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Interrelationships between agronomic traits with seed yield in safflower (*Carthamus tinctorius* L.) under different irrigation regimes

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ABSTRACT: Drought is one of the main limiting factors in crop production in many part of world. To determine the association between seed yield and morphological traits in safflower accessions from different sources, two separate field experiment (Irrigated and rainfall conditions) were conducted with 64 different landrace, breeding lines and cultivated safflower genotypes using an 8 × 8 lattice square design with 2 replications in the 2013 growing season. Analysis of variance revealed significant differences among genotypes for all traits in both irrigated and rainfall environments. Grain yield (g/plant) showed high significant positive correlation with number of heads per plant (NHP), number of seeds per head (NSH) and 1000-seed weight (TSW) in both irrigated and rainfall environments. Cluster analysis based on seed yield and morphological traits assorted the genotypes in four groups in both environments. Comparatively, high genetic variation was found in grain yield and other characteristics. Our results showed that there is large genetic variation in studied genotypes for grain yield in both environments and landrace accessions showed more stable and lower yield reduction in rainfall environment. These results can be used for future breeding program in safflower.

Key words: safflower, drought stress, morphology, yield

INTRODUCTION

Drought is one of the main environmental stresses that adversely affect the plant growth, metabolism and grain yield. In Iran water is a scarce resource due to the high variability of rainfall. The effects of water stress depend on the timing, duration and magnitude of the deficits (Pandey *et al.,* 2001). Safflower (*Carthamus tinctorius* L.) is one of the most important annual oil seed crop which is grown throughout the semiarid regions. It is a deep- rooted annual plant which has the ability to meet its water requirements by exploring a larger volume of soil than the other oil-yielding crops (Dordas and Sioulas 2008). In the past few years, the area under safflower cultivation in Iran has increased to 15,000 ha, mostly under rain-fed conditions (Pourdad and Mohammadi 2008). An analysis of the variability among the traits and the association of a particular plant character to other traits contributing to the yield of a crop would be of great value in planning a successful breeding program (Mary and Gopalan 2006). Appearance of several traits often changes as the changing breeding material and environment. Consequently, the information of characters association between the traits themselves and with seed yield is important for the breeding program subject to selection for high yielding genotypes(Omidi Tabrizi 2002). Grain yield in safflower can be analyzed in term of four primary yield components (Number of heads per plant, number of seeds per head, number of seeds per plant, 1000-seed weight) (Mohammadi and Pourdad 2009; Ahmadzadeh *et al.* 2012; Tariq *et al.* 2014). In the Mediterranean region like Iran, these grain yield components could be limited by low and unpredictable seasonal rainfall as well as higher temperatures towards the end of the crop cycle. In this region, most rain falls during autumn and winter, and water deficit occurs in the spring, resulting in moderate stress for rain-fed wheat around anthesis, which increases in severity throughout grain filling (Salamati *et al.* 2011; Ahmadzadeh *et al.* 2012). The development of high-yielding varieties with stable yield in different environment requires a thorough knowledge of the existing genetic variation for yield and its components (Mohammadi and Pourdad 2009).Therefore characterization of important traits in crops with sound and positive association with drought tolerance necessary (Richards, 1996; Rauf and Sadaqat, 2008). Similarly, the landrace acessions are well adapted in stress environments and farmers prefer landraces due to their ability to produce some yield even in difficult conditions where modern cultivars are less reliable (Brush, 1999). Previous litteraures proved the effect on water deficit on yield and its components of safflower (Marita and Muldoon, 1995; Omidi, 2009; Zareie *et al.* 2013). The objective of this study were: (i) investigate the genetic diversity in iranian landrace and exocit safflower germplasm in different irrigation regimes and (ii) to assess correlated response of different morphological characters with grain yield under optimum irrigation and rain-fall environment.

