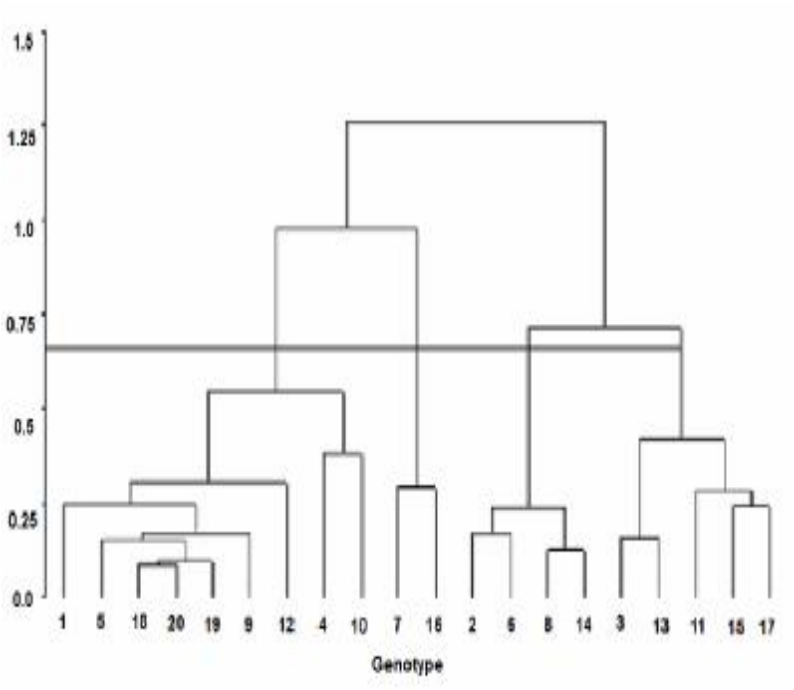

Fig. 2. Tree dendrogram of 20 chickpea genotypes under rainfed condition (digits refer to name of genotypes explained in Table 1)

Table 8. Traits mean in different groups of genotypes under the irrigated and rainfed conditions

	Grain yield	100SW	GWP	NSP	NPP	Total
Irrigated						
Group 1	**128.08** [c]	**29.22** [a]	**5.35** [a]	**19.47** [a]	**18.45** [a]	**40.12** [c]
Group 2	**201.26** [b]	**30.21** [a]	**6.22** [a]	**23.40** [a]	**22.12** [a]	**56.65** [b]
Group 3	**335.94** [a]	**27.50** [a]	**6.11** [a]	**27.86** [a]	**27.62**[a]	**86.00** [a]
Rainfed						
Group 1	**72.98** [b]	**28.38** [a]	**3.54** [b]	**12.78** [a]	**12.41** [ab]	**26.02** [b]
Group 2	**112.32** [a]	**29.52** [a]	**5.18** [a]	**15.67** [a]	**16.14** [a]	**35.76** [a]
Group 3	**18.04** [c]	**26.29** [a]	**1.33** [c]	**4.86** [b]	**5.24** [c]	**11.11** [d]
Group 4	**45.32** [d]	**25.53** [a]	**3.52** [b]	**10.38** [a]	**10.01** [b]	**18.96** [c]

The numbers with different letters are significantly different in columns. Total: denotes for total mean of all traits

DISCUSSION

The highly significant differences among genotypes indicated substantial variation among genotypes under both irrigated and rainfed conditions for all traits. The highest mean value for NPP, NSP and grain yield under irrigated conditions belonged to the genotype S95274, and under rainfed conditions to X95TH69. Under rainfed conditions, the genotype X95TH69 showed the highest mean value of GWP. Moreover, GWP had a high effect on grain yield in rainfed conditions which was confirmed by its high correlation with grain yield. Therefore, in breeding programs, traits of NPP, NSP and GWP can be used as selection criteria in indirect selections to increase grain yield in both conditions. Although genotype S95274 had the highest grain yield under normal irrigated conditions, its performance under rainfed conditions was low, indicating its susceptibility to water stress conditions. On the other hand, genotypes X96TH54 and X95TH69 showed the highest grain yield in both conditions which can be considered as stable genotypes in limited water conditions.

In the present study, the relationships between grain yield per plant and NPP was significantly positive. Such a positive correlation has also been reported by Guler *et al*. (2001), Singh and Shing (1989) and Akdag and Sehirali (1992). A high and significant correlation coefficient between NPP and NSP clearly indicates that an increase in NPP amount leads to an increase in NSP. Therefore, the traits NPP and NSP can be used as indirect characters in order to increase chickpea grain yield. The lowest correlation in the irrigated conditions was observed between grain yield and 100SW which is in agreement with the reports of Guler *et al.* (2001), Singh and Shing (1989) and Akdag and Sehirali (1992). In the rainfed condition, the correlation between 100SW and yield was positive and significant indicating the considerable contribution of 100SW in grain yield variation under limited water conditions.

