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Leaf epidermal anatomy of dominant aquatic plant species in Swat Valley, Pakistan

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Abstract

Total 21 species (15 genera and 12 botanical families) were studied for their foliar anatomy for the first in district Swat, Pakistan because the said plants have multiple diagnostic economic importance and foliar anatomical characters which play a key role in taxonomy. The use of light microscopy has possible in depth to study leaf surface features. Both qualitative (Shape and structure) and quantitative (number, length and width) of epidermis, trichomes and stomatal cells of both leaf surfaces were studied. Mostly the observed traits were similar at both leaf surfaces except few cases i.e stomata were not observed at any leaf surface in totally submerged plants (*Hydrilla verticillata, Potamegeton crispus, P. natans, P. perfoliatus*), the studied plants were mostly amphistomatic except plant species *Sparganium erectum* L. which was epistomatic and trichomes were observed in few aquatic plants species which were mostly amphitrichomic except plant species *Nasturtium officinale* which was hypetrichomic. Aims and objectives of the research project were to explore, document and conserve the aquatic flora of Swat valley and to analyze both quantitative and qualitative characters of their foliar epidermal anatomy.

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Introduction

Aquatic flora is the basic component of the healthy water environment. All types of soil and aquatic vegetation exhibit the process of photosynthesis contributing to accumulation of oxygen in the aquatic environment (Lembi, 2000). Aquatic plants species complete their life cycle in lentic or lotic water bodies (Philbrick and Les,1996). Compare to terrestrial habitat, water bodies i.e. spring, river, lake and stream, ponds, ditches, water logged localities etc. provide permanent and stable habitat as exhibited by its greater thermal and chemical stability (Tiffney, 1981). The term Aquatic plants is now preferred by another term known as hydrophytic plants or simply hydrophytes in the reports on plants geography by many researchers (Tiner, 1991). A dutch plant ecologist (Moss *et, al.*1909) used hydrophyte along with other terms to describe various habitat form of different plants groups (e.g. halophyte, mesophyte and xerophyte). Aquatic plants can be ferns or angiosperms and belonging to varieties of families including monocots and dicots (Sculthorpe, 1967). Hydrophytes are those species which normally stand in water and must spent any part of their life cycle in water either completely submersed or immersed (Muenscher, 1944). Seeds of aquatic plants germinate in either the water phase or the substrate of a body of water which must spend part of their life cycle in water (Reid, 1961). In present work the concept of (Cook, 1996) has been followed who defined aquatic vascular plants as all Pteridophytes and Spermatophytes whose photosynthetic active parts (leaves and herbaceous stems) are permanently or at least for several months each year partly or wholly submerged in water or float on the surface of water bodies. Distributions, abundance, species diversity and species composition of aquatic plants depends on quality of water bodies and worldwide there are more than 100 families of vascular aquatic plants species (Oyedeji and Abowei, 2012). Many aquatic plants species has broad worldwide or continental ranges of distribution (*Ceratophyllum demersum* L. *Lemna minor* L. *Potamogeton pectinatus* L. and *Typha latifolia* L.) (Stuckey, 1993). In halophytes *(Phragmites australis)* is perhaps the most cosmopolitan angiosperm (Hutchinson, 1975). About 60% identified and recorded hydrophytes have extensive worldwide distribution (occur in multiple continent), while only 40% were confined to a single continent (Sculthorpe, 1967). Local endemism is rare, although their abundance seems to increases in the tropics (Cook, 1983; Cook, 1985). Rare endemic species tend to have large geographic distribution ranges (rare Indian endemic *Wiesneria triandra* occupies approximately 900km) (Camenisch and Cook, 1996). Patterns of long distance dispersal and geographical barriers are often referred to as contributors to the distribution of hydrophytes (Jordan, 2001). Biogeographical analysis of freshwater flora of Australasia best explained the distributional pattern by combination of dispersal and local speciation (Jacobs and Wilson, 1996). Aquatic genera that are distributed in certain regions following arrival of long distance dispersal rate (Jacobs and Wilson, 1996). All in all concluded that the biogeography of water plants shows the lasting diversity of water birds migration, super imposed on a major disjunction determined by climatic factors (Jacobs and Wilson, 1996). As compare to terrestrial groups of plants aquatic plants show relatively little taxonomic differentiation. (Sculthorpe, 1967; Hutchinson, 1975; Les, 1988; Cook, 1990). Typical hydrophytes grow in water or in water saturated soil and classified hydrophytes in to three groups i.e. Submerged, floating (including floating leaved) and amphibious (Weaver and Clements, 1938). Wetland flora are classified in to seven plant divisions: Cyanobacteria, Chlorophyta, Rhodophyta, Xanthophyta, Bryophytes, Pteridophyta and Spermatophyta which are represented by 33 orders and 88 families with concerning 2,614 species in Ca. 412 genera (Chambers *et al*., 2008). According to Ahmad and Younus, 1979, Aquatic flora may be submerged, free floating, emergent rooted (rooted in the bottoms of water bodies) or rooted on the bank of impoundment adopting semi aquatic habitat. The present study provides comprehensive analysis of both qualitative and quantitative features, their dominancy and occurrence of the said plants in the area.

