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Full Length Research Paper

Genetic variability of some agronomic traits in the Iranian Fenugreek landraces under drought stress and non-stress conditions

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This study was carried out to assess the genetic diversity and heritability of various agronomic traits using twenty fenugreek landraces from Iran. The trial was conducted at Maragheh experiment station in North-west of Iran under rainfed (RF) and irrigated (IR) conditions during 2008 cropping season. Results of combined analysis of variance showed significant differences among landraces for all traits except for harvest index under rainfed conditions and in number of pods per plant, number of seeds per plant and dry biomass under irrigated conditions. The highest phenotypic and genotypic variances are found for grain yield under rainfed conditions and plant type and growth habit in both rainfed and irrigated conditions. The highest heritabilities were shown by thousand kernel weight, days to flowering and plant type under both rainfed and irrigated conditions. Cluster analysis allowed to classify the landraces into similar four groups for rainfed and irrigated conditions.

Key words: Fenugreek, landrace, heritability, variability, agronomic traits.

INTRODUCTION

Crop breeders are seeking genetic diversity in crops gene pools to ensure sustainable genetic gains (Frankel et al., 1995). The potential of landraces and wild relative species as source of genetic variation for crop improvement was recognized early in the twentieth century (Tanksley and Mc Couch, 1997). Landraces evolved by natural and artificial selection under environmental conditions where they were grown and there-fore have accumulative adaptive genes (Abdel Ghani et al., 1999). Landraces generally have tolerance to biotic and abiotic stresses and are adapted to low input cultivation conditions where they produced reasonable yield (Byerlee and Husain, 1993; Tesemma and Bechere, 1998; Chang, 1985).

Fenugreek (*Trigonella foneum-graecum* L.) is an annual crop belonging to the Legume family and native to an area extending from Iran to Northern India and widely cultivated in China, India, Egypt, Ethiopia, Morocco, Ukraine, Greece, Turkey, etc. (Polhil and Raven, 1981; Petropoulos, 2002; Acharya et al., 2006). In different part of the world, seeds and young seedlings of fenugreek are often used as curries, dyes, medicines and as a vegetable (Rajagopalan, 1998; Rajagopalan, 2001; Sharma, 1990; Al-Habori and Raman, 2002; Basch et al., 2003; Acharya et al., 2006). Fenugreek can be a very useful legume crop for incorporation into short-term rotation (Moyer et al., 2003), for hay and silage (livestock) and allow fixation of nitrogen in soils.

Acharya et al. (2006) reported significant genetic variability in morphology, growth habit, biomass and seed production among fenugreek genotypes and developed the cultivar "Tristar" for Western Canada that could produce very high quality forage.

Almost in all parts of Iran, fenugreek is cultivated as vegetable and spice crop for a long time and its cultivated area is about 400 ha. Annual fenugreek production in Iran is 800 tons and its grain yield is 0.8 t/ha. There is not any breeding background for this crop in Iran and local landraces are using by farmers commonly.

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Table 1. Abbreviation, units of measurement and scoring system for agronomic traits collected from 20 fenugreek landraces.

Traits	Unit of measurement	Explanation
Days to flowering (DF)	Day	Counted from first irrigation until 50% flowering.
Days to maturity (DM)	Day	Recorded when 50% of the plants in each plot had lost their green coloration since first irrigation.
Plant height (PLH)	Centimeter	Measured in 10 randomly selected plants in each plot at maturity stage.
Pod number (Pd. No.)	Number	Mean number of pods in 10 randomly selected plants in each plot at maturity stage.
Seed number (Sd. No.)	Number	Mean number of seeds in 10 randomly selected plants in each plot at maturity stage
Seed weight (Sd. W)	Grams	Mean weight of total kernels in 10 randomly selected plants in each plot.
Thousand kernel weight (TKW)	Grams	Weighting 1000 seeds.
Plant type (TYP)	Score	1 = Prostrate growth habit.
		3 = Semi erect growth habit.
		5 = Erect growth habit.
Growth vigor (GV)	Score	1 = Poor vigor at flowering stage.
		3 = Medium vigor at flowering stage.
		5 = High vigor at flowering stage.
Biological yield (Bio.)	Kg/hectare	Weighting total dry matter above soil surface.
Grain yield (GY)	Kg/hectare	Weighting total kernel weight in unit area.
Harvest index (HI)	Ratio	Grain yield/Biological yield.

The present study was undertaken with the objective of analyzing genetic diversity in different fenugreek landraces from Iran.

MATERIALS AND METHODS

Twenty fenugreek landraces originated from different parts of Iran were used in this study. The experiment was conducted at Maragheh experiment station of the Dryland Agricultural Research Institute (DARI) located in North-west of Iran (37° 12´ N and 46° 25´ E, 1730 m above see level) during spring and summer of 2008 cropping season. The soil type was loamy clay with pH < 8.5 without salinity (EC < 2 mmhos/cm). Mean long-term annual precipitation and mean annual temperature in the station are 380 mm and 9.5°C, respectively.

