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THE TAXONOMIC SIGNIFICANCE OF LEAF EPIDERMAL MICROMORPHOLOGICAL CHARACTERS OF SOME BRASSICACEAE SPECIES IN TURKEY

AYŞE ERDEN[1]* AND YUSUF MENEMEN[2]

[1]*Kırıkkale University, Graduate School of Natural and Applied Sciences, 71450, Yahşihan, Kırıkkale, Turkey*
[2]*Kırıkkale University, Faculty of Science and Art, Department of Biology, 71450, Yahşihan, Kırıkkale, Turkey*
**Corresponding author's email: ayse.pektas79@hotmail.com*

Abstract

Leaf epidermal micromorphological characters were examined using light and scanning electron microscopes in 43 taxa belonging to 30 genera of Brassicaceae. The cell curvature of the periclinal wall has an important influence on the surface roughness and stands out as an important character in the separation of some closely related species. The course of the anticlinal cell wall can be straight or uneven. Uneven anticlines could be further divided into arched, straight to arched, repand, sinuous, and undulate. Undulations of anticlinal cell walls could increase the mechanical stability of the epidermis tissue. Epicuticular surface ornamentation comprised 4 types: smooth, striate, wrinkled, and ridged. In general, wrinkled and ridged were the most common types. Different types of wax layers were found in different taxa growing in the same climatic conditions. Therefore, wax diversification may be is an important feature at all taxonomic hierarchy from species to tribal level. The stomata were amphistomatic, and anisocytic in all the species, while anomocytic stomata were found in some species too. It was revealed that the low stomatal index values of some species growing on high, stony-rocky areas are directly related to the climatic conditions and habitat that the plant is exposed to. It was also observed that the stomatal index was higher in species growing in lower areas and prefer moist soil. As a result, this study showed that the shape, measurement, surface curvature, anticlinal cell wall, stomata type, stomatal index, epicuticular surface ornamentation and waxy cover of the leaf epidermis cells could be important characters for distinguishing the species, genera and tribes within the familly.

Key words: Anticlinal cell wall, Cruciferae, Curvature, Stomata, Surface ornamentation, Wax.

Introduction

The systematic applicability of leaf epidermal features at the generic and specific level of different flowering plant families has been reported (Stace, 1984; Haron & Moore, 1996; Adedeji & Dloh, 2004; Celka *et al*., 2006; Zou *et al*., 2008; Yasmin *et al*., 2009; Khan *et al*., 2011; Lin & Tan, 2015; Ecevit-Genç *et al*., 2017). Cole & Behnke (1975) and Dahlgren (1979–1980) reported that micromorphological data plays an important role in understanding the evolution of seed plants and in classifying angiosperms on modern systems. Barthlott (1981) stated that he adopted and coined the terminology for the plant surface by using previous studies (Uphof, 1962; Stace, 1965; Napp-Zinn, 1966, 1973-1974; Martin & Juniper 1970; Dilcher, 1974; Barthlott & Ehler, 1977; Theobald *et al*., 1979; Wilkinson, 1979; Barthlott & Wollenweber, 1981).

Barthlott (1981) investigated the epidermal surface characters in seed plants and recognised 4 different categories of surface: 1) basic structure of the epidermis cells, such as trichome, gland, and stomata, 2) Shape of the cells (primary sculpture of the surface), 3) Relief of the outer sculpture (secondary sculpture superimposed on the primary sculpture), and 4) Epicuticular secretions (tertiary sculpture superimposed on the secondary sculpture, i.e. mainly waxes and related substances). He was also of this opinion that these epidermal characters were slightly influenced by environmental conditions and observed that their high structural diversity provided very valuable criteria for classification at the species and family level.

Brassicaceae is one of the largest families distributed in Turkey. Although trichome characters are widely used in the diagnosis of family members, a limited number of studies have been conducted on the other epidermal characters.

Erden & Menemen (2017) studied the leaf trichomes of 42 Turkish species of Cruciferae using a light microscope (LM) and scanning electron microscope (SEM). The taxa were divided into 3 groups: taxa with no trichomes, and with sparsely and densely trichomes. The trichomes were distinguished as glandular and eglandular. Eglandular trichomes were single-celled and grouped as simple, Y-shaped, 2, 3, or 4-armed, dendritic, stellate, peltate, and hooked. Glandular trichomes consisted of a multicellular stem and spherical multicellular head. Trichome surface ornamentation was classified as plain, spotted-tuberculate, linear-tuberculate, warty, and nipple tubercle. They were of this opinion that these features could be used taxonomically.

In a micromorphological study of *Lepidium* species, Sun & Li (2007) reported that stomata was present on both sides of the leaf, and they were mostly anisocytic, rarely anomocytic, followed by paracytic. They also found that the leaf epidermis cells were polygonal or irregularly shaped with anticlinal cell walls, straight, arched, repand, and sinuous, and the lower and upper surfaces had similar in characteristics. They concluded that the leaf epidermal features could be used as criteria for separating *Lepidium* species.

Furthermore, in a light microscopic study of some species belonging to the genus *Sisymbrium*, Sun & Li (2008) reported that the upper leaf epidermis cells were usually polygonal in shape, with straight or arched anticlinal cell walls. They stated that the lower epidermis had irregular shaped cells with sinuous anticlinal cell walls, and on both surfaces of the leaf, the stomata were mainly anisocytic, rarely anomocytic, and paracytic.

Gostin (2009) observed anisocytic stomata on the lower and upper epidermis of the leaves of *Erysimum wittmanii*, and the trichomes had thick cell walls with 3 arms and rarely 2 arms.

Tuo & Zhou (2010) identified 3 types of leaf epidermis cell forms and demonstrated that *Isatis* and 5 other Euclidieae taxa generally had polygonal or amorphous epidermis cells and mostly anisocytic and anomocytic stomata. They also found that there were no significant differences among the species.

The stem and leaf anatomy of the species of *Ricotia* in Turkey was studied by Selvi & Paksoy (2013). They calculated the stomatal index and stomatal index ratio of *Ricotia* species, and used presence of trichomes, cortex parenchyma, sclerenchyma, mesophilic structures, and epidermal surface features in *Ricotia* species as important taxonomical characters to distinguish them.

In the present study, the stomata, epidermal cells, and epicuticular features related to the surface of the leaf epidermis (cell curvature, cell surface reliefs, and epicuticular waxes) of 43 species and subspecies belonging to 30 genera distributed in19 tribes of the family Brassicaceae were investigated, and their taxonomical uses were discussed. The most recent categorization of these taxa was based on the current classification of Kiefer *et al*., (2014) and BrassiBase (2018).

1. **Tribe Aethionemeae**
    1. Genus: *Aethionema* W.T.Aiton
        1. *A. armenum* Boiss.
        2. *A. dumanii* Vural & Adıgüzel
2. **Tribe Alysseae**
    2. Genus: *Alyssum* L.
        3. *A. turkestanicum* Regel & Schmalh.
        4. *A. simplex* Rudolphi
    3. Genus: *Meniocus* Desv.
        5. *M. linifolius* (Stephan ex Willd.) DC.
    4. Genus: *Odontarrhena* C.A. Mey. ex Ledeb.
        6. *O. muralis* (Waldst. & Kit.) Endl.
        7. *O. sibirica* (Willd.) Španiel & al.
    5. Genus: *Fibigia* Medik.
        8. *F. clypeata* (L.) Medik. subsp. *clypeata*
3. **Tribe Anchonieae**
    6. Genus: *Matthiola* W.T. Aiton
        9. *M. longipetala* (Vent.) DC. subsp. *bicornis* (Sibth. & Sm.) P. W. Ball
4. **Tribe Arabideae**
    7. Genus: *Aubrieta* Adans.
        10. *A. libanotica* Boiss. & Hohen.
    8. Genus: *Draba* L.
        11. *D. nana* Stapf
5. **Tribe Brassiceae**
    9. Genus: *Brassica* L.
        12. *B. nigra* (L.) W. D. J. Koch
        13. *B. Elongata* Ehrh.
    10. Genus: *Crambe* L.
        14. *C. tataria* Sebeök
    11. Genus: *Diplotaxis* DC.
        15. *D. tenuifolia* (L.) DC.
    12. Genus: *Eruca* Mill.
        16. *E. vesicaria* (L.) Cav.
    13. Genus: *Hirschfeldia* Moench
        17. *H. incana* (L.) Lagr.-Foss.
    14. Genus: *Sinapis* L.
        18. *S. arvensis* L.
6. **Tribe Calepineae**
    15. Genus: *Calepina* Adans.
        19. *C. irregularis* (Asso) Thell.
7. **Tribe Camelineae**
    16. Genus: *Capsella* Medik.
        20. *C. bursa-pastoris* (L) Medik.
    17. Genus: *Camelina* Crantz
        21. *C. hispida* Boiss. var. *hispida*
        22. *C. rumelica* Velen.
    18. Genus: *Neslia* Desv.
        23. *N. apiculata* Fisch. & C.A. Mey.
8. **Tribe Cardamineae**
    19. Genus: *Barbarea* W.T. Aiton
        24. *B. vulgaris* R. Br.
9. **Tribe Chorisporeae**
    20. Genus: *Chorispora* R.Br. ex DC.
        25. *C. tenella* (Pall) DC.
10. **Tribe Coluteocarpeae**
    21. Genus: *Microthlaspi* F.K.Mey.
        26. *Mic. perfoliatum* (L.) F. K. Mey.
11. **Tribe Conringieae**
    22. Genus: *Conringia* Heist. ex Fabr.
        27. *C. orientalis* (L.) Dumort.
12. **Tribe Descurainieae**
    23. Genus: *Descurainia* Webb & Berth.
        28. *D. sophia* (L.) Webb ex Prantl
13. **Tribe Erysimeae**
    24. Genus: *Erysimum* L.
        29. *E. cuspidatum* (M. Bieb.) DC.
        30. *E. repandum* L.
        31. *E. smyrnaeum* Boiss. & Balansa
        32. *E. crassipes* Fisch. & C. A. Mey.
14. **Tribe Euclidieae**
    25. Genus: *Strigosella* Boiss.
        33. *S. africana* (L) Botsch.
15. **Tribe Hesperideae**
    26. Genus: *Hesperis* L.
        34. *H. bicuspidata* (Willd) Poir.
16. **Tribe Isatideae**
    27. Genus: *Isatis* L.
        35. *I. glauca* Aucher ex Boiss. subsp. *exauriculata* (Bornm.) P. H. Davis
        36. *I. quadrialata* Al-Shehbaz, Moazzeni & Mumm.
17. **Tribe Lepidieae**
    28. Genus: *Lepidium* L.
        37. *L. draba* L.
        38. *L. perfoliatum* L.
18. **Tribe Sisymbrieae**
    29. Genus: *Sisymbrium* L.
        39. *S. altissimum* L.
        40. *S. orientale* L.
        41. *S. irio* L.
        42. *S. loeselii* L.
19. **Tribe Thlaspideae**
    30. Genus: *Thlaspi* L.
        43. *T. arvense* L.

