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AGRO-MORPHOLOGICAL CHARACTERIZATION OF WILD SAFFLOWER (*CARTHAMUS* L.-ASTERACEAE) SPECIES IN TURKEY

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Abstract

The genus *Carthamus* L. belongs to Asteraceae family, has approximately 25 taxa with worldwide. The naturally distributed species belonging to this genus in Anatolia are as follows: *Carthamus dentatus* (Forssk.) Vahl., *C. glaucus* M. Bieb., *C. lanatus* L., *C. tenuis* (Boiss. & Blanche) Bornm. And *C. persicus* Desf. ex Wild. And *C. tinctorius* L. (safflower). *Carthamus tinctorius* is the cultivated species. In the present study, the seeds of *C. dentatus* were collected from 31 localities of Turkey, *C. lanatus* from 32 localities, *C. persicus* from 3 localities, *C. glaucus* from 8 localities, *C. tenuis* from 3 localities. Seeds were germinated in the cabins and transferred to viols for obtaining seedlings and then the seedlings were transferred to the field. Data on various morphological traits such as rosette period, days to flowering and maturity, plant height (cm), branches per plant and 1000 seed weight (g) were recorded. There were substantial variations for the investigated morphological characteristics. The analysis of variance revealed that the differences among 77 accessions were significant for all the studied characters. Some localities revealed very good agronomic performance for some traits. Positive and negative correlations existed among different morphological and agronomic traits. These findings indicate a number of useful traits in the gene pools and a wide range of phenotypic variation that provides a good source of diversity for their use in modern safflower breeding programs.

Key words: Agro-morphology, *Carthamus*, Crop wild relatives, Safflower.

Introduction

Carthamus L., belonging to the Asteraceae family, has 25 species worldwide, which are classified into four sections based on cytological and morphological properties (Ashri, 1957; Ashri& Knowles, 1960). Section I (2n = 24 chromosomes) includes *C. tinctorius* L., *C. oxyacantha* M. Bieb., *C. flavescens* Willd., *C. arborescens* L., and *C. caeruleus* L., Section II (2n = 20 chromosomes) includes *C. tenuis* (Boiss. & Blanche) Bornm., *C. dentatus* Vahl., and *C. glaucus* M. Bieb., Section III (2n = 44 chromosomes) includes *C. lanatus* L. and Section IV (2n = 64 chromosomes) includes *C. baeticus* (Boiss. & Reut.) Nyman and *C. turkestanicus* Popov. *Carthamus* species belonging to natural flora of Turkey are *C. lanatus*, *C. dentatus*, *C. persicus* (syn. *C. palaestinus*), *C. glaucus*, and *C. tenuis* (Tarıkahya, 2012).

The cultivated safflower is closely related to two wild species: *C. flavescens* from Turkey, Syria, and Lebanon, and *C. palaestinus* from Iraq (Ashri & Knowles 1960; Hanelt, 1961). *C. persicus* (2n = 24 chromosomes) is closest wild relative of cultivated safflower (Tarıkahya Hacıoğlu *et al*., 2014), though its ancestors may be *C. palaestinus* and *C. oxyacanthus* (Sehgal *et al*., 2008). Instances of natural crossings between *C. tinctorius* and its wild relative *C. persicus* have been observed near Ankara, İçel, and Şanlıurfa provinces in Turkey.

Meanwhile breeders use the wild relatives as gene sources to improve resistance in a cultivated species (Baloch *et al*., 2015; 2017). For example, Heaton, (1981) used *C. lanatus* for improving disease resistance in *C. tinctorius* and reported that the resulting hybrid, *C. tinctorius* × *C. lanatus* was highly resistant to *Alternaria* and *Pseudomonas* leaf diseases and *Fusarium* wilt, while *C. tinctorius* was susceptible to all the three pathogens. Prasad & Anjani, (2005) obtained safflower lines durable to leaf stain disease (*Alternaria carthami*) via wide hybridization with wild species such as *C. palaestinus, C. lanatus, C. criticus,* and *C. turkestanicus,* which are also durable to this disease. Safflower fly causes significant damage to cultivated safflower, but the wild species such as *C. oxyacanthus, C. flavescens,* and *C. lanatus* carry tolerance/resistance genes (Kumar, 1993; Sabzalian *et al*., 2010).

