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Morphological study of some *Euphorbia* taxa in Iran

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Abstract. *Talebi SM, Noori M, Davijani SS. 2016. Morphological study of some* Euphorbia *taxa in Iran. Nusantara Bioscience 8*: *103-110. Euphorbia* (Euphorbiaceae) has nearly 2000 species and great morphological diversity present between its members. For this reason, species of this genus are classified into different infrageneric ranks. In the present study, morphological characteristics of fifteen taxa of this genus were examined in Iran. Thirty one qualitative and quantitative morphological characteristics from the vegetative and reproductive organs of the studied taxa were examined. ANOVA test showed significant variations for all of studied quantitative features. PCA-biplot of the studied traits confirmed that some of them were very useful for identification of the treated taxa. In addition, the obtained results did not confirm species classifications in sections/subsections according to Flora Iranica as well as Flora of Turkey and proved high morphological variations between these species; therefore traditional classification of species in subsection must be changed and our results confirmed previous molecular studies.

Keywords: *Euphorbia*, morphology, section, taxonomy

INTRODUCTION

Euphorbia L., a genus of Euphorbiaceae Juss., is one of the largest genera in angiosperm group and has approximately 2000 species. The great diversity present in their growth forms, and many xerophytic taxa were seen in this genus. In contrast to great diversity in vegetative traits, members of the genus are connected by a very important morphological feature named cyathium. This is a much-reduced inflorescence, which indicates a single flower (Steinmann and Porter 2002). The members of genus *Euphorbia* manufacture caustic lattices, which have many different types of secondary metabolites, such as alkaloids, diterpenes, glucosinolates, tannins, lactone-forming acids, phenolic compounds and triterpenes (Rice 1974; Kringstad 1980; Seigler 1994).

Rechinger and Schiman-Czeika (1964) listed ninety-six species for the genus *Euphorbia* in Flora Iranica which were classified into five sections namely, *Anisophyllum* Haw., *Dichanthium* Boiss., *Tirucalli* Boiss., *Sclerocyathium* (Prokh.) Prokh, and *Tithymalus* Boiss. Taxa of *Tithymalus* was divided into seven subsections: *Oppositifoliae* Boiss., *Crotonopsideae* Boiss., *Osyrideae* Boiss., *Carunculares* Boiss., *Galarrhei* Boiss., *Esulae*, and *Myrsiniteae* Boiss.. Although sections *Anisophyllum* (365 spp.) and *Euphorbia* (343 spp.) are the largest sections in the genus *Euphorbia* (Yang et al. 2012; Dorsey et al. 2013), according to Rechinger and Schiman-Czeika (1964), section *Tithymalus* is the biggest section in this genus in Iran and contains most of species, which high rate of morphological diversity exists on it.

Most leafy spurges species were grouped in *Euphorbia* section *Tithymalus* by Boissier (1862). Most taxa of this section have well-expanded leaves without stipules. Their cyathia are arranged in cymose rays around a terminal cyathium. Cyathium rays are later divided into dichasial branches, entire or crenate involucral glands that may have horn-like (but never petaloid) appendages. Capsules are smooth and seeds are usually pitted with sulcate or shallowly sculptures, and always carunculate (Peirson et al. 2014).

The main deficiency of Euphorbiaceae in Rechinger and Schiman-Czeika (1964) is the absence of taxa descriptions and only a few prominent characteristics were presented. The Iranian taxonomists have been accumulated much new data for nearly fifty years ago, therefore a new revision of the genus *Euphorbia* is very necessary. In addition, the country has the biggest number of taxa in southwest Asia, and also has several endemics as well as some undescribed taxa (Rechinger and Schiman-Czeika 1964; Akhani 2004; Pahlevani 2007; Pahlevani et al. 2011; Pahlevani and Mozaffarian 2011). For these reasons, we investigated morphological characteristics of fifteen species and subspecies (including some endemic species) and compared their traditional classification to the more recent study (Riina et al. 2013). According to Rechinger and Schiman-Czeika (1964), the studied taxa were classified into section *Tithymalus*, and, as far as we were able to investigate, no comparative study has been done on the species of this section.

MATERIALS AND METHODS

Plant materials

Morphological traits of fifteen taxa of the genus *Euphorbia* were studied. These species, according to Rechinger and Schiman-Czeika (1964) belong to section

Tithymalus and were classified into four subsections, namely subsection *esula* Boiss. including: *E. esula, E. aleppica* L., *E. teheranica* Boiss. (endemic), *E. aucheri* Boiss. (endemic), *E. microsciadia* Boiss. (endemic)., *E. kopetdaghi* Prokh.**,** *E. virgata* Waldst. & Kit., *E. seguieriana* Neck subsp. *niciciana* (Borb.) Rech. f.: subsection *Myrsiniteae* Boiss. containing *E. denticulata* Lam., *E. myrsinites* L., and *E. marschalliana* Boiss. (endemic): subsection *Carunculares* Boiss. including: *E. heteradena* Jaub. & Spach.: subsection *Galarrhei* containing: *E. helioscopia* L., *E. orientalis* L. and *E. microsphaera* Boiss. These taxa were collected from west and northwest of Iran during spring 2014-2015 (Table 1) and were identified based on keys and descriptions provided in the *Flora Iranica* (Rechinger and Schiman-Czeika 1964); as well as *Flora of Turkey* (Davis 1967). Three specimens were investigated per each taxon. The herbarium specimens were stored in the Herbarium of Arak University, Markazi, Iran.

Plant morphology

Thirty-one qualitative and quantitative morphological characteristics from both vegetative and reproductive organs of the studied taxa were examined. These included stems traits (include length, shape, color and the mode of branching), leaf features (leaf apex, margin, shape, and base, length and width, petiole length), cyathium traits (cyathium rays number and length), involucres shape and diameter and shape and number of glands. For each trait, two replications were measured per each flowering stem. Selections of morphological traits were based on similar studies (e.g. Yakoub Zokian 2006).

