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Trichome micromorphology in drupe of *Amygdalus* L. (Rosaceae) from Iran

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For delimitation of species and systematic resolution, pericarp indumentum in drupes of 17 species and two hybrids of the genus *Amygdalus* L., representing two subgenera and two sections distributed in Iran, were studied using scanning electron microscopy (SEM) in order to assess whether in this genus, pericarp micromorphological characters are of taxonomic value. The pericarp indumentum type is velutinous with different density of trichomes. Glabrous pericarp was observed solely in *A. reticulata* Runemark ex Khatamsaz. All trichomes are simple. Two basic types of trichomes were distinguished on the surface of the pericarp: tubular and flattened. Among these, tubular trichomes are more frequent than other trichomes in most species except for *A. kotschyi* Boiss. et Hohen., *A. eburnea* Spach, *A. spinosissima* Bge. subsp. *spinosissima* and *A. lycioides* Spach var. *lycioides*. Density of trichomes was variable among the studied taxa. In the first subgenus (subgen. *Amygdalus*) with two sections, there was enough difference between sections. While density of trichomes in sect. *Spartioides* Spach was very low, most of species in the another section, sect. *Amygdalus* showed dense pericarp indumentum. Regarding density, the second subgenus, subgen. *Dodecandra* (Spach) Browicz showed dense indumentum. Two hybrids studied, *A.*×*keredjensis* Browicz and *A.*×*kamiaranensis* Khatamsaz et Assadi showed different pericarp indumenta, dense and sparse respectively. In conclusion, micromorphological investigation of pericarp indumentum in drupes is a useful tool for distinguishing taxa in some cases, especially those of the two sections in the first subgenus in *Amygdalus*.

Key words: *Amygdalus*, pericarp, drupe, indumentum, micromorphology

Introduction

The genus *Amygdalus* L. with approximately 40–45 species in the world is distributed mainly in southwest Asia, central Asia and Middle East, although a few species in this genus are distributed in the east of Asia (China and Mongolia) as well as southeast Europe (BROWICZ and ZOHARY 1996). The main phytogeographical region for *Amygdalus* distribution is the Irano-Touranian region. The genus *Amygdalus* is classified in the tribe Amyg-

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daleae, subfamily Spiraeoideae, former subfamily Amygdaloideae (CRONQUIST 1981, TAKHTAJAN 1997), in family Rosaceae (POTTER et al. 2007). Classification of *Amygdalus* has changed over the course of time. In most classic classifications, *Amygdalus* was considered as a subgenus or as a section in the genus *Prunus*. For example, REHDER (1940) considered five subgenera in *Prunus*: *Prunus*, *Amygdalus*, *Cerasus*, *Laurocerasus* and *Padus* (LEE and WEN 2001). This treatment is the most acceptable classifications in the world. Phylogenetic classifications treated a new state for this genus. According to phylogeny and classification of Rosaceae (POTTER et al 2007), *Amygdalus* has been inserted within the genus *Prunus* with *Armeniaca*, *Cerasus*, *Laurocerasus*, *Padus*, *Pygeum* and *Maddenia* in the tribe Amygdaleae, subfamily Spiraeoideae. In the *Flora of Iran*, in Persian, *Amygdalus* is treated as a single genus in the subfamily Prunoideae. We say that there are sufficient morphological differences between *Amygdalus* and *Prunus* for them to be considered different genera.

According to the study of BROWICZ (1969), there are 15 species and two hybrids of *Amygdalus* in Iran. However, according to studies of KHATAMSAZ (1992), in Persian, 21 species and six hybrids of this genus occur in Iran. Among those, seven species, one variety and all the hybrids are endemic elements for the flora of Iran (KHATAMSAZ 1992). This genus includes two subgenera, subgen. *Amygdalus* and subgen. *Dodecandra* (BROWICZ 1969, KHATAMSAZ 1992). The former subgenus includes 15 species as trees or shrubs in two sections, sect. *Amygdalus* and sect. *Spartioides* Spach. The second subgenus includes six species (KHATAMSAZ 1992). Regarding vegetative features, two sections of the former subgenus are different from each other as follows. The main morphological feature of sect. *Amygdalus* is the presence of brachyblast (short shoots) whereas species in sect. *Spartioides* lack brachyblast and exhibit junciform feature (these species include shoots that show them as *Juncus*-like form). The second subgenus, subgen. *Dodecandra,* is completely different from the first, the species in this subgenus being spiny and shrubby with thick spines (BROWICZ 1969, KHATAMSAZ 1992). In fact, this genus is one of the most important elements of the Elburz and Zagros mountains, steppes, rocky places and semi-arid habitats in Iran. *Amygdalus* is one of the most problematic genera of the family Rosaceae. This genus involves numerous taxonomic problems including a high degree of morphological variation even in different populations of one species and interspecific hybridization; so boundaries between species are not clear and delimitation of species in this genus is not possible based on morphological characters alone. In addition, we need more evidence including micromorphological, anatomical, molecular and phytochemical information to elucidate the taxonomic complexity in this problematic genus.

