Pak. J. Bot., 50(2): 561-573, 2018.

NUMERICAL TAXONOMIC STUDY OF THE GENUS *ONOSMA* L. (BORAGINACEAE) FROM EASTERN MEDITERRANEAN REGION IN TURKEY

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Abstract

Twenty-five *Onosma* L. (Boraginaceae) taxa belonging to two subsections (*Haplotricha* (Boiss.) Gürke and *Asterotricha* (Boiss.) Gürke) were classified by numerical taxonomic methods from Eastern Mediterranean region in Turkey. A total of 30 metric and 60 non-metric morphological characters were utilised for the genus *Onosma*. The classification obtained by numeric taxonomic methods was compared to that of obtained by conventional methods. The positions of *O. bracteosa* Hausskn. and Bornm. and *O. taurica* Pall ex Willd. in *Asterotricha* subsection were better resolved by numerical methods. Although belonging to different subsections, *O. rutila* Hub.-Mor. showed close morphological relationship to *O. roussaei* DC. In general, both (numerical and classical) classifications agreed forming in similar groupings based on morphological similarities. Newer *Onosma* key was also provided.

Key words: DFA, Numerical taxonomy, Boraginaceae, Onosma, PCA, UPGMA.

Introduction

Onosma L. belongs to the family Boraginaceae, order Boraginales. Linnaeus used the name *Onosma* as feminine inspired from Dioscorides, and several other researchers used similarly (Stearn, 1993) although the name *Onosma* is neutral in both Greek and Latin (Meikle, 1985).

The genus *Onosma* is represented by approximately by 150 species based on the reports by Al-Shehbaz (1991), El-Shazly *et al*., (2003) and Naz *et al*., (2006). However more complete studies showed that the number of species was underestimated. According to nine Floras, more than 230 *Onosma* taxa were covered (Boissier 1897, Hayek and Markgraf, 1931, Dinsmore, 1932, Tutin *et al.,* 1972, Shishkin, 1974, Riedl, 1978, Meikle, 1985, Teppner, 1991, Ge-Ling *et al.,* 1995).

The taxonomy of the genus *Onosma* in Flora of Turkey is mainly based on indumentum characteristics. The genus *Onosma* (Boraginaceae) is represented by about 110 taxa (105 species) in Turkey and the rate of endemism among native *Onosma* species is 50% (53 endemic species and a single endemic variety) (Riedl, 1978, Davis *et al.,* 1988, Yıldırımlı, 2000, Riedl *et al.,* 2005, Binzet & Orcan, 2007, Kandemir & Türkmen, 2010, Aytaç & Türkmen, 2011, Koyuncu *et al.,* 2013, Binzet, 2016a, Binzet, 2016b). After the publication of Flora of Turkey and East Aegean Islands Riedl (1978), several new *Onosma* species recorded from Turkey. These species include *O. propontica* Aznavour, *O. kaheirei* Teppner, *O. taurica* Pall. ex Willd var. *viridis* Borbas, *O. mirabilis* A. P. Khokhrjakov, *O. nydeggeri* Hub.-Mor., *O. mersinana* Riedl, Binzet and Orcan, *O. riedliana* Binzet and Orcan, *O. beyazoglui* Kandemir & Türkmen and *O. aksoyii* Aytaç & Türkmen, *O. atila-ocakii* O. Koyuncu & Yaylacı, *O. malatyana* Binzet, *O. anatolica* Binzet. The genus *Onosma* has been divided into three sections in Flora of Turkey: *Protonosma, Podonosma* and *Onosma*. *Protonosma* and *Podonosma* sections are represented by only one species each, the rest of the *Onosma* species belong to section *Onosma*. This section is further separated into two subsections based solely on indumentum type: *Asterotricha* (Boiss.) Gürke. and *Haplotricha* (Boiss.) Gürke.

The members of this genus are used as folk medicine, herbs, and dyes. Some *Onosma* species (*O. sericea* Willd., *O. microcarpa* Steven ex DC.) are used for the treatment of wounds in rural areas in Turkey (Özgen *et al.,* 2003). The flowers of some species are consumed as vegetables (Öztürk & Özçelik, 1991). Several local names of *Onosma* species were recognized as "Emzik otu-Eskişehir", "Emcek-Kemaliye-Erzincan", Yalancı havaciva ve emzik-Kemah-Erzincan" (Baytop, 1994).

Riedl (1978) pointed out that the classification of *Onosma* appeared to be partly artificial and in need of re-investigation and also stated that a new data (karyological and palynological) might provide useful reference points in the future classification of the genus. This can be easily seen in the taxonomic position of several *Onosma* species in Flora of Turkey, for example *O. taurica* and *O. bracteosa* Hausskn. and Bornm. appear in two different levels of the key for the genus *Onosma*. In order to clarify this, we aimed to apply a numerical taxonomic approach to the genus. Since numerical taxonomy has been applied earlier in the classification of different plant taxa in Turkey (see Togan *et al.,* 1983, Kence, 1988, Doğan *et al.,* 1992, Doğan & Tosunoğlu, 1992, Doğan, 1997, Tütel *et al.,* 2005), we have attempted to classify 25 *Onosma* taxa on the basis of morphological and palynological characters and compared the resulting classification with that of traditional methods.

Materials and Methods

The plant samples used in this study were collected in the field during the period of 2003-2005 by one of us (Riza Binzet) from the east Mediterranean belonging to the Mediterranean phytogeographical region in Turkey.

A total of 25 *Onosma* species belonging to *Onosma* section was collected. Among these, five species belong to subsection *Haplotricha* and the other 20 species belong to subsection *Asterotricha*. Fourteen of the 25 studied species (56%) are endemic to Turkey. The localities and the grid square system used in *Flora of Turkey* (Davis *et al.,* 1965-1988) were represented in Appendix 1.

Appendix 1. The localities of *Onosma* taxa collected according to grid square system in Flora of Turkey from Eastern Mediterranean region in Turkey.

O. sericea Willd.

C6: Hatay: İskenderun, Belen–Antakya, 4 km, Kıcı around, stone slopes, 740 m, 24.V.2004, Binzet 68; Kilis: Kilis-Gaziantep 20 km, roadside, 700 m, 36^0 53' N 037^0 21' E, 25.V.2004, Binzet 67; Gaziantep: Gaziantep-Nurdağı 30 km, roadside and underforest, 1150 m, 37^0 10' N 037^0 11' E, 26.V.2004, Binzet 62; Nurdağı, Sakcagöze around, slopes, 780 m, 37^0 10' N 036^0 55 E ', 26.V.2004, Binzet 65. Kahramanmaraş: Kahramanmaraş–Çağlayancerit, 3 km, slopes, 780 m, 37^0 36' N 036^0 49' E, 26.V.2004, Binzet 63; Osmaniye: Osmaniye-Yarpuz 16 km, roadside, rocky places, 37^0 03' N 036^0 25' E, 30.VI.2004, Binzet 69.

B6: Adana: Tufanbeyli-Saimbeyli 25 km, rocky places, 1300 m, 38^0 01' N 036^0 06' E, 28.V.2004, Binzet 66.

O. cassia Boiss.

C5: Hatay: İskenderun, Arsuz, Işıklı village-Kale village, rocky slopes and open forest, 36^0 19' N 035^0 47' E, 29.VI.2004, 150 m, Binzet 11; 24.IV.2005, Binzet 12.

O. papillosa Riedl

B6: Adana, Tufanbeyli-Saimbeyli 5 km, steppe, 1400 m, 38^0 12' N, 36^0 12' E, 28.V.2004, Binzet 20; 01.VII.2004, Binzet 2; Yeşilkent-Tufanbeyli 7 km, Kan pass around, steppeland, 1560 m, 38^0 15' N, 36^0 20' E, 16.VI.2005, Binzet 22.

O. rutila Hub.-Mor.

C4: Mersin: Silifke-Gülnar, Balandız plateau, under and open forest, roadside, stony and rocky slopes, 36^0 20' N 033^0 44' E, 14.V.2005, 820 m, Binzet 13; 14.V.2005, Binzet 14.

O. frutescens Lam.

C3: Antalya: Gazipaşa, Northern of Sugözü village, stony slopes, 36^0 25' N 032^0 27' E, 19.V.2005, 800 m, Binzet 30.

C4: Mersin: Anamur, Yukarı Kükür village, rocky slopes, 36^0 14' N 032^0 43' E, 20.V.2005, 600 m, Binzet 31; Anamur, Aşağı Kükür village-Anamur 2 km, rocky slopes, 36^0 10' N 032^0 48' E, 20.V.2005, 250 m, Binzet 32.

