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New morphological characters for some *Erysimum* (Brassicaceae) species

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Abstract: Trichome shapes were investigated on the outer and inner surfaces of fruit valves of 43 species of *Erysimum* L., 20 of which are endemic to Turkey, by light microscopy (LM) and scanning electron microscopy (SEM). Five species, *Erysimum sorgerae* Polatschek., *E. huber-morathii* Polatschek, *E. cheiri* (L.) Crantz, *E. repandum* L. and *E. vuralii* Yild. were identified, in which there are trichomes on the inner surface of fruit valves, which was determined for the first time in these species. Two morphological distinct types of trichomes were observed on the inner surfaces of the fruit valves of *E. huber-morathii* and *E. repandum*, and more than 8-rayed and branched trichomes. Electron micrographs of these species were obtained.

Key words: Brassicaceae, *Erysimum*, indumentum types, SEM, Turkey

Bazı *Erysimum* (Brassicaceae) türleri için yeni morfolojik karakterler

Özet: Bu çalışmada 20'si Türkiye için endemik olan 43 *Erysimum* L. türünün meyve kapağı dış ve iç yüzeyi ışık (LM) ve taramalı elektron mikroskobu (SEM) ile araştırılmıştır. *Erysimum* cinsi içinde 5 türün, *E. sorgerae* Polatschek, *E. huber-morathii* Polatschek, *E. cheiri* (L.) Crantz, *E. repandum* L. ve *E. vuralii* Yild. meyve kabuğu iç yüzeyinde tüylerin olduğu ilk defa belirlenmiştir. İki morfolojik farklı tipte tüy (8'den fazla parçalı ve dallanmış tüy) *E. huber-morathii* ve *E. repandum* türlerinin meyve iç yüzeyinde gözlenmiştir. Bu türlere ait taramalı elektron mikroskobu resimleri verilmiştir.

Anahtar sözcükler: Brassicaceae, *Erysimum*, tüy çeşiti, SEM, Türkiye

Introduction

The number of species reported for *Erysimum* L. is the range of 290 and 350 species and they are mostly perennial and biennial plants, distributed throughout Europe, the Mediterranean area, the Near East, and East Asia as well as North and Central America (Polatschek & Snogerup, 2002). However, recent taxonomical and molecular studies indicated that *Erysimum* is in the tribe *Erysimeae* Dumort (Warwick et al., 2007; Garmen & Al-Shehbaz, 2008), with a species number of 223 (Warwick et al., 2006).

Erysimum is the second richest genus in Brassicaceae according to the *Flora of Turkey*, in which this genus is represented by 43 species in

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addition to 1 species that has been categorised as a doubtful species in this genus (Cullen, 1965, Davis et al., 1988; Yıldırımlı, 2000). Four of these species, i.e. *E. horizontale* Candargy, *E. hayekii* (Jáv. & Rech.f.) Polatschek, *E. rhodium* Snogerup, and *E. senoneri* (Heldr. & Sart.) Wetts. subsp. *icaricum* Snogerup, have been reported to be present only in the East Aegean Islands. However, 4 new species, i.e. *E. euphraticum* Polatschek (2008), *E. serpentinicum* Polatschek (2008), *E. munzuriense* Polatschek (2008), and *E. kostkae* Polatschek (2008), and 1 new finding, namely *E. bulgaricum* (Velen.) Ančev & Polatschek (Ančev & Polatschek, 2003), were described, following the publication of the second supplement of the *Flora of Turkey* in 2000 (Güner et al., 2000). Additionally, studies reported a change in the taxonomical position of *E. thyrsoideum* Boiss.; first *E. thyrsoideum* Boiss. was divided into 2 subspecies: subsp. *thyrsoideum* and subsp. *ponticum* (Hausskn. & Bornm.) Cullen (Cullen, 1965). These taxa were regarded as different species by Greuter et al. (1986), namely *E. pycnophyllum* J.Gay and *E. ponticum* Hausskn. & Bornm., respectively. Nine species, namely *E. macrostigma* Boiss., *E. alpestre* Kotschy ex Boiss., *E. goniocaulon* Boiss., *E. deflexum* Cullen, *E. tenuissimum* J.Gay, *E. torulosum* Hub.-Mor., *E. hamosum* J.Gay, *E. passgalense* Boiss., and *E. eginense* Hausskn. ex Bornm., were considered synonyms of *E. caespitosum* DC., *E. sintenisianum* Bornm., *E. scabrum*, *E. szowitsianum* Boiss., *E. tenellum* DC., *E. huber-morathii*, *E. oleifolium* J.Gay, *E. aucherianum* J.Gay, and *E. smyrnaeum* Boiss. & Bal., respectively (Greuter et al., 1986).

