

*Full Length Research Paper*

# Taxonomic significance of leaf epidermal anatomy of selected *Persicaria* Mill. species of family Polygonaceae from Pakistan

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Leaf epidermal anatomy of selected *Persicaria* Mill. species of the family Polygonaceae revealed variation in size and shape of epidermal cells, stomata, glandular and non glandular trichomes. This study proves to be taxonomically important tool in the delimitation of taxa. Epidermal cell shapes are variable but mostly polygonal. Five different stomatal patterns are reported for *Persicaria* Mill. Two types of non glandular trichomes are observed only in *P. barbata*, *P. stagnina* and *P. orientalis* which serve as their distinguishing characters. Glandular trichomes are 1, 2 and 4-celled peltate, capitate and spheroidal. Cluster analyses elucidate relationship among different taxa by utilization of leaf epidermal characters.

**Key words:** Leaf anatomy, spheroidal, capitate, Polygonaceae, non glandular.

## INTRODUCTION

Polygonaceae Juss., the Buckwheat, Smartweed or Knotweed family are a group of dicots containing approximately 1,200 species in 48 genera (Freeman and Reveal, 2005; Sanchez and Kron, 2008). The family is geographically distributed from the tropics to the arctic although most species are concentrated in the northern temperate region (Heywood, 1978). The family is represented in Pakistan by 19 genera and 103 species (Qaiser, 2001).

*Persicaria*, is a variable genus of Polygonaceae containing approximately 120 species, generally weeds occupying disturbed areas and crop fields (McDonald 1980; Kim and Donoghue, 2008) and easily recognized by the presence of thin filament of stamens and the rectangular cells of tepal epidermis (Ronse Decraene and Akeroyd, 1988). It is distributed in north temperate regions of both hemisphere and in Pakistan; it is represented by 21 species (Qaiser, 2001).

Anatomical studies have amply shown that foliar characters are comparable over a wide taxonomic range and quite reliable. Comprehensive foliar anatomy and its

variability in the family Polygonaceae was examined by many previous workers (Metcalf and Chalk, 1950; Inamdar, 1971; Kapoor et al., 1971; Mitchell, 1971; Lersten and Curtis, 1992; Ayodele and Olwokudejo, 2006; Yasmin et al., 2009).

In this study we included 15 species of *Persicaria* instead of 21 species found in Pakistan due to the non availability of few species in herbarium collection. The main objectives of this study are to add supplementary information on leaf anatomy and to distinguish different species of the genus on the basis of epidermal cells, stomata and trichomes types, both qualitatively and quantitatively

## MATERIALS AND METHODS

Dried leaves of representative specimens from Quaid-i-Azam University herbarium, Islamabad, Pakistan of *Persicaria* Mill. of the family Polygonaceae given in Table 1 were used for anatomical studies. Dried leaves were placed in boiling water for few min so that they became soft and unfolded and then ready for epidermal scrapping. Leaf samples were prepared according to modified method of Cotton (1974), who followed Clark's (1960) technique. The leaves were placed in a tube filled with 88% lactic acid kept hot in boiling water bath (Model, Memmert-91126-FRG, Germany) for about 30 to 40 min. Lactic acid softens the leaf due to which it was possible to scrap the leaf surface with sharp scalpel. Slides of both

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**Table 1.** List of *Persicaria* Mill. species investigated, with location, district and accession numbers.

S/N	Species	Locality	District	Accession no.
1	<i>Persicaria barbata</i> (L.) Hara	Basir, Gulmit	Chitral, Hunza	38938, 122657
2	<i>P. glabra</i> (Willd.) M. Gómes	Near Kachura lake, Broze	Skardu, Chitral	119033, 42054
3	<i>P. amphibia</i> (L.) S. F. Gray	Kasarkot	Muzaffarabad	70246
4	<i>P. maculosa</i> S. F. Gay	Astore, Wah gardens	Gilgit, Campbellpur	63847, 67832
5	<i>P. longiseta</i> (De Bruyn) Kitagawa	Sandus, Kuraiz	Skardu, Orakzai agency	96752, 75557
6	<i>P. chinensis</i> (L.) H. Gross	Susal Gali ± 4000ft	Hazara	39063
7	<i>P. Oriental's</i> (L.) Spach	CDA nursery, Islamabad	Rawalpindi	76099
8	<i>P. lapathifolia</i> (L.) S. F. Gray	Islamabad Murree road to Rawal Dam	Rawalpindi	16113, 08904
9	<i>P. hydropiper</i> (L.) Spach	Chikar (stony soil), Kaghan	Muzaffarabad, Hazara	66372, 09212
10	<i>P. tenella</i> (Blume) Hara	Chilas, Dadan	Gilgit, Hazara	36647, 51245
11	<i>P. nepalensis</i> (Meisn.) H. Gross	Doongi Haji Kumbar	Kotli Hazara	55525, 39069
12	<i>P. capitata</i> (Buch.-Ham. ex D. Don) H. Gross	Babusar village	Gilgit	122648
13	<i>P. stagnina</i> (Buch.-Ham. ex Meisn.) Qaisar.	Near Government College Loralai, Hamidgar	Quetta, Skardu	26552, 94664
14	<i>P. posumbu</i> (Buch.-Ham. ex D. Don) H. Gross	Chinar Bagh	Gilgit	58999
15	<i>P. sinuata</i> (Royle ex Bab.) K. R. Rajbhandari and R. Joshi	Chalter, Ghurial	Poonch, Bannu	112217, 111470

abaxial and adaxial surface of leaf were prepared and mounted in clean 88% lactic acid. Both qualitative and quantitative micro-morphological foliar characteristics were observed using light microscope. Microhistological photographs of both surfaces were taken by Nikon (FX-35) Camera equipped light microscope.