Several studies on safflower have shown that winter planting increases yield and quality (Yazdi-Samadi & Zali, 1979; Esendal, 1990; McPherson *et al*., 2004; Coşge*et al*., 2007; Esendal *et al*., 2008). While safflower is drought tolerant, it has low tolerance to some diseases and cold temperatures. Resistance to cold temperature may be increased when safflower is intercrossed with some of its wild relatives (Heaton & Klisiewicz, 1981; Singh & Nimbkar, 1993; Sujatha, 2008; Arslan *et al*., 2010; Sabzalian *et al*., 2010; Majidi *et al*., 2011). Plants with longer rosette periods tend to be more resistant to cold (Esendal, 1988), as demonstrated by *C. flavescens*, a wild species of safflower (2n = 24 chromosomes), with a long rosette period and consequential survival rates of up to 80% even at temperatures as low as -13 to -15°C. *Carthamus flavescens* can give fertile pollens when crossed with safflower, therefore could be used as gene source for cold tolerance in cultivated safflower.

This study was aimed to determine agro-morphological characteristics of wild safflower species collected from different localities and altitudes and their potential use as a gene sources for safflower breeding programs.

Materials and Methods

Plant material and crop sowing: Plant material consisted of 77 accessions belonging to 5 different wild safflower species collected from 77 different Turkish localities: including 31 localities for *C. dentatus*, 32 localities for *C. lanatus*, 8 localities for *C. glaucus*, and 3 localities for *C. persicus* and 3 localities for *C. tenuis* were used (Table 1). Seed and flower morphology of Turkish wild *Carthamus* species were illustrated in Figure 1. Five different commercial cultivars (Dinçer, Remzibey, Balcı, Linas, and Oleas) were also used as control in the field experiment. Some wild safflower species have previously been collected in Turkey, however this is the first report to collect all five wild safflower species from nearly all recorded localities and from some new areas in Turkey. The localities and altitudes of wild *Carthamus* species in Anatoliawere givenin Table 1.

Fig. 1. Seed and flower morphology of Turkish wild *Carthamus* species a: *C. dentatus,* b: *C. glaucus* subsp. *glaucus,* c: *C. lanatus,* d: *C. persicus,* e: *C. tenuis.*

Table 1. Localities and altitudes of wild *Carthamus* species in Anatolia.

Localities	Altitude (m)	Localities	Altitude (m)
***C. dentatus* (2n=20)**		***C. lanatus* (2n= 22)**	
1. Afyon	998	1. Antalya, Manavgat	45
2. Antalya, Serik	14	2. Antalya, Manavgat	50
3. Antalya, Kemer	502	3. Antalya, Demre	451
4. Muğla	122	4. İzmir, Kuşadası	9
5. Muğla, Yatağan	320	5. İstanbul, Silivri	36
6. İzmir, Kuşadası	253	6. Karabük, Eskipazar	644
7. İzmir	46	7. Kastamonu	386
8. Manisa	46	8. Sinop	6
9. Manisa, Salihli	86	9. Amasya, Suluova	485
10. Edirne	94	10. Bursa	422
11. Bursa	24	11. Ankara, Akyurt	1060
12. Çanakkale	48	12. Ankara, Kalecik	934
13. Çanakkale	17	13. Ankara, Temelli	790
14. Afyon	1146	14. Kırıkkale	794
15. Antalya, Demre	10	15. Kırıkkale	892
16. Uşak	863	16. Kırıkkale	892
17. Kütahya	1145	17. Yozgat, Sorgun	1090
18. Kırşehir	1103	18. Kayseri, İncesu	1109
19. Kırıkkale	689	19. Tekirdağ, Malkara	125
20. Koyulhisar	674	20. Ankara	1599
21. Nevşehir,	1091	21. Ankara, Sincan	856
22. Kırıkkale	879	22. Ankara, Gölbaşı	1065
23. Karaman	1139	23. Niğde	1155
24. Afyon, Sandıklı	1013	24. Eskişehir	906
25. Ankara, Çubuk	1170	25. Nevşehir, Topaklı	1220
26. Muğla, Fethiye	133	26. Ankara, Kalecik	1001
27. İstanbul, Silivri	36	27. Ankara, Kalecik	715
28. Antalya	107	28. Ankara, Anayurt	795
29. Ankara	948	29. Ankara, Sincan	822
30. Ankara	948	30. Ankara, Sincan	856
31. Kırşehir	1114	31. Ankara, Kalecik	1060
***C. glaucus* (2n=20)**		***C. persicus* (2n=24)**	
1. Antalya, Kemer	328	1. Ankara, Gölbaşı	1074
2. Karabük	644	2. İçel, Erdemli	4
3. Sinop	6	3. Şanlıurfa,	454
4. İçel, Anamur	12	*C. tenuis* (2n=20)	
5. Adana	96	1. Antalya, Kalkan	103
6. Ankara, Polatlı	811	2. Antalya, Kalkan	144
7. Sinop	6	3. İçel, Erdemli	22
8. Antalya	103		