Materials and methods

Geographical overview of the study area

The research area Swat is the part of glorious, hilly and tree green Malakand division, the most attractive region of the northwest corner of province Khyber Pakhtunkhwa, Pakistan, located in the range of 34°34` to 35° 55` N latitude and 72°08` to 72°50` E longitudes (Hamayun, 2007).

It shares its boundary in the north with Chitral and Ghizar districts, in the south with Shangla and Kohistan districts, in the east with Buner and Malakand districts and in the west with lower and upper Dir districts respectively.

Area and population

Total area of the valley is 1251612 acres at average elevation of 975 meters above the sea level, inhabitant by about 1.7 million people. Estimated increase in population is approximately 3-4% per anum (District census report 1998, population Census organization Govt: of Pakistan). The said valley is subdivided in to eight tehsils (District revenue report 2014-2015, Govt: of Pakistan).

Climatic conditions

Summer temperature is fairly moderate and reaches up to 36-38°C but the harsh coldest months being December to February with observed temperature from 0° to 2.4°C. The average annual rainfall ranges from 500 mm to 1200 mm and snowfall ranges 423.56cm to 600cm (Khan, 1995; Abbasi *et al.*, 2010).

Specimen collection

The plant specimens were collected by regular field visits during December 2016 to June 2017. Different areas of Swat valley were selected for the collection of aquatic plants i.e the river of Chail valley, Ghar shin, Khwaza khela, Gashkor, Marghuzar, river of Miandam, marshes and Springs of Chalyar, Tegdari, Gashkore, Alamganj, Fizagut etc. Collection was made from various aquatic habitats such as slow running water, sides of stagnant ponds, paddy fields, streams, sewerage canals and marshy places of the study area.

Identification and Authentication of the plants specimens

The specimens were identified in Biodiversity and Taxonomy lab of Quaid -i- Azam University Islamabad by comparing with voucher specimens at the herbarium of the said department and university. Literature used for identification include (Jafri, 1966), (Bhopal and Chaudhri, 1977), (Ahmad and Younus, 1979), (Leghari *et al.*, 1999) and (Leghari *et al.*, 2004). The identified and authenticated plants specimens were preserved and dried at herbarium of Quaid-i-Azam University Islamabad (ISL). For preservation of plant species, the method of (Lawrence, 1951) and (Jain and Rao, 1977) were followed. The specimens were deposited to the herbarium of Pakistan, department of Plant sciences, Quaid-i-Azam University Islamabad (ISL) as reference materials.

Results and discussion

Analyzed characters

In the present study both qualitative and quantitative traits were analyzed shown in detail in (Fig 1).

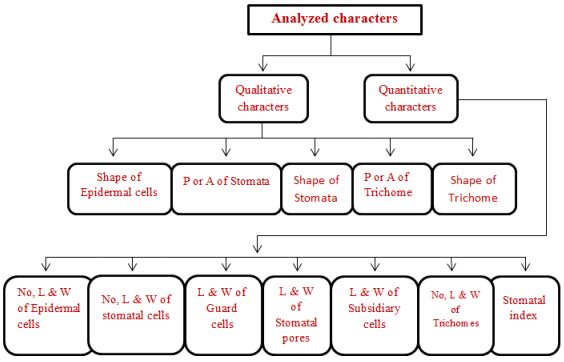

Fig1. Key for qualitative and quantitative characters: No = number, L = length, W = width, A = absent, P = present.).

Qualitative analysis

Epidermal cells

Qualitatively the epidermal cells in all examined species of wild aquatic plants varied in their shapes. Most of the species possess characteristically epidermal cells that are, irregular, polygonal and rectangular.

