



Seven New Species of *Onosma* L. (Boraginaceae) with emphasis on their habitats in Iran

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ABSTRACT: In this paper, seven new species of *Onosma* are described and illustrated. Besides, a diagnostic key is provided for new species. Hence, based on a wide range of the assessments conducted, the mentioned samples are considered as distinct species when compared with the previously introduced species in the region. Thus, it strengthens our justification as to whether they are new species. Our argument for mentioned novelties is significant differences in the most important morphological and micro-morphological characteristics following trichome type, shape and size of cauline and basal leaves, shape and size of calyx, annulus hairs, shape and size of corolla, nutlets morphology, anther length as well connection and their exertion as well pollen type and size compared to their nearest species. Besides, the recent novelties are confirmed by obviously ecological differentiations.

KEY WORDS: Boraginaceae, Diagnostic key, Iran, New species, Nutlets morphology, *Onosma*, Pollen grain, Trichome type.

INTRODUCTION

Onosma L. is an old-world (Cecchi *et al.* 2016) and rich species of tribe *Lithospermeae* Dumort. (Boraginaceae) which includes about 150–180 species (Weigend *et al.*, 2009, Kolarčik *et al.*, 2010, Mehrabian 2015) centered mainly in xero-habitats, including rock and sandy soils as well as serpentine geological formations (Cecchi *et al.*, 2011) in the mountainous habitats of the Irano–Turanian regions of Asia as along with the Mediterranean region, especially Iran and Turkey (Fig. 1A) (Meusel *et al.*, 1978, Mehrabian *et al.*, 2013., Cecchi *et al.*, 2016). These species have been facing several taxonomical challenges (Teppner, 1986), and numerous related species are distinguishable only based on weak and unclear morphological evidence. They also show varied polymorphism and a huge diversity (Kolarik *et al.*, 2010) leading to identification problems (Ball, 1972., Mehraian, 2014, 2015) in these complex species. The taxonomic study on *Onosma* dates back to Candolle (1846), who provided the primary classification of sect. (Eu) *Onosma* and sect. *Aponosma* based on some calyx characteristics. Later, Schur (1866) as well as Borbás (1877) used indumentum features as the most important diagnostic characteristics in *Onosma*, which, until now, maintained their values (Mehrabian *et al.*, 2014, Cecchi *et al.*, 2016). In addition, Boissier (1879) provided the first taxonomic classification in this genus dividing all the *Onosma* species based on trichome types in three groups including *Haplotricha* Boiss., *Heterotricha* Boiss. and *Asterotricha* Boiss. These are considered as natural groups by Peruzzi and Passalacqua (2008). On the other hand, Popov (1953) in Flora of

USSR put far less emphasis on the shape of trichomes and tubercles. Also, Cohen (2011), Cecchi *et al.*, (2011) and Weigend *et al.*, (2016) classified these groups as integrative sections or “informal groups” as well as the sister groups of *Maharanga* DC. and *Podonosma* (Boiss) Gürke. Afterwards, this opinion was confirmed by Cohen (2011). Karyological, molecular, and trichome evidence confirmed the recent classification. In addition, the intermediate evolutionary lineages (*heterotricha*) probably evolved through hybridization. In addition, interspecific hybridization was introduced as a significant strategy for stimulating divergence and speciation in these species (Kolarcik *et al.*, 2010, Kolarcik *et al.*, 2015a). Owing to the mentioned complexities, a wide spectra of characteristics including pollen morphology, anatomy, karyology, phytogeography, and molecular characteristics have been assessed to solve taxonomic problems and elucidate phylogenetic relationships (Sayadi *et al.*, 2017).

The taxonomic studies on *Onosma* L. in scale of Iran dates back to Riedl (1967) examining Iranian Plateau, who published the first literature on *Onosma* L. He introduced 59 species from three (3) sections (*Onosma* L., *Podonosma* (Boiss) Gürke. and *Protonosma* Lehm.), 3 subsections (*Haplotricha* Boiss and *Asterotricha* Boiss) and 33 series. Later on, Khatamsaz (2001) in the Flora of Iran, reported 37 species with a similar classification to that of Riedl. Thereafter, Mehrabian (2011a, 2012, 2014, 2015) reported 47 species classified in three subsections as follows: *Haplotricha* Boiss, *Heterotricha* Boiss, and *Asterotricha* Boiss; belonging to section *Onosma* plus one taxon (*O. rostellata* Lehm.) belonging to section *Protonosma* M. Pop. Further, Popov (1953) in

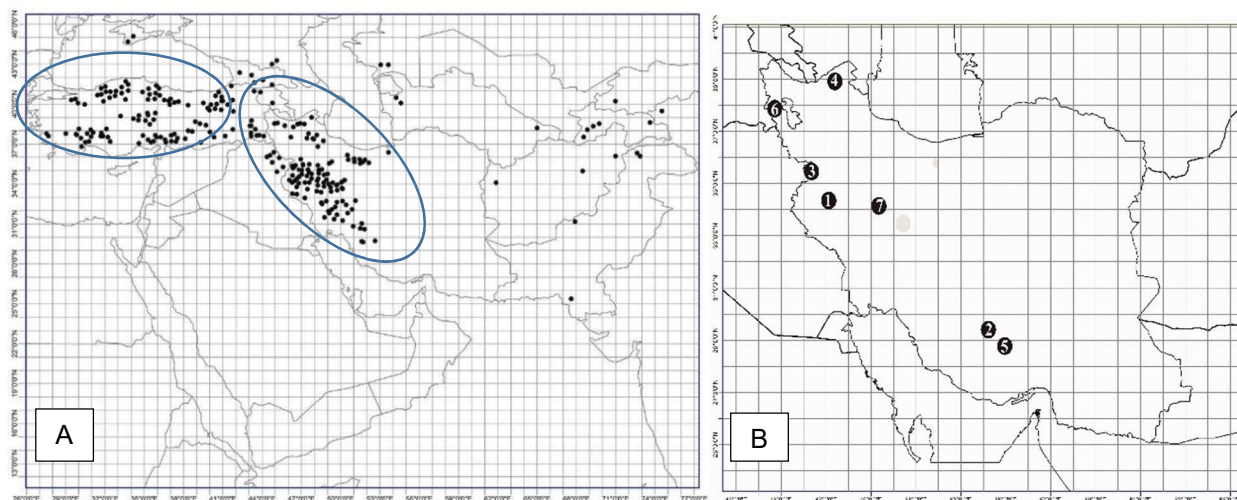


Fig. 1. A. Endemism Zones of *Onosma* in West Asia (Mehrabian 2015), **B.** Distribution map of new taxa: 1. *O. sanandajensis*, 2. *O. sarvestanica*, 3. *O. marivanensis*, 4. *O. assadi*, 5. *O. bakhteganensis*, 6. *O. targevarensis*, 7. *O. wendelboi*.

Flora of USSR introduced 35 species belonging to 2 subsections (*haplotricha* Boiss. and *Asterotricha* Boiss) from two sections (*Euonosma* DC., *Aponosma* DC.) and 14 groups. Moreover, Riedl (1978) in Flora of Turkey described three subsections (*Haplotricha* Boiss., *Heterotricha* Boiss. and *Asterotricha* Boiss) belonging to three sections (*Onosma* L., *Podonosma* (Boiss) Gürke., and *Protonosma* Lehm.).

In addition, some studies on the valuable characteristics on the taxonomy of *Onosma* include Karyology (Teppner 1972, 1991, 1996, 2008, 2011, 2012, Vouillamoz, 2001, Mártonfi *et al.*, 2008, Ranjbar & Almasi 2013) trichome morphology (Teppner, 2008, Mehrabian *et al.*, 2014); anatomy and morphology (Popov 1950, 1951., Azizian *et al.*, 2000, Akcin 2007a, 2007b, Peruzzi & Passalacqua 2008, Binzet & Akcin 2009, Akcin & Engin 2001, 2005, Akcin *et al.*, 2013, Martonfi *et al.*, 2014), Pollen (Qureshi & Qaiser 1987, Zemskova & Popov 1991, Binzet & Orcan 2003, Maggi *et al.*, 2008, Binzet *et al.*, 2010, Binzet 2011, Mehrabian *et al.*, 2012, Kolarčik *et al.*, 2015); Nutlet and petal (Akcin 2009, Binzet & Akcin 2009, Akcin & Binzet 2011, Arab Ameri *et al.*, 2015); Stigma (Bigazzi & Selvi 2000, Arab Ameri *et al.*, 2017); phytogeography and ecology (Kolarčik & Martonfi 2006, Mehrabian 2015, Naghizadeh 2018, Moradi 2018); as well as molecular evidence (Vouillamoz, 2001, Mengoni *et al.* 2006, Cecchi & Selvi 2009, Weigend *et al.* 2009, 2013, 2016, Cohen 2011, Kolarčik *et al.*, 2010, 2014 Mehrabian *et al.*, 2011, 2012, Sheidai *et al.*, 2015). They have analyzed the taxonomic problems and elucidated some phylogenetic relationships. Moreover, *O. orientale* Boiss. was accepted by some authors (Thomas *et al.* 2008., Cohen, 2011., sayadi *et al.*, 2017) as a different genus (*Podonosma* Boiss.) which was previously named by Boissier (1879). Despite the numerous mentioned

studies, the phylogenetic and evolutionary lines of *Onosma* are poorly recognized (Hilger *et al.*, 2004., Weigend *et al.*, 2009, Kolarčik *et al.*, 2010, Mehrabian *et al.*, 2011a, b., Sheidai *et al.*, 2015).

Methods

The new discovered specimens were collected by V. Mozaffarian and M. Assadi during scientific excursions in the West, North West, and the South West of Iran (Fig. 1B). Holotypes were deposited and preserved in the TARI Herbarium (herbarium abbreviations according to Thiers (2008)). The mentioned specimens were then compared with principal diagnostic keys reported in Flora Iranica (Riedl, 1967), Flora of Iran (Khatamsaz 2002), Flora USSR (Popov 1953), Flora Turkey (Riedl, 1979), some basic old literature including Boissier (1879), Johnston (1954), Post (1966), Polunin (1969), Ball (1972), Nasir & Ali (1979) as well as some new literature including Mehrabian *et al.* (2011a, 2011b, 2012, 2013, 2014), Teppner, (1980), Ghahreman and Attar (1996), Attar and Joharchi (2006), Attar and Hamzehee (2007), Kandemir and Türkemen (2010), Koyuncu *et al.*, (2013), Aytac and Türkmen (2011), Mehrabian *et al.* (2013), Ahmad (2014), Naqinezhad and Attar (2016), and Cecchi *et al.*, (2016).

Nutlets were photographed by a dinolite microscope. Also, the selected sections of dried leaves as well pollen grains were mounted on stubs using double-sided adhesive tape and were coated with gold by a DC magnetron sputtering machine desktop. In the final stage, the aforementioned samples were photographed by a Cam Scan Hitachi SU3500 Electron Microscope. The pollen assessments were performed on 20–30 pollen grains. Further, the morphological evidence was compared with a huge data on about 4000 *Onosma*



accessions belonging to HSBU, IRAN, TARI, W and WU as well as some photos of specimen types of C, B, G, LE, JE, BG, Kyo and K. The morphological terminology was according to Riedl (1967), Riedl (1979), Harris and Harris (2001), Simpson (2006), alongside the pollen terminology based on Punt et al., (2007), Halbritter et al., (2008), and Hesse et al., (2009).

Based on main basic literature (Popov 1953, Post (1966), Riedl(1967), Polunin (1969), Ball (1972), Riedl (1979), Nasir & Ali (1979), and Khatamsaz (2002) on *Onosma* valuable characters, including the trichome type, shape, and size of the cauline and basal leaves, the shape and size of calyx were studied along with the presence the annulus hairs, the shape and size of corolla, the nutlets morphology, anther length and connection as well as their exertion as well pollen type and size. They were assessed in new species and compared against similar species. Finally, these new species and their closest allied species of different ecological localities were compared through a comparative table (Table 1).