Field experiments were conducted during the 2012–13 cropping season at the research and implementation area of Field Crops Agricultural Research Institute, Ankara, Turkey (39°57'20.39"N, 32°48'53.00"E). All wild *Carthamus* species and the five cultivars were sown in March 2012 on a well-prepared seedbed using an augmented field design. All accessions were grown in plots of eleven rows, each 6 m in length. The distance between plants within the row was 30 cm and 60 cm between rows. All plots were treated identically with manual agricultural practices.

Twenty plants per plot were randomly selected and labeled, and 6 morphological and agronomical traits were recorded: rosette period (days), days to flowering and maturity (days), plant height (cm), branches per plant (number), and thousand seed weight (g). Data were recorded based on procedures of the International Plant Genetic Resources Institute (IPGRI) and International Center for Agricultural Research in the Dry Areas (ICARDA; 1985). Rosette period was calculated when 90% of the plant germinated. Days to flowering was recorded once 50% of plants had flowered. Days to maturity was calculated from the date of emergence to date of harvesting. Plant height was measured as an average of ten plants from the ground level to the highest growing point using a meter rod. Number of branches per plant were counted from twenty plants and then mean values were calculated. Thousand-seed weight was obtained from four random samples of 100 seeds from each plot.

Climate and soil properties of the test field: 294.6 mm of total precipitation occurred during the 2012-13 crop season, while the lowest and highest temperature levels were recorded as -12.1ºC in January and 33.2ºC in August. The test field on which the research was conducted consisted of well-drained, deep or medium deep, slightly rocky or rock less, loamy-clayey soils. Soil pH was 8.06, salt ratio was 0.041%, organic matter was 1.57%, and lime ratio was 2.65%. The altitude of the trial area was 847 m.

Statistical analyses: Standard one-way analyses of variance was performed for each trait using the JUMP statistical software package (SAS Institute, 2002), with standard deviations calculated for each population. Significant differences ($p<0.05$) were detected between localities for all studied agro-morphological and quality traits. The differences between the blocks were removed using the correction term. All analyses were carried out on the corrected values. Correlation among traits was calculated using the Pearson correlation procedure implemented in JUMP. Standardized trait mean values were used to perform principal component analysis (PCA) using NTSYS-pc (Rohlf, 2004).

Results

Among the *Carthamus* species, the longest average rosette period was in *C. glaucus* (70.9 days) and the shortest was *C. persicus* (49.0 days). Average days to flowering was highest in *C. glaucus* (111.4 days) and lowest in *C. lanatus* (95.9 days). Average days to maturity was highest in *C. glaucus* (148.1 days) and lowest in *C. tenuis* (97.7 days). Average plant height was highest in *C. lanatus* (71.7 cm) and lowest in *C. dentatus* (64.1 cm). Average number of branches per plant was highest in *C. persicus* (12.2 per plant) and lowest in *C. lanatus* (8.4 per plant). Average thousand seed weight was highest in *C. dentatus* and *C. persicus* (29.8 g), while lowest in *C. glaucus* (18.8 g) (Table 2).

