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Taxonomic Implications of Foliar Epidermal Characteristics with Special Reference to Stomatal Variations in the Genus *Artemisia* (Asteraceae)

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ABSTRACT

The systematic associations between the individual species of genus *Artemisia* have been very divisive and need all over revisions and investigations. In continuation to our preceding papers, at this time we account the taxonomic importance of foliar epidermal cells characteristics along with stomatal diversity in the 24 taxa of the genus *Artemisia* by using light microscopy and scanning electron microscopy. In addition to previously studied anomocytic and anisocytic stomatal types, here we report four new types of stomata (anomotetracytic, paratetracytic, diacytic & paracytic) first time in the genus *Artemisia*. Detail of variations in epidermal cells, of both abaxial and adaxial surfaces, of leaves was also given in relation to the taxonomy of the genus and it was found that most of the *Seriphidium* spp. have elongated smooth wall cells while other *Artemisia* spp., have wavy margined irregular shape cells with few exceptions. This study also indicates that foliar epidermal anatomical characteristics are valuable taxonomic traits, which can be utilized to address the taxonomic issues within the genus. © 2010 Friends Science Publishers

Key Words: *Artemisia*; *Seriphidium*; Anthemideae; Asteraceae; Anatomy; Leaf epidermis; Taxonomy

INTRODUCTION

Artemisia L. is one of the major polymorphic genera of the family Asteraceae, comprising over 500 species of herbs and shrubs (Valles & McArthur, 2001; Martin *et al*., 2001 & 2003). Its members are anemophilic and mostly naturalized in temperate areas of mid to high latitudes of the northern hemisphere, inhabited in arid and semiarid climates and rarely occurred in southern hemisphere (McArthur & Plummer, 1978; Valles & McArthur, 2001). Most of *Artemisia* species have economic importance as therapeutics, foodstuff, fodder, esthetics and soil binders in destructive habitats; some taxa are poisonous or allergenic and some others are noxious weeds, which can badly affect crops (Pareto, 1985; Tan *et al*., 1998; Hayat *et al*., 2009a, b, c & d). Apart from few annuals or biannuals, most of *Artemisia* species are perennial (Valles *et al*., 2003). The genus *Artemisia* is also recognized as sign of steppe environment (Erdtman, 1952) and reasonable rainfall (El-Moslimany, 1990).

Traditionally, using the floral characters as taxonomic marker for the establishment of a natural classification, the genus has been divided into four groups, which has been treated as sections or subgenera; *Absinthium* (Tournefort) de Cand., *Artemisia* Tournefort (=*Abrotanum* Besser), *Dracunculus* Besser, *Seriphidium* Besser (Hooker, 1881; Martin *et al*., 2001 & 2003). McArthur *et al*. (1981) proposed a new group within the genus designated as *Tridantatae* (Rydb.) McArthur that is totally endemic to North America. Ling (1982, 1991a & b, 1995a & b) took apart *Seriphidium* (Besser *ex* Hooker) as autonomous genus. Bremer and Humphries (1993) and Bremer (1994) accepted this division. But Kornkven *et al*. (1998), Torrell *et al*. (1999) and Watson *et al*. (2002) in their molecular studies again combine *Seriphidium* with *Artemisia* and rejected the separation of *Seriphidium* from *Artemisia*. This starts a new debate about its subgeneric phylogeny and classification (Hayat *et al*., 2009d).

Due to great diversity in forms and hybrids, the classification of genus *Artemisia* is still a challenging task for many taxonomists (Lodari *et al*., 1989; Hayat *et al*., 2009d). Its classical classification was based only on floral characters variations and has many objections, for example section *Artemisia* only differ from section *Absinthium* by a single character i.e., receptacle naked (*Artemisia*) or receptacle cover with long hairs (*Absinthium*) (Kaul & Bakshi, 1984). Nonetheless classification of *Artemisia* and relationships among its different taxa are still controversial

(Hayat *et al*., 2009b).

Scotland *et al*. (2003) opinioned that careful and decisive anatomical studied of fewer morphological characters, in the framework of molecular phylogenies is productive to integrating the powers of morphological data with those of sequence information. Since the leaf epidermal studies are considered important in phylogeny and taxonomy (Taia, 2005), attention of plant taxonomists has been attracted toward the leaf epidermal anatomical studies to resolve the taxonomic problems (Hardin, 1979; Fang & Fan, 1993). Although many studies carried on the histochemistry of the secretory chemicals of the glandular trichomes of *Artemisia* (Smith & Kreitner, 1983; Slone & Kelsey, 1985; Ascensao & Pais, 1987; Duke & Paul, 1993; Duke *et al*., 1994), but little attention is paid toward the systematic significance of comparative foliar leaf anatomy of *Artemisia*. In the current paper, we report the foliar epidermal anatomical characteristics in *Artemisia* using light microscopy (LM) and scanning electron microscopy (SEM). However the pin point objectives of the present study were to: (a) identify and compare the variation of different stomatal types in different species of the genus, (b) observe the quantitative and qualitative characters of leaf epidermal cells and (c) elaborate the taxonomic value of leaf epidermal anatomical features among different taxa of *Artemisia* based on both stomatal and epidermal cells diversity.