Key to Iran *Onosma*

- 1a. Anthers Connected along their entire length, beak like, sharply exerted *Onosma rostellata* (sect. *Protonosma* M. Pop.)
1b. Anthers Connected only at base or free, shorter than corolla 2
2a. Setae with hairy tubercles 3
2b. Setae with glabrous tubercles 4
3a. Setae with short and scatter rays, besides some with and some without rays subsect. *Heterotricha* Boiss. (30)
3b. Setae with long and dense rays ... subsect. *Asterotricha* Boiss. (32)
4a. Corolla with long and linear lobes 5
4b. Corolla with short lobes 6
5a. Leaves oblong - lanceolate, ovate- lanceolate. Corolla tubular- campanulate 12-14mm; annulus glabrous *O. platyphylla*
5b. Leaves oblanceolate to lanceolate. Corolla tubular, 8-19mm; annulus glabrous *O. longiloba*
6a. Calyx accrescent 7
6b. Calyx non accrescent 17
7a. Plants robust, with coarse setae 8
7b. Plant not robust, without coarse setae 9
8a. Corolla white, 18-22 mm; annulus pilose, anthers up to 9mm *O. bulbotricha*
8b. Corolla first yellow, gradually become purple, 25-40 mm, annulus glabrous, anthers 9-12mm *O. dichroantha*
9a. Setae sericeous to canescens 10
9b. Setae non sericeous or canescens 15
10a. Annulus pilose. Corolla tubular-campanulate, yellow. Bracts lanceolate, ca, 10 mm. *O. cornuta*
10b. Annulus glabrous 11
11a. Leaves lanceolate-linear. Bracts ca. 24 mm. Corolla campanulate-clavate, yellow gradually become violet ca. 28 mm. ... *O. subsericea*
11b. Leaves lanceolate to lanceolate-oblong 12
12a. Corolla shorter than 25mm 13
12b. Corolla to 25mm or more 14
13a. Anthers free at base. Corolla campanulate, 14-16mm. Cauline leaves lanceolate to lanceolate-oblong *O. marivanensis*
13b. Anthers connected at base. Corolla clavate to clavate-campanulate, 16-20mm. Cauline leaves lanceolate *O. sericea*
14a. Leaves lanceolate, 40-50x7-12mm, sericeous to canescens. Inflorescence apical, branched *O. bodeana*
14b. Leaves lanceolate, 70-80x15-18mm, canescens. Inflorescence severely branched in lower parts to upper parts of stem

- *O. pachypoda*
15a. Cauline leaves linear-lanceolate, up to 25mm. Corolla campanulate, ca. 21 mm, light blue. Anthers ca. 9 mm. *O. khorassanica*
15b. Cauline leaves lanceolate to lanceolate-oblong 16
16a. Corolla up to 10mm, yellow. Anthers to 6mm. Calyx to 25mm ... *O. sanandajensis*
16b. Corolla longer than 24-27 mm, yellow gradually become violet in top parts. Anthers to 8mm. Calyx to 18 mm *O. demawendica*
17a. Cauline leaves reduced. Plant caespitosus 18
17b. Cauline leaves longer. Plant non caespitosus 20
18a. Bracts ca. 17mm. Cauline leaves linear-lanceolate, 25-60 mm long, 3-6 mm wide. Corolla campanulate, 15-20mm *O. sabalanica*
18b. Bracts ca. 10mm. 20
19a. Calyx divided to base, lobes free, ca. 15mm. Pedicle ca. 8mm. Cauline leaves 40-55 mm. *O. ghahremani*
19b. Calyx divided near to base, ca. 22mm. Pedicle ca. 4mm. Cauline leaves 15-30 mm. *O. gaubae*
20a. Stems spotted. Calyx 11-16 mm. Cauline leaves oblong to lanceolate 8-12 mm long *O. maculata*
20b. Stems non spotted. 21
21a. Leaves linear to linear-lanceolate to narrowly spatulate 22
21b. Leaves lanceolate 25
22a. Leaves linear to linear-lanceolate 23
22b. Leaves, linear spatulate *O. microcarpa*
23a. Annulus pilose. Corolla tubular-campanulate, 15-22 (25) mm ... *O. chrysochaeta*
23b. Annulus glabrous 24
24a. Corolla tubular. Leaves linear-lanceolate, 20-55 mm *O. azarbaijanensis*
24b. Corolla clavate. Leaves linear, 20-90 mm *O. assadi*
25a. Corolla long shorter than 10mm. Annulus (nectary ring) pilose ... *O. kotschyi*
25b. Corolla long longer than 10mm. Annulus (nectary ring) glabrous ... 26
26a. Setae appressed. Annulus glabrous. Cauline leaves lanceolate, setae densely *O. kilouyense*
26b. Setae non appressed 27
27a. Anthers free at base, ca. 12 mm. Bracts ca. 4 mm. Calyx ca. 18 mm *O. bakhteganensis*
27b. Anthers connate at base. 28
28a. Calyx accrescent, ca. 8 mm. Corolla tubular. 10-12 mm. Cauline leaves widely lanceolate. Pedicle ca. 6 mm. *O. sheidai*
28b. Calyx nonaccrescent 29
29a. Corolla tubular, tubular-clavate, 18-20 mm. Cauline leaves lanceolate, oblong-elliptic. Annulus setolous *O. sarvestanica*
29b. Corolla tubular-campanulate, 18-25 mm. Cauline leaves lanceolate. Annulus glabrous *O. asperrima*
30a. Calyx accrescent 31
30b. Calyx non accrescent 33
31a. Annulus pilose, Bract linear, ca. 20 mm. Corolla tubular *O. lanceolata*
31b. Annulus glabrous. Bracts lanceolate 32
32a. Corolla ca 22mm, tubular-clavate. Leaves widely lanceolate *O. olivieri*
32b. Corolla ca 20mm, tubular-campanulate. Leaves lanceolate *O. elwendica*
33a. Annulus glabrous, Leaves large with prominent veins 34
33b. Annulus pilose. Leaves linear-lanceolate, 20-150 mm long, lack of prominent veins. Corolla red to pink. Bract ca. 20 mm. Anthers ca. 8 mm. *O. straussii*
34a. Sterile leaves lanceolate, corolla yellow, 12-14mm. Anthers connected at base setae yellow to yellowish white. Bract linear-lanceolate, 3-10 mm. *O. nervosa*
34b. Sterile leaves widely lanceolate, corolla 17-19mm, Anthers free at base, setae white. Bract linear, 2-3 mm *O. macrophylla*
35a. Plant with canescens setae 36
35b. Plant without canescens setae 38
36a. Anthers free at base. Cauline leaves ca. 30 mm, obovate-oblanceolate. Corolla ca. 19 mm, yellow to dark blue *O. bistounensis*



36b. Anther connate at base	37
37a. Corolla ca. 28mm, leaves ovate-lanceolate, setae appressed. Bract ca (10) 12 mm. Anthers ca. 7 mm	<i>O. dasytricha</i>
37b. Corolla ca. 30mm, leaves obovate, setae non appressed. Bract leaf like, ca. 20 mm. Anthers ca. 9 mm.	<i>O. albo-rosea</i>
38a. Calyx longer than 25 mm.	39
38b. Calyx clearly shorter than 25 mm	42
39a. Bracts ca. 30 mm	40
39b. Bracts shorter than 20 mm	41
40a. Basal leaves obovate-lanceolate, ca. 200 mm long. Corolla tubular-clavate, ca. 25 mm long. Calyx ca. 34 mm long.....	<i>O. kurdicum</i>
40b. Basal leaves oblanceolate-spathulate, ca. 80 mm long. Corolla tubular-campanulate, ca. 23 mm long. Calyx ca. 27 mm long.....	<i>O. cardiostegia</i>
41a. Corolla clavate-campanulate, ca. 20 mm. Cauline leaves spathulate-lanceolate ca. 50 mm long, ca. 20 mm wide	<i>O. iranshahri</i>
41b. Corolla Tubular-clavate, ca. 30 mm. Cauline leaves oblanceolate-lanceolate, oblong-spathulate ca. 110 mm long, ca. 25 mm wide.....	<i>O. bilabiata</i>
42a. Bract ca. 25 mm. Cauline leaves lanceolate-linear ca. 60 mm long, ca. 9 mm wide. Corolla clavate, ca. 27 mm	<i>O. targevarensis</i>
42b. Bracts shorter than 25 mm	43
43a. Bracts ca. 12 mm	44
43b. Bracts ca. 20 mm	45
44a. Calyx accrescent, ca. 17 mm long. Anthers ca. 8 mm. Basal leaves oblong -spathulate, ca. 100 mm long, ca. 30 mm wide	<i>O. hebebulba</i>
44b. Calyx non accrescent, ca. 22 mm long. Anthers ca. 6 mm. Basal leaves lanceolate- ovate, ca. 150 mm long, ca. 40 mm wide	<i>O. mozaffariani</i>
45a. Corolla ca. 26 mm, clavate. Calyx ca. 20 mm.	<i>O. rascheyana</i>
45b. Corolla shorter than 20 mm.	46
46a. Basal leaves ca. 60mm long, ca. 13 mm wide. Calyx ca. 18 mm	<i>O. wendelboi</i>
46b. Basal leaves ca. 35 mm or shorter	47
47a. Cauline leaves, lanceolate lanceolate-linear or spathulate, Anthers connected at base	48
47b. Basal leaves up to 150 mm long, ca. 40 mm wide. Corolla clavate-campanulate, 18–20 mm	<i>O. mozaffariani</i>
48a. Basal leaves ovate. Annulus sparsely pilose. Calyx ca. 27 mm long, ca. 6 mm wide.	<i>O. iranshahrii</i>
48b. Basal leaves widely ovate, obovate or spathulate. Annulus glabrous	49
49a. Corolla campanulate-clavate. Anthers ca. 10 mm	<i>O. bilabiata</i>
49b. Corolla tubular, sub-clavate. Anthers shorter.....	50
50a. Corolla up 20–30 (40) mm	51
50b. Corolla up to 20 mm.....	54
51b. Basal leaves linear, linear-lanceolate.....	52
51b. Basal leaves wider.....	53
52a. Basal leaves up to 200 mm, Calyx linear ca. 38mm long	<i>O. kurdica</i>
52b. Basal leaves up to 50 mm. Calyx linear-lanceolate, ca.18 mm	<i>O. targevarensis</i>
53a. Corolla tubular-campanulate, yellow. Bract up to 30 mm.	<i>O. cardiostegia</i>
53b. Corolla clavate, pink-red. Bract 15–20 mm	<i>O. rascheyana</i>
54a. Calyx not accrescent. Basal leaves oblong-elliptic ...	<i>O. wendelboi</i>
54b. Calyx accrescent.....	55
55a. Bract to 17 mm, Corolla tubular to tubular-subclavate.	<i>O. armena</i>
55b. Bract to 12 mm. Corolla tubular to tubular-clavate	<i>O. caeruleascens</i>

TAXONOMIC TREATMENTS

Onosma assadi Mehrabian & Mozaff., *sp. nov.*

Fig.2

Type: Iran. East Azerbaijan, East of Hurand near Gharasu, 700m, 3 Jun 2004, *Assadi 86652* (holotype TARI).

Perennial, with woody rootstock, creeping rhizome. Stems numerous, growing 40–50 cm tall, partially erect to diffuse, partially geniculate, with remains leaves of previous year shoots, covered by sparse and short setae. Rosette leaves fallen at the present. Upper and middle cauline leaves similar, sessile, linear-lanceolate, obtuse to acute, rolled inward, 25–40 mm long, 2.5–4(5) mm wide, setae with glabrous tubercles (subsect. *Haplotricha*), 0.5–1.8 mm long, white, more densely in upper surface, especially near the margins and along midrib, non appressed, with sparse tiny hairs among them (Fig. 9A–C). Inflorescence 2–3 scorpioid cymes, apical, each cyme with 5–7 flowers. Peduncles partially tubular, white to cream. Flowering pedicels 4–5 mm. Bract linear-lanceolate, 8–10 mm long, 1–1.5 mm wide, pubescent, white to white yellowish. Flowering as well fruiting Calyx divided to base, lobes linear, 9–10 mm long, ca. 1 mm wide, densely setose especially near the margins, white yellowish. Corolla campanulate, 12–15 mm long, pale yellow, setae white to white yellowish, pubescent; lobes obtuse, reflexed, 8–1.5 mm long, ca. 0.5 mm wide; Annulus tomentose; Anthers connate at the base, to 5 mm, inserted upper ½ corolla tube. Style shortly longer than corolla, stigma bilobate. Nutlet not found.

Remarks: Closely allied to *O. chrysochaeta* Bornm., an endemic taxon distributed in the restricted zone of central Iran. Nevertheless, it is differentiated by linear-lanceolate cauline leaves, the absence of basal leaves, shorter corolla, glabrous annulus, and sparse leaf trichomes (Fig. 9A–C). Besides, near to *O. azarbaijanensis* Mehrabian and Mozaffarian an endemic taxon to NW Iran different by campanulate corolla, shorter anther and shorter bract as well densely leaf trichomes. Also nearly to *O. microcarpa* DC. widely distributed in Iran, Iraq, Turkey, transcaucasica, Armenia, Turkey as well Syria, however different by linear-lanceolate cauline leaves, glabrous annulus, white corolla as well sparsely leaf trichomes compared to *O. microcarpa*. (Table.1).

Etymology: named in the honor of the eminent botanist Prof. Dr. Mostafa Assadi, who has played a prominent role in improving Iranian botany.

Pollen characteristics: Heteropolar, tricolporate subprolate, polar axis: 13.1–15.1 µm, mean: 14.2 µm, equatorial axis: 10.6–12.3µm, mean: 11.4 µm, exine granulate: 0.16–0.25 µm, mean: 0.19 µm (Fig. 11A–D).

Habitat: *O. assadi* is distributed in lowland gravelly slopes in igneous geological formations, compared to *O. microcarpa* which is broadly dispersed in Asia and Europe. Also, it shows a great divergence in terms of habitat with *O. chrysochaeta* and has been reported from only a restricted zone in Central Zagros. Moreover, it has clear habitat distinctions with the closely related species



Fig. 2. *Onosma assadi* Mozaff. & Mehrabian. A. habit, B. Corolla, C. leaf trichomes.



of *O. azarbaijanensis* which is distributed in the steppes deployed in sedimentary rocks in a limited area in NW Iran. Besides, the area of occupancy of the new taxon is relatively wide and involves a pure vegetation type.