Fenugreek landraces were evaluated in four trials, two under rainfed conditions (with 30 mm irrigation at sowing = RF) and two another under irrigation (every two weeks based on field capacity = IR), using randomized complete block design with four replications. Planting was done on April 4th with a density of 20 kg/ha. Each plot contained 4 rows of 3 m length with 25 cm row spacing. Phosphorus fertilizer (Triple super phosphate, P_2O_5) was applied at 30 kg/ha prior to planting (in autumn) and nitrogen fertilizer (Urea) at 20 kg/ha used as topdressing, applied one month after planting. The amount of water for irrigation, measured by counter, is determined based on field capacity.

Nine agronomic traits were recorded on plot basis (Table 1). Dry biomass, grain yield and harvest index were determined at harvest from the inner rows of each plot (0.5 × 1.5 m^2).

Analysis of variance was performed for each individual condition and combined analysis (for two IR and two RF) to asses the genotypic and environment effects. Phenotypic and genotypic variances and broad sense heritability (h^2) estimates for traits were determined in each growing conditions (RF and IR) through the following formula (Falconer, 1981) using MSTATC package:

V_G = [(Ms Genotype) – (Ms Genotype × Environment)] / re

$h^2 = (V_G / V_P) \times 100$

Where; V_G, V_P are genotypic and phenotypic variances, r and e are number of replications and environments, respectively.

Cluster analysis was performed using WARD's method (Ward,1963) by SPSS software.

RESULTS

The results of combined analysis of variance over environments (two RF and two IR trials) indicated high significant differences between genotypes for all traits except HI under RF condition as well as Pd. No., Sd. No. and Bio. under IR condition (Table 2). Comparisons of traits means under RF and IR conditions are summarized in Tables 3 and 4 and the results indicating that under different conditions, the genotypes had different response for traits except for DF and grain yield (GY). Landraces number 2, 5, 16 and 17 were early flowering under both conditions and 1 and 11 had the highest and the lowest GY under both conditions, respectively. The response to photoperiod could be the reason of no differences among the landraces for DF under IR and RF conditions.

Genenotypic and phenotypic variances, genotypic and phenotypic coefficient of variation and broad sense heritability of studied traits are presented in Table 5. The estimates of genotypic coefficient of variability were high for plant type (TYP), growth vigor (GV), thousand kernel weight (TKW) and seed production by plant (S.d W) under both IR and FR conditions. Significant phenotypic and genotypic variation for agronomic traits of fenugreek genotypes were also reported by other authors (Acharya

Table 2. Combined analysis of variance for agronomic traits in Iranian fenugreek landraces under rainfed and irrigated conditions in Maragheh during 2008 season.

	Source of variation	df	Mean square											
			DF†	DM	PLH	Pd. No.	Sd. No.	Sd.W	Bio.	GY	HI	TKW	TYP	GV
Rainfed condition	Field (F)	1	1587.6**	15.63*	154.3**	518.4**	6678158**	1051.1**	1.19**	1.12**	0.002 ns	16.26**	4.23**	3.03 ns
	Error	6	8.92	24.80	48.30	11.42	185877	38.90	0.86	0.105	0.013	5.30	1.63	4.53
	Genotype(G)	19	212.8**	55.12**	26.43**	5.94**	54549**	12.77**	0.19*	0.05**	0.002 ns	58.50**	18.28**	8.96**
	G×F	19	15.43**	5.60 ns	1.80 ns	2.43 ns	40302**	5.67 ns	0.10 ns	0.02 ns	0.002 ns	0.74 ns	0.49 ns	0.97 ns
	Error	114	2.50	3.90	2.94	1.48	19554	3.50	0.11	0.02	0.002	0.64	0.63	0.86
	C.V%	-	2.80	2.0	9.40	19.90	24.20	28.9	20.95	22.60	11.40	7.00	23.70	25.80
Irrigated condition	Field (F)	1	731.0**	339.3**	80.20**	50.63**	191407**	97.30**	11.4**	0.19*	0.06**	4.20 ns	8.10**	3.60*
	Error	6	8.35	28.0	42.50	8.15	155883	28.90	3.40	0.27	0.01	2.60	1.10	3.65
	Genotype(G)	19	307.3**	32.6**	17.50**	4.40 ns	63632 ns	22.60**	0.27 ns	0.07**	0.007**	60.40**	10.60**	12.80**
	G×F	19	22.10 ns	14.70*	2.40 ns	2.70 ns	38670 ns	5.40 ns	0.20 ns	0.02 ns	0.001 ns	1.09 ns	1.40*	1.20 ns
	Error	114	17.30	7.30	3.70	3.06	42057	8.06	0.22	0.03	0.002	1.62	0.68	0.84
	C.V%	-	7.20	2.50	8.80	25.70	29.8	31.90	17.60	20.0	13.40	9.45	27.40	26.40

** and * Significant at the 1 and 5% levels of probability, respectively. ns = not significant.
†DF = Days to flowering, DM = Days to maturity, PLH = Plant height, Pd. No. = Pod number, Sd. No. = Seed number , Sd. W = Seed weight , Bio. = Biological yield, GY = Grain yield, HI = Harvest index, TKW = Thousand kernel weight, TYP = Plant type, GV = Growth vigor.

