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LEAF ARCHITECTURAL STUDIES ON THE GENUS *CORCHORUS* L. (GREWIOIDEAE-MALVACEAE) FROM PAKISTAN

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Abstract

The genus *Corchorus* comprises ca. 74 species of worldwide distribution in the tropical and subtropical regions of the world. In Pakistan it is represented by eight species including six wild species viz., *C. aestuans* L., *C. depressus* L., *C. olitorius* L., *C. pseudo- olitorius* Islam & Zaid., *C. tridens* L., *C. trilocularis* L., *C. fascicularis* Lam. and two species namely *C. capsularis* L. and *C. olitorius* L. are cultivated as commercial crops. *Corchorus* species are characterized by hairy petioles, simple, alternate, unlobed leaves with or without awns at the leaf base, mostly symmetrical sometimes slightly to completely asymmetrical, ovate, lanceolate, elliptic, oblong, margin serrate. In addition, the study of leaf venation showed that 1° leaf venation was acrodromous and 2° leaf venation was craspedodromous. Further, leaf epidermal studies in *Corchorus* manifested paracytic stomatal type followed by anisocytic, tetracytic, anomocytic types and dominant unicellular, attenuate trichomes. Most of the aspects studied were significant to delimit the species consequently an artificial key was designed. The data was also analyzed numerically to perceive the relationship among the species of the genus from Pakistan. This study was conducted to develop an understanding of leaf architecture, venation patterns, and epidermal characters of the genus *Corchorus* from Pakistan. The data was also found useful as an aid to taxonomic delimitation of the genus *Corchorus* from Pakistan.

Key words: *Corchorus*, Leaf architecture, Grewioideae-Malvaceae, Pakistan, Stomata, Trichomes.

Introduction

The genus *Corchorus* described by Linnaeus (1753), was previously treated under the family Tiliaceae. However, based on the molecular evidence of the chloroplast genome (Anon., 2003), it is now cirucmscribed within sub-family Grewioideae of the family Malvaceae (s.l.).

The genus *Corchorus* comprises c. 74 species around the world mainly distributed in tropical and subtropical regions of the world (Ghafoor, 1974). The number of species in the genus *Corchorus* is rather debateable for instance Ghosh *et al*., (2014) accepted 50-60 species. Whereas Ya *et al*., (2007) accepted 40-100 species in Flora of China. However, Ghafoor (1974) reported 8 species from Pakistan viz., *C. aestuans*, *C. capsularis*, *C. depressus*, *C. fascicularis*, *C. olitorius*, *C. pseudo-olitorius*, *C. tridens* and *C. trilocularis.* Among these, two species *C. olitorius* and *C. capsularis* are cultivated. These species are important cash crops as they yield fiber, while other species are considered weeds in the agricultural fields. Several *Corchorus* species are medicinally important as their leaves contain pharmacological properties (Al-Snafi, 2016; Kumari *et al*., 2019). The gross morphology of the leaves, especially venation, is considered to be hereditarily fixed and can be utilized as a taxonomic evidence (Larano & Buot, 2010). Likewise, leaf characters are valuable in taxonomic studies, particularly in tropical plants where regenerative organs were missing for study (Dilcher, 1974). While, Ettingshausen (1861) probably was the first to summarize the description of leaf characters and classified them based on venation patterns.

Leaf venation is an important two-dimensional ramifying structure of the leaf. It is a series of connected veins and veinlets that form the leaf's vascular network (Melville, 1969). Leaf venation is not only a helpful tool in the recognition and classification of the living taxa but also useful for the identification of fossil taxa (Roth-Nebelsick, 2001). Hickey (1973) classified dicot leaves based on architectural features and found it useful in taxonomy of living and extinct taxa. Moreover, Vârban *et al*., (2021) studied the micromorphology of *C. oliotorus* leaves from Romania. However, no comprehensive report is available for the delimitation and relationship of various species of the genus *Corchorus* based on leaf structural data. This detailed study of the macro and micromorphological leaf characters aimed at investigating phenetic relationship among the wild and cultivated *Corchorus* species occurring in Pakistan.

Materials and Methods

Leaf morphology: Mature leaves were collected from fresh or dried herbarium specimens of 8 *Corchorus* species. Mostly 10-15 samples per species (depending on the availability of the material) were examined (Appendix I). Overall, 29 leaf architectural and morphological characters were assessed following the Manual of Leaf Architecture (Ash *et al.,* 1999). All the quantitative observations were recorded, and mean values were determined with standard deviations. Leaf venation patterns were observed under a stereomicroscope (Nikon XN model) and light microscope (Nikon Type 102) by following the clearing and staining methods of Vasco (2014) with slight modifications (Table 1).

Clearing of leaves: Complete dried leaves of each species were placed in 5% NaOH solution at room temperature overnight in separate petri dishes. After 13-24 hours, leaves were rinsed with tap water and then placed in a 5% sodium hypochlorite solution overnight or for two to three days until they turned colourless.

Staining of leaves: Cleared leaves were dehydrated with the help of 50%, 70% and 90% ethanol series for at least 20-30 minutes, then placed in 95% saturated safranin dye overnight.

Appendix I.