MATERIALS AND METHODS

Sixty four Iranian landrace, improved and introduced safflower lines were planted for study of yield and yields components in well-watered and rain-fall conditions using a simple lattice design (8 × 8) in Sanandaj, Iran (Table 1). Sowing was done in March 2013 in both experiments. Each plots consisted of three rows, 2 m long rows with 50 cm between each row. The experimental plots were hand weeded as needed during the growing season. The measured traits were containing: plant height (PH), number of head per plant (NHP), number of grains per head (NSH), 1000- grain weight (TSW), Harvest index (HI), Plant biomass (B) and grain yield (ten randomly selected plants in each plot). Grain yield was determined in middle row of plot after elimination of the marginal effects. Analysis of variance for the measured traits in both experiments based on simple lattice design was done using SAS (SAS Institute Inc. 2004). The correlation coefficient between seed yield and other quantitative traits was performed using SPSS17.0 package which has been used. Cluster analysis based on complete linkage algorithm using Jaccard's coefficient, were performed using the NTSYS-pc version 2.01 software.

Table 1: List of safflower accessions used in this study.

No.	genotype	Source	No.	genotype	Source
1	Koseh	Landrace-Iran	33	zarghan	Iran
2	Ilam	Landrace-Iran	34	Marand	Landrace-Iran
3	PI-750190	Pakistan	35	PI-253384	China
4	Sharekord-1	Landrace-Iran	36	G508	Landrace-Iran
5	n/27	Iran	37	PI-537636	USA
6	IL	Iran	38	C4110	Iran
7	-168S6-58141	USA	39	C111	Iran
8	Lorestan	Landrace-Iran	40	LRV-51-51	Iran
9	G46	Landrace-Iran	41	Syrian	Syria
10	PI-98844	France	42	Sharekord-2	Landrace-Iran
11	G376	Landrace-Iran	43	Daran	Landrace-Iran
12	Kordestan	Landrace-Iran	44	versankhast	Landrace-Iran
13	Kordestan-1	Landrace-Iran	45	Sharekord-3	Landrace-Iran
14	Yasooj-1	Landrace-Iran	46	Kordestan-6	Landrace-Iran
15	Yinice	Turkey	47	G36	Landrace-Iran
16	301055	Turkey	48	Kino-76	mexico
17	PI-537636-S	USA	49	Isfahan	Landrace-Iran
18	G5	Landrace-Iran	50	Arak	Landrace-Iran
19	PI(53)-250534	Egypt	51	Kordestan-2	Landrace-Iran
20	C411	Iran	52	CyprusBregon	Cyprus
21	G3	Landrace-Iran	53	2-Isfahan	Landrace-Iran
22	PI-506426	China	54	Hartman	USA
23	67	Landrace-Iran	55	Kordestan-7	Landrace-Iran
24	G67	Landrace-Iran	56	Kordestan-3	Landrace-Iran
25	-324S6-697	USA	57	Kordestan-5	Landrace-Iran
26	GILA	USA	58	Isfahan-4	Landrace-Iran
27	C116	Iran	59	W-4440	USA
28	Dincer	Turkey	60	S541-	USA
29	-307S6-697	USA	61	C111	Iran
30	Arak	Landrace-Iran	62	Kordestan-4	Landrace-Iran
31	G47	Landrace-Iran	63	Sina	Iran
32	G44	Landrace-Iran	64	Faraman	Iran

RESULTS AND DISCUSSION

A. Variance analysis

Analysis of variance on the studied traits presented in the Table 2, revealed significant differences among genotypes for most of the measured characters in both irrigated and rainfall environments. The variability between genotypes was high for all traits ($P<0.01$), except for number of seeds per head (NSH), indicated that differences existed between the genotypes for yield and other yield related traits. The experimental coefficient of variation (CV) varied from 5.7 to 32.11 and 8.11 to 28.16 in irrigated and rainfall environments, respectively (Table 2). In general, CV value lower than 30% is considered to be good, indicating the accuracy of conducted experiments. These results revealed the presence of sufficient variability in the experimental materials.

B. Phenotypic correlations

The phenotypic correlation among the various characteristics in both well-watered and rain fed conditions are presented in Tables 3. Grain yield (g/plant) showed high significant positive correlation with number of heads per plant (NHP), number of seeds per head (NSH) and 1000-seed weight (TSW) in both irrigated and rainfall environments.

Table 2: Mean squares for 7 agronomic traits in 64 safflower accessions evaluated in irrigated and rainfall environments.