MATERIALS AND METHODS

All particulars about the, origin and collection of leaf material, processing of the tissues were essentially the same as we reported in the previous papers (Hayat *et al.*, 2009a, b & c).

Source and collection information of studied taxa is given in Table I. Using modified methodology of Shaheen *et al*. (2009) and Yasmin *et al*. (2009) foliar tissues were at first observed by OLYMPUS/BX-51 light microscope. Dried leaves were infused in 30% nitric acid and boiled along with 1.5 g of potassium chloride in a test tube for 2-3 min. Then these leaf pieces were washed down with distal water. Epidermis was peeled off and kept in 60% potassium hydroxide solution for 2 h. Finally, these thin leaf sections were suspended in lactic acid and moved to glass slides for LM study. For SEM examine, the fully dried leaves were fixed on aluminum stubs with the help double adhesive tape, sputter coated with gold by SPI-Module Sputter Coate and observed with a Jeol-JSM 5910 scanning electron microscope. Basic terminology, used for stomatal and epidermal cells identification and explanation, was adopted from Dilcher (1974).

RESULTS AND DISCUSSION

Total six types of stomata were found in 24 taxa of *Artemisia*. These types comprised of anomocytic, anisocytic, anomotetracytic, paratetracytic, diacytic and paracytic stomata. Features of these stomatal types, based on observations of SEM and LM, were presented in Table II and illustrated in Fig. 1 and 2. Furthermore, two types of foliar epidermal cells, elongated smooth wall and wavy

Table I: List of taxa studied for leaf epidermal anotomy and their herbarium vouchers. ISL: Herbarium, Quaid-i-Azam University, Islamabad. PUP, Herbarium, University of Peshawar, Peshawar

Taxon	Collection data	Herbarium Voucher
Section *Artemisia* Tournefort		
A. amygdalina Decne.	Mansehra: Naran to Lake Saif-ul-Malook track. *T. Malik*, 1972.	ISL, 32315
A. biennis Willd.	Rawalpindi: Murree Hills, PLT, Ayubia National Park. *M. Q. Hayat*, 2007.	PUP, PH005 (ART005)
A. dubia Wall. ex Besser	Rawalpindi: Murree Hills, PLT, Ayubia National Park. *M. Q. Hayat*, 2007.	PUP, PH002 (ART002)
A. moorcroftiana Wall. ex DC.	Azad Jummu & Kashmir: Muzafrabad. *T. Malik*, 1972.	ISL, 26550
A. roxburghiana Wall. ex Besser	Rawalpindi: Murree Hills, PLT, Ayubia National Park. *M. Q. Hayat*, 2007.	PUP, PH001 (ART001)
A. rutifolia Spreng.	Gilgit: Nattar valley. *A. Rashid*, 1988.	PUP, 244 (1105)
A. santolinifolia Turcz. ex Krasch.	Gilgit: Nattar valley. *A. Rashid*, 1986.	PUP, 239 (1108)
A. tournefortiana Reichenbach	Rawalpindi: Murree Hills, PLT, Ayubia National Park. *M. Q. Hayat*, 2007.	ISL, 21921
A. vestita Wall. ex DC.	Jahlum: Soon vally, Sakasar. *M. Farooq*, 2005.	ISL, 20093
A. vulgaris L.	Azad Jummu & Kashmir: Pearl valley, Mutyal Mara. *M. Q. Hayat*, 2008.	PUP, PH006 (ART006)
Section *Absinthum* (Mill.) DC		
A. absinthium L.	Gilgit: Nattar valley. *M. Q. Hayat*, 2007.	PUP, PH004 (ART004)
A. macrocephala Jacq. ex Basser	Gilgit: Nattar valley. *Lal Badshah*, 1997.	PUP, 121(556)
A. persica Boiss.	Swat: *Nighat Akhter*, 1990	PUP, 27
A. siversiana Ehrh.	Gilgit: Nattar valley. *A. Rashid*, 1986.	PUP, 222 (1057)
A. tangutica Pampanini	Gilgit: Hunza vally. *M. Q. Hayat*, 2007.	ISL, 32144
Section *Seriphidium* (Besser) Besser		
S. leucotrichum (Kra. ex Lad.) Bre. & Hum. ex Ling	Gilgit: Nattar valley. *M. Q. Hayat*, 2007.	ISL, 92453
A. maritima L.	Skardu: *M. Q. Hayat*, 2007.	PUP, PH003 (ART003)
S. brevifolium (Wall. ex DC.) Ling & YR Ling	Mansehra: Ujtar, Naran to Lalusar lake track. *M. Q. Hayat*, 2007.	PUP, PH007 (ART007)
S. kurramense (Qaz.) YR Ling	Kurram Agency: Burki. *N. A. Qazilbash*, 1937.	PUP, 22419
S. stenocephalum (Krasch. ex Poljakov) Poljakov	Gilgit: Chalas. *M. Q. Hayat*, 2008.	PUP, PH010 (ART010)
S. turanicum (Krasch.) Poljakov	Gilgit: Nattar vally. *M. Q. Hayat*, 2008.	PUP, PH009 (ART009)
Section *Dracunculus* Besser		
A. japonica Thunb.	Rawalpindi: Murree Hills, PLT, Ayubia National Park. *M. Q. Hayat*, 2007.	PUP, PH008 (ART008)
A. scoparia Waldst. et Kit.	Islamabad: Quaid-i-Azam university campus. *M. Q. Hayat*, 2008.	ISL, 32313
A. stricta Edgew.	Kashmir: Muzafrabad. *T. Malik*, 1972.	ISL, 25650