Micromorphological studies are useful in resolving taxonomic problems because of high efficiency and reliability as well as the detailed data they provide. Plant hairs (trichomes) are of great interest to descriptive and experimental botanists and data on these and indumenta are routinely included in many types of studies (JURIŠIĆ GRUBEŠIĆ et al. 2007). Scanning electron microscopy (SEM) provides useful data on surface indumentum ultrastructure of seed, fruit, leaf and stem. Several researchers have focused on hair micromorphology of different families and genera including *Eugenia* L., Myrtaceae (FONTENELLE et al. 1994), *Ranunculus* L., Ranunculaceae (XUHAN and VAN-LAMMEREN 1994), *Cordia* L. and *Onosma* L., Boraginaceae (RAPISARDA et al. 1997, AKCIN 2007), Rosaceae and *Sanguisorba* L. (DOWIDAR et al. 2003, LATIF 2004), *Astragalus* L. and *Arbus* Adanson, Fabaceae (ZARRE 2003, AGBAGWA and OKOLI 2006), *Verbascum* L., Scrophula-

riaceae (ATTAR et al. 2007), *Teucrium* L. and *Nepeta* L., Lamiaceae (JURIŠIĆ GRUBEŠIĆ et al. 2007, KAYA et al. 2007) and *Isatis* L., Brassicaceae (MOAZZENI et al. 2007). So far, micromorphology of pericarp indumentum in the drupe of *Amygdalus* has not been studied and this study was conducted to investigate the pericarp indumentum of Iranian species of *Amygdalus*. Regarding the drupe, among allied genera in the tribe Amygdaleae, subfamily Spiraeoideae, or as formerly classified in the subfamily Amygdaloideae, *Amygdalus* has a unique feature as its mesocarp is thin and completely dried after fruit maturation and together with pericarp is separated from the endocarp, which is stony with various surface ornamentations. Generally, the surface of the pericarp is hairy in *Amygdalus*. The main aims of this study are to document a pericarp micromorphology of Iranian species of *Amygdalus* and then to use this feature for evaluating taxonomic relationships in this genus.

Material and methods

Matured, dried and clean drupes of 17 species and two hybrids of Iranian species of *Amygdalus* were selected and their pericarp was removed. The specimens are deposited in the Central Herbarium of the University of Tehran (TUH) and the voucher specimens are presented in table 1. A piece of pericarp was mounted on a 12.5 mm diameter aluminium stub with double sided adhesive and then was coated in a sputter coater with approximately 25 nm of Gold-Palladium at an accelerating voltage of 10–15 kv. The specimens were examined and photographed with Leo SEM-440I and Tscan SEM-Vega mostly at magnifications of 300–400×. The terminology for indumentum description follows that of HARRIS and HARRIS (1994).

Results

The main features of pericarp indumentum of the studied species of Iranian *Amygdalus* are presented in table 2 and SEM micrographs in plates 1–3 (figs. 1–23). The pericarp indumentum type is velutinous. Except for *A. reticulata* Runemark ex Khatamsaz with glabrous pericarp (Fig. 11), all other examined taxa were hairy. The trichomes could be studied with respect to different aspects including density, shape and length. Regarding density, trichomes were subdivided into four subtypes: dense, dense-sparse, sparse and very sparse. All trichomes are simple but two basic types of shape were found in the pericarp: tubular and flattened. Trichome length differs among the studied species. The length of tubular trichomes showed a diverse range from approximately 100–200 µm in *A. communis* L. and *A. carduchorum* Bornm. to more than 1000 µm in *A. korshinskyi* (Hand.-Mazz.) Bornm., *A. haussknechtii* (C. K. Schneider) Bornm. var. *pubescens* Bornm., *A. lycioides* Spach var. *horrrida* (Spach) Browicz and *A.* ×*kamiaranensis* Khatamsaz et Assadi. The length of flattened trichomes was in the range of 100–150 µm in *A.* ×*kamiaranensis* to an approximately 800–900 µm or more in *A. kotschyi* Boiss. et Hohen., *A. lycioides* Spach var. *lycioides* and then followed by *A. arabica* Spach, *A. spinosissima* Bge. subsp. *spinosissima*. Tubular trichomes were more frequent than other trichome in most species except for *A. kotschyi* (subgen. *Amygdalus*) and the three studied taxa of subgen. *Dodecandra* (Spach) Browicz including *A. eburnea* Spach, *A. spinosissima* Bge. subsp. *spinosissima* and *A. lycioides* var. *lycioides* (Figs. 8, 17, 19, 21).