Specimens examined (Paratypes): Iran: East Azerbaijan, Hurand, Laghlan village, 883-1000 m, *Moradi s.n.*, HSBU-2017146., Hurand, Near to Laghlan village, 586-800 m, *Moradi s.n.*, HSBU-2017156., West of Hurand, 1400 m, *Moradi s.n.*, HSBU-2017166., Hurand to Abesh ahmad, 1300 m, *Moradi s.n.*, HSBU-2017189.

Additional specimens examined for closest species:

***O. microcarpa* DC.:** Iran: West & Stapf, WU-7115 (Holotypus), Azarbaijan, Khalkhal, Mehrabian, 1651 m, HSBU-2010252., Ardebil, Neor Lake, Mehrabian, 1950 m, HSBU-2010241., Azarbaijan, Nikpey to mahnesan, 2200 m Mehrabian, HSBU-2011399., Zanzan, 25 km Takab, Belghais Mts, Mehrabian, 2600 m, HSBU-2010248, Kurdistan, Marivan, 1950 m, HSBU-2010255, Paveh, 1474 m, Mehrabian, 2600 m, HSBU-2010248., Kermanshah, Eslamabad, Gahvareh, Mehrabian & Mohammadi, 1566 m, HSBU-2010246., Kermanshah, Bistoon, Mehrabian, HSBU-2011456., Kurdistan, Marivan to Saqez, Mehrabian, HSBU-2010243., Azarbaijan, Khoy to Ghotor, Mehrabian, HSBU-2010242., Hamedan, Ganjnameh, Mehrabian, 2136 m, HSBU-2010251., Hamedan, Avaj, Mehrabian, 2360 m, HSBU-2010334., Fars, Firozabad, Meimand, Sepidar Mt., 1750-2850 m, Mozaffarian, TARI-71453., Bakhtiari, Shahr Kord, Baba Heydar, 2750 m, Mozaffarian, TARI-57659., Tehran, Kolak Chal, Mehrabian, 2400 m, HSBU-2010240., Qom, Kohandan, 2200 m, Mehrabian, HSBU-2010250., Lorestan, Dowrod to Pirabdollah, Hamzeh, 1550 m, TARI-71782., Qazvi, Taleghan, 1850 m, Mehrabian, HSBU-2010245.

***O. chrysochaeta* Bornm.:** Iran: Khansar, Damaneh, Feridan, Bornmuller, W-1040 (Holotypus).

***Onosma bakhteganensis* Mozaff. & Mehrabian, sp. nov.**

Fig. 3

Type: Iran. Fars, 20 km from Estahbanat to Neiriz, S. of Daryache Bakhtegan (BT2), 1750m, 8 Apr 1983, *Mozaffarian 47123* (holotype TARI!).

Perennial. Stem numerous, growing 30–40 cm tall, partially erect to diffuse, white, glabrous to very sparsely setose. Basal leaves absent. Cauline and middle leaves similar, lanceolate, 20–50 mm long, 6–12 mm wide, leaves perfoliate, acute, rolled inwards; Setae glabrous at the base (subsect. *Haplotricha*), sparse, white, 0.2–1.2 mm long, covered by dense tiny hairs among them (Fig. 9D–F). Inflorescence with 2–3 scorpioid cymes, elongated after flowering, each cyme with (5)7–12 flowers. Bracts linear-lanceolate, cordate at base, 8–12 mm long, 0.8–1 mm, sparsely pubescent. Fruiting pedicles 10–12(15) mm. Fruiting calyx divided to base, lobes linear-lanceolate, 18–20 mm long, 0.8–0.9(1) mm wide, sparsely setose. Corolla tubular to tubular clavate, 18–20 mm long, yellow, violet at the tip of flowers, lobes obtuse, 1.1–1mm long, tomentose outside. Annulus pilose; anthers free at base, 5–6 mm, inserted upper 2/3 corolla tube. Style much shorter than corolla, stigma bilobed. Nutlet ovoid ca. 4.5 mm long, ca. 3 (3.5) mm wide, navicular, creamy, dark brown spotted (Fig. 10A).

Remarks: Close to *O. asperrima* Bornm., though it can be differentiated from it based on longer anthers free at base, shorter bract, hairy annulus and presence of

sparse pilies. Furthermore, apparently closely allied to *O. kotschyi* Boiss. endemic taxon to the West, North West, and South West of Iran, but differentiate by longer calyx as well as longer corolla, longer pedicle, anthers longer which are free at the base, hairy annulus, sparsely leaf trichomes, and sparsely pilies among leaf trichomes (Table 1).

Etymology: The specific epithet was based on the geographical origin of the species in the South of Iran

Pollen characters: not seen

Habitat: *O. bakhteganensis* grows in spiny shrub lands (e.g. *Astragalus* spp., *Acantholimon* spp.) in quaternary deposits of sedimentary rocks in the southern districts of Zagros compared to closely related species of *O. kotschyi* as well as *O. asperrima* that is widely distributed in the middle to southern Zagros. Moreover, the area of occupancy is limited including about 20 individuals.

Paratypes: Iran: Fars, 10. Km S. E. of Sarvestan, Post-e Chena Region, 1650-1750 m, 4 Jun 1983. TARI-46732. Fars, 25 km S.E. of Fasa, Salou village, Kuh-e Raz, 1600-2200 m, 5 Jun 1983, *Mozaffarian s.n.*, TARI-46792.

Additional specimens examined for closest species:

***O. asperrima* Bornm.:** Iran: Lorestan, Aligudarz, Ghalikuh, IRAN-2697., Fars, Abadeh, Behbodi, W-7148., Fars, Norabad, Doshman Ziari, 1900-2500 m, Mozaffarian, TARI-45772., Fars, Bamo Protected Area, 1650-1800 m, Wendelbo & Foroghi, TARI-17568., Fars, Shiraz, Dast e- Arjan, Mozaffarian, 2250-3000 m, TARI-71367., Fars, Firozabad, 170-26660 m, Mozaffarian, TARI-71449., Fars, Abadeh, Kahkoli, IRAN-2698., Fars, 15 km Shiraz toward Estahbanat, Mianjangan, 1700-2400 m, Mousavi & Tehrani, IRAN-2699., Dena Mts, Sharif, IRAN-26701., Fars, Shiraz, Dasht Arjan, Kazeron old road, 2200 m, Foroghi, TARI-17437., Kerman, between Bam and Jiroft, Jebal Barez Mts, Allen and Esfandiari, W-6742.

***O. kotschyi* Boiss.:** Iran: Fars, Shiraz Delo Mts, Kotschy, W-503 (holotypus), Hamedan, Garin Mts, Gamasiab, 2600 m, Assadi & Mozaffarian, TAR_-36966., Lorestan, Nahavand to Norabad, 2100-2800 m, Assadi & Mehregan, TARI-89124., Lorestan, Aleshtar, 2130-2900 m, Assadi & Mehregan, TARI-88881., Kobara, Koelz, W-1571., Kohkilouyeh and Boyerahmad, Dena Mts. To Gardaneh Bijan, Termeh and zargani, IRAN-2812., Fars, Estahbanat, 1700-2200 m, TARI-46999.

***Onosma marivanensis* Mozaff. & Mehrabian, sp. nov.**

Fig. 4

Type: Iran. Kordestan: Marivan to Paveh, Gardan-e Tate, between Dezli and Hanigarmale, 1800-2600 m, 9 Jul 1995, *Mozaffarian 74707* (holotype TARI!).

Perennial, growing up to 60 cm tall, diffuse, glabrous to sparsely setose. Basal leaves absent. Cauline leaves 25–85 mm long, 10–35 mm wide, broadly ovate-lanceolate, sessile, acute at the apex; setae with small glabrous tubercles (subsect. *Haplotricha*), white, 0.1-0.8 mm, sparsely adpressed (Fig. 9G–I). Inflorescence with 2–3 elongated scorpioid cymes, 13–15(17) cm, each cyme with 5–7 flowers, densely pilose. Bracts broadly lanceolate, ca. 12 mm long, ca. 2.5 mm wide, densely pilose. Pedicle 3-5 mm, after flowering up to 10 mm. Calyx 13–15(17) mm, lobes divided near to base; accrescent, ca. 20 mm long, ca. 8 mm wide, densely

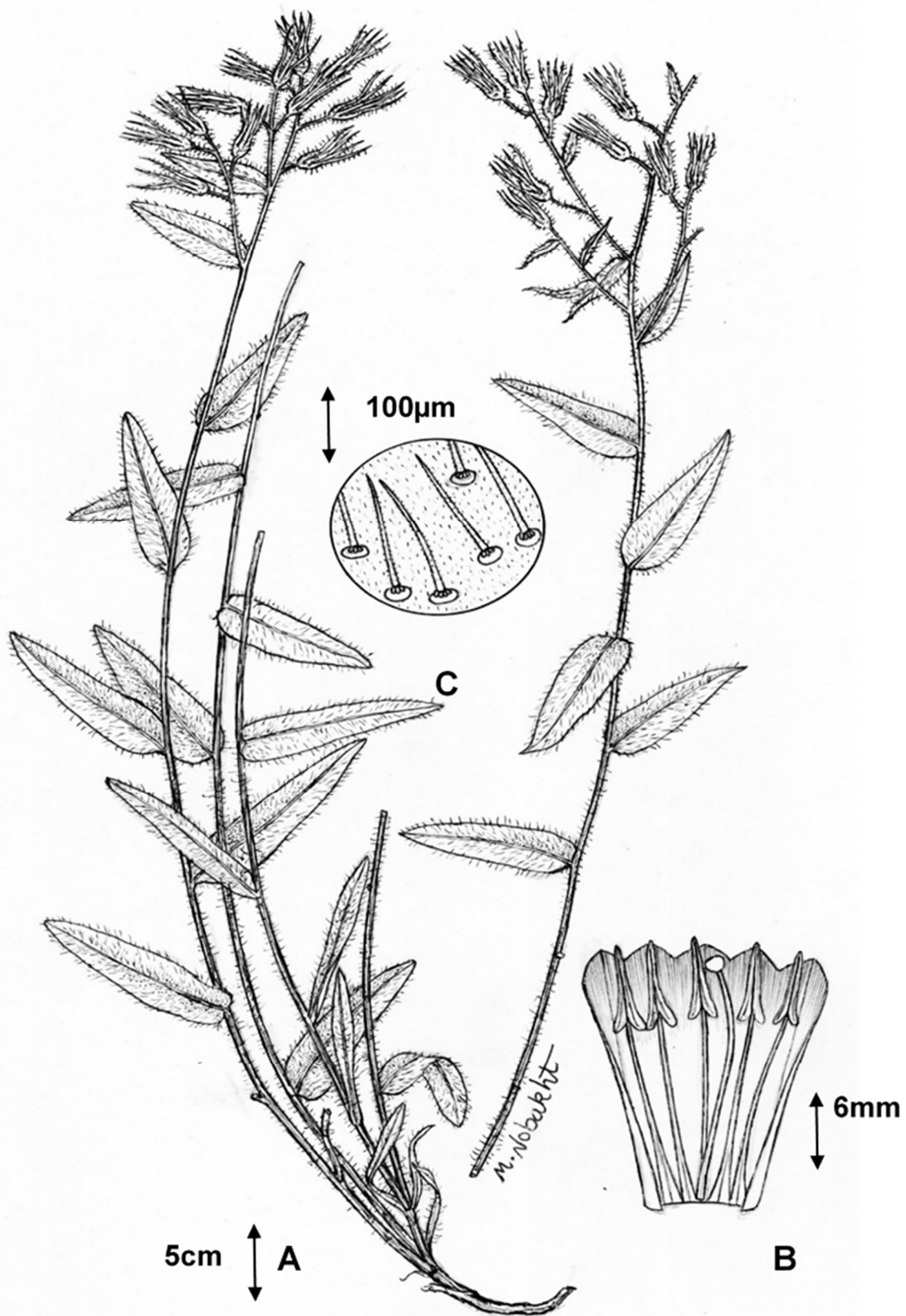


Fig. 3. *Onosma bakhteganensis* Mozaff. & Mehrabian. A. Habit, B. Corolla, C. leaf trichomes