*Adopted from Hayat *at al*. (2009a), Hayat *at al*. (2009b) and Hayat *at al*. (2009c)

Table II: Stomatal characteristics in *Artemisia* species

Taxa	Surface	Shape	Length µm	Width µm	Guard cell		Stomatal aperture		Stomatal complex		
					Length µm	Width µm	Length µm	Width µm	No. of subsidiary cells	Length µm	Width µm
A. amygdalina	Abaxial	Anomocytic	20.76-21.91	16.87-17.06	19.45-20.70	7.13-8.00	18.93-19.10	2.23-3.08		Not differentiated	
	Adaxial	Anomocytic	19.89-20.53	16.30-16.92	18.98-19.72	6.94-7.43	18.95-19.68	2.28-2.45		Not differentiated	
A. biennis	Abaxial	Anomotetracytic	27.18-27.91	21.60-23.03	27.17-27.46	10.60-11.22	17.09-18.10	5.32-5.95	4	51.62-53.09	48.86-50.07
	Adaxial	Anomotetracytic	39.80-41.38	28.73-23.00	39.80-41.38	11.04-14.99	14.43-27.34	3.98-4.08	4	52.07-52.87	49.13-50.12
A. dubia	Abaxial	Anomocytic	37.90-35.18	24.40-27.55	34.91-35.10	10.64-13.57	25.16-24.12	2.78-3.06	4	85.23-86.27	81.79-84.27
	Adaxial	Anomocytic	28.95-29.25	25.93-26.13	36.17-37.44	13.24-14.49	23.06-23.92	2.82-3.19	4	83.57-84.62	80.11-83.01
A.	Abaxial	Anomocytic	26.47-27.12	25.31-25.93	25.93-26.77	9.58-10.56	17.29-18.88	4.66-5.00		Not differentiated	
moorcroftiana	Adaxial	Anomocytic	26.23-27.82	24.42-25.35	25.00-26.08	10.90-11.20	17.89-18.10	4.21-5.03		Not differentiated	
A.	Abaxial	Anomocytic	23.22-24.98	20.26-22.03	21.43-22.29	8.94-9.12	10.66-11.48	3.34-3.91	5	60.30-63.32	58.22-58.73
roxburghiana	Adaxial	Anomocytic	24.80-25.45	19.54-21.22	21.70-22.97	8.88-9.67	10.55-10.99	3.27-3.42	5	60.00-61.49	59.15-60.30
A. rutifolia	Abaxial	Anomocytic	18.36-19.30	16.23-17.53	18.33-17.92	7.96-8.87	10.03-11.11	3.08-3.76		Not differentiated	
	Adaxial	Anomocytic	18.12-19.91	17.34-17.65	18.38-19.47	8.03-9.74	10.16-11.31	3.00-3.64		Not differentiated	
A. santolinifolia	Abaxial	Paratetracytic	16.44-17.16	7.95-8.26	15.83-16.07	3.23-3.94	15.54-16.13	2.75-3.00	4	33.94-35.03	21.91-23.21
	Adaxial	Paratetracytic	16.00-17.04	7.09-8.93	14.56-17.04	3.00-4.00	16.39-16.49	2.10-3.12	4	34.87-35.19	22.86-23.35
A.	Abaxial	Anomocytic	33.84-34.00	20.47-22.08	31.59-32.86	7.68-9.06	16.43-17.00	8.81-10.03	4-5	75.55-76.73	73.83-74.65
tournefortiana	Adaxial	Anomocytic	32.33-33.65	21.76-22.37	32.00-33.12	8.34-9.80	15.79-16.93	9.37-10.55	4	28.34-29.99	23.11-25.00
A. vestita	Abaxial	Diacytic	11.34-13.56	7.43-9.64	10.67-14.45	5.38-8.78	11.89-22.34	2.97-4.67	2	27.54-30.11	27.03-27.00
	Adaxial	Diacytic	12.45-14.24	6.89-8.78	11.56-13.12	5.34-8.34	10.56-20.54	3.11-4.67	2	27.10-27.67	26.88-26.93
A. vulgaris	Abaxial	Anisocytic	24.23-25.99	21.27-23.04	22.44-23.30	9.94-10.13	11.67-12.49	3.35-4.92	3	62.31-65.32	59.23-59.74
	Adaxial	Anisocytic	24.81-25.45	20.55-22.23	22.71-22.98	8.89-9.68	11.56-11.60	4.28-4.43	3	61.10-61.50	60.25-61.31
A. absinthium	Abaxial	Anomocytic	23.63-30.36	18.45-23.27	22.56-29.65	8.96-9.07	17.45-18.23	4.91-7.32		Not differentiated	
	Adaxial	Anomocytic	25.56-30.46	23.56-28.95	24.89-31.56	7.86-9.08	16.89-18.56	3.95-8.12		Not differentiated	
A.	Abaxial	Paracytic	25.53-28.76	22.56-23.87	24.99-28.02	7.15-7.90	20.22-21.74	4.56-4.86	2	24.44-25.13	20.45-21.66