Tab. 1. Voucher specimens of Iranian species of *Amygdalus* used in the drupe pericarp indumentum study

Collectors	Collection data	Species
Attar, Maroofi & Zamani	Iran, Kurdistan: Ca. 30 km to Ghorveh, 36323-TUH	*A. arabica* Olivier
Attar, Maroofi & Zamani	Iran, Kurdistan: Kamiaran to Marivan, Takht-zangi village, 36333-TUH	*A. communis* L.
Maroofi & Naseri	Iran, Kurdistan: Marivan, Dezli, 6285-kurdistan Herbarium	*A. carduchorum* Bornm.
Mobayen	Iran, Fars: Road of Nourabad, 8621-TUH	*A. eburnea* Spach
Attar & Zamani	Iran, Fars: Pass after Dasht-e Ardzan, 36286-TUH	*A. elaeagnifolia* Spach subsp. *elaeagnifolia*
Attar & Zamani	Iran, East Azerbayjan: After Kaleibar, 37212-TUH	*A. fenzliana* (Fritsch) Lipsky
Attar & Zamani	Iran, Fras: Kotal Pir-e Zan, 36299-TUH	*A. glauca* Browicz
Attar, Maroofi & Zamani	Iran, Kurdistan: Ca.15 km to Kamiaran, Morvarid pass, 36330-TUH	*A. haussknechtii* (C. K. Schneider) Bornm. var. *pubescens* Bornm.
Attar, Maroofi & Zamani	Iran, Kurdistan: Dezli pass, 36343-TUH	*A. korshinskyi* (Hand.-Mazz.) Bornm.
Attar, Maroofi & Zamani	Iran, Kurdistan: Ca. 30 km from Saqqez to Baneh, Nakarouz mountain, 363673-TUH	*A. kotschyi* Boiss. et Hohen.
Mobayen	Iran, Tehran: Kiasman, Fasham mountain, 19425-TUH	*A. lycioides* Spach var. *horrida* (Spach) Browicz
Attar & Zamani	Iran, Esfahan: Fereidoonshahr, Vahdatabad village, Pishkooh mountain, 36319-TUH	*A. lycioides* Spach var.*lycioides*
Attar & Zamani	Iran, East Azerbayjan: After Ahar to Tabriz, 37219-TUH	*A. nairica* Fed. et Takht.
Attar, Khatamsaz & Sheikh	Iran, Fars: Shiraz, Bamou National Park, 20390-TUH	*A. reticulata* Runemark ex Khatamsaz
Attar & Zamani	Iran, Fars: Dasht-e Ardzan, 36285-TUH	*A. scoparia* Spach
Ghahreman, Attar, Okhovvat & Mehdigholi	Iran, Khorasan: Mashhad to Torbat-e Heidariyeh, Robat-e Sang, 27289-TUH	*A. spinosissima* Bge. subsp. *spinosissima*
Attar, Maroofi & Zamani	Iran, Kurdistan: Takht-zangi village, 36331-TUH	*A. trichamygdalus* (Hand.-Mazz.) Woronow
Mirtadzadini	Iran, Kerman: Bam, Mij, 37820-TUH	*A. wendelboi* Freitag
Attar, Maroofi & Zamani	Iran, Kurdistan: Ca. 35 km from Sanandaj to Kamiaran, 36322-TUH	*A.* × *kamiaranensis* Khatamsaz et Assadi
Rieben	Iran, Tehran: Karaj, Koohdashteh, 8618-TUH	*A.* × *keredjensis* Browicz