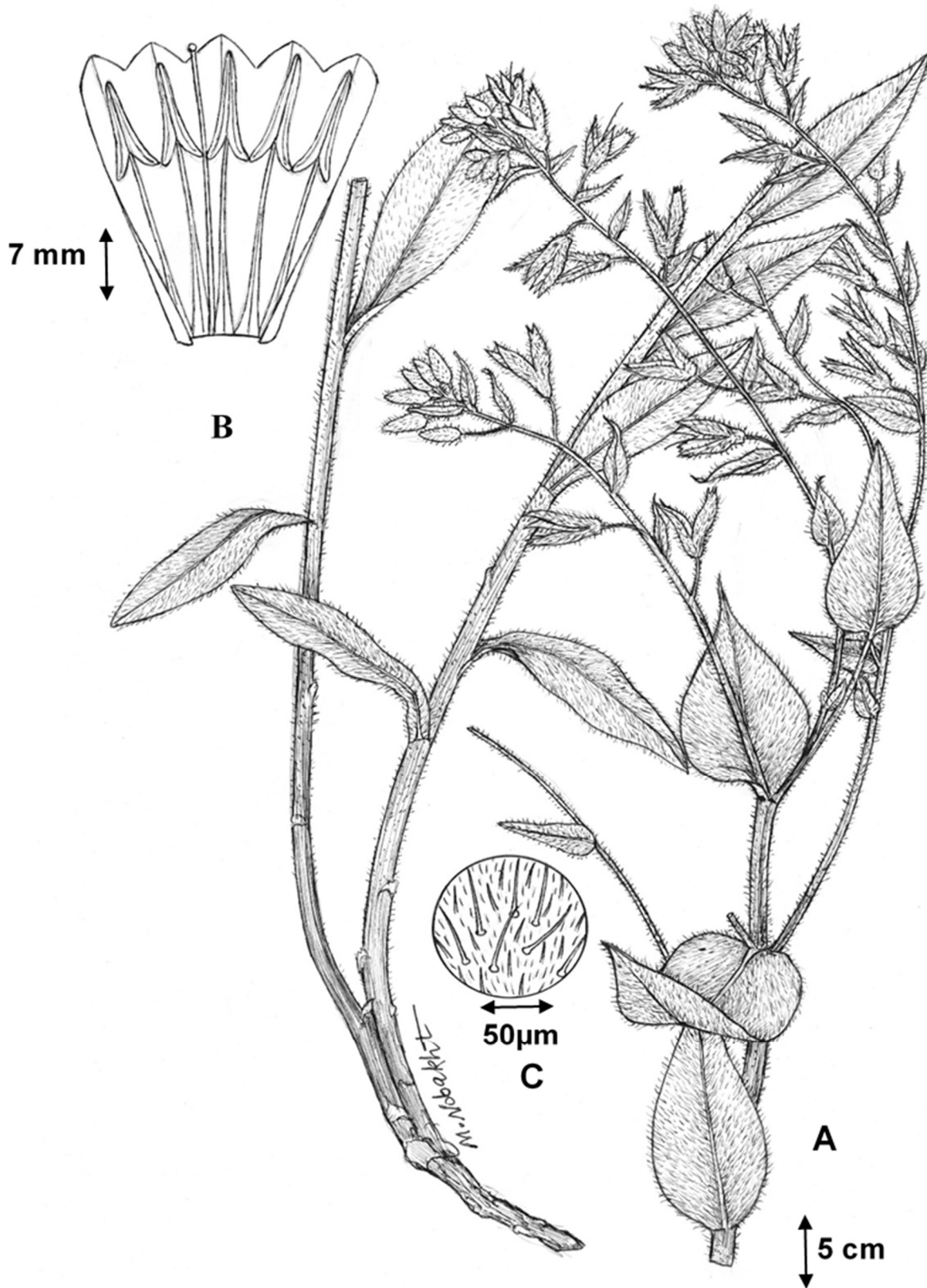


Fig. 4. *Onosma marivanensis* Mozaff. & Mehrabian. A. habit, B. Corolla, C. leaf trichomes



pubescent. Corolla campanulate, white 14–16 mm, pubescent in outside, lobes triangular, 5×2 mm, sparsely pubescent insides; annulus glabrous; Anthers free at the base, to 9 mm, inserted upper ½ corolla tube. Style much longer than corolla; stigma discioid-globose. Nutlet ca. 6 mm long, ca. 2 mm wide, oblong- rhomboid, Brown (Fig. 10B).

Remarks: closely allied to *O. cornuta* H. Riedl, however differentiate by wider cauline leaves, absence the basal leaves, anthers longer as well free at base, glabrous annulus as well sparsely leaf trichomes compared to *O. cornuta*. Moreover, represent divergence by shorter as well campanulate corolla, anthers free at base, cordate bract as well sparsely leaf trichomes, compared to *O. sericea* Willd. (Table 1).

Etymology: Specific epithet is based on the geographical origin of the species in West of Iran

Pollen characters: Heteropolar, tricolporate, subprolate, polar axis: 10.8–14.18 µm, mean: 12.35 µm, equatorial axis: 8.55–12.39 µm, mean: 10.64 µm, exine granulate to microechinate: 0.05–0.29µm, mean: 0.18 µm (Fig. 11E–H).

Habitat: *O. marivanensis* is also distributed in the western grassy mountain slopes in opiolitic rocks in Zagros near the borderline of Iran and Iraq with significant habitat distinctions near the closely related species including *O. sericea* widely distributed species in the xeric habitats of the Irano-Turania region as well as *O. cornuta*, an endemic species distributed in the Alborz and Zagros Mountains. Besides, the area of occupancy is relatively limited including less than 10 individuals.

Additional specimens examined for closest species:

***O. cornuta* H. Riedl:** Iran, Azarbaidjan, 85 km. W. Zanjan to Bijar, 1500 m, Rechinger, W-06142., Kurdistan, Bijar, Mehrabian, 1800 m, HSBU-2010274., Kurdistan, Between Sanandaj and Saqez, Rechinger, W-19841., Kermanshah, 40 km Sarpol-e Zahab from Eslam Abad, Mehrabian, HSBU-2011105., Kermanshah, Between Eslam Abad and Ivan, 1420 m, Mozaffarian, TARI74735., Hamedan, 20 km Nahavand, Garin Mts, 1800-2200 m, Assadi & Mozaffarian, TARI-36904.

***O. sericea* Willd.:** Iran, Azarbaidjan, Khoy to Ghare Ziaedin, 1500-1700 m, Rechinger, W-06094, Azarbaidjan, Between Balansh & Oshnavieh, 1650-1900 m, Rechinger, W-13487., Azarbaidjan, 51 km w Uromia, 1700 m, Grant., Yam, Misho Dagh Mts, Mehrabian, HSBU-287., Khoy, 1200 m, Gauba & Sabeti, W-19959., Azarbaidjan, % km Bostan Abad from Mianeh, Mehrabian, HSBU-264., Kurdistan, 18 km Sanandaj, 1500 m, Wendelbo, W-11756., Kurdistan, Between Saanandaj and Saqez, Rechinger, W-19841., 10 km, Sanandaj toward Kermanshah, Kamyaran road, 1700 m, Mehrabian, HSBU-269., 20 km Sanandaj to Divandareh, Mehrabian, 1590 m, HSBU-257., Kermanshah, Bijar, Mehrabian, HSBU-276., Karaj, Rechinger, W-894, between Taleghan and Ziaran, Mehrabian, HSBU-288, Lorestan, 60 km E. Khoram Abad, 1850-2000 m, Rechinger, W-05711., Lorestan, Ostorankoh, 1200-2200 m, Rechinger, W-05646.

***Onosma sanandajensis* Mehrabian & Mozaff., sp. nov.**

Fig. 5

Type: Iran. Kordestan, 36km from Sanandaj to Kamiaran, Nashure valley, ca. 2000 m a.s.l, 15 Jun 1987, *Assadi 60621* (holotype TARI!).

Perennial, creeping rhizome, with woody rootstock. Stems up to 60 cm tall, partly diffuse; pubescent, covered by sparse hairs in lower parts, dense hairs in upper parts. Basal leaves absent; cauline leaves lanceolate- oblong, sessile, partly perfoliate, acute, 20–60 mm long, 2–9 mm wide; setae on glabrous tubercles (subsect. *Haplotricha*), adpressed, white, 0.1–0.8 mm long, with densely pubescent in dorsal surface as well along the midrib in ventral surface, non adpressed, with sparse tiny hairs (pilies) among them (Fig. 9M–O). Inflorescence apical, simple or with 2–3 capitate scorpioid cymes, diffuse, each cyme with (7) 9–12 flowers, 150-180 mm long, densely pubescent. Pedicels to 5mm, at the flowering time, up to 7mm. Calyx divided nearly to base, fruiting calyx accrescent, to 18 mm long or more, 3–5 mm wide, with 3–4 lobes, sparsely pubescent. Bracts linear-lanceolate 5-9(10) mm long, ca. 0.5 mm wide, covered with short hairs. Corolla campanulate, ca. 10 mm long, yellow, pubescent; lobes 5, ca 1.3 mm long, ca. 1 mm wide; annulus glabrous. Anthers ca. 6 mm long, connate at base, sagittate, inserted in the middle of corolla tube. Style protruding outside the corolla limb, stigma globose-discoid. Nutlets ovoid, ca.7 mm long, ca. 4.5 mm wide, dorsal surface navicular, farinose, Creamy brownish, brown spotted (Fig. 9C).

Remarks: Closely allied to *O. cornuta* H. Riedl., an endemic taxon in the west as well as the North of Iran, however, differentiate by wider and lanceolate-oblong cauline leaves, shorter corolla, longer pedicle, and larger seeds compared to *O. cornuta*. Moreover, represent divergence by absence the basal leaves, longer pedicles, longer calyx as well campanulate corolla to *O. sericea* Willd. that widely distributed in SW Asia, Caucasia and Armenia (Table 1).

Etymology: A Specific epithet is based on the geographical origin of the species in the western zones of Iran.

Pollen characters: Heteropolar, tricolporate, subprolate, polar axis: 11.5-15.7 µm, mean: 13.9µm, equatorial axis: 11.4-13.2µm, mean: 9.5µm, exine granulate to microechinate: 0.16-0.32µm, mean: 0.23 µm (Fig. 11:I-L).

Habitat and population: including about 10 individuals in mountain slopes, open forests of *Quercus* with a limited range in the opiolitic rocks of the western slopes of Zagros which is affected by the Mediterranean climate which shows an ecological divergence compared to the sely related species following *O. sericea* widely distributed species in the xeric habitats of the Irano-Turania region, as well as *O. cornuta* an endemic species distributed in the Alborz and Zagros Mountains.

Additional specimens examined for closest species:

***O. cornuta* H. Riedl:** Iran, Azarbaidjan, 85 km. W. Zanjan to Bijar, 1500 m, Rechinger, W-06142., Kurdistan, Bijar, Mehrabian, 1800 m, HSBU-2010274., Kurdistan, Between Sanandaj and Saqez, Rechinger, W-19841., Kermanshah, 40 km Sarpol-e Zahab from Eslam Abad, Mehrabian, HSBU-2011105., Kermanshah, Between Eslam

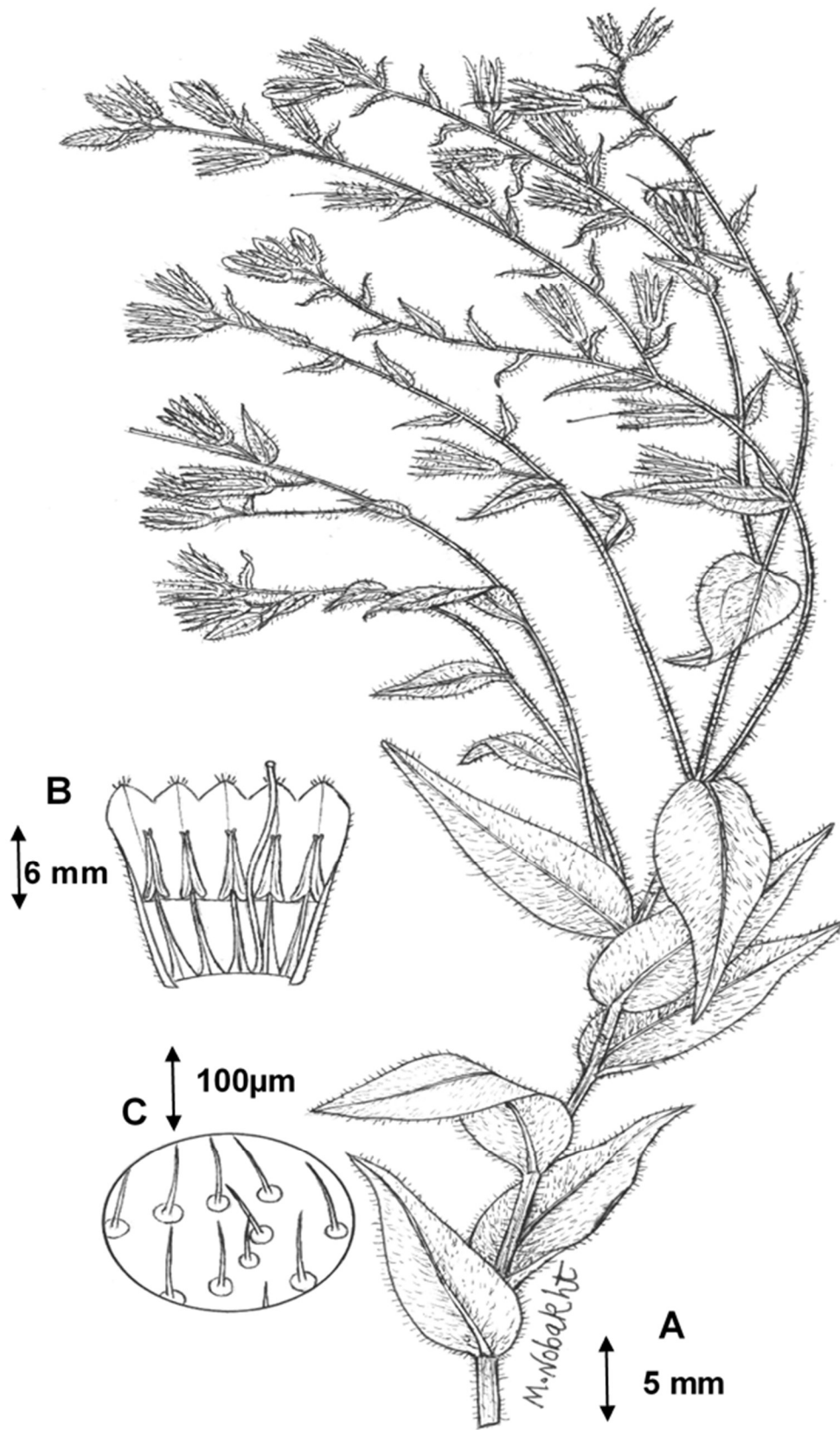


Fig. 5. *Onosma sanandajensis* Mehrabian & Mozaff. A. habit, B., Corolla, C. leaf trichomes.