#### Statistical analysis

A dendrogram was constructed by un weighted paired group method with EUCLIDEAN option, using MVSP software version 3.13 (Kovach, 2007).

## RESULTS AND DISCUSSION

In the present study, foliar epidermal anatomy of 15 species of *Persicaria* Mill. was investigated. Both qualitative and quantitative characteristics of adaxial and abaxial foliar epidermis of *Persicaria* Mill. were evaluated. During this study the use of light microscopy has made it possible in depth to evaluate leaf surface features such as shape of epidermal cells, stomata and trichomes types and their distribution frequency. Such comprehensive foliar anatomical studies of *Persicaria* Mill. species has been conducted first time from Pakistan.

Great range of variation was observed in epidermal cells shape among 15 species of *Persicaria* Mill. and found to be helpful as additional taxonomic character. The cells were pentagonal, hexagonal, heptagonal, octa-

hedral, polygonal or irregular, tubular or elongated, smooth, thick walled and perhaps not arranged in specific pattern. In *P. lapathifolia* large size irregularly shaped epidermal cells with undulating walls were present on both leaf surfaces. These undulating walls are the characteristics of the plants growing in humid conditions (Stace, 1965; Ayodele and Olwokudejo, 2006). Kapoor et al. (1971) reported irregular shaped epidermal cells only on abaxial surface of *P. lapathifolia*, *P. glabra* and *P. nepalensis* while Ayodele and Olwokudejo (2006) proposed irregular cells on abaxial surface of *P. nepalensis*. In *P. sinuata* irregular cells with undulating walls were found on adaxial surface while abaxial cells were pentagonal, hexagonal and smooth walled. In *P. amphibia*, epidermal cells were pentagonal, hexagonal and octahedral on both surfaces while only pentagonal shape in *P. chinensis*. In *P. barbata*, cells were typically benzene ring like. Epidermal cells size varied from 20 - 30 × 10 - 20 μm (*P. orientalis* adaxial surface) to 45 - 115 × 35 - 50 μm (*P. nepalensis* adaxial surface) indicating size variation. Ayodele and Olwokudejo (2006) gave cells width in *P. nepalensis* varied from 47.50 μm to 82.50 on adaxial surface and 40 - 100 μm on abaxial surface (Table 2).

All species of the genus were amphistomatic except *P. chinensis* (Kapoor et al., 1971) and *P. sinuata* which were hypostomatic. Kapoor et al. (1971) described hypostomatic leaves for *P. nepalensis* while Inamdar (1971) reported amphistomatic leaves for the same species. Ayodele and Olwokudejo (2006) recorded amphistomatic

**Table 2.** Summary of qualitative and quantitative epidermal characteristics of genus *Persicaria*. Mill. (All measurements are in  $\mu\text{m}$ )