S. No.	Species	Collector, Number and Herbarium
1.	*C. aestuans*	Zamarrud 1454 (KUH); S. Omer & M. Qaiser 2232 (KUH); Ghafoor & Tahir Ali 3508 (KUH); S.M.H Jafri 4109 (KUH); S.M.H Jafri 2515 (KUH); M. Qaiser 7028 (KUH); S.M.H. Jafri 1174 (KUH); Zamarrud 520 (KUH); Ghafoor 3201 (KUH); M. Qaiser and Ghafoor 3728 (KUH); Sadiq Masih 29 (KUH).
2.	*C. capsularis*	Anonymous s.n. (KUH); Abrar Hussain s.n. (KUH); Khush gul s.n. (KUH).
3.	*C. depressus*	Sultan ul Abdin & Abrar Hussain 7300 (KUH); S.M.H Jafri 1138 (KUH); A. Ghafoor 458 (KUH); S.M.H Jafri 892 (KUH); S. I Ali *et al.* 333 (KUH); M. Imran 233 (KUH); S.M.H Jafri 1040 (KUH); Sultan ul Abdin & M. Qaiser 8534 (KUH); Dr. Rubina Akhter 670 (NARC); M. Rashid et al. 3394 (PMNH).
4.	*C. fascicularis*	S.M.H Jafri 1060 (KUH); S.M.H Jafri 1027 (KUH); W.T Saxton 3245 (NARC).
5.	*C. olitorius*	Mushtaq Hussain s.n. (KUH); Anonymous s.n. (KUH); M. Qaiser & A. Ghafoor 4857 (KUH); A. Ghafoor & Tahir Ali 3513 (KUH); M. Qaiser & A. Ghafoor 4576 (KUH); M. Qaiser & A. Ghafoor 4664 (KUH); M.A Siddiqi & Y. Nasir 6592 (KUH); Y. Nasir & Nazir 9182 (KUH); Prem Nath s.n. (NARC); M.A Siddique 6592 (NARC).
6.	*C. pseudo-olitorius*	S.M Omer & M. Qaiser 2248 (KUH); A Ghafoor & Rafiq Ahmed 887 (KUH); M. Qaiser *et al.* 3627 (KUH); Sultan ul Abdin 3774 (KUH); Aslam s.n. (KUH).
7.	*C. tridens*	S.A. Farooqi s.n. (KUH); Sultan ul Abdin 3746 (KUH); Abrar Hussain s.n. (KUH); Khush Gul s.n. (KUH); Abrar Hussain s.n. (KUH); M. Qaiser & A. Ghafoor 3945 (KUH); M. Qaiser *et al.* 3723 (KUH); M. Qaiser *et al.* 3693 (KUH); E. Nasir & M.A. Siddique 3643 (NARC); A. Rehman 25688 (NARC).
8.	*C. trilocularis*	S.I Ali *et al.* 549 (KUH); Khush gul s.n. (KUH); Rais Fatima s.n. (KUH); Abrar Hussain s.n. (KUH); Qamar Sultana s.n. (KUH); M.A Moid s.n. (KUH); Sultan ul Abdin 3904 (KUH); R.R. Stewart & E. Nasir s.n. (NARC); M. Arshad 1954 (NARC); Khalid Saeed & Javed s.n. (PMNH).

De-staining of leaves: When leaves were completely dyed with safranin, they were de-stained with the 95% ethanol acidified with 3-6 drops of 37% HCl. De-staining continued until the mesophyll area was cleared again and veins were clearly visible.

Stomata and trichomes: Stomata and trichomes were studied by scanning electron microscopy (SEM). A small section of leaf was mounted on a metal stub with the help of double adhesive tape and platinum plated in a fine auto coater (JEC-3000FC). 20mA current was used for 30 seconds for coating. Then observed under scanning electron microscope (JEOL JSM 5910) Stomata types, sizes, density, trichomes, structure, base, head and length were studied following the terminologies of Metcalfe and Chalk (1950) (Table 2).

Numerical analysis: Numerical analysis of eight species of the genus *Corchorus* viz., *C. aestuans*, *C. capsularis*, *C. depressus*, *C. fascicularis*, *C. olitorius*, *C. pseudo-olitorius*, *C. tridens* and *C. trilocularis* were carried out. Hierarchical clustering was performed using 81 characters of leaves including leaf architectural, macromorphological and micromorphological features based on Euclidean distance index using IBM-SPSS software (Anon., 2011). Each taxon was considered as an operational taxonomic unit (OTU). Qualitative characters were recorded in binary state and characters which were either absent or present were coded as 0 or 1 respectively. For quantitative characters, average quantitative values were directly used for the data analysis (Tables 3, 4).

Observations and Results

Leaf macromorphology

Twenty-nine macromorphological characteristics of 8 *Corchorus* species from Pakistan were analyzed (Table 1; Fig. 1.1). Leaves were simple, alternate, unlobed, stipulate and petiolate. Petiole was 3-50 mm long with a swollen base and hairy surface. Awns or filiform appendages were either present or absent. The shape of the mature leaf lamina varied from ovate, broadly ovate, lanceolate, elliptic, oblong, oblong-lanceolate, ovate-lanceolate, linear-lanceolate with symmetrical, asymmetrical or slightly asymmetrical leaves. Lamina size ranged between 6–150 × 4–80 mm. Blade classes comprised leptophyll, nanophyll, microphyll, notophyll and mesophyll. Leaf margins were serrate or crenate, while teeth order 1° or 2°, teeth apical side concave (cc), straight (st) or flexuous (fl), teeth basal side concave (cc), straight (st) or convex (cv), leaf apex ranged from acute to obtuse; leaf base ranged from cuneate or obtuse, base symmetrical, asymmetrical or slightly asymmetrical. Primary (1°) leaf venation acrodromus, 2° veins craspedodromus, 2° vein spacing increasing towards the base, 2° vein angle 20° or 50°; 3° veins varied from opposite, percurrent, random reticulate, regular polygonal reticulate or alternate percurrent (Fig. 1.2).

Leaf micromorphology

Stomata Paracytic, anisocytic, tetracytic or anomocytic, 7-27.1×4-24, aperture linear, lanceolate, oblong, elliptic, stomatal density 150-538 mm^2, Leaves pubescent with unicellular, eglandular or glandular trichomes, head attenuate or peltate, base broad (Table 2; Figs. 2.1, 2.2).

Table 1. Macromorphological characters of the species of the genus *Corchorus*.