Mostly the epidermal cells shape on both leaf surface that is, adaxial and abaxial were similar except 1 or 2 species i.e *Persicaria capitata* (irregular at adaxial surface while polygonal at abaxial surface). Rest of plant species along with their epidermal cells shapes are given in (Table 1).

Stomatal cells

Three different types of stomata were observed in all the examined species of wild aquatic plants. These types comprise anisocytic, anomocytic and brachyparacytic. In all these species stomata are mostly present on adaxial surface and were amphistomatic except single case in which the stomata was restricted to only adaxial surface i.e epistomatic (*Sparganium erectum*) and in few.

aquatic plant species i.e totally submerged species (*Hydrilla verticellata, Potamogeton crispus, P. natans, P. perfoliatus*) stomata were not observed at any leaf surface. The observed stomata shapes were similar at both leaf surfaces given in (Table 1).

Table 1. Qualitative analysis of both leaf surfaces.

S.no	Plant name	Family name	Adaxial and Abaxial Surfaces	Shape of Epidermal cell	Stomata (P/A)	Type of Stomata	Trichome or Gland (P/A)	Type of Trichome/Gland
1	*Alisma plantago aquatic* L.	Alismataceae	Adaxial	Polygonal	Present	Brachyparacytic	Absent	-
			Abaxial	Polygonal	Present	Brachyparacytic	Absent	-
2	*Sagittaria sagittifolia L*	Alismataceae	Adaxial	Polygonal	Present	Anomocytic	Absent	-
			Abaxial	Polygonal	Present	Anomocytic	Absent	-
3	*Oenanthe javanica* (Blume) DC	Apiaceae	Adaxial	Polygonal	Present	Anisocytic	Absent	-
			Abaxial	Polygonal	Present	Anisocytic	Absent	-
4	*Cardamine hirsuta* L	Brassicaceae	Adaxial	Irregular	Present	Anisocytic	Absent	-
			Abaxial	Irregular	Present	Anisocytic	Absent	-
5	*Nasturtium officinale* R.Br	Brassicaceae	Adaxial	Irregular	Present	Anisocytic	Absent	-
			Abaxial	Irregular	Present	Anisocytic	Present	Globose Glandular
6	*Cerastium fontanum* Baumg.	Caryophyllaceae	Adaxial	Irregular	Present	Anomocytic	Present	Multicellular & Peltate
			Abaxial	Irregular	Present	Anomocytic	Present	Multicellular & Peltate
7	*Hydrilla verticillata* (R.f.) Royle	Hydrocharitacea e	Adaxial	Rectangular	Absent	-	Absent	-
			Abaxial	Rectangular	Absent	-	Absent	-
8	*Epilobium laxum* Royle	Onagraceae	Adaxial	Irregular	Present	Anomocytic	Absent	-
			Abaxial	Irregular	Present	Anomocytic	Absent	-
9	*Veronica anagallis aquatic*a L.	Plantaginaceae	Adaxial	Irregular	Present	Anisocytic	Present	Multicellular
			Abaxial	Irregular	Present	Anisocytic	Present	Multicellular
10	*V.beccabunga* L.	Plantaginaceae	Adaxial	Irregular	Present	Anisocytic	Present	Globose Glandular
			Abaxial	Irregular	Present	Anisocytic	Present	Globose Glandular
11	*Plantago ovata* Forssk.	Polygonaceae	Adaxial	Irregular	Present	Anisocytic	Present	Multicellular
			Abaxial	Irregular	Present	Anisocytic	Present	Multicellular
12	*Persicaria capitata* (Buch.-Ham. ex D.Don) H.Gross	Polygonaceae	Adaxial	Irregular	Present	Anomocytic	Absent	-
			Abaxial	Polygonal	Present	Anomocytic	Absent	-
13	*P.maculosa* Gray	Polygonaceae	Adaxial	Irregular	Present	Anomocytic	Present	Glandular
			Abaxial	Irregular	Present	Anomocytic	Present	Glandular
14	*Monochoria vaginallis (Burm.f.) C.Presl*	Pontederiaceae	Adaxial	Polygonal	Present	Brachyparacytic	Absent	-
			Abaxial	Polygonal	Present	Brachyparacytic	Absent	-
15	*Potamogeton crispus* L.	potamegetanace ae	Adaxial	Rectangular	Absent	-	Absent	-
			Abaxial	Rectangular	Absent	-	Absent	-
16	*P.natans* L.	Potamegetanace ae	Adaxial	Rectangular	Absent	-	Absent	-
			Abaxial	Rectangular	Absent	-	Absent	-
17	*P.perfoliatus* L.	Potamegetanace ae	Adaxial	Rectangular	Absent	-	Absent	-
			Abaxial	Rectangular	Absent	-	Absent	-
18	*Ranunculus laetus* Wall. ex Hook. f. & J.W. Thomson	Rananculaceae	Adaxial	Irregular	Present	Anomocytic	Present	Multicellular & Peltate
			Abaxial	Irregular	Present	Anomocytic	Present	Non-glandular
19	*R. muricatus* L.	Rananculaceae	Adaxial	Irregular	Present	Anomocytic	Absent	-
			Abaxial	Irregular	Present	Anomocytic	Absent	-
20	*R.sceleratus* L.	Rananculaceae	Adaxial	Irregular	Present	Anomocytic	Absent	-
			Abaxial	Irregular	Present	Anomocytic	Absent	-
21	*Sparganium erectum L.*	Typhaceae	Adaxial	Polygonal	Present	Brachyparacytic	Absent	-
			Abaxial	Polygonal	Absent	-	Absent	-