Statistical analysis

The mean and also standard deviation of the studied quantitative morphological traits were calculated. For grouping the studied taxa on the basis of phenotypical characteristics, data were standardized (mean = 0, variance = 1), then multivariate analyses such as UPGMA (Unweighted Paired Group using Average method) and Principal Coordinate Ordination (PCO) and Principal Coordinate Analysis (PCA) were performed (Podani 2000).

Furthermore, one-way ANOVA (analyses of variances) test was used to assess the significant quantitative morphological variations between the studied taxa and also the correlations coefficient of Pearson was used to show significant correlations between quantitative morphological features. The used software for statistical analyses were MVSP ver. 2 (1998) and SPSS ver. 9 (1998).

RESULTS AND DISCUSSION

Results

All of the studied taxa are perennial herbs, except for *E. aleppica, E. microsphaera* and *E. helioscopia* that are annual plants. Habit form of *E. denticulata* is succulent, while other species are not. Shape of stem leaves varied among species: linear, linear-lanceolate, lanceolate, elliptic, oblanceolate or obovate. In addition, leaf apex differed among the studied samples: acute (*E. microsphaera, E. heteradena, E. myrsinites, E. teheranica, E. orientalis, E. kopetdaghi* and *E. esula*), obtuse (*E. helioscopia*) and acuminate (the rest). Leaf margin is entire, rarely sinuate (*E. orientalis* and *E. esula*) or serrate (*E. helioscopia*). The shape and color of cyathial glands varied: red (*E. myrsinites* and *E. denticulata*), yellow (*E. microsciadia, E. microsphaera* and *E. teheranica*), dark green (*E. aleppica, E. esula* and *E. helioscopia*), orange (*E. orientalis, E. kopetdaghi* and *E. aucheri*) as well as yellow-green (the remaining taxa). The apex of glands may be granulated, horned or smooth (Table 2).

The average number of cyathium rays differed among taxa. Highest number of them (16) were recorded in *E. myrsinites*, while lowest ones (1) have occurred in *E. heteradena*. Largest (68.66 mm) and shortest (11.66 mm) stem leaves are found in *E. heteradena* and *E. aucheri*, respectively. Shape, length as well as width of ray leaves varied between the studied plants. Their shapes may be lanceolate, oblanceolate, ovate and rarely obovate or linear. Largest (26×17.6 mm) and smallest (5.33×2.66 mm) ray leaves were recorded in *E. denticulata* and *E. teheranica*, respectively.

Table 1. Localities of the studied *Euphorbia* taxa in Iran.

Taxa	Habitat	Voucher specimen
Euphorbia kopetdaghi Prokh.	Kurdistan, Sanandaj, Abidar mountains, 1645 m.	CSS_1
Euphorbia aleppica L.	Kurdistan, Marivan, 1765 m.	CSS_2
Euphorbia aucheri Boiss.	West Azerbaijan, Urmia, Sero, 1656 m. (endemic)	CSS_3
Euphorbia virgata Waldst. & Kit.	Kurdistan, Marivan,1900 m.	CSS_4
Euphorbia denticulata Lam.	Kurdistan, Marivan, 1870 m.	CSS_5
Euphorbia esula	West Azerbaijan, Salmas, 1577 m.	CSS_6
Euphorbia helioscopia L.	Zanjan, Dandi, 1900 m.	CSS_7
Euphorbia heteradena Jaub. & Spach.	Zanjan, 1513 m.	CSS_8
Euphorbia marschalliana Boiss.	Mazandaran, Chalous road Kandovan, 2565 m. (endemic)	CSS_9
Euphorbia myrsinites L.	Hamadan, Qurveh, 1800 m.	CSS_{10}
Euphorbia orientalis L.	Qazvin, Avaj, 2104 m.	CSS_{11}
Euphorbia seguieriana Neck subsp. *niciciana* (Borb.) Rech. f.	Zanjan, Dandi, 1676 m.	CSS_{12}
Euphorbia microsciadia Boiss.	Markazi, Nobaran, 1602 m. (endemic)	CSS_{13}
Euphorbia microsphaera Boiss.	Qazvin, Avaj, 2104 m.	CSS_{14}
Euphorbia teheranica Boiss.	Zanjan, Dandi, 1863 m (endemic).	CSS_{15}

The ANOVA test showed significant variations ($p<0.01$) for all of the studied quantitative traits (Table 3). PCA plot of morphological traits (Figure 1) showed that some of them were more variable than others. For example, stem leaf length is highly variable features and others were placed in lower grads. PCA-biplot (Figure 2) showed that some morphological traits had significant value in identifications of the studied taxa. For example, length, as well as length/width ratio of stem leaf, were two main characteristics for identifications of *E. heteradena* from the rest.

The studied taxa were separated from each other in UPGMA tree (Figure 3). Furthermore, PCO and PCA plots (Figures 4-5) produced similar results. Therefore, taxa arrangements of UPGMA tree were discussed here: two main branches (A and B) were seen in the tree. *E. heteradena* were clustered separately and others were arranged in bigger branch, which had two sub-branches (C and D). In the smaller (C), two species, *E. esula* and *E. denticulata* existed and other species clustered in bigger sub-branch (D) that consists of two main groups (E and F); the one with (E) three species, *E. seguieriana* subsp. *nicicianа*, *E. teheranica* and *E. myrsinites* and in the other (F) the remaining species were grouped. These species are divided into two distinct subgroups. In one subgroup, *E. microsciadia*, *E. microsphaera* and *E. orientalis* and in other subgroup *E. kopetdaghi*, *E. aucheri*, *E. marschalliana* and *E. aleppica*.

Discussion

In this study, we used morphological traits for examining the infrageneric classification of some *Euphorbia* species. Based on the traditional classifications (Rechinger and Schiman-Czeika 1964), these species belong to section *Tithymalus*.