Traits	*C. aestuans*	*C. capsularis*	*C. depressus*	*C. fascicularis*	*C. olitorious*	*C. pseudo-olitorious*	*C. tridens*	*C. trilocularis*
Petiole length (mm)	8(14.2)31 ± 7.671	11(30)50 ± 12.516	6(12)20 ± 5.734	3(7.9)15 ± 3.725	7(13.9)25 ± 6.100	7(9.8)15 ± 2.973	4(8.4)15 ± 4.033	7(8.9)12 ± 1.663
Petiole surface	Densely hairy	Scarcely hairy	Densely hairy	Densely hairy	Densely hairy	Densely hairy	Densely hairy	Densely hairy
Stipule (mm)	3(5.1)7 ±1.523	6(8)10 ±1.333	1(1.4)2 ±0.516	1(2.9)5 ±1.728	5(17.1)32 ±9.503	4(5.9)8 ±1.663	2(4.5)7 ±1.779	5(6.5)8 ±1.080
Awns (Present = +) (Absent = -)	-	(+)	-	-	(+)	(+)	(+)	(+)
Leaf length (mm)	31(57.1)117 ± 26.061	55(91.5)150 ± 30.938	6(12.6)27 ± 5.738	9(21.7)40 ± 9.967	43(69)112 ± 21.166	37(47.7)58 ± 8.111	23(59.2)104 ± 22.880	19(39.3)59 ± 13.408
Leaf breadth (mm)	20(30.3)59 ± 13.132	15(52.1)80 ± 24.460	4(8)12 ± 2.867	4(8.7)18 ± 4.473	17(27.9)61 ± 13.177	12(15.8)21 ± 3.457	7(15.3)25 ± 6.111	9(20.1)33 ± 8.478
Laminar size (Area of Leaf in mm² x 2/3)	454(1343.7)4602 ± 1288.640	550(3575)7500 ± 2465.724	16(72.4)198 ± 51.518	24(147.9)348 ± 121.68	688(1414.7)4554 ± 1216.562	320(493.26)630 ± 85.299	153(667.533)1594 ± 486.846	114(591.466)1180 ± 396.968
Blade class	Microphyll to Mesophyll	Microphyll to Mesophyll	Leptophyll to Nanophyll	Leptophyll to Microphyll	Microphyll to Mesophyll	Microphyll	Nanophyll to Microphyll	Nanophyll to Microphyll
Lamina shape	Ovate, Broadly Ovate	Linear-Lanceolate, Ovate-lanceolate	Elliptic	Ovate-Oblong, Lanceolate, Elliptic	Ovate-Lanceolate	Ovate-Lanceolate	Lanceolate	Ovate, Broadly Ovate
Lamina symmetry	Symmetrical	Symmetrical/ Slightly asymmetrical	Symmetrical	Symmetrical	Symmetrical	Symmetric/ Asymmetrical	Symmetric/ Asymmetrical	Symmetrical
Apex angle	40°-100°	20°	30°-80°	25°-40°	25°-65°	20°-40°	20°-40°	20°-70°
Apex shape	Acute, Sharp	Acute	Obtuse	Acute, Obtuse	Acute	Acute	Acute	Acute
Base angle	60°-90°	30°	30°-90°	40°	35°-110°	30°-40°	20°-60°	30°-80°
Base shape	Convex, Obtuse	Obtuse	Cuneate	Cuneate, Obtuse	Obtuse	Oblique Truncate	Oblique Obtuse	Obtuse
Base symmetry	Symmetrical	Symmetrical	Symmetrical	Symmetrical	Symmetrical	Asymmetrical	Symmetrical/ Slightly asymmetrical	Symmetrical
Margin	Serrate	Serrate	Crenate, Serrate	Serrate	Crenate, Serrate	Serrate	Crenate, Serrate	Crenate
Teeth orders	2°	1°	1°	2°	2°	2°	2°	2°
Tooth spacing	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular
Teeth/Cm	3(5.6)8 ± 1.837	4(4.6)5 ± 0.516	2(4.3)5 ± 1.059	3(5.5)8 ± 1.581	4(6)8 ± 1.154	4(5.2)7 ± 1.135	3(4)5 ± 0.942	3(4.9)8 ± 1.370
Tooth apical side	cc	st	st	st	st	fl	st	st
Tooth basal side	cc	st	cc	cv	cv	cv	cc	cc
Tooth shape	cc/cc	st/st	st/cc	st/cv	st/cv	fl/cv	st/cc	st/cc
Sinus	Angular	Angular	Angular	Angular	Angular	Angular	Angular	Angular
Tooth apex	Simple	Simple	Simple	Simple	Simple	Simple	Simple	Simple
1° Vein Category	Acrodromus basal 5 Costate	Acrodromus basal 3 Costate	Acrodromus	Acrodromus basal 3 Costate	Acrodromus basal 4, 5 Costate	Acrodromus basal	Acrodromus basal 3 Costate	Acrodromus basal 3 Costate
2° Vein Category	Craspedodromus	Craspedodromus	Craspedodromus	Craspedodromus	Craspedodromus	Craspedodromus	Craspedodromus	Craspedodromus
2° Vein Spacing	Increasing towards Base	Increasing towards Base	Increasing towards Base	Increasing towards Base	Increasing towards Base	Increasing towards Base	Increasing towards Base	Increasing towards Base
2° Vein Angle	50°	50°	50°	50°	50°	50°	20°	50°
3° Vein Category	Random reticulate	n/a	Random reticulate	Regular polygonal reticulate	Random reticulate	n/a	Alternate percurrent	Mixed, opp/alt

Key: **cc**=concave; **cv**=convax; **st**=straight; **fl**=flexous

Key to the species of *Corchorus* based on leaf characteristics

1 + Leaf lamina with filiform appendages or awns at the base ……..... 2
- Leaf lamina without filiform appendages or awns at the base 6
2 + Lamina ovate to broadly ovate ……..……..... *C. trilocularis*
- Lamina linear-lanceolate, ovate-lanceolate, lanceolate 3
3 + Teeth order 1° (Teeths of same size) ..... *C. capsularis*
- Teeth order 2° (Teeths of two different sizes) ……..... 4
4 + Base truncate, tooth apex flexuous ……..... *C. pseudo-olitorius*
- Base oblique, obtuse, tooth apex straight ……..... 5
5 + Trichome head peltate ……..... *C. olitorius*
- Trichome head attenuate ….....…..... *C. tridens*
6 + Lamina ovate or broadly ovate ……..…….... *C. aestuans*
- Lamina lanceolate, ovate, oblong, elliptic 7
7 + Stomata tetracytic with elliptic aperture ……..... *C. depressus*
- Stomata anomocytic with linear/lanceolate aperture …..... *C. fascicularis*

Fig. 1.1. Photographs pf leaf structures. A: *C. aestuans*; B; C. *capsularis*; C; *C.depressus*; D: *C. fascicularis*; E: *C. oliotoris*; F: *C. pseudo-oliotoris*; G: *C. tridens*; H: *C. trilocularis*.