Very high variation levels were observed among accessions of *C. lanatus* and *C. dentatus* for branches per plant and high variation in thousand seed weight. Medium variation was observed for rosette period and plant height, and low variation for days to flowering and maturity. Among accessions of *C. persicus*, variation levels were very high in branches per plant, high in thousand seed weight and plant height, medium in rosette period and days to maturity, and low in days to flowering. For accessions of *C. glaucus*, variation levels were very high in branches per plant, high in thousand seed weight, medium in rosette period and plant height, and low in days to flowering and maturity.

Among accessions of *C. tenuis*, variation levels were very high in branches per plant, high in thousand seed weight, medium in rosette period and plant height, and low in days to flowering and maturity (Table 2). For all species studied, the highest diversity was generally most noticeable in branches per plant, with the lowest variation occurring in days to flowering and maturity. Variation was high for thousand seed weight across all locations and species, except for *C. glaucus*(low variation). *C. glaucus* also exhibited low variation for rosette period and plant height, compared to the medium variation observed in other species (Table 3; Figs. 2-6).

Multivariate analyses have been utilized to measure the diversity in germplasm collections and evaluate the relative contributions that various traits add to total variability (Baloch *et al*., 2014). These analyses enable germplasm entries to be classified into groups with similar traits. Our study used PCA to identify patterns of variation for six agro-morphological traits within a set of five species representing 77 geographical regions.

Results for species and their accessions showed a consistent and large diversity in the traits (Table 4). The first two PCAs were used to draw a graph in order to see the pattern of variation among localities. The PCA based correlation matrix for the first two principal components accounted for 62.20, 57.56, 100.00, 75.77, 100.00 % in *C. lanatus*, in *C. dentatus*, in *C. persicus*, in *C. glaucus* and in *C. tenuis* respectively (Figs. 2-6).

Table 4 shows the trait correlation matrices for the *Carthamus* species. For *C. lanatus*, there were significant and positive correlations between rosette period, days to flowering and maturity, and plant height, as well as days to flowering and maturity, days to maturity and altitude. For *C. dentatus* there was a significant positive correlation between rosette period and days to flowering, but a significant negative correlation between rosette period and thousand seed weight was observed. There were also significant positive correlations between days to maturity

and days to flowering; and between branches per plant and altitude. In *C. persicus*, there was a positive correlation between rosette period and thousand seed weight and a negative correlation between rosette period, days to flowering, and plant height. There was positive correlation between days to flowering and maturity and between plant height and thousand seed weight; and a negative correlation. Between branches per plant and thousand seed weight. There were also positive correlations between days to maturity, plant height plus altitude and negative correlation with branches per plant. In *C. glaucus*, there was a significant positive correlation between rosette period and days to flowering and between days to maturity and days to flowering. There was a significant negative correlation between rosette period and plant height. In *C. tenuis*, there was positive correlation between rosette period and days to flowering and maturity and plant height; there were negative correlations between rosette period and branches per plant, and thousand seed weight and altitude. There were positive correlations between days to flowering, maturity, and plant height and negative correlations between these and branches per plant, thousand seed weight, and altitude. There was a positive correlation between days to maturity and plant height but there were negative correlations between days to maturity, plant height and branches per plant, thousand seed weight, and altitude. There were positive correlations between branches per plant and thousand seed weight and altitude whereas there were negative correlations between plant height and branches per plant, thousand seed weight, and altitude. There was also a positive correlation between 1000 seed weight and altitude.

Table 2. Average values concerning some plant characteristics of *Carthamus*species grown in test field.