Table 1. Voucher specimens of the plants examined in the leaf epidermal studies of Brassicaceae taxa for LM and SEM.

Taxa	Specimen collectors & number
Aethionema armenum	A.Erden 1072 & Y.Menemen
A. dumanii	A.Erden 1440 & Y.Menemen
Alyssum simplex	A.Erden 1383 & Y.Menemen
A. turkestanicum	A.Erden 1103 & Y.Menemen
Aubrieta libanotica	A.Erden 1362, 1360 & Y.Menemen
Barbarea vulgaris	A.Erden 1287, 1340 & Y.Menemen
Brassica nigra	A.Erden 1330 & Y.Menemen
B. elongata	A.Erden 1129, 1390 & Y.Menemen
Calepina irregularis	A.Erden 1095 & Y.Menemen
Camelina hispida	A.Erden 1156, 1110 & Y.Menemen
C. rumelica	A.Erden 1139, 1119 & Y.Menemen
Capsella bursa-pastoris	A.Erden 1238, 1336 & Y.Menemen
Chorispora tenella	A.Erden 1283, 1284 & Y.Menemen
Conringia orientalis	A.Erden 1501 & Y.Menemen
Crambe tataria	A.Erden 1037, 1342 & Y.Menemen
Descurainia sophia	A.Erden 1083, 1169 & Y.Menemen
Diplotaxis tenuifolia	A.Erden 1075 & Y.Menemen
Draba nana	A.Erden 1365, 1367 & Y.Menemen
Eruca vesicaria	A.Erden 1231, 1230 & Y.Menemen
Erysimum crassipes	A.Erden 1054, 1113 & Y.Menemen
E. cuspidatum	A.Erden 1220 & Y.Menemen
E. repandum	A.Erden 1300 & Y.Menemen
E. smyrnaeum	A.Erden 1135 & Y.Menemen
Fibigia clypeata	A.Erden 1088 & Y.Menemen
Hesperis bicuspidata	A.Erden 1364, 1261 & Y.Menemen
Hirschfeldia incana	A.Erden 1108, 1130 & Y.Menemen
Isatis glauca	A.Erden 1195, 1196 & Y.Menemen
I. quadrialata	A.Erden 1052 & Y.Menemen
Lepidium draba	A.Erden 1049 & Y.Menemen
L. perfoliatum	A.Erden 1239, 1346 & Y.Menemen
Matthiola longipetala	A.Erden 1070, 1388 & Y.Menemen
Meniocus linifolius	A.Erden 1043 & Y.Menemen
Microthlaspi perfoliatum	A.Erden 1266 & Y.Menemen
Neslia apiculata	A.Erden 1242 & Y.Menemen
Odontarrhena muralis	A.Erden 1222, 1144 & Y.Menemen
O. sibirica	A.Erden 1117, 1450 & Y.Menemen
Sinapis arvensis	A.Erden 1133, 1150 & Y.Menemen
Sisymbrium altissimum	A.Erden 1272, 1151 & Y.Menemen
S. irio	A.Erden 1452 & Y.Menemen
S. loeselii	A.Erden 1098, 1191 & Y.Menemen
S. orientale	A.Erden 1120 & Y.Menemen
Strigosella africana	A.Erden 1116, 1379 & Y.Menemen
Thlaspi arvense	A.Erden 1351 & Y.Menemen

Materials and Methods

Specimens belonging to the family Brassicaceae were collected during the 2012-2017 vegetation seasons in Kırıkkale, Turkey, and its surroundings. The studied specimens were deposited in the Anadolu Herbarium (ADO) of Kırıkkale University, Faculty of Arts and Sciences, Biology Department.

Leaf epidermis characteristics of 43 taxa were studied for each taxon 1 to 4 specimens were examined under Light microscope (LM) and Scanning Electron Microscope (SEM) (Table 1). Leaf epidermis samples for LM examination were prapered by 2 methods: In the first method, the epidermis was peeled from fresh and succulent leaves from both surfaces by hand. In the second method, the dry leaf material was boiled in distilled water for 1–2 min, epidermis fragments were selected from both the lower and upper surfaces using a needle and pliers under a stereo microscope. The pieces of leaf epidermis were placed on slides and stained with 1% safranine, and then passed through an ethanol series (50%, 70%, 90%, and 100%), ethanol and xylol mixture (1:1), and 100% xylol, respectively. Finally, they were dipped in entellan and covered with a coverslip.

An ocular micrometer was used to determine the stomatal index and number of stomata and epidermis cells in 1 mm² on the lower and upper surfaces of the leaves. Stomata indices and stomatal index ratios for the upper and lower surfaces of the taxa were calculated according to the method of Meidner & Mansfield (1965). The epidermal structures in the samples were examined using a Nikon LM and photographed. The length and width of, at least 10 to 15, epidermis cells and stomata were measured under LM.

Scanning electron microscope (SEM): Both surfaces of each leaf sample for each taxa were placed on top of the stubs using double-sided adhesive tape and then coated with gold for 5-6 minutes. The JSM-6060 JEOL model SEM was used to achieve different magnifications using 20 kV and the epicuticular surface charecteristics of the leaves were determined. The terminology used here is basically of Barthlott (1981).

Results

Epicuticular Surface

Epidermis cell surface curvature: Epidermis comprised of 2 types of cellsflat and convex, according to whether the central parts of the cells form a hump. In species having convex cells, on both the upper and lower surfaces, such as *Diplotaxis tenuifolia*, *Neslia apiculata*, *Microthlaspi perfoliatum*, *Lepidium draba*, *Draba nana*, and *Aethionema dumanii*, deflexion existed along the junction of neighboring cells. In the other species, the epidermis cells on both surfaces were flat, except for *Aethionema armenum*, which had convex upper epidermis cells and flat lower epidermis cells (Table 2, Fig. 1).

Epicuticular surface ornamentation: The main epicuticular surface ornamentations can be classified into 4 types: smooth, striate, wrinkled, and ridged. Only smooth surfaces were observed in *Crambe tataria*, *Draba nana*, and *Aethionema dumanii*, while only striate surfaces were observed in *Lepidium draba*, which was also the case in *Meniocus linifolius* and *Erysimum cuspidatum*. Wrinkled surfaces were observed in *Odontarrhena sibirica*, *Alyssum simplex*, *Fibigia clypeata*, *Matthiola longipetala*, *Brassica nigra*, *B. elongata*, *Diplotaxis tenuifolia*, *Eruca vesicaria*, *Calepina irregularis*, *Conringia orientalis*, *Strigosella africana*, *Hesperis bicuspidata*, *Sisymbrium irio*, *S. altissimum*, *S. loeselii*, *Camelina hispida*, *C. rumelica*, *Erysimum smyrnaeum*, *E. crassipes*, *Neslia apiculata*, *Barbarea vulgaris*, *Descurainia sophia*, *Isatis quadrialata*, *I. glauca*, *Chorispora tenella*, *Thlaspi arvense* and *Aethionema armenum*. Ridged surfaces were observed in all the species, except for *Crambe tataria*, *Hesperis bicuspidata*, *Lepidium draba*, *Draba nana* and *Aethionema dumanii* (Table 2, Fig. 2).