O. isaurica Boiss. & Heldr.

C4: Mersin: Mut-Karaman 27 km, roadside, stony slopes, 1430 m, 36^0 51' N 033^0 16' E, 19.VI.2004, Binzet 70; Karaman: Karaman-Ermenek, Southern of İhsaniye, slopes, 1700 m, 36^0 51' N 032^0 56' E, 19.VI.2004, Binzet 72; Mut-Karaman 14 km, roadside, stony slopes, 1050 m, 36^0 47' N 033^0 20' E, 19.VI.2004, Binzet 73.

C6: Kilis: Hassa-Kilis 20 km, Kazıklı village surroundings, roadside, rocky slopes, 430 m, 36^0 50' N 036^0 41' E, 25.V.2004, Binzet 71.

O. lycaonica Hub.-Mor.

C4: Mersin, Mut-Karaman, Sertavul pass, steppe, 1670 m, 36^0 54' N 033^0 16' E, 29.V.2004, Binzet 88; 19.06.2004, Binzet 89; 06.V.2005, Binzet 90.

O. bracteosa Hausskn. & Bornm.

C4: Karaman: Ermenek, Aşağıakın village–Yukarıakın village, slopes, 850 m, 36^0 52' N 033^0 00' E 19.VI.2004, Binzet 38; Mersin: Anamur-Gazipaşa 15 km, Tenzile around, roadside, under forest and open forest, 220 m, 36^0 02' N 032^0 43' E, 19.V.2005, Binzet 36; Anamur, Aşağı Kükür village-Anamur 10 km, rocky slopes, 210 m, 36^0 09' N 032^0 51' E, 20.V.2005, Binzet 37.

C5: Mersin: Arslanköy-Mersin 2 – 8 km, roadside, open field, steppe, 1450 m, 37^0 01 N ',034^0 17' E, 19.V.2005, Binzet 39.

O. stenoloba Hausskn. ex Riedl

B6: Kahramanmaraş: Göksun-Kayseri 45 km, roadside, slopesyamaç, 150 m, 38^0 21' N 036^0 26' E, 27.V.2004, Binzet 40; Kahramanmaraş-Göksun 65 km, roadside, stony and rocky slopes, 1230 m, 37^0 54'N 036^0 35'E 27.V.2004, Binzet 41; Göksun-Sarız 10 km, roadside, slopes, 1400 m, 38^0 05'N 036^0 28'E, 27.V.2004, Binzet 42; Yeşilkent-Tufanbeyli 5 km, roadside, 1600 m, 38^0 14' N 036^0 22'E, 28.V.2004, Binzet 43.

C5: Mersin: Mersin–Arslanköy, Yeniköy around, roadside, open forest, under forest, 930 m, 36^0 57'N 034^0 30'E, 11.V.2003; Binzet 45; Fındıkpınarı entrance, roadside, under forest, 1000 m, 36^0 54'N 034^0 22'E, 01.VI.2003, Binzet 46; Mersin–Arslanköy 23 km, Yeniköy around, roadside, open forest, under forest, 850 m, 36^0 58'N 034^0 29'E 01.VI.2003, Binzet 95; Çağlarca köyü – Fındıkpınarı, roadside, slopes, 1150 m, 36^0 57'N 034^0 24'E, 01.VI.2003 Binzet 47; Mersin–Arslanköy 30 km, roadside, stonyland, 1030 m, 37^0 00' N 034^0 29' E 01.VI.2003, Binzet 48; Yeniköy-Arslanköy 3 km, roadside, rocky and stony slopes, 1050 m, 37^0 00' N 034^0 29' E, 01.VI.2003, Binzet 44.

O. sieheana Hayek

C4: Karaman: Karaman-Mut 20 km, open forest, 1430 m, 37^0 01' N 033^0 16' E 06.V.2005, Binzet 33; 29.V.2005, Binzet 35; Mersin: Kırobası-Mut 8 km, roadside, 1430 m, 36^0 42' N 033^0 47'E 06.V.2005, Binzet 34.

O. mutabilis Boiss.

B6: Kahramanmaraş: Göksun-Sarız 50 km, rocky places, 1540 m, 38^0 24'N, 036^0 27'E, 27.V.2004, Binzet 7.

C5: Mersin: Gözne, Soğucak-Mersin 1 km, rocky slopes, 900 m, 36^0 57'N, 034^0 34'E, 20.IV.2004, Binzet 96; Arslanköy-Yeniköy, Southern of Çağlarca village, rocky slopes, 1200 m, 37^0 00' N, 034^0 26' E, 20.IV.2004, Binzet 97; Adana: Gülek, Fortress around, rocky places, 1550 m, 37^0 16' N 034^0 47' E, 26.VI.2004, Binzet 6.

O. alborosea Fisch. & Mey. subsp. *alborosea* var. *alborosea*

B6: Kahramanmaraş: Kahramanamaraş-Göksun 70 km, rocky places, 1500 m, 37^0 57' N 036^0 32' E, 27.V.2004, Binzet 77; Kayseri: Sarız-Göksun 5 km, roadside, slopes, rocky places, 1750 m, 38^0 34' N 036^0 26' E, 27.V.2004, Binzet 79.

Appendix 1. (Cont'd.).

C4: Mersin: Gülnar-Ermenek, Bereket tower around, roadside, rocky places, 36^0 21' N 033^0 13' E, 24.V.2003, Binzet 78; 05.VI.2004, Binzet 80; Silifke-Mut 12 km, Çobançeşmesi around, Shore of Göksu, rocky slopes, 100 m, Binzet 74; Kırobası-Silifke 20 km, rocky places, 1350 m, N 36^0 36' E 033^0 52' 06.V.2005, Binzet 75; Aydıncık, Soğuksu around, 3 m, 36^0 08' N 033^0 17' E, 19.V.2005, Binzet 76.

O. rascheyana Boiss.

C6: Kahramanmaraş: Çağlayancerit-Kahramanmaraş 8 km, roadside, stony and rocky slopes, 1550 m, $37^0$44'N $037^0$14'E, 26.V.2004, Binzet 86; Çağlayancerit-Pazarcık 15 km, roadside, stony and rocky slopes, 970 m, $37^0$42'N $037^0$25'E, 26.V.2004, Binzet 87.

O. inexspectata Teppner

C6: Osmaniye: Hasanbeyli-Fevzipaşa 2 km, slopes, open forest, 1150 m, 37^0 06' N 036^0 36' E, 25.V.2004, Binzet 3.

O. caerulescens Boiss.

C6: Kahramanmaraş: Pazarcık-Gölbaşı 20 km, roadside, open forest, 900 m, 37^0 34'N 037^0 28 E ', 27.V.2004, Binzet 2.

O. taurica Pallas ex Willd. var. *taurica*

C4: Mersin: Gülnar-Ermenek 8-10, Ulutu village, Döşeme around, roadside, 1150 m, 37^0 06'N 034^0 41'E, 24.V.2003, Binzet 4.

C6: Hatay: Antakya-Yayladağı 42 km, roadside, slopes, 760 m, 35^0 54'N 036^0 06' E, 25.V.2004, Binzet 5.

O. O. angustissima Hausskn. & Bornm.

C3: Antalya: Gazipaşa, Sugözü plateau, rocky places, 1230 m, 36^0 26' N 032^0 28' E, 19.V.2005, Binzet 59.

C4: Mersin: Anamur, Abanoz plateau-Bardat plateau, Fersakan around, 1300 m, 36^0 21'N 032^0 49'E, 20.05.2005, Binzet 58.

C5: Adana: Gülek, Fortress around, stony and rocky slopes, 1430 m, 37^0 16' N 034^0 47' E, 26.VI.2004, Binzet 60; Gülek, Fortress around, stony and rocky slopes, 1550 m, 37^0 16' N 034^0 47' E, 26.VI.2004, Binzet 61.

O. bornmuelleri Hausskn.

C5: Mersin: Çağlarca village-Fındıkpınarı, under forest, open forest, roadside, 1270 m, 36^0 57' N 034^0 24' E 01.VI.2003, Binzet 94; northern of Çağlarca village, roadside, 1030 m, 37^0 00' N 034^0 26' E 01.VI.2003, Binzet 92; western of Çağlarca village, open forest, roadside, slopes, 1070 m, 37^0 00' N 034^0 26' E, 01.VI.2003, Binzet 91; Mersin–Arslanköy 25 km, roadside, under forest, 850 m, 36^0 58' N 034^0 29' E, 01.VI.2003, Binzet 93.