macrocephala	Adaxial	Paracytic	9.45-10.89	8.56-9.57	9.33-11.67	4.56-7.88	9.32-10.35	2.78-8.50	2	22.34-28.76	20.45-26.67
A. persica	Abaxial	Pericytic	25.51-25.71	18.30-21.16	24.12-25.15	5.72-7.49	16.28-23.89	3.45-7.89	1	42.13-42.70	41.88-45.34
	Adaxial	Pericytic	24.91-25.76	18.54-20.18	23.34-25.17	6.89-8.01	13.70-15.00	3.98-4.12	1	42.86-63.67	41.45-50.23
A. siversiana	Abaxial	Anomocytic	34.90-35.19	25.40-28.55	31.91-34.10	11.64-12.57	24.16-25.12	3.78-4.06	4	84.23-85.27	80.79-81.27
	Adaxial	Anomocytic	29.95-30.25	24.93-26.13	30.17-31.44	10.24-13.49	24.06-24.92	3.82-4.19	4	84.57-84.62	80.19-82.01
A. tangutica	Abaxial	Anomocytic	30.89-33.14	26.00-27.06	30.74-32.39	9.23-11.01	15.42-17.07	5.14-6.83		Not differentiated	
	Adaxial	Anomocytic	30.78-34.27	25.76-26.02	31.65-33.54	8.90-11.55	16.78-17.71	4.56-6.95		Not differentiated	
S. leucotrichum	Abaxial	Anomocytic	26.73-27.44	22.82-23.52	24.55-24.76	7.49-7.85	17.14-18.00	4.53-6.70		Not differentiated	
	Adaxial	Anomocytic	25.69-26.59	23.12-24.17	25.78-26.00	7.12-8.09	18.21-18.91	3.09-5.17		Not differentiated	
A. maritima	Abaxial	Anisocytic	29.83-30.41	24.63-25.14	29.14-30.20	10.88-12.06	17.21-18.18	9.52-10.28	3	52.89-55.19	51.89-54.17
	Adaxial	Anisocytic	28.54-29.77	23.56-23.89	27.67-28.78	10.77-11.89	16.89-17.88	9.12-9.98	3	51.67-55.10	54.14-54.12
S. brevifolium	Abaxial	Anomocytic	21.76-22.91	17.87-18.06	20.45-21.70	8.13-9.01	19.93-20.81	3.23-4.81		Not differentiated	
	Adaxial	Anomocytic	20.19-21.53	17.30-17.83	19.81-19.82	6.84-7.34	19.95-20.68	3.28-4.45		Not differentiated	
S. kurramense	Abaxial	Anomocytic	27.95-29.35	23.58-24.48	27.50-27.57	4.84-5.57	13.27-14.14	3.98-4.25		Not differentiated	
	Adaxial	Anomocytic	26.99-28.78	24.77-24.89	26.11-27.18	4.12-5.67	12.45-14.32	3.23-4.63		Not differentiated	
S.	Abaxial	Anomotetracytic	30.16-32.44	21.89-23.50	31.07-32.32	7.05-8.06	19.70-20.53	6.22-7.33	4	45.11-45.68	44.34-44.58
stenocephalum	Adaxial	Anomotetracytic	29.17-31.67	21.34-22.43	30.65-32.10	6.92-7.73	18.82-19.60	6.00-7.41	4	44.11-45.82	43.21-44.19
S. turanicum	Abaxial	Anomotetracytic	32.00-33.00	27.12-27.27	31.98-33.11	9.83-10.20	15.37-16.83	6.22-7.81		Not differentiated	
	Adaxial	Anomotetracytic	32.18-33.18	27.16-27.11	30.12-33.00	8.89-10.67	15.34-15.98	6.32-7.11		Not differentiated	
A. japonica	Abaxial	Anomotetracytic	32.27-34.52	25.08-26.66	34.86-36.03	10.57-11.22	23.32-24.51	11.89-13.09	4	28.39-30.11	28.86-30.19
	Adaxial	Anomotetracytic	28.27-29.96	22.00-23.73	24.58-25.00	8.11-8.72	24.12-26.34	10.03-11.00	4	27.61-28.00	26.87-27.01
A. scoparia	Abaxial	Anomocytic	18.98-24.86	13.33-14.27	23.73-24.35	4.52-5.09	13.21-14.06	4.23-6.11		Not differentiated	
	Adaxial	Anomocytic	20.22-22.00	12.98-15.15	21.16-22.83	4.40-5.72	9.11-11.22	5.62-6.21		Not differentiated	
A. stricta	Abaxial	Anomocytic	12.12-14.56	9.55-10.26	11.25-12.57	3.88-4.46	8.45-9.72	2.44-3.31		Not differentiated	
	Adaxial	Anomocytic	13.12-15.66	8.89-9.26	10.55-11.52	3.34-4.78	7.45-9.72	2.11-3.98		Not differentiated	