Table 3. Mean and comparisons of agronomic traits of Iranian fenugreek landraces planted under rainfed conditions in Maragheh experiment station during 2008 cropping season.

No.	Landrace	DF†	DM	PLH	Pd. No.	Sd. No.	Sd. W	Bio.	GY	HI	TKW	TYP	GV
1	Ardestan	55 c*	97 abcd	20 ab	6 cde	67 a	7.0 abcd	1.70 abc	0.73 a	0.43 a	10.6 d	4.5 abc	4.0 abc
2	Esfahan	51 a	97 abc	19 ab	7 bcd	52 bcd	7.4 abc	1.70 abc	0.67 abcd	0.39 ab	14.8 ab	4.5 abc	4.8 a
3	Ahvaz	63 f	102 g	17 cde	6 bcd	57 abcd	4.9 de	1.49 abcd	0.55 bcdef	0.37 b	9.1 e	1.3f	2.5de
4	Borazjan	51ab	98 abcd	20 ab	7 bc	58 abcd	7.9 ab	1.46 abcd	0.57 bcdef	0.40 ab	14.1 b	4.5abc	4.8 a
5	Broojerd	51a	99 cde	20 ab	6 bcd	49 d	7.0 abcd	1.74 ab	0.70 ab	0.41 ab	14.8 ab	5.0 a	4.8 a
6	Khash	63 f	104 g	16 ef	6 bcd	58 abcd	5.0 de	1.35 abc	0.51 ef	0.38 ab	8.4 e	1.0 f	2.0 e
7	Khorasan	53 b	99 de	18 bcd	6 cde	49 cd	6.0 bcde	1.78 a	0.71 ab	0.39 ab	12.5c	4.0 bcd	3.3 cd
8	Khoramabad	63 f	103 g	17 def	5 e	45 d	4.1 e	1.45 abcd	0.56 bcdef	0.39 ab	8.9 e	1.0 f	2.0 e
9	Raey	63 f	102 g	17 def	6 bcd	66 abc	5.8 bcde	1.41 abcd	0.52 cdef	0.37 b	8.5 e	1.8 f	2.8 de
10	Zanjan	63 f	103 g	17 def	6 bcd	73 a	6.7 abcd	1.33 cd	0.52 def	0.39 ab	8.9e	1.3 f	2.0 e
11	Semnan	62 ef	102 fg	15 f	5 de	51 bcd	4.3 e	1.20 d	0.48 f	0.42 ab	7.5 f	1.0 f	2.0 e
12	Shiraz	58 d	98 abcd	20 ab	6 bcd	59 abcd	6.1 bcde	1.62 abc	0.65 abcde	0.41 ab	10.4 d	3.5 de	4.5 ab
13	Yazd	55 d	97 abc	19 bc	6 bcd	60 abcd	6.6 abcd	1.50 abcd	0.59 abcdef	0.40 ab	10.4d	4.3 abcd	4.5 ab
14	Ghaenat	61 e	102 fg	15 f	6 bcd	61 abcd	5.4 cde	1.49 abcd	0.53 cdef	0.36 b	8.9 e	3.0 e	3.3 cd

Table 3. Contd.

15	Kashan	52 ab	100 ef	19 ab	7 b	56 bcd	8.1 ab	1.68 abc	0.67 abcd	0.40 ab	15.4 a	5.0 a	3.5 bcd
16	Kerman	51 ab	98 abcde	19 bc	6 bcd	46 d	6.7 abcd	1.70 abc	0.69 abc	0.40 ab	14.8 ab	4.0 bcd	4.5 ab
17	Kermanshah	51 ab	98 bcde	21 a	9 a	67 ab	8.7 a	1.65 abc	0.58 abcdef	0.36 b	14.2 b	4.8 ab	4.5 ab
18	Neyshaboor	51 a	97 abcd	20 ab	6 bcd	51 bcd	7.5 abc	1.59 abc	0.61 abcdef	0.39 ab	14.6 ab	4.5 abc	4.8 a
19	Yasooj1	57 cd	96 ab	19 bc	6 cde	61 abcd	6.6 abcd	1.51 abcd	0.61 abcdef	0.40 ab	10.3 d	3.8 cde	4.0 abc
20	Yasooj2	57 d	96 a	19 bc	6 bcd	73 a	7.6 abc	1.61 abc	0.63 abcdef	0.39 ab	10.3 d	4.2 abcd	3.5 bcd

*Means followed by similar letters in each column are not significantly different at 5% level, using Dancan's Multiple Range Test.
†DF = Days to flowering, DM = Days to maturity, PLH = Plant height, Pd. No. = Pod number, Sd. No. = Seed number, Sd. W = Seed weight, Bio.= Biological yield, GY = Grain yield, HI = Harvest index, TKW = Thousand kernel weight, TYP = Plant type, GV = Growth vigor.