Variables/Species		***C. lanatus***	***C. dentatus***	***C. persicus***	***C. glaucus***	***C. tenuis***
	Min.	44.0	28.0	46.0	56.0	55.0
	Max.	67.0	66.0	53.0	85.0	57.0
Rosette period	Mean	55.7	56.9	49.0	70.9	56.0
	SD	5.7	8.1	3.6	10.7	1.0
	CV	10.1	14.0	6.0	14.1	1.5
	Min.	88.0	94.0	95.0	97.0	96.0
	Max.	110.0	123.0	104.0	123.0	99.0
Days to flowering	Mean	95.9	109.6	98.7	111.4	97.7
	SD	4.5	7.1	4.7	9.1	1.5
	CV	4.6	6.4	3.9	7.7	1.3
	Min.	112.0	102.0	119.0	139.0	124.0
	Max.	140.0	149.0	141.0	162.0	127.0
Days to maturity	Mean	129.8	137.3	128.7	148.1	125.7
	SD	6.9	9.0	11.2	7.1	1.5
	CV	5.2	6.4	7.1	4.5	1.0
	Min.	53.0	46.2	57.0	47.4	67.0
	Max.	84.4	79.2	70.6	74.9	71.5
Plant height	Mean	71.7	64.1	64.8	65.6	69.2
	SD	7.5	7.0	7.0	9.8	2.3
	CV	10.3	10.8	8.8	13.9	2.7
	Min.	4.8	4.7	9.1	6.6	5.4
	Max.	16.3	26.0	14.9	21.3	12.4
Branches per plant	Mean	8.4	9.6	12.2	10.9	9.1
	SD	3.6	4.9	2.9	4.7	3.5
	CV	42.3	50.9	19.5	40.0	31.6
	Min.	13.0	16.4	28.0	15.0	16.1
	Max.	39.0	51.5	33.1	31.3	27.4
1000 seed weight	Mean	28.5	29.8	29.8	18.8	22.0
	SD	5.7	7.3	2.9	5.4	5.7
	CV	19.8	24.1	7.9	27.0	21.1

Table 3. Eigenvectors, eigenvalues, individual and cumulative percentages of variation explained by the first six principal components (PC) after assessing morphological properties in Turkish wild *Carthamus* L. accessions.

Species	Properties	PCA1	PCA2	PCA3	PCA4	PCA5	PCA6
C. lanatus	Rosette period	0.548	-0.054	-0.152	0.151	-0.010	-0.265
	Flowering day	0.491	-0.153	-0.287	0.332	-0.235	-0.343
	Maturation day	0.497	-0.123	0.022	0.079	0.263	0.808
	Plant height	0.285	0.501	-0.164	-0.520	0.532	-0.237
	Branch number	-0.247	-0.569	-0.255	0.190	0.696	-0.174
	1000 Seed weight	-0.111	0.581	0.138	0.744	0.279	-0.010
	Eigenvalue	2.894	1.460	0.923	0.747	0.526	0.337
	Variability (%)	41.350	20.851	13.183	10.674	7.520	4.808
	Cumulative %	41.350	62.201	75.384	86.058	93.578	98.386
C. dentatus	Rosette period	0.481	0.229	0.181	-0.571	0.188	-0.366
	Flowering day	0.575	-0.094	-0.140	0.161	0.412	-0.177
	Maturation day	0.516	-0.230	-0.218	0.258	0.033	0.592
	Plant height	-0.115	0.021	0.780	0.216	0.522	0.236
	Branch number	0.196	0.570	0.089	0.661	-0.257	-0.317
	1000 Seed weight	-0.342	0.266	-0.530	0.109	0.673	-0.074
	Eigenvalue	2.420	1.609	1.272	0.683	0.508	0.399
	Variability (%)	34.577	22.979	18.166	9.753	7.259	5.700
	Cumulative %	34.577	57.556	75.722	85.475	92.734	98.434
C. persicus	Rosette period	-0.198	0.571	-	-	-	-
	Flowering day	0.473	-0.015	-	-	-	-
	Maturation day	0.414	0.304	-	-	-	-
	Plant height	0.397	-0.342	-	-	-	-
	Branch number	-0.392	-0.351	-	-	-	-
	1000 Seed weight	-0.326	0.456	-	-	-	-
	Eigenvalue	4.465	2.535	-	-	-	-
	Variability (%)	63.787	36.213	-	-	-	-
	Cumulative %	63.787	100.000	-	-	-	-
C. glaucus	Rosette period	0.518	-0.031	0.179	0.316	-0.274	0.203
	Flowering day	0.441	0.157	-0.359	0.623	0.337	0.022
	Maturation day	0.413	0.044	-0.49	-0.613	0.362	-0.089
	Plant height	-0.464	-0.209	-0.344	0.167	0.317	0.642
	Branch number	0.116	-0.555	0.508	0.039	0.626	-0.159
	1000 Seed weight	0.136	0.581	0.469	-0.225	0.266	0.53
	Eigenvalue	3.398	1.906	1.119	0.322	0.193	0.06
	Variability (%)	48.539	27.227	15.982	4.595	2.752	0.856
	Cumulative %	48.539	75.766	91.748	96.342	99.094	99.95
C. tenuis	Rosette period	0.381	0.018	-	-	-	-
	Flowering day	0.374	0.554	-	-	-	-
	Maturation day	0.374	0.554	-	-	-	-
	Plant height	0.381	-0.164	-	-	-	-
	Branch number	-0.380	0.216	-	-	-	-
	1000 Seed weight	-0.380	0.223	-	-	-	-
	Eigenvalue	6.876	0.124	-	-	-	-
	Variability (%)	98.232	1.768	-	-	-	-
	Cumulative %	98.232	100.000	-	-	-	-