Sr. No	Species	Ordinary epidermal cells shape Adaxial / Abaxial	Stomata Adaxial / Abaxial	Trichomes Adaxial / Abaxial		Epidermal cells Adaxial / Abaxial		Stomata Adaxial / Abaxial		Non glandular Trichomes Adaxial / Abaxial		Glandular trichomes Adaxial / Abaxial	
				Non glandular	Glandular	Length ( $\mu\text{m}$ )	Width ( $\mu\text{m}$ )	Length ( $\mu\text{m}$ )	Width ( $\mu\text{m}$ )	Length ( $\mu\text{m}$ )	Width ( $\mu\text{m}$ )	Length ( $\mu\text{m}$ )	Width ( $\mu\text{m}$ )
01	<i>P. barbata</i>	Thick walled, hexagonal cells / irregular in shape with undulating walls	Paracytic / Paracytic	Aggregated narrow celled, fused at base, compound trichomes, rosette forming / Compound rosette forming trichomes	Four-celled peltate and spheroidal glands / Four-celled and spheroidal glands	40 $\pm$ 6.07 (25-60) / 43 $\pm$ 5.61 (35-65)	25 $\pm$ 2.2 (20-30) / 29 $\pm$ 1.8 (25-35)	17 $\pm$ 1.2 (15-20) / 20 $\pm$ 2.2 (15-25)	12 $\pm$ 1.22 (10-15) / 12 $\pm$ 1.2 (10-15)	115 $\pm$ 2.23 (110-120) / 12 $\pm$ 1.22 (12.5-30)	12 $\pm$ 1.22 (10-15) / 11 $\pm$ 1.0 (10-15)	Four-celled 17 $\pm$ 1.22 (15-20) / 18 $\pm$ 0.5 (17.5-20) / Spheroidal glands- 25 / 25	Four-celled 15.5 $\pm$ 0.50 (15-17.5) / 10 $\pm$ 0.79 (7.5-12.5) / Spheroidal glands- 17.5 / 20
02	<i>P. chinensis</i>	Pentagonal, somewhat elongated, smooth walled, closely packed / Pentagonal closely packed cells	Absent / Staurocytic	Absent / Absent	One and two-celled peltate glands with striations	44 $\pm$ 7.48 (25-65) / 43 $\pm$ 4.58 (35-55)	26 $\pm$ 2.80 (20-35) / 21 $\pm$ 2.9 (15-30)	Absent / 17 $\pm$ 1.2 (15-20)	Absent / 7 $\pm$ 0.93 (5-10)	Absent / Absent	Absent / Absent	One-celled 16.25 $\pm$ 2.3 (10-20) / 18 $\pm$ 2.54 (10-25) / Two-celled 16 $\pm$ 1.00 (15-20) / 16 $\pm$ 1.00 (15-20)	One-celled 10 / 11 $\pm$ 1.00 (10-15) / Two-celled 12 $\pm$ 2.00 (10-20) / 13 $\pm$ 2.00 (10-20)
03	<i>P. sinuata</i>	Irregular shaped cells with undulating walls / Pentagonal, hexagonal and heptagonal	Absent / Pericytic	Absent / Absent	Absent / Two-celled peltate	42 $\pm$ 2.42 (37.5-50) / 46.3 $\pm$ 2.1 (42-52.5)	28 $\pm$ 0.5 (27.5-30) / 24 $\pm$ 4.00 (15-35)	Absent / 16 $\pm$ 0.6 (15-17.5)	Absent / 10 $\pm$ 2.2 (5-15)	Absent / Absent	Absent / Absent	Absent / Two-celled 25.5 $\pm$ 0.50 (25-27.5)	Absent / Two-celled 12 $\pm$ 1.0 (10-15)

leaves for *P. nepalensis* which corresponds with present findings. In the present study, diversity in stomatal patterns was noted (Figures 2E, 2M and 2N). Most common type of stomata was paracytic. Different authors identified different stomata types in the genus (Inamdar, 1969,

1971; Kapoor et al., 1971; Haraldson, 1978; Ayodele and Olwokudejo, 2006). More than one stomata types were also present on single leaf surface, for instance; in *P. glabra* anisocytic, paracytic and staurocytic stomata and anisocytic and paracytic pattern in *P. stagnina*

and *P. hydropiper* (Figure 2E). Inamdar (1969 and 1971) recorded anomocytic, anisocytic and paracytic stomata in *P. glabra*. Presence of different stomatal types on same leaf surface has also been reported by different taxonomists (Pant and Kadwai, 1964; Inamdar, 1969, 1971)

Table 2. Continued...

04	<i>P. glabra</i>	Pentagonal and hexagonal cells / Pentagonal and hexagonal	Paracytic, anisocytic and staurocytic / Paracytic, anisocytic and staurocytic	Absent / Absent	(a) Capitate with short stalk (b) Two-celled peltate, slightly striated (c) Spheroidal gland	62 ± 10.0 (40-100) / 55 ± 2.2 (50-60)	31 ± 4.00 (25-45) / 31 ± 2.91 (25-40)	25±4.74 (15-40) / 18±5.14 (10-35)	16 ± 1.87 (10-20) / 22 ± 2.00 (15-25)	Absent / Absent	Absent / Absent	Capitate 18 ± 1.22 (15-20) / 18 ± 1.2 (15-20) Two-celled- 14 ± 2.12 (10-20) / 21 ± 1.00 (20-25) Spheroidal gland- 22 ± 1.22 (20-25) / 21 ± 1.00 (20-25)	Capitate 11± 1.0 (10-15) / 11 ± 1.0 (10-15) Two-celled 12 ± 1.00 (10-15) / 18 ± 1.22 (15-20) Spheroidal glands 19 ± 2.42 (15-25) / 20
05	<i>P. nepalensis</i>	Pentagonal, hexagonal, polygonal, wider smooth walled cells / Irregular in shape with undulating walls	Paracytic / Paracytic	Absent / Absent	Two-celled peltate / Two-celled peltate	79 ± 14.5 (45-115) / 67 ± 1.2 (65-70)	43 ± 3.39 (35- 50) / 27 ± 1.22 (25-30)	24±1.87 (20-30) / 28±1.22 (25-30)	18 ± 0.93 (15-20) / 17 ± 1.22 (15-20)	Absent / Absent	Absent / Absent	Two-celled 19 ± 2.44 (15-25) / 18 ± 1.22 (15-20)	Two-celled 14.5 ± 1.99 (10-20) / 15
06	<i>P. stagnina</i>	Smooth and thick walled, polygonal, benzene ring like cells / Polygonal, smooth and thick walled cells	Anisocytic and paracytic / Anisocytic and paracytic	Unicellular, thin and long, 3-5 hair arising from same cavity, with swollen base and tapering apex, more frequently distributed / Thin and long, unicellular hair with buldging base and tapering apex, less frequently distributed	Two-celled peltate / Two-celled peltate	43 ± 4.03 (30-65) / 38 ± 2.54 (30-45)	27 ± 2.54 (20-35) / 27 ± 2.54 (20-35)	22± 1.22 (20-25) / 23± 1.22 (20-30)	12 ± 1.22 (10-15) / 13 ± 1.22 (10-15)	176 ± 23.20 (125-255) / 385 ± 27.1 (335-455)	27 ± 1.22 (25-30) / 55 ± 5.77 (45-65)	Two-celled 28 ± 1.22 (25-30) / 17 ± 1.22 (15-20)	Two-celled 23 ± 0.93 (20-25) / 13 ± 0.93 (10-15)