Trichomes

Indumentum characteristics, composition, distribution, composition and density of trichomes appear in few aquatic plant species and were mostly amphitrichomic (present on both leaf surfaces) except one species which was hypotrichomic i.e trichomes restricted to only abaxial surface (*Nasturtium officinal*). Two main types of trichomes were observed in examined aquatic plant species that is, glandular and multicellular.

In some plant species two types of trichomes were observed in same plant at same leaf surface i.e *Cerastium fontanum* has multicellular and peltate trichomes at both leaf surfaces. Rest of plant species along with their trichome shapes are given in (Table 1).

Quantitative analysis

In the present documented aquatic plant species traits like epidermal cells (number, length and width of epidermal cells), trichomes (number, length and width of trichomes) and stomatal cells (number, length and width of stomata along with length and width of stomatal pores, guards cells and subsidiary cells) were examined.

All the mentioned characters were studied for both leaf surfaces along with their average, maximum and minimum values. The detail quantitative results of epidermal cells and trichomes are given in (Table 2) and of stomatal cells in (Table 3).

Table 2. Quantitative analysis of epidermal cells and trichomes of both leaf surfaces.

S.no	Plant and family	Adaxial and Abaxial surfaces	Average No. of Epidermal cell	Epidermal cells Length & width (µm)		Trichome Number	Trichome/Gland (µm)	Length & Width
				L	W	Average	L	W
1	*Alisma plantago aquatica L. (Alismataceae)*	Adaxial	60.4	46.5(32.5-57.5)	28.5(25-40)	-	-	-
		Abaxial	48.8	73(55-95)	33.5(30-40)	-	-	-
2	*Sagittaria sagittifolia L (Alismataceae)*	Adaxial	66	59.5(50-75)	37(25-45)	-	-	-
		Abaxial	55.6	63.5(50-72.5)	35(25-42.5)	-	-	-
3	*Oenanthe javanica* (Blume) DC (Apiaceae)	Adaxial	78.6	35.5(27.5-45)	17.5(15-25)	-	-	-
		Abaxial	70.8	34(27.5-37.5)	22.5(15-25)	-	-	-
4	*Cardamine hirsuta* L (Brassicaceae)	Adaxial	40.2	84(47.5-150)	41(27.5-62.5)	-	-	-
		Abaxial	23.2	113.5(75-140)	44(25-70)	-	-	-
5	*Nasturtium officinale* R.Br (Brassicaceae)	Adaxial	79.4	93(80-107.5)	23.5(20-27.5)	-	-	-
		Abaxial	59	75(45-105)	29.5(25-35)	1.3	20(15-25)	8(7.5-20)
6	*Cerastium fontanum* Baumg. (caryophyllaceae)	Adaxial	39.8	81(55-110)	54.5(40-65)	1.5 & 1	273.7(175-425) & 192(150-207.5)	23.7(15-30) & 160(125-182.5)
		Abaxial	23.4	101.5(75-132.5)	62(47.5-80)	1 & 1	266(175-325) & 104.3(87.5-130)	30.8(10-50) & 104.3(87.5-130)