O. aucherana DC.

C4: Mersin: Gülnar-Ermenek 8 km, roadside, 1100 m, 24.V.2003, Binzet 8; Gülnar-Ermenek, Erik deresi aroundopen field, under forest, 1350 m, 36^0 28' N 033^0 01' E, 24.V.2003, Binzet 98; Gülnar-Ermenek 11 km, roadside, 1100 m, 36^0 21' N 033^0 18' E, 24.V.2003, Binzet 9; Gülnar-Ermenek 5 km, roadside, 1100 m, 36^0 21' N 033^0 18' E, 24.V.2003, Binzet 10.

O. roussaei DC.

C4: Mersin: Gülnar-Sütlüce, rocky places, 1230 m, 36^0 23' N 033^0 27' E, 14.V.2005, Binzet 27; Gülnar-Ermenek 27 km, roadside, under forest, open forest, rocky places, 1400 m, 36^0 24' N 033^0 10' E, 05.VI.2004, Binzet 28; Silifke-Gülnar, Balandız plateau, Çuvanın area, rocky places, 1160 m, 36^0 20' N 033^0 35' E, 14.V.2005, Binzet 29.

O. armena DC.

C4: Mersin: Silifke–Mut 30 km, roadside, open forest, 130 m, 36^0 28'N 033^0 37'E, 08.VI.2003, Binzet 83; Mut-Kırobası 10 km, open field, roadside, 560 m, 36^0 40'N 033^0 28'E, Binzet 84; Mut–Gülnar 40 km, roadside, open forest, 1000 m, 08.VI.2003, Binzet 85; Silifke–Mut 40 km, roadside, open forest, 270 m, 36^0 29' N 033^0 36' E, 06.V.2005, Binzet 82; Karaman: Ermenek-İhsaniye, roadside, slopes, 1670 m, 36^0 46' N 032^0 53' E, 19.VI.2004, Binzet 81.

O. auriculata Aucher ex DC.

C4: Mersin: Mut–Silifke 25 km, slopes, 130 m, 36^0 31' N 033^0 30' E, 08.VI.2003, Binzet 15; Mut–Silifke 7 km, slopes, 230 m, 36^0 35' N 033^0 25' E, 06.V.2005, Binzet 16.

O. gigantea Lam.

B6: Adana: Saimbeyli-Feke, roadside, under forest, 1180m, 37^0 51' N 035^0 57' E, 28.V.2004, Binzet 56; Kahramanmaraş: Kahramanmaraş-Göksun 68 km, roadside, slopes, 1280 m, 37^0 55' N 036^0 34' E, 01.VII.2004, Binzet 51.

C4: Mersin: Mut, Çampınar-İhsaniye 3 km, roadside, landslide area, 850 m, 36^0 52' N 033^0 02' E, 19.VI.2004, Binzet 50.

C5: Mersin: Mersin-Fındıkpınarı, Cemilli village around, roadside, open field, 36^0 48' N 034^0 26' E 27.V.2004, Binzet 49.

C6: Osmaniye: Hasanbeyli-Bahçe (Kalecik), roadside, 700 m, 37^0 09' N 036^0 28' E, 25.V.2004, Binzet 53; Kahramanmaraş: Kahramanmaraş-Göksun 14 km, roadside, slopes, 470 m, 37^0 36' N 036^0 46 E ', 27.V.2004, Binzet 55; Adana: Karaisalı, Hacılı village around, roadside, 240 m, 37^0 16' N 035^0 07' E, 28.V.2004, Binzet 54; Osmaniye: Yarpuz-Hasanbeyli 15 km, roadside, 750 m, 37^0 06' N 036^0 28' E, 30.VI.2004, Binzet 52; Kahramanmaraş: Kahramanmaraş-Çağlayancerit 25 km, slopes, open forest, 850m, 37^0 35' N 037^0 05' E, 16.VI.2005, Binzet 57.

O. mersinana Riedl, Binzet & Orcan

C5: Mersin: Müğlü deresi around, rocky slopes, 1100 m, 36^0 49' N 034^0 16' E, 15.VI.2001, Binzet 19; 05.VI.2005, Binzet 17; 07.V.2003, Binzet 18; 04.V.2004, Binzet 99.

O. riedliana Binzet & Orcan

C4: Mersin: Gülnar-Sütlüce, rocky places, 1230 m, 36^0 23' N 033^0 27' E, 14.V.2005, Binzet 23; Gülnar-Ermenek 42 km, roadside, open field, 1300 m, 36^0 26' N 033^0 06' E, 05.VI.2004, Binzet 24; 24.V.2003, Binzet 25; 05.VI.2004, Binzet 26.

Table 1. List of metric characters used in numerical taxonomic analysis (in mm except for 2,5,10,17).

1.	Plant length
2.	The number of rays of stellate hairs in stems
3.	Length of basal leaves
4.	Width of basal leaves
5.	The number of rays of stellate hairs in basal leaves
6.	Length of setae on basal leaves
7.	Length of stellate on basal leaves
8.	Length of stem leaves
9.	Width of stem leaves
10.	The number of rays of stellate hairs in stem leaves
11.	Length of setae on stem leaves
12.	Length of stellate on stem leaves
13.	Length of bracts
14.	Width of bracts
15.	Length of pedicel (in anthesis)
16.	Length of pedicel (in nuks)
17.	Number of flower each cymes
18.	Length of calyx (in anthesis)
19.	Width of calyx (in fruit)
20.	Length of corolla
21.	Width of corolla (widest point below lobes)
22.	Length of lobes of corolla
23.	Width of lobes of corolla (at base)
24.	Length of anther
25.	Width of anther
26.	Length of filament
27.	Length of style
28.	Width of style
29.	Length of nutlets
30.	Width of nutlets

Only adult and flowering plants were included in the present study. Qualitative and Quantitative (measurements) data were made on at least 10 samples and the character averages were calculated. Total number of specimens was more than 300 and all the materials used in this study were stored in the Department of Biology, Faculty of Arts and Sciences at Mersin University.

Two data sets were prepared; the first data matrix was formed by the 30 metric measurements of morphological characters (Table 1, Appendix 2) and the second data matrix formed by the 60 non-metric morphological characters (presence:1, absence:0 or character states:0-7) belonging to *Onosma* taxa (Table 2, Appendix 3). In the Discriminant Function Analysis, 25 *Onosma* taxa with 10 samples each were analysed with 25 morphometrical characters (Subsection *Haplotricha* has only 25 morphometrical characters) by using SPSS 13 (2004). The averages of metric measurements were standardised so that the new character data set has a new distribution with mean 0 and the standard deviation 1. Morphometric similarity was calculated and the phenograms were constructed by using the UPGMA (Unweighted, pair-group method using arithmetic averages) method. Later Principle Component Analysis was applied by using NTSYS-pc package program (Rohlf, 2004).

Results

Numerical taxonomic analysis of the genus *Onosma* in east Mediterranean region in Turkey was carried out using 30 metric and 60 non-metric morphological characters (Appendices 2 and 3). The results of the Discriminant Function Analysis, Principal Component Analysis and UPGMA phenogram were compared with the classical *Onosma* classification in Turkey.

Discriminant Function Analysis (DFA): DFA was only applied to 25 morphometrical characters of *Onosma* taxa. All characters showed statistical significant differences between *Onosma* species ($p<0.001$). Relative positions of each species were displayed in a scatterplot in DFA (Fig. 1). All species were 100% distinguishable between each other. Moreover the biggest taxa in size, *O. gigantea* Lam. and *O. auriculata* DC. were well separated from the larger group. However, two subsections were not clearly separated from each other. Four species belonging to Subsection *Haplotricha* were visualized on the lower right part of the scatterplot. *O. papillosa* Riedl the fifth member of the *Haplotricha* subsection was located far away from the group that it actually belonged.

Total variation in DFA was explained by 20 components. The first three discriminant factors explained 66.5% of the total variation. The first factor explained 31.7%, the second and third factors explained 17.8% and 17.0% of the variation respectively. In the DFA, in the first and second axes (factors), mostly flower and nutlet characteristics were highly loaded. In the third axes flower, calyx and basal leaves were heavily weighted.

Principal Component Analysis (PCA) and UPGMA phenogram: This analysis was applied to both metric and non-metric morphometric characteristics. The metric measurements were averaged and the standardised data were used in PCA and the UPGMA clustering. The results obtained from both analyses were presented separately for clarity.