Table 2. Leaf epicuticular surface ornamentation, cell surface curvature and waxy cover types of Brassicaceae taxa (Figs. 1, 2 & 3; Epidermis: Epi., membraneous platelets: memb. platelets, papillae: pap.).

Taxa / Characters	Surface ornamentation types								Cell surface/Curvature		Epicuticular waxy cover types	
	Lower epidermal surface				Upper epidermal surface				Lower Epi. convex	Upper Epi. convex	Lower epidermal surface	Upper epidermal surface
	Smooth	Striate	Wrinkled	Ridged	Smooth	Striate	Wrinkled	Ridged				
Aethionema armenum	-	-	+	+	+	-	-	-	-	+	film	film
A. dumanii	+	-	-	-	+	-	-	-	+	+	crystalloids / memb. platelets	crystalloids / memb. platelets
Alyssum turkestanicum	-	-	+	+	-	-	+	+	-	-	film	film
A. simplex	-	-	+	+	-	-	+	+	-	-	film	film
Meniocus linifolius	-	+	+	+	-	+	+	+	-	-	film	film
Odontarrhena muralis	-	-	+	+	-	-	+	+	-	-	film	film
O. sibirica	-	-	+	+	-	-	+	+	-	-	film	film
Fibigia clypeata	-	-	+	+	-	-	+	+	-	-	film	film
Matthiola longipetala	-	-	+	+	-	-	+	+	-	-	film	film
Aubrieta libanotica	+	-	-	+	+	-	-	+	-	-	smooth layer	smooth layer
Draba nana	+	-	-	-	+	-	-	-	+	+	smooth layer	smooth layer
Brassica nigra	-	-	+	+	-	-	+	+	-	-	film	film
B. elongata	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
Crambe tataria	+	-	-	-	+	-	-	-	-	-	crystalloids /granular	crystalloids /granular
Diplotaxis tenuifolia	-	-	+	+	-	-	+	+	+	+	crust	crust
Eruca vesicaria	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
Hirschfeldia incana	-	-	-	+	-	-	-	+	-	-	smooth layer/pap.	smooth layer/pap.
Sinapis arvensis	-	-	-	+	-	-	-	+	-	-	smooth layer	smooth layer
Calepina irregularis	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
Capsella bursa-pastoris	-	-	-	+	-	-	-	+	-	-	smooth layer	smooth layer
Camelina hispida	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
C. rumelica	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
Neslia apiculata	-	-	+	+	-	-	+	+	+	+	film	film
Barbarea vulgaris	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
Chorispora tenella	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
Microthlaspi perfoliatum	+	-	-	+	+	-	-	+	+	+	crystalloids / platelets and rodlets	crystalloids / platelets and rodlets
Conringia orientalis	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
Descurainia sophia	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
Erysimum cuspidatum	-	+	-	+	-	+	-	+	-	-	smooth layer	smooth layer
E. repandum	-	-	-	+	-	-	-	+	-	-	crystalloids / platelets	crystalloids/platelets
E. smyrnaeum	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
E. crassipes	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
Strigosella africana	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
Hesperis bicuspidata	+	-	+	-	+	-	+	-	-	-	film	film
Isatis quadrialata	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
I. glauca	+	-	+	+	+	-	+	+	-	-	smooth layer	smooth layer
Lepidium draba	-	+	-	-	-	+	-	-	+	+	film	film
L. perfoliatum	-	-	-	+	-	-	-	+	-	-	crystalloids / platelets	crystalloids / platelets
Sisymbrium altissimum	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
S. orientale	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
S. irio	-	-	-	+	-	-	-	+	-	-	smooth layer	smooth layer
S. loeselii	-	-	+	+	-	-	+	+	-	-	smooth layer	smooth layer
Thlaspi arvense	-	-	+	+	-	-	+	+	-	-	film	film

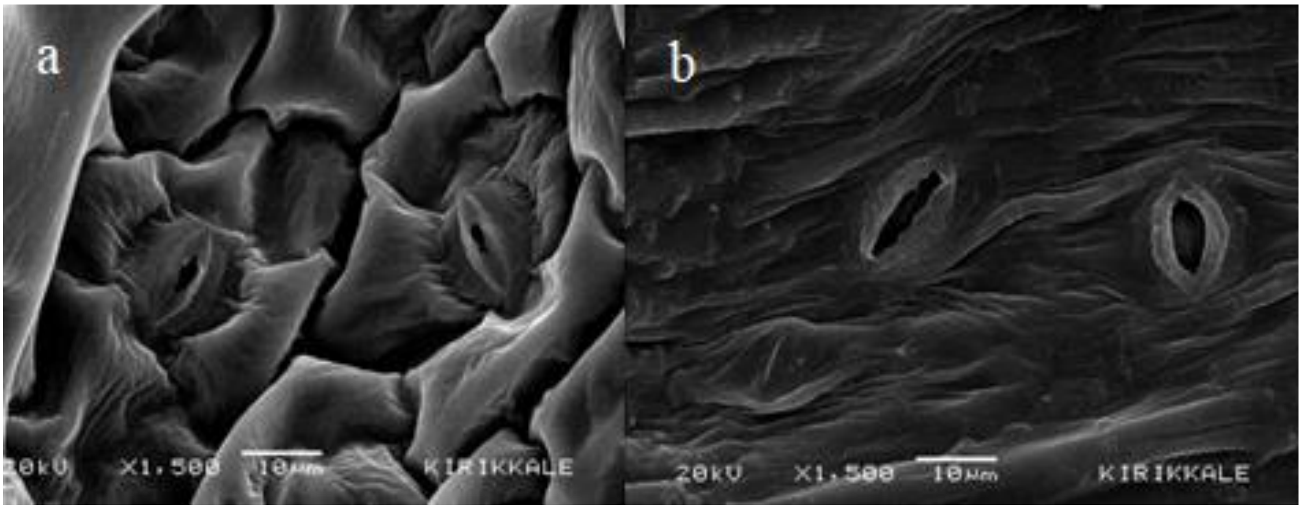

Fig. 1. SEM images of cell surface curvature types: a. convex (upper epidermis of *Neslia apiculata),* b. flat (lower epidermis of *Eruca vesicaria*).

