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Comparative foliar morphological and palynological studies of Cleomaceae of Assam, India

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Abstract. *Das B, Roy S, Kalita S, Boro KK, Nath M, Nath N. 2022. Comparative foliar morphological and palynological studies of Cleomaceae of Assam, India. Biodiversitas 23: 2920-2934.* The Cleomaceae is a well-known angiospermic family. There is no record of extensive study on the members of the family Cleomaceae in the state of Assam. Though the species *Cleome houtteana* is found abundantly in the studied area, it was not reported in any of the major floristic works of the region and it was misidentified as *Gynandropsis gynandra* by many of the earlier workers. So, the present work was carried out to do a detailed comprehensive study on the morphology, foliar macro and micro-morphology (epidermis, stomata, and trichome), leaf venation pattern, along with palynological characters of the four species of Cleomaceae viz. *Gynandropsis gynandra*, Cleome houtteana, *Sieruela rutidosperma*, and *Arivela viscosa* of Assam, India. These species show similarities with each other, but can be well differentiated using the studied characters here. Detailed taxonomic descriptions have been given along with relevant information and color photographs for the correct identification of all four different species.

Keywords: Assam, Cleomaceae, India, morphology, palynology

INTRODUCTION

Cleomaceae is one of the closest relatives of Brassicaceae, it is also known as 'Sister of the Crucifers' and 'Spider flower family'. The family comprises 17 genera and about 150 species (Zhang and Tucker 2008). According to POWO, the family comprises 2 genera and 223 species. The survey of India (BSI) has reported five genera and 16 species from all over India. In Assam, Barooah and Ahmed (2014) have enlisted one genus with five species so far.

The members of the genus *Cleome* are used in traditional medicines by ethnic people around the world (Burkill 1985; Mnzava and Ngwerume 2004; Schippers 2000). The various species of the *Cleome* genus contain beneficial pharmacological activities and their chemical compounds have valuable research topics for the researchers (Aparadh and Karadge 2010). Kanjilal and his co-workers reported the species under the family Capparidaceae with five genera and 14 species. They had reported only *Arivela viscosa* under the *Cleome* genus and described *Gynandropsis gynandra* as *G. pentaphylla.* Choudhury (2005), Barooah and Ahmed (2014) mentioned five species of the genus *Cleome* - *C. angustifolia*, *C. burmanii*, *C. gynandra*, *C. rutidosperma*, and *C. viscosa* in their book "Assam's Flora". But *C. angustifolia* is not found in this region and there is no record at ASSAM (Botanical Survey of India, Eastern Regional Circle, Shillong) herbaria. Recent taxonomic studies and changes in nomenclature report that *C. burmanii* is not a species but a variety of *Sieruela rutidosperma*. *C. houtteana* is widely found in damp areas. but it is misidentified as *G. gynandra* by various authors. There are few nomenclatural shifting of the genus *Cleome* done by workers like Barrett et al. (2017), Arigela et al. (2021).

Workers like Hall et al. (2002); Kers (2003); Patchell et al. (2011) studied the floral pattern and monosymmetry of the family Cleomaceae. The *Cleome* genus shows many variations in terms of foliar characteristics (Jafri 1973). Morphological characters, including foliar characteristics, are being used to delimit the *Cleome* genus by various taxonomists (Hooker f., 1875; Hutchinson and Dalziel 1959; Blakelock and Townsend 1980; Thulin 1993; Tucker and Vanderpool 2010). Bhattacharya and Maiti (1978) analyzed the morphology of seeds of 12 *Cleome* species and developed a taxonomic key based only on seed morphology. Micromorphological studies of the genus *Cleome* were done by various workers like Jelani (1990); Okonwu et al. (2017); Sowunmi et al. (2018). Aleykutty & Inamdar (1978) described stomatal features of eight species of the genus *Cleome* included in Capparidaceae. Joshi (2015) studied the stomatal type in. *viscosa*. Workers like Puri (1971); Aleykutty & Inamdar (1978); Jelani et al. (1990); Jansen (2004) studied and described trichomes in different *Cleome* species. Marshall et al. (2007) studied the vein densities of various *Cleome* species. Mitra (1970); Ruiz et al. (1997); Maria et al. (1998); Edeoga et al. (2009) studied the pollen of the genus *Cleome*. Melitopalynological studies by Fagundez (2003) reported the presence of *C. houtteana* pollen in honey samples for the first time; it showed the importance of the *Cleome* species in the production of honey.

There is no record of extensive study on the members of Cleomaceae *of this state of Assam;* it is only mentioned in some notable floristic works of the region. There is no mention of *C. houtteana* in those works and it is misidentified as *G. gynandra* till today by many workers. So, the present work was carried out to do a detailed, comprehensive study on the taxonomy, morphology, foliar macro and micro-morphology, leaf venation, and palynology of the members of the family Cleomaceae in Assam, India.

MATERIALS AND METHODS

Study site: The state of Assam is the center of the North-Eastern region of the Indian Sub-continent. It is located between 22˚19´ N to 28˚16 ´ N latitude and 89˚42´ E to 96˚30´E longitude. It comprises of 34 districts untill today. The total area of the state is 78,438 km^2 (Figure 1).

An extensive field survey was carried out from October 2019 to March 2021. The four species of the genus *Cleome* can be diagnosed for their floral morphology and for their herbaceous habit. *Cleome houtteana*, *S. rutidosperma* and *A. viscosa* are found throughout the state. But *G. gynandra* is found only in some specific districts such as Dibrugarh, Dhemaji, Sivsagar, Lakhimpur and Jorhat.

Preparation of voucher specimen: Photographs were taken of different floral parts for compiling the taxonomic photo plates. By following standard herbarium techniques by Jain and Rao (1977) voucher specimens were prepared. The voucher specimens were then deposited at GUBH (Gauhati University).

The voucher specimens were identified by following various taxonomic literature and comparing them at ASSAM and GUBH. The specimens were also compared with herbarium microfilms available online by KEW & NYBG. For valid nomenclature, various literature were followed and finally confirmed with the online database of "POWO: Plants of the World Online".

Foliar morphology: Foliar morphology possesses many specific characteristics that provide taxonomic statements. "Manual of Leaf Architecture" by Hickey (1999) was followed for describing various foliar macro-morphological characters. Characters like epidermis, type of stomata, the shape of stomata, stomatal index and frequency, area of guard cell, type of trichome, and trichome density were studied thoroughly by following the slightly modified methods of Boulos and Beakane (1971).

For the study of epidermal characteristics, peeling is a must. Due to the herbaceous nature of these specimens, normal peeling was not possible. For this, mature leaves were collected and submerged in 10% aq. Nitric Acid (HNO_3) solution for 24 hours. Peeling was done on both surfaces with the help of a brush or forceps, whichever is convenient. The peels were stained with the Safranin. Then peels of the specific surface were mounted on separate slides with 50% glycerin and then sealed with DPX. For proper epidermal cell counting, peels were made 1 mm^2 and studied under 40X magnification under the compound microscope. From this, stomata and trichomes were also enumerated for both surfaces specifically.

The average size of epidermal cells was measured by taking the mean value of three random readings. The epidermal characters were described through the terminology given by Stace (1965). Stomata and trichomes were measured through Scanning Electron Microscopy at Department of Chemistry, Gauhati University.

The absolute number of stomata was calculated by following the formula provided by Gupta (1961).

Stomatal frequency: This was calculated by using the formula of Ghose and Davis (1973).

$$S.F. = \frac{\text{Number of stomata per field (S)}}{\text{Area of the field (A)}}$$

Stomatal index: By following the formula given by Dilcher (1974) stomatal index was calculated.

$$\mathbf{S}.I = \frac{\text{Number of stomata per field}}{\text{Epidermal cell + stomata per field}} \times 100$$

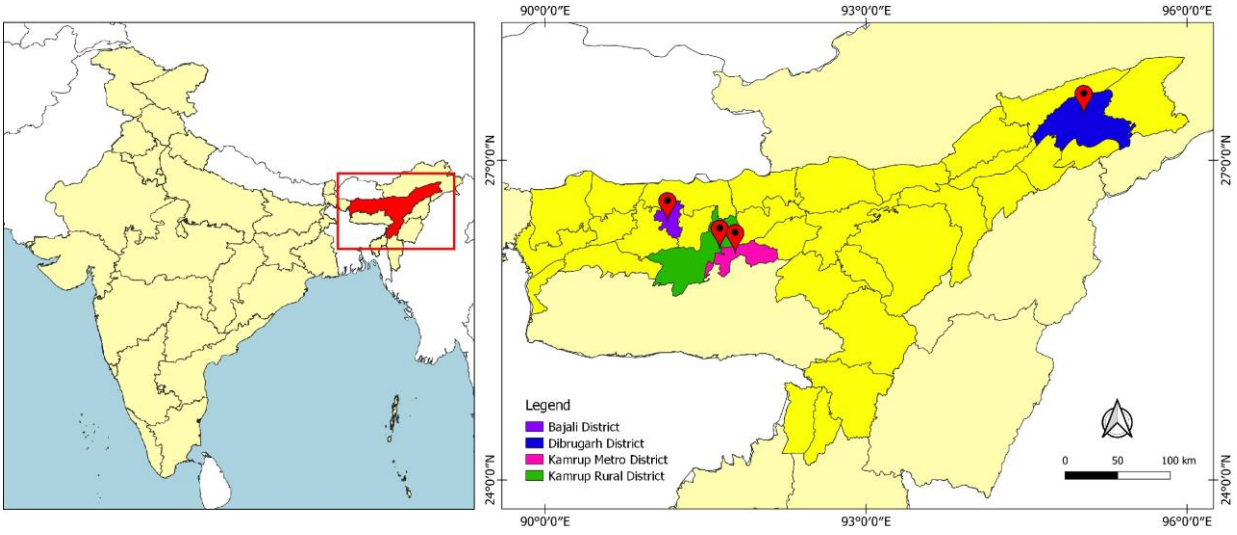

Figure 1. Map of study site in Assam State, India, such as Bajali, Dibrugarh, Kamrup Metro, and Kamrup Rural.