Metric variables: A total of 30 morphometrical variables were used and the variation was explaind by a total of 18 vectors. The first three vectors explained 51.38% of the variation and in detail, the first, the second and the third vectors explained 20.38%, 18.48% and 12.51% of the variation respectively. PCA indicated that different data sets of characters displayed differential character loadings in three vectors (Table 3). In the first vector, the flower characteristics were highly loaded. On the other hand, in the second vector mainly indumentum, pedicel and nutlets characteristics were found highly discriminative. In the last third vector, mainly indumentum characteristics played an important role in the separation of the groups.

Appendix 2. The data matrix of metric characters used in the numerical taxonomy.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**3**
										0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
O. angustissima	249.1	21.6	83.6	5.8	15.3	1.8	0.4	33.8	6.9	18.2	1.0	0.4	16.4	7.2	1.7	2.0	14.0	8.3	10.6	21.8	7.6	1.9	3.0	8.0	0.8	18.9	26.3	0.3	3.8	2.7
O. aucherana	237.3	7.8	31.4	3.9	13.6	1.8	0.6	30.6	3.3	14.1	2.6	0.3	13.8	2.7	1.0	3.3	15.1	10.1	11.4	19.0	7.4	1.7	2.4	7.6	1.1	14.5	20.9	0.3	3.0	2.5
O. bracteosa	279.1	8.4	34.6	3.7	10.3	1.8	0.5	30.8	4.7	10.3	1.5	0.3	13.6	3.8	1.9	4.8	16.2	11.4	19.6	22.0	8.2	1.8	3.0	8.0	0.8	17.2	26.1	0.5	2.7	1.8
O. cassia	354.5		51.4	10.9		1.7		45.8	19.8		1.5		12.9	4.3	6.0	8.8	13.5	10.7	15.7	15.1	5.6	1.0	1.5	7.6	0.8	11.3	17.2	0.3	4.2	4.6
O. frutescens	348.2		6.1	11.6		2.6		36.3	10.4		1.5		10.3	5.5	4.2	7.9	12.7	10.7	14.4	14.7	5.7	1.8	1.3	9.1	0.7	12.0	19.9	0.2	4.0	3.0
O. inexspectata	214.5	7.2	18.9	7.1	20.5	1.6	0.4	30.9	4.8	13.2	1.0	0.3	16.2	4.3	1.8	1.8	13.6	13.3	15.0	18.1	6.5	1.2	2.5	7.6	0.9	14.3	22.0	0.4	3.0	2.5
O. isaurica	262.7	10.4	5.3	13.7	20.1	1.9	0.3	5.7	9.8	11.4	1.7	0.3	17.3	7.4	3.3	8.8	11.9	11.8	24.3	20.5	7.2	1.5	3.1	9.1	1.0	16.3	24.2	0.3	4.4	3.3
O. lycaonica	75.5	9.5	32.9	3.9	13.1	2.0	0.4	25.5	3.3	8.1	1.8	0.3	13.2	4.3	1.6	2.8	9.2	11.2	9.3	20.6	8.6	1.5	2.5	7.4	0.8	17.5	24.9	0.3	3.0	2.0
O. mutabilis	252.7	25.5	4.4	1.1	40.0	1.6	0.7	32.5	7.9	22.1	1.7	0.7	17.8	8.6	3.6	7.1	8.7	16.3	19.8	23.3	11.0	1.8	3.3	8.4	0.8	17.1	25.5	0.3	5.2	4.3
O. rascheyana	203.6	8.3	30.7	5.9	23.3	2.1	0.4	26.2	5.6	21.9	1.9	0.6	20.4	7.8	2.1	2.7	16.7	16.5	23.8	21.3	6.3	1.3	2.0	9.1	0.8	16.5	26.7	0.3	5.0	3.0
O. riedliana	268.2	13.5	4.3	4.1	12.9	2.0	0.4	40.8	6.3	8.6	3.0	0.4	14.3	6.1	2.6	3.1	13.0	14.7	17.5	15.1	6.0	1.0	1.8	7.0	0.6	13.6	18.2	0.4	2.5	2.0
O. sericea	362.7		57.3	11.3		1.3		56.3	9.9		1.6		13.4	4.9	3.9	7.2	8.7	12.5	25.6	18.3	7.5	2.0	2.5	9.6	1.0	14.7	21.6	0.4	4.8	3.9
O. sieheana	161.6	13.0	54.1	5.6	23.2	1.0	0.5	43.2	5.2	13.4	1.5	0.3	30.0	7.1	1.6	3.3	11.1	10.5	11.1	20.2	9.7	1.8	3.7	7.0	0.8	15.8	23.7	0.5	3.0	2.6
O. stenoloba	278.2	8.0	21.2	3.6	17.5	1.7	0.4	35.1	4.2	13.3	1.2	0.3	16.8	4.9	2.4	4.2	10.7	13.0	14.7	16.0	7.0	1.8	2.8	7.0	0.9	11.6	19.2	0.4	2.8	2.2
O. papillosa	269.1		50.0	3.5		4.9		46.0	3.8		4.1		20.7	4.0	1.7	3.4	16.5	16.0	18.9	23.5	9.4	1.5	3.0	9.0	0.9	17.4	28.3	0.6	4.0	2.5
O. alborosea	196.4	15.3	42.8	6.9	25.0	1.8	0.5	38.8	4.5	16.3	1.7	0.4	17.1	3.1	3.3	6.7	5.2	14.2	23.1	25.7	7.3	2.6	3.5	8.7	0.9	20.4	28.1	0.5	6.4	4.5
O. armena	257.3	27.3	16.2	2.6	29.0	1.6	0.5	19.3	3.3	25.8	2.4	0.3	13.0	2.5	2.6	2.6	15.1	10.6	17.8	18.4	7.2	1.5	2.8	7.6	0.9	13.9	23.6	0.4	3.0	2.3
O. auriculata	489.1	16.5	84.6	14.7	11.8	1.8	0.5	66.3	8.4	10.3	2.3	0.4	28.8	7.1	8.8	12.3	28.6	10.9	17.4	18.5	7.7	2.0	3.0	7.6	1.0	13.6	20.3	0.4	4.3	3.3
O. bornmuelleri	235.5	6.5	26.8	4.0	13.0	1.5	0.4	3.3	4.6	14.3	1.8	0.3	11.3	3.9	1.6	4.0	19.6	12.9	12.8	26.1	9.2	1.5	4.0	8.6	0.9	20.5	28.8	0.5	2.8	2.5
O. caerulescens	254.5	11.3	3.5	5.6	25.6	2.8	0.4	8.1	6.7	12.4	2.2	0.3	23.5	8.7	3.3	7.6	15.3	10.7	21.8	16.4	8.5	1.0	2.7	7.4	0.9	12.7	20.5	0.4	4.0	3.0
O. gigantea	786.4	16.5	23.3	1.3	19.5	2.0	0.5	18.0	11.6	13.6	2.0	0.5	7.1	9.0	7.7	9.8	25.7	10.8	9.4	15.7	7.4	2.0	3.0	6.3	0.8	12.8	17.9	0.4	3.6	2.1
O. mersinana	216.4	8.8	19.8	3.3	13.1	1.4	0.4	31.8	3.9	9.7	1.3	0.3	18.3	7.6	2.2	4.3	13.2	11.4	13.9	18.6	6.0	1.3	2.0	6.2	0.6	13.7	18.5	0.4	3.0	2.0
O. roussaei	180.9	35.7	18.7	3.6	41.2	1.9	0.4	27.8	4.6	44.8	1.3	0.4	12.5	3.0	2.9	3.1	9.7	8.0	9.2	14.6	6.0	1.3	2.1	6.9	1.0	10.6	17.5	0.3	3.4	2.5
O. rutila	224.5		30.6	8.7		2.0		22.7	7.3		1.5		13.8	3.6	4.1	8.1	14.4	7.8	11.9	14.3	5.0	1.5	1.8	6.5	0.8	11.5	17.4	0.3	3.5	3.0
O. taurica	243.6	18.0	6.0	4.2	21.8	1.0	0.4	33.0	4.2	17.0	1.4	0.4	20.4	4.3	2.8	2.8	9.4	7.6	11.5	22.0	7.5	1.3	3.4	7.0	0.7	17.4	22.0	0.5	3.3	3.2

Table 2. List of non-metrical characters used in numerical taxonomic analysis.