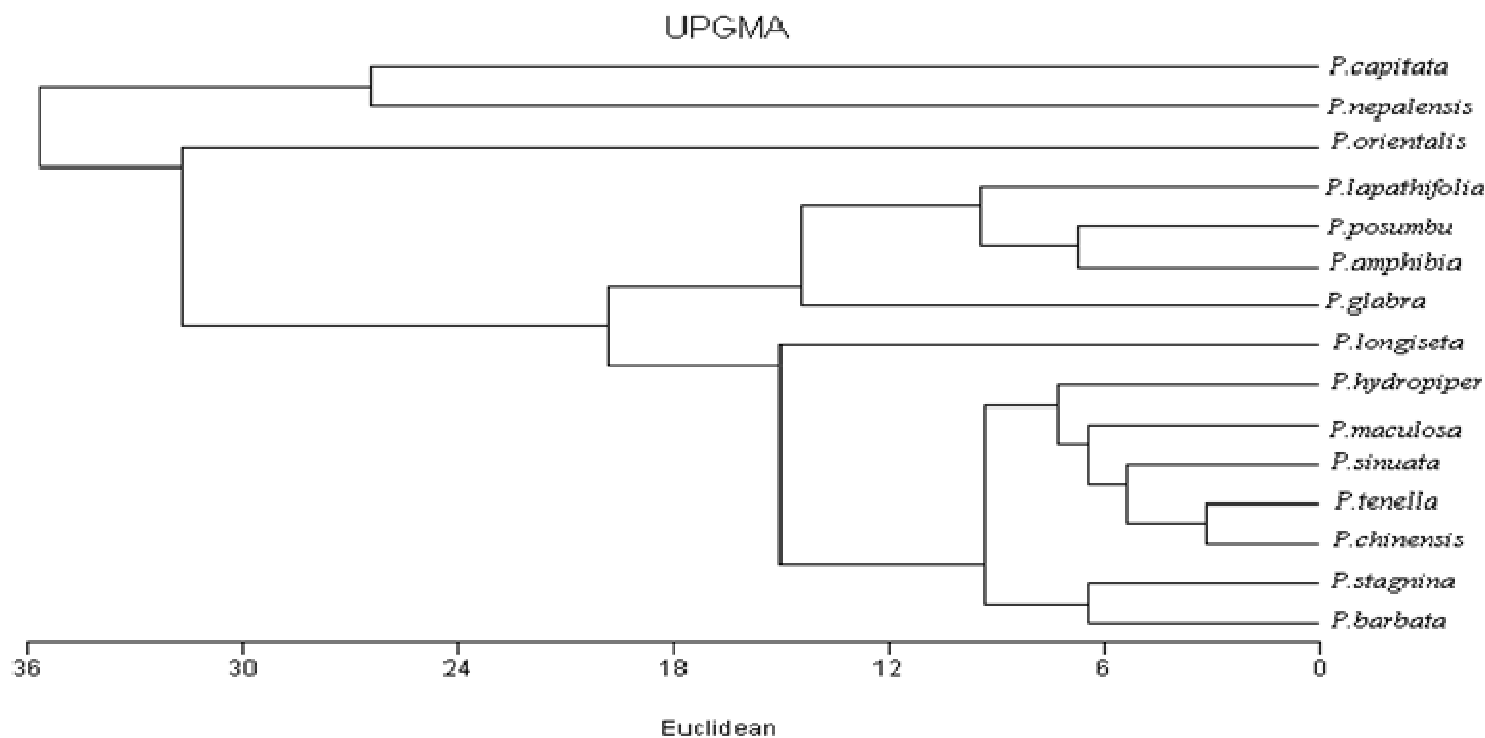
Table 2. Continued...