7	*Hydrilla verticillata* (R.f.) Royle (Hydrocharitaceae)	Adaxial	53	79.5(50-100)	36(30-40)	-	-	-
		Abaxial	61.4	96(82.5-107.5)	28(25-32.5)	-	-	-
8	*Epilobium laxum* Royle (Onagraceae)	Adaxial	92	48(32.5-65)	24(20-27.5)	-	-	-
		Abaxial	192.6	35.5(25-47.5)	19.5(15-22.5)	-	-	-
9	*Veronica anagallis aquatica* L. (Plantaginaceae)	Adaxial	34.6	64(32.5-95)	36(20-50)	1.2	36(20-47.5)	24(15-25)
		Abaxial	29.8	75.5(32.5-105)	40.5(20-50)	1	35.6(32.5-40)	31.5(25-45)
10	*V.beccabunga* L. (Plantaginaceae)	Adaxial	42.4	71(50-92.5)	43.5(25-95)	1.6	40(30-47.5)	23.5(20-25)
		Abaxial	36	74.5(70-77.5)	43.5(37.5-50)	1.4	36(27.5-45)	23.5(20-27.5)
11	*Plantago ovata* Forssk. (Polygonaceae)	Adaxial	98.2	49.5(45-55)	24.5(20-27.5)	2.4	109.5(47.5-200)	35.5(10-75)
		Abaxial	80.2	56(32.5-87.5)	25.5(20-30)	2.8	122(47.5-237.5)	35.5(25-50)
12	*Persicaria capitata* (Buch.-Ham. ex D.Don) H.Gross (Polygonaceae)	Adaxial	45.4	61(47.5-85)	30(25-40)	-	-	-
		Abaxial	57.8	56(50-70)	34.5(27.5-47.5)	-	-	-
13	*P.maculosa* Gray (Polygonaceae)	Adaxial	112.6	56(45-67.5)	23.5(15-32.5)	1	332.5(265-400)	45(32.5-57.5)
		Abaxial	86.4	49.5(40-60)	23(20-27.5)	1	221.8(145-312.5)	38.1(20-50)
14	*Monochoria vaginallis (Burm.f.) C.Presl (Pondeteriaceae)*	Adaxial	144.8	37.5(30-50)	23.5(20-30)	-	-	-
		Abaxial	138.4	37.5(30-50)	26.5(25-30)	-	-	-
15	*Potamogeton crispus* L. (Potamegetanaceae)	Adaxial	319.8	29(25-37.5)	22(17.5-25)	-	-	-
		Abaxial	258.6	36.5(25-47.5)	23.5(20-25)	-	-	-
16	*P.natans* L. (Potamegetanaceae)	Adaxial	1144.8	23.5(20-27.5)	12.5(7.5-15)	-	-	-
		Abaxial	940.8	19.5(17.5-22.5)	11.5(7.5-15)	-	-	-
17	*P.perfoliatus* L. (Potamegetanaceae)	Adaxial	371.4	29.5(25-32.5)	20.5(15-25)	-	-	-
		Abaxial	307.8	28(25-32.5)	20(17.5-25)	-	-	-
18	*Ranunculus laetus* Wall. ex Hook. f. & J.W. Thomson (Ranunculaceae)	Adaxial	34.2	68(50-92.5)	40(32.5-47.5)	2 & 1	356.2(262-450) & 125(100-150)	16.2(15-17.5) & 116.6(100-125)
		Abaxial	61.8	65.5(52.5-80)	48(37.5-62.5)	1 & 1	250(250-250) & 106.2(100-112.5)	20(20-20) & 100(75-125)
19	*R. muricatus* L. (Ranunculaceae)	Adaxial	21.2	103.5(90-132.5)	70.5(50-82.5)	-	-	-
		Abaxial	22.2	126.5(100-155)	83(65-100)	-	-	-
20	*R.sceleratus* L. (Ranunculaceae)	Adaxial	18.2	106(95-122.5)	57(35-75)	-	-	-
		Abaxial	16.8	101(92.5-112.5)	47.5(25-62.5)	-	-	-
21	*Sparganium erectum L.* (Typhaceae)	Adaxial	341.2	29.5(22.5-35)	21.5(20-25)	-	-	-
		Abaxial	365.4	39.5(32.5-47.5)	15.5(12.5-17.5)	-	-	-

Table 3. Quantitative analysis of stomatal cells of both leaf Surfaces.