1- Habitat rocky: 1, other habitats: 2
2- Setae hairs present on stem: 1, Setae hairs not present on the stem: 2
3-Setae on stem adpressed: 1, ± adpressed: 2, patent: 3, ± patent: 4
4-Stellat hairs present on stem: 1, Stellate hairs not present on the stem: 2
5-Surface of stem hairs (except for setae and stellate hairs): 1, Surface of stem glabrous autside setae and stellate hairs: 2, Surface of stem ± hairs (except for setae and stellate hairs): 3
6- Surface of stem hairs is adpressed (except for setae and stellate hairs):1
Surface of stem hairs is ± adpressed (except for setae and stellate hairs): 2
Surface of stem hairs is patent (except for setae and stellate hairs): 3
Surface of stem hairs is ± patent (except for setae and stellate hairs): 4
7-Margin of basal leaves revolute: 1, not revolute: 2, ± revolute: 3
8- Setae hairs present on stem leaves: 1, Setae hairs not present on the stem leaves: 2
9- Setae on stem leaves adpressed: 1, ± adpressed: 2, patent: 3, ± patent: 4
10-23: Shape of basal leaves
10-linear-obovate: 1, not linear-obovate: 0
11-oblanceolate-spathulate: 1, not oblanceolate-spathulate: 0
12-linear-spathulate: 1, not linear-spathulate: 0
13-oblong-spathulate: 1, not oblong-spathulate: 0
14-lanceolate-oblanceolate: 1, not lanceolate-oblanceolate: 0
15-oblanceolate-narrow obovate: 1, not oblanceolate-narrow obovate: 0
16-linear, linear-lanceolate: 1, not linear and linear-lanceolate: 0
17-spathulate, oblong-spathulate: 1, not spathulate and oblong-spathulate: 0
18-spathulate-linear lanceolate: 1, not spathulate-linear lanceolate: 0
19-spathulate-obovate: 1, not spathulate-obovate: 0
20-oblong-obovate: 1, not oblong-obovate: 0
21-spathulate: 1, not spathulate: 0
22-lanceolate-oblong: 1, not lanceolate-oblong: 0
23-obovate, lanceolat-spathulate: 1, not obovate and lanceolat-spathulate: 0
24- Surface of basal leaves hairs (except for setae and stellate hairs): 1, Surface of basal leaves glabrous (except for setae and stellate hairs): 2
25- Hairs on basal leaves is adpressed autside setae and stellate hairs: 1
Hairs on basal leaves is ± adpressed (except for setae and stellate hairs): 2
Hairs on basal leaves is patent (except for setae and stellate hairs): 3
Hairs on basal leaves is ± patent (except for setae and stellate hairs): 4
26- Basal leaves petiolate: 1, basal leaves sessile: 2, ± basal leaves petiolate: 3
27- Margin of stem leaves revolute: 1, not revolute: (2) ± revolute: 3
28- Setae hairs present on stem leaves: 1, Setae hairs not present on the stem leaves: 2
29- Setae on stem leaves adpressed: 1, ± adpressed: 2, patent: 3, ± patent: 4
30-41: Shape of stem leaves
30-linear-obovate: 1, not linear-obovate: 0
31-oblanceolate-spathulate: 1, not oblanceolate-spathulate: 0
32-linear-spathulate: 1, not linear-spathulate: 0
33-oblong-spathulate: 1, not oblong-spathulate: 0
34-lanceolate-oblanceolate: 1, not lanceolate-oblanceolate: 0
35-oblanceolate-narrow obovate: 1, not oblanceolate-narrow obovate: 0
36-linear, linear-lanceolate: 1, not linear and linear-lanceolate: 0
37-spathulate, oblong-spathulate: 1, not spathulate and oblong-spathulate: 0
38-spathulate-linear lanceolate: 1, not spathulate-linear lanceolate: 0
39-spathulate: 1, not spathulate: 0
40-lanceolate-oblong: 1, not lanceolate-oblong: 0
41-obovate, lanceolate-spathulate: 1, not obovate and lanceolate-spathulate: 0
42- Surface of stem leaves hairs (except for setae and stellate hairs): 1, Surface of stem leaves glabrous (except for setae and stellate hairs): 2
43- Hairs on stem leaves is adpressed (except for setae and stellate hairs): 1
Hairs on stem leaves is ± adpressed (except for setae and stellate hairs): 2
Hairs on stem leaves is patent (except for setae and stellate hairs): 3
Hairs on stem leaves is ± patent (except for setae and stellate hairs): 4
44- Stem leaves petiolate: 1, stem leaves sessile: 2, ± stem leaves petiolate: 3
45- Inflorescence 1-2 terminal cymes: 1, 2-3 cymes: 2, 1-3 terminal cymes: 3
Cymes very numerous, forming a corymb: 4, Cymes numerous, forming a compact panicle: 5, 1-5 cymes: 6, subcorymbose: 7, very numerous terminal and lateral cymes: 8
46-51: Shape of corolla
46-Cylindrical: 1, not cylindrical: 0
47-tubular: 1, not tubular: 0
48-campanulate: 1, not campanulate: 0
49-subcylindrical: 1, not subcylindrical: 0
50-subcylindrical-campanulate: 1, not subcylindrical-campanulate: 0
51-clavate-campanulate: 1, not clavate-campanulate: 0
52- Corolla glabrous: 1, hairs: 2
53- Color of corolla changes with age: 1, does not change wiyh age: 2, ± changes with age: 3
54- Shape of apex anther emarginate: 1, acute: 2
55- Anthers exserted: 1, included: 2, ± exserted: 3
56-60: Apex of nutlets
56-acute: 1, not acute: 0
57-acuminate: 1, not acuminate: 0
58-cuspidate: 1, not cuspidate: 0
59-obtuse: 1, not obtuse: 0
60-subacute: 1, not subacute: 0

Appendix 3. The data matrix of non-metric characters used in the numerical taxonomy.

	1	2	3	4	5	6	7	8	9	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	6
										0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
O. angustissima	1	1	1	1	0	2	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0		1	2	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0		1	1	0	0	1	0	0	0	0	2	1	0	0	1	0	0	0
O. aucherana	1	1	3	1	1	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0		1	2	1	0	0	0	0	0	0	0	0	0	1	0	0	0		1	3	1	0	1	0	0	0	0	2	1	0	1	1	0	0	0
O. bracteosa	1	1	3	1	1	4	1	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0		2	0	1	3	0	0	0	0	0	0	1	0	0	0	0	0	0		1	3	1	1	1	0	0	0	0	2	1	0	0	1	1	0	0
O. cassia	1	1	3	2	1	3	2	1	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	2	1	3	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	7	0	0	0	1	0	0	1	2	1	0	0	0	0	0	1
O. frutescens	1	1	3	2	1	3	2	1	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	2	1	3	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	6	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0
O. inexspectata	1	1	3	1	1	1	1	1	3	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0		1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0		1	1	0	0	0	0	0	1	0	1	1	2	0	1	0	0	0
O. isaurica	1	1	2	1	1	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		1	2	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0		0	0	0	0	1	0	0	0	0	2	1	0	0	1	0	0	0
O. lycaonica	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0		1	1	0	0	0	0	0	1	0	0	1	0	1	1	0	0	0
O. mutabilis	0	0	3	1	1	4	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0		0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0		1	2	1	0	1	0	0	0	0	1	1	0	0	1	0	0	0
O. rascheyana	1	1	3	1	1	4	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0		1	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0		1	1	0	0	0	0	0	1	0	1	1	2	1	0	0	0	0
O. riedliana	1	1	3	1	1	2	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		2	0	1	3	0	1	0	0	0	0	0	0	0	0	0	0	0		1	2	1	0	0	1	0	0	0	2	1	2	0	1	0	0	0
O. sericea	1	1	1	2	1	1	2	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	0	2	1	2	1	1	0	0	0
O. sieheana	1	1	1	1	1	4	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		1	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0		1	1	0	0	1	0	0	0	0	2	1	2	1	1	0	0	0
O. stenoloba	1	1	3	1	1	1	1	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0		1	0	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0		1	3	1	1	0	0	0	0	1	2	1	2	1	1	0	0	0
O. papillosa	1	1	3	2	1	3	0	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	3	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1	0	0	0	2	1	0	0	1	0	0	0
O. alborosea	0	0	3	1	2	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0		1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0		1	3	0	0	0	0	0	1	0	1	1	0	1	1	0	0	0
O. armena	1	1	3	1	1	1	1	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0		1	3	1	0	1	0	0	0	0	2	1	0	0	1	0	0	0
O. auriculata	1	1	3	1	2	0	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0		1	2	1	3	0	0	0	0	0	0	1	0	0	0	0	0	0		1	5	1	0	1	0	0	0	1	2	1	0	1	0	0	0	0
O. bornmuelleri	1	1	3	1	1	2	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		1	2	1	3	0	0	0	1	1	0	0	0	0	0	0	0	0		1	1	0	0	1	0	0	0	0	2	1	2	0	0	1	0	0
O. caerulescens	1	1	3	0	1	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0		1	2	1	3	0	0	0	0	0	0	0	1	0	0	0	0	0		1	1	1	0	0	0	0	0	1	1	1	0	0	1	0	0	0
O. gigantea	1	1	3	1	2	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		1	2	1	3	0	0	0	0	1	0	0	0	0	0	0	0	0		1	4	1	0	1	0	0	0	0	2	1	0	1	0	0	0	0
O. mersinana	1	1	0	1	1	2	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0		2	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0		1	1	0	0	0	0	1	1	1	2	1	0	0	1	0	1	0
O. roussaei	0	1	3	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		2	0	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0		1	1	0	0	0	0	0	0	0	0	1	2	0	0	1	0	0
O. rutila	1	1	3	2	1	3	0	1	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	2	1	3	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	3	1	0	1	0	0	0	1	1	1	0	0	0	0	0	0
O. taurica	1	1	1	1	2	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0		1	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0		1	1	0	0	1	0	0	0	1	2	1	0	1	1	0	0	0