Genotypic and phenotypic coefficients of variation for all traits under rainfed conditions were higher than those in normal irrigated conditions. Therefore, the water limited condition imposed larger discrimination among genotypes compared with the normal irrigated experiment, but under irrigated condition the lowest variation was related to 100SW confirming the results of the analysis of variance. The highest value for coefficients of variation was obtained for grain yield indicating a high response to selection among chickpea genotypes. High values of the traits'

heritability indicate the significant contribution of genetic variance in phenotypic variation and low environmental effects on the expression of the traits under both conditions. Grain yield showed the highest value of heritability in both conditions. Moreover, under irrigated condition, NPP presented high heritability and therefore, based on its high correlation with grain yield, could be a useful trait for selection of valuable cultivars under normal conditions. On the other hand, due to high heritability of GWP in rainfed conditions it can be used as an effective character in producing high yielding cultivars in water limited conditions.

The results of cluster analysis confirmed the existence of high genetic variation among genotypes evaluated in both experiments, particularly in rainfed conditions. Based on cluster analysis, it can be concluded that the third group of genotypes is the most appropriate in order to select high grain chickpea genotypes while under rainfed conditions, the second group showed the highest grain yield.

In general, due to high genetic variation and heritability of grain yield in both conditions, selection of higher grain yield increases the efficiency of breeding programs of chickpea cultivars. In addition, NPP and NSP traits had significant effects on grain yield and therefore, can be used as an indirect criterion in both conditions. On the other hand, results of cluster analysis showed that hybridization of genotypes of second and third groups under normal irrigated and rainfed conditions could lead to the expansion of genetic variations of agronomic traits in chickpea breeding.

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تنوع ژنتیکی و ارزیابی ارقام نخود برای عملکرد دانه و اجزای آن در شرایط کشت آبی و دیم

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چکیده -کمبود آب از جمله عوامل مهم در کاهش عملکرد گیاهان زراعی در جهان است. به منظور برآورد تنوع ژنتیکی، وراثت پذیری و تنوع فنوتیپی و ژنوتیپی بین صفات مرفولوژیک در شرایط کشت آبی و دیم، بیست ژنوتیپ نخود در قالب طرح بلوک‌های کامل تصادفی با سه تکرار در ایستگاه تحقیقاتی دانشگاه رازی، کرمانشاه، ایران در سال زراعی ۸۵-۸۴ کشت گردیدند. در کشت آبی گیاهان در سه مرحله شامل ساقه دهی، ظهور و پر شدن غلاف آبیاری شدند ولی در آزمایش دیم هیچ گونه آبیاری انجام نشد. ژنوتیپ‌های S 95274 در شرایط آبیاری و X95TH69 در کشت دیم دارای بیشترین تعداد غلاف و تعداد دانه در بوته و همچنین عملکرد دانه بودند. ژنوتیپ‌های X96TH54 و X95TH69 عملکرد نسبتاً بالایی در هر دو شرایط آبی و دیم داشتند. بالاترین مقدار ضریب تنوع ژنوتیپی و فنوتیپی در شرایط آبی (به ترتیب ۳۲/۶۱ و ۳۴/۶۷ درصد) و در شرایط دیم (به ترتیب ۷/۸۸ و ۴۹/۳۹ درصد) و همچنین برآورد وراثت‌پذیری (به ترتیب ۸۸ و ۹۳ درصد در شرایط آبی و دیم) به عملکرد دانه تعلق داشت. در شرایط دیم، همبستگی بین عملکرد دانه و اجزای آن مثبت و معنی‌دار بود در حالی که در شرایط آبی عملکرد دانه همبستگی مثبت معنی‌داری با تعداد غلاف در بوته (r=۰/۵۰) و تعداد دانه در بوته (r=۰/۴۹) داشت. بر اساس نتایج تجزیه ضرایب مسیر، بیشترین آثار مستقیم (۰/۹۹ و ۰/۷۳ به ترتیب در آزمایش آبی و دیم) و غیر مستقیم (۰/۸۹ در کشت آبی و ۰/۷۱ در شرایط دیم) بر عملکرد دانه به ترتیب به صفات تعداد دانه در بوته و تعداد غلاف در بوته تعلق داشت. با استفاده تجزیه خوشه‌ای، ارقام در شرایط آبی به سه و در شرایط دیم به چهار گروه تقسیم بندی شدند. بر اساس نتایج این تحقیق، تعداد غلاف در بوته و تعداد دانه در بوته می‌توانند به عنوان شاخص‌های انتخاب ژنوتیپ‌های برتر در برنامه‌های بهنژادی نخود مورد استفاده قرار گیرند.

واژه های کلیدی: **تنوع ژنتیکی، کشت دیم، نخود، وراثت پذیری**

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** مکاتبه کننده