Table 4. Mean and comparisons of agronomic traits of Iranian fenugreek landraces planted under irrigated conditions in Maragheh experiment station during 2008 cropping season.

No.	Landrace	DF†	DM	PLH	Pd. No.	Sd. No.	Sd. W	Bio.	GY	HI	TKW	TYP	GV
1	Ardestan	54 abc*	105 a	23 a	6 bc	74 ab	9.8 abcd	2.75 abc	1.11 a	0.41 a	13.6 e	4.5 a	4.8 ab
2	Esfahan	51a	106 abc	22 abcd	7 abc	62 bc	10.2 abc	2.57 abc	0.83 c	0.34 bc	18.1 a	4.3 ab	5.0 a
3	Ahvaz	65 d	112 h	22 abc	6 bc	64 abc	7.2 cde	2.77 abc	0.78 c	0.28 d	11.0 f	2.0 ef	2.0 d
4	Borazjan	53 ab	108 abcdefg	22 abc	8 ab	75 ab	12.6 a	2.70 abc	0.92 bc	0.34 bc	16.9 ab	3.8 abc	4.0 abc
5	Broojerd	51 a	109 bcdefg	23 ab	8 abc	70 ab	11.4 ab	2.77 abc	0.84 c	0.31 cd	16.5 bcd	3.3 cd	4.3 abc
6	Khash	70 e	109 bcdefg	21 bcd	7 abc	78 ab	8.2 bcde	2.69 abc	0.81 c	0.31 cd	9.9 f	1.3 fg	1.2 d
7	Khorasan	51 a	107 abcd	22 abcd	7 bc	59 bc	8.5 bcde	2.88 abc	0.86 c	0.30 cd	15.4 cd	3.8 abc	4.5 ab
8	Khoramabad	65 d	111 efgh	20 cde	7 abc	76 ab	8.1 cde	2.44 bc	0.82 c	0.34 bc	10.1 f	1.3 fg	2.0 d
9	Raey	65 d	111 efgh	23 ab	6 bc	69 ab	7.5 cde	3.04 a	0.92 abc	0.31 cd	10.5 f	1.5 fg	1.8 d
10	Zanjan	64 d	111 efgh	20 de	7 abc	75 ab	7.8 cde	2.72 abc	0.84 c	0.31 cd	10.4 f	1.5 fg	2.0 d
11	Semnan	64 d	109 cdefgh	19 e	6 bc	64 abc	6.1 e	2.40 c	0.76 c	0.33 bcd	10.0 f	1.0 g	1.2 d
12	Shiraz	57 bc	106 abc	22 abc	7 abc	88 a	11.2 ab	2.93 abc	0.98 abc	0.34 bc	13.1 e	4.3 ab	4.0 abc
13	Yazd	57bc	107 abc	23 ab	7 bc	71 ab	8.9 bcde	2.86 abc	0.96 abc	0.35 bc	13.0 e	3.5 bcd	3.8 bc
14	Ghaenat	65 d	110 defgh	18 e	6 bc	66 abc	6.6 de	2.57 abc	0.86 c	0.34 bc	10.9 f	2.8 de	3.3 c
15	Kashan	52 a	108 abcdefg	23 ab	7 abc	63 abc	9.7 abcd	2.61 abc	0.88 c	0.34 bc	16.4 bcd	3.3 cd	4.3 abc
16	Kerman	51 a	108 abcdef	22 abcd	6 c	45 c	7.0 cde	2.61 abc	0.89 c	0.34 bc	16.8 bc	3.5 bcd	4.5 ab
17	Kermanshah	51 a	107 abc	22 abcd	9 a	71 ab	9.7 abcd	2.63 abc	0.78 c	0.30 cd	15.1 d	4.3 ab	4.8 ab
18	Neyshaboor	53 ab	108 abcde	23 ab	8 abc	62 bc	9.6 abcd	2.49 abc	0.78 c	0.32 cd	16.1 bcd	3.8 abc	4.0 abc
19	Yasooj1	57 bc	106 ab	23 ab	6 bc	69 abc	8.7 bcde	2.98 ab	1.09 ab	0.38 ab	12.8 e	3.5 bcd	3.8 bc
20	Yasooj2	58 c	105 a	23 ab	7 abc	77 ab	9.3 bcde	2.45 bc	0.89 bc	0.37 ab	13.0 e	3.3 cd	4.5 ab

* Means followed by similar letters in each column are not significantly different at 5% level, using Dancan's Multiple Range Test.