Table 3. ANOVA test of quantitative studied morphological traits

Parameters	Characteristics	Sum of Squares	df	Mean Square	F	Sig.
Branch number	Between Groups	378.578	14	27.041	15.023	.000
	Within Groups	54.000	30	1.800		
	Total	432.578	44			
Cyathial branch no.	Between Groups	472.311	14	33.737	151.814	.000
	Within Groups	6.667	30	.222		
	Total	478.978	44			
Rey leaves length	Between Groups	2286.311	14	163.308	5.530	.000
	Within Groups	886.000	30	29.533		
	Total	3172.311	44			
Rey leaves width	Between Groups	671.867	14	47.990	13.668	.000
	Within Groups	105.333	30	3.511		
	Total	777.200	44			
Raylet leaves length	Between Groups	877.644	14	62.689	22.568	.000
	Within Groups	83.333	30	2.778		
	Total	960.978	44			
Raylet leaves width	Between Groups	862.133	14	61.581	15.835	.000
	Within Groups	116.667	30	3.889		
	Total	978.800	44			
Raylet leaves length/ width ratio	Between Groups	14.849	14	1.061	26.292	.000
	Within Groups	1.210	30	.040		
	Total	16.059	44			
Cyathium ray length	Between Groups	409.778	14	29.270	52.686	.000
	Within Groups	16.667	30	.556		
	Total	426.444	44			
Stem length	Between Groups	391.411	14	27.958	14.256	.000
	Within Groups	58.833	30	1.961		
	Total	450.244	44			
Stem leaf length	Between Groups	40.275	14	2.877	64.042	.000
	Within Groups	1.348	30	.045		
	Total	41.623	44			
Stem leaf width	Between Groups	468.800	14	33.486	22.831	.000
	Within Groups	44.000	30	1.467		
	Total	512.800	44			
Stem leaf length/width ratio	Between Groups	844.812	14	60.344	52.612	.000
	Within Groups	34.408	30	1.147		
	Total	879.220	44			
Involucral bracts number	Between Groups	275.244	14	19.660	68.055	.000
	Within Groups	8.667	30	.289		
	Total	283.911	44			

Table 2. Some important morphological characteristics in the studied taxa (measurements value are in mm)

Taxa		Habit	Stem length	Stem branches	Glands shape	Stem leaf length	Cyathium leaves shape	Raylet leaf shape	Cyathium leaves length	Cyathium leaves width	Raylet leaf length	Raylet leaf width	Cyathium ray length	Glands color	Stem leaf shape
E. kopetdaghi	Mean	Perennial	207	Present	Smooth	13.00	Ovate	Ovate	10.00	10.00	6.00	7.00	5.00	Orange	Lanceolate
	N		3			3			3	3	3	3	3		
	SD.		0.00			.000			0.00	0.00	0.00	0.00	0.00		
E. myrsinites	Mean	Perennial	245	Present	Smooth	16.33	Oblanceolate	Absent	7.33	3.66	0.00	0.00	4.00	Red	Lanceolate
	N		3			3			3	3	3	3	3		
	SD.		1.32			0.57			1.15	0.57	0.00	0.00	0.00		
E. orientalis	Mean	Perennial	326	Present	Smooth	24.66	Lanceolate	Linear-lanceolate	18.00	7.66	14.33	7.00	3.33	Orange	Linear-lanceolate
	N		3			3			3	3	3	3	3		
	SD.		3.78			3.78			1.44	2.51	0.57	1.00	0.57		
E. seguieriana subsp. *niciciana*	Mean	Perennial	370	Present	Smooth	20.33	Linear	Ovate	13.66	2.33	4.33	3.66	2.33	Yellow-green	Lanceolate
	N		3			3			3	3	3	3	3		
	SD.		7.00			3.78			2.08	0.57	0.57	0.57	0.57		
E. microsciadia	Mean	Perennial	396	Present	Smooth	25.33	Oblanceolate	Oblanceolate	16.66	7.66	7.33	5.66	2.33	Yellow	Oblanceolate
	N		3			3			3	3	3	3	3		
	SD.		1.52			1.15			3.21	2.51	0.57	0.57	0.57		
E.microsphaera	Mean	Annual	190	Present	Smooth	21.33	Lanceolate	Lanceolate	20.33	7.00	10.33	5.00	2.00	Yellow	Lanceolate
	N		3			3			3	3	3	3	3		
	SD.		2.00			3.51			0.57	0.00	0.57	0.00	0.00		
E. teheranica	Mean	Perennial	310	Present	Horned	15.33	Ovate	Absent	5.33	2.66	4.00	4.66	0.00	Yellow	Lanceolate
	N		3			3			3	3	3	3	3		
	SD.		1.00			0.57			0.57	0.57	0.00	1.52	0.00		
E. aleppica	Mean	Annual	181	Present	Smooth	16.66	Lanceolate	Ovate	13.66	4.33	9.00	7.00	4.00	Dark green	Lanceolate
	N		3			3			3	3	3	3	3		
	SD.		2.88			0.57			2.51	0.57	1.00	1.00	0.00		
E. aucheri	Mean	Perennial	218	Absent	Horned	11.66	Ovate	Ovate	10.00	9.33	7.66	9.33	5.33	Orange	Elliptic
	N		3			3			3	3	3	3	3		
	SD.		1.89			2.08			2.00	1.52	1.15	0.57	0.57		
E. virgata	Mean	Perennial	300	Present	Horned	25.00	Lanceolate	Triangle	18.33	12.00	9.66	14.66	4.33	Yellow-green	Oblanceolate
	N		3			3			3	3	3	3	3		
	SD.		2.50			5.00			2.51	1.00	0.57	1.52	0.57		
E. denticulata	Mean	Perennial	386	Absent	Granulate	30.00	Obovate	Ovate	26.00	17.66	15.00	14.66	13.66	Red	Obovate
	N		3			3			3	3	3	3	3		
	SD.		4.16			1.00			2.64	4.04	2.00	0.57	1.52		
E. esula	Mean	Perennial	546	Present	Horned	46.66	Oblanceolate	Ovate	31.00	6.00	10.66	12.00	3.33	Dark green	Lanceolate
	N		3			3			3	3	3	3	3		
	SD.		8.32			1.70			1.27	2.64	3.78	7.00	0.57		
E. helioscopia	Mean	Annual	296	Absent	Smooth	17.00	Obovate	Elliptic	18.00	11.33	13.00	9.33	7.00	Dark green	Elliptic
	N		3			3			3	3	3	3	3		
	SD.		4.50			2.64			5.29	2.30	4.35	0.57	2.00		
E. heteradena	Mean	Perennial	381	Present	Smooth	68.66	Lanceolate	0	25.66	7.66	0.00	0.00	3.00	Yellow-green	Linear-lanceolate
	N		3			3			3	3	3	3	3		
	SD.		5.05			4.04			1.15	2.08	0.00	0.00	0.00		
E.marschalliana	Mean	Perennial	176	Present		17.00	Ovate	Circular	9.66	7.66	8.33	11.00	2.00	Yellow-green	Oblanceolate
	N		3		Horned	3			3	3	3	3	3		
	SD.		2.51			1.00			1.52	1.52	0.57	1.00	0.00		