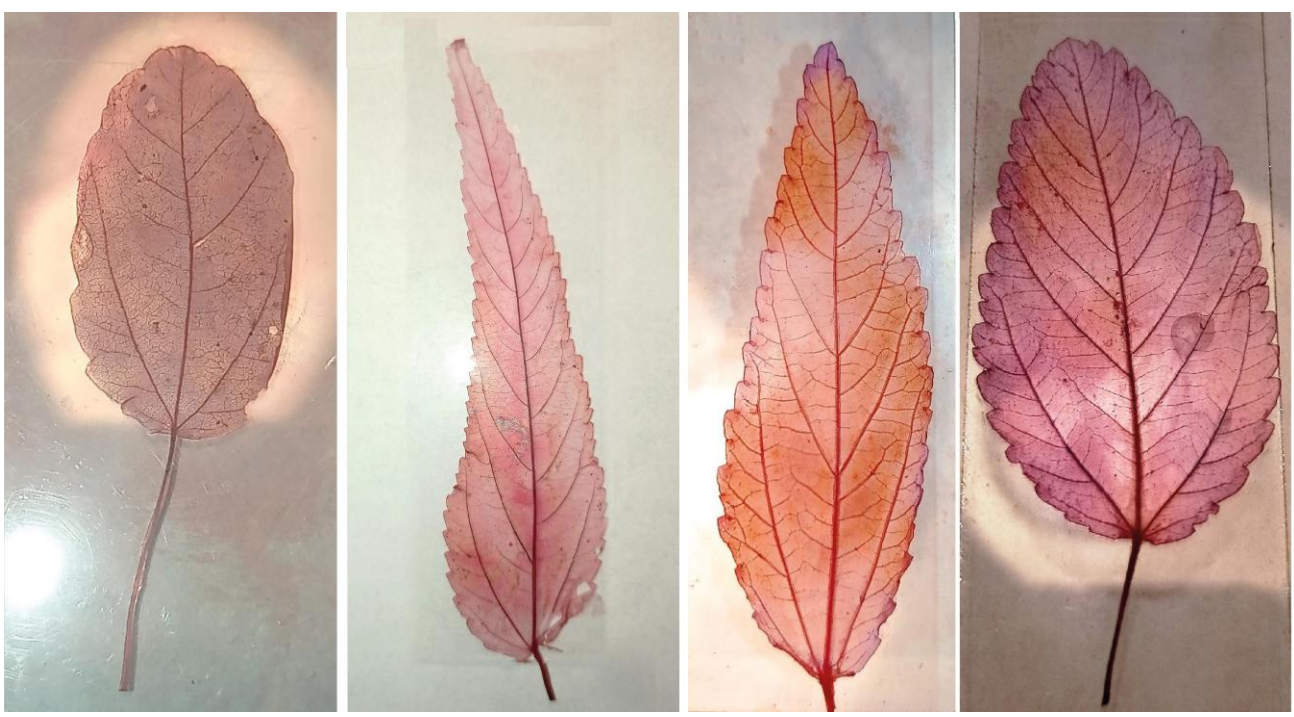

Fig. 1.2. Light Micrographs of leaf venation (5X) A: *C. depressus*; B: *C. tridens*; *C: pseudo-oliotoris*; D: *C. trilocularis*.

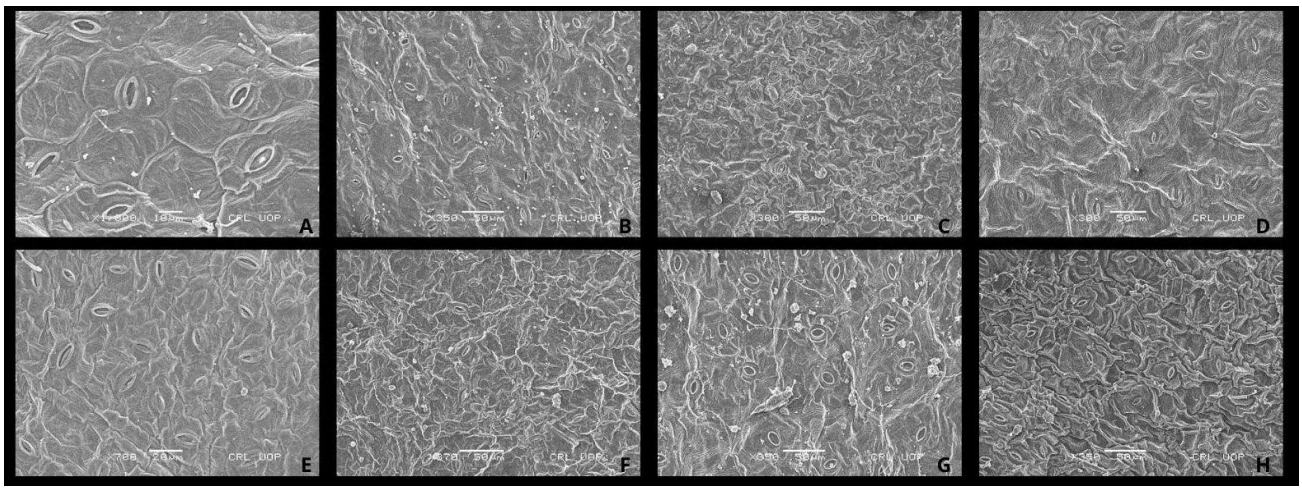

Fig. 2.1. Scanning electron micrographs showing leaf stomata. A: *C. aestuans*; B: *C. capsularis*; C: *C. depressus*; D: *C. fascicularis*; E: *C.oliotoris*; F: C. *pseudo-oliotoris*; G: *C. tridens*; H: *C. trilocularis* (Scale bar: A= 10µm; E= 20µm; B,C, D, F, G, H= 50µm).