For trichome frequency and trichome index, the same above formula has been applied by replacing number of stomata per field with number of trichome per field.

Leaf venation: Leaf venation was studied and described with the help of "Manual of Leaf Architecture" by Hickey (1999). For this, epidermis from both sides were carefully removed. The veins were then stained with 1% safranin and observed under 10x magnification of compound microscope (if necessary) for better observation as the leaves were very minute.

Palynology: For the palynological study, pollen samples were taken from flowers before complete anthesis. Slides were put together with silica gel for moisture absorption. The pollens were then studied under SEM, measurements were recorded and morphology was studied thoroughly.

RESULTS AND DISCUSSION

Taxonomic enumeration

Gynandropsis gynandra (L.) Briq., Conserv. Jard. Bot. Geneve 17:382 (1914); *Cleome gynandra* L., Species Plantarum, 2: 671 (1753); Grierson & Long, Flora of Bhutan, 1 (2): 416 (1984); Raghavan in Balakrishnan (ed.), Flora of India, 2: 309 (1993); *Cleome pentaphylla* (Linn.) Linn., Species Plantarum (ed. 2), 938 (1763); *Gynandropsis pentaphylla* (L.) DC., Prodr., 1: 238 (1824); Hooker f. & Thomson, Flora of British India, 1: 171 (1872).

Annual herb; stem erect, branched, aromatic, all parts glandular- puberulous; leaves alternate, palmately compound, leaflets 3-5, commonly five leaflets, petiole with glandular hairs and swollen base, 2-9 cm long; leaflet size 1.5-8 x 1-4 cm, middle leaflet symmetrical and largest, lateral leaflets with asymmetrical base; apex shape convex, base cuneate-complex, leaflets unlobed, margin entire or finely toothed/rounded, venation pinnate; inflorescence terminal, determinate racemes, elongated, showy; flowers complete, bisexual, zygomorphic, hypogynous, pedicellate, pedicel glabrous, 2-3 cm long, subtended by bracts, bracts foliaceous, simple above, trifoliate below, smaller than foliar leaves; sepals 4, free, glandular, narrowly ovate to lanceolate, apex acute, green in color, 0.3-0.9 x 0.1-0.3 cm, glandular-pubescent; petals free, 4, whitish, clawed, equal or unequal. 1.1- 2 x 0.2-0.5 cm, oval-spathulate, tip rounded; androgynophore 1-3 cm long, stamens 6, filaments slender, purple in color, 1-2 cm long, anthers oblong, linear, yellow, 0.1-0.3 cm long; gynophore 1-2.2 cm long, sessile ovary, style short, 0.12-0.15 cm long, stigma capitate, ovary unilocular, bicarpellary-syncarpous, parietal placentation, presence of false septum; fruit capsule, silique, spindle in shape, 5-14 x 0.3-0.5 cm, tapering at both ends; seeds numerous, sub-orbicular, black, 0.12-0.16 cm in diameter, narrow seed cleft. (Figure 2)

Vernacular name: Bhutmula (Assamese); African Spider flower, Cat whiskers (English).

Flowering and fruiting: Throughout the year.

Ecology: A roadside weed. Also found in waste places and sandy banks of a river.

Geographical distribution: An old world species. It is native to tropical and subtropical regions.

Cleome houtteana Schltdl., Linnaea 24(6): 669 (1851); *Cleome hassleriana* Chodat, Bull. Herb. Boissier 6:12 (1898); *Tarenaya hassleriana* (Chodat) Iltis, Novon 17:450 (2007).

Annual or perennial herb, upto 1.2-1.5 m tall; stems erect, glandular-pubescent, occasionally spiny, longitudinally grooved; leaves alternate, palmately compound, 3-7 leaflets, stem glandular-pubescent, branched, petiole long, glandular, one pair of stipular spine at the base of each petiole, 3-7 cm long; leaflets 2.5-9 x 1.0- 2.5 cm, elliptical-oblanceolate, both surface glandular, middle leaflet symmetrical and largest, laterals with asymmetrical base; apex shape straight; apex angle acute; base complex, base angle acute, leaflets unlobed, margin serrate, spines in the midrib of abaxial surface; inflorescence terminal racemes, 20- 35 cm long; flowers showy, bisexual, complete, zygomorphic, pedicellate, pedicel glandular-pubescent, 3-5 cm long, subtended by folious bracts; bracts smaller than the foliage leaves, 1-2 x 0.5-1.1 cm; calyx 4, 0.7-1.4 x 0.2 cm, free, valvate, greenish in colour, glandular, linear to lanceolate in shape, apex acuminate, persistent; Petals 4, free, 3-4.8 x 1.5-2.8 cm, pink to whitish in colour, clawed, claw slender, ovate to oblong in shape; androphore absent, stamen 6, filaments purple to pinkish in colour, 4-4.8 cm long, anthers yellow, bithecous, oblong, 0.5-1.0 cm long; gynophore 3-7.2 cm long, style slender or absent, stigma capitate, placentation parietal, anatropous ovule, unilocular; fruit capsule, spindle shaped, beaked, 6-9.5 x 0.3-0.5 cm; seeds numerous, reniform or sub-spherical, spiny ornamentation, 0.2- 0.24 cm in diameter, seed cleft narrow. (Figure 3)

Vernacular name: Xial-kotohiya (Assamese); Spider flower (English)

Flowering and fruiting: February to May.

Ecology: Mostly found in moist and shady places.

Geographical distribution: A new world species. It is native to neotropical regions.

Sieruela rutidosperma (DC.) Roalson & J.C.Hall, Syst. Bot. 42:938 (2017); *Cleome rutidosperma* DC., Prodr. 1: 241 (1824); B.D. Sharma (edt.) Flora of India, 2: 313 (1993); Ghosh & Prasad JBNHS. 67(1): 129, (1970); Chowdhury et al. 187 (2005); *Sieruela rutidosperma* (DC.) Roalson & J.C. Hall, Syst. Bot. 42: 938 (2017).

Annual herb; stem erect or procumbent or trailing, striate or sparsely setulose to pubescent, well branched; white soft hairs all over the plant; leaves alternate, compound, trifoliate, petiolate, petiole with u-shaped furrow, 2.5-3.5 cm long, petiole marginally attached with slightly swollen base, exstipulate, leaflets lanceolate to rhomboidal-elliptical, middle leaflet symmetrical and larger, side ones smaller with asymmetrical base; apex shape straight, apex angle acute; base cuneate-convex, base angle acute, leaflets unlobed, margin obscurely crenullate to serrulate, sinus round, leaflet 2-4 x 1-1.8 cm in size; inflorescence lax terminal racemes; flowers complete, zygomorphic, hypogynous, pedicellate, pedicel 1-3 cm long; bracts resemble the foliage leaves; sepals 4, free, apex caudate, sparsely pubescent and glandular, narrowly

lanceolate,0.3-0.5 x 0.1-0.15 cm; petals 4, free, purplish-bluish in color, 0.9- 1.5 x 0.25- 0.3 cm, mucronate with basal claw of 1/3 length; androphore absent, stamens 6 incurved towards posterior side, different in length, posterior 4 of 0.5 cm long, anterior 2 of 0.8 cm long, filament slender, anthers bluish, 0.15-0.25 cm long; gynophore very short, 0.15-0.2 cm long, ovary linear and glandular, style short or absent, stigma capitate, 0.6-1.0 cm; fruit capsule, ellipsoid, glabrous with a persistent style modified to beak, 4-6.5 x 0.2-0.4 cm; seeds numerous, subglobose, 0.1- 0.15 cm in diameter, dark brown to black in color, white elaiosome present (Figure 4).

Vernacular name: Soru hurhuri, Neel-bon (Assamese); Fringed Spider flower (English).

Flowering and fruiting: Throughout the year.

Ecology: A weed found in disturbed places. It is also found in roadside areas, and cultivated lands.

Geographical distribution: An old world species. It is cosmopolitan, mainly found in tropical areas.

Arivela viscosa (L.) Raf., Sylva Tellur.:110 (1838); *Cleome viscosa* L., Sp. Pl. 2: 672 (1753); Hooker f. & Thomson, FBI, 1: 170 (1872); Kanjilal et al. Flora of Assam, 1:72 (1934); Raghavan in Balakrishnan (ed.), Flora of India, 2: 318, (1993); Yadav & Sardesai, Flora of Kolhapur Dist., 44 (2002); Chowdhury et al. Assam's FIora, 187 (2005).

Erect annual herb, 40-90 cm tall; branched, stem angular & glandular, dense glandular hairs present all over the body, viscid; leaf alternate, compound, paltate, 3-7 leaflets, petiole marginally attached, glandular, 1.5-5 cm long; both surface of the leaflet glandular - hirsute, laminar shape obovate to elliptical, leaflets unequal in size, middle leaflet largest & symmetrical, side ones with asymmetrical base; apex shape straight, apex angle acute; base cuneate, base angle acute, leaflets unlobed, margin ciliate, sinus round, 1.5-4 x 1.2-1.5 cm; inflorescence racemes with few corymbose flowers, flowers complete, zygomorgic, hypogynous, pedicellate, pedicel 1-2.5 cm long, bracteate, bracts foliaceous smaller than foliage leaves, trifoliate; sepals 4, free, 0.5-0.8 x 0.1-0.3 cm, lanceolate, glandular, green, margin entire, base cuneate, persistent; petals 4, free, yellow in colour, subequal,0.8-1.2 x 0.3-0.5 cm, ovate-oblong, clawed, tips rounded, distinctly veined; androphore absent, stamens dimorphic, many (10-20), adaxial ones shorter, filaments filiform, 0.3-0.9 cm, anthers bithecous and linear, 0.1-0.3 cm, pollen tricolporate; gynophore absent, sessile ovary, pistil glandular, style 0.2-0.6 cm long, capitate stigma; fruit capsule, 3-9 x 0.2-0.4 cm, longitudinally ridged, glandular pubescent, hairy; seeds numerous, glabrous, spherically compressed, fine transverse ridges and longitudinal striations, 0.15-0.2 cm in diameter, brownish, cleft narrow (Figure 5).