Environment	S.O.V	df	PH (cm)	NHP	NSH	TSW (g)	HI	B (g/plant)	Y (g/plant)
Irrigated	Replicate (R)	1	1987.78**	118.19	6.68	1632.37**	110.12	2559.18**	29.12
	Genotype (G)	63	464.61**	238.8**	70.98	1821.12**	129.12**	1579.54**	381.16**
	Col × Rep	14	66.82*	62.23	14.97	1590.71*	77.16	1271.35*	51.10
	Row × Rep	14	71.19*	197.12*	29.81	1811.12*	66.11	1616.12**	47.16
	Error	28	3.23	29.18	46.23	91.12	18.77	110.8	68.84
	CV (%)		5.07	9.37	6.91	32.11	25.23	27.12	10.29
Rainfall	Replicate (R)	1	81.29	11.92	5.29	1061.12**	212.16*	1716.12*	21.12
	Genotype (G)	63	589.12*	86.25**	18.89	2101.12**	219.81*	2712.12**	39.88**
	Col × Rep	14	407.12*	10.75	19.21	1812.11**	179.14*	1716.10*	14.77
	Row × Rep	14	605.1*	14.22	18.16	821.11*	86.12	811.2	29.16*
	Error	28	19.28	27.12	11.21	21.17	49.17	98.99	6.73
	CV (%)		8.11	16.13	19.75	18.16	21.16	19.77	28.16

PH = plant height; NHP = number of heads per plant; NSH = number of seeds perhead; TSW = 1000-seed weight; HI = harvest index, B=plant biomass; Y = grain yield
*,** significant at P = 0.05 and 0.01, respectively.

Table 3: Phenotypic correlation between seed yield and other morphologic traits in 64 safflower accessions in irrigated environments (Upper diameter) and rainfall environment (bottom diameter).

	PH	NHP	NSH	TSW	HI	B	Y
PH	-	0.41*	0.14	-0.14	0.71*8	0.41*	0.39*
NHP	0.12	-	-0.11	0.16	0.51*	0.39*	0.81**
NSP	-0.41*	-0.31	-	0.18	0.41*	0.31	0.58**
TSW	-0.37*	-0.41*	-0.18	-	0.48*	0.29	0.79**
HI	0.49*	0.27	0.12	0.19	-	0.61**	0.48*
B	0.31	0.28	0.21	-0.11	0.72**	-	0.41*
Y	-0.11	0.62**	0.36*	0.66**	0.18	0.29	-

PH = plant height; NHP = number of heads per plant; NSH = number of seeds per head; TSW = 1000-seed weight; HI = harvest index, B = plant biomass; Y = grain yield
*,** significant at P = 0.05 and 0.01, respectively.

This is similar with previous studies by Mohammadi and Pourdad (2009), Salamati *et al.* (2011) and Zareie *et al.* (2013). In irrigated environment, seed yield showed positive significant correlation with all measured characters. This means that when the plant able to receive sufficient water for growth, increasing in height and biomass leads to increase the seed yield in plant. This is in agreement with Talebi *et al.* (2010) that reported in durum wheat. In rainfall environment, plant height showed negative correlation with seed yield and correlation between seed yield with plant. These results indicated that selection for high yield genotypes in irrigated environment might be possible based on all plant characters, especially for number of heads, number of seeds and plant biomass. But in rainfall environment the best indices for selection of genotypes might be possible for genotypes that can produce more reproductive flowers with high number of seeds per head and 1000-seed weight. This is in agreement with Dordas and Sioulas (2008), Mohammadi and Pourdad (2009) and Istanbulluoglu *et al* (2009).

C. Cluster analysis

The objective of cluster analysis was to define thedegree of relatedness in yielding ability under drought stress and optimum conditions in safflower genotypes. In irrigated environment, genotypes grouped in four distinct cluster (Fig 1). Cluster I consisted of 24 genotypes that mainly were Iranian landraces originated from west and north-west of Iran and genotypes originated from Turkey and USA. This genotypes showed moderately low yield in compare to genotypes in other cluster and mostly were sensitive to drought. Second cluster consisted 17 genotypes that mainly were improved cultivars from Iran, USA. These genotypes showed high yield potential in irrigated environment. Third cluster consisted 12 genotypes that all of them were improved cultivars from different sources which showed relatively high yield potential. Fourth cluster consisted of 11 genotypes that mainly were improved cultivars and these genotypes showed high yield potential in compare to other genotypes and identified as high yield genotypes among all genotyped for irrigated environment (Fig. 1). Cluster analysis based on morphological data obtained in rainfall environment, grouped genotypes in four clusters (Fig. 2). Cluster I, included 15 genotypes that mainly were landraces originated from west and north west of Iran. This genotypes showed relatively low yield potential and most of them were similar to those grouped in Cluster I in irrigated environment. Cluster II consisted of 23 genotypes.