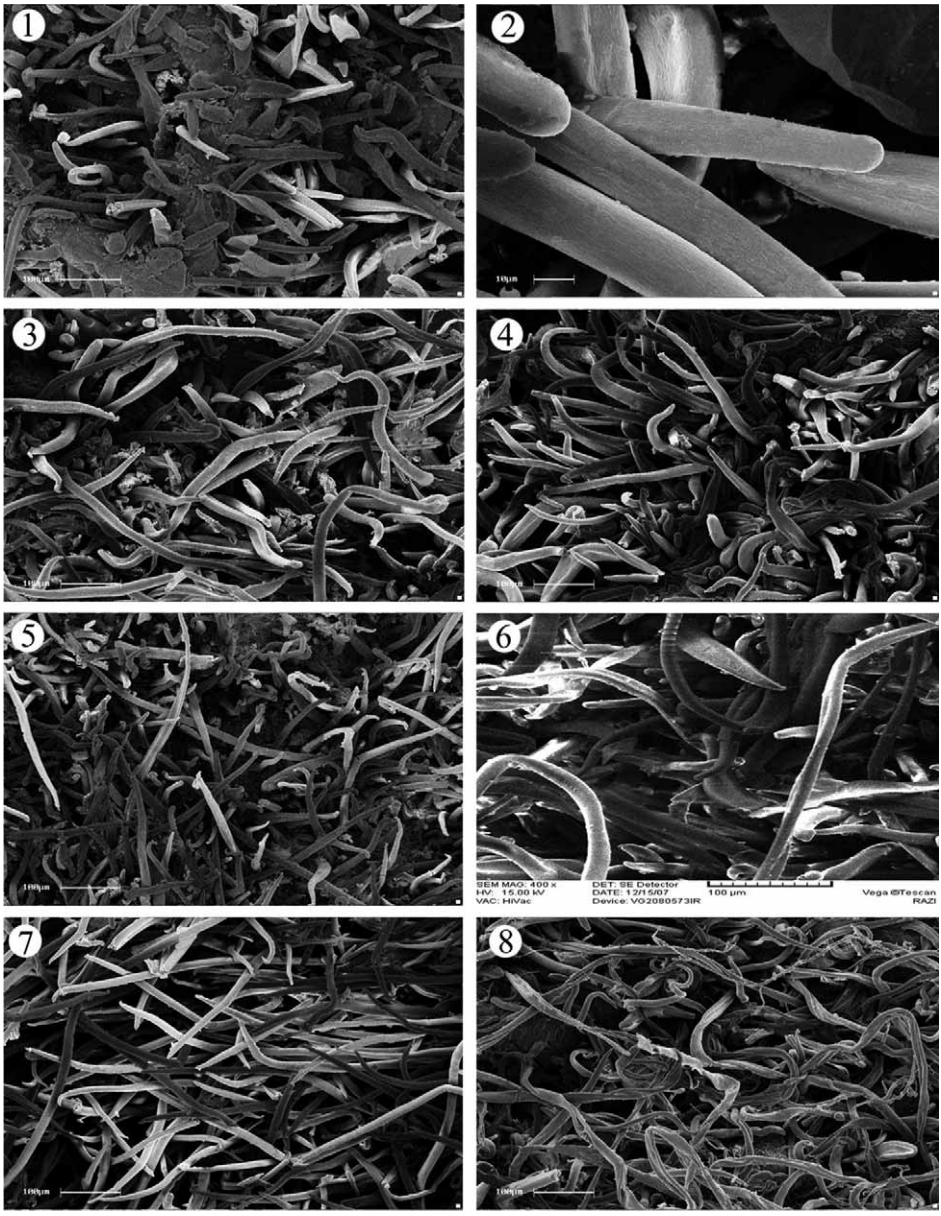

Plate 1. SEM micrographs of drupe pericarp indumentum of Iranian species of *Amygdalus*. **1, 2** – *A. communis*, **3** – *A. trichamygdalu*s, **4** – *A. wendelboi*, **5** – *A. korshinskyi*, **6** – *A. fenzliana*, **7** – *A. haussknechtii* var. *pubescens,* dense tubular trichomes, **8** – *A. kotschyi*, frequent flattened trichomes.

Amygdalus haussknechtii var. *pubescens* contained only tubular hairs (Fig. 7). In three studied taxa including *A. kotschyi*, *A. arabica* and *A. lycioides* var. *lycioides*, flattened trichomes were folded (Figs. 8, 12, 13, 21). Most studied species of sect. *Amygdalus* (subgen.

Amygdalus) except for *A. reticulata* contained indumentum with dense trichomes including *A. communis* L., *A. trichamygdalus* (Hand.-Mazz.) Woronow, *A. wendelboi* Freitag, *A. korshinskyi, A. fenzliana*, *A. haussknechtii* var. *pubescens*, *A. kotschyi* and *A. elaeagnifolia* Spach subsp. *elaeagnifolia* (Figs. 1, 3, 4, 5, 6, 7, 8, 10) but in *A. carduchorum,* indumentum was dense-sparse (Fig. 9). In contrast to the former section, three species of sect. *Spartioides* Spach showed very sparse indumentum with tubular and flattened trichomes (Figs. 12, 15, 16). The density of trichomes was very low and trichomes were very sparse. Examined species of subgen. *Dodecandra* including *A. spinosissima* subsp. *spinosissima*, *A.*

Tab. 2. Features of pericarp indumentum of Iranian species of *Amygdalus.* Abbreviations: F. T. – flattened trichomes; T. T. – tubular trichomes.

Species	Trichome density	Tubular trichomes	Flattened trichomes	Dominance of trichomes
subgen. *Amygdalus*				
sect. *Amygdalus*				
A. communis	Dense	+	+	T. T.
A. trichamygdalus	Dense	+	+	T. T.
A. wendelboi	Dense	+	+	T. T.
A. korshinskyi	Dense	+	+	T. T.
A. fenzliana	Dense	+	+	T. T. and F. T.
A. haussknechtii var. *pubescens*	Dense	+	–	T. T.
A. kotschyi	Dense	+	+	F. T.
A. carduchorum	Dense-sparse	+	+	T. T.
A. elaeagnifolia subsp. *elaeagnifolia*	Dense	+	+	T. T.
A. reticulata	Glabrous	–	–	–
sect. *Spartioides*				
A. arabica	Very sparse	+	+	Both rare
A. glauca	Very sparse	+	+	Both rare
A. scoparia	Very sparse	+	+	Both rare
subgen. *Dodecandra*				
A. spinosissima subsp. *spinosissima*	Dense	+	+	F. T.
A. eburnea	Dense	+	+	F. T.
A. nairica	Dense	+	+	T. T. and F. T.
A. lycioides var. *horrida*	Dense	+	+	T. T. and F. T.
A. lycioides var. *lycioides*	Dense	+	+	F. T.
Hybrids				
A. ×keredjensis	Dense	+	+	T. T.
A. ×kamiaranensis	Sparse	+	+	Both few

Abbreviations: F. T.: Flattened Trichomes; T. T.: Tubular Trichomes.