Vernacular name: Atharua, Hurhuria (Assamese); Tickweed, Asian Spider flower, Yellow Spider flower (English).

Flowering and fruiting: Throughout the year.

Ecology: A roadside weed. Also found in Railway tracks and wasteland.

Geographical distribution: An old world species. It is distributed in tropical and subtropical regions.

Foliar macro-morphological studies

All the studied species contain compound leaves. Except for *S. rutidosperma* (trifoliate), the other 3 species have palmately compound leaves. *C. houtteana* has the largest leaves. The study species differ mainly in their leaf margins (Table 1).

Foliar micro-morphological studies

Epidermis

The epidermal cells of all the species are mostly polygonal in shape with undulate anticlinal walls (Figure 7). But only the abaxial epidermal cells of the species *G.gynandra* show a sinuous anticlinal cell wall. The number of epidermal cells per unit area is higher in the upper epidermis, and *C. houtteana* has the highest number of epidermal cells per unit area of the other 3 species (Table 2).

Table 1. Comparative foliar morphological characters of the studied species

Characters	***Gynandropsis gynandra***	***Cleome houtteana***	***Sieruela rutidosperma***	***Arivela viscosa***
Leaf arrangement	Alternate, Palmately Compound; 3-5 leaflets	Alternate, Palmately Compound; 3-7 leaflets	Alternate, Palmately Compound; 3 leaflets	Alternate, Palmately Compound; 3-7 leaflets
Petiole features and attachment	Base slightly swollen, Marginal	Base swollen, Marginal	Base slightly swollen, Marginal	Base not swollen, Marginal
Blade class	Microphyll	Notophyll, mesophyll	Micro-Nanophyll	Micro- nanophyll
Shape and symmetry of Lamina	Obovate-elliptical, Middle one symmetrical, side ones with asymmetrical base	Elliptical, Middle one symmetrical, lateral ones with asymmetrical base	Elliptical-oblong, Middle one symmetrical, side ones with asymmetric base	Obovate- elliptical, Middle one symmetrical, side ones with asymmetrical base
Laminar ratio	2:1	4:1	2:1	2:1
Apex angle and shape	Obtuse, convex	Acute, straight	Acute, straight	Acute, straight
Base angle and shape	Acute, cuneate-complex	Acute, complex	Acute, cuneate- convex	Acute, cuneate
Lobation	Unlobed	Unlobed	Unlobed	Unlobed
Margin type	Finely toothed	Serrate	Obscurely crenulate or serrulate	Ciliate
Sinus shape	Round	Angular	Round	Round
Tooth shape	Absent	Absent	Absent	Absent

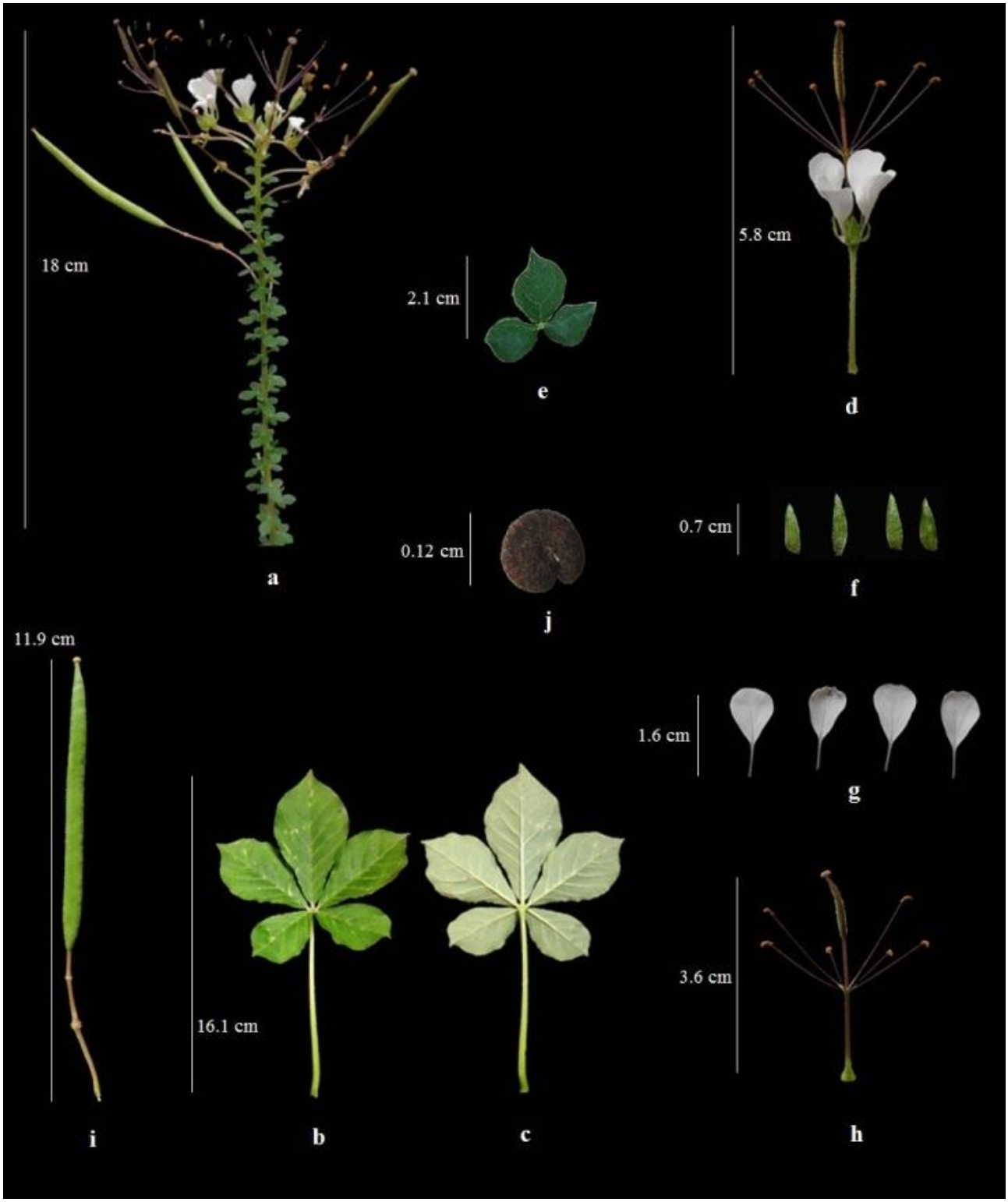

Figure 2. *Gynandropsis gynandra*: A. habit; B. leaf (adaxial view); C. leaf (abaxial view); D. complete flower; E. bract; F. sepals; G. petals; H. androgynophore; I. fruit; J. seed

Key to the species (based on morphology)

1a. Androphore present ..…… ***Gynandropsis gynandra***
1b. Androphore absent
2a. Gynophore present
3a. leaflets 3-7, stipular spine present ……
……..……..….. ***Cleome houtteana***
3b. leaflets trifoliate, stipular spine absent ……..…
…..……. ***Sieruela rutidosperma***
2b. Gynophore absent …… ***Arivela viscosa***

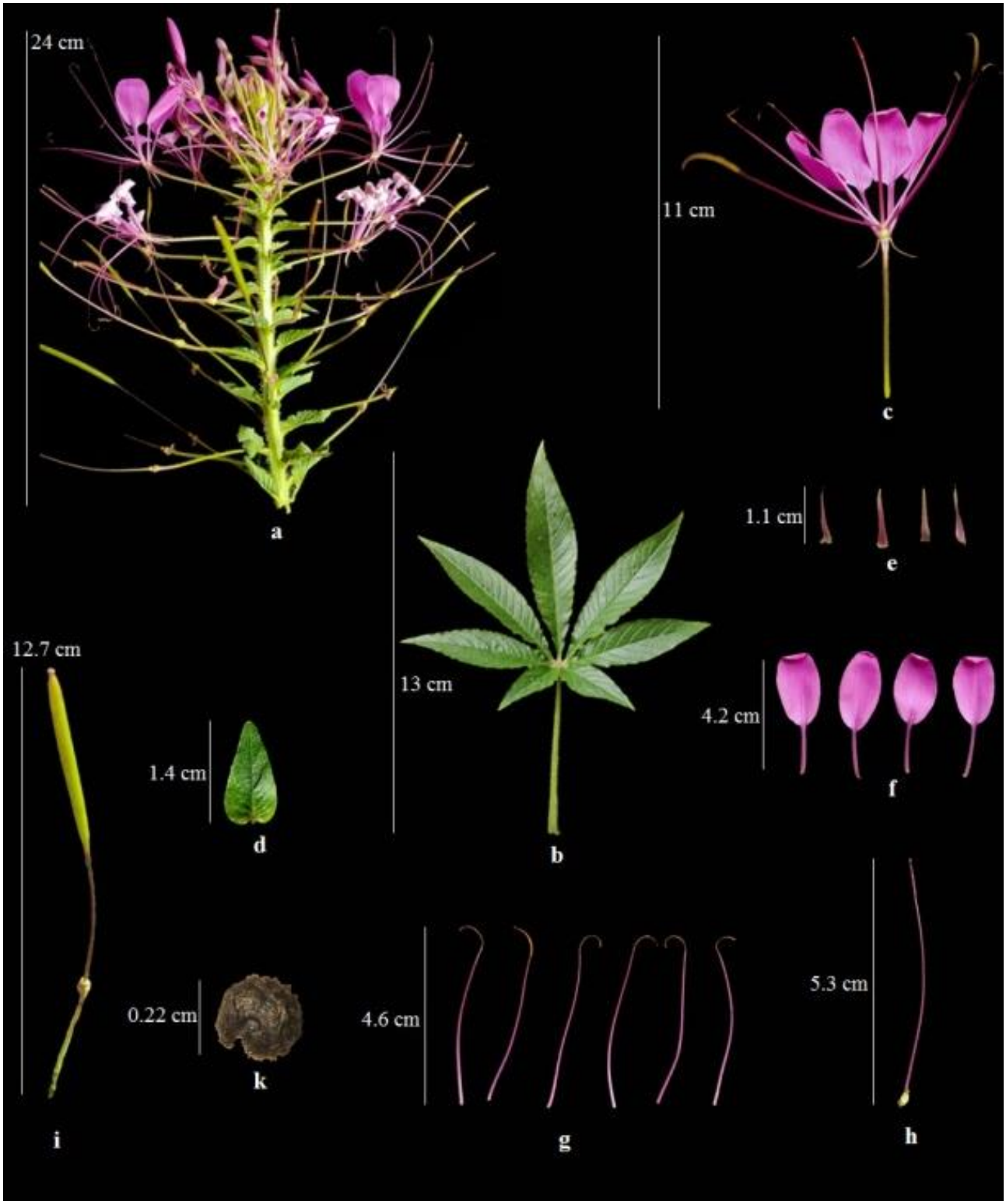

Figure 3. *Cleome houtteana*: A. habit; B. leaf (adaxial view); C. complete flower; D. bract; E. sepals; F. petals; G. stamens; H. gynoecium; I. fruit; J. seed