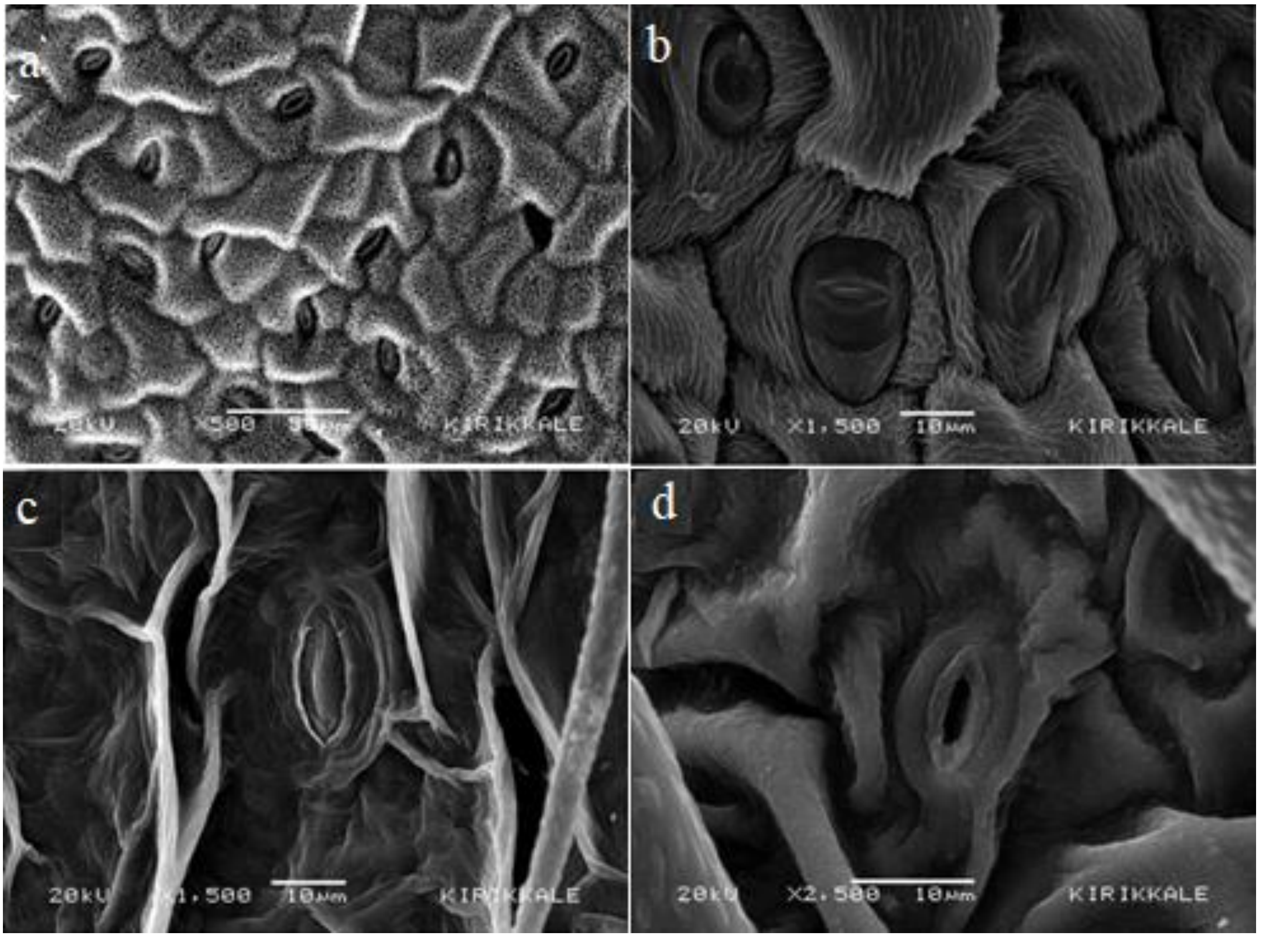

Fig. 2. SEM images of leaf epidermal surface ornamentation types: a. smooth, (upper epidermis *of Aethionema dumanii*), b. striate (upper epidermis *of Lepidium draba*), c. wrinkled (upper epidermis of *Matthiola longipetala*), d. ridged (upper epidermis of *Sisymbrium orientale*).

Epicuticular wax covering: In the studied species, 4 types were observed: i) crust type was present in *Diplotaxis tenuifolia*, ii) crystalloids type was present in *Microthlaspi perfoliatum*, *Aethionema dumanii*, *Lepidium perfoliatum*, *Eryssimum repandum*, and *Crambe tataria*, iii) film type was present in *Neslia apiculata*, *Lepidium draba*, *Alyssum turkestanicum*, *Meniocus linifolius*, *Odontarrhena muralis*, *Odontarrhena sibirica, Alyssum simplex*, *Fibigia clypeata*, *Matthiola longipetala*, *Brassica nigra*, *Thlaspi arvense*, *Aethionema armenum*, and *Hesperis bicuspidata*, and iv) smooth layer type was present in all the other species. The smooth layer was with a more or less papillae structure in *Hirschfeldia incana.* Crystalloids differed in different species they were found in, with dense platelets and rodlets in *Microthlaspi perfoliatum*, membraneous platelets in *Aethionema dumanii*, dense platelets in *Lepidium perfoliatum*, sparse plateles in *Erysimum repandum*, and densely granular in *Crambe tataria* (Table 2, Fig. 3).

Shape, Size and Anticlinal Cell Walls of Epidermal Cells

Upper epidermal surface: The cells were irregular, rectangular, or polygonal in shape. There were some instances where 2 types were found together. The cells were polygonal in *Alyssum turkestanicum*, *Meniocus linifolius*, *Fib. clypeata*, *Diplotaxis tenuifolia*, and *Hirschfeldia incana*; irregular and polygonal in *Odontarrhena muralis*, *Odontarrhena sibirica*, *Crambe tataria*, *Sisymbrium orientale*, *Erysimum cuspidatum*, *E. smyrnaeum*, *Neslia apiculata*, *Aubrieta libanotica*, *Aethionema armenum*, *A. dumanii*, and *Lepidium draba*; rectangular and polygonal in *Draba nana*, and irregular in all the other species. The length of the epidermal cell varied between 9.50 and 113.65 µm, while the width was between 7.15 and 61.50 µm. The minimum and maximum width was 7.95 µm in *Lepidium perfoliatum* and 56.825 µm as in *Strigosella africana*, respectively (Table 3, Fig. 4).

There were 5 different types of anticlinal walls observed in the upper epidermis cells: arched, straight to arched, repand, sinuous, and undulate. They were arched in *Aethionema armenum*, straight to arched in *Alyssum turkestanicum*, *Meniocus linifolius*, *Odontarrhena muralis*, *O. sibirica*, *Alyssum simplex*, *Fibigia clypeata*, *Crambe tataria*, *Diplotaxis tenuifolia*, *Lepidium draba*, *Sisymbrium orientale*, *Erysimum smyrnaeum*, *E. crassipes*, *Neslia apiculata*, *Draba nana* and *Aethionema dumanii*, repand in *Brassica elongata*, *Hirschfeldia incana*, *Sinapis arvensis*, *Hesperis bicuspidata*, *Sisymbrium loeselii*, *Capsella bursa-pastoris*, *Camelina rumelica*, *Erysimum cuspidatum*, *E. repandum*, *Aubrieta libanotica*, *and Isatis glauca*, sinuous in *Eruca vesicaria* and *Sisymbrium irio*, and undulate in all the other species (Table 3, Fig. 5).

Lower epidermal surface: The cells were polygonal in *Fibigia clypeata*, *Meniocus linifolius*, *Alyssum turkestanicum*, rectangular and polygonal in *Draba nana*, irregular and polygonal in *Odontarrhena sibirica*, *O. muralis*, *Aethionema armenum*, *Lepidium draba*, *Crambe tataria*, and *Aethionema dumanii*, and irregular in the other species. The epidermal cell length varied between 9.15 and 115.00 µm and the width was between 4.50 and 50.00 µm. In the lower epidermal cells, the anticlinal walls were straight, arched, repand, sinuous, and undulate, as was in the upper epidermis. They were arched in *Aethionema armenum*, straight to arched in *Aethionema dumanii* and *Erysimum crassipes*, repand *in Sisymbrium orientale*, and *Erysimum cuspidatum*, sinuous in *Sisymbrium irio* and *Eruca vesicaria*, and undulate in all of the other species (Table 4, Figs. 4 & 5).

Stomata: Stomata type, shape, size, and stomatal index ratios for the leaf upper and lower epidermis of each taxa are presented in Tables 3 and 4; Fig. 6.

Stomata of upper epidermis: The stomata were basically anisocytic. However, a combination of that and anomocytic was observed in *Meniocus linifolius*, *Sisymbrium altissimum*, *Descurainia sophia*, *Chorispora tenella*, and *Aubrieta libanotica*. The stomata were elliptical, large elliptical, and round in shape. The stomatal index ranged from 15.78 to 25.92 µm. The lowest index was 13.04 in *Aubrieta libanotica* and 13.23 µm in *Fibigia clypeata*, while the highest index was 27.27 µm in *Brassica elongata* and 27.77 µm in *Sisymbrium altissimum.* The stomata length ranged between 9.10 and 34.10 µm. The smallest stomata were between 9.10 and 11.365 µm in *Lepidium perfoliatum*, while the largest were between 29.55 and 34.10 µm in *Strigosella africana.* The width of stomata ranged from 5.65, as in *Lepidium perfoliatum*, to 25.00 µm in *Strigosella africana* and *Isatis glauca* (Table 3).

Stomata of lower epidermis: The stomata types were similar to those in the upper surface, i.e. basically anisocytic, and a combination of that and anomocytic in *Meniocus linifolius*, *Sisymbrium altissimum*, *Descurainia sophia*, *Chorispora tenella*, *Aubrieta libanotica*, *Calepina irregularis* (Fig. 6a) and *Sinapis arvensis.* The stomata were elliptical, large elliptical, and round in shape. The stomatal index ranged from 10.71 to 33.33 µm. The lowest index was 10.71 µm in *Aubrieta libanotica*, while the highest was 33.33 µm in *Sisymbrium altissimum.* The stomata length generally varied between 14.50 and 31.82 µm. However, the shortest stomata were 11.50–14.50 µm in *Lepidium perfoliatum*, while the longest were 29.549–36.368 µm in *Isatis glauca*. The stomata width generally ranged from 9.20 to 25.00 µm, with the minimum in *Lepidium perfoliatum* at 9.10–11.30 µm, while the maximum was in *Isatis glauca* at 25.00–29.54 µm.

The stomatal index ratio of the studied species was between 0.73 and 1.42 µm; it was the lowest in *Sisymbrium loeselii* and the highest in *Draba nana* (Table 4).

Discussion

For the characterization of plant micromorphology, the outline of the epidermal cells could be important characters for distinguishing the species of a genus and the genera as well in a tribe. For example, the species of *Erysimum cuspidatum* and *E. smyrnaeum* by their polygonal cell shapes together with irregular ones differed from those of *E. repandum* and *E. crassipes.* In Alysseae tribe, *Alyssum turkestanicum* and *Meniocus linifolius* differed from *Odontarrhena muralis* and *O. sibirica* by their polygonal epidermal cells.

The cell sculpture or curvature of the outer epidermis wall (periclinal wall) has an important influence on the surface roughness. The cell surface curvature stands out as an important character in the separation of some closely related species. For example, *Lepidium draba* and *Aethionema dumanii* are, respectively, distinguished by their convex cell surface curvature from their close relatives, *Lepidium perfoliatum* and *Aethionema armenum* species. At the generic level, *Neslia* and *Diplotaxis* differ from the other genera by their convex cell surface curvature.