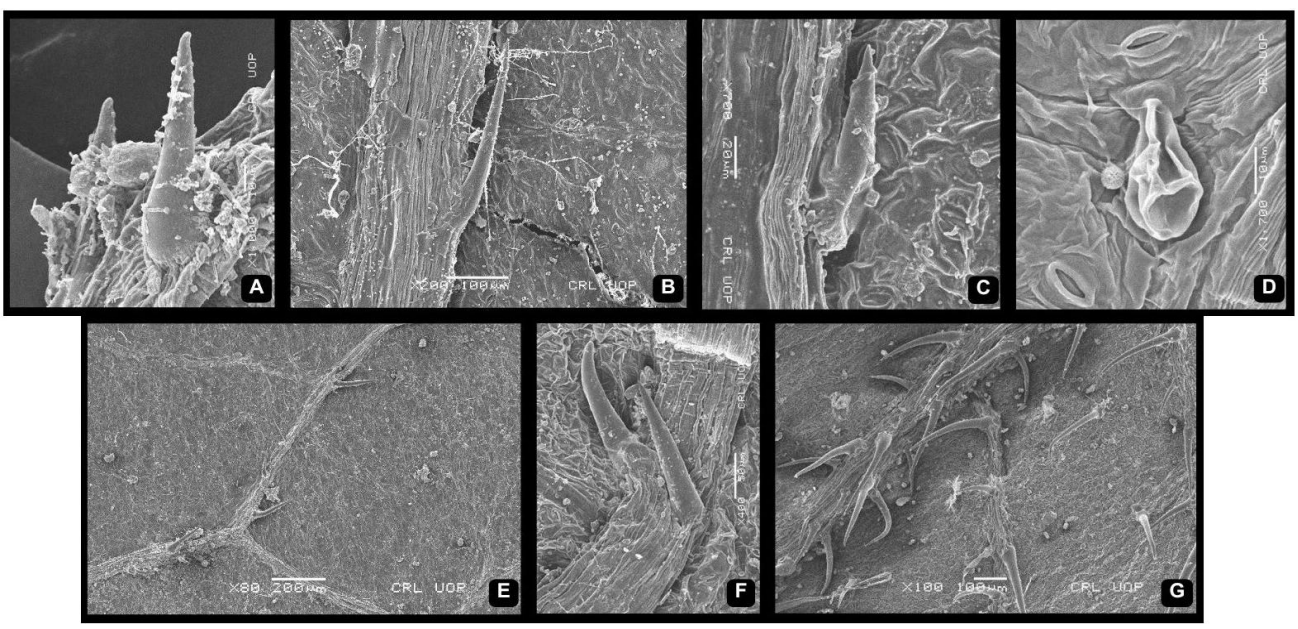

Fig. 2.2. Scanning electron micrographs showing leaf trichomes. A: *C. aestuans*; B: *C. capsularis*; C: *C. depressus*; D: *C. oliotoris*; E: *C. tridens*; F: *C. pseudo-oliotoris*; G: *C. trilocularis* (Scale bar: A, D= 10µm; C= 20µm; F= 50µm, B, G= 100µm. E= 200µm).

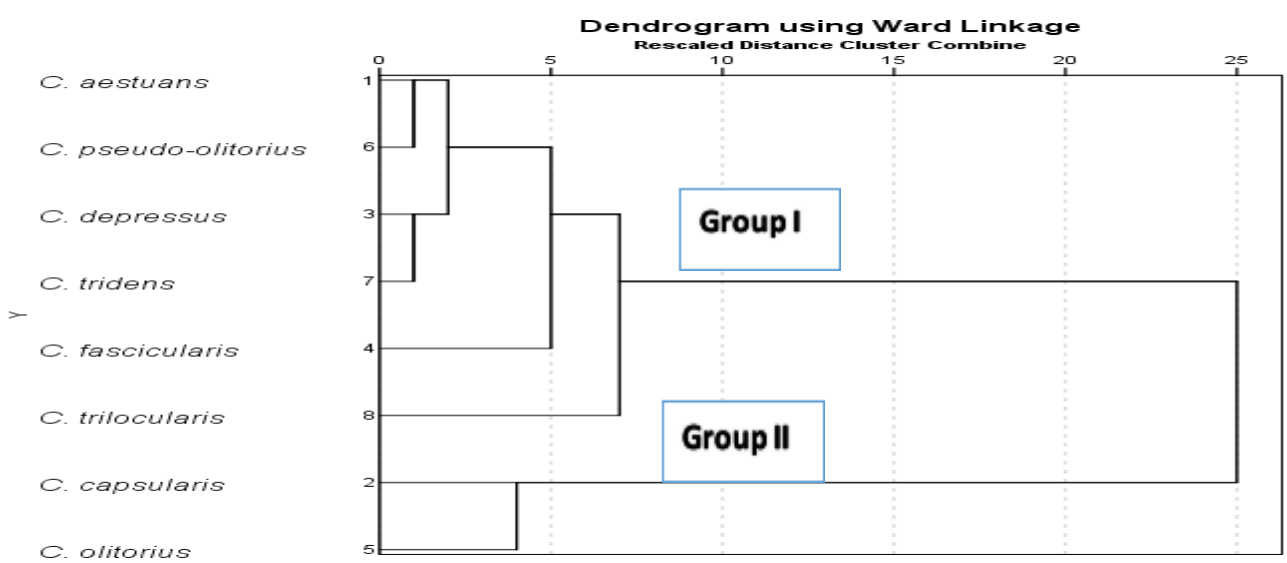

Fig. 3. Dendrogram showing the relationship of *Corchorus* species.

Table 4. Data matrix of the genus *Corchorus* L. for characters presented in Table 3.