Table 5. Some statistical estimates on Iranian fenugreek landraces under rainfed and irrigated conditions.

Trait	Range	Mean	Phenotypic variance	Genotypic variance	Phenotypic CV%	Genotypic CV%	Broad sense heritability (%)
DF*	46-66‡	56.4	39.4	24.7	11.1	8.80	91.0
	47-97	57.6	56.7	35.7	13.1	10.4	67.3
DM	94-108	99.3	11.1	6.4	3.4	2.5	62.2
	87-118	108.1	14.1	2.2	3.5	1.4	24.0
PLH	11-25.2	18.3	8.3	2.9	15.7	9.4	50.0
	13.8-28.7	21.8	7.1	1.9	12.3	6.3	34.0
Pd.	2.3-12.5	6.0	5.7	0.6	39.4	12.3	27.4
No.	3-14	6.8	3.6	0.2	28.0	6.8	6.6
Sd.	16-144.5	57.8	74.4	1.8	47.1	7.3	8.3
No.	24.9-144.3	68.9	49.5	3.1	32.3	8.1	6.9
Sd.	1.7-16.5	6.5	12.8	1.2	55.3	16.6	25.0
W	2.6-20.1	8.9	10.8	2.2	37.0	16.5	21.0
Bio.	0.7-2.8	10.6	0.15	0.01	25.1	6.8	9.5
	1.35-4.41	2.69	0.42	0.01	24.0	4.0	3.8
GY	0.25-1.40	0.60	0.26	0.003	26.7	9.5	15.1
	0.38-1.46	0.88	0.05	0.006	24.0	9.1	17.1
HI	0.27-0.53	0.39	0.002	0.000	11.4	1.8	2.5
	0.22-0.46	0.33	0.003	0.001	16.5	8.3	27.5
TKW	6.7-17	11.4	7.48	7.2	24.1	23.7	91.9
	9-22	13.5	8.84	7.4	22.1	20.0	82.1
TYP	1-5	3.3	2.78	2.21	49.9	44.5	77.9
	1-5	3.0	2.01	1.16	47.3	36.0	63.1
GV	1-5	3.6	2.00	1.01	39.3	28.1	54.1
	1-5	3.5	2.44	1.44	44.9	34.6	63.1

* DF = Days to flowering, DM = Days to maturity, PLH = Plant height, Pd. No. = Pod number, Sd. No. = Seed number, Sd. W = Seed weight, Bio. = Biological yield, GY = Grain yield, HI = Harvest index, TKW = Thousand kernel weight, TYP = Plant type, GV = Growth vigor.
‡ In each row, data on above and below are related to rainfed and irrigated conditions, respectively.

et al., 2006; Marzougui et al., 2007) which supports the present findings.

Under RF and IR conditions, high heritability estimates were recorded for TKW followed by DF and TYP (Table 5).

Cluster analysis using WARD's method, based on all studied traits was performed separately for each growing condition (IR and RF). The discriminated function ana-lysis showed that the highest difference is found when landraces are categorized into four groups (Figures 1 and 2). Mean values of fenugreek landraces groups in cluster analysis under RF and IR conditions are summarized in Table 6. The clustering pattern was highly similar under RF and IR conditions and each group had almost similar landraces (Figures 1 and 2). Under RF and IR condition, the first group included the same landraces (1, 12, 13, 19 and 20) which are characterized by moderate DF and earliness (DM) under both conditions and have high PLH, Sd. No., Bio. GY, HI and TYP compared with the other landraces under IR conditions which show their suitability for IR conditions. The second groups under RF and IR conditions had some differences in landraces compo-sition. The landrace 17 under RF conditions formed a separate group alone and under IR conditions land-races 7 and 16 were included in a separate group, but under both IR and RF conditions landraces 2, 4, 5, 15 and 18 were in the grouped in the same cluster (2nd group). Under RF conditions, the landrace 17 was included in group 3 alone and is the earliest landrace among the others with the highest PLH, Pd. No., Sd. No., Sd. W, TYP and GV compared to other groups which showing its adaptation to RF condition. Meanwhile based on high Bio., GY, TKW and HI, the second group of landraces (2, 4, 5, 7, 15, 16 and 18) are also adapted to RF conditions. Finally, the fourth group included the same landraces (3, 6, 8, 9, 10, 11 and 14) under RF and IR conditions. Dia-grams of groups based on percent of standard deviation from total means showed that under RF condition, land-races of the fourth group were characterized by lateness and the lowest PLH, Pd. No., Sd. W, Bio., GY, TKW, TYP and GV , which were not desirable for such condi-tion(Figures 3 and 4).