Table 3. Characteristics of the leaf upper epidermal surfaces of the studied taxa (Figs. 4,5 and 6; anisocytic: aniso., anomocytic: anomo., round: rou., elliptical: ell., anticlinal wall shape: ant. wall shape).

Taxa / Characters	Upper epidermal cells				Upper surface stomata				
	Length (µm)	Width (µm)	Shape	Ant. wall shape	Type	Shape	İndex (%)	Length (µm)	Width (µm)
Aethionema armenum	9,50-77,50	9,50-34,50	irregular/polygonal	arched	aniso.	rou.	20	19-27,25	18,20-22,75
A. dumanii	16,50-72,50	10,50-33,50	irregular/polygonal	straight to arched	aniso.	large ell.	17,64	25-34	18-24
Alyssum turkestanicum	22,50-56,50	9,50-34,50	polygonal	straight to arched	aniso.	large ell.	22,72	18,50-22,50	13,50-15,90
A. simplex	20,50-56,50	16-34,50	irregular	straight to arched	aniso.	ell./large ell.	20,68	23-25	14,50-16
Meniocus linifolius	20,50-102,50	18,50-61,50	polygonal	straight to arched	aniso./anomo.	ell.	21,42	19-23,50	10,50-12,50
Odontarrhena muralis	14,50-54,50	9,50-25,00	irregular/polygonal	straight to arched	aniso.	large ell.	17,64	18,20-20,50	11,50-15,90
O. sibirica	16,50-102,50	11,50-31,50	irregular/polygonal	straight to arched	aniso.	large ell.	17,64	13,50-18,20	9,15-13,50
Fibigia clypeata	18,50-36,50	11,50-20,50	polygonal	straight to arched	aniso.	large ell.	13,23	16,50-18,50	9,10-12,50
Matthiola longipetala	18,50-95,50	11,50-27,50	irregular	undulate	aniso.	ell.	19,04	25-29,50	9,50-13,50
Aubrieta libanotica	16-52,5	7,15-25	irregular/polygonal	repand	aniso./anomo.	large ell./rou.	13,04	18,5-25	13,5-16,5
Draba nana	20,50-81,50	9,50-22,50	rectangular/polygonal	straight to arched	aniso.	rou./rarely large ell.	15,78	22,50-25,50	13,50-18,20
Brassica nigra	17,50-85,50	13,50-25,00	irregular	undulate	aniso.	ell.	23,07	19,50-21,50	12,50-13,65
B. elongata	20,50-110	9,25-29,50	irregular	repand	aniso.	ell.	27,27	21,50-29,50	13,70-20,50
Crambe tataria	20,50-68,50	15,50-40,50	irregular/polygonal	straight to arched	aniso.	large ell.	20,83	22,75-27,25	13,50-18,15
Diplotaxis tenuifolia	13,63-34,10	9,10-22,73	polygonal	straight to arched	aniso.	rou.	20	20,457-22,73	18,18-20,45
Eruca vesicaria	13,65-56,0	9,50-27,25	irregular	sinuous	aniso.	large ell.	20	20,50-25,00	15,80-18,10
Hirschfeldia incana	14,50-58,50	9,20-36,25	polygonal	repand	aniso.	large ell.	19,23	15,50-18,20	11,50-13,60
Sinapis arvensis	13,65-98,50	11,50-31,50	irregular	repand	aniso.	large ell./rou.	21,73	16,50-20,50	12,50-14,50
Calepina irregularis	14,50-104,50	12,50-29,50	irregular	undulate	aniso.	large ell./rou.	21,05	18,25-20,50	12,50-16
Capsella bursa-pastoris	16,25-83,50	11,50-20,50	irregular	repand	aniso.	rou./rarely large ell.	24,32	14,50-16,50	11,50-12,50
Camelina hispida	16,50-98,50	11,5-31,50	irregular	undulate	aniso.	large ell.	21,42	20,5-25	14,5-17,50
C. rumelica	18,50-70,50	11,50-20,50	irregular	repand	aniso.	ell./large ell.	21,05	22,75-25,00	14,50-18,50
Neslia apiculata	20,50-94,50	18-34	irregular/polygonal	straight to arched	aniso.	large ell.	23,52	22,50-25	15,60-18,90
Barbarea vulgaris	13,50-102,50	11,5-27,25	irregular	undulate	aniso.	large ell./rou.	21,42	18,50-25	14,50-18,50
Chorispora tenella	15,80-90,50	9,20-20,50	irregular	undulate	aniso./anomo.	large ell./rou.	22,72	20,50-22,50	14,50-16,50
Microthlaspi perfoliatum	16-90,50	11,50-40,50	irregular	undulate	aniso.	ell./large ell.	23,07	18,50-21,50	13,50-15,50
Conringia orientalis	16-92,50	7-34,50	irregular	undulate	aniso.	large ell.	21,05	16-22,50	13,50-18
Descurainia sophia	13,75-88,50	11,50-25	irregular	undulate	aniso./anomo.	ell.	22,22	16,25-19,30	9,50-12,50
Erysimum cuspidatum	13,50-54,50	9,50-29,50	irregular/polygonal	repand	aniso.	ell.	18,18	16,50-20,50	11,50-13,50
E. repandum	13,60-52,27	11,35-29,50	irregular	repand	aniso.	large ell.	22,22	15,91-22,73	11,36-14,75
E. smyrnaeum	18,50-73,50	13,50-22,50	irregular/polygonal	straight to arched	aniso.	rou./rarely large ell.	20	13,50-16,50	12,50-15,50
E. crassipes	13,50-72,50	9-27,25	irregular	straight to arched	aniso.	large ell.	19,23	19,50-22,75	13,50-15,90
Strigosella africana	27,27-90,92	22,73-56,825	irregular	undulate	aniso.	ell.	20	29,55-34,10	20,46-25,00
Hesperis bicuspidata	18,20-56,50	11,50-25,00	irregular	repand	aniso.	ell.	19,04	26,50-29,50	16,50-20,50
Isatis quadrialata	11,36-88,50	9,09-27,28	irregular	undulate	aniso.	ell./large ell.	19,23	15,92-20,46	11,36-13,64
I. glauca	20,46-61,37	11,37-36,37	irregular	repand	aniso.	large ell.	23,07	27,27-29,55	22,73-25,003
Lepidium draba	15,91-50,00	13,64-36,37	irregular/polygonal	straight to arched	aniso.	rou./rarely large ell.	18,75	20,45-22,73	15,91-18,19
L. perfoliatum	11,00-40,90	7,95-18,00	irregular	undulate	aniso.	large ell.	25,92	9,10-11,365	5,65-9,10
Sisymbrium altissimum	11,50-92,50	9,50-25	irregular	undulate	aniso./anomo.	rou./rarely large ell.	27,77	20,50-22,75	14,50-19,50
S. orientale	11,50-84,50	11,25-22,75	irregular/polygonal	straight to arched	aniso.	large ell.	25	16-18,50	11,25-12,50
S. irio	13,70-59	11,35-27,25	irregular	sinuous	aniso.	rou./rarely large ell.	22,22	18,50-22,50	14,50-18
S. loeselii	11,50-63,50	8,50-25,50	irregular	repand	aniso.	large ell.	22,22	13,65-16,50	11,50-13,70
Thlaspi arvense	13,63-113,65	9,10-27,27	irregular	undulate	aniso.	large ell.	25	18,19-25,00	15,91-20,45