Three species, namely *E. oleifolium*, *E. hayekii* and *E. tenellum*, were known as members of the genus *Erysimum* in the *Flora of Turkey* (Cullen, 1965). However, the existence of these species in Turkey was changed by Greuter et al. (1985) and Strid (1986). Two species, namely *E. subulatum* J.Gay and *E. stenophyllum* Polatschek, were included in the *Flora of Turkey* as new records (Polatschek, 1983; Greuter et al., 1985). Although these changes in the status, inclusion, and exclusion of the species had been made before their respective supplements of the *Flora of Turkey* (Davis, 1988; Yıldırımlı, 2000), these changes were not indicated.

A recent taxonomical study on the *Erysimum* species was published by Yıldırımlı (2008). In that study, 17 new species (*E. bagcii* Yild., *E. baytopiae* Yild., *E. dinci* Yild., *E. dirmilense* Yild., *E. duranii* Yild., *E. guneri* Yild., *E. ikizdereense* Yild., *E. jacquemondii* Yild., *E. kartalkayaensis* Yild., *E. ketenoglui* Yild., *E. rizeense* Yild., *E. sivasicum* Yild., *E. tuteliae* Yild., *E. vuralii* Yild., *E. yaltirikii* Yild., *E. yildirimli* M.Dinç, and *E. zeybekianum* Yild.), 3 new subspecies (*E. pulchellum* (Willd.) J.Gay subsp. *siehanum* Yild., *E. thyrsoideum* Boiss. subsp. *ekici* Yild., and *E. tuteliae* Yild. subsp. *doganii* Yild.), 2 new varieties (*E. baytopiae* Yild. var. *asliae* Yild., *E. repandum* L. var. *linnaeaum* Yild. & A.Doğru-Koca), and 5 new records (*E. aciphyllum* Boiss., *E. boissieri* Polatschek, *E. nasturtioides* Boiss. & Hausskn. (synonym of *E. hakkaricum* Cullen), *E. pseudocheiri* Boiss., and *E. verrucosum* Boiss. & Gaill.) in Turkey were described. With addition of the new records, the total number of species of the genus *Erysimum* in Turkey has now reached 66.

Trichome morphology was used by many authors as a character in the classification of the Brassicaceae (Hayek, 1925; Janchen, 1942; Nyárády, 1955; Dudley, 1964; Greuter, 1974; Rollins & Banerjee, 1979; Al-Shehbaz, 1987; Ančev & Goranova, 2006). Detailed trichome morphology of *Erysimum* was investigated by different authors (Polatschek & Snogerup, 2002; Ančev & Polatschek, 2003; Maciejewska-Rutkoska et al., 2007). According to these authors, trichome shapes on the outer surfaces of siliqua are mostly used to distinguish *Erysimum* species. These shapes are medifixed, 3-, 4-, 5-, 6-, 7-, and 8-rayed, but trichome shapes on the inner surfaces of fruit valves had not been investigated until this study.

The present study is the first to investigate the trichome shapes of the inner surfaces of siliqua valves of some *Erysimum* species and its allies in a taxonomic context. It deals with 43 species of the tribe *Erysimeae* Dumort in Turkey.

Materials and methods

The morphology of the trichomes on siliqua surface of 43 species of the genus *Erysimum* was studied using light microscopy (LM) and scanning electron microscopy (SEM). The investigation is based on herbarium materials, which were collected from different parts of Anatolia deposited in INU and as compared with Ankara (ANK, GAZI, and HUB),

Bolu (AIBU), Trabzon (KATO), İstanbul (ISTE), İzmir (EGE), Malatya (INU), Van (VANF), and Kayseri (Erciyes Hb.) herbaria. Information on the species analysed, the collection data, and the vouchers used are given in the Table.