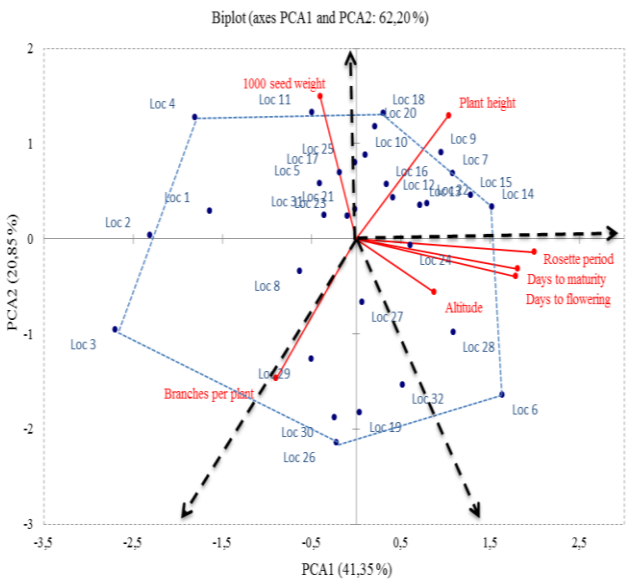

Fig. 2. Biplot diagram of agro-morphological properties of *C. lanatus*.

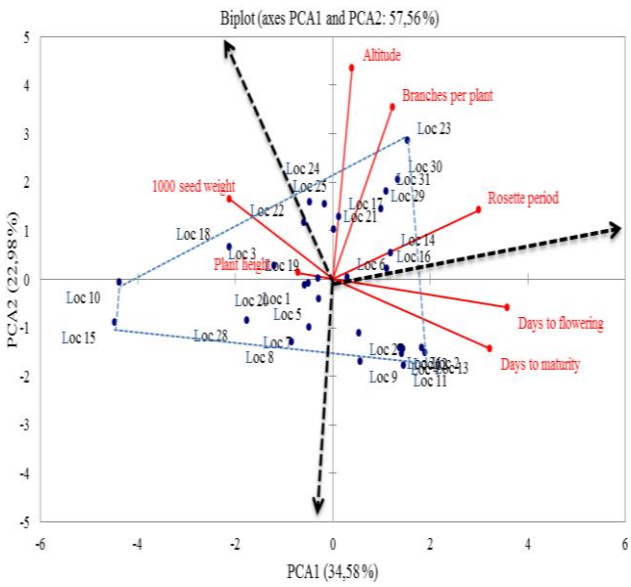

Fig. 3. Biplot diagram of agro-morphological properties of *C. dentatus*.

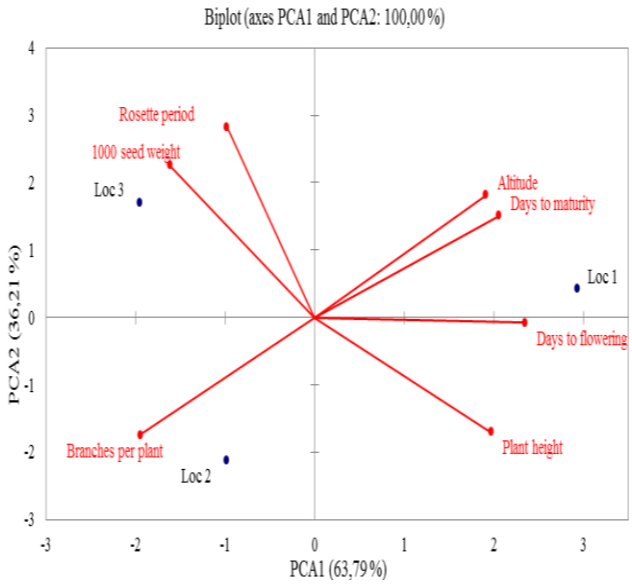

Fig. 4. Biplot diagram of agro-morphological properties of *C. persicus*.