Stomata

In the study, 7 different stomatal types have been observed (Figure 7-8). Anomocytic and Anisocytic types of stomata are found to be common in all the studied species. The stomatal index is higher on the lower surface in comparison to the upper surface of all the species. *A. viscosa* shows the highest stomatal index (abaxial surface), while *S. rutidosperma* shows the lowest one (abaxial surface) (Table 3).

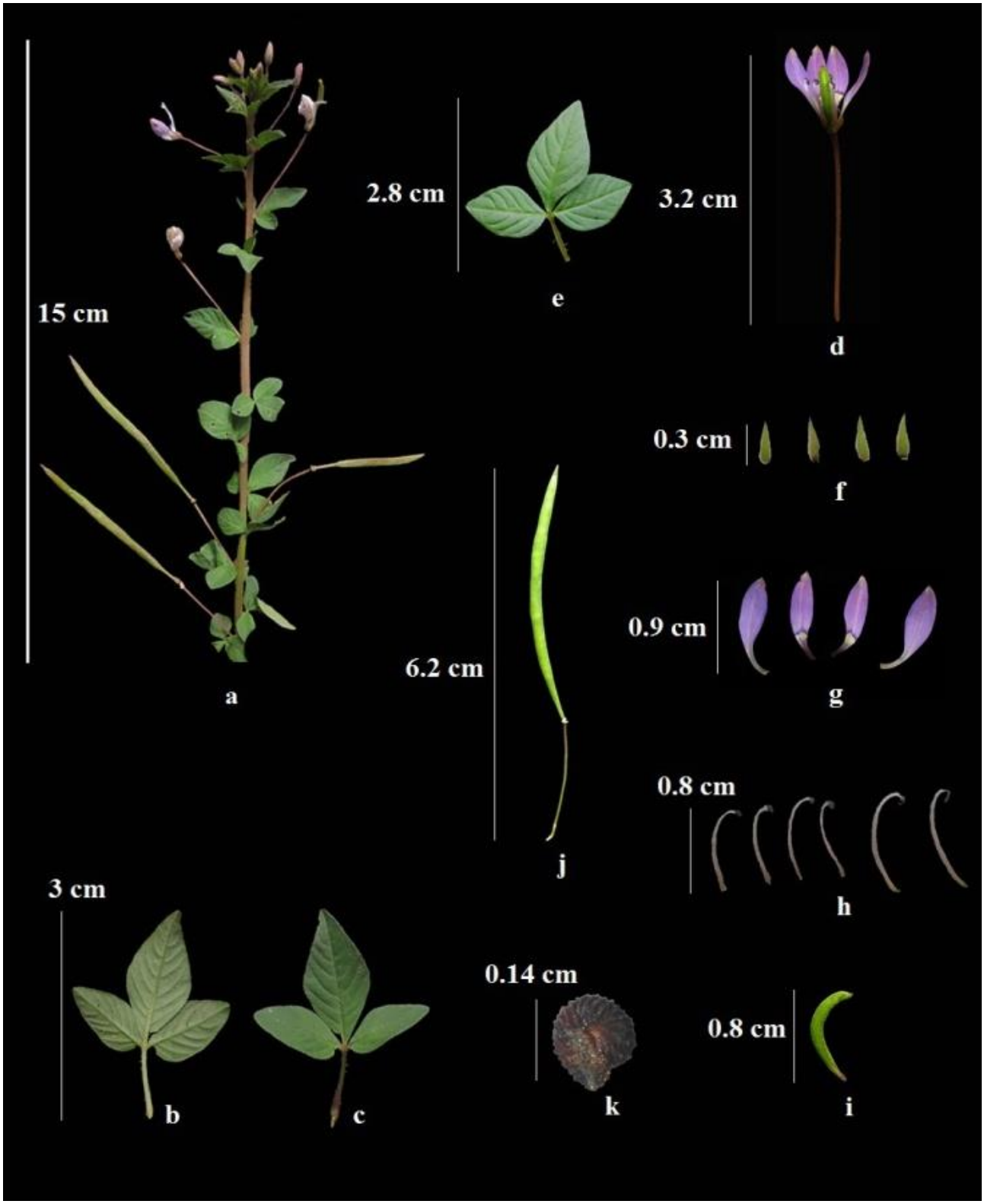

Figure 4. *Sieruela rutidosperma*: A. habit; B. leaf (adaxial view); C. leaf (abaxial view); D. complete flower; E. bract; F. sepals; G. petals; H. stamens; I. gynoecium; J. fruit; K. seed

Trichomes

All the species contain glandular, multicellular trichomes which make them sticky in nature (Figure 9). It is interesting to note that *A. viscosa* shows the highest trichome index which is the cause behind its excessive viscous nature. On the other hand *G. gynandra* shows the lowest trichome index (Table 4).

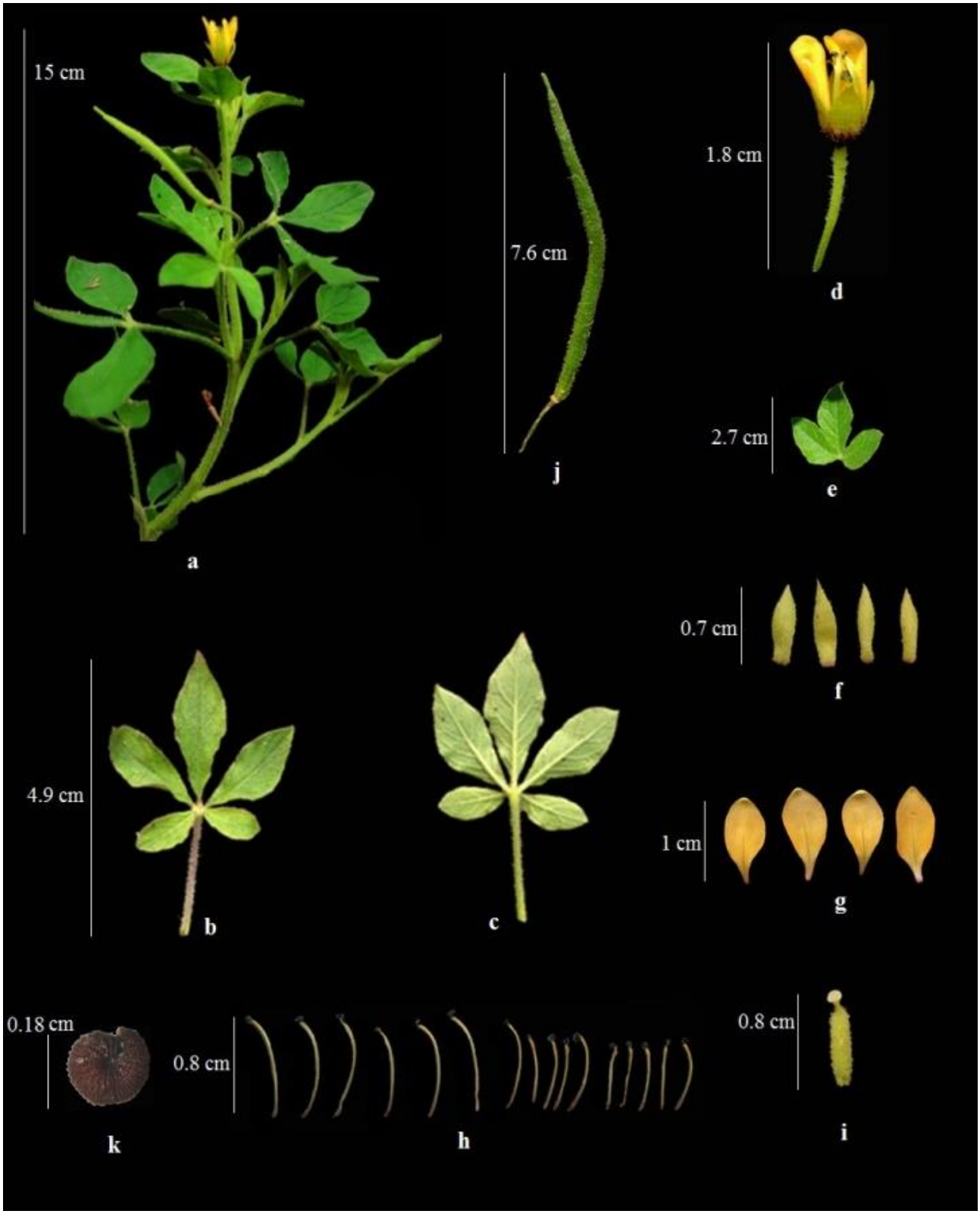

Figure 5. *Arivela viscosa*: A. habit; B. leaf (adaxial view); C. leaf (abaxial view); D. complete flower; E. bract; F. sepals; G. petals; H. stamens; I. gynoecium; J. fruit; K. seed

Leaf venation

All 4 species show primary pinnate venation, but they differ in other secondary, tertiary, or even further minute venations (Figure 10-13). As no such comparative study of venation patterns was done earlier, in the present study, a dichotomous key is also provided for delimiting the related taxa (Table 5).