Yakoub Zokian (2006) studies in the genus *Euphorbia* showed that some morphological characteristics of leaf such as its shape, arrangement, dimensions, color, trichomes as well as petiole presence, stem shape, size, color, presence of stipules and also trichomes, type of stem and branching, shape, size, appendages of cyathium and its glands are very important for taxonomical treatments. *Tithymalus* is the biggest section, on the basis of Rechinger and Schiman-Czeika (1964), in the genus *Euphorbia*. High morphological variations exist between the members of the genus and for this reason different synonyms as well as plant types (such as holotype) are introduced for its species in different flora (Rechinger and Schiman-Czeika 1964). Various reasons are possible for these variations; it seems that one of them has wide geographical distributions. The species of the genus *Euphorbia* are not only widespread in different regions of Iran, but also naturally grow in different countries all over the worlds. Previous studies

(Steinmann and Porter 2002; Haevermans et al. 2004; Bruyns et al. 2006, 2011; Park and Jansen 2007; Yang et al. 2012) proved that *Euphorbia* has a complex biogeographic history, which leads to nearly worldwide distribution. Therefore, its species were occurred in the wide range of habitats in different elevations from sea level to nearly 4000 m, such as littoral grits, rocky slopes, cultivated regions, salty soils, gypsum hills, quicksand, gravelly deserts, margins of river and jungles (Pahlevani and Akhani 2011). It seems that species of *Euphorbia* had high morphological plasticity and made various ecotypes in different ecological conditions. Previous studies, for example, Metcalfe and Chalk (1950), suggested that *Euphorbia* taxa display differences such as ecotypes/ecophene when grown under various ecological conditions. In addition, Ramakrishan (1960) and Mangaly et al. (1979), found two ecotypes in species *E. helioscopia* and *E. hirta*.

Most of studied taxa were perennial herbs and only three species were annual. Our findings confirmed those of Peirson et al. (2014). They reported in *Euphorbia* section *Tithymalus* two forms, annual and perennial, were present, while the ancestral reconstructions showed that multiple alternations occurred in life history of this section. Their findings confirmed that the ancestral state for the section was perennial.

All of the studied *Euphorbia* taxa had unique inflorescence structure, named cyathium. The morphological traits of cyathium were used in identification keys of this genus in different flora and were unique morphological features. Mishra and Sahu (1985) said that morphological traits of cyathium in various *Euphorbia* taxa might prove precious. This structure taken into attention associated with other morphological traits for easy recognition and also distinguishing the existing relationships between taxa. Prenner and Rudall (2007) believed that cyathium is intermediate between a single flower and an inflorescence contains a cup-like involucre enclosing numerous male flowers and a single female flower. The male and female flowers have been reduced to single stamens and single pistil, respectively. From this fundamental construction, different complications have evolved, containing colorful subtending bracts, secretory glands of cyathium with petaloid supplements as well as fusion or addition of cyathial glands. Some of the mentioned features display synapomorphies for special clades within this genus. Contrary to the provided data by the cyathium and its variations, relationships between species in the genus *Euphorbia* on the bases of morphological features have been proved to be ambiguous in many cases (Steinmann and Porter 2002).

Our findings showed that different characteristics of cyathium such as shape, number as well as color of nectar glands, ray leaves shape, size and the number of cyathial rays varied between the studied taxa and had taxonomic value. Our results confirmed previous investigations, for example, Radcliffe-Smith (1980) showed that in this genus involucres almost always have one or more special nectar glands and most often on the upper rim, and these glands differed greatly in size as well as in shape. Therefore, these characteristics were used in identification keys of the genus *Euphorbia* in different flora such as Rechinger and Schiman-Czeika (1964) and Davis (1967); furthermore, Yakoub Zokian (2006) studies confirmed them.

The shapes of apex, margin, and blade of cauline leaves differed between our studied taxa and investigations showed that these characteristics were important and useful in identification of species or even infraspecific ranks in *Euphorbia*. For example, the leaf shape was a useful feature in distinguishing of two varieties of *E. peplus* (Davis 1967).

Habit form was a prominent and taxonomic characteristic in this genus. Previous studies (Radcliffe-Smith 1980; Pritchard 2003) showed that most members of the genus *Euphorbia* are succulent and have thickened and photosynthetic stems, while their leaves are very ephemeral. These conditions did not hold true for the studied taxa and only one species was succulent and also leaves were durable and were remain on the stem until the end of growing season.