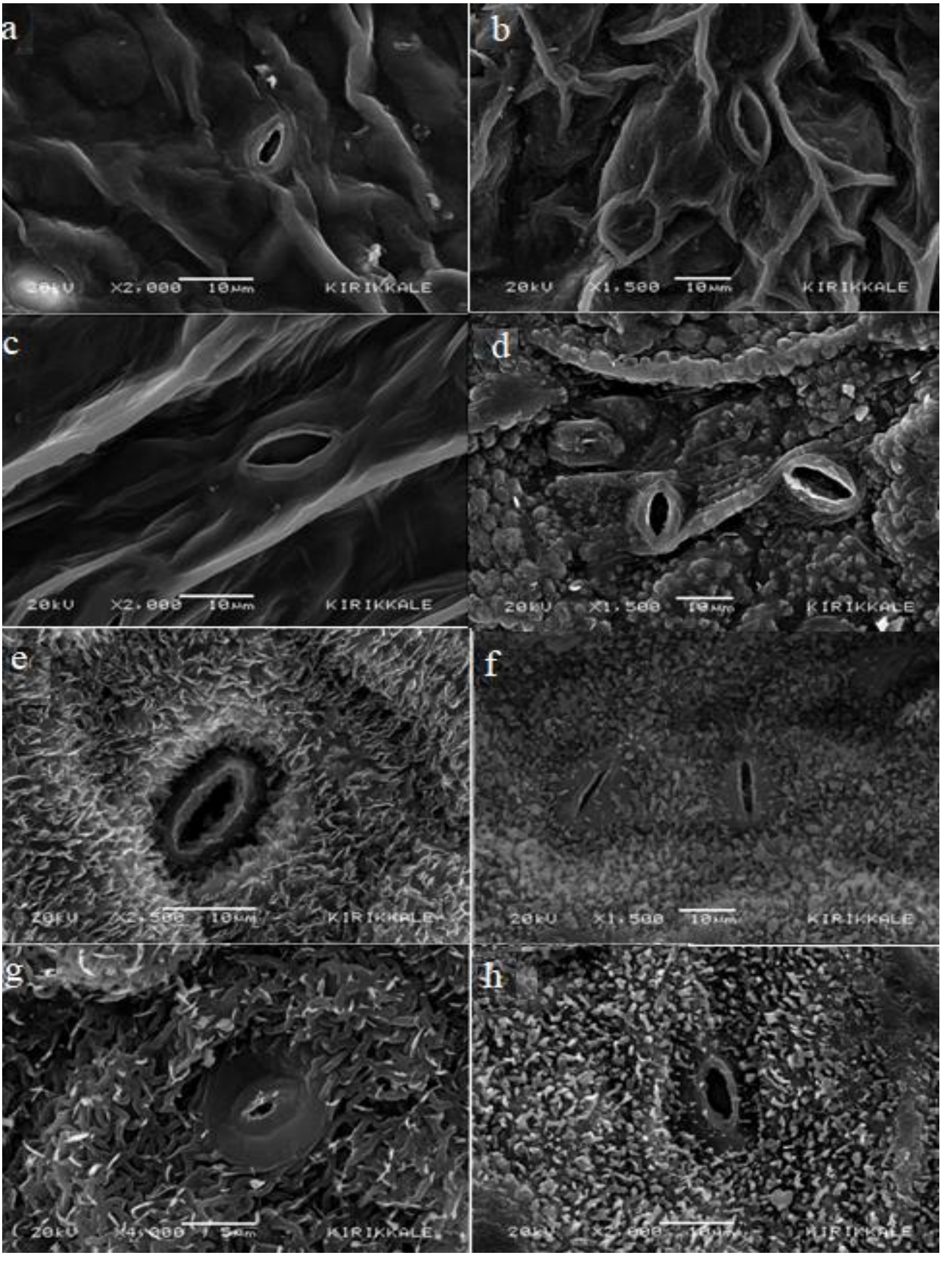

Fig. 3. SEM images of leaf epicuticular waxy cover types: a. smooth layer (lower epidermis of *Chorispora tenella*), b. smooth layer/papillae (lower epidermis of *Hirschfeldia incana*), c. film (upper epidermis of *Thlaspi arvense*), d. crust (lower epidermis of *Diplotaxis tenuifolia*), e. crystalloids / membraneous platelets (upper epidermis of *Aethionema dumanii*), f. crystalloids / granular (upper epidermis of *Crambe tataria*), g. crystalloids / platelets (upper epidermis of *Lepidium perfoliatum)* h. crystalloids / platelets and rodlets (lower epidermis of *Microthlaspi perfoliatum).*

Table 4. Characteristics of the leaf lower epidermal surfaces of the studied taxa (Fig. 4,5 and 6; anisocytic: aniso., anomocytic: anomo., round: rou., elliptical: ell., anticlinal wall shape: ant. wall shape, stomata index ratio: stom. ind. rt.).

Taxa / Characters	Lower epidermal cells				Lower surface stomata					Stom. ind. rt.
	Length (µm)	Width (µm)	Shape	Ant. wall shape	Type	Shape	İndex (%)	Length (µm)	Width (µm)	
Aethionema armenum	14-77,50	9,50-31,50	irregular/polygonal	arched	aniso.	rou.	17,64	16,50-22,50	13,50-18,50	1,134
A. dumanii	18,50-112,50	7,50-38,50	irregular/polygonal	straight to arched	aniso.	large ell.	18,75	22,50-36,50	19,50-27,25	0,941
Alyssum turkestanicum	23,20-61,50	11,50-36,50	polygonal	straight to arched	aniso.	large ell.	23,07	19,50-23,50	14,50-16	0,985
A. simplex	13,50-67,50	12,50-29,50	irregular	repand	aniso.	ell./large ell.	20	22,50-27,20	13,50-16,50	1,034
Meniocus linifolius	18,50-95,50	15,50-57	polygonal	straight to arched	aniso./anomo.	ell.	23,07	18,50-21,50	9,20-11,50	0,929
Odontarrhena muralis	14,20-50	9,20-22,75	irregular/polygonal	straight to arched	aniso.	ell./large ell.	16,66	16,50-20,50	13,50-16	1,059
O. sibirica	14-85,50	11,50-40,50	irregular/polygonal	straight to arched	aniso.	large ell.	23,07	15,50-18,50	10,50-12,50	0,765
Fibigia clypeata	11,50-36,50	9,50-20,50	polygonal	straight to arched	aniso.	large ell.	14,28	16,50-20,50	11,50-14,25	0,927
Matthiola longipetala	18,50-90,50	13,50-31,80	irregular	undulate	aniso.	ell.	20	22,70-25,20	11,30-13,50	0,952
Aubrieta libanotica	9,15-38,5	4,50-17,50	irregular	repand	aniso./anomo.	large ell./rou.	10,71	14-20,50	13,5-18,20	1,218
Draba nana	13,50-72,50	9,50-18,30	rectangular/polygonal	straight to arched	aniso.	rou.	11,11	23,50-25,00	19,50-21,50	1,420
Brassica nigra	19,50-95,50	12,50-13,50	irregular	undulate	aniso.	ell.	21,05	19,20-20,50	12,25-13,65	1,096
B. elongata	19,50-78,50	11,50-27,20	irregular	repand	aniso.	ell./large ell.	30	20,50-30,50	15-20,50	0,909
Crambe tataria	20,45-75,20	15,50-40,50	irregular/polygonal	straight to arched	aniso.	large ell.	22,72	20,45-27,50	14,25-18,15	0,917
Diplotaxis tenuifolia	18,19-56,83	13,64-34,10	irregular	repand	aniso.	rou.	21,05	22,73-25,003	18,19-20,48	0,950
Eruca vesicaria	15,50-84,50	9,50-50,00	irregular	sinuous	aniso.	large ell.	26,31	18,50-25,00	13,60-20,50	0,760
Hirschfeldia incana	13,50-88,50	11,50-34,50	irregular	undulate	aniso.	large ell.	21,42	15,50-22,50	11,50-15,50	0,898
Sinapis arvensis	15,50-102,50	11,50-22,75	irregular	undulate	aniso./anomo.	large ell./rou.	22,72	16,50-20,50	11,50-13,50	0,956
Calepina irregularis	14,50-72,50	11,50-29,50	irregular	undulate	aniso./anomo.	ell./large ell.	22,22	18,50-22,75	11,50-13,70	0,947
Capsella bursa-pastoris	16-90,50	11,50-20,50	irregular	undulate	aniso.	ell./large ell.	17,64	18,50-22,75	11,50-13,70	1,378
Camelina hispida	16-95,50	9,50-22,50	irregular	undulate	aniso.	large ell./rou.	25	20,50-27,25	15,50-18,20	0,857
C. rumelica	16,50-59,50	11,50-22,75	irregular	undulate	aniso.	ell.	23,07	20,50-21,50	12,25-14,20	0,912
Neslia apiculata	18,50-80,50	15,50-34,50	irregular	repand	aniso.	ell./large ell.	26,31	22,50-25	13,50-15,90	0,894
Barbarea vulgaris	16-115	9,50-22,50	irregular	undulate	aniso.	large ell.	23,07	20,5-25	15,5-18,50	0,929
Chorispora tenella	14,50-102,50	9,25-20,50	irregular	undulate	aniso./anomo.	large ell./rou.	21,73	16-25	14,50-20,50	1,046
Microthlaspi perfoliatum	11,50-100,50	9,20-22,75	irregular	undulate	aniso.	ell./large ell.	29,41	14,50-20,50	9,50-15,50	0,784
Conringia orientalis	25-90,50	13,50-34	irregular	undulate	aniso.	large ell.	21,42	18-25,50	15,75-20,45	0,982
Descurainia sophia	15,50-80,50	11,50-29,50	irregular	undulate	aniso./anomo.	ell.	19,04	18,25-20,50	11,50-13,60	1,167
Erysimum cuspidatum	11,50-63,50	9,50-18	irregular	repand	aniso.	large ell.	19,04	18,20-20,50	12,50-13,50	0,955
E. repandum	13,70-85,50	9,5-31,80	irregular	repand	aniso.	large ell.	27,27	21,20-25,00	14,25-16,20	0,815
E. smyrnaeum	15,50-63,50	11,50-29,50	irregular	repand	aniso.	ell./large ell.	22,72	18,50-20,50	12,50-15,50	0,880
E. crassipes	18,50-65,50	9,50-27,50	irregular	straight to arched	aniso.	large ell.	20	18,25-22,75	11,50-16,50	0,962
Strigosella africana	27,27-68,19	13,64-40,20	irregular	undulate	aniso.	ell.	22,22	27,27-31,82	22,73-25,003	0,900
Hesperis bicuspidata	18,50-56,80	13,65-27,25	irregular	undulate	aniso.	large ell.	23,07	26,50-29,50	16,50-21,50	0,825
Isatis quadrialata	18,20-100	9,10-27,28	irregular	undulate	aniso.	ell.	26,08	15,91-28,05	11,36-15,91	0,737
I.glauca	18,19-94,05	11,37-22,73	irregular	repand	aniso.	large ell. and rou.	22,22	29,55-36,37	25,00-29,55	1,038
Lepidium draba	22,73-40,914	13,64-27,28	irregular/polygonal	straight to arched	aniso.	rou. and large ell.	21,73	18,18-22,73	13,63-18,184	0,863
L. perfoliatum	9,50-40,90	7,50-20,45	irregular	undulate	aniso.	large ell.	25	11,50-14,50	9,10-11,30	1,037
Sisymbrium altissimum	11,50-73,50	9,50-27,50	irregular	undulate	aniso./anomo.	rou. and large ell.	33,33	21,50-23,50	14,50-18,20	0,833
S. orientale	18,50-86,50	13,50-22,50	irregular	repand	aniso.	large ell.	23,33	15,50-20,50	11,30-13,50	1,072
S. irio	13,50-68,50	12,50-25	irregular	sinuous	aniso.	rou. and large ell.	22,72	18,50-25	14,50-18,10	0,978
S. loeselii	15,90-77,50	7,50-20,50	irregular	repand	aniso.	rou. and large ell.	30,43	15,50-20,45	11,50-15,50	0,730
Thlaspi arvense	13,64-102,29	11,36-25,00	irregular	undulate	aniso.	large ell.	25,92	20,46-25,00	15,91-20,46	0,965