Specimens were cross-checked with various accounts of *Erysimum* in the relevant floras, namely *Flora Orientalis* (Boissier, 1867), *Flora of Syria, Palestine and Sinai* (Post, 1932), *Flora of USSR* (Komarov, 1939), *Flora Iranica* (Polatschek & Rechinger, 1968), *Flora of Iraq* (Hedge & Lamond, 1980), *Flora Europaea* (Ball, 1993), *Flora Iberica* (Feliner, 1996), *Flora Hellenica* (Polatschek & Snogerup, 2002) and revisions (Polatschek, 1979; Ančev & Polatschek, 2006), as well as new species descriptions (Polatschek, 1994; Ančev & Polatschek, 2003; Polatschek, 2008). Authorities of all cited plant

Table. List of taxa of *Erysimum* used in the present study. (*): endemic species.

	Taxon	Place of origin	Herbarium	Voucher number
*	1. *E. amasianum* Hausskn. & Bornm.	Amasya, 1300 m, 09/07/2006	INU	BM 10122
	2. *E. armeniacum* (Sims) J.Gay	Van, 2847 m, 01/08/2008	INU	BM 10688
	3. *E. artwinense* N.Busch	Artvin, 291 m, 25/06/2008	INU	BM 10643
	4. *E. aucherianum* J.Gay	Malatya, 1376 m, 06/06/2006	INU	BM 10062
*	5. *E. aznavourii* Polatschek.	Istanbul, 99 m, 23/05/2009	INU	BM 10781
	6. *E. bulgaricum* (Velen.) Ančev & Polatschek	Edirne, 96 m, 24/05/2009	INU	BM 10787
	7. *E. cheiri* (L.) Crantz	Malatya, 960 m, 08/06/2008	INU	BM 10606
	8. *E. crassipes* Fisch. & Mey.	Manisa, 486 m, 24/04/2007	INU	BM 10453
	9. *E. cuspidatum* (Bieb.) DC.	Yozgat, 1515 m, 03/07/2008	INU	BM 10665
*	10. *E. degenianum* Aznav.	Balıkesir, 385 m, 24/04/2007	INU	BM 10456
	11. *E. diffusum* Ehrh.	Erzincan, 1568 m, 12/06/2007	INU	BM 10405
*	12. *E. echinellum* Hand-Mazz.	Elazığ, 2140 m, 16/06/2008	INU	BM 10613
*	13. *E. euphraticum* Polatschek	Gaziantep, 595 m, 07/4/2008	INU	BM 10514
	14. *E. graecum* Boiss. & Heldr.	Kırklareli, 311 m, 24/05/2009	INU	BM 10792
	15. *E. hirschfeldioides* Boiss. & Hausskn. ex Boiss.	Urfa, 415 m, 14/05/2006	INU	BM 9981
*	16. *E. huber-morathii* Polatschek	Ankara, 974 m, 19/05/2008	INU	BM 10576
*	17. *E. idae* Polatschek	Balıkesir, 1676 m, 24/04/2007	INU	BM 10461
*	18. *E. kartalkayaensis* Yild.	Bolu, 2157 m, 14/08/2008	INU	BM 10706
*	19. *E. kotschyanum* J.Gay	Muğla, 80 m, 16/05/2001	INU	BM 6614
*	20. *E. kotskae* Polatschek	Sivas, 1251 m, 25/05/2007	INU	BM 10345
*	21. *E. leptocarpum* J.Gay	Erzurum, 1000 m, 03/06/1999	INU	BM 4830
	22. *E. leptophyllum* (Bieb.) Andrz.	Antalya, 1756 m, 22/06/2007	INU	BM 10447
	23. *E. leucanthemum* (Stech.) Fedtsch.	Van, 2003 m, 01/08/2008	INU	BM 10692
*	24. *E. lycaonicum* (Hand.-Mazz.) Hub.-Mor.	Karaman, 1230 m, 15/07/2006	INU	BM 10159
*	25. *E. pallidum* Boiss.	Antalya, 2525 m, 03/08/2001	INU	BM 7741
*	26. *E. ponticum* Hausskn. & Bornm.	Amasya, 1698 m, 08/07/2006	INU	BM 10125
*	27. *E. pseudopurpureum* Polatschek	Kastamonu, 715 m, 09/05/200	INU	BM 9955
	28. *E. pulchellum* (Willd.) J.Gay	Çankırı, 1989 m, 10/07/2006	INU	BM 10128
	29. *E. purpureum* Aucher	Malatya, 1315 m, 13/05/2006	INU	BM 9966
	30. *E. pycnophyllum* J.Gay	Sivas, 1518 m, 10/07/2006	INU	BM 10132
	31. *E. repandum* L.	Sivas, 1193 m, 25/05/2007	INU	BM 10332
	32. *E. scabrum* DC.	Antalya, 850 m, 08/06/2003	INU	BM 8619
*	33. *E. serpentinicum* Polatschek	Muğla, 130 m, 13/04/2008	INU	BM 10527
	34. *E. sintenisianum* Bornm.	Rize, 3228 m, 13/07/2007	INU	BM 10499
	35. *E. sisymbrioides* C.A.Mey.	Konya, 970 m, 09/04/2007	INU	BM 8878
*	36. *E. sivasicum* Yild.	Sivas, 1350 m, 03/07/2008	INU	BM 10655
	37. *E. smyrnaeum* Boiss. & Bal.	Malatya, 1376 m, 16/05/2006	INU	BM 9988
*	38. *E. sorgerae* Polatschek	Kırklareli, 362 m, 06/08/2008	INU	BM 10704
	39. *E. stenophyllum* Polatschek	İzmir, 1024 m, 23/06/2007	INU	BM 10451
	40. E. *szowitsianum* Boiss.	Trabzon, 1326 m, 13/06/2007	INU	BM 10413
	41. *E. verrucosum* Boiss. & Gaill.	Gaziantep, 954 m, 09/06/2007	INU	BM 10358
*	42. *E. vuralii* Yild.	Muğla, 17 m, 13/04/2008	INU	BM 10530
*	43. *E. zeybekianum* Yild.	Ardahan, 897 m, 25/06/2008	INU	BM 10651