Palynology

The pollens of the studied species are similar in terms of their shape and aperture type while they mainly differ in size and exine ornamentation (Figure 14). All four species have tricolporate aperture. They fall under Minutae (10-25 µm**)** and Mediae (25-50 µm**)** class of Pollen based on the length of the longest axis (Erdtman 1945) (Table 6).

Table 2. Dimension of epidermal cells in studied the studied species

Species	Surface	Epidermal cells				
		Anticlinal cell wall shape	Average length of epidermal cell	Average breadth of epidermal cell	Average no. of epidermal cell per mm^2	L/H
Gynandropsis gynandra	Abaxial	Sinuous	82.517	28.523	270	2.893
	Adaxial	Undulate	47.167	43.6	480	1.082
Cleome houtteana	Abaxial	Undulate	28.527	26.49	360	1.077
	Adaxial	Round or slightly undulate	36.983	26.893	755	1.375
Sieruela rutidosperma	Abaxial	Undulate	45.233	22.413	305	2.018
	Adaxial	Round or slightly undulate	32.6	32.09	525	1.016
Arivela viscosa	Abaxial	Slightly undulate	25.713	16.63	335	1.546
	Adaxial	Slightly undulate	27.177	15.62	585	1.739

Table 3. Dimensions of stomata in the studied species

Species	Surface	Stomata			Guard cell area		Types of stomata
		Absolute no. of stomata (millions)	Stomatal frequency stomata/mm^2	Stomatal index	Length	Wide	
Gynandropsis gynandra	Abaxial	0.19845936	121	30.946	13.23	5.891	Anomotetracytic, Brachyparatetracytic, Anomocytic, Anisocytic
	Adaxial	0.14269392	87	18.125	14.26	7.046	Anomotetracytic, Brachyparatetracytic, Anomocytic, Anisocytic, Paratetracytic
Cleome houtteana	Abaxial	0.60069922	491	57.697	15.48	7.205	Anomotetracytic, Anomocytic, Anisocytic, Paratetracytic
	Adaxial	0.39883492	326	30.157	14.76	7.543	Anomotetracytic, Anomocytic, Anisocytic, Diacytic
Sieruela rutidosperma	Abaxial	0.08411175	225	42.453	19.67	12.70	Anomotetracytic, Anomocytic, Anisocytic, Paratetracytic
	Adaxial	0.02766342	74	12.354	19.85	11.72	Anomotetracytic, Anomocytic, Anisocytic, Paratetracytic, Staurocytic
Arivela viscosa	Abaxial	0.08560992	484	59.096	17.59	21.43	Anomocytic, Anisocytic, Paratetracytic, Anomotetracytic
	Adaxial	0.03307656	187	24.223	11.18	11.42	Brachyparatetracytic, Anomocytic, Anisocytic

Table 4. Dimensions of trichomes in the studied species

Species	Surface	Trichome frequency (mm^2)	Trichome index	Trichome length µm	Trichome breadth µm	L/B	Type
Gynandropsis gynandra	Abaxial	3	1.099	158.4	26.47	5.98	Glandular
	Adaxial	1	0.208	237.8	29.90	7.95	Glandular
Cleome houtteana	Abaxial	6	1.639	137.68	27.65	4.98	Glandular
	Adaxial	16	2.075	238.4	40.42	5.9	Glandular
Sieruela rutidosperma	Abaxial	8	2.556	141.6	29.40	4.82	Glandular
	Adaxial	12	2.235	201.8	50.06	4.03	Glandular
Arivela viscosa	Abaxial	14	2.337	135.4	51.41	2.63	Glandular
	Adaxial	38	10.188	161.7	49.36	3.28	Glandular

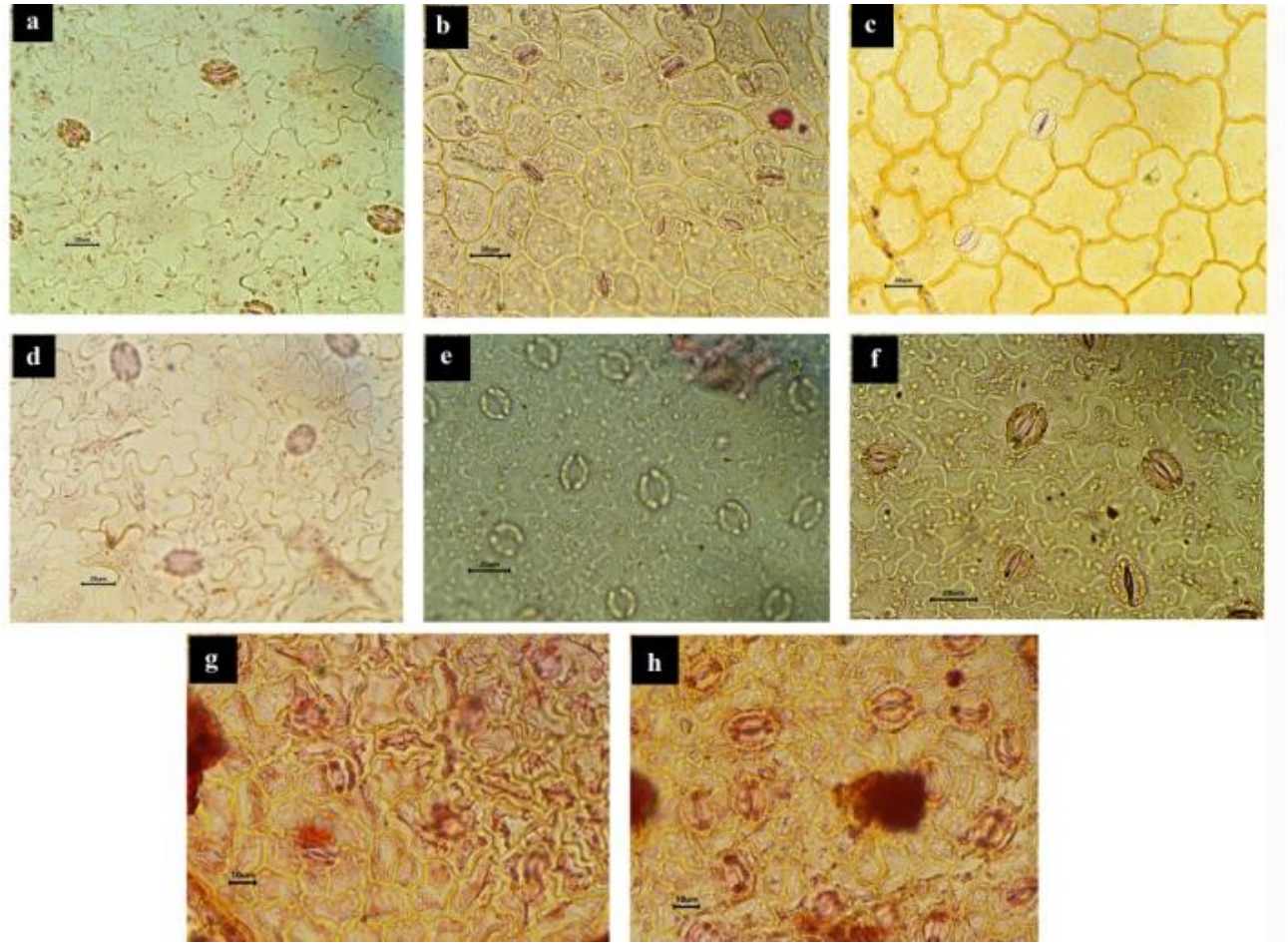

Figure 6. Epidermis*; G. gynandra,* A. upper, D. lower); *C. houtteana,* B. upper, E. lower; *S. rutidosperma,* C. upper, F. lower); *A. viscosa*, G. upper), H. lower

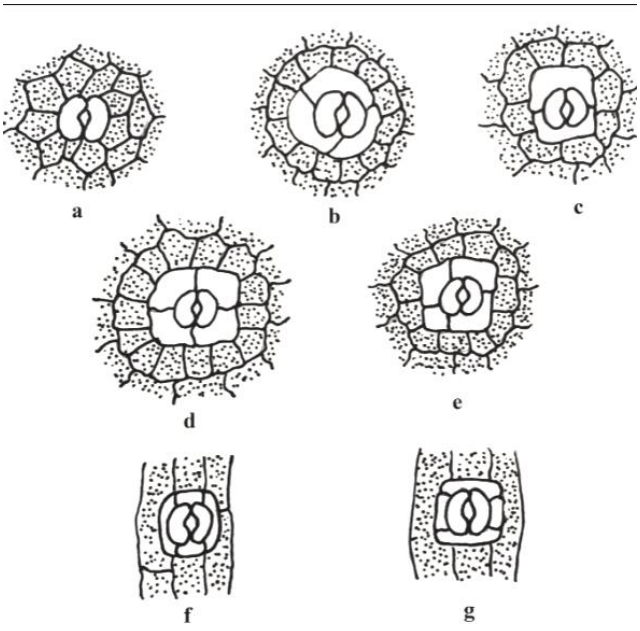

Figure 7. Type of stomata found in all the studied species; A. anomocytic, B. anisocytic, C. diacytic, D,E. Anomotetracytic, F. paratetracytic, G. Brachyparatetracytic

Key to the species (based on leaf venation)

1a. Inter 2˚veins present
- 2a. 3˚vein category sinuous …… ***C. houtteana***
- 2b. 3˚vein category extremely ramified
  - 3a. Areolation Well developed, Marginal ultimate incomplete loops ..…… ***S. rutidosperma***
  - 3b. Areolation moderately developed, Marginal ultimate looped …..…… ***A. viscosa***

1b. Inter 2˚veins absent ……***G. gynandra***

Key to the species (based on palynology)