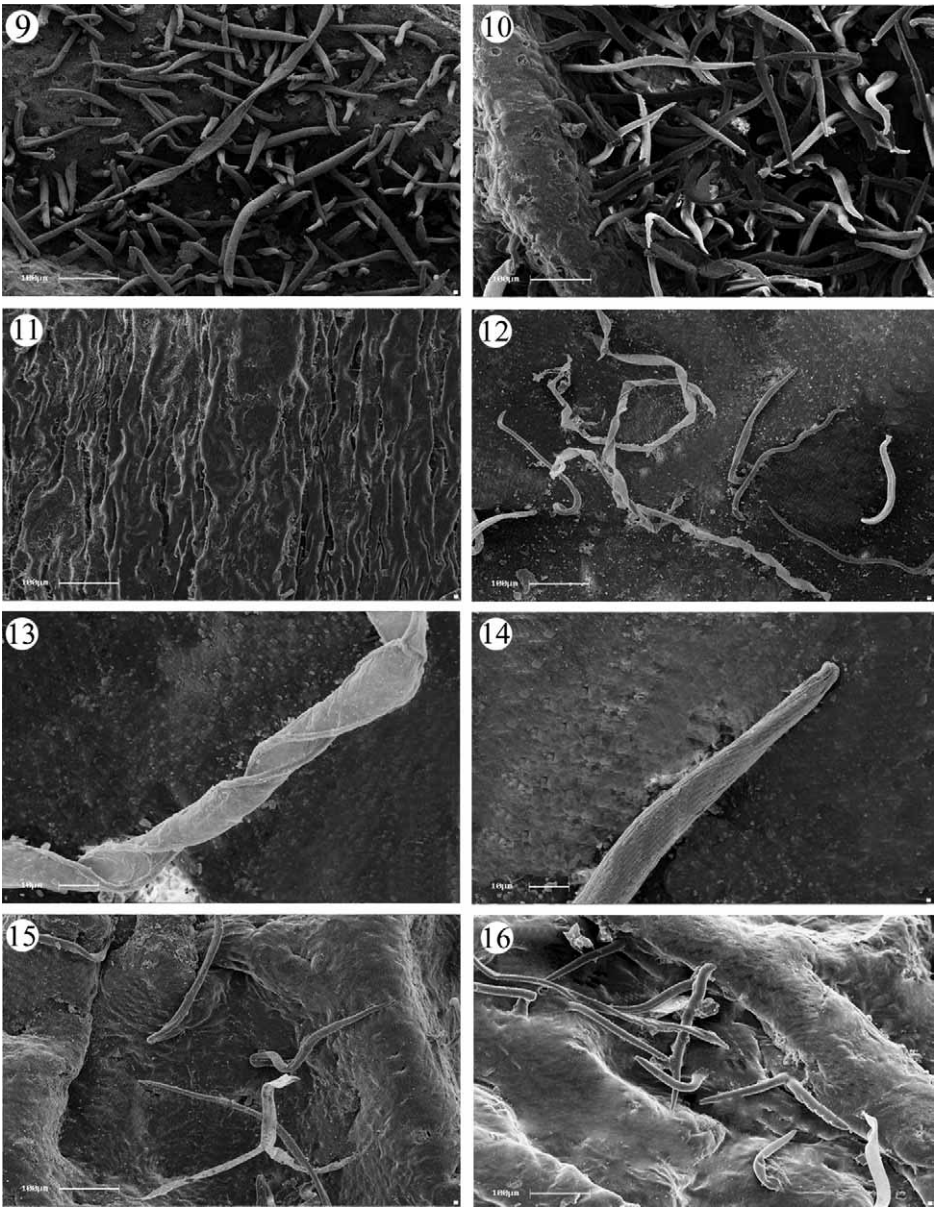

Plate 2. SEM micrographs of drupe pericarp indumentum of Iranian species of *Amygdalus*. **9 –** *A. carduchorum*, **10 –** *A. elaeagnifolia* subsp. *elaeagnifolia*, **11 –** *A. reticulata*, showing the glabrous pericarp, **12–14 –** *A. arabica*, **15 –** *A. glauca*, **16 –** *A. scoparia***.**

eburnea, *A. nairica* and *A. lycioides* (both varieties) showed dense indumentum (Figs. 17, 18, 19, 20, 21). Two varieties of *A. lycioides* showed different portions of trichomes as follows: in *A. lycioides* var. *horrida*, both tubular and flattened trichomes were frequent while in another variety, var. *lycioides*, flattened trichomes were more frequent (Figs. 20, 21)