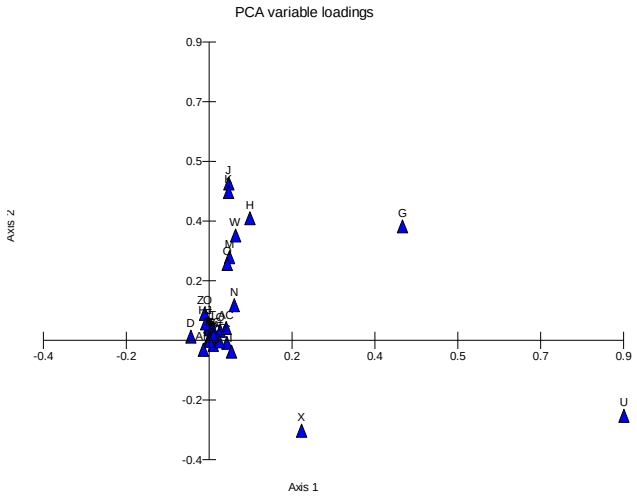

Figure 1. PCA plot of studied characteristics. Abbreviations: U: stem leaf length, X: leaf length/wide ratio, G: cyathium leaves length, H: cyathium leaves width, W: stem leaf width, J: Raylet leaf length, K: Raylet leaf length

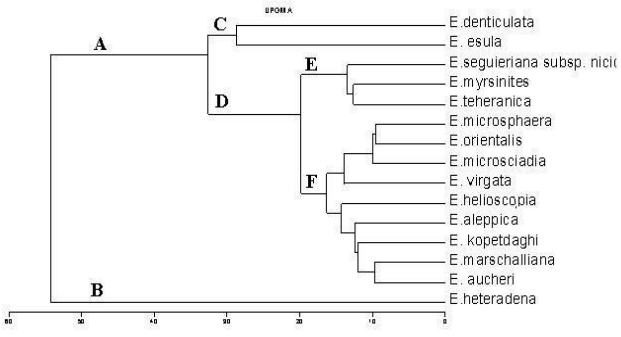

Figure 3. UPGMA tree of the studied taxa on the base of morphological traits

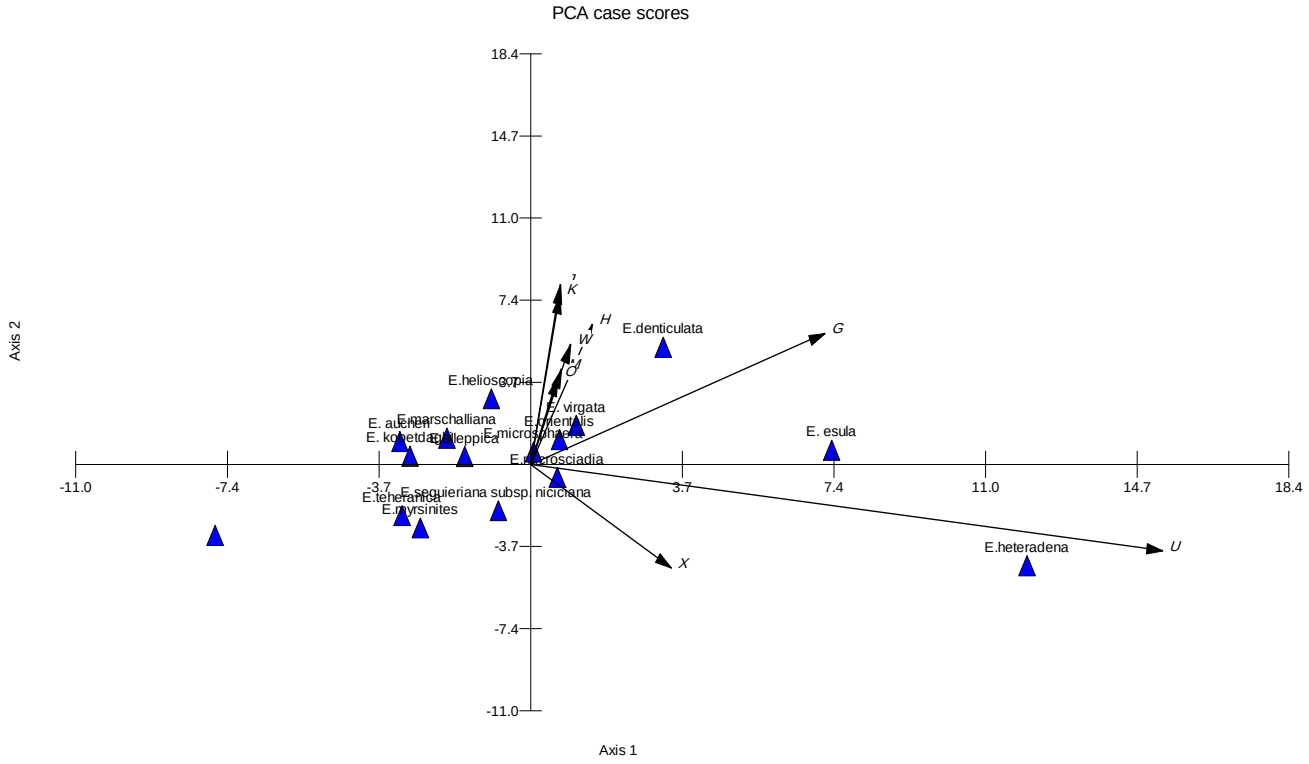

Figure 2. PCA-biplot of morphological traits. Abbreviations: U: stem leaf length, X: leaf length/wide ratio, G: cyathium leaves length, H: cyathium leaves width, W: stem leaf width, J: Raylet leaf length, K: Raylet leaf length.