Table 6. Mean values of different agronomic traits of fenugreek landraces groups determined using cluster analysis under rainfed and irrigated conditions.

	Group	Landrace		DF*	DM	PLH	Pd. No.	Sd. No.	Sd .W	Bio.	GY	HI	TKW	TYP	GV
Rainfed condition	1	1-12-13-19-20	Mean	56	97	19.2	6	640	6.77	1.59	0.64	0.41	10	4	4
			SD%†	-1.06	-2.68	5.06	-4.78	10.58	4.65	2.56	6.17	3.32	-8.31	21.35	14.29
	2	2-4-5-7-15-16-18-	Mean	51	98	19.3	6	518	7.09	1.67	0.66	0.40	14	5	4
			SD%	-9.05	-1.18	5.76	3.21	-10.50	9.64	7.84	10.04	1.22	23.86	34.83	21.95
	3	17	Mean	51	98	21.2	9	666	8.74	1.65	0.58	0.36	14	5	5
			SD%	-9.88	-1.15	16.06	42.78	15.13	35.08	6.87	-3.51	-7.79	23.09	42.32	25.44
	4	3-6-8-9-10-11-14	Mean	63	102	16.1	6	586	5.17	1.39	0.52	0.38	9	1	2
			SD%	11.16	3.23	-11.77	-7.10	1.38	-20.01	-10.32	-13.21	-2.49	-24.05	-56.13	-34.30
	Total mean			56	99	18.3	6	578	6.47	1.55	0.60	0.39	11	3	4
Irrigated condition	1	1-12-13-19-20	Mean	57	106	22.8	7	756	9.58	2.79	1.01	0.37	13	4	4
			SD%	-1.99	-2.10	5.04	-2.91	9.74	7.75	3.74	14.40	11.13	-2.67	26.67	19.42
	2	2-4-5-15-17-18	Mean	52	108	22.4	8	672	10.52	2.63	0.84	0.32	17	4	4
			SD%	-9.98	-0.43	3.14	12.50	-2.46	18.25	-2.38	-4.94	-2.63	23.12	25.00	25.90
	3	7-16	Mean	51	107	21.8	6	519	7.75	2.75	0.87	0.32	16	4	5
			SD%	-11.1	-0.66	-0.01	-10.75	-24.72	-12.90	2.02	-1.05	-3.69	18.83	20.83	29.50
	4	3-6-8-9-10-11-14	Mean	65	110	20.4	6	704	7.34	2.66	0.83	0.32	10	2	2
			SD%	13.15	2.06	-6.29	-5.57	2.22	-17.49	-1.21	-5.75	-4.64	-23.29	-46.43	-44.50
	Total mean			58	108	21.8	7	689	8.89	2.69	0.88	0.33	13	3	3

*DF = Days to flowering, DM = Days to maturity, PLH = Plant height, Pd No. = Pod number, Sd. No. = Seed number, Sd. W = Seed weight, Bio. = Biological yield, GY = Grain yield, HI = Harvest index, TKW = Thousand kernel weight, TYP = Plant type, GV = Growth vigor.
† SD%= Percent of standard deviation from total mean.

DISCUSSION

Little information is available regarding the evaluation of germplasm collection of fenugreek as well as the inheritance of seed yield itself and seed yield components. This work assessed a collection of Iranian *Trigonella foenum-graecum* accessions for its morphological and physiological diversity in order to develop plant selection criteria for fenugreek breeding programs, or providing breeding material with traits suited to the contained accessions that vary widely in plant type (TYP), growth vigor (GV), thousand kernel weight (TKW) and potential of seed production per plant (Sd. W) under both irrigated and rainfed conditions. Similarly, significant phenotypic and genotypic variations were shown for agronomic traits of fenugreek genotypes (Acharya et al., 2006; Marzougui et al., 2007). Large genetic variation in fenugreek accessions has previously been reported for the growth habit, flowering time and grain yield (McCormick et al., 1998).

This study showed a wide variation for grain yield potential among the genotypes. Variation in grain yield was predominately related to variation in plant height, days to maturity, seed weight and biological yield under both RF and IR conditions. The genotypes with higher plant height, days to maturity seed weight and biological yield had the great yield (e.g. Ardestan) and vice versa (e.g. Semnan). Hence, these traits seem to be reasonnable selection criteria for grain yield improvement programs.