names are given according to *Authors of Plant Names* (Brummitt & Powell, 1992).

The trichomes were investigated on the outer or inner surface of siliqua valves. Trichome description and classification follow the Polatschek system (Polatschek, 1994). The indumentums of the outer and inner surfaces of all studied species were examined by LM. For this purpose, specimens were viewed and photographed with an Olympus SZ61 light microscope (×90). For the SEM studies, fruit pairs were fixed on aluminium stubs using double sided adhesive tape. The SEM micrographs were taken in an EVO 40XVP (LEO Ltd., Cambridge, UK) scanning electron microscope.

Results and discussion

The genus *Erysimum* belongs to the family Brassicaceae. The genus is distinguished from the other genera by the predominantly malpighiaceous and stellate trichomes with unbranched rays, many seed siliqua, and predominantly yellow flowers (German & Al-Shehbaz, 2008).

Although the revisional study of the *Erysimum* in Turkey has been the focus of several studies, distinctions between some species are not yet fully resolved. Trichome characters have been shown to be an important tool in taxa delimitation in the genus.

Fruit of the genus *Erysimum* is dehiscent siliqua, compressed dorsally or laterally, terete, tetragonal, and winged. The indumentums of the outer surface of siliqua valves in species of *Erysimum* consisted of medifixed, 3-,4-,5-,6-,7-, and 8-rayed hairs (Figures 1 and 2) distributed on both the surface of the siliqua and stigma. The trichomes of some species are more abundant along the surface of the mature and immature siliqua. In young siliqua, trichome shapes partly obscure it and it appears that they mature at an early stage of siliqua development.