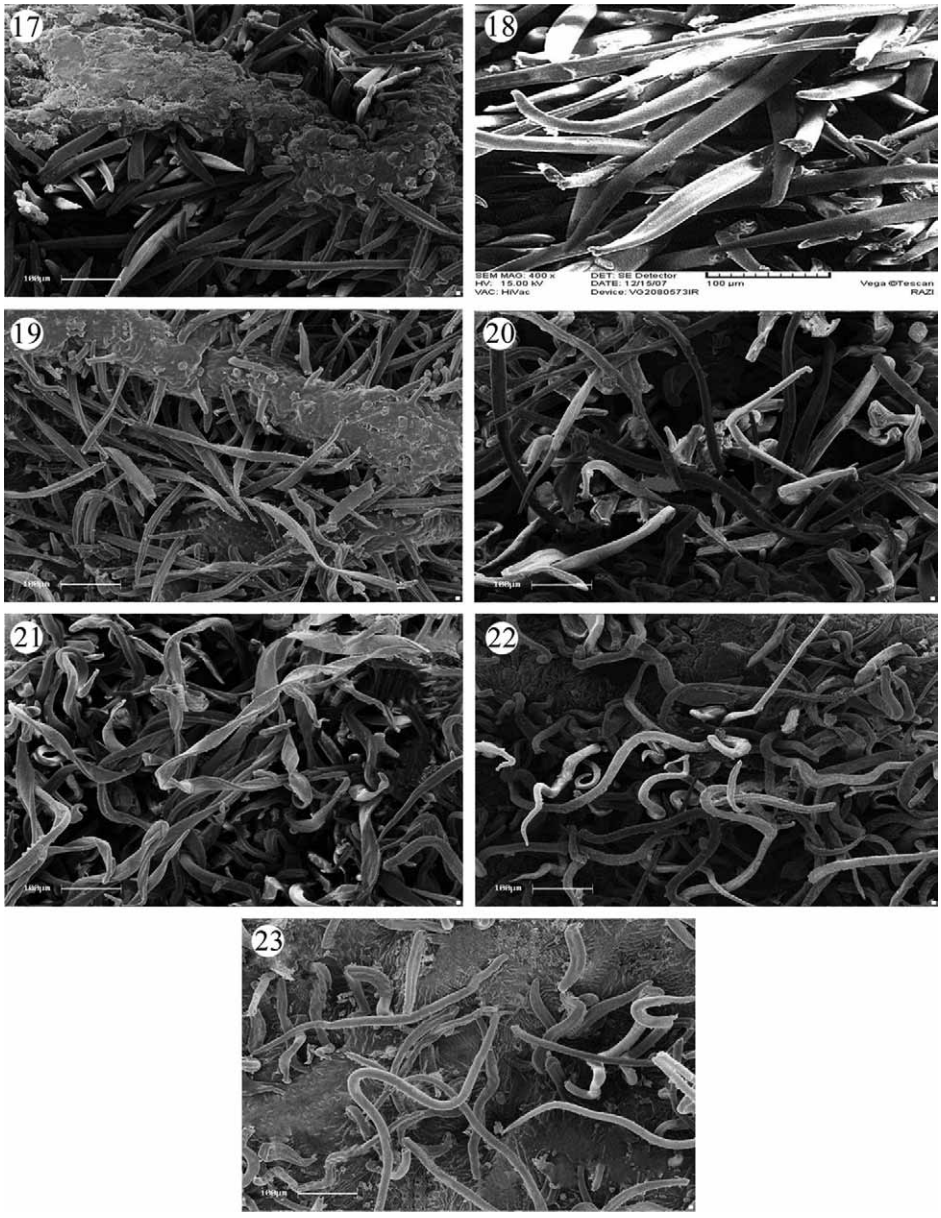

Plate 3. SEM micrographs of drupe pericarp indumentum of Iranian species and hybrids of *Amygdalus*. **17 –** *A. eburnea*, **18 –** *A. nairica*, **19 –** *A. spinosissima* subsp. *spinosissima*, **20 –** *A. lycioides* var. *horrid*, **21 –** *A. lycioides* var. *lycioides*, **22 –** *A.* ×*keredjensis*, **23 –** *A.*×*kamiaranensis*.

(Tab. 2). Two studied hybrids, *A.*×*keredjensis* and *A.*×*kamiaranensis* showed different indumentum types, dense and sparse respectively (Figs. 22, 23). Worthy of note, these two hybrids showed different details of trichomes, as well (Tab. 2).

Discussion

In the present study, we studied pericarp indumentun in the drupe of Iranian *Amygdalus*. Trichome micromorphology has been the subject of several studies for taxonomic goals in different plant families which include trichomes in various parts especially leaf, stem, and seed-fruit coat (FONTENELLE et al. 1994, XUHAN and VAN-LAMMEREN 1994, ZARRE 2003, AGBAGWA and OKOLI 2006, AKCIN 2007, ATTAR et al. 2007, JURIŠIĆ GRUBEŠIĆ et al. 2007, KAYA et al. 2007, MOAZZENI et al. 2007). Reports that have assessed hair micromorphology of the family Rosaceae are rare. These studies deal with surface of seed and achene coat that is mostly glabrous and possesses different seed coat pattern including reticulate, faviulariate, ruminate, coolleculate, honey-combed, different cell wall features and different shapes of epidermal cells (DOWIDAR et al. 2003, LATIF 2004). In the following sections, we will summarize the pericarp indumentum of the drupe of Iranian taxa of *Amygdalus*.