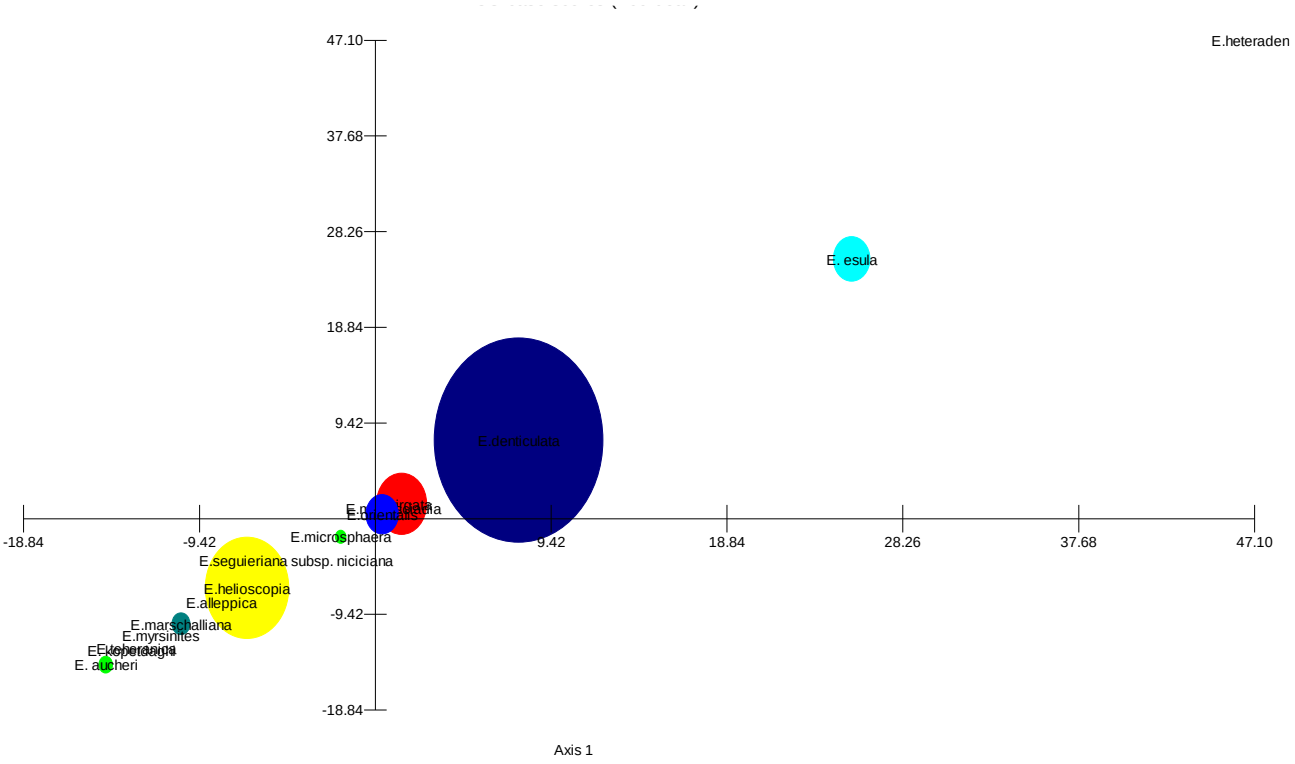

Figure 4. Morphological PCoA plot of the studied taxa

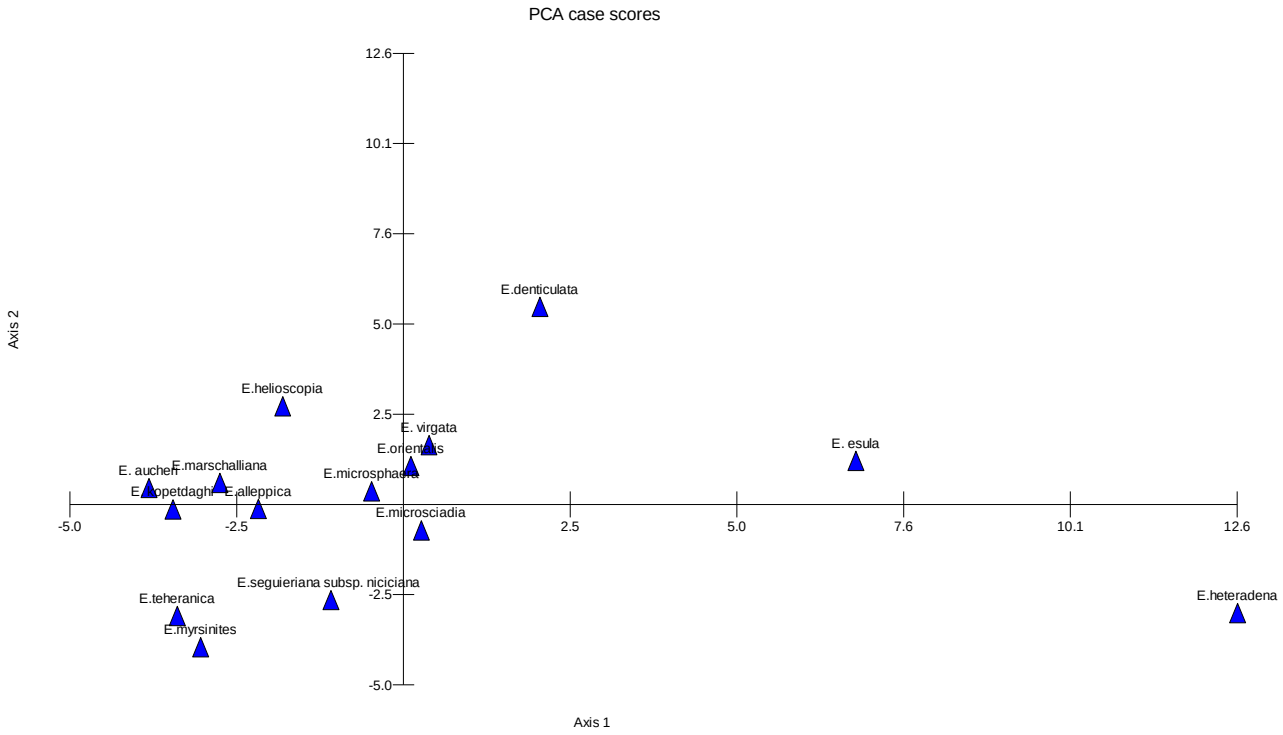

Figure 5. PCA plot of the studied taxa based on the morphological features

Infrageneric classification of the genus in Rechinger and Schiman-Czeika (1964) was on the basis of traditional classification system. In this reference, *Euphorbia* species were only classified into sections and subsections and these ranks were not classified into subgenera. It should be noted that in a lot of subjects, the new classification systems significantly varied from traditional systems.