S. No.	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1.	*C. aestuans*	1	1	1	1	14.2	1	1	0	1	0	1	1	0	0	1	0	0	1	0	0	0	0	0	57.1
2.	*C. capsularis*	1	1	1	1	30	1	1	0	1	0	0	1	0	0	1	0	0	1	1	0	0	0	0	91.5
3.	*C. depressus*	1	1	1	1	12	1	1	1	0	0	0	1	0	0	1	1	1	0	0	1	0	0	0	12.6
4.	*C. fascicularis*	1	1	1	1	7.9	1	1	1	1	0	0	1	0	0	1	0	0	1	0	1	1	1	0	21.7
5.	*C. olitorius*	1	1	1	1	13.9	1	1	0	1	0	1	1	0	0	1	0	0	1	0	0	0	0	1	69
6.	*C. pseudo-olitorius*	1	1	1	1	9.8	1	1	0	0	1	1	0	1	0	1	1	1	1	0	0	0	0	1	47.7
7.	*C. tridens*	1	1	1	1	8.4	1	1	0	1	0	1	1	0	1	1	1	1	0	1	0	0	0	0	59.2
8.	*C. trilocularis*	1	1	1	1	8.9	1	1	0	1	0	1	1	0	0	1	0	0	1	0	0	0	0	0	39.3

		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
1.	*C. aestuans*	30.3	0	0	1	1	1	0	0	1	1	0	0	1	0	0	1	0	1	1	0	0	0	1	0
2.	*C. capsularis*	52.1	0	0	1	1	1	0	1	0	0	1	0	0	1	0	1	0	1	1	0	0	0	1	0
3.	*C. depressus*	8	1	1	0	1	1	1	1	0	0	1	0	1	0	1	0	1	1	1	0	0	0	1	0
4.	*C. fascicularis*	8.7	1	1	1	1	1	0	0	1	0	1	0	0	0	1	1	1	1	1	0	0	0	0	1
5.	*C. olitorius*	27.9	0	0	1	1	1	1	0	1	0	1	0	0	0	1	1	0	1	1	0	0	0	1	0
6.	*C. pseudo-olitorius*	15.8	0	0	1	1	1	0	0	1	0	0	1	0	0	1	1	0	1	1	0	0	0	1	0
7.	*C. tridens*	15.3	0	0	1	0	1	1	0	1	0	1	0	1	0	0	1	0	1	1	0	0	0	0	0
8.	*C. trilocularis*	20.1	0	1	1	1	0	1	0	1	0	1	0	1	0	0	1	0	1	1	1	1	0	0	0

		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
1.	*C. aestuans*	0	1	1	0	0	1	250	15.3	11.2	1	0	0	0	9.3	2.9	1	2	1	166.8	0	1
2.	*C. capsularis*	0	1	0	0	0	1	416	14.654	7.556	0	1	0	0	9.7	3.444	1	1	1	164	0	1
3.	*C. depressus*	0	0	0	1	0	1	250	25.3	14.2	0	0	1	0	18.1	6.2	1	1	1	103.15	0	1
4.	*C. fascicularis*	0	0	0	0	1	1	180	20.7	13.6	0	1	0	1	12.028	1.2	1	1	1	-	0	1
5.	*C. olitorius*	0	1	0	0	0	1	538	15.4	8.6	1	0	0	0	10.2	3.2	1	1	2	31	1	0
6.	*C. pseudo-olitorius*	0	1	0	1	0	1	263	22.1	15.8	1	0	1	0	12.516	3.3	1	1	1	181.33	0	1
7.	*C. tridens*	1	0	1	1	0	1	185	22.4	21.6	1	0	0	0	13.2	8	1	1	1	119.4	0	1
8.	*C. trilocularis*	0	0	1	0	0	1	150	20.412	15.3	1	0	0	0	8.5	2.91	1	1	1	280.5	0	1

Table 2. Micromorphological Characters of the species of the genus *Corchorus*.

Traits	*C. aestuans*	*C. capsularis*	*C. depressus*	*C. fascicularis*	*C. olitorious*	*C. pseudo-olitorious*	*C. tridens*	*C. trilocularis*
Types of stomata	Paracytic, Anisocytic	Paracytic	Tetracytic	Anomocytic	Paracytic, Tetracytic	Paracytic	Anisocytic, Tetracytic	Anisocytic
Stomatal frequency/ mm²	250	416	250	180	538	263	185	150
Stomata length (µm)	7.27 (15.3) 24.99 ± 7.362	14 (14.654) 15.7 ± 0.689	21.42(25.3)27.13 ± 3.717	19.04(20.7)20.94 ± 1.835	13 (15.4) 19 ± 2.190	17.85(22.1)26.46 ± 3.217	12 (22.4) 28 ± 6.228	17.13 (20.412) 22 ±2.016
Stomata width (µm)	4.28 (11.2) 19.27 ± 6.723	5.71 (7.556) 10 ± 1.644	11.42(14.2)16.66 ± 2.120	12.25(13.6)14.28 ± 0.902	4 (8.6) 11 ± 2.792	14.7 (15.8) 17.85 ± 1.549	20 (21.6) 24 ± 1.673	14(15.3)16.18 ±1.091
Aperture shape	Oblong	Linear	Elliptic	Linear, Lanceolate	Oblong	Oblong, Elliptic	Oblong	Oblong
Aperture length (µm)	2.99(9.3)14.2 ± 5.586	9.28(9.7)10.7 ± 0.640	14.2(18.1)20.7 ± 2.666	9.52 (12.028) 14.28 ± 2.397	7 (10.2) 13 ± 2.167	10.71 (12.516)11.76 ± 2.912	10 (13.2) 16 ± 2.280	7.61 (8.5) 10.47 ±1.137
Aperture width (µm)	0.85(2.9)4.99 ± 1.944	2.14 (3.444) 6 ± 1.577	0.37(6.2)12.85 ± 4.550	0.95 (1.2) 1.9 ± 0.424	1 (3.2) 5 ± 1.483	2.94 (3.3) 4.28 ± 0.595	6 (8) 10 ± 1.414	2 (2.91) 4 ±0.711
Types of indumentum	Pubescent	Pubescent	Pubescent	Pubescent	Pubescent	Pubescent	Pubescent	Pubescent
Location	Mid-rib	Mid-rib	Mid-rib and veins	Only on Margin	Mid-rib and veins	Mid-rib and veins	Veins	Mid-rib and veins
Glandular/Eglandular	Eglandular on lamina Glandular towards the margins	Eglandular	Eglandular	Eglandular	Eglandular	Eglandular	Eglandular	Eglandular
Head	Attenuate	Attenuate	Attenuate	Attenuate	Peltate	Attenuate	Attenuate	Attenuate
Trichome type	Unicellular	Unicellular	Unicellular	Unicellular	Multicellular	Unicellular	Unicellular	Unicellular
Trichome base	Broad	Broad	Broad	Broad	Broad	Broad	Broad	Broad

Discussion

The genus *Corchorus* is treated under the sub-family Grewioideae of the family Malvaceae s.l. (Anon., 2003). Presently leaf architectural studies of the genus *Corchorus* are conducted from Pakistan, along with leaf epidermal characters like stomata and trichomes. Furthermore, the data was analyzed numerically to infer the taxonomic affinities of the taxa.