Abad and Ivan, 1420 m, Mozaffarian, TARI74735., Hamedan, 20 km Nahavand, Garin Mts, 1800-2200 m, Assadi & Mozaffarian, TARI-36904.

***O. sericea* Wild.:** Iran, Azarbaijan, Khoy to Ghare Ziaedin, 1500-1700 m, Rechinger, W-06094, Azarbaijan, Between Balansh & Oshnavieh, 1650-1900 m, Rechinger, W-13487., Azarbaijan, 51 km w Uromia, 1700 m, Grant., Yam, Misho Dagh Mts, Mehrabian, HSBU-287., Khoy, 1200 m, Gauba & Sabeti, W-19959., Azarbaijan, 10 km Bostan Abad from Mianeh, Mehrabian, HSBU-264., Kurdistan, 18 km Sanandaj, 1500 m, Wendelbo, W-11756., Kurdistan, Between Saanandaj and Saqez, Rechinger, W-19841., 10 km, Sanandaj toward Kermanshah, Kamyaran road, 1700 m, Mehrabian, HSBU-269., 20 km Sanandaj to Divandareh, Mehrabian, 1590 m, HSBU-257., Kermanshah, Bijar, Mehrabian, HSBU-276., Karaj, Rechinger, W-894, between Taleghian and Ziaran, Mehrabian, HSBU-288, Lorestan, 60 km E. Khoram Abad, 1850-2000 m, Rechinger, W-05711., Lorestan, Ostorankoh, 1200-2200 m, Rechinger, W-05646.

Onosma sarvestanica* Mozaff. & Mehrabian, *sp. nov.

Fig. 6

Type: Iran. Fars, Mian Jangal Protected area, Tange Ahram, 1900-2200m, 27 Apr 2003, *Mozaffarian 83624* (holotype TARI!).

Perennial, with woody rootstock, fertile stems numerous, diffuse to erect, up to 35 cm tall, remaining leaves of previous year at the base, cream to whitish brown, glabrous to sparsely pubescent. Basal leaves linear-oblong, attenuate base on a long petiole, obtuse to acute, rolled inward, 20–45(50) mm long, 3-5(6) mm wide, setae with glabrous tubercles (subsect. *Haplotricha*), white, adpressed 1-1.8 mm long, densely pubescent in upper surface. Upper and middle cauline leaves similar, lanceolate, oblong-elliptic, attenuate at the base, sessile, acute in apex, 25–50 mm long, 7–14 mm wide, setae adpressed, white to yellowish white, more dense in upper surface, with dense tiny hairs among them (Fig. 9J–L). Inflorescence apical, nearly capitate, seldom elongated, 2-3 dense scorpioid cymes, 60-100 mm long, each cyme with (4)5–7 flowers. Flowering pedicels 3–5 mm. Bracts linear-lanceolate 9–11 mm long, ca. 1 mm wide, with short hairs, more dense along the central vein. Calyx divided to base, linear-lanceolate lobes, 12-14 mm long, ca. 1 mm wide, covered by dense and white bristles, severely dense at the base. Corolla 18-20 mm, tubular to tubular-clavate, yellow, light violet at the tip of flowers, densely pubescent outside; lobes triangular, ca. 2 mm long, ca. 1.8 mm wide; annulus with short and nearly dense bristles, ca. 1.5 mm; Anthers ca. 8 mm long, connate at base, inserted upper 2/3 corolla tube; style exerted; stigma bilobed. Nutlets rhomboid, 7 mm long, 3.5 mm wide, light brown, dark brown spotted (Fig. 10D).

Remarks: Near to *O. asperrima* Bornm.; regardless, they differ by larger cauline leaves, hairy annulus, longer and free-at-base anthers, as well as the presence of sparsely pilies among the setae. In addition, apparently close to *O. kotschy* Boiss., endemic species to W, NW and SW Iran. Nevertheless, it is distinct by thinner cauline leaves, absence the basal leaves, longer corolla and bracts as well the free anthers at base compared to *O. kotschy*.

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Etymology: The specific epithet is based on the geographical origin of the species in the South of Iran.

Habitat: *Onosma sarvestanica* is allocated to rocky slopes in the open shrub lands of *Pistacia atlantica* and *Amygdalus soperia* well-known in quaternary deposits compared to closely related species of *O. kotschy* as well as *O. asperrima* that is widely distributed in the middle to southern Zagros. Besides, the area of occupancy is relatively limited including more than 50 individuals belonging to 2–3 populations.

Pollen characters: Heteropolar, tricolporate, subprolate, polar axis: 10.9–14.8 μm , mean: 12.5 μm , equatorial axis: 8.5–14.7 μm , mean: 11.9 μm , exine granulate to micro-echinate: 0.17–.45 μm , mean: 0.24 μm (Fig. 11M-P)

Specimens examined (paratypes): Iran: Fars, 25 km S.E. Fasa. Salou Village, Kuh-e Raz, 1600–2200 m, Mozaffarian, TARI-46792.

Additional specimens examined for closest species:

***O. asperrima* Bornm.:** Iran: Lorestan, Aligudarz, Ghalikuh, IRAN-2697., Fars, Abadeh, Behbodi, W-7148., Fars, Norabad, Doshman Ziari, 1900-2500 m, Mozaffarian, TARI-45772., Fars, Bamo Protected Area, 1650-1800 m, Wendelbo & Foroghi, TARI-17568., Fars, Shiraz, Dast e- Arjan, Mozaffarian, 2250-3000 m, TARI-71367., Fars, Firozabad, 170-26660 m, Mozaffarian, TARI-71449., Fars, Abadeh, Kahkoli, IRAN-2698., Fars, 15 km Shiraz toward Estahbanat, Mianjangal, 1700-2400 m, Mousavi & Tehrani, IRAN-2699., Dena Mts, Sharif, IRAN-26701., Fars, Shiraz, Dasht Arjan, Kazeron old road, 2200 m, Foroghi, TARI-17437., Kerman, between Bam and Jiroft, Jebal Barez Mts, Allen and Esfandiari, W-6742.

***O. kotschy* Boiss.:** Iran: Fars, Shiraz Delo Mts, Kotschy, W-503 (holotypus), Hamedan, Garin Mts, Gamasiab, 2600 m, Assadi & Mozaffarian, TARI-36966., Lorestan, Nahavand to Norabad, 2100-2800 m, Assadi & Mehregan, TARI-89124., Lorestan, Aleshtar, 2130-2900 m, Assadi & Mehregan, TARI-88881., Kobara, Koelz, W-1571., Kohkilouyeh and Boyerahmad, Dena Mts. To Gardaneh Bijan, Termeh and zargani, IRAN-2812., Fars, Estahbanat, 1700-2200 m, TARI-46999.

Onosma targevarensis* Mozaff. & Mehrabian, *sp. nov.

Fig. 7

Type: Iran. Azerbaijan, Urumieh, Mavan, Hakki, Mts. W. of the village, Kuhe Dare rash. 2100-2700m, 31 Jul 1995, *Mozaffarian 74866* (holotype TARI!).

Perennial, with woody rootstock, stem numerous, diffuse, growing to 40 cm tall, sparsely pubescent, with remaining leaves of previous years. Leaves of the sterile shoots linear-lanceolate to spatulate, attenuate to long petiole, acute to obtuse, 20–90 mm long, 2–10 mm wide, and sparsely to densely setolouse upper surface, especially near the margins and along the central vein, sparsely setolouse in lower surface. Basal leaves linear, attenuate at the base 25–50 mm long, 2–3.5 mm wide, with similar setae to sterile shoots. Cauline leaves lanceolae-linear, sessile, acute to obtuse, 20-60 mm long, 1.5–9 mm wide, setae with hairy tubercles (subsect. *Onosma*), 0.3–1.5 mm, white to yellowish white, non adpressed, with sparse tiny hairs among them (Fig. 9P-R). Inflorescence apical, 2-3 scorpioid cyme, 7–15 cm, each cyme with 7–12 flowers. Bracts linear to linear-lanceolate, 20–25 mm long ca. 1 mm wide, sparsely

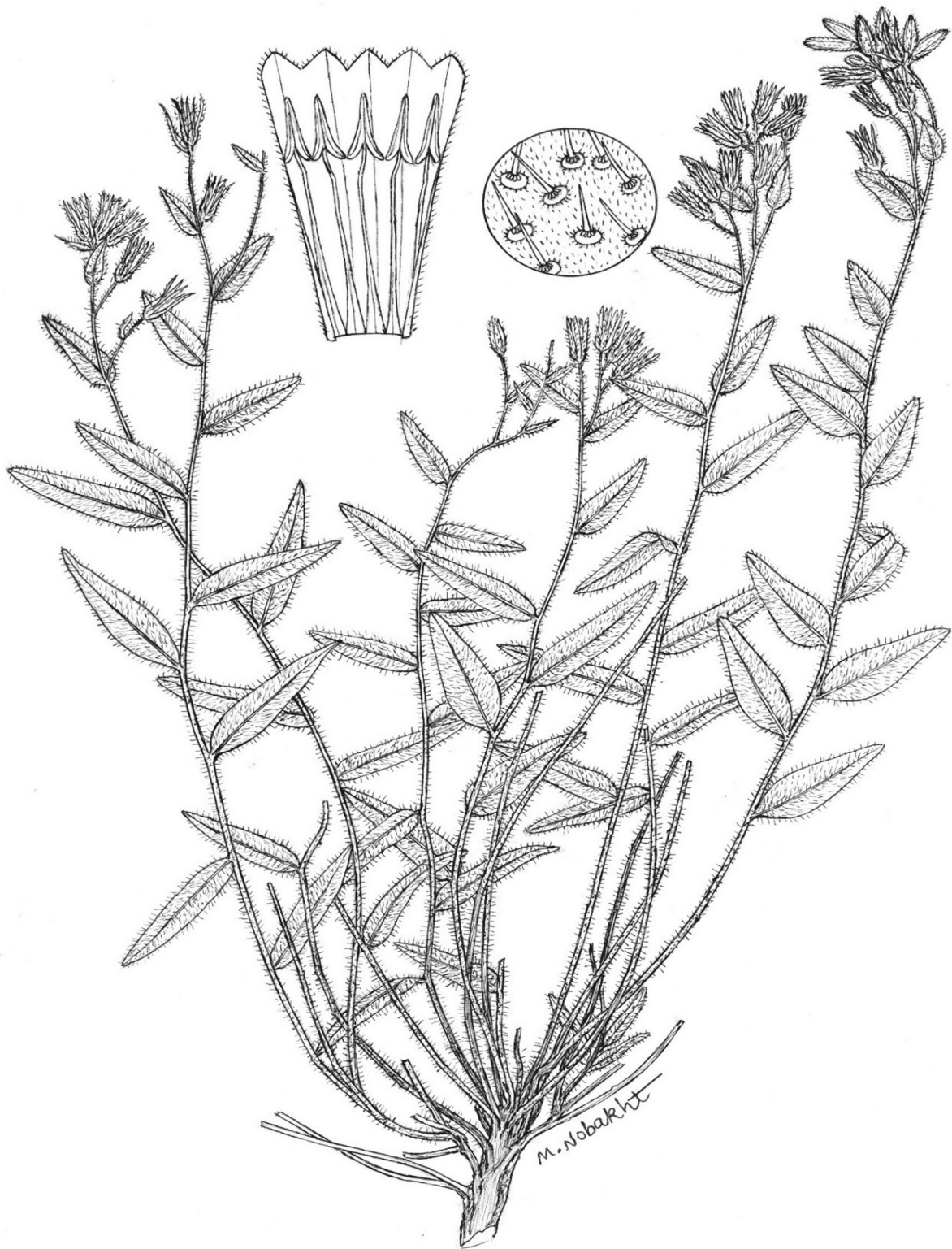


Fig. 6. *Onosma sarvestanica* Mozaff. & Mehrabian. A. habit, B., Corolla, C. leaf trichomes