Subgen. *Amygdalus*

A. sect. *Amygdalus*

In this section, there are two vegetative groups regarding habit, tree (three species) and shrub (nine species). Tree species are: *A. communis*, *A. trichamygdalus* and *A. wendelboi* (KHATAMSAZ 1992). The first two species are distributed in the west and northwest of Iran but the third, *A. wendelboi*, an endemic species for the flora of Iran (KHATAMSAZ 1992), has a distribution range far from the two former localities and is found in the south of Iran. *A. communis* also has been found in some other areas including Turkey (BROWICZ 1972), Russia (SHISHKIN and YUZEPCHUK 1941) and China (LU and BARTHOLOMEW 2003). *Amygdalus trichamygdalus* is also distributed in Turkey (BROWICZ 1972). Regarding pericarp indumentum micromorphology, except the length of tubular trichomes, longer in *A. trichamygdalus* than in the two closely related species, these three species show similarities and homogeneity in pericarp trichomes including dense indumentum and frequent tubular trichomes (Figs. 1, 3, 4). It seems that in this subgroup, different ecological conditions including semi-humid to semi-arid environments in the west and northwest Iran in Zagros region and arid environments in the south Iran do not affect the indumentum density of the pericarp. This finding is in contrast to findings concerning the indumentum of other plant parts including leaf or stem showing that their trichomes are dependent on habitat conditions; in arid environments, the indumentum is dense for adaptation to severe conditions (ZARRINKAMAR 1993, ZARRINKAMAR and DINARVAND 2006).

Nine shrubby species are included in sect. *Amygdalus* (KHATAMSAZ 1992). Among them, seven species were investigated for pericarp indumentum study including *A. korshinskyi* (west and northwest Iran), *A. fenzliana* (northwest Iran), *A. haussknehtii* var. *pubescens* (west and central Iran), *A. kotschyi* (west and northwest Iran), *A. carduchorum* (west and northwest Iran), *A. elaeagnifolia* subsp. *elaeagnifolia* (central and south Iran) and *A. reticulata* (south Iran) (BROWICZ 1969, KHATAMSAZ 1992). Among those, three species including *A. haussknechtii*, *A. elaeagnifolia* and *A. reticulata*, are endemic species for the flora of Iran (BROWICZ 1969, KHATAMSAZ 1992). Some species of this subgroup are found in neighboring countries especially in Turkey (BROWICZ 1972). Regarding pericarp indumentum, this shrubby subgroup is the most heterogeneous group with emphasis on indumentum type, density and portion of trichomes (Tab. 2). Except for *A. reticulata* from

the south of Iran with glabrous pericarp (Fig. 11), other species have dense or dense-sparse indumentum (Figs. 5, 6, 7, 8, 9, 10). *A. haussknechtii* var. *pubescens* and *A. korshinskyi* possessed the longest tubular trichomes among the studied species of this subgroup (Figs. 5, 7) and *A. kotschyi* possessed the longest flattened trichomes (Fig. 8). In *A. korshinskyi* and *A. fenzliana*, two related species, we observed a number of differences (Tab. 2, Figs. 5, 6). Also, two closely related species (according to morphological evidence) including *A. kotschyi* and *A. carduchorum* exhibit extreme difference regarding to density and portion of trichomes as follows: as against most of the species, in *A. kotschyi* with dense indumentum, the flattened hairs were long and more frequent (Fig. 8), while in *A. carduchorum*, the tubular trichomes were short and more frequent (Fig. 9). It is worthy of mention that pericarp indumentum in this species is dense-sparse. Pericarp indumentum heterogeneity is observed in the last closely related species of this subgroup including *A. elaeagnifolia* and *A. reticulata*. In *A.reticulata*, the pericarp was completely glabrous, a unique feature among the studied species (Fig. 11) but in *A. elaeagnifolia* subsp. *elaeagnifolia*, it is dense (Fig. 10). Worthy of note, like the findings in former subgroup, in this subgroup, different ecological conditions could not affect the pericarp indumentum and as seen above, most species from the west and northwest Iran and south Iran exhibit dense indumentum except for the *A. reticulata*. As discussed above, as against the first subgroup in subgen. *Amygdalus*, our findings of pericarp indumentum show considerable variation in this shrubby subgroup even between closely related species. It is interesting that this subgroup is the most problematic subgroup in the genus *Amygdalus* from a morphological point of view.

A. sect. *Spartioides*

This section includes three junciform species: *A. arabica*, *A. glauca* and *A. scoparia*. The main morphological feature of this section is the absence of brachyblast (short shoots) (BROWICZ 1969, KHATAMSAZ 1992). Among those, *A. glauca* is an endemic element for the flora of Iran (BROWICZ 1969, KHATAMSAZ 1992). *Amygdalus arabica* is mainly distributed in the west of Iran as well as Turkey (BROWICZ 1972). *Amygdalus scoparia* is distributed in many different localities in Iran except for the west and northwest and is one of the most widespread species of *Amygdalus* in Iran. It is found in Russia as well (SHISHKIN and YUZEPCHUK 1941). *Amygdalus glauca* is found in a limited region in the south of Iran in Fars province (BROWICZ 1969, KHATAMSAZ 1992). Regarding pericarp indumentum, there was significant difference between this and the former section. In contrast to sect. *Amygdalus* with dense indumentum in most studied species, all species in sect. *Spartioides* exhibited very sparse indumentum with more or fewer similarities (Figs. 12, 15, 16).