margined irregular were also examined in this study. Their qualitative and quantitative attributes based on SEM and LM investigations, were specified in Table III and elaborated in Fig. 3, 4 and 5.

As the features of trichomes were generally considered as valuable tool for ascertaining the taxonomic relations within the genus *Artemisia* (Hall & Clements, 1923), therefore many authors focused their attention toward the trichomes study of *Artemisia* (Smith & Kreitner, 1983; Kelsey, 1984; Slone & Kelsey, 1985; Ascensao & Pais, 1987; Lodari *et al*., 1989; Ferreira & Janick, 1995). In our previous papers (Hayat *et al*., 2009a & b), we also reported 16 types of glandular and non-glandular foliar trichomes in *Artemisia* and unveiled the phylogenetic relationships among different species of the genus on the bases of these trichomes types. But little work has been done, which explains the stomatal and foliar epidermal variations in taxonomic context of *Artemisia*. Nautiyal and Purohit (1980) only discussed stomatal frequency and anatomical changes in leaves of few *Artemisia* species. Recently few Iranian authors have tried to explain the taxonomic utility of foliar anatomical characteristics in *Artemisia* (Rabie *et al*., 2006; Noorbakhsh *et al*., 2008; Saedi *et al*., 2009). But most of the species covered in present study were not the subject matter of their studies. Similarly their main research focus was the leaf anatomy instead of foliar epidermal features.

In addition to formerly studied anomocytic and anisocytic stomata types (Rabie *et al*., 2006; Noorbakhsh *et al*., 2008; Saedi *et al*., 2009), four new types of stomata are described in present study. These stomatal types include: anomotetracytic, paratetracytic, diacytic and paracytic (for details see Table II; Fig. 1 & 2). Types of stomata, variations in size of stomata, guard cell, aperture and stomatal complex and presence or absence of subsidiary cells along with their numbers suggests that such foliar epidermal anatomical features can be served as taxonomic