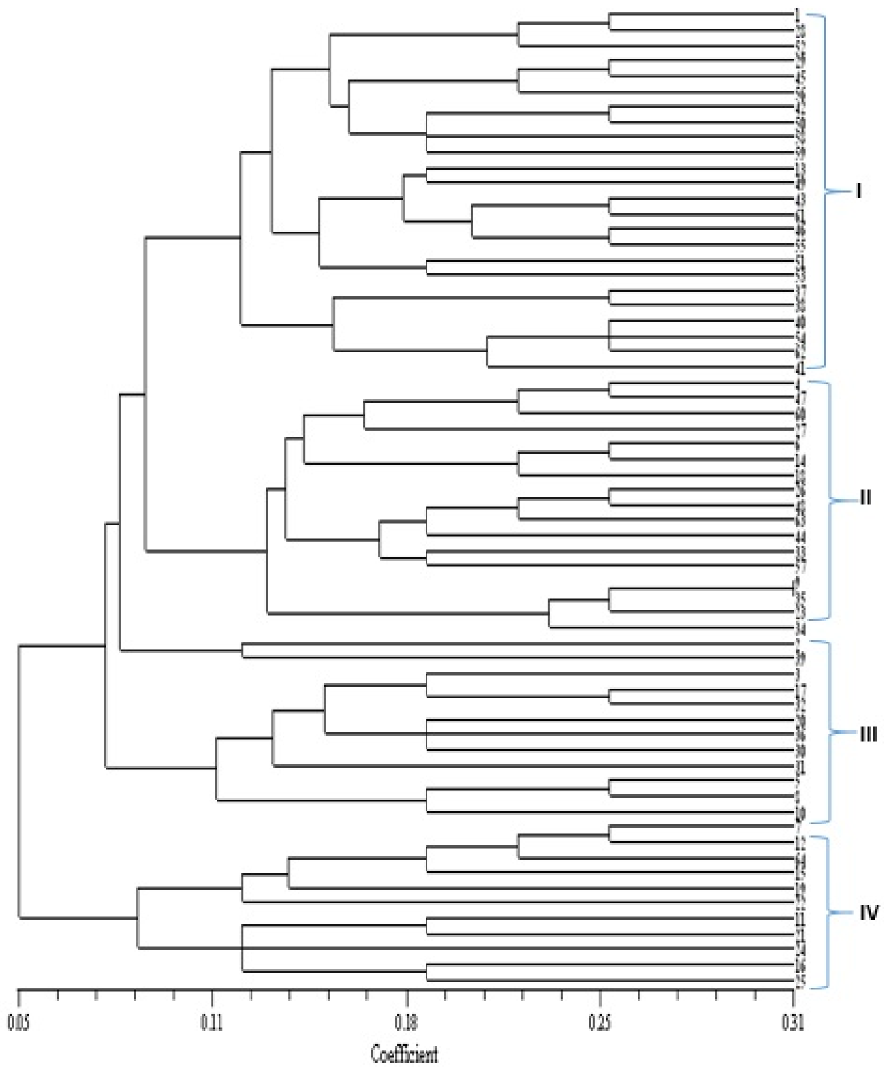

Fig. 1. Dendogram of cluster analysis of safflower accessions classified according to yield ability in irrigated condition.

These genotypes showed high yield in irrigated environment, but showed relatively low yield in rainfall environment. Cluster III consisted 21 genotypes that mostly were improved genotypes from different sources. These genotypes showed higher yield in rainfall environment in compare to genotypes grouped in cluster I and II, but compare to their yield potential in irrigated environment these genotypes showed high yield reduction. Cluster IV included 5 genotypes that all of them were Iranian landrace genotypes. These genotypes showed relatively high yield in rainfall environment and also had low yield reduction under water stress. These genotypes identified as highly resistance genotypes to drought stress.