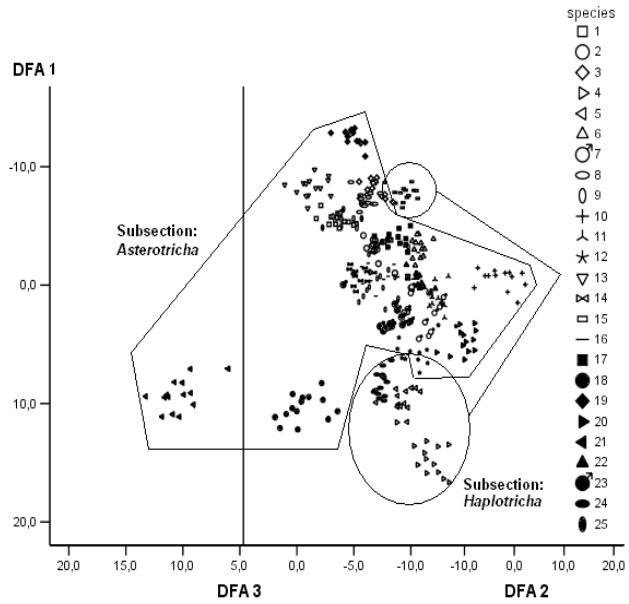

Fig. 1. DFA scatter plot of 25 *Onosma* taxa. 1- *O. angustissima*, 2-*O. aucherana*, 3-*O. bracteosa*, 4-*O. cassia*, 5-*O. frutescens*, 6-*O. inexspectata*, 7-*O. isaurica*, 8-*O. lycaonica*, 9-*O. mutabilis*, 10-*O. rascheyana*, 11-*O. riedliana*,12-*O. sericea*, 13-*O. sieheana*, 14-*O. stenoloba*, 15-*O. papillosa*, 16-*O. alborosea*, 17-*O. armena*, 18-*O. auriculata*, 19-*O. bornmuelleri*, 20-*O. caerulescens*, 21-*O. gigantea*, 22-*O. mersinana*, 23-*O. roussaei*, 24-*O. rutila*, 25-*O. taurica* var. *taurica*

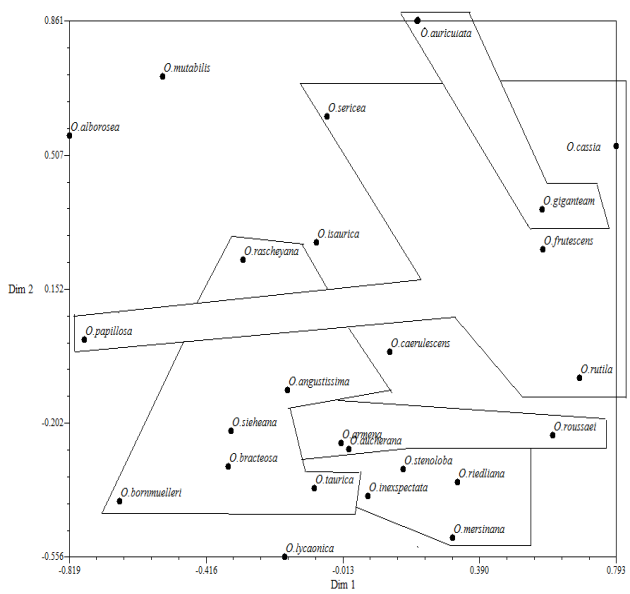

Fig. 2. PCA of metric morphometrical characters.

When groupings were projected on the 2-dimensional scatterplot (Fig. 2), new clusters were formed that clarified the positions of *O. bracteosa* and *O. taurica*. The general grouping was very similar to what we obtained in DFA of the metric variables. In both scatterplots *O. gigantea* and *O. auriculata* were very close to each other. As in DFA, subsection *Haplotricha* displayed similar clustering in that *O. papillosa* was away from the major group. *O. bracteosa* has close morphological relationships to *O. sieheana* Hayek, *O. taurica*, *O. angustissima* Hausskn. and Bornm. and *O. bornmuelleri* Hausskn. and Bornm.. The importance of this grouping is that, it clarified the position of two taxa whose relationships were not very clear in conventional taxonomy, because *O. taurica wa*s mentioned twice in the key of the genus *Onosma*, and similarly *O. bracteosa* which was mentioned three times in the same key. Thus in this study, we obtained *O. taurica* was closest to *O. sieheana, O. angustissima, O. bracteosa* and *O. bornmuelleri* but not to *O. isaurica*, Boiss. and Heldr., *O. lycaonica* Hub.-Mor., *O. mutabilis* Boiss. and Hausskn. ex Boiss. and *O. alborosea*.

The dendrogram constructed from the UPGMA clustering using general distance as the similarity coefficient is displayed in Fig. 3. Similar groupings were visualized as in the DFA and in the PCA. *O. taurica* and *O. bracteosa* have similar affinities to other *Onosma* species. One interesting group was visualized between *O. roussaei* DC. and *O. rutila* Hub.-Mor. which actually were close to each other in all of the analysis. These two species were found in Mersin, so there is a geographic proximity and this similarity was also found in DFA, PCA and UPGMA.

Non-metric variables: A total of 60 non-metrical variables was utilized and the total variation was explained by a total of 21 vectors. The first three vectors explained 33.77% of the total variation which was lower than that of the metric variables and the first, the second and the third axes explained 14.51%, 10.60% and 8.66% of the variation respectively. Different non-metric characters have different loadings on the three axes (Table 4). In the first axes indumentum and flower characteristics were highly loaded. In the second axes mainly indumentum and shape of leaves have a high loadings. In the third axes, indumentum, flower and leaf shape characteristics played an important role in the discrimination of the groups.

PCA resulted in two goupings according to subsections of the section *Onosma* as *Haplotricha* and *Asterotricha* (Fig. 4). We did not obtained any detailed groupings as were obtained in PCA and DFA of the metric variables.

Similar to PCA of non-metric characters, UPGMA dendrogram constructed using the same data set resulted in the same subsection groupings (Fig. 5) as *Haplotricha* and *Asterotricha*. In general, these groupings were more similar to conventional classification of the genus *Onosma*.

Revised taxonomic key for the identification of 25 *Onosma* species in east mediterranean region: During data formation both metric and non-metric characters as well as pollen characters (Binzet *et al.*, 2010) revealed a relatively newer identification key to the genus *Onosma*. 25 *Onosma* species from east Mediterranean region in Turkey can be distinguished by the morphological and palynological characters as shown in the following key.

Partially revised key to *Onosma* subsection *Haplotricha* (Boiss.) Gürke. and *Asterotricha* (Boiss.) Gürke. Riedl (1978) in Turkey.

Table 3. Summary of character loadings (highest 5) on the three axes.