07	<i>P. hydropiper</i>	Polygonal, somewhat benzene ring like structure, thick and slightly pitted walls / irregular in shape	Anisocytic and paracytic / Anisocytic and paracytic	Absent / Absent	Centrally single celled peltate gland / One-celled peltate, trichomes and stomata are in close proximity	45 ± 7.07 (25-65) / 41 ± 5.87 (25-65)	23 ± 3.39 (15-30) / 18 ± 2.43 (10-25)	18 ± 1.22 (15-20) / 25	12 ± 1.22 (10-15) / 17 ± 1.22 (15-20)	Absent / Absent	Absent / Absent	One-celled 20 ± 2.23 (15-25) / 17 ± 2.00 (15-25)	One-celled 15 ± 2.23 (10-20) / 13 ± 2.00 (10-20)
08	<i>P. amphibia</i>	Pentagonal, hexagonal, octahedral, straight and smooth walled / Penatgonal	Pericytic / Pericytic	Absent / Absent	Two- celled peltate trichomes, thick walled / Two-celled peltate	54 ± 4.1 (45-75) / 41 ± 2.91 (35-50)	36 ± 1.87 (30-40) / 28 ± 2.54 (20-35)	24 ± 2.44 (20-30) / 28 ± 1.22 (25-30)	12 ± 1.22 (10-15) / 12 ± 1.22 (10-15)	Absent / Absent	Absent / Absent	Two-celled 22 ± 1.22 (20-25) / 41 ± 2.91 (35-50)	Two-celled 13 ± 1.22 (10-15) / 28 ± 2.5 (20-35)
09	<i>P. orientalis</i>	Polygonal, smooth walled, not much elongated cells / Irregular in shape with undulating walls	Anomocytic / Anomocytic	Slightly shorter and thicker with tapering apex and bulbous base more frequent	(a) Two-celled peltate (b) Spheroidal	25 ± 2.23 (20-30) / 52 ± 4.8 (35-65)	14 ± 1.87 (10-20) / 12 ± 2.0 (10-20)	13 ± 1.22 (10-15) / 17.5 ± 0.9 (15-20)	8 ± 0.93 (5-10) / 9 ± 1.87 (5-15)	118 ± 21.8 (55-190) / 156 ± 41.4 (80-255)	12 ± 2.00 (10-20) / 12 ± 2.64 (10-20)	Two-celled peltate 19 ± 4.30 (10-35) / 28 ± 2.54 (20-35) Spheroidal 27 ± 1.22 (25-30) / 25 ± 2.23 (20-30)	Two-celled peltate 18 ± 2.54 (10-25) / 16 ± 1.87 (10-20) Spheroidal 25 / 25 ± 3.67 (15-35)
10	<i>P. tenella</i>	Smooth and thick walled, polygonal / Irregular in shape with slightly undulating walls	Paracytic / Paracytic	Absent / Absent	(a) Two-celled peltate trichomes (b) Spheroidal trichomes / Two-celled peltate and spheroidal glands	42 ± 3.74 (35-55) / 43 ± 1.22 (40-45)	28 ± 3.39 (20-35) / 20 ± 1.58 (15-25)	25 ± 1.58 (20-30) / 29 ± 1.87 (25-35)	6 ± 1.00 (5-10) / 16 ± 2.82 (10-20)	Absent / Absent	Absent / Absent	Two-celled peltate 25 ± 2.23 (20-30) / 22 ± 1.22 (20-25) Spheroidal 24 ± 2.23 (20-30) / 22 ± 1.58 (20-25)	Two-celled peltate 23 ± 1.22 (20-25) / 17 ± 1.22 (15-20) Spheroidal 23 ± 1.22 (20-25) / 20

Table 2. Continued...