Recently, molecular investigations have confirmed that the common infrageneric taxonomy does not consent with the natural restriction of monophyletic ancestry; therefore four clades were recognized in *Euphorbia* s.l. (Steinmann and Porter 2002). Later, these clades were called subgenus: *Rhizanthium* (Boiss.) Wheeler (subgenus. *Athymalus* Neck. ex Rchb. Peirson et al. 2013), *Chamaesyce* Raf., *Euphorbia* and *Esula* Pers. (Bruyns et al. 2006). Further studies (e.g. Bruyns et al. 2011; Park and Jansen 2007) confirmed this classification and it is now accepted by most of taxonomists.

On the bases of recent studies (Steinmann and Porter 2002), section *Tithymalus* belongs to subgenus *Esula* and it seems that the section includes many species of it. The subgenus is very big and on the basis of analyses of the combined ITS + ndhF dataset, and in total 21 sections were accepted for it (Riina et al. 2013).

The morphological clustering of the studied taxa did not confirm the traditional classification of taxa in the subsections according to Rechinger and Schiman-Czeika (1964), and showed high morphological variations in this section.

Of three studied species of subsection *Galarrhei*, two species *E. orientalis* and *E. microsphaera* grouped together and the third, *E. helioscopia* was away. This condition held true for subsection *esula*. Some members of it, such as *E. aucheri*, *E. kopetdaghi* and *E. aleppica* closed together, while others placed separately. Furthermore, none members of the subsection *Myrsiniteae* were together. In addition, phylogenetic investigations of Peirson et al. (2014) confirmed partly high molecular differentiation between the New World annual species in section *Tithymalus*.

To resolve this problem, Radcliffe-Smith (1982) introduced a different taxonomical pattern in *Flora of Turkey*. He classified our studied taxa in four different sections. In addition, the name, as well as members of many subsections, differed in his classifications. For example, two species of section *Tithymalus* subsection *esula, E. aleppica and E. seguieriana* subsp. *niciciana*, were transferred to two different sections. *E. aleppica* classified in section *Cymatospermum*, while *E. seguieriana* subsp. *niciciana* placed in section *Paralias* subsection *Conicocarpae*.

Radcliffe-Smith (1980) placed *E. microsphaera* and *E. stricta* in section *Helioscopia*, but in Rechinger and Schiman-Czeika (1964) the mentioned species in company with *E. helioscopia* were placed in section *Galarrhei*. Seed morphological studies with molecular data of phylogenetic analysis of Kryukov et al. (2010) showed that Radcliffe-Smith (1980) pattern needs to be revised.

There are many discussions about infrageneric classifications of the genus and yet many different taxonomic schemes were proposed for it. Various studies (e.g. Frajman and Schönswetter 2011; Riina et al. 2013) showed that previous sectional classifications in subgenus

Esula, which strongly relied on the difference between annual and perennial species, were not quite right. It has proven that the mentioned classification is largely incongruent with the evolutionary history of this subgenus. For instance, all annual species that have bicornate nectary glands (e.g. *E. exigua* L., *E. falcata* L., *E. medicaginea* Boiss., *E. peplus*, *E. sulcata* Lens ex Loisel. and *E. turczaninowii* Kar. & Kir.) were classified into section *Cymatospermum* (Prokh.) Prokh. by Prokhanov (1949), while recent study (Peirson et al. 2014) showed that the mentioned taxa pertain to five apart sections of the genus. In addition, Prokhanov clustered perennial species, which have oval nectary glands and verrucose capsules into section *Chamaebuxus* Lázaro, but investigations of Riina et al. (2013) did not confirm it. They believed that those taxa belong to a larger section *Helioscopia*. This section consists of annual as well as perennial species.

Our studied taxa, according to Riina et al. (2013) studies, were classified into six sections: section *Esula*: *E. esula*, *E. virgata*, section *Myrsinites: E. aleppica*, *E. denticulate*, *E. myrsinites*, *E. marschalliana*, section *Pithyusa*: *E. teheranica*, *E. kopetdaghi*, *E. seguieriana* subsp. *niciciana*, section *Herpetorrhizae*: *E. aucheri*, section *Chylogala*: *E. heteradena* and section *Helioscopia*: *E. helioscopia*, *E. stricta*, *E. orientalis*, *E. microsphaera*. The results of our studied confirmed the above mentioned classification in some cases. For example, *E. heteradena* is placed separately. And two members of section *Pithyusa*, namely *E. teheranica* and *E. seguieriana* subsp. *niciciana* are clustered together. This condition hold true for section *Helioscopia*, and three of four members of this section grouped closely. It seems that infrageneric classification of Riina et al. (2013) is more suitable for Iranian *Euphorbia* species.

REFERENCES

Akhani H. 2004. A new spiny, cushion-like *Euphorbia* (Euphorbiaceae) from south-west Iran with special reference to the phytogeographic importance of local endemic species. Bot J Linn Soc 146: 107-121.

Boissier E. 1862: Euphorbiaceae Juss. In: Candolle ADe (ed.). Prodromus systematis naturalis regni vegetabilis, Paris.

Bruyns PV, Klak C, Hanacek P. 2011. Age and diversity in Old World succulent species of *Euphorbia* (Euphorbiaceae). Taxon 60: 1717-1733.

Bruyns PV, Mapaya RJ, Hedderson T. 2006. A new subgeneric classification for *Euphorbia* (Euphorbiaceae) in southern Africa based on ITS and *psbA-trnH* sequence data. Taxon 55: 397-420.

Davis PH. 1967. Flora of Turkey and the East Aegean Islands. Edinburgh.