Metric characters	Axis1	Axis 2	Axis 3
Plant Length			0.427
Number of rays of stellate in stem			-0.670
Number of rays of stellate in basal leaves			-0.865
Number of rays of stellate hairs in stem leaves			-0.859
Length of stellate on stem leaves		0.697	
Length of pedicel at anthesis		0.712	
Legth of pedicel at nuks		0.759	
Number of flower in each cymes			0.632
Length of corolla	-0.936		
Width of corolla (widest point below lobes)	-0.740		
Width of lobes of corolla (at base)	-0.732		
Length of filament	-0.893		
Length of style	-0.938		
Length of nutlets		0.826	
Width of nutlets		0.794	

Table 4. Summary of non-metric character loadings (first 5 highest loadings) on three axes.

Non-metric characters	Axes 1	Axes 2	Axes 3
Setae hairs present on stem			0.626
Setae position on stem	0.596		
Stellate hairs present on stem		0.775	
Setae position on basal leaves	0.616		
Shape of basal leaves		0.706	0.617
Indumentum of basal leaves (except for setae and stellate hairs)		0.799	
Setae hairs present on stem leaves			0.626
Setae position on stem leaves	0.596		
Shape of stem leaves		0.706	0.717
Indumentum of stem leaves (except for setae and stellate hairs)		0.799	
Inflorescence	0.621		
Shape of corolla	0.677		0.617

1. Setae on leaves arising from glabrous (stellate hairs are absent) (indumentum haplotrichous) …… ..... Group A
2. Setae on leaves arising from stellate setuled tubercles (stellate hairs are present) (indumentum asterotrichous) ……. …… Group B

Taxonomic identification key for *Onosma* species in the group A:
Group with indumentum *Haplotrichous*

1. + Anthers exserted for more than ½ their length, sterile apex of anthers are acute …… ……. *O. frutescens*
   - Anthers included, or sterile apex exserted, sterile apex of anthers are emarginated ..…….. 2
2. + Calyx lobes united at base, 20-30 mm in nuks, with adpressed setae at base ……..…… ……..……..... *O. sericea*
   - Calyx divided to base, 10-20 mm, with patent setae at base ……..... 3
3. + Corolla 22-24 mm, hairy, upper surfaces of leaves setae and papillose, beneath surface of leaves papillose (except for setae only margins and midrib) ……..…… *O. papillosa*
   - Corolla 13-16 mm, glabrous, leaves with setae on both surfaces ……..... 4
4. + Calyx 10-12 mm in flower, corolla yellow, cauline leaves 20-70 x 10-30 mm ……..... *O. cassia*
   - Calyx 6-8 mm in flower, corolla yellow and ½ toward apex reddish, cauline leaves 10-35 x 3-10 mm ……. ……..……..... *O. rutila*

Taxonomic identification key for *Onosma* species in the group B:
Group with indumentum *Asterotrichous*

1. Biennials, with a single flowering stem, basal leaves 4-30 x 0.7-1.8 cm, cauline leaves 3-25 x 0.5-1.4 cm
2. Stellate hairs with 15-23 rays on basal leaves, cauline leaves 8-25 cm, bracts 2-9 cm, calyx 7-8 mm in flower, -10 in fruit, corolla -17 mm, hairy …… *O. gigantea*
2. Stellate hairs with 8-15 rays on basal leaves, cauline leaves 3-10 cm, bracts 1-4 cm, calyx 8-11 mm in flower, -19 in fruit, corolla 15-20 mm, glabrous ……..... *O. auriculata*
1. Biennials or perennials, often with several flowering stems, basal leaves 1-10 x 0.1-2 cm, cauline leaves 1-8 x 0.2-1.5 cm
3. Color of corolla changes with age, corolla hairy
4. Corolla white or pale blue at first, becoming pink or purple and finally bluish-violet, calyx 10-25 mm in flower, nutlets 4-7 x 3-5 mm
5. Corolla 20-25 mm, corolla lobes 1-1.5 mm, beak of nutlets weakly curved …….. *O. rascheyana*
5. Corolla 22-30 mm, corolla lobes 1.5-3 mm, beak of nutlets not curved
6. Cauline shortt hairy (except setae and stellate hairy), corolla 20-25 mm, corolla lobes 1.5-2 mm ……..... *O. mutabilis*
6. Cauline glabrous (except setae and stellate hairy), corolla 22-30 mm, corolla lobes 2-3 mm …… *O. alborosea*
4. Color of corolla not as above, calyx 6-12 mm in flower, nutlets 3.5 x 2.5 mm
7. Corolla yellow, apex turning brick red, 14-17 mm, setae on basal leaves adpressed or patent
8. Stellate hairs on cauline leaves with 5-15 rays, pedicels -9 mm in fruit …….. *O. caerulescens*
8. Stellate hairs on cauline leaves with 40-50 rays, pedicels -4 mm in fruit ……... *O. roussaei*
7. Corolla pale reddish-orange finally turning blue, 15-20 mm, setae on basal leaves patent ……..... *O. inexspectata*
3. Color of corolla not changing with age, corolla hairy or glabrous
9. Stem 5-11 cm, basal leaves hairy (except setae and stellate hairs) …… *O. lycaonica*
9. Stem 10-40 cm, basal leaves glabrous (except setae and stellate hairs)
10. Calyx 6-10 mm in flower
11. Stellate hairs with 3-10 rays on cauline, setae 1.5-3 mm on cauline leaves, corolla cream, 16-20 mm ……..... *O. aucherana*
11. Stellate hairs with 15-50 rays on cauline, setae 0.8-1.5 mm on cauline leaves, corolla lemon yellow or pale yellow, 20-23 mm
12. Pedicels 2-3 mm, corolla glabrous, basal leaves 2-8 x 2-5 mm ……..... *O. taurica*
12. Pedicels 1-2 mm, corolla hairy, basal leaves 60-120 x 2-8 mm …..... *O. angustissima*
10. Calyx 10-28 mm in flower
13. Corolla glabrous, cream
14. Corolla -17 mm, lobes 1.5-2 mm, pollen shape subprolate …… *O. stenoloba*
14. Corolla -20 mm, lobes 1-1.5 mm, pollen shape prolate ……..... *O. mersinana*
13. Corolla hairy, cream-pale yellow
15. Calyx 13-17 mm, corolla lobes 1-1.5 mm
16. Corolla cylindrical-subcylindrical, 13-17 mm, anthers 7 mm, nutlets 2.5 x 2 mm, basal leaves revolute ……..... *O. riedliana*
16. Corolla narrowly campanulate, 15-24 mm, anthers 8-10 mm, nutlets 3.5-5 x 3-3.5 mm, basal leaves not revolute …….. *O. isaurica*
15. Calyx 10-13 mm, corolla lobes 1.5-2 mm
17. Cauline setae adpressed, anthers 7 mm …… *O. sieheana*
17. Cauline setae patent, anthers 7-9 mm
18. Corolla 24-27 mm, inflorescence 1-2 terminal cymes, calyx -13 mm in fruit ..... *O. bornmuelleri*
18. Corolla 15-23 mm, inflorescence 1-3 terminal cymes, calyx 15-23 mm in fruit
19. Corolla 15-20 mm, cauline retrorse adpressed hairs (except setae and stellate hairs), cauline leaves oblong, oblong-spathulate, nutlets acuminate …… *O. armena*
19. Corolla 20-23 mm, cauline patent hairs (except setae and stellate hairs), cauline leaves linear, linear-lanceolate, nutlets cuspidate-acuminate ……..... *O. bracteosa*

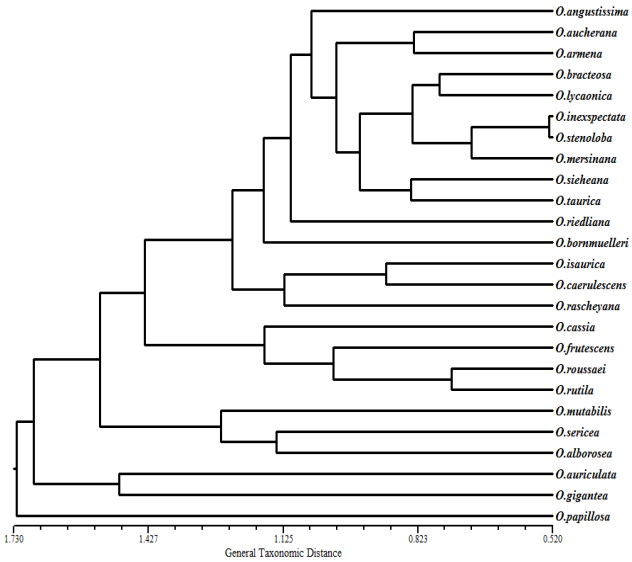

Fig. 3. UPGMA dendrogram showing the relationships within the genus *Onosma* using metric characters.