S. no	Plant & Family	Adax & Abax Surface	Avg. stomatal number	Stomata length and Width (µm)		Stomatal pore length & width (µm)		Guard cells length & width (µm)		Subsidiary cell length & width (µm)		Stomatal Index (S.I)
				L	W	L	W	L	W	L	W	S.I
1	*Alisma plantago aquatica L.* (Alismataceae)	Adaxial	7	45.5(40-50)	43(40-45)	25.5(20-30)	7(5-7.5)	45.5(40-50)	18(15-20)	51.5(45-55)	41(17.5-22.5)	10.3
		Abaxial	4	42.5(32.5-47.5)	31(25-35)	30.5(22.5-35)	6(5-7.5)	42.5(32.5-47.5)	14(10-17.5)	45(35-50)	16.5(12.5-20)	7.5
2	*Sagittaria sagittifolia L* (Alismataceae)	Adaxial	8	47(42.5-52.5)	28(25-30)	39(32.5-45)	6.5(5-7.5)	45(37.5-50)	12(10-15)	50(45-55)	15(12.5-17.5)	10.8
		Abaxial	5	44(37.5-50)	23.5(20-25)	34.5(27.5-40)	7(5-7.5)	44(37.5-50)	13.5(12.5-15)	49(42.5-55)	18(17.5-20)	8.2
3	*Oenanthe javanica* (Blume) DC (Apiaceae)	Adaxial	31.4	24.5(22.5-30)	20.5(20-22.5)	14(12.5-15)	5(5-5)	24.5(22.5-30)	8.5(7.5-10)	28.5(27.5-30)	11(10-12.5)	3.8
		Abaxial	13.8	25(22.5-27.5)	22.5(20-25)	14(12.5-15)	5(5-5)	25(22.5-27.5)	8(7.5-10)	30(27.5-32.5)	12(10-15)	16.3
4	*Cardamine hirsuta* L (Brassicaceae)	Adaxial	25.2	19(17.5-20)	19(17.5-20)	13.5(12.5-15)	6(5-7.5)	19(17.5-20)	7(5—7.5)	29(27.5-32.5)	15.5(12.5-20)	38.5
		Abaxial	5.6	16(12.5-20)	17(15-20)	10.5(10-12.5)	5.5(5-7.5)	16(12.5-20)	5.5(5-7.5)	26.5(22.5-32.5)	13(10-15)	19.4
5	*Nasturtium officinale* R.Br (Brassicaceae)	Adaxial	29.2	26.5(25-27.5)	21(20-22.5)	20(17.5-22.5)	5.5(5-7.5)	26.5(25-27.5)	7.5(5-10)	33(30-35)	16.5(15-17.5)	26.8
		Abaxial	15.4	26(20-30)	19.5(15-25)	19.5(12.5-27.5)	4(2.5-5)	26(20-30)	11.5(10-15)	35(27.5-40)	17(15-20)	20.6
6	*Cerastium fontanum* Baumg. (caryophyllaceae)	Adaxial	8.8	33.5(30-40)	21(20-22.5)	16.5(15-20)	6.5(5-7.5)	34(30-40)	8(7.54-10)	37(35-40)	34.5(10-15)	18.1
		Abaxial	5	28(25-32.5)	24(22.5-25)	15.5(15-17.5)	6.5(5-7.5)	28(25-32.5)	9(7.5-12.5)	33.5(30-37.5)	13(10-15)	17.6
7	*Hydrilla verticillata* (R.f.) Royle (Hydrocharitaceae)	Adaxial	-	-	-	-	-	-	-	-	-	-
		Abaxial	-	-	-	-	-	-	-	-	-	-
8	*Epilobium laxum* Royle (Onagraceae)	Adaxial	34	25.5(22.5-27.5)	21(17.5-25)	17(15-20)	8(7.5-10)	25.5(22.5-27.5)	10.5(7.5-12.5)	30.5(27.5-32.5)	15.5(12.5-17.5)	26.6
		Abaxial	29.2	25(20-27.5)	20(17.2-22.5)	15.5(12.5-20)	8(7.5-10)	25(20-27.5)	9.5(7.5-10)	30(25-32.5)	14.5(12.5-15)	13.1
9	*Veronica anagallis aquatica* L. (Plantaginaceae)	Adaxial	14.8	29.5(25-35)	28(25-30)	20(17.5-22.5)	6.5(5-7.5)	29.5(25-35)	12.5(10-15)	33.5(30-37.5)	9.5(7.5-12.5)	29.9
		Abaxial	25.5	28.5(25-32.5)	22(20-25)	21.5(20-22.5)	6(5-7.5)	28.5(25-32.5)	10(10-10)	31.5(27.5-35)	11(7.5-12.5)	46.1
10	*V.beccabunga* L. (Plantaginaceae)	Adaxial	16.8	27(25-30)	23(20-27.5)	18.5(15-22.5)	7(5-7.5)	27(25-30)	8.5(7.5-10)	29.5(27.5-32.5)	11(10-12.5)	28.3