11	<i>P. maculosa</i>	Polygonal, elongated, slightly undulating walls / Polygonal	Paracytic / Paracytic	Absent / Absent	Centrally one-celled peltate gland / One-celled peltate trichomes	48 ± 2.25 (35-65) / 42 ± 5.83 (30-60)	28 ± 2.44 (25-35) / 23 ± 2.5 (15-30)	32 ± 3.39 (20-40) / 22 ± 1.22 (20-25)	13 ± 1.22 (10-15) / 12 ± 1.22 (10-15)	Absent / Absent	Absent / Absent	One-celled 17 ± 1.22 (15-20) / 27 ± 2.54 (20-35)	One-celled 10 ± 2.23 (5-15) / 32 ± 3.00 (25-40)
12	<i>P. posumbu</i>	Pentagonal, hexagonal, heptagonal, smooth and thick slightly pitted walls / Pentagonal, hexagonal and heptagonal cells	Paracytic / Paracytic	Absent / Absent	One-celled peltate glands / One-celled peltate glands, distribution of trichomes is same on both surfaces	57 ± 6.44 (40-75) / 47 ± 8.1 (25-75)	35 ± 4.47 (25-50) / 28 ± 2.00 (25-35)	20 ± 3.53 (10-30) / 23 ± 1.22 (20-25)	18 ± 2.00 (10-20) / 12 ± 1.22 (10-15)	Absent / Absent	Absent / Absent	One-celled 25 ± 1.58 (20-30) / 22 ± 1.22 (20-25)	One-celled 18 ± 1.22 (15-20) / 12 ± 1.22 (10-15)
13	<i>P. lapathifolia</i>	Irregular in shape, larger in size / Irregular	Pericytic / Pericytic	Absent / Absent	Two-celled peltate with striations / Two-celled peltate	59 ± 5.56 (50-80) / 45 ± 4.47 (35-55)	34 ± 4.84 (25-50) / 20 ± 2.73 (15-30)	28 ± 1.22 (25-30) / 16 ± 1.00 (15-20)	18 ± 1.22 (15-20) / 12 ± 1.22 (10-15)	Absent / Absent	Absent / Absent	Two-celled 22 ± 1.22 (20-25) / 23 ± 4.06 (15-35)	Two-celled 10 / 19 ± 3.67 (10-30)
14	<i>P. capitata</i>	Polygonal in outline, not much elongated / Irregular in shape	Pericytic / Pericytic	Absent / Absent	Two-celled peltate glands / Two-celled peltate	58 ± 9.02 (35-80) / 68 ± 3.39 (60-75)	27 ± 3.00 (20-35) / 27 ± 3.00 (20-35)	14 ± 2.44 (10-20) / 22 ± 1.22 (20-25)	10 / 15	Absent / Absent	Absent / Absent	Two-celled 28 ± 1.22 (25-30) / 27 ± 1.22 (25-30)	Two-celled 25 / 17 ± 1.22 (15-20)
15	<i>P. longiseta</i>	Polygonal, elongated / Irregular in shape with undulating walls	Pericytic / Pericytic	Absent / Absent	Two-celled peltate / Two-celled peltate	40 ± 5.70 (30-60) / 56 ± 4.00 (50-70)	24 ± 2.44 (20-30) / 23 ± 0.93 (20-25)	17 ± 1.22 (15-20) / 23 ± 1.22 (20-25)	12 ± 1.22 (10-15) / 15	Absent / Absent	Absent / Absent	Two-celled 17 ± 0.93 (15-20) / 22 ± 1.22 (20-25)	Two-celled 22 ± 1.22 (20-25) / 17 ± 0.93 (15-20)

\*Mean values followed by min-max in parentheses. ± = Standard error



**Figure 1.** Cluster analysis of different species of *Persicaria* Mill. based on anatomical characters.

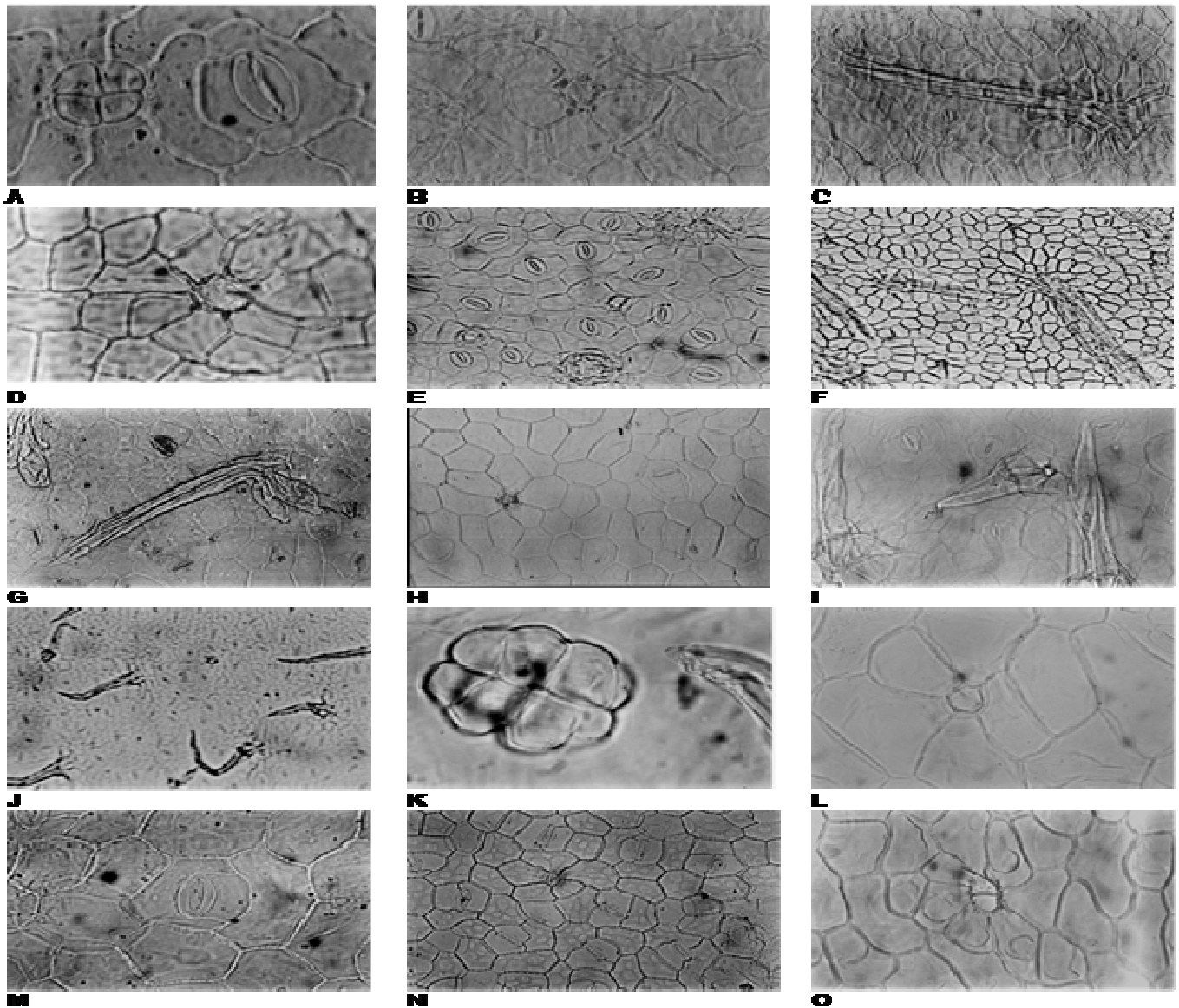
and considered it as an important taxonomic character (Ayodele and Olwokudejo, 2006). On the other hand, stomatal pattern in Polygonaceae cannot be used to distinguish different genera of the family (Haraldson, 1978; Lersten and Curtis, 1992). The length of stomata varied between 13 $\mu$ m (*P. orientalis* adaxial surface) to 32  $\mu$ m (*P. maculosa* adaxial surface). In *P. amphibia* and *P. stagnina* the width of stomata was of same range on both surfaces, that is, 10 - 15  $\mu$ m (Table 3).