Under rainfed condition, harvest index did not differ between Ardestan (with the highest grain yield) and Semnan (with the lowest grain yield), which is not expected since the literature shows that grain yield is positively correlated with HI (Gains et al., 1999; Huyghe, 1998). In contrast,

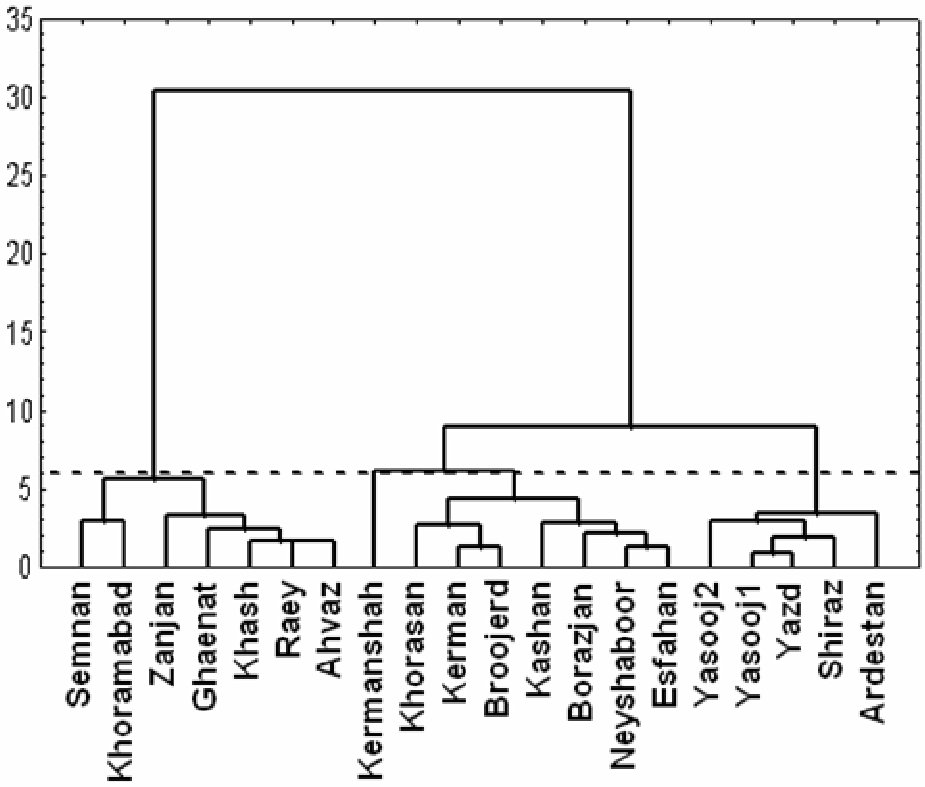

Figure 1. Clustering of Iranian fenugreek landraces using WARD's method based on agronomic traits measured under rainfed conditions.

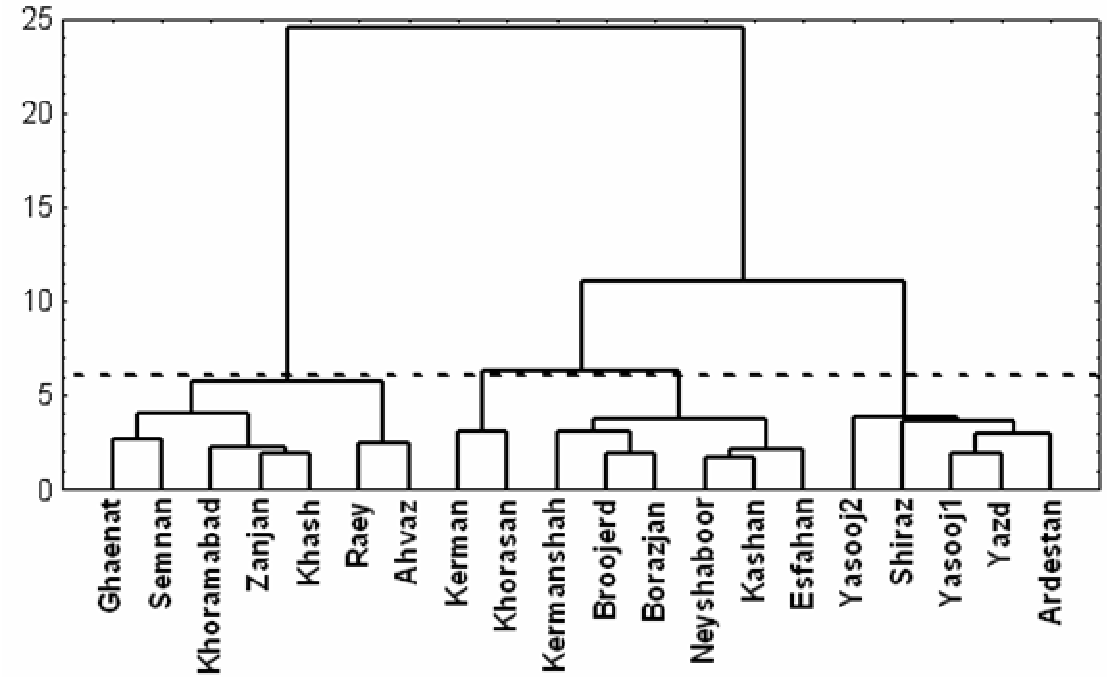

Figure 2. Clustering of Iranian fenugreek landraces using WARD's method based on agronomic traits measured under irrigated conditions.