The genus *Corchorus* is characterized by petiolate, simple and hairy leaves with various stomatal types, while trichomes were mostly unicellular and attenuate. The species of *Corchorus* occurring in Pakistan can be bifurcated by having filiform appendages/awns or without filiform appendages/awns (Ghafoor, 1974). The species having awns include *C. capsularis*, *C. olitorius*, *C. pseudo-olitorius*, *C. tridens* and *C. trilocularis.* While the species without awns are *C. aestuans*, *C. depressus* and *C. fascicularis*. Among the awned species, *C. trilocularis* remained distinct from other species due to its ovate or broadly ovate lamina. While, the other species have lanceolate, linear-lanceolate, and ovate-lanceolate lamina. Similarly, *C. capsularis* was distinct by its 1° teeth order while rest of the species were characterized by having 2° teeth order. Amongst these *C. pseudo-olitorius* differed from *C. tridens* and *C. oliotoris* by its truncate base and flexous tooth apex. Similarly, *C. olitorius* and *C. tridens* were distinguishable by the shape of their peltate and attenuate trichome head, respectively.

Similarly, within awnless species *C. aestuans,* stood distinct from other species by having ovate to broadly ovate lamina (Ya *et al*., 2007). Furthermore, *C. depressus* and *C. fascicularis* can be differentiated by having tetracytic stomata with elliptic aperture and anomocytic stomata with linear, lanceolate aperture, respectively.

Numerical analysis yielded two prominent clusters (group I and group II) (Fig. 3). Both may be differentiated from each other by having the difference in stomatal frequency. Group I comprised of 6 species viz., *C. aestuans*, *C. depressus*, *C. fascicularis*, *C. pseudo-olitorius*, *C. tridens* and *C. trilocularis* having comparatively smaller leaves with low stomatal frequency (≤ 263/mm^2). While, group II comprised of two species viz., *C. capsularis*, *C. olitorius* with somewhat larger leaves and high stomatal frequency (≥ 416/ mm^2).

Within group I, *C. trilocularis* was distinct from other species due to mixed and opposite 3° vein category. Similarly, *C. fascicularis* was characterized by oblong, oblong-lanceolate lamina and anomocytic stomata. The other 4 species i.e., *C. aestuans*, *C. depressus*, *C. pseudo-olitorius* and *C. tridens* were grouped in one subgroup. Among them, *C. aestuans* and *C. pseudo-olitorius* formed a clade and were characterized by ovate lamina and paracytic stomata. While, the other two species *C. depressus* and *C. tridens* formed a sub-clade and were characterized by crenate margin and by a straight tooth apex. However, these two species differed by the absence and presence of awns. Awns were absent in *C. aestuans* and present in *C. pseudo-olitorius*. The species of the other sub-clade differed from each other by the shape of stomatal aperture. Apertures were elliptic in C. depressus while oblong apertures in *C. tridens*.

Group II comprised of *C. capsularis* and *C. olitorius*. These species can be differentiated on the basis of 1° teeth order in *C. capsularis* while 2° teeth order in *C. olitorius.* These two species also showed close affinity in gross morphology as well as leaf micro-characteristics (Ya *et al*., 2007; Fawzi, 2018).

Considering the ongoing discussion, it is clear that different leaf characters like phyllotaxy, petiole length, lamina size, symmetry and shape, blade class, apex and base with angle, leaf margin and vein categories were numerically analyzed for the *Corchorus* species, the affinities may be well correlated with the foliar macro and micro-morphological features.

Table 3. List of characters scored for cluster analysis of the *Corchorus* species.

S. No.	Characters description
	Leaves Organization
1.	Simple: Absent (0), present (1)
	Leaves attachment
2.	Alternate: Absent (0), present (1)
	Leaves lobation
3.	Unlobed: Absent (0), present (1)
	Petiole Characters
4.	Stipulate: Absent (0), present (1)
5.	Length (mm)
6.	Base swollen: Absent (0), present (1)
7.	Hairy: Absent (0), present (1)
	Leaf Base
8.	Cuneate: Absent (0), present (1)
9.	Obtuse: Absent (0), present (1)
10.	Truncate: Absent (0), present (1)
11.	Awn: Absent (0), present (1)
12.	Symmetrical: Absent (0), present (1)
13.	Asymmetrical: Absent (0), present (1)
14.	Slightly asymmetrical: Absent (0), present (1)
	Lamina symmetry
15.	Symmetrical: Absent (0), present (1)
16.	Asymmetrical: Absent (0), present (1)
17.	Slightly asymmetrical: Absent (0), present (1)
	Lamina Shape
18.	Ovate: Absent (0), present (1)
19.	Lanceolate: Absent (0), present (1)
20.	Elliptic: Absent (0), present (1)
21.	Oblong: Absent (0), present (1)
22.	Oblong-lanceolate: Absent (0), present (1)
23.	Ovate-lanceolate: Absent (0), present (1)
24.	Lamina length (mm)
25.	Lamina width (mm)
	Blade class
26.	Leptophyll: Absent (0), present (1)
27.	Nanophyll: Absent (0), present (1)
28.	Microphyll: Absent (0), present (1)
29.	Mesophyll: Absent (0), present (1)
	Leaf Margin
30.	Serrate: Absent (0), present (1)
31.	Crenate: Absent (0), present (1)
	Teeth Order
32.	1°: Absent (0), present (1)
33.	2°: Absent (0), present (1)
	Teeth apical side
34.	Concave: Absent (0), present (1)
35.	Straight: Absent (0), present (1)
36.	Flexous: Absent (0), present (1)
	Teeth basal side
37.	Concave: Absent (0), present (1)
38.	Straight: Absent (0), present (1)
39.	Convex: Absent (0), present (1)
	Leaf Apex
40.	Actue: Absent (0), present (1)
41.	Obtuse: Absent (0), present (1)
	1° leaf venation
42.	Acrodromus: Absent (0), present (1)
	2° leaf venation
43.	Craspedodromus: Absent (0), present (1)
	3° leaf venation
44.	Mixed: Absent (0), present (1)
45.	Opposite: Absent (0), present (1)
46.	Percurrent: Absent (0), present (1)
47.	Random reticulate: Absent (0), present (1)
48.	Regular polygonal reticulate: Absent (0), present (1)
49.	Alternate percurrent: Absent (0), present (1)
	Stomata
	Stomatal types
50.	Paracytic: Absent (0), present (1)
51.	Anisocytic: Absent (0), present (1)
52.	Tetracytic: Absent (0), present (1)
53.	Anomocytic: Absent (0), present (1)
	Location
54.	At the level of epidermal cells: Absent (0), present (1)
55.	**Frequency (f)**
56.	**Stomatal length (µm)**
57.	**Stomatal width (µm)**
	Stomatal aperture
58.	Oblong: Absent (0), present (1)
59.	Linear: Absent (0), present (1)
60.	Elliptic: Absent (0), present (1)
61.	Lanceolate: Absent (0), present (1)
62.	**Aperture length (µm)**
63.	**Aperture width (µm)**
	Leaf Indumentum
64.	Hair: Absent (0), present (1)
65.	Eglandular: (1), Glandular: (2)
	Trichome type
66.	Unicellular: (1), Multicellular: (2)
67.	**Trichome length (µm)**
	Trichome head
68.	Peltate