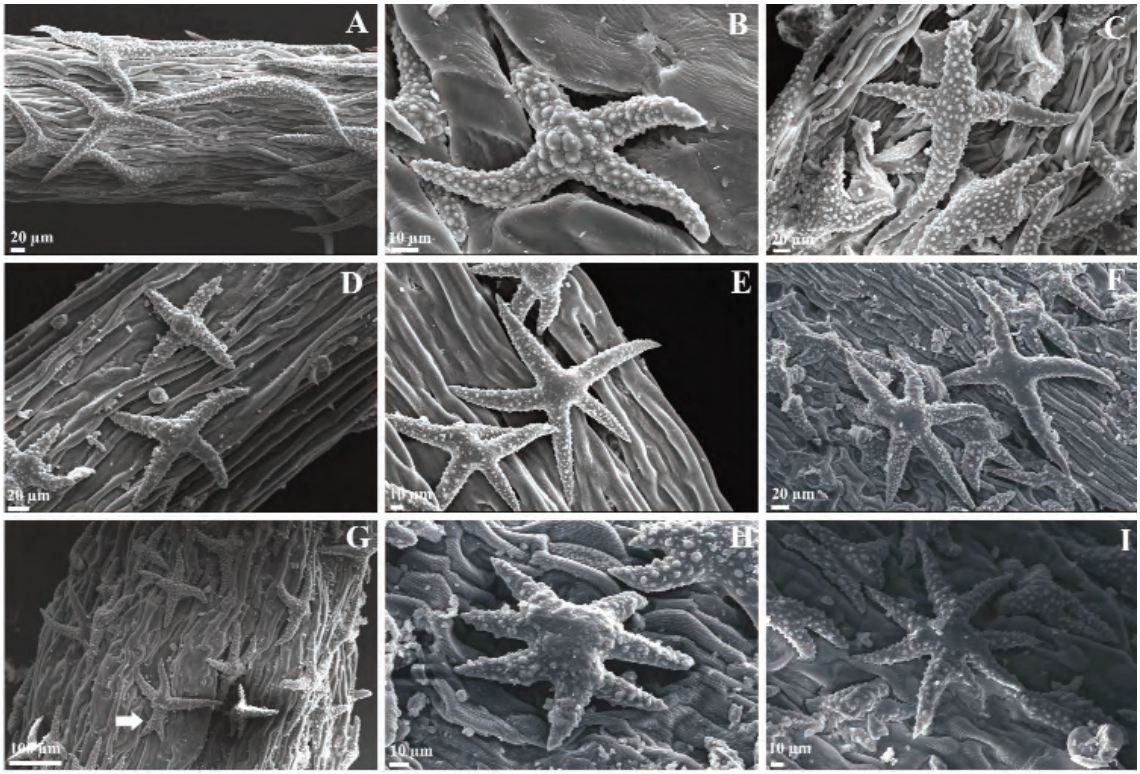

Figure 1. SEM micrographs showing distribution and types of trichomes on upper surface of siliqua. (A) *Erysimum diffusum*; (B) *E. scabrum*; (C) *E. leptocarpum*; (D) *E. idae*; (E) *E. leucanthemum*; (F, H) *E. aucherianum*; (G) *E. huber-morathii*; (I) *E. pulchellum*; (A) medifixed and 3-rayed; (B, C, D, E, F, G) 4-rayed; (E, G) 5-rayed; (F) 6-rayed; (H) 7-rayed; (I) 8-rayed. Arrow indicates a branched trichome.