Dorsey BL, Haevermans T, Aubriot X, Morawetz JJ, Riina R, Steinmann VW, Berry PE. 2013. Phylogenetics, morphological evolution, and classification of *Euphorbia* subgenus *Euphorbia*. Taxon 62(2): 291-315.

Frajman B, Schönswetter P. 2011. Giants and dwarfs: molecular phylogenies reveal multiple origins of annual spurges within *Euphorbia* subg. *Esula*. Mol Phylogenet Evol 61: 413-424.

Haevermans T, Hoffmann P, Lowry PP, Labat JN, Randrianjohany E. 2004. Phylogenetic analysis of the Madagascan *Euphorbia* subgenus *Lacanthis* based on ITS sequence data. Ann Mo Bot Gard 91: 247-259.

Kringstad R. 1980. Hydroxyacids and their relation to vacuoles in higher plants. A study with emphasis on the accumulated lactones-forming acids in succulents and the role of vacuoles in plants showing crassulacean acid metabolism. [Ph.D. Dissertation], University of Oslo, Oslo.

Kryukov AA, Geltman DV, Maches EE, Rodionov AV. 2010. Phylogeny of *Euphorbia* subgenus *Esula* based on sequences of internal transcribed spacers 5.8 s RNA. Bot Zhurn 95: 801-819.

Mangaly J, Swarupanandan K, Madhusoodan P. 1979. Seed and seedling morphology of two species of *Euphorbia hirta* (Euphorbiaceae). Proc. Indian Acad Sci. 88 (2): 87-94.

Metcalfe C, Chalk L. 1950. Anatomy of the dicotyledons leaves, stems and wood in relation to taxonomy with notes on economic uses Vol. 2. Clarendon Press, Oxford.

Mishra DP, Sahu TR. 1985. Cyathial characteristic of some prostrate Euphorbias common in India. Phyton (Austria) 25 (1): 43-49.

Pahlevani AH. 2007. Notes on some species of the genus *Euphorbia* in Iran. Rostaniha (8) 2: 89-103.

Pahlevani AH, Akhani H. 2011: Seed morphology of Iranian annual species of *Euphorbia* (Euphorbiaceae). Bot J Linn Soc167: 212 - 234.

Pahlevani AH, Geltman DV, Riina R. 2011. Taxonomic revision of *Euphorbia* subsect. *Myrsiniteae* Boiss. for the flora of Iran. Ann Bot Fenn 48 (6): 483-493.

Pahlevani AH, Mozaffarian V. 2011. *Euphorbia iranshahri* (Euphorbiaceae), a new endemic species from Iran. Adansonia 33 (1): 93-99.

Park KR, Jansen RK. 2007. A phylogeny of Euphorbieae subtribe Euphorbiinae (Euphorbiaceae) based on molecular data. J Plant Biol 50: 644-649.

Peirson JA, Bruyns PV, Riina R, Morawetz JJ, Berry PE. 2013. A molecular phylogeny and classification of the largely succulent and mainly African *Euphorbia* subg. *Athymalus* (Euphorbiaceae). Taxon 62 (6): 1178-1199.

Peirson JA, Riina R, Mayfield MH, Ferguson CJ, Urbatsch LE, Berry PE. 2014. Phylogenetics and taxonomy of the New World leafy spurges, *Euphorbia* section *Tithymalus* (Euphorbiaceae). Bot J Linn Soc 175 (2) 191 - 228.

Podani J. 2000. Introduction to the exploration of multivariate biological data. Backhuys Publishers, Leiden.

Prenner G, Rudall PJ. 2007. Comparative ontogeny of the cyathium in *Euphorbia* (Euphorbiaceae) and its allies: exploring the organ-flower-inflorescence boundary. Am J Bot 94: 1612-1629.

Pritchard A. 2003. Introduction to the Euphorbiaceae. Cuctus and Co. Libri. Tradate (VA), Italy.

Prokhanov YI. 1949. *Euphorbia* L. In: Komarov VL (ed.). Flora SSSR. Moscow, Izdatel'stvo Akademii nauk, SSSR.

Radcliffe-Smith A. 1980. Family Euphorbiaceae. In: Townsend C, Guest E (eds). Flora of Iraq. Ministry of Agriculture and Agrarian Reform, Baghdad.

Radcliffe-Smith A. 1982. Family Euphorbiaceae. In: Davis PH. (Ed).Flora of Turkey and the east Aegean islands. Edinburgh University Press, Edinburgh.

Ramakrishan P.1960. Studies in the Autecology of *E. hirta* L. Journal of the Indian Botany Society. 39: 455-473.

Rechinger KH, Schiman-Czeika H. 1964: *Euphorbia* L. in Flora Iranica. Akademische Druck- und Verlagsanstalt, Graz.

Rice EL. 1974. Alleopathy. Academy Press, London.

Riina R, Peirson JA, Geltman DV, Molero J, Frajman B, Pahlevani A, Barres L, Morawetz JJ, Salmaki Y, Zarre S, Kryukov A, Bruyns PV, Berry PE. 2013. A worldwide molecular phylogeny and classification of the leafy spurges, *Euphorbia* subgenus *Esula* (Euphorbiaceae). Taxon 62 (2): 316-342.

Seigler DS. 1994. Phytochemistry and systematic of the Euphorbiaceae. Ann Missouri Bot Gard 81: 380-401.

Steinmann VW, Porter JM. 2002. Phylogenetic relationships in *Euphorbieae* (Euphorbiaceae) based on ITS and *ndhF* sequence data. Ann Mo Bot Gard 89: 453-490.

Yakoub Zokian SA.2006. Biosystematics of four species of *Euphorbia* L. grown in Baghdad University Campus-Jadiriyah. [Ph.D. Dissertation]. University of Baghdad, Baghdad.

Yang Y, Riina R, Morawetz JJ, Haevermans T, Aubriot X, Berry PE. 2012. Molecular phylogenetics and classification of *Euphorbia* subgenus *Chamaesyce* (Euphorbiaceae). Taxon 61: 764-789.