There were 2 types of non glandular trichomes recorded in *P. barbata*, *P. orientalis* and *P. stagnina* which served as their distinguishing characters. Elongated, thin and unicellular trichomes with tapering ends were found in *P. barbata* and *P. stagnina* (Figure 2C, 2D, 2F, 2E and 2G). Inamdar (1971) used the term, small shaggy trichome in *P. barbata* which are noteworthy in angiosperms (Lersten and Curtis, 1992). Payne (1978) did not give any description for such form of trichome in his vocabulary of plant hair terminology.

Another type of trichomes were short and thick with tapering apex and swollen base forming a thick covering on adaxial surface of *P. orientalis* (Figure 2I - 2K). Lersten and Curtis (1992) noted large multicellular eglandular trichomes in *P. capitata* but during the present investigations only glandular trichomes were recorded in *P. capitata*. Size of eglandular trichomes in *P. stagnina* abaxial surface varied from 335 - 455  $\times$  45 - 65  $\mu$ m greater than trichomes size in *P. barbata* (Table 2). Haraldson (1978) believed that *Persicaria* Mill. is an

extremely developed genus on the basis of the trichome structure. Great diversity in glandular trichomes of the genus was recorded; centrally one-celled, two-celled and four-celled peltate trichomes, capitate trichomes and spheroidal trichomes. The most common type is two-celled peltate trichome (Figures 2H and 12). Striated two-celled trichomes were noted in *P. glabra*, *P. chinensis* and *P. lapathifolia* (Figure 2O). Centrally four-celled peltate trichome along with spheroidal gland was present only in *P. barbata* (Figures 2A and 2B). Typical capitate trichomes with short stalk along with spheroidal and two-celled peltate were found only in *P. glabra* (Figure 2E). Schotsman (1950) described spheroidal glands from *P. maculosa*. Mitchell (1971) used the term of multicellular plate-glands for spheroidal glands and examined these trichomes from *P. amphibia*. Lersten and Curtis (1992) observed spheroidal glands in 21 species of *Persicaria* Mill. along with capitate trichomes. The length of two-celled peltate trichomes varied between 10 - 20  $\mu$ m in *P. glabra* adaxial surface to 35 - 50  $\mu$ m in *P. amphibia* abaxial surface. In *P. chinensis*, striated peltate trichomes were of same size on both epidermises, that is, 15 - 20  $\times$  10 - 20  $\mu$ m while in *P. hydropiper* size range of one-celled trichomes was same on both surfaces (15 - 25  $\times$  10 - 20  $\mu$ m). However, average size variation in spheroidal glands was very small, that is, 22  $\times$  19  $\mu$ m to 27  $\times$  25  $\mu$ m (Table 2).

Dendrogram was constructed on the basis of length/width of epidermal cells, presence or absence of stomata,



**Figure 2.** Light micrographs (LM) of the foliar anatomy of *Persicaria* spp. **A.** Spheroidal trichome and paracytic stomata in *P. barbata* (1000X). **B.** Four-celled peltate trichome in *P. barbata* (400X). **C.** Unicellular eglandular trichomes in *P. barbata* (1000X). **D.** One-celled peltate trichome in *P. chinensis* (1000X). **E.** Anisocytic, paracytic and staurocytic stomata and capitate trichomes in *P. glabra* (200X). **F.** Unicellular trichomes in *P. stagnina* (200X). **G.** Bunch of unicellular trichomes with swollen base in *P. stagnina* (1000X). **H.** Two-celled peltate trichome in *P. stagnina* (400X). **I.** Short cone shaped eglandular trichomes in *P. orientalis* at high focus (1000X). **J.** Glandular trichomes at low focus in *P. orientalis* (100X). **K.** Spheroidal trichome in *P. orientalis* (1000X). **L.** Two-celled trichome of *P. tenella* (400X). **M.** Pericytic stomata in *P. amphibia* (400X). **N.** Paracytic stomata and one-celled peltate trichome in *P. posumbu* (400X). **O.** Two-celled peltate trichome with striations in *P. chinensis* (400X).