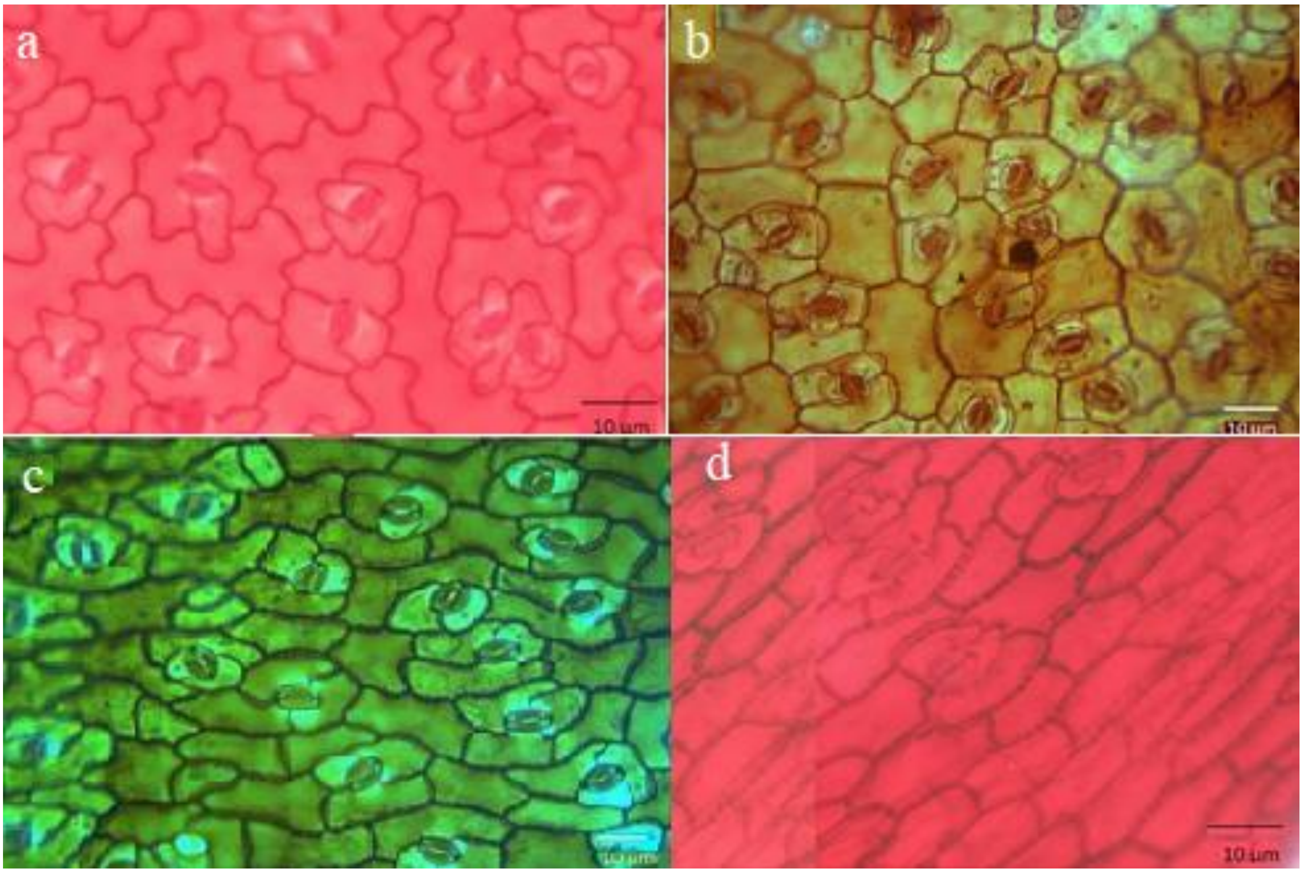

Fig. 4. LM images of leaf epidermal cell shapes: a. irregular (upper epidermis of *Isatis quadrialata*), b. polygonal (upper epidermis of *Diplotaxis tenuifolia),* c. irregular/polygonal (upper epidermis of *Neslia apiculata),* d. rectangular/polygonal (upper epidermis of *Draba nana*).

No difference was observed along the junction of neighboring cells, the epicuticular surface ornamentation, or epicuticular waxy cover both the upper and lower surfaces of the leaves. However, in *Aethionema armenum* the cells were convex with smooth ornamentation in the upper epidermis, and flat with wrinkled and ridged ornamentation in the lower epidermis.

The course of the anticlinal cell wall can be straight or uneven. Uneven anticlines could be further divided into arched, repand, sinuous, and undulate. Undulations of anticlinal cell walls are important in increasing the mechanical stability of the epidermis tissue. In some taxa, the shape of the anticlinal cell wall varies between the upper and lower epidermis. For instance, while the shape of the cell wall of the upper epidermis in *Sisymbrium orientale*, *Erysimum smyrnaeum*, *Alyssum simplex*, *Neslia apiculata*, and *Diplotaxis tenuifolia* was straight to arched, the shape of the lower epidermis anticlinal cell wall was repand. The shape of the anticlinal cell wall of the lower epidermis was undulate, while the shape of the anticlinal cell wall of the upper epidermis in *Capsella bursa-pastoris*, *Camelina rumelica*, *Hesperis bicuspidata*, *Sinapis arvensis*, and *Hirschfeldia incana* was repand. In terms of the shape of the upper epidermis anticlinal cell wall, on the basis of tribe, only members of Alysseae had a homogeneous (straight to arched) shape. There were at least 2 different wall shapes in the tribes that had 2 or more taxa. It can be seen that this feature can often be used to delimit some of the species.

The results obtained in this study indicated that some stomata features were important both taxonomically and ecologically. When the upper and lower epidermis of the stomata were examined, it was found that the lowest stomatal index on the upper surface was 13.04 in *Aubrieta libanotica*, while the highest was 27.77 in *Sisymbrium altissimum*. However, on the lower surface, the lowest stomatal index value was 10.71 in *Aubrieta libanotica*, while the highest was 33.33 in *Sisymbrium altissimum*.

Thus, it was revealed that the low stomatal index values of *Aubrieta* and *Fibigia* growing at high, stony-rocky areas were directly related to the climatic conditions and habitat that the plants were exposed to. It was also observed that the stomatal index was higher in species like *Sisymbrium* and *Brassica*, which grew in lower areas and preferred moist soil. In the investigated species, the upper epidermis stomatal index was generally higher than that of the lower one. Considering that the studied species were collected from the central Anatolian region, where the climate was semiarid, the number of epidermal cells and the stomatal index was increased.

The stomatal index ratio of the studied species was between 0.73 and 1.42. The lowest was in *Sisymbrium loeselii* and the highest in *Draba nana*. *Draba nana's* preferrence of very high and rocky habitats explains the effect of ecological conditions on its stomatal index ratio. The highest value stomatal index ratio was seen in the tribe Arabideae (*Aubrieta* and *Draba*).