1a. Exine ornamentation reticulate
- 2a. Pollen class mediae ……***A. viscosa***
- 2b. Pollen class minutae …… ***S. rutidosperma***

1b. Exine ornamentation not reticulate
- 3a. Exine ornamentation striate … ***G. gynandra***
- 3b. Exine ornamentation microechinate …… ……..…..….. ……***C. houtteana***

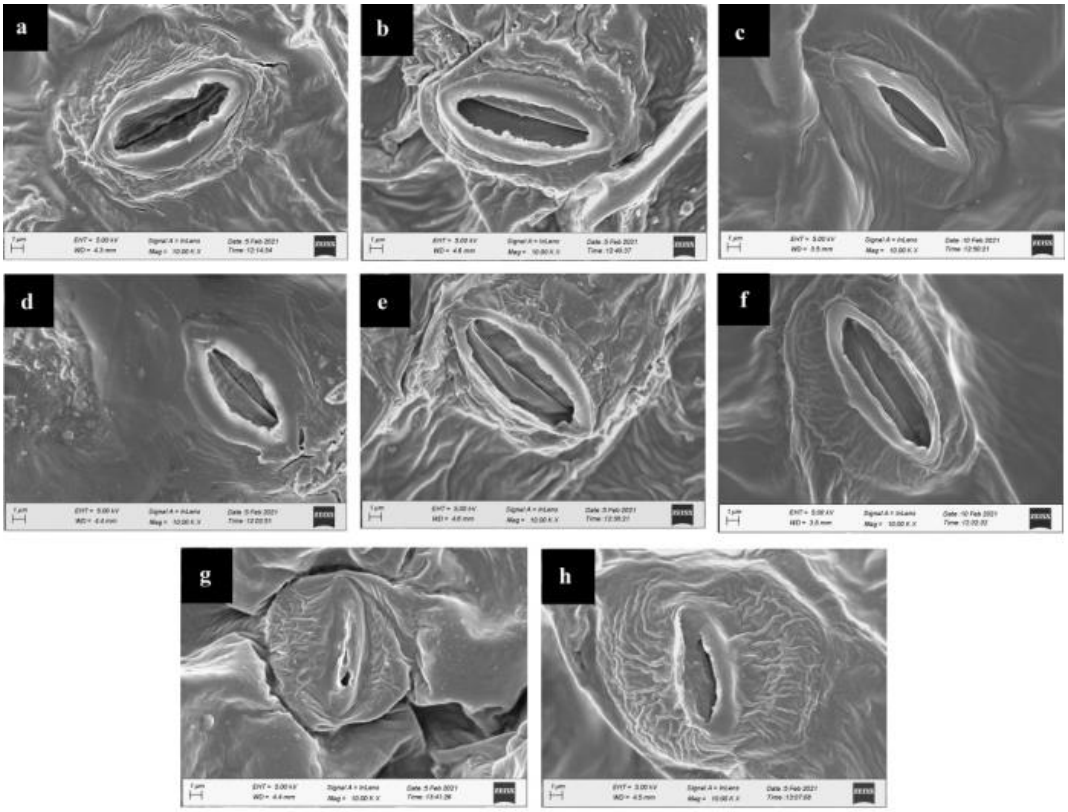

Figure 8. Stomata*; G. gynandra*, A. upper, D. lower; *C. houtteana*, B. upper, E. lower; *S. rutidosperma*, C. upper, F. lower; *A. viscosa*, G. upper, H. lower

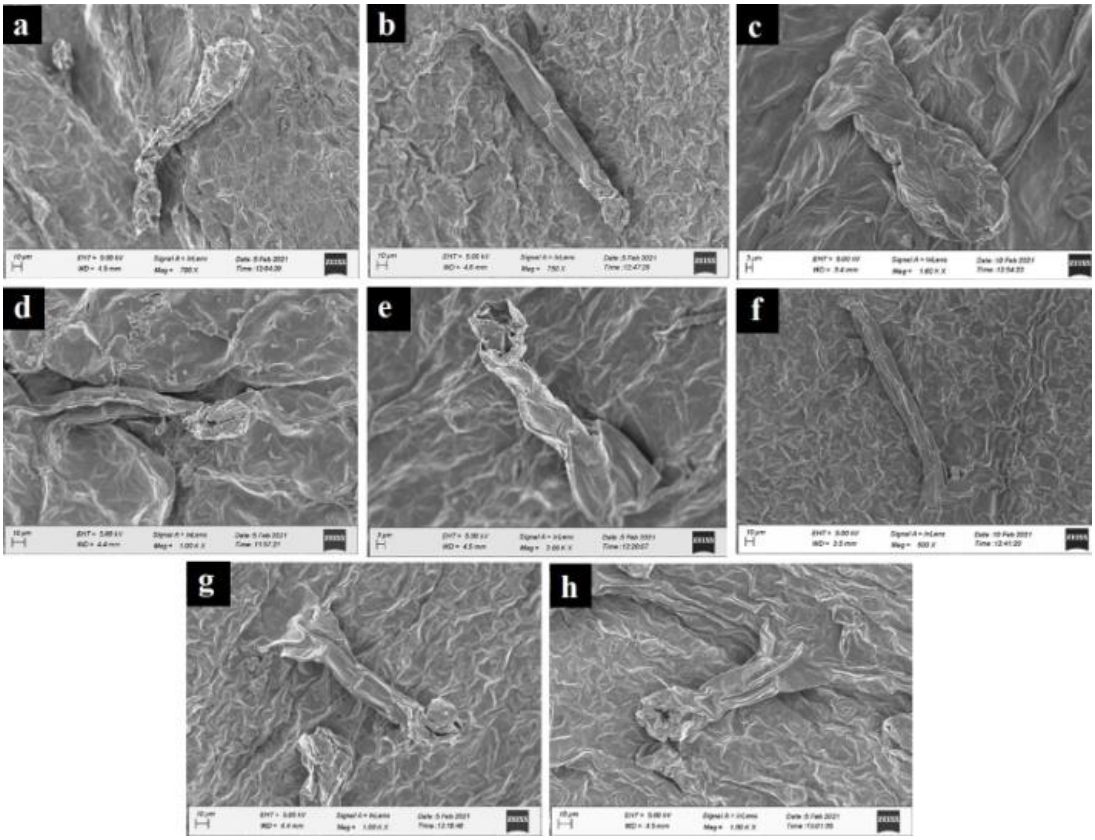

Figure 9. Stomata*; G. gynandra*, A. upper, D. lower; *C. houtteana*, B. upper, E. lower; *S. rutidosperma*, C. upper, F. lower; *A. viscosa*, F. upper, H. lower

Table 5. Leaf venation characteristics of the studied species

Characters	*Gynandropsis gynandra*	*Cleome houtteana*	*Sieruela rutidosperma*	*Arivela viscosa*
1 vein category	Pinnate	Pinnate	Pinnate	Pinnate
2 category	Feestooned brochidedromous	Weak brochidedromous, cladodrpmous	Weak brochidedromous	Feestooned brochidedromous
2 spacing and angle	Irregular; smoothly decreasing towards base	Irregular; smoothly decreasing towards base	Irregular; smoothly decreasing towards base	Irregular; smoothly increasing towards base
Inter 2 veins	Absent	Strong intersecondaries	Weak intersecondaries	Strong intersecondaries
3 vein category	Random reticulate	Random reticulate	Random reticulate	Random reticulate
3 vein course	Exmedially ramified	sinouos	Exmedially ramified	Exmedially ramified
3 vein angle to 1°	Obtuse	Obtuse	Obtuse	Obtuse
3 vein angle variability	Inconsistent	Inconsistent	Inconsistent	Inconsistent
4 vein category	Alternate percurrent	Alternate percurrent	Regular polygonal reticulate	Regular polygonal reticulate
5 vein category	Dichotomizing	Dichotomizing	Dichotomizing	Dichotomizing
Areolation	Moderately developed	Moderately developed	Well developed	Moderately developed
FEVs	Unbranched/1-2 or more branched	Unbranched/1-branched	Unbranched/1-2 or more branched	Unbranched/1-2 or more branched
Marginal ultimate	Looped	Looped	Incomplete loops	Looped

Table 6. Palynological data of the studied *Cleome* species

Species	Pollen unit	Polar diameter (µm)	Equatorial diameter (µm)	P/E	Aperture type	Pollen shape	Pollen class	Exine ornamentation
Gynandropsis gynandra	Monad	21.84	16.50	1.32	3 colporate	Isopolar, sub-prolate	Minutae	Striate, perforate
Cleome houtteana	Monad	25.26	20.99	1.20	3 colporate	Isopolar, sub-prolate	Mediae	Microechinate, perforate
Sieruela rutidosperma	Monad	23.96	16.25	1.47	3 colporate	Isopolar, prolate	Minutae	Reticulate, perforate
Arivela viscosa	Monad	34.13	21.76	1.57	3 colporate	Isopolar, prolate	Mediae	Reticulate, perforate

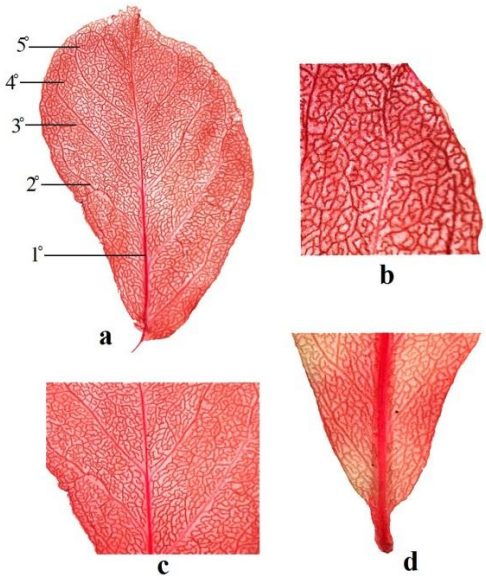

Figure 10. Leaf venation, *G. gynandra*; A. Complete leaf, B. marginal portion, C. middle portion, D. basal portion