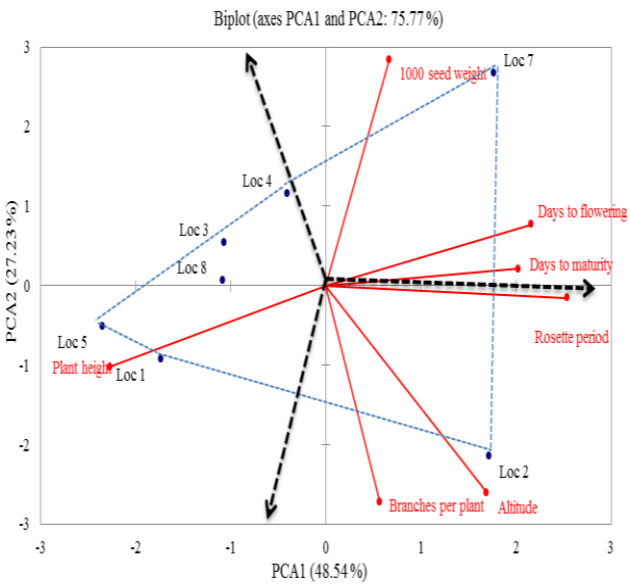

Fig. 5. Biplot diagram of agro-morphological properties of *C. glaucus*.

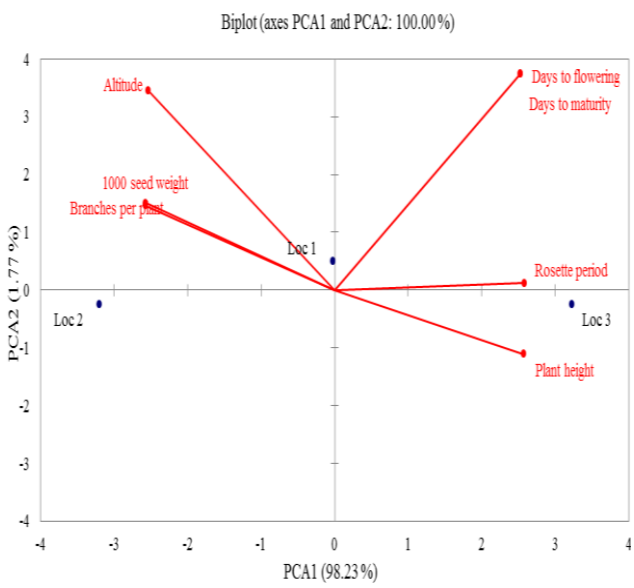

Fig. 6. Biplot diagram of agro-morphological properties of *C. tenuis*.

Table 4. Pearson's correlation coefficient analysis for different plant characteristics of *Carthamus* species.