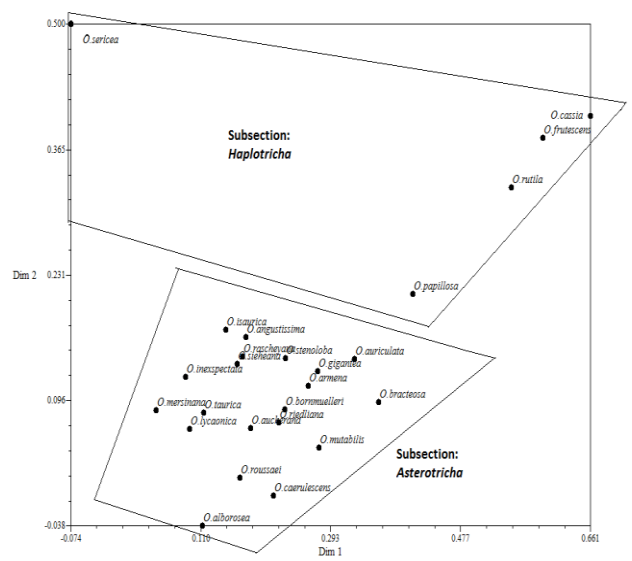

Fig. 4. PCA scatter plot of 60 non metric characters.

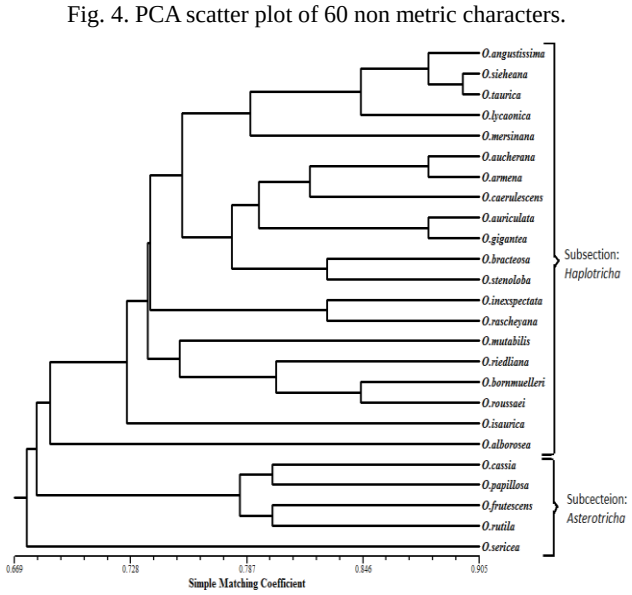

Fig. 5. The UPGMA dendrogram showing the relationship withing the genus *Onosma* using non-metric characters.

Discussion

Different studies have been carried out in order to solve the systematic problems of *Onosma* genus. Stigma morphology (Bigazzi & Selvi, 2000, Arab Ameri *et al.*, 2014; Mehrabian *et al.*, 2017), trichome (Mehrabian *et al.*, 2014), Palynological (Binzet, 2011; Binzet *et al.*, 2010; Mehrabian *et al.*, 2011), Karyological (Teppner, 1971 and 1972; Voulamoz, 2001; Martonfi *et al.*, 2008; Ranjbar & Almasi, 2013; Almasi & Ranjbar, 2015) and Molecular (Kolarcik *et al.*, 2010; Kolarcik *et al.*, 2014) studies have been done. However, none of the studies have completely solved the systematic problems of *Onosma*. For this purpose, in this study, the numerical analysis has been done to resolve the problems.

In the present study, twenty-five *Onosma* taxa belonging to two subsections (*Haplotricha* (Boiss.) Gürke. and *Asterotricha* (Boiss.) Gürke.) from the East Mediterranean region in Turkey were classified by numerical taxonomic methods. It seems that the metric characters were better reflected the taxonomic relationships than the non-metric characters. Non-metric characters were only separated the larger groups, however metric variables resulted in detailed groupings within each subsections.

Numerical taxonomy uses a large number of characters and gives equal weightage to all of the characters used to construct a classification not like conventional utilization of character sets in classical taxonomy. Thus, the classification attained by numerical taxonomy gave more information than did conventional methods on the relationship among the *Onosma* taxa used in the present study (like character loadings, spatial relationships). The results of this study showed the usefulness of numerical methods in resolving the obscured relationships between taxonomic units like *O. taurica* and *O. bracteosa*.

The members of the genus *Onosma* are very similar to each other and this resemblance often causes problems in identification of the species. In order to overcome such difficulties, numerical taxonomy is considered as the best way to establish the morphological relationship and their identities among the species of the genus *Onosma*. For example in Flora of Turkey, *O. taurica* was mentioned twice and *O. bracteosa* three times in the *Onosma* key. Within this key, species having closer relationship to these two species were provided. The latter species *O. bracteosa* was grouped with *O. sieheana, O. rascheyana, O. angustissima, O. taurica* and *O. bornmuelleri*. In another grouping *O. bracteosa* was clustered with *O. inexspectata, O. caerulescens, O. stenoloba, O. mersinana* and *O. riedliana*. In the third grouping *O. bracteosa* was grouped with *O. aucherana, O. armena* and O. *roussaei*. Thus it is obvious that the position of *O. bracteosa* is questionable and need to be resolved. Numerical taxonomic study of metric and and partially non-metric characters showed that *O. bracteosa* actually grouped with *O. sieheana, O. rascheyana, O. angustissima, O. taurica* and *O. bornmuelleri.*

Other difficulty was the placement of *O. taurica* within subsection *Asterotricha*. Similar to previous situation, *O. taurica* was placed in two different groups in Flora of Turkey. The position of this species was also indetermined. In the first group, *O. taurica* was clustered with *O. isaurica, O. lycaonica, O. mutabilis* and *O. alborosea*. In the second group, *O. taurica* was grouped with *O. bracteosa, O. sieheana, O. rascheyana, O. angustissima,* and *O. bornmuelleri*. In the current study, *O. taurica* was placed in its actual group with *O. bracteosa, O. sieheana, O. rascheyana, O. angustissima,* and *O. bornmuelleri*.

The *Onosma* species (*O. cassia, O. rutila, O. frutescens, O. sericea* and *O. papillosa*) belonging to Group A are easily distinguishable on the basis of absence of stellate hairs on the leaves in conventional classification. Similar results were obtained with numerical taxonomy using both metric and non-metrical characters (Figs. 1-3).

Within *Asterotricha* subsection, *O. gigantea* and *O. auriculata* were observed in the same group expectedly. These two species were the largest members of the subsection with respect to their size. Thus the variables both metric and non-metric characters always bring these two species together without any question.

The strange close relationship between two subsections was also encountered. A close affinity between *O. roussaei* and *O. rutila* was obtained in all of the analyses. Interestingly the collection localities of these species were adjacent to each other and both the studies were distributed closely in Mersin province in the Mediterranean Region.

The member of *Haplotricha* subsection *O. papillosa* was not grouped together with its own members in all of the analysis. This is might be due to the setae patent on margins and midrib beneath the leaves. This species has another interesting feature; *O. papillosa* is the only endangered (EN) (Ekim *et al.*, 2000) species of the genus *Onosma* in this study. In previous years, it was collected from C5 Niğde and C4 Konya respectively in 1898 and 1906 by Siehe (Riedl 1978). During the present study, this species was collected again from a different locality (B6 Adana) other than previously reported.

Although the present study was limited to the known species, distributed in Eastern Mediterranean region in Turkey, but it added new findings to the knowledge of the genus *Onosma* and also highlights the needs for the revision of the genus *Onosma*. A comprehensive study including all of the Turkish *Onosma* species seems to be necessary to construct a more satisfactory and correct classification using numerical taxonomic methods.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Acknowledgements

The authors are grateful to Prof. Dr. Musa Doğan, Prof. Dr. Arzu Kanık and Assoc. Prof. Dr. Ferhat Celep for their valuable critisms. This academic work was linguistically supported by the Mersin Technology Transfer Office Academic Writing Center of Mersin University. This study was a part of a PhD. Thesis by Rıza BİNZET and was supported by the Research Fund of Mersin University in Turkey with Project Number: BAP-FBE BB (RB) 2004-1 DR.

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(Received for publication 21 December 2016)