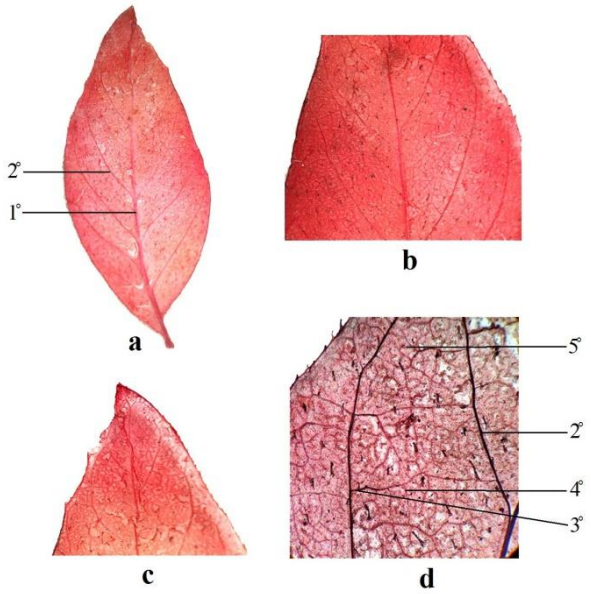

Figure 11. Leaf venation, *C. houtteana*; A. Complete leaf, B. middle portion, C. apex portion, D. marginal portion

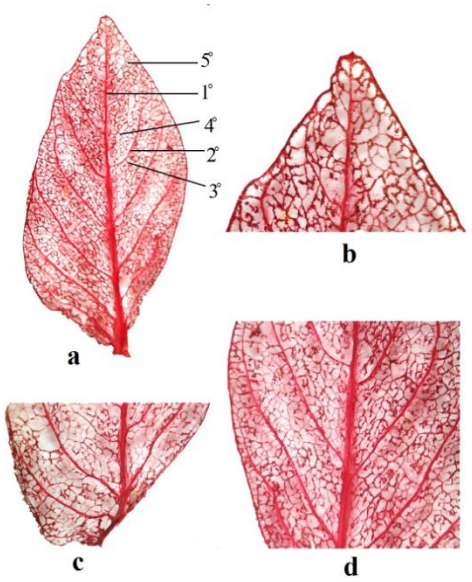

Figure 12. Leaf venation, *S. rutidosperma*; A. Complete leaf, B. apex portion, C. basal portion, D. middle portion

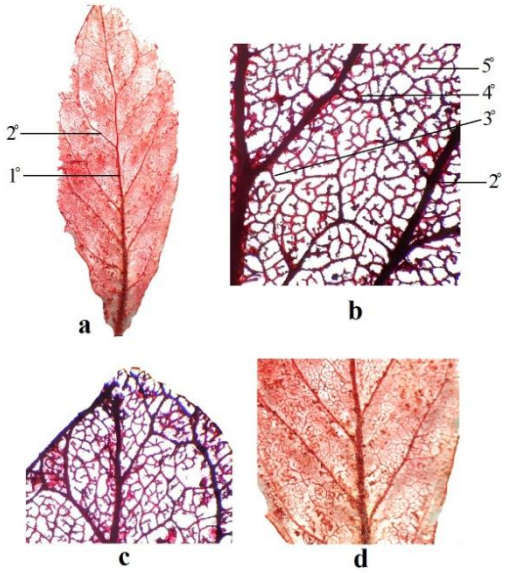

Figure 13. Leaf venation, *A. viscosa*; A. Complete leaf, B. middle portion, C. apex portion, D. Basal portion

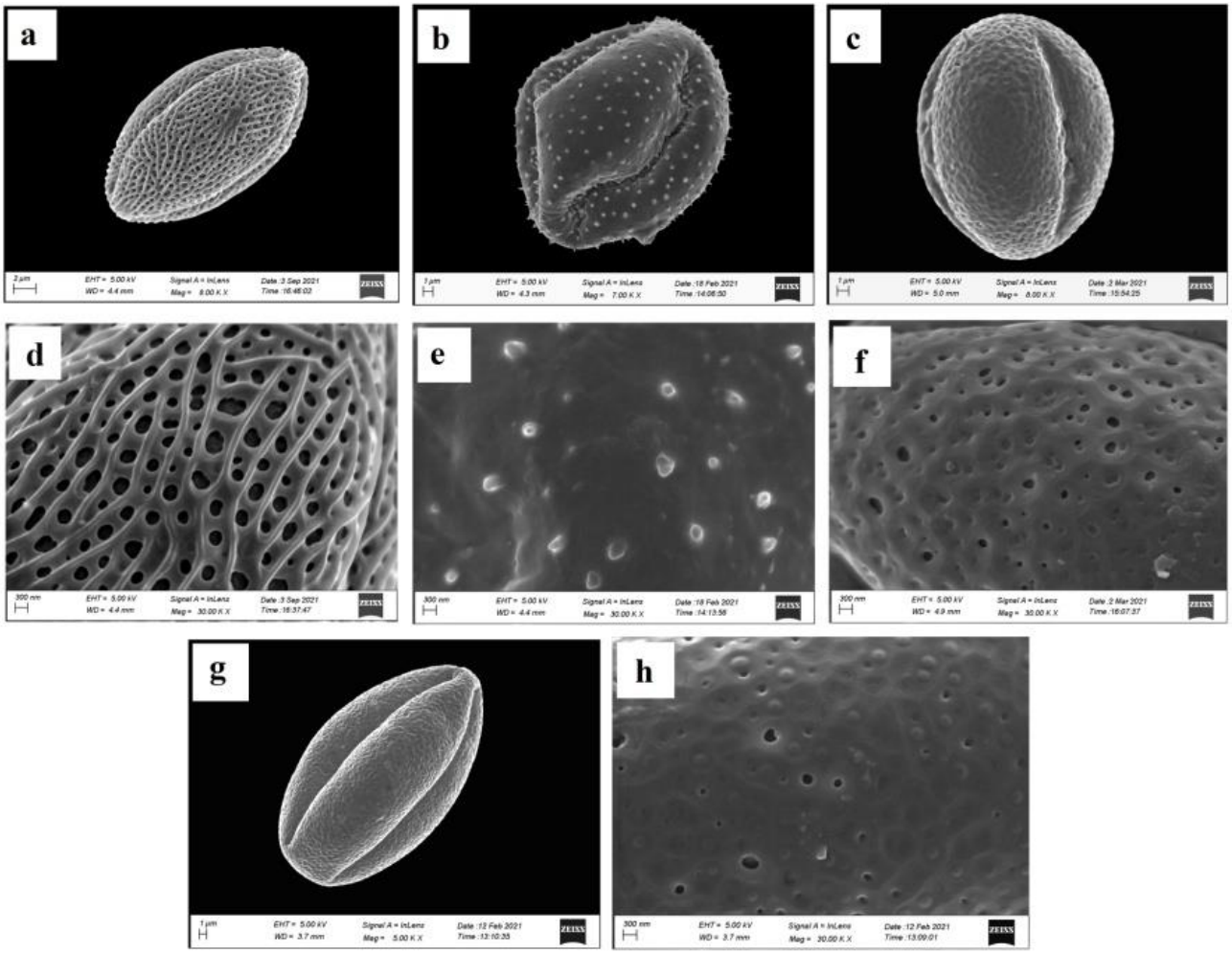

Figure 14. Pollen; Single pollen, A. *G. gynandra*, B. *C. houtteana*, C. *S. rutidosperma*, G. *A. viscosa*; Exine ornamentation D. *G. gynandra*, E. *C. houtteana*, F. *S. rutidosperma*, H. *A. viscosa*

In conclusion, there were controversies regarding the placement of the genus *Cleome* and the family Cleomaceae; finally, in APG IV, the family Cleomaceae was placed under the order Brassicales and the genus was shifted to the family Cleomaceae. The species *C. houtteana*, which is abundantly found in the state of Assam is not reported in any of the major floristic work of the region and is misidentified as *G. gynandra* by many of the workers. All 4 species are herbaceous in nature and quite different from each other. Except for *G. gynandra*, all the 3 species are found abundantly throughout the state.

Morphological features like the tetramerous nature of flowers, fruit type and dehiscence, the shape of the seeds, and pollen apertures bring these 4 species very close together under the same genus. The features like foliar macro-morphology, flower color, androgynophore, number of stamens etc., help in differentiating these closely related species under the same genus family Cleomaceae. *G. gynandra* has an androgynophore, which makes it different from the other three species. *C. houtteana* contains stipular spines which help in delimiting the taxa. Though there are many modern approaches to taxonomy, morphology is still the basic part of any taxonomical studies. There is a lack of scientific evaluation in many fields, mostly in the field of plant taxonomy. Many endemic, medicinal, and economically important plants still lack proper recognition. Unexplored places in NE India will provide various opportunities in the field of taxonomy. It is our responsibility to bring such topics to the new generation so that they can understand the importance of this wealth of nature. Young and enthusiastic researchers can perform extensive floristic work to provide proper scientific identification of the native flora of this diverse floristic region of India. The native flora also needs to be conserved; we have lost many endemic and native floras due to anthropogenic activities. So, we must prepare conservation strategies for maintaining this diversity among the plants of this region.

From a taxonomic point of view, this work provides clear identification of *G. gynandra* and *C. houtteana*. *C. houtteana* was misidentified as *G. gynandra* by many workers of this region. There was no detailed study on leaf venation of the four species of the family Cleomaceae. In this work, a taxonomic key is prepared based on leaf venation which differentiates the related taxa.

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REFERENCES

Aleykutty KM, Inamdar JA. 1978. Structure, ontogeny and taxonomic significance of trichomes and stomata in some Capparidaceae. Fedd Repert 89 (1): 19-30. DOI: 10.1002/fedr.19780890104.

Aparadh VT, Karadge BA. 2010. Seed ornamentation studies in some *Cleome* L. species. Bioinfolet 7 (1): 73-76.