		Abaxial	9.8	26(25-27.5)	22.5(20-25)	16(15-17.5)	7(5-7.5)	26(25-27.5)	8.5(7.5-12.5)	28.5(27.5-30)	13(10-15)	21.3
11	*Plantago ovata* Forssk. (Polygonaceae)	Adaxial	13	27.5(22.5-32.5)	25(22.5-27.5)	21(17.5-25)	7(5-7.5)	27.5(22.5-32.5)	9(7.5-10)	34.5(32.5-37.5)	18(15-20)	11.6
		Abaxial	12	23.5(20-27.5)	20(17.5-22.5)	17(15-20)	5(5-5)	23.5(20-27.5)	8.5(7.5-10)	32.5(27.5-35)	16(15-17.5)	13
12	*Persicaria capitata* (Buch. Ham.ex D.Don) H.Gros (Polygonaceae)	Adaxial	19.6	27(25-27.5)	25(22.5-27.5)	17.5(15-20)	7(5-7.5)	27(25-27.5)	12(10-12.5)	32.5(30-35)	14.5(12.5-17.5)	30.1
		Abaxial	4.8	28.5(27.5-30)	23(20-25)	19.5(15-22.5)	7(5-7.5)	28.5(27.5-30)	12.5(10-20)	34(32.5-37.5)	13.5(12.5-15)	7.6
13	*P.maculosa* Gray (Polygonaceae)	Adaxial	35.2	25.5(22.5-27.5)	21(20-22.5)	21(20-22.5)	6(5-7.5)	25.5(22.5-27.5)	12.5(9.6-15)	27.5(25-30)	18.5(15-20)	23.8
		Abaxial	21.4	25.5(22.5-30)	19.5(17.5-22.5)	20.5(20-22.5)	6(5-7.5)	25.5(22.5-30)	10.5(7.5-12.5)	30.5(27.5-35)	16.5(12.5-20)	19.8
14	*Monochoria vaginallis* (Burm.f.) C.Presl (Pontederiaceae)	Adaxial	18	29.5(27.5-30)	21.5(20-22.5)	19.5(17.5-20)	5.5(5-7.5)	29.5(27.5-30)	11.5(10-12.5)	35(32.5-37.5)	17.5(15-20)	11
		Abaxial	11	30.5(27.5-35)	20(17.5-22.5)	20.5(20-22.5)	5.5(5-7.5)	30.5(27.5-35)	8(7.5-10)	37(35-42.5)	16(15-20)	7.3
15	*Potamogeton crispus* L. (Potamegetanaceae)	Adaxial	-	-	-	-	-	-	-	-	-	-
		Abaxial	-	-	-	-	-	-	-	-	-	-
16	*P.natans* L. (Potamegetanaceae)	Adaxial	-	-	-	-	-	-	-	-	-	-
		Abaxial	-	-	-	-	-	-	-	-	-	-
17	*P.perfoliatus* L. (Potamegetanaceae)	Adaxial	-	-	-	-	-	-	-	-	-	-
		Abaxial	-	-	-	-	-	-	-	-	-	-
18	*Ranunculus laetus* Wall. ex Hook. f. & J.W. Thomson (Rananculaceae)	Adaxial	6.6	49(45-55)	44.5(35-50)	33(25-40)	8.5(5-10)	49(45-55)	20(17.5-22.5)	20.5(47.5-52.5)	20(17.5-25)	16.1
		Abaxial	2	43(40-50)	30.5(25-35)	28(20-40)	7.5(5-10)	43(40-50)	17.5(15-20)	45.5(42.5-52.5)	15.5(12.5-17.5)	3.1
19	*R. muricatus* L. (Ranunculaceae)	Adaxial	9	51.5(47.5-57.5)	40.5(35-45)	35(27.5-42.5)	10(7.5-10)	51.5(47.5-57.5)	17.5(17.5-20)	57(50-62.5)	22.5(20-27.5)	29.8
		Abaxial	5	61(52.5-75)	44.5(42.5-47.5)	39.5(30-50)	7.5(5-10)	61(52.5-75)	18.5(17.5-20)	63(55-72.5)	26.5(25-30)	18.3
20	*R.sceleratus* L. (Ranunculaceae)	Adaxial	6.6	47.5(45-50)	36.5(32.5-40)	29(25-32.5)	10.5(7.5-15)	47.5(45-50)	13(12.5-15)	52.5(50-55)	18(17.5-20)	26
		Abaxial	4.6	38.5(37.5-42.5)	35(32.5-40)	22.5(20-25)	9(7.5-10)	38.5(37.5-42.5)	13(12.5-15)	43.5(42.5-47.5)	16(15-17.5)	21.4
21	*Sparganium erectum L.* Typhaceae	Adaxial	23.2	25(22.5-27.5)	19(17.5-20)	20.5(17.5-22.5)	6.5(5-7.5)	25(22.5-27.5)	9(7.5-12.5)	34(25-40)	15.5(12.5-20)	6.7
		Abaxial	-	-	-	-	-	-	-	-	-	-