non glandular and glandular trichomes on adaxial and abaxial surface in order to establish relationship among different taxa of *Persicaria* Mill. On the basis of anatomical characters *P. tenella* and *P. chinensis* were found to be closely related. *P. stagnina* and *P. barbata* showed only 6.481 dissimilarity. This analysis also proved that foliar anatomical studies are taxonomically significant to delimit taxa (Figure 1).

## Conclusion

It is proved during this study that most of anatomical characters are stable in most of the species of *Persicaria* Mill. However, it is clear from the dendrogram that anatomical studies are potentially significant to delimit the taxa and on the basis of which identification keys (Table 3) are provided.



**Table 3.** Key to *Persicaria* Mill. species on the basis of foliar anatomy.

1a	Pentagonal, hexagonal shaped epidermal cells on adaxial surface, peltate trichomes four-celled.----- ----- 1. <i>P. barbata</i>
1b	Epidermal cells on adaxial surface pentagonal, hexagonal, heptagonal, octahedral, polygonal or irregular in outline, four-celled peltate glands absent.-----2
2a	Epidermal cells pentagonal on both leaf surfaces one and two-celled peltate trichomes present on the same leaf surface.-----2 <i>P. chinensis</i>
2b	Epidermal cells variable in shape, one and two-celled trichome not seen together on the same leaf surface.-----3
3a	Leaves hypostomatic, two-celled peltate trichomes present only on abaxial surface.----- ----- 3. <i>P. sinuata</i>
3b	Leaves amphistomatic, two-celled peltate trichomes present on both surface.--4
4a	Capitate trichomes present, paracytic, anisocytic and staurocytic stomata types on the same surface.--- ----- 4. <i>P. glabra</i>
4b	Capitate trichomes absent, three different stomatal types not found on the same surface.----- -----5
5a	Adaxial epidermal cells pentagonal, hexagonal and polygonal, on adaxial surface epidermal cells 79 $\mu\text{m}$ long.-----5. <i>P. nepalensis</i>
5b	Adaxial epidermal cells pentagonal, heptagonal, octahedral or irregular, length of epidermal cells on adaxial surface less than 79 $\mu\text{m}$ .-----6
6a	Length of non glandular trichomes on adaxial surface ranges from 335-455 $\mu\text{m}$ , similar width of stomata and two-celled peltate on abaxial surface. -----6. <i>P. stagnina</i>
6b	Different length range of non glandular trichomes, stomata and two-celled peltate width on abaxial surface not same.-----7
7a	Two types of stomatal patterns found on the single surface, similar length of epidermal cells on both leaf surfaces.----- 7. <i>P. hydropiper</i>
7b	Only one type of stomatal pattern, length of the epidermal cells different on both surfaces.-----8
8a	Epidermal cells pentagonal, hexagonal and octahedral on both surfaces, width of stomata equal on both surfaces.-----8. <i>P. amphibian</i>
8b	Epidermal cells shape variable; different width of stomata on both surfaces. ----- -----9
9a	Stomata anomocytic, non glandular trichomes present.----- --9. <i>P. orientalis</i>
9b	Anomocytic stomata and eglandular trichomes absent.-----10
10a	Spheroidal trichomes present, width of two-celled peltate and spheroidal trichomes same on adaxial surface.-----10. <i>P. tenella</i>
10b	Spheroidal trichomes absent, two types of glandular trichome with different width.----- ----- 11
11a	Epidermal cells polygonal on both leaf surfaces, width of one-celled peltate on abaxial surface greater than its length.-----11. <i>P. maculosa</i>
11b	Epidermal cells not polygonal, length of trichomes higher than width.-----12
12a	Epidermal cells pentagonal, hexagonal and heptagonal on both surfaces, peltate trichome one-celled.-- -----12. <i>P. posumbu</i>
12b	Epidermal cells polygonal or irregular in outline, one-celled peltate trichome absent.----- -----13
13a	Epidermal cells irregular in outline on both surfaces, abaxial stomata length and adaxial width varies from 15-20 $\mu\text{m}$ .-----13. <i>P. lapathfolia</i>
13b	Epidermal cells polygonal and irregular in shape, stomata length on abaxial surface and width on adaxial surface with different range.-----14
14a	Stomata width on both surfaces varies from 20-35 $\mu\text{m}$ , epidermal cells 58 $\mu\text{m}$ in length on adaxial surface.-----14. <i>P. capitata</i>
14b	Variable width of stomata, length of epidermal cells 40 $\mu\text{m}$ in length on adaxial surface. -----15. <i>P. longiseta</i>

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