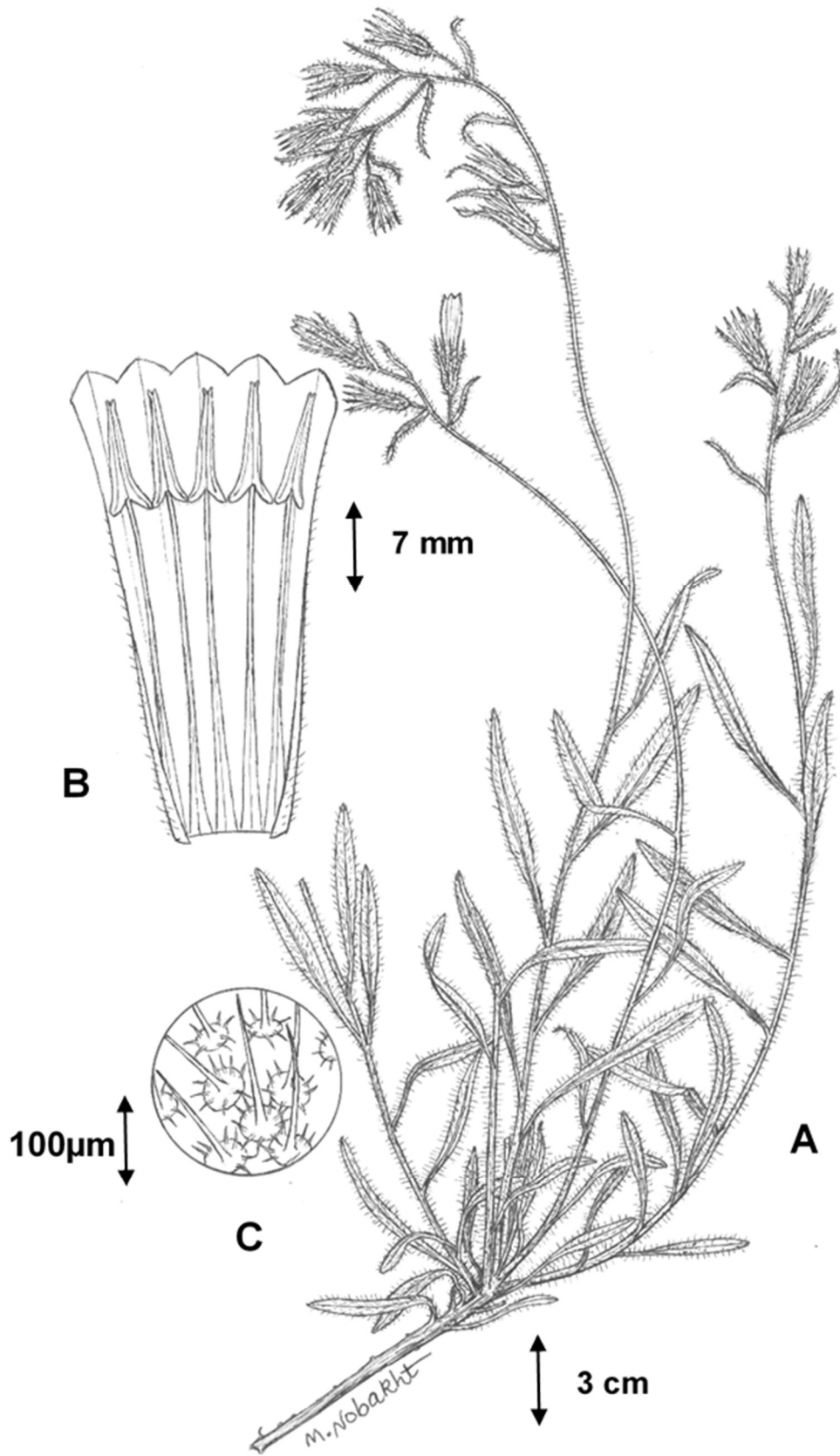


Fig. 7. *Onosma targevarens* Mozaff. & Mehrabian. A. habit, B. Corolla, C. leaf trichomes.



pilose. Fruiting pedicle 4–7 mm. calyx divided to base; lobes 18–20 mm as well ca. 1.5 mm wide long in fruiting, densely pilose especially at the base. Corolla clavate, 25–27 mm long, yellow, glabrous to sparsely ciliate outside, lobes triangular; ca. 3 mm long, ca. 2.5 mm wide; annulus glabrous. Style longer than corolla, stigma discoid-globous. Anthers connate at base, to 9 mm, inserted upper 2/3 corolla tube. Nutlet rhombic, 4 mm long, ca. 2.5 mm wide, Creamy brownish (Fig. 10E).

Remarks: Related closely with *O. hebebulba* DC. Endemic taxon to West Iran, nevertheless differentiated by shorter and linear basal leaves, clavate corolla, shorter pedicle as well as sparsely pilies in comparison to *O. hebebulba*. In addition, it is apparently closely allied to *O. iranshahri* Ghahreman and Attar, an endemic species to the West of Iran; however different by linear basal leaves, non-accessecent as well shorter calyx, longer corolla as well rhomboid nutlet to *O. iranshahri* (Table. 1).

Etymology: The Specific epithet is based on the geographical origin of the species in North West Iran.

Pollen characters: Heteropolar, tricoloporate, subprolate to prolate, polar axis: 11.2–13.7 μm , mean: 12.9 μm , equatorial axis: 10.3–13.1 μm , mean: 11.7 μm , exine microechinate: 0.17–0.24 μm , mean: 0.21 μm (Fig.11:17-20).

Habitat: *O. targevarensis* is mainly distributed in tagacanthic *Astragalus* shrublands in the metamorphic rocks of the western slopes of Zagros compared to *O. hebebulba* with relatively wide dispersal in middle Zagros as well as *O. iranshahri*, a restricted endemic species in the ophiolitic rocks in western slopes in Middle Zagros. Besides, the area of occupancy is relatively limited including more than 20 individuals belonging to 2-3 populations distributed relatively close distance.

Specimens examined (Paratypes): Iran, Azarbaijan, W-7093

Additional specimens examined for closest species:

***O. hebebulba* DC.:** Iran: Kurdistan, 45 km Kerend, Dalahoo Mts, 2000-2200 m, Assadi, TARI-60835., Kermanshah, Eslam Abad to Illam, Sharif, IRAN-5329, Illam, N.W. Ziam, Malegavan, 2200 m, Mozaffarian 95495.,

***O. iranshahri* Ghahreman & Attar.:** Iran: Kurdistan, Marivan to Paveh, Gardan-e tate, between Dezli and Hanigarmaleh, Mozaffarian, 1800-2600 m, TARI-75701 (Isotypus)

***Onosma wendelboii* Mehrabian & Mozaff., sp. nov.**

Fig. 8

Type: Iran. Lorestan, Tang-e Tir ca. 40 km. W. of Khorramabad, 1300m, 5 May 1975, Wendelbo and Assadi 60621 (holotype TARI!).

Perennial, with creeping rhizome. Stem growing up to 30 cm tall, diffuse, covered by dense hairs in lower parts. Rosette leaves spatulate, 25–70 mm long, 4–13 mm wide, setae white to white yellowish, densely villose, attenuate at base to a long petiole, obtuse to acute, rolled inwards. Basal leaves oblong-elliptic to linear-lanceolate, attenuate at the base to a long petiole, obtuse to acute,

rolled inwards, 25–60 mm long, 1.5–3 mm wide, densely villose in dorsal surface, sparsely in ventral surface. Cauline leaves 20–60 mm long, 4–12 mm wide, lanceolate, setae on a dense stellate tubercle (subsect. *Onosma*), 1.1–1.8 mm, sub-adressed setae (Fig. 9S–U). Covered by dense hairs in upper surface especially near the margins and along the midrib, obtuse to acute. Inflorescent 2-3, apical cymes, pubescent, each cymes with (3)4–5 flowers. Bracts lanceolate, ca. 17 mm long, ca. 2.5 mm wide. Fruiting pedicle 3–4(5) mm long. Calyx divided to base, lobes linear, ca. 18 mm long, ca. 1 mm wide, non acrescent, densely villose, white to white yellowish. Corolla tubular-clavate, 15–17 mm long, pale yellow, sparsely villous outside, lobes ca. 1 mm long, ca. 1 mm wide; annulus glabrous, anthers connate, up to 7mm at the base, inserted upper 2/3 corolla tube. Style little out of corolla. Nutlet ovoid, 5 mm long, ca. 2.5 mm wide, navicular, Cream, dark brown spotted (Fig. 10F).

Remarks: near to *O. armena* DC. Distributed in W and NW Iran as well Armenia, regardless different by lanceolate cauline leaves, longer basal leaves, shorter corolla, longer calyx as well densely pilies compared to *O. armena*. Also near to *O. raschyana* Boiss. distinct by lanceolate cauline leaves, shorter corolla, longer pedicle, ovoid nutlet as well densely pilies (Table 1)

Etymology: Named in the honor of the eminent botanist Dr. Per Wendelbo, who has played a prominent role in the improvement of Iranian botany.

Pollen characters: not seen

Habitat: *O. wendelboii* shows a distribution in the open forests of *Quercus* in sedimentary rocks in a limited area in central Zagros compared to *O. armena* and *O. rascheyana* that are widely distributed in N. Zagros and Western Alborz. Besides, the area of occupancy is limited including to 15 individuals.

Additional specimens examined for closest species:

***O. rascheyana* Boiss.:** Iran: Between Rasch and Damascus, Boissier, G (Holotypus), Iran, Azarbaijan, W. Piranshahr, 2400 m, Amini & Torabi, IRAN, W. Azarbaijan, Bazargan, 2100-2250 m., Rechinger, W-06099., Azarbaijan, Kani Ziarat, Habasi bala, 2300-3000 m, Rechinger & Renz, W-05734., Chali Kuh be Rajan, Rechinger & Renz, 2600-3200 m, W-05728., Zanjan, Mahneshan to Takab, Bekgheis Mts., 2700 m, Mehrabian, HSBU-281., Mahneshan, Angoran, 2700-2900 m, TARI-64841., Kurdistan, Sanandaj to Hamedan, Salavatabad, IRAN-2919, 10 km E. Sanandaj, Furse, W-12625.

***O. armena* DC.:** Iran: Armenia, Aucher, G-2358 (Holotypus), Iran, Azarbaijan, Mako to Khoy, 2400–2650 m, Assadi & Mozaffarian, TARI-30353., W. Uromia, Ghoshchi, Mousavi & Tehrani, 1400–2100 m, IRAN-2692., Uromia, Silvana, 1700 m, Runemark & Forooghi, TARI-19595., Zanjan, Mahneshan, Alam kandi, Ghalan Mts, 1900-2500 m, Mousavi et al., IRAN-2689., E. Azarbaijan, Khoy to Ghotor, Sharif, IRAN2693., Kurdistan, Sanandaj, Salavatabad, TARI-1289.

DISCUSSION

Iran is a prominent speciation center for numerous plant species (Frey and Probst, 1986). This is as a result of its great climatic heterogeneity, geomorphologic

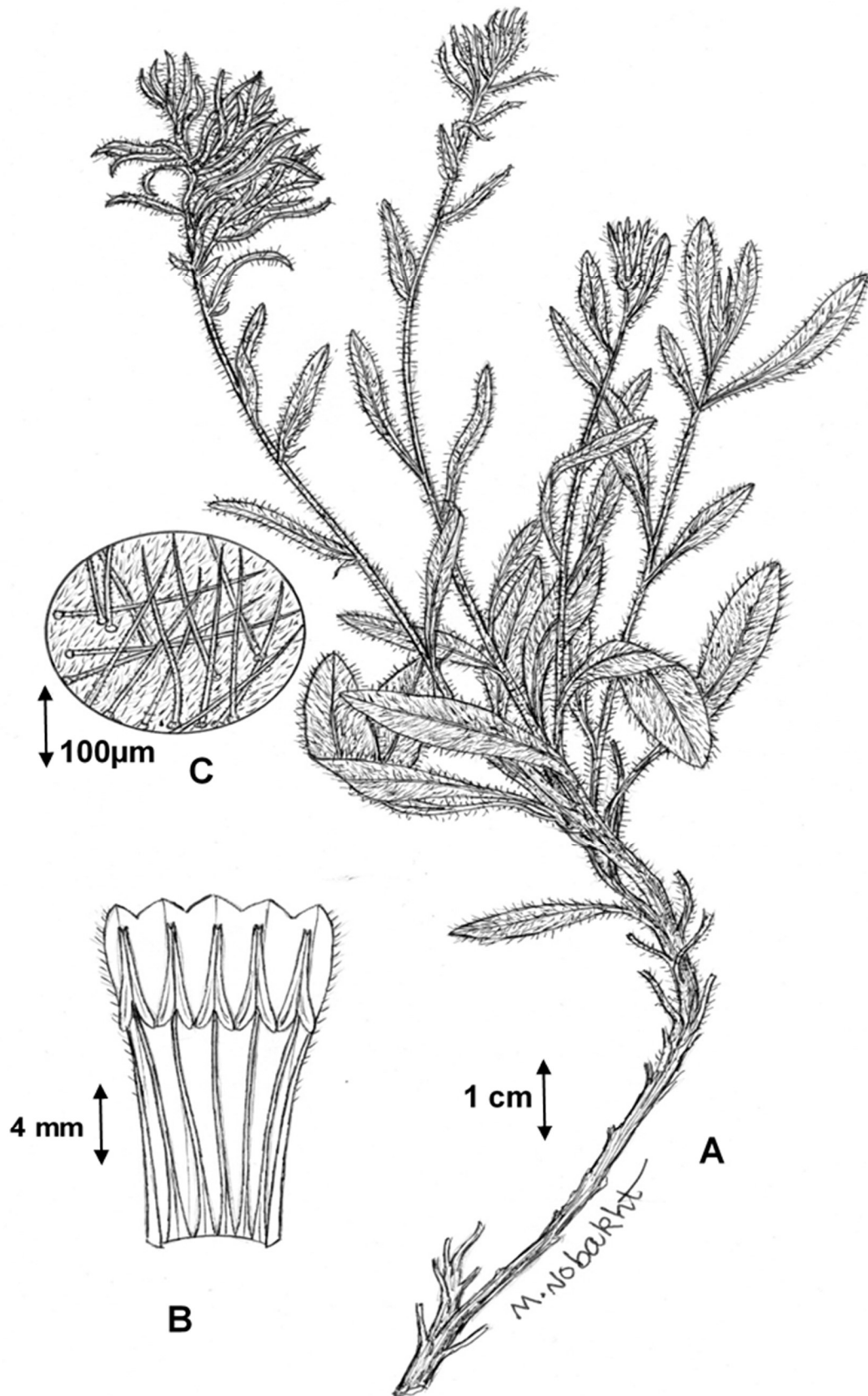


Fig. 8. *Onosma wendelboii* Mehrabian & Mozaff. A. habit, B. Corolla, C. leaf trichomes.