Stomatal index (S.I)

The values of stomatal index among all the investigated aquatic plant species show a wide range of variation. By this character the hybrid plants differentiate very clearly and easily from parental plants and concentration level of atmospheric CO_2 determined. Therefore, this character is used to declare the degree of atmospheric pollution. Variation in stomatal index values in both leaf surfaces shown in (Table 3). The highest value of stomatal index is an indicative of highest transpiration rate, metabolism and highest rate for the absorption of mineral and water.

Stomatal index of species can also be used as a geographical indicator.

Stomatal index was not observed in totally submerged plants species (*Hydrilla verticillata, Potamegeton crispes, P.natans* and *P.perfoliates*) in both leaf surfaces while in plant species *Sparganium erectum* L. observed only in adaxial surface. In rest of aquatic plants species, at adaxial surface, the highest stomatal index value was observed in plant species *Cardamine hirsuta* L of family Brassicaceae (38.5µm) followed by plant species *Persicaria capitata* (Buch.-Ham.ex.D.Don) H.Gros of family Polygonaceae (30.1µm). At adaxial surface, the least stomatal index value was observed in plant species *Oenanthe javanica* (Blume) DC of family Apiaceae (3.8µm) followed by plant species *Sparganium erectum* L. of family Typhaceae (6.7µm). At abaxial surface the highest stomatal index was observed in plant species *Veronica anagallis aquatica* L. of family Plantaginaceae (46.1µm) followed by plant species *Ranunculus sceleratus* L. of family Ranunculaceae (21.4µm). The least stomatal index value at abaxial surface was observed in species *Ranunculus laetus* (3.1µm) followed by plant species *Monochoria vaginallis* (7.3µm). The total average stomatal index value of the reported plants species was (20.4µm) at adaxial surface and (16.2µm) at abaxial surface.

Discussion

The lush green, farfetched and charming Swat valley is situated at the northwest corner of Pakistan between 34°34` to 35°55` N latitude and 72°08` to 72°50` E longitudes (Hamayun, 2007). It shares its boundary in the north with Chitral and Ghizar districts, in the south with Shangla and Kohistan districts, in the east with Buner and Malakand districts and in the western with lower and upper Dir districts respectively. The research area is the part of Malakand division. The twins cities of Mingora and Saidu sharif are the districts as well as the divisional headquarters of the valley. The total area of the valley is 1251612 acres at average elevation of 975 meters above the sea level. Area of the said valley is divided in to eight tehsils (District revenue report 2014-2015, Govt: of Pakistan), Explained in Table 1. Total human population of the district is about 1.7 million, with 295 persons per square kilometer. Increase in population of the area is estimated to 3-4% per year (District census report 1998, population Census organization Govt: of Pakistan).

In the present work 21 aquatic plant species were studied for their foliar anatomy in district Swat. All the reported plants species were herb, wild in nature and belonging to different families and ecological groups (emergent anchored, floating leaves and submerged anchored). At family and species level, family Potamegetanaceae, Polygonaceae and Ranunculaceae remain the dominant ones (each having 3 species), While plant species *Nasturtium officinale* was very common and dominant while *veronica beccabunga* was very rare in occurrence in the said area.

Conclusion

Leaf epidermal anatomy with special emphasis on stomata types, position of stomata, number of stomata, types of trichomes and stomatal index are very useful tools and features in the field of taxonomy. Stomatal index is found to be very useful for determining the level atmospheric co_2.

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