Species	Variables	V1	V2	V3	V4	V5	V6	V7
	Rosette period (V1)	1						
	Days to flowering (V2)	0.847	1					
	Days to maturity (V3)	0.722	0.628	1				
C. lanatus	Plant height (V4)	0.380	0.181	0.297	1			
	Branches per plant (V5)	-0.277	-0.174	-0.197	-0.445	1		
	1000 seed weight (V6)	-0.158	-0.174	-0.182	0.101	-0.226	1	
	Altitude (V7)	0.286	0.165	0.353	-0.013	-0.124	-0.137	1
	Rosette period (V1)	1						
	Days to flowering (V2)	0.573	1					
	Days to maturity (V3)	0.304	0.752	1				
C. dentatus	Plant height (V4)	-0.012	-0.189	-0.263	1			
	Branches per plant (V5)	0.230	0.200	0.055	0.053	1		
	1000 seed weight (V6)	-0.377	-0.280	-0.353	-0.233	-0.003	1	
	Altitude (V7)	0.332	-0.073	-0.101	-0.044	0.465	0.211	1
	Rosette period (V1)	1						
	Days to flowering (V2)	-0.440	1					
	Days to maturity (V3)	0.074	0.863	1				
C. persicus	Plant height (V4)	-0.846	0.852	0.470	1			
	Branches per plant (V5)	-0.161	-0.815	-0.996	-0.390	1		
	1000 seed weight (V6)	0.947	-0.706	-0.251	-0.972	0.165	1	
	Altitude (V7)	0.188	0.799	0.993	0.365	-1.000	-0.138	1
	Rosette period (V1)	1						
	Days to flowering (V2)	0.740	1					
	Days to maturity (V3)	0.545	0.730	1				
C. glaucus	Plant height (V4)	-0.864	-0.565	-0.494	1			
	Branches per plant (V5)	0.307	-0.149	-0.126	-0.122	1		
	1000 seed weight (V6)	0.269	0.163	0.042	-0.603	-0.271	1	
	Altitude (V7)	0.629	0.306	0.482	-0.332	0.627	-0.435	1
	Rosette period (V1)	1						
	Days to flowering (V2)	0.982	1					
	Days to maturity (V3)	0.982	1.000	1				
C. tenuis	Plant height (V4)	0.998	0.968	0.968	1			
	Branches per plant (V5)	-0.997	-0.963	-0.963	-1.000	1		
	1000 seed weight (V6)	-0.996	-0.962	-0.962	-1.000	1.000	1	
	Altitude (V7)	-0.983	-0.930	-0.930	-0.992	0.995	0.995	1

*Values in bold are different from 0 with a significance level alpha=0.05

Discussion

There are no previous studies on the agro-morphological studies on wild safflowers, thus our discussions were based on studies conducted using cultivated safflower. Mayerhofer *et al.,* (2011) concluded that, in Canada, the rosette period, days to flowering, and thousand seed weight were 22 days, 63.2 days and 44.4 g, respectively, for *C. glaucus* and 66.6 days, 122.8 days, and 32.5 g, respectively, for *C. lanatus*. Meanwhile Derakhshan *et al.* (2014) determined that the days to flowering and maturity, plant height, branches per plant, and thousand seed weight of *C. lanatus* were 119-135 days, 153-161 days, 48-93 cm, 5-10 per plant, and 15–41 g respectively, in Iran. Tonguç & Erbaş (2012) asserted that the thousand seed weight of *C. dentatus* in Isparta (Turkey) was 32.71 g. Esendal, (1973) determined that the rosette period for some *C. tinctorius* varieties was 44-55 days. The cultivated species (*C. tinctorius)* had higher values in terms of the days to flowering and maturity, plant height, branches per plant and though seed weight than the wild species of safflower, though fewer branches. This is to be expected as having more branches per plant is common in wild species. Wild species also require fewer days to flowering and to seed production than cultivated species, in order to compete with other plants in their natural habitats. The longer rosette period of wild species is an adaptation to protect itself from winter cold, since plants are more durable to cold when bearing rosette leaves instead of elongated stems.

This study found variations among different accessions of each species and we also observed that agro-morphological traits were affected by altitude, though not to the same extent for each species and characteristic (some experienced negative effects, and some positive). In addition, there was difference in the correlations between the analyzed traits of different species.

A shorter plant height is a desired character for safflower. Thus wild safflower species with shorter plant heights (e.g. *C. dentatus, C. persicus* and *C. glaucus*) could be gene sources for this trait in breeding. Earlier days to flowering and maturity is also important. The wild species *C. lanatus*, *C. persicus* and *C. tenuis* exhibited earlier flowering and maturity and could be evaluated in Safflower breeding programs. As previously discussed, a longer rosette period is advantageous for cold endurance, thus *C. persicus* could be a useful gene source. To increase the

yield of safflower in breeding programs, *C. persicus* could be the species of choice among the wild species of *Carthamus* species in Turkey with the same chromosome number as *C. tinctorius*, also because it is considered the ancestor of cultivated safflower (Sehgal *et al*., 2008).

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