Table III: Foliar epidermal cells characteristics in *Artemisia* species

Taxa	Surface	Shape	Margin	Length µm	Width µm
A. amygdalina	Abaxial	Irregular	Wavy	22.34-23.94	17.89-19.04
	Adaxial	Irregular	Wavy	21.35-23.45	16.68-18.12
A. biennis	Abaxial	Irregular	Wavy	30.03-31.77	28.12-29.56
	Adaxial	Irregular	Wavy	35.42-37.21	30.34-32.42
A. dubia	Abaxial	Irregular	Wavy	76.66-81.01	33.74-36.64
	Adaxial	Irregular	Wavy	61.28-66.26	35.04-58.19
A. moorcroftiana	Abaxial	Irregular	Wavy	24.44-25.84	19.25-21.08
	Adaxial	Irregular	Wavy	24.27-24.94	16.83-17.12
A. roxburghiana	Abaxial	Irregular	Wavy	34.22-31.54	15.87-16.78
	Adaxial	Irregular	Wavy	36.21-37.89	24.68-29.18
A. rutifolia	Abaxial	Irregular	Wavy	26.86-27.77	13.93-15.50
	Adaxial	Irregular	Wavy	25.82-26.43	11.97-14.41
A. santolinifolia	Abaxial	Irregular	Wavy	26.54-29.37	20.27-23.17
	Adaxial	Irregular	Wavy	24.61-26.30	21.25-23.13
A. tournefortiana	Abaxial	Irregular	Wavy	48.54-52.36	18.94-22.55
	Adaxial	Irregular	Wavy	40.23-42.32	22.46-24.78
A. vestita	Abaxial	Irregular	Wavy	14.20-16.51	10.23-12.83
	Adaxial	Irregular	Wavy	16.65-18.02	20.93-21.22
A. vulgaris	Abaxial	Irregular	Wavy	23.00-27.64	16.73-21.40
	Adaxial	Irregular	Wavy	30.26-40.31	18.70-22.08
A. absinthium	Abaxial	Irregular	Wavy	30.36-32.00	23.27-25.26
	Adaxial	Irregular	Wavy	33.35-51.38	18.68-23.06
A. macrocephala	Abaxial	Irregular	Wavy	19.03-20.38	16.70-17.53
	Adaxial	Irregular	Wavy	14.34-16.38	11.24-10.15
A. persica	Abaxial	Irregular	Wavy	30.56-31.36	29.17-29.91
	Adaxial	Irregular	Wavy	41.19-42.33	26.80-27.00
A. siversiana	Abaxial	Irregular	Wavy	45.87-46.65	21.62-24.04
	Adaxial	Irregular	Wavy	40.54-42.09	23.40-24.92
A. tangutica	Abaxial	Irregular	Wavy	49.04-50.98	14.63-19.75
	Adaxial	Irregular	Wavy	39.12-45.32	33.10-34.33
S. leucotrichum	Abaxial	Elongated	Smooth	46.17-46.99	16.59-20.00
	Adaxial	Elongated	Smooth	45.21-47.56	17.95-18.12
A. maritima	Abaxial	Elongated	Smooth	38.33-39.36	23.68-24.59
	Adaxial	Elongated	Smooth	35.00-36.66	22.46-24.07
S. brevifolium	Abaxial	Elongated	Smooth	35.04-36.09	9.24-10.26
	Adaxial	Elongated	Smooth	34.62-33.11	11.15-12.81
S. kurramense	Abaxial	Elongated	Smooth	28.63-29.02	14.53-16.81
	Adaxial	Elongated	Smooth	28.22-30.00	15.36-17.03
S. stenocephalum	Abaxial	Irregular	Wavy	51.51-51.63	19.54-26.75
	Adaxial	Elongated	Smooth	49.15-52.52	20.28-21.22
S. turanicum	Abaxial	Elongated	Smooth	39.00-41.55	19.92-20.98
	Adaxial	Elongated	Smooth	37.41-39.50	18.69-20.03
A. japonica	Abaxial	Irregular	Wavy	39.89-35.22	18.40-22.67
	Adaxial	Irregular	Wavy	37.75-38.45	22.11-24.12
A. scoparia	Abaxial	Elongated	Smooth	47.67-48.00	17.37-19.12
	Adaxial	Elongated	Smooth	24.30-25.75	16.70-19.9
A. stricta	Abaxial	Irregular	Wavy	42.11-44.74	18.88-19.08
	Adaxial	Irregular	Wavy	32.61-34.24	13.12-15.58

tools to remove the conflicts at different taxonomic levels within the genus *Artemisia*. As for example *A. santolinifolia* can be distinguished from the rest of species by paratetracytic type of stomata. Similarly Diacytic types of stomata are the unique feature of *A. vestita*. Paracytic and paricytic type of stomata are only associated with *A. macrocephala* and *A. persica,* respectively.