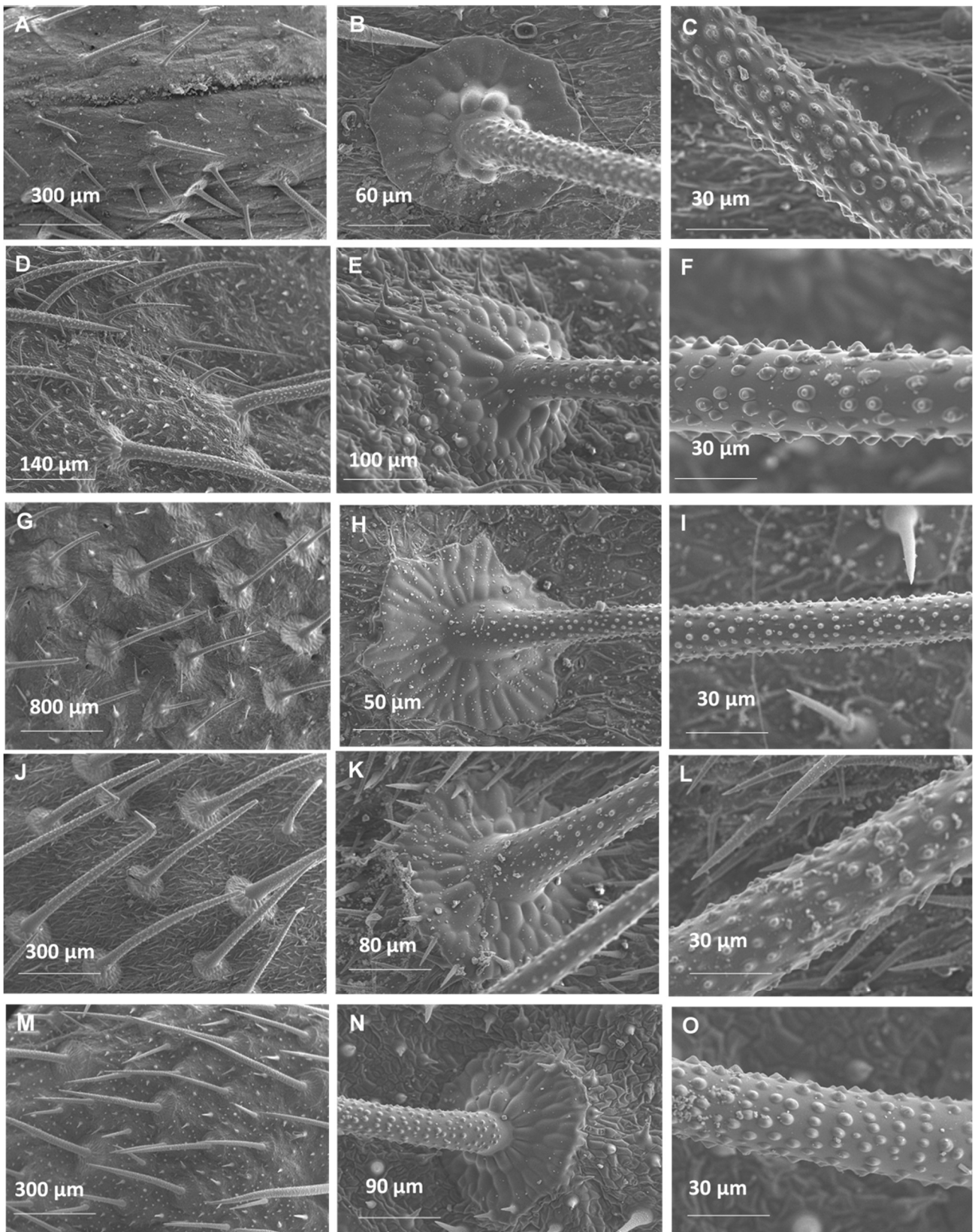


Fig. 9. SEM of leaf trichomes (adaxial surface) in new taxa: **A-C:** *O. assadi*, **D-F:** *O. bakhteganensis*, **G-I:** *O. marivanensis*, **J-L:** *O. sarvestanica*, **M-O:** *O. sanandajensis*.

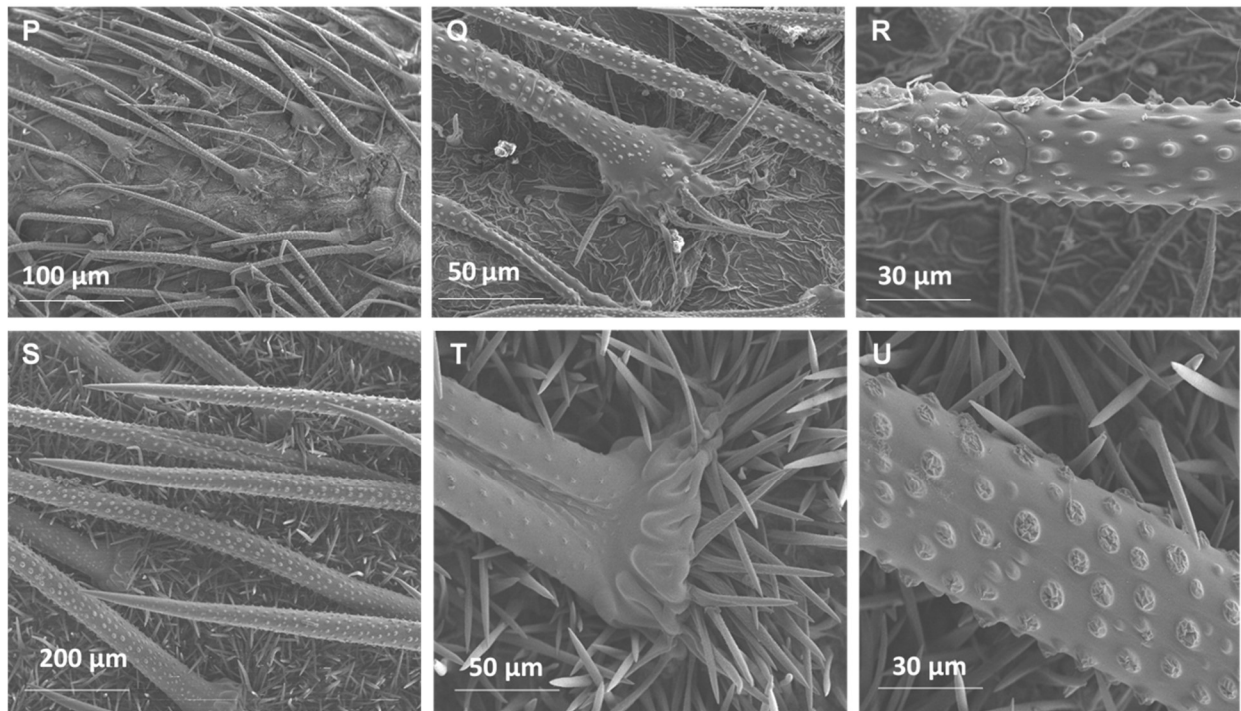


Fig. 9. Continued. P-R: *O. targevarens*, S-U: *O. wendelboi*

complexities (Stöcklin, 1968), diverse paleobiogeographical history (Sales and Hedge, 1996), diverse phytogeographic zones (Takhtajan, 1986), and being the chief corridor to botanical immigrations for several species that have penetrated to Iran by the Pliocene period (Zohary, 1963). Further, Iran is a center of plant endemism in SW Asia (Hedge and Wendelbo, 1978) and center of endemism for the prominent Irano-Turanian species (e.g. *Onosma*, *Astragalus* etc.) (Klein, 1981 & 1992, Leonard, 1991). Therefore, there is a high probability of identifying new species in the mentioned region confirmed by detection of several novelties during botanical excursions. The western slopes of central Zagros and southern slopes of central Alborz are considered as the main diversity centers of *Onosma* in the region (Mehrabian, 2015). The recent new species have been collected in the Zagros Mountainous ecosystem, which have been affected by the Mediterranean climate (Zahran, 2010), where some new species of *Onosma* have been reported in recent years. Pedologic factors and bed rocks serve as key factors for shaping specific habitats to endemism in *Onosma* (Cecchi *et al.*, 2011; Naqizadeh, 2018; Moradi, 2018) in response to isolation and distinctiveness as stressed by Rechinger, as a main factor to plant endemism in Iran (Hedge & Wendelbo, 1978). Also, the geologic and pedologic features of habitats in new detected species have confirmed their ecological divergence as new species.

Boissier (1879), Popov (1953), Johnston (1954), Post (1966), Riedl (1967), Polunin (1969), Ball (1972),

Riedl (1978), Nasir & Ali (1979), and Khatamsaz (2002) have emphasized the following characteristics for delimitation of species in *Onosma*: trichome type, shape and size of cauline and basal leaves, shape and size of calyx, annulus hairs, shape and size of corolla, nutlets morphology, anther length, and connection along with their exertion. The mentioned characteristics have been evaluated based on studying observed samples and samples collected through field observations consisting of over 4000 samples from both Iranian (HSBU, TARI, IRAN) and European (WU W) Herbariums, as well as imahes of type samples from a wide range of *Onosma* species. Among the morphological characteristics, trichome, nutlet, calyx and corolla were observed by several authors (Popov, 1953, Riedl, 1967 & 1979, Peruzzi & Passalacqua 2008, Binzet & Akcin 2009a, Akcin & Binzet, 2011, Mehrabian *et al.*, 2013, Arab Ameri *et al.*, 2014, Sayadi *et al.*, 2017) as the definitive evidence to delimitation and differentiation of the species. Hence, based on a wide range of the assessments conducted, the mentioned samples are considered as distinct species when compared with the previously introduced species in the region. Thus, it strengthens our justification as to whether they are new species. However, a phylogenetic study on all known species in SW Asia, provide a realistic insight into the relationships as well as systematic situation of species.

Besides, a wide range of *Onosma* species have been mainly reported from restricted localities. Thus, according to IUCN threatened categories, about 50% of species have been classified in critically endangered (CR)

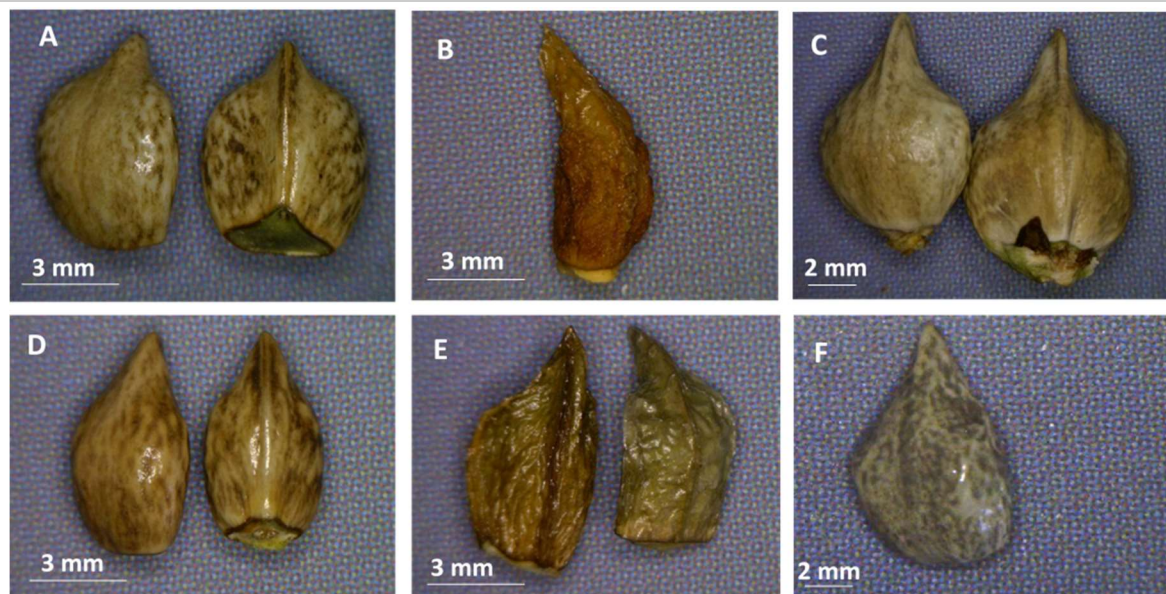


Fig. 10. Nutlet of new taxa: A. *O. bakhteganensis*, B. *O. marivanensis*, C. *O. sanandajensis* D. *O. sarvestanica*, E. *O. targevarensis*, F. *O. wendelboi*.

and endangered (En) categories on the scale of Iran (Mehrabian, 2015). *O. marivanensis*, *O. sanandajensis*, *O. sarvestanica* and *O. wendelboi* are only known based on the type locality, so are classified in the category CR on the basis of IUCN criteria B₁ (IUCN 2011). Besides, *O. assadi*, *O. targevarensis* and *O. bakhteganensis* are classified in the category EN on the basis of IUCN criteria B₁ (IUCN 2011). Unfortunately, the extreme anthropogenic pressures on their habitats is a serious issue necessitating planning management actions for *in-situ* and *ex-situ* conservation of these historic species.