References

Al-Snafi, A.E. 2016. The contents and pharmacological importance of *Corchorus* capsularis-A review. *IOSR J. Pharm*., 6(6): 58-63.

Anderberg, A.A. 1989. Phylogeny and reclassification of the tribe Inuleae (Asteraceae). *Can. J. Bot*., 67(8): 2277-2296.

Anonymous. 2003. APG (Angiosperm Phylogeny Group) II. An update of the angiosperm phylogeny group for the orders and families of flowering plants. *Bot. J. Linn. Soc.*, 141: 435.

Ash, A., B. Ellis, L.J. Hickey, K. Johnson, P. Wilf and S. Wing. 1999. *Manual of leaf architecture*. Smithsonian Institution: Washington.

Ather, A., R. Abid and M. Qaiser. 2013. The seed atlas of Pakistan-IX. Orobanchaceae, *Pak. J. Bot*., 45(5): 1677-1692.

Benor, S. 2018. Molecular phylogeny of the genus *Corchorus* (Grewioideae, Malvaceae s.l.) based on nuclear rDNA ITS sequences. *The Crop J.*, 6(5): 552-563.

Blackmore, S. 1981. Palynology and intergeneric relationships in subtribe Hyoseridinae (Compositae: Lactuceae). *Bot. J. Linn. Soc.*, 82(1): 1-13.

Bremer, K. 1994. Asteraceae: Cladistics and Classification. Portland, Timber Press.

Dilcher, D.L. 1974. Approaches to the identification of angiosperm leaf remains. *The Bot. Rev.*, 40(1): 1-157.

Ettingshausen, C.F. 1861. *The leaf-skeletons of the dicotyledons:* with special reference to the study and determination of the fossil plant remains. KK Hof- und Staatsdruckerei.

Fawzi, N.M. 2018. Seed morphology and its implication in classification of some selected species of genus *Corchorus* L. (Malvaceae). *Mid. East J. Agri. Res.*, 7(1): 1-11.

Ghafoor, A. 1974. Tiliaceae. In: (Eds.): Nasir, E. and S.I. Ali. *Flora of Pakistan*. (No. 75, pp. 1-14). Department of Botany, University of Karachi.

Ghosh, R.K., A. Wongkaew, T. Sreewongchai, S. Nakasathien and C. Phumichai. 2014. Assessment of genetic diversity and population structure in jute (*Corchorus* spp.) using simple sequence repeat (SSR) and amplified fragment length polymorphism (AFLP) markers. *Agri. Nat. Res.*, 48(1): 83-94.

Hickey, L.J. 1973. Classification of the architecture of dicotyledonous leaves. *Amer. J. Bot.*, 60(1): 17-33.

Anonymous. 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

Kanwal, D., R. Abid and M. Qaiser. 2015. The Seed Atlas of Pakistan-XII. Nyctaginaceae. *Int. J. Biotechnol*., 12(3): 447-456.

Kumari, N., S.B. Choudhary, H.K. Sharma, B.K. Singh and A.A. Kumar. 2019. Health-promoting properties of *Corchorus* leaves: A review. *J. Herb. Med.*, 15: 100240.

Laraño, A.A.P. and Jr. Buot. 2010. Leaf architecture of selected species of Malvaceae Sensu APG and its taxonomic significance. *Philip. J. Syst. Biol.*, 4: 21-54.

Linnaeus, C. 1753. Species Plantarum. (Vol. 1. pp. 529-530). London, British Museum (Natural History).

Melville, R. 1969. Leaf venation patterns and the origin of the angiosperms. *Nature*, 224(5215): 121-125.

MetCalfe, C.R. and L. Chalk. 1950. Anatomy of the Dicotyledons (Vol. 1). Oxford, Clarendon Press.

Ornduff, R. and T.J. Crovello. 1968. Numerical taxonomy of Limnanthaceae. *Amer. J. Bot.,* 55(2): 173-182.

Roth-Nebelsick, A. 2001. Evolution and Function of Leaf Venation Architecture: A Review. *Ann. Bot.*, 87(5): 553-566.

Vârban, R., D. Vârban and I. Crișan. 2021. Leaf micromorphology of jute (*Corchorus olitorius* L.) in conditions from Cluj County. Scientific Papers. Series B. Horticulture, 65(2).

Vasco, A., M. Thadeo, M. Conover and C. Douglas. 2014. Preparation of samples for leaf architecture studies, a method for mounting cleared leaves. *Appl. Plant Sci.*, 2(9):

Ya, T., M.G. Gilbert and L.J. Dorr. 2007. In: (Eds.): Wu, Z.Y., P.H. Raven & D.Y. Hong. Flora of China. Vol. 12 (Hippocastanaceae through Theaceae). Science Press, Beijing, and Missouri Botanical Garden Press, St. Louis.

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