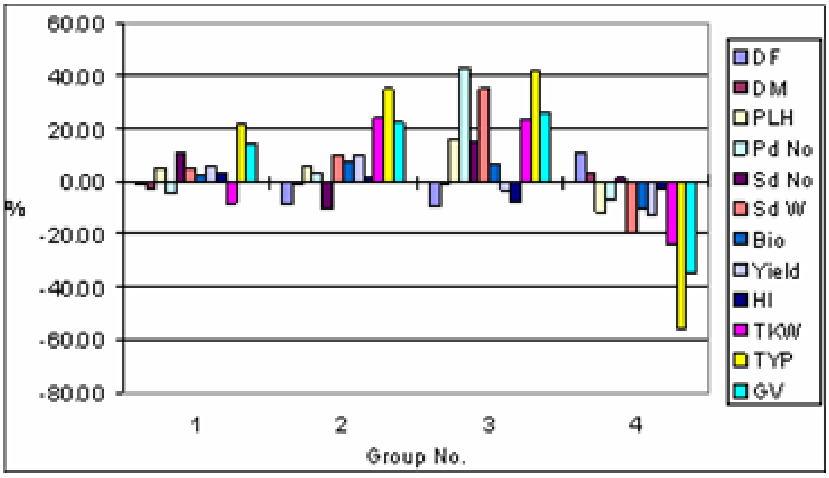

Figure 3. Diagram of Iranian fenugreek landraces groups based on percent of standard deviation from total means under rainfed conditions.

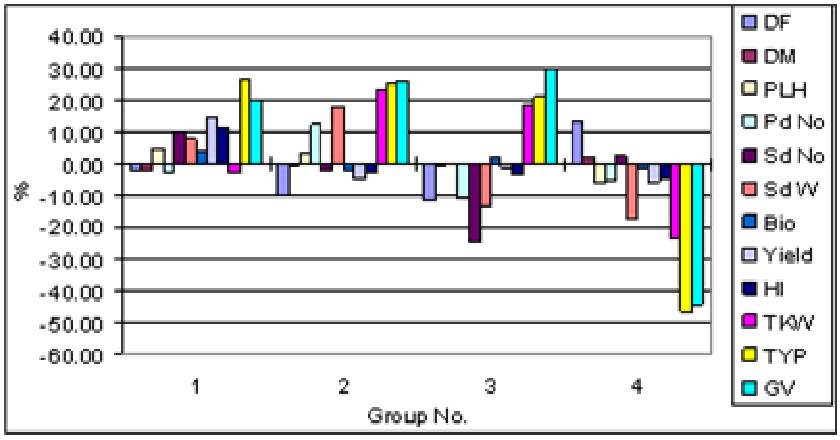

Figure 4. Diagram of Iranian fenugreek landraces groups based on percent of standard deviation from total means under irrigated conditions.

under IR condition, Ardestan had higher HI compared with Semnan. Variation in grain yield among the genotypes can be related to variation in HI, as expected since HI is calculated from grain yield. Genetic improvement of fenugreek grain yield through a higher HI could be similar to the objectives in alfalfa or grain legume breeding (Huyghe et al., 2002; Huyghe, 1998).

High heritability estimated values for TKW, DF and TYP in this study indicate that selection will be efficient for the breeding fenugreek genotypes for these traits under rainfed and irrigated conditions.

Under RF conditions, the lowest broad sense heritabilities were observed for HI, Sd. No., and dry biomass (Bio.), and under IR conditions the lowest heritabilities were shown for Bio. followed by Sd. No. indicating that difficulties can be encounters for improving these traits through selection.

Further more, under RF condition, heritabilities of GY, HI and GV were lower compared with those under IR condition showing that growing condition could affect broad sense heritability estimates. Similar results of changing herita-bilities of agronomic traits with environment conditions in fenugreek and other crops were reported by others (Ali et al., 2008; Marzougui et al., 2007; Statti et al., 2004).

In this study the phenotypic coefficient of variability values are higher than genotypic coefficient of variability values almost for all the traitsunder both IR and RF conditions (Table 5) which reflect the influence of environment on the expression of traits.

It can be concluded that this collection of Iranian Fenugreek landraces contains accessions that vary widely in studied agronomic traits and grain yield. This is a good starting point for selecting lines, or providing breeding

material with traits suited to Maragheh and similar cropping environment. Furthermore, the traits such as growth vigor, flowering time, days to maturity, PLH and TKW might be implemented as selection criteria to improve grain yield in fenugreek breeding programs under dryland condition.

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