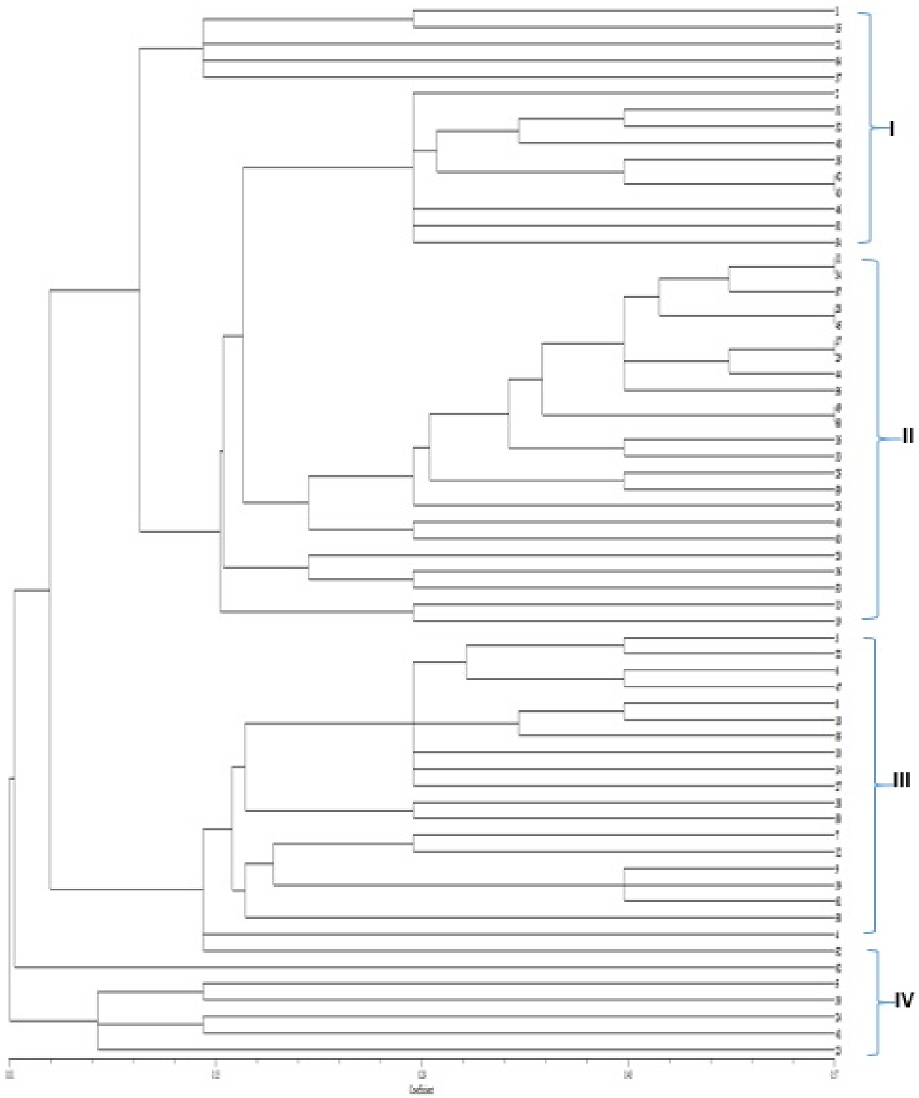

Fig. 2. Dendogram of cluster analysis of safflower accessions classified according to yield ability in Rainfall condition.

CONCLUSION

To improve drought tolerance in crop plants, the genetic variation of the crop for traits related to drought tolerance must be investigated (Ali *et al.*, 2009; Dhanda *et al.*, 2004). The description of agronomically important and useful characteristics is an important prerequisite for effective and efficient utilization of germplasm collections in breeding programs. In this study, the effect of drought treatments and their interaction with genotypes were significant for all studied traits indicating a very high variability within the genotypes and it can therefore be concluded that landraces and improved genotypes from different sources responded differently to the different irrigation regimes. Some traits such as harvest index and plant biomass showed difference correlation with grain yield in both the environments. Cluster analysis assorted the genotypes in four groups in both environments. Although results of this investigation provided information about the potential in genetic variability among Iranian landrace safflower accessions but evaluation of more germplasm is needed for effective improvement of breeding program.

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