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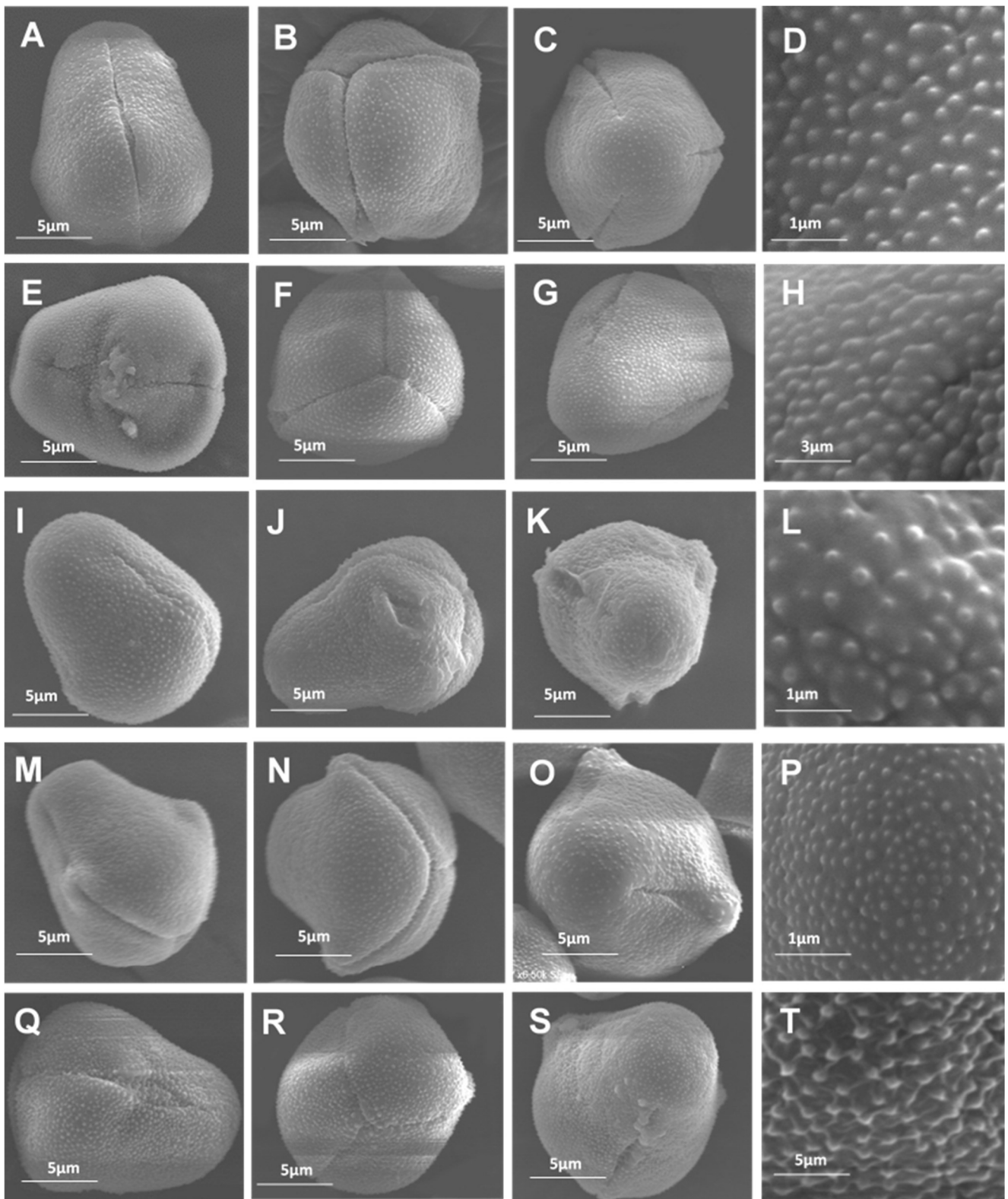


Fig. 11. Pollen grains of new taxa: A-D: *O. assadi*, E-H: *O. marivanensis*, I-L: *O. sanandajensis*, M-P: *O. sarvestanica*, Q-T: *O. targevarensis*.

**Table 1.** characters between new species and the morphologically closely related species.

Character/ Taxa	<i>O.</i> <i>sanandaje</i> <i>nsis</i>	<i>O.</i> <i>cornota</i>	<i>O.</i> <i>sericea</i>	<i>O.</i> <i>marivanen</i> <i>sis</i>	<i>O.</i> <i>assadi</i>	<i>O.</i> <i>microcarpa</i>	<i>O.</i> <i>chrysocha</i> <i>eta</i>	<i>O.</i> <i>azarbaidja</i> <i>nensis</i>	<i>O.</i> <i>bakhtegan</i> <i>ensis</i>
Cauline leaves size (mm)	20-60 × 2-9	20-60 × 2-20	18-70 × 5-25(30)	25-85 × 10-35	20-30 (40) × 2.5-4(5)	10-40×2-5	10-40(50) × 2-5(10)	15-22 × 2-4 mm	20-50 × 6-12
Caluline leaves shape	lanceolate- oblong	obovate- lanceolate	Lanceolate to lanceolate- obovate	broadly ovate- lanceolate	linear- lanceolate	lanceolate, spathulate, oblancheolat e-oblong	linear- lanceolate- oblong	Linear- lanceolate	lanceolate
Basal leaf size(mm)	-	15-100×3-20	25-100×5-22	-	-	15-60 ×2.5-8	15-60 ×25-8c	20-50×1- 2(2.5) mm	not seen
Basal leaf shape	-	obovate- oblong	obovate to lanceolate	-	-	spathulate, linear- lanceolate, linear	linear- lanceolate- oblong	Linear- lanceolate	not seen
Corolla shape	campanulate	tubular- campanulate	clavate to tubulate	campanulate	campanulate	tabulate, tubulate- campanulate	tubular- campanulate	tubular	tubular- clavate
Corolla long (mm)	ca.10	14-15	15-20	14-16	12-15	12-22(25)	(12)15-22(25)	Ca.10	ca.20
Calyx long (mm)	ca.18	Ca. 20	ca. 30	ca. 15(20)	Ca. 10	ca.15	ca. 12	Ca.12	ca.18
Accrescent calyx	+	+	+	+	-	-	-	-	-
Pedicle(mm)	ca.7	ca. 3.5	ca. 5	ca. 7(10)	5-6	ca.5	ca.3	Ca.4	ca.12(15)
Anther connection	connate at base	connate at base	connate at base	free at base	connate at base	connate at base	connate at base	Connate at base	free at base
Anther long (mm)	ca.6	Ca. 6	ca. 8	ca. 9	ca. 5	ca. 6.5	ca. 6	Ca. 10	ca.12
Annulus hairs	glabrous	pubescent	glabrous	glabrous	glabrous	glabrous	vilose	glabrous	setolous
Bract long(mm)	8-10	5-10 × 1-1.2	18-24 × 1-2 (3)	10-12 × 2.25	8-10 × 1-1.5	ca. 12	ca. 12	Ca. 22	4-4.5 × 3
Bract shape	linear	lanceolate to linear- lanceolate	lanceolate- linear	cordate- lanceolate	linear- lanceolate	lanceolate	linear- lanceolate	lanceolate	linear- lanceolate
Nutlet size (mm)	7×4.5	3-3.5×3	4-5-3×4	12×2.5	-	3×2.5	4×3	5×4	4.5×3
Nutlet shape	ovoid	ovoid	ovoid	rhomboid	-	ovoid	ovoid	pyramidal	ovoid
Leaf setae (trichome)	densely- appressed	densely- semi appressed	sericeous	sparsely- appressed	densely- appressed	densely	sparsely	sparsely	sparsely
Leaves pili (tiny hairs)	sparsely	sparsely	densely	sparsely	sparsely	densely	densely	sparsely	sparsely
Elevation range (m)	1900-2200	1260-2200	500-2150	1800-2600	586-1400	300-2750	1800-2200	1800-1900	1750
Habitat	Open scrubland	Open scrubland	Open scrubland	Grassy steppes	Gravelly slopes	A wide range of habitats	Grassy steppes	Grassy steppes	Spiny shrublands
Geological formation	Quaternary deposits	Sedimentary, volcano- sedimentary	Sedimentary, volcano- sedimentary, igneous, metamorphic	Ophiolitic rocks	Sedimentary, igneous	volcano- sedimentary, igneous, metamorphic	Sedimentary	volcano- sedimentary, igneous, sedimentary	Quaternary deposits
Geomorphologic unit	SW	SW, Za, N	NW, N, Za	W	NW	NW, N, Za, CI	Za	NW	SW

Za: Zagros, N: North, W: West, S: South, CI: Central Iranian

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Table 1. Contined.

Character /Species	<i>O. asperrima</i>	<i>O. kotschyi</i>	<i>O. sarvestanica</i>	<i>O. targevarensis</i>	<i>O. hebebulba</i>	<i>O. iranshahri</i>	<i>O. wendelboi</i>	<i>O. armena</i>	<i>O. rascheyana</i>
Cauline leaves size(mm)	18-65 × 4-40	18-60 × 4-35	25-50 × 7-14	20-60 × 1.5-9	20-50 × 5-12	25-50 × 10-20	20-60 × 4-12	15-35 × 1-3.5	20-43 × 3-9
Caluline leaves shape	lanceplate, lanceolate-ovovate, lanceplate-oblong	Lanceolate, lanceolate-ovovate, lanceplate-oblong	lanceolate, oblong-elliptic	lanceolate-linear	lanceolate, lanceolate-oblong	spathulate, lanceolate	lanceolate	spathulate	oblong
Basal leaf size(mm)	not seen	20-40 × 2-3	20-45(50) × 3-5(6)	20-50 × 2-3.5	70-100 × 25-30	50-70 × (10)20-25	25-60 × 1.5-3	20-35 × 2-3.5	20-40 × 3-8
Basal leaf shape	not seen	linear	linear-oblong	linear	obovate-spathulate	spathulate, ovate, obovate	lanceolate, oblong-elliptic	spathulate	spathulate, linear-spathulate
Corolla shape	tubular-campanulate	tubular	Tubular, tubular-clavate	clavate	tubular, tubular-campanulate	clavate, campanulate	tubular-clavate	tubular, tubular-clavate	clavate
Corolla long(mm)	18-25	(7)8-10	18-20	25-27	ca.15	20	15-17	16-20	20-25
Calyx long(mm)	Ca. 18	ca. 14	12-14	ca. 20	ca. 17	ca.30	ca. 18	ca. 10(15)	ca. 20
Accrescent calyx	-	-	-	-	+	+	-	-	-
Pedicle (mm)	ca. 12 (15)	ca. 7	ca. 10(15)	ca. 7	ca. 17	ca.7	ca.5	ca. 2	ca. 2
Anther connection	connate at base	connate at base	connate at base	connate at base	connate at base	connate at base	connate at base	connate at base	connate at base
Anther long(mm)	Ca. 6	ca. 6	ca. 8	ca. 9	ca. 8	ca. 8.5	ca. 7	ca. 6	ca. 8
Annulus hairs	glabrous	pubescent	setolouse	glabrous	glabrous	-	glabrous	glabrous	glabrous
Bract long (mm)	15-17 × 1.5-2	14-15 × 1.5-2	9-11 × 1	20-25 × 0.8-1	10-12 × 2-3	ca. 10	ca. 17	ca. 20	ca. 20
Bract shape	linear	linear - lanceolate	linear, linear - lanceolate	linear-lanceolate	lanceolate-linear	lanceolate	lanceolate	linear-lanceolate	lanceolate
Nutlet size (mm)	5×2.5	5×2.5	7×3	12×2.5	not seen	8×4.5	5×2.5	3×2	3×2
Nutlet shape	ovoid	ovoid	rhomboid	rhomboid	not seen	ovoid	ovoid	ovoid	deltoid
Leaf setae (trichome)	semi densely	sparsely	densely, adpressed	densely	densely	densely	densely	densely	semi densely
Leaves pili (tiny hairs)	absent	densely	sparsely	sparsely	densely	densely	densely	sparsely	sparsely
Elevation range (m)	1650-2400	1700-3000	1600-2200	2100-2700	1600-2200	1800-2600	1300	800-2650	950-3000
Habitat	woodlands, grassy steppes	Open shrublands, grassy steppes	Open shrub lands	Tragacanthic Astragalus shrubland	woodlands, grassy steppes	grassy steppe	Open forests	grassy steppe Tragacanthic cushions	grassy steppe Tragacanthic cushions
Geological formation	Sedimentary, igneous	Metamorphic, sedimentary	Quaternary deposits	Metamorphic rocks	sedimentary	Opiolithic	Sedimentary rocks	Sedimentary, igneous, metamorphic	Sedimentary
Geomorphologic unit	Za, CI	Za	SW	NW	Za	Za	W	N, NW, Za	N, Za, NW

Za: Zagros, N: North, W: West, S: South, CI: Central Iranian

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