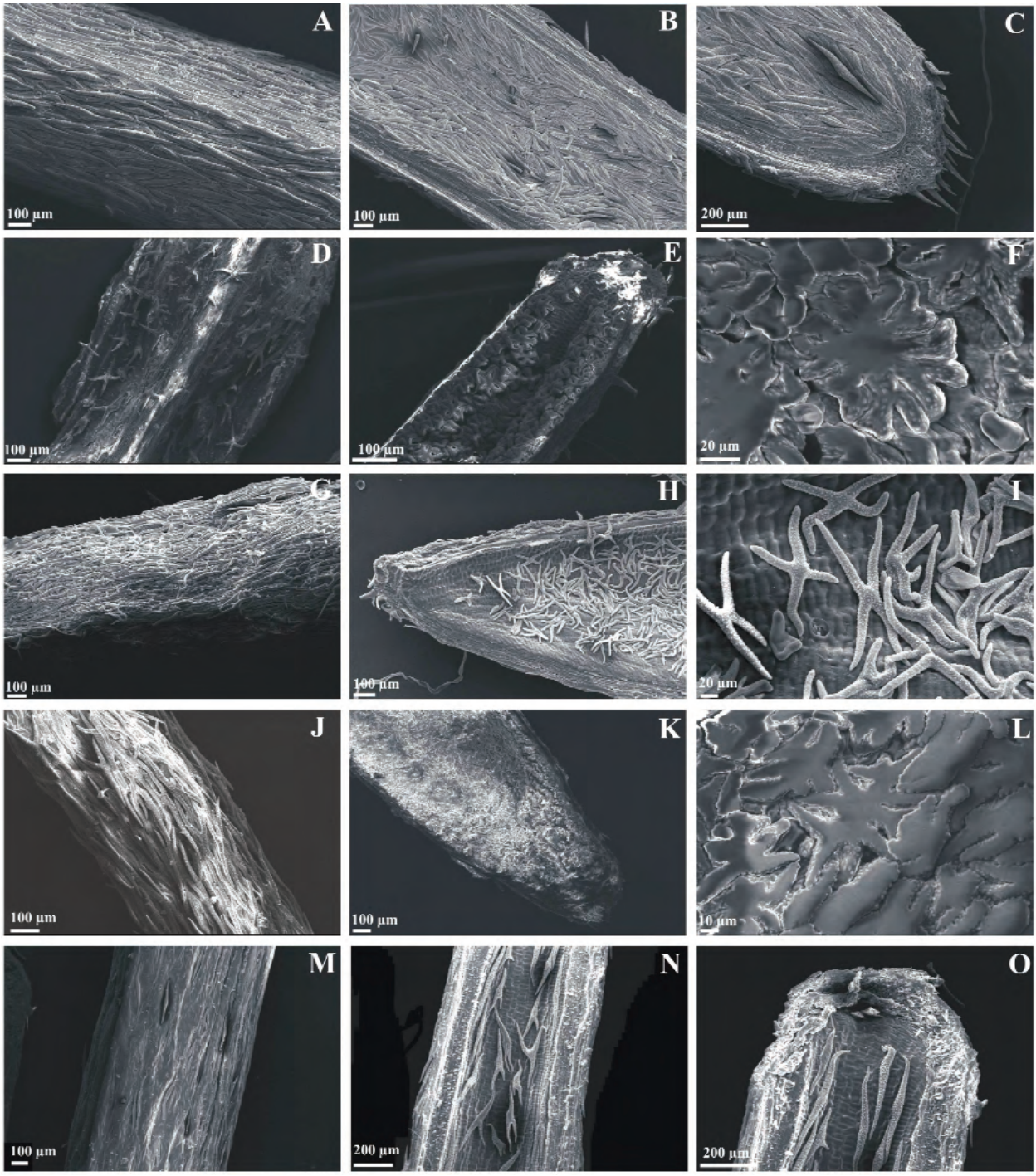

Figure 2. SEM micrographs showing distribution and types of trichomes on siliqua. (A, B, C) *Erysimum sorgerae*; (D, E, F) *E. hubermorathii*; (G, H, I) *E. cheiri*; (J, K, L) *E. repandum*; (M, N, O) *E. vuralii*; (A, D, G, J, M) upper surface of siliqua valve; (B, C, E, F, H, I, K, L, N, O) inner surface of siliqua valve; (F, L) sublepidote hairs.

Presence of trichomes on the inner surface of siliqua valves was first described by Zhou et al. (2002). In their study, 3 species were determined as having trichomes on the inner surface of siliqua valves and these species were *E. cheiranthoides*, *E. macilentum*, and *E. hieracifolium*.

Observations with the SEM and LM revealed the presence of trichomes on the inner surface of siliqua valves (Figure 2). Five species, namely *E. sorgerae*, *E. cheiri*, *E. huber-morathii*, *E. repandum*, and *E. vuralii*, were identified in which there were trichomes on the inner surface of siliqua valves. *E. sorgerae* had only medifixed hairs on the inner surface of siliqua valves, but *E. cheiri* and *E. vuralii* had many 4- and 5-rayed, few 3-rayed, and rare 6- and 7-rayed trichomes (Figure 2).

Two morphological distinct types of trichomes that are sublepidote (more than 8-rayed and branched) were observed on the inner surface of fruit valves of *E. huber-morathii* and *E. repandum* (Figure 2). At the same time, 3 species, namely *E. huber-morathii*, *E. repandum,* and *E. aucherianum* had branched hairs on the outer surface of siliqua valves. The trichomes on the inner surface of siliqua valves and sublepidote hairs' shape, which covered the inner surface of siliqua valves, were identified for the first time in these species.

E. sorgerae and *E. diffusum* are classified as very confusing species by some taxonomists, because the vegetative characters, the life form, and hairs of siliqua (Figure 2) are very similar in these species. However, hairs of the inner side of siliqua valves are only found in species of *E. sorgerae*. *E. repandum* and *E. huber-morathii* have similar taxonomical problems. Annual life form and runcinnate-dentate leaf shape are characteristic of these species, but the rate of different shapes of hairs on siliqua surface is distinguishable. *E. repandum* has mostly medifixed, 3-rayed and few 4-rayed hairs while *E. huber-morathii* has mostly 4-rayed, some 3-5-rayed, and few medifixed hairs. Hairs of the inner surface of the species separate these species from the other annual species, which is *E. sisymbrioides* (Figure 2).

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