Arigela RK, Singh RK, Reddy CS, Sadasivaiah B. 2021. A new synonym for *Corynandra aspera* (J. Koenig ex DC.) Roalson, with notes on morphological variation in Cleomaceae of southern India. Ann Bot Fennici 58: 331-339.

Barooah C, Ahmed I. 2014. Plant Diversity of Assam (A checklist of Angiosperms and Gymnosperms). ASTEC, Bigyan Bhawan, Guwahati, Assam.

Barrett RL, Roalson EH, Ottewell K, Margaret B, Sanjay PG, Shrirang RY, Asif ST, Avinash RG. 2017. Resolving generic boundaries in Indian - Australasian Cleomaceae: circumscription of *Areocleome*, *Arivela*, and *Corynandra* as distinct genera. Syst Bot 42 (4): 694-708. DOI: 10.1600/036364417X696401.

Bhattacharya A, Maiti GG. 1978. Seed morphology of Indian *Cleome*, Cleomaceae. Bull Bot Soc Bengal 32 (1-2): 23-30.

Blakelock N, Townsend CC. 1980. Capparis. In: Townsend CC, Guest E (eds.) Flora of Iraq, vol. 4. Ministry of Agriculture, Iraq.

Boulos ST, Beakane AB. 1971. A chemical method for separating leaf epidermis from mesophyll tissues. J Bot United Arab Rep 14: 317-322.

Burkill HM. 1985. The useful plant of west tropical Africa. 1. Families of A-D. Royal Botanic Garden, Kew.

Candolle AP. 1824. Prodromus Systematis Naturalis Regni Vegetabilis, Sive, Enumeratio Contracta Ordinum Generum Specierumque Plantarum Huc Usque Cognitarium, Juxta Methodi Naturalis, Normas Digesta. Parisii: Sumptibus Sociorum Treuttel et Wurtz.

Choudhury S. 2005. Assam's Flora (Present status of Vascular Plants). ASTEC, Bigyan Bhawan, Guwahati, Assam, India.

Dilcher DL. 1974. Approaches to identification of Angiosperm leaf remains. Bot Rev 40: 2-157. DOI: 10.1007/BF02860067.

Edeoga HO, Okwu DE, Mbaebie BO. 2003. Minerals and nutritive value of some Nigerian medicinal plants. J Med Aromatic Plant Sci 25(4): 1010-1015.

Edeoga HO, Omosun G, Osuagwu GGE, Mbaebie BO, Madu BA. 2009. Micromorphological characters of the vegetative and floral organs of some *Cleome* species from Nigeria. Am-Eur J Sci Res 4 (3): 124-127.

Erdtman G. 1945. Pollen Morphology and Plant Taxonomy. III. *Morina* L., with an addition on pollen-morphological terminology. Svensk Botanisk Tidskrift 39: 279-285.

Fagundez GA. 2003. Pollen diagnosis of characteristic species in honey of island of the Entre Rios Province, Argentine. Revista del Museo Argentino de Ciencias Naturales Nueva Serie 5 (2): 351-361. DOI: 10.22179/REVMACN.5.65

Ghose M, Davis TA. 1973. Stomata and trichomes in leaves of young plants. Phytomorphology 23: 216-219.

Ghosh RB, Prasad R. 1970. Cleome rutidosperma DC. (Capparaceae)- a new record for Assam. Bombay Nat Hist Soc J 67 (1): 128-129.

Grierson AJC, Long DG. 1894. Flora of Bhutan Vol 1 (2). Royal Botanic Gardens Edinburgh, Edinburgh.

Gupta B. 1961. Correlation of tissues in Leaves. Absolute vein-islet number and vein-termination numbers. Ann Bot 25: 65-70. DOI: 10.1093/oxfordjournals.aob.a083733.

Hall JC, Roalson EH. 2017. New generic concepts for African Cleomaceae. Syst Bot 42 (4): 925-942. DOI: 10.1600/036364417X696393.

Hall JC, Sytsma KJ, Iltis HH. 2002. Phylogeny of Capparaceae and Brassicaceae based on chloroplast sequence data. Am J Bot 89: 1826-1842. DOI: 10.3732/ajb.89.11.1826.

Hickey LJ, Ash A, Wilf P. 1999. Manual of Leaf Architechture. Architechture Working Group, Washington, USA.

Hooker JD Thomson T. 1872. Cleome. In: Hooker JD (eds.) The Flora of British India. L. Reeve & Co. London. https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:60444784-2

Hutchinson J. 1959. The Families of Flowering Plants. Oxford Univ. Press, London.

Iltis HH, Cochrane TS. 2007. Studies in the Cleomaceae V: a new genus and ten new combinations for the Flora of North America. Novon 17: 447-451. DOI: 10.3417/1055-3177(2007)17[447:SITCVA]2.0.CO;2.

Jafri SMH. 1973. Capparidaceae. In: Nasir E, Ali SI (eds.) Flora of Pakistan, Vol. 34. The Herbarium, Dept. of Botany, University of Karachi, Pakistan.

Jain SK, Rao RR. 1977. A Handbook of Field and Herbarium Technique. Today and Tomorrow's Publication, New Delhi, India.

Jansen PC. 2004. C*leome rutidosperma* L. and *C. viscosa* L. In: Grubben GJH, Denton OA (eds). Plant Resources of Tropical Africa 2: Vegetables. Prota Foundation, Backhurys Publishers, Leiden Netherlands/CTA Wageningen.

Jelani S, Leelavathi P, Prabhakar M. 1990. Foliar epidermis in relation to taxonomy of *Cleome* l. capparaceae. Asian J Plant Sci 2 (2): 13-24.

Joshi T, Kumar N, Kothiyal P. 2015. A review on *Cleome viscosa*: An endogenous herb of Uttarakhand. Intl J Pharm Res Rev 4 (7): 25-31.

Kanjilal UN, Kanjilal PC, Das A, De RN. 1934. Flora of Assam, Vol. I. Govt. of Assam Press, Shillong, India.

Kers LE**.** 2003. Capparaceae. In: Kubitzki K Bayer C (eds.) The Families and Genera of Vascular Plants, vol. 5. Springer, Berlin.

Linnaeus C. 1753. Species Plantarum. Laurentius Salvius.

Maria AG, Kevin CN, William LC. 1998. A new fossil flower from the Turonian of New Jersey: *Dressiantha bicarpellata* gen. et sp. nov. (Capparales). Am J Bot 85 (7): 964-974.

Marshall DM, Muhaidat R, Brown NJ. 2007. *Cleome*, a genus closely related to *Arabidopsis*, contains species spanning a developmental progression from C3 to C4 photosynthesis. Plant J 207: 886-896. DOI: 10.1111/j.1365-313X.2007.03188.x.

Mitra K. 1970. Pollen morphology of some Indian Capparaceae. J Indian Bot Soc 49: 136-140.

Mnzava NA, Ngwerume FC. 2004. *Cleome gynandra* L. In: Grubben, GJH, Denton OA (eds.) Plant Resources of Tropical Africa 2. Vegetables, PROTA Foundation, Wageningen, Netherlands/Backhurys Publishers, Leiden Netherlands/CTA Wageningen.

Okonwu K, Ekeke C, Mensah SI. 2017. Micromorphological and phytochemical studies on *Cleome rutidosperma* Linn. J Adv Biol Biotechnol 11 (3): 1-8. DOI: 10.9734/JABB/2017/31028.

Patchell MJ, Bolton MC, Mankowski P, Hall JC. 2011. Comparative floral development in Cleomaceae reveals two distinct pathways leading to monosymmetry. Intl J Plant Sci 172 (3): 352-365. DOI: 10.1086/658158.

Puri HS. 1971. Macro and micromorphology of leaf and seed of *C. viscosa* L. J d'Agri Trop et de Bot Appl 18 (12): 566-571.

Puri HS. 1971. Macro morphology and micro morphology of leaf and seed of *Gynandropsis pentaphylla*. Quarterly J Crude Drug Res 11 (4): 1805-1811. DOI: 10.3109/13880207109068234.

Raghavan RS. 1993. Capparaceae. In: Sharma BD, Balakrishnan NP (eds). Flora of India. Vol. 2. Botanical Survey of India, Howrah, Indoa.

Ruiz ZT, Xena DE, Nereida. 1997. Pollen morphology of *Cleome* L. (Capparidaceae) in relation to its taxonomy and pollination syndromes. Acta Botanica-Venezuelica 20 (1): 67-80.

Schippers RR. 2000. African Indigenous Vegetables: An Overview of the Cultivated Species. Natural Resources Institute, ACP/EU Technical Centre for Agricultural and Rural Cooperation, Chatham, UK.

Schlechtendal DFLV. 1851. Linnaea: Ein Journal fur die Botanik in ihrem ganzen Umfange, Vol 24. F. Dummler, Berlin.

Sharma BD. 1993. Cleomaceae. In: Sharma BD, Balakrishnan NP (eds.). Flora of India. Botanical Survey of India, Govt. of India, India.

Sowunmi IL, Oyedeji OF, Amadi JO, Adebusuyi GA, Dunmade YA. 2018. Micromorphology of *Cleome Gynandra* L. (Capparaceae) from the Eastern Cape Province, South Africa. Intl J Innov Sci Res Technol 3 (9): 588-91.

Stace CA. 1965. Cuticular studies as an aid to plant taxonomy. British Museum (Natural History), London.

Thulin M. 1993. Flora of Somalia. Royal Botanic Gardens, Kew.

Tucker GC, Vanderpool SS. 2010. Cleomaceae In: Flora of North America Editorial Committee (eds.) Flora of North America north of Mexico, vol. 7. Oxford University Press, New York.

Yadav SR, Sardesai MM. 2002. Cleomaceae. In: Flora of Kolhapur District, Shivaji University Press, Kolhapur, India.

Zhang ML, Tucker GC. 2008. Cleomaceae. In: Wu CY, Raven PH, Hong DY (eds.) Flora of China Vol. 7. Science Press, Beijing and Missouri Botanical Garden Press, St. Louis.