Subgen. *Dodecandra*

This subgenus is completely different from the former regarding its habit feature, because in this subgenus there are six shrubby species with thick spiny shoots (BROWICZ 1969, KHATAMSAZ 1992). Species in this subgenus are found in different ecological conditions in the west, northwest, east, northeast, central, north and south Iran. Some of them are found in the neighboring countries (SHISHKIN and YUZEPCHUK 1941, BROWICZ 1969, 1972). From six species in this subgenus, we studied four species. Among them, *A. lycioides* is widely distributed in Iran. In all studied species, the pericarp indumentum was dense (Figs. 17, 18, 19, 20, 21). Studied species in this subgenus show differences in pericarp trichomes in shape and trichome portions (Tab. 2). Two varieties of *A. lycioides* exhibit significant difference. *A. lycioides* var. *lycioides* possessed the longest flattened trichomes and *A.*

lycioides var. *horrida* the longest tubular trichomes (Figs. 20, 21). While in *A. lycioides* var. *horrida*, an endemic variety for the flora of Iran (KHATAMSAZ 1992), both tubular and flattened trichomes were frequent (Fig. 20), in another variety, var. *lycioides*, flattened trichomes were more frequent and they were folded as well (Fig. 21). According to results in this subgenus, the density of trichomes in the pericarp is independent of ecological conditions.

Hybrids

Among *Amygdalus* hybrids, two hybrids were examined for pericarp indumentum study. Both hybrids are endemic elements for the flora of Iran (KHATAMSAZ 1992). These two hybrids show different features regarding to pericarp trichomes (Tab. 2). *Amygdalus* ×*keredjensis* from the north of Iran showed dense indumentum. Tubular hairs were more frequent (Fig. 22). *Amygdalus* ×*kamiaranensis*, a hybrid from the west of Iran, showed sparse indumentum (Fig. 23). Also, *Amygdalus* ×*kamiaranensis,* together with a few other species, possessed the longest tubular trichomes. *Amygdalus* × *keredjensis* is a hybrid resulting from a hybridization process between *A. scoparia* and *A. lycioides* (BROWICZ 1969, KHATAMSAZ 1992). Comparison of pericarp features between this hybrid and its parents showed that regarding pericarp indumentum, *A.* × *keredjensis* was related to *A. lycioides* (Figs. 20, 22). Also according to Khatamsaz (1992), *A.* × *kamiaranensis* is a hybrid between *A. haussknectii* and *A. scoparia*, but based on our studies on Iranian *Amygdalus*, two other species are its parents: *A. arabica* and *A. lycioides*, because *A.* × *kamiaranensis* is a hybrid that found in the west of Iran but *A. scoparia* is found in different localities in Iran except for the west and northwest. The presence of thin spiny shoots in this hybrid shows that one of its parents is a spiny species from the second subgenus as well; so *A. haussknechtii* could not be another parent. Khatamsaz' hypothesis is based on morphological evidence as is the hypothesis presented in this paper. Unfortunately, she did not introduce the exact parents because she did not consider the distribution of parent species and morphological features exactly, whereas evidence for the present hypothesis was shown above. We have collected numerous specimens of this hybrid from the distribution localities in the west Iran. *Amygdalus scoparia* is not distributed in the west of Iran and based on presence of thin spiny shoots in this hybrid, one spiny species should be another parent. Unfortunately there are no crossing studies about these hybrids in Iran. A molecular phylogenetic study on Iranian species and hybrids of *Amygdalus* is currently being undertaken. Perhaps this investigation will be able to throw light on the real parents of *A.* × *kamiaranensis*. A comparison of pericarp results only showed some similarities to *A. lycioides* (Figs. 20, 23).

Conclusion

With an emphasis on pericarp indumentum micromorphological findings, it is clear that in some cases, these results confirm classic classifications in the genus *Amygdalus*. For example, two sections of subgen. *Amygdalus* were easily distinguished from each other. But two subgenera were not separated according to pericarp indumentum results. Within sect. *Amygdalus* there was enough variation even between two closely related species in the shrubby subgroub such as *A. elaeagnifolia* and *A. reticulata*. Regarding our findings in this study, it is clear that the density of trichomes in pericarp is not dependent on habitat condi-

tions. As there has been no molecular phylogenetic study about Iranian species of *Amygdalus* and since molecular investigations on genus *Prunus* s. l. include only a few species of *Amygdalus*, with only one species being found in Iran (LEE and WEN 2001, BORTIRI et al. 2001, WEN et al. 2008), the phylogenetic importance of micromorphological studies could not be evaluated here.

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