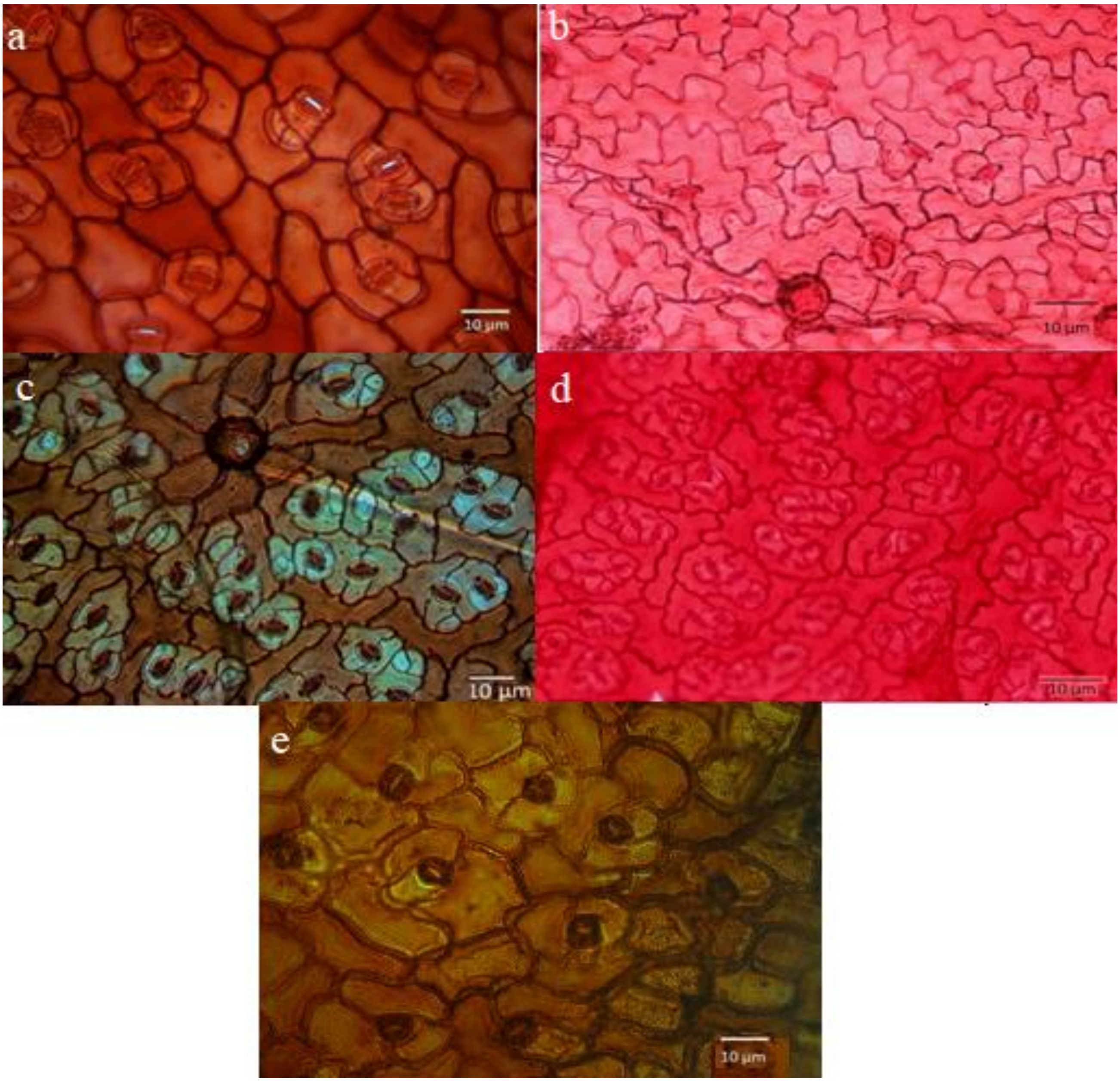

Fig. 5. LM images of leaf anticlinal cell wall shapes: a. straight to arched (upper epidermis of *Lepidium draba*), b. undulate (lower epidermis of *Descurainia sophia*), c. repand (lower epidermis of *Sisymbrium loeselii), d.* sinuous (lower epidermis of *Eruca vesicaria), e.* arched (upper epidermis of *Aethionema armenum*).

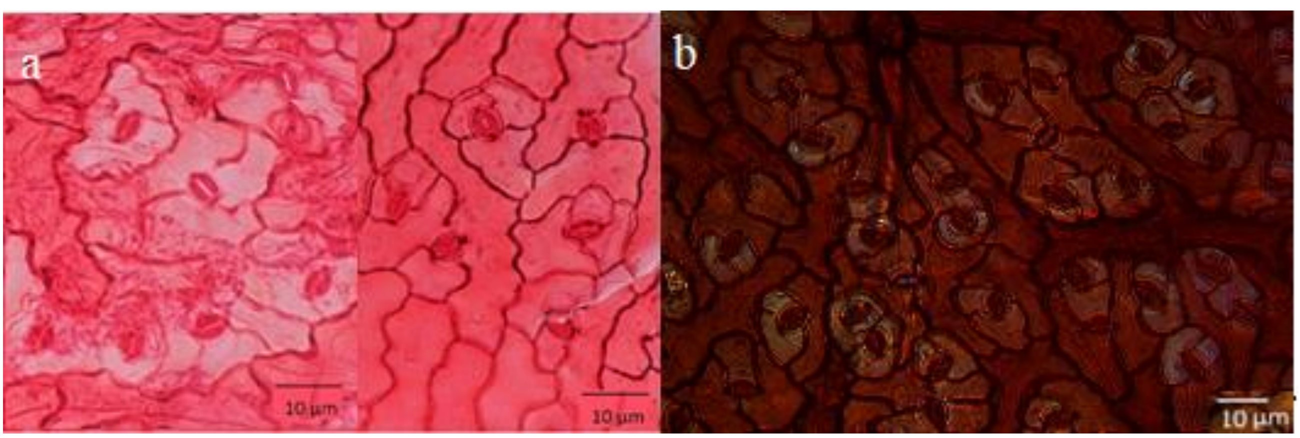

Fig. 6. LM images of leaf stomata shapes: a. elliptical and large elliptical (lower and upper epidermis of *Calepina irregularis*), b. round and large elliptical (upper epidermis of *Sisymbrium loeselii*).

The stomatal index ratio generally showed almost similar values in the taxa within the same tribe, but it was observed that some taxa had quite different values. For example, the index ratio of *Odontarrhena sibirica* in the tribe Alysseae was 0.77, while it was 1.06 in *O. muralis*.

The stomata were amphistomatic, and anisocytic in all the species, while in some species such as *Aubrieta libanotica, Calepina irregularis, Chorispora tenella, Descurainia sophia, Meniocus linifolius, Sisymbrium altissimum* and *Sinapis arvensis,* anomocytic stomata were also found. Although paracytic stomata in some species belonging to the genus *Sisymbrium* were reported (Sun & Li, 2008), no paracytic stomata were detected in any of the taxa in the present study. There wasn't much difference in the stomata dimension and the shape among the species, and therefore, they were of little taxonomical value.

Cuticular folds may originate due to the cuticle itself, by the expression of the bulk of the cell wall below, or by sub-cuticular deposits (Koch *et al*., 2008). Epicuticular surface ornamentation comprised of 4 types: smooth, striate, wrinkled, and ridged. In general, wrinkled and ridged were the most common types. Among the four *Sisymbrium* species in the tribe Sisymbrieae, only *Sisymbrium orientale* showed a difference, by the absence of wrinkles in the epicuticular surface ornamentation while other 3 species had wrinkled epicuticular surface. All of the remaining features were the same for the other species of the tribe. In Alysseae, all of the features were the same, except for the striate ornamentation observed in *Meniocus linifolius*. Species belonging to 2 different genera in Arabideae had the same features, with the exception of ridged ornamentation, only in *Aubrieta*. Only 2 species belonging to the genus *Camelina* of the tribe Camelineae were the same in terms of the features examined herein.

The taxonomic importance of the waxy cover emerged in the examined taxa. It is known that the wax layer on the epidermis is expected to be thick in plants living in arid regions, but there is a lack of scientific studies about the shape of the wax layer on the plant surface in the short term. In this study, different types of wax layers were found in different taxa living in the same climatic conditions. Therefore, wax diversification may be a feature of the plant in its own evolutionary process and it may be taxonomically important at the species, generic and tribal level. For example, *Aethionema armenum* had a film waxy cover, while *A. dumanii* had a dense membraneous platelets. It was observed that there were sparse platelets in *Erysimum repandum*, of the 4 species of Erysimum examined in Erysimeae, whereas a smooth layer waxy cover was observed in the other 3 species. However, all of the members of Alysseae had a film wax layer. In the tribe Camelineae, smooth layer was seen in all of the species, except for the genus *Neslia*, which had a film waxy cover.

Conclusion

In this study, the taxonomic importance of leaf micromorphological characters was investigated in 43 species of Brassicaceae in Turkey. The results obtained clearly showed that the leaf epidermal surface features demonstrated great similarities at the family level, but they are important to delimit the tribes, sometimes genera, and species also.

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