Rabie *et al*. (2006) discussed the epidermal cells variation in *A. absinthium*, *A. vulgaris* and *A. scoparia*. Our results, about these species, agreed with their findings regarding the shapes and arrangements of epidermal cells (Fig. 3, 4 & 5) but little variations in quantitative measurements (Table III) may reflect the environmental changes. Based on variation of epidermal cells two groups of *Artemisia* were recognized; one with irregular shape (wavy margined) and other with elongated shape (smooth margined). Detail of variation in epidermal cells, of both abaxial and adaxial surfaces, also explained that most of the *Seriphidium* spp. have elongated smooth wall cells, while other *Artemisia* spp. have wavy margined irregular shape cells with few exceptions. But present study also shows that epidermal cells variations are not important when utilize alone, however they can serve as supportive characters with

Fig. 1: Stomatal variations in *Artemisia* by means of SEM; A, *A. absinthium*; B, *A. biennis*; C, *A. japonica*; D, *A. macrocephala*; E, *A. persica*; F, *A. santolinifolia*; G, *A. scoparia*; H, *A. stricta*; I, *A. leucotrichum* (Scale bar = 10 µm)

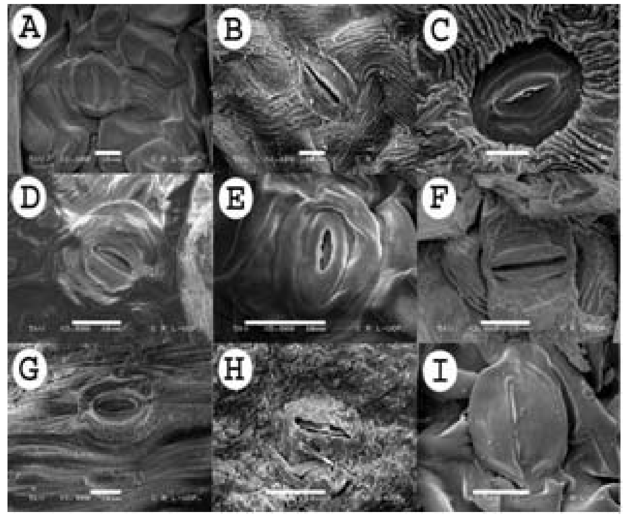


Fig. 2: Stomatal variations in *Artemisia* by means of LM; A *A. roxburghiana*; B, *A. tournefortiana*; C, *S. stenocephalum*; D, *A. scoparia*; E, *A. biennis*; F, *A. japonica*; G, *A. biennis*; H, *A. persica*; I, *A. absinthium* (Scale bar = 10µm)

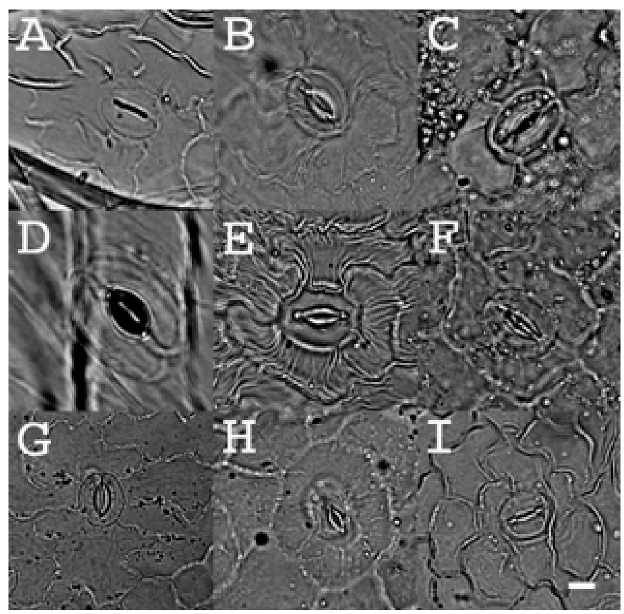


Fig. 3: Adaxial leaf epidermal cells in *Artemisia tangutica* by means of SEM. (Scale bar = 10 µm)

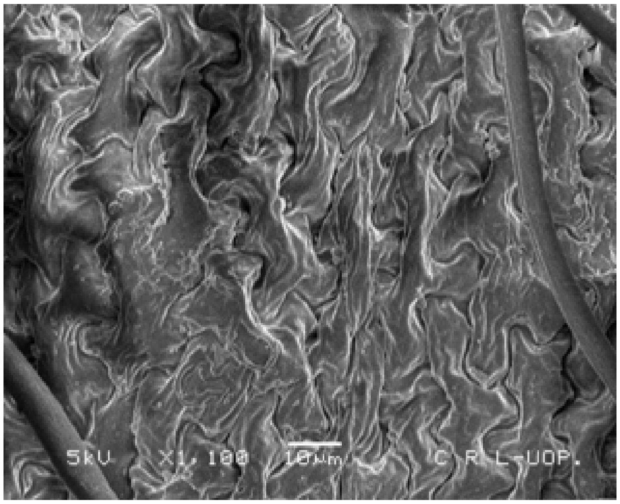
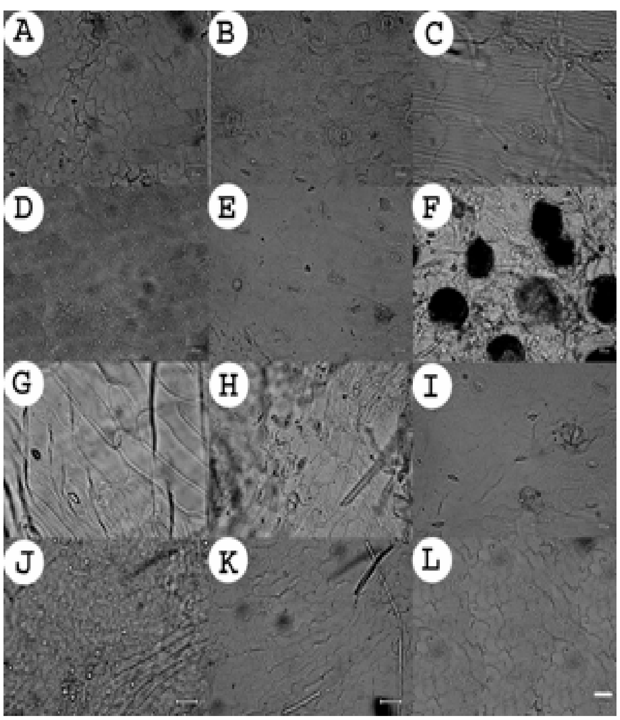


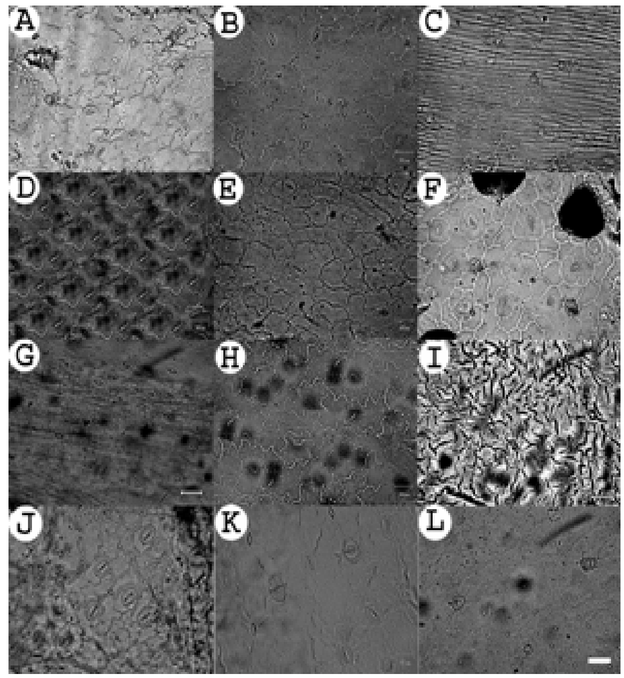
Fig. 4: Abaxial foliar surface variations in *Artemisia* by means of LM; A, *A. absinthium*; B, *A. biennis*; C, *S. brevifolium*; D, *A. dubia*; E, *A. japonica*; F, *A. persica*; G, *A. scoparia*; H, *S. stenocephalum*; I, *A. tournefortiana*; J, *A. vulgaris*; K, *A. vestita*; L, *A. roxburghiana* (Scale bar = 30 µm)



other features of great taxonomic interest such as characteristics of stomata.

In conclusion, foliar epidermal anatomy with special reference to stomata possesses a significant taxonomic potentiality. Nonetheless, there is a need to develop a better strategy to analyze and integrate this data with molecular investigations for a comprehending picture about the *Artemisia* phylogeny and classification.

Fig. 5: Adaxial foliar surface variations in *Artemisia* by means of LM; A, *A. absinthium*; B, *A. biennis*; C, *S. brevifolium*; D, *A. dubia*; E, *A. japonica*; F, *A. persica*; G, *A. scoparia*; H, *A. roxburghiana*; I, *A. vestita*; J, *S. stenocephalum*; K, *A. tournefortiana*; L, A. vulgaris (Scale bar = 30 µm)



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