



# Taxonomic revision and molecular phylogeny of *Flemingia* subgenus *Rhynchosioides* (Leguminosae)

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## Key words

*Cajaniinae*  
endemism  
lateritic plateaus  
molecular phylogeny  
taxonomy  
tuber crops

**Abstract** A taxonomic revision of *Flemingia* subg. *Rhynchosioides* based on morphology and molecular information (*matK* and ITS) is presented. The subgenus comprises six herbaceous taxa (*F. gracilis*, *F. mukerjeeana*, *F. nilgherensis*, *F. rollae*, *F. tuberosa* and *F. vestita*). All species except *F. vestita* are endemic to India. Morphological evidence and molecular phylogeny revealed that the subgenus is monophyletic. Nevertheless, the systematic position of *F. tuberosa* remains unclear on account of its unique ecology and inflorescence. A new species, *F. mukerjeeana*, is described and four binomials, namely *F. gracilis*, *F. nilgherensis*, *F. tuberosa* and *F. vestita* have been lectotypified. Furthermore, all species have been described, illustrated and their ecology discussed. A taxonomic key including the recently described species from Thailand, *F. sirindhorniae*, is also provided for easy identification.

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## INTRODUCTION

*Flemingia* Roxb. ex W.T.Aiton (Leguminosae Juss., Papilionoideae DC.) is an old world genus. It is one of the members of the quaternary gene pool of *Cajanus cajan* (L.) Millsp. (Mallikarjuna et al. 2011). Furthermore, some species are economically important. *Flemingia grahamiana* Wight & Arn. is a source of an orange-red coloured dye called 'waras' used for colouring silk whereas *F. vestita* Benth. ex Baker, commonly known as 'sohphlong' is cultivated as a tuber crop in north-eastern regions of India. *Flemingia macrophylla* (Willd.) Merr. and *F. semialata* Roxb. are cultivated as the host plant for the lac insect (Kumar et al. 2017). The genus comprises 46 taxa (44 species and 2 varieties) and as far as India is concerned there are 27 taxa (26 species and 1 variety) (modified after Gavade et al. 2017).

The taxonomy of *Flemingia* in the Indian subcontinent has been worked out by Roxburgh (1832), Baker (1876), Prain (1897) and Mukerjee (1953). Baker (1876) split the genus into five subgenera, viz. *Chalaria* (Wight & Arn.) Baker, *Flemingiastrum* (DC.) Baker, *Lepidocoma* (Jungb.) Baker, *Ostryodium* (Desv.) Baker and *Rhynchosioides* Baker. He reported 11 species and 8 varieties in the 'Flora of British India'. The most comprehensive account of the genus (under the name *Moghania* J.St.-Hil.) has been that of Mukerjee (1953). Mukerjee (1953) enumerated 26 species and 7 varieties under five sections. In his thesis Satyanarayana (1993) treated 20 species and 2 varieties for India in five sections, the same as the subgenera mentioned before.

The subg. *Rhynchosioides* is characterized by trailing herbs with tuberous roots (as against the usually shrubby nature of the genus), digitately trifoliolate leaves and minute caducous bracts (Baker 1876). Mukerjee (1953) broadened this circum-

scription by mentioning that the flowers are in corymbs or in long-peduncled heads. Baker (1876) included three taxa, namely *F. tuberosa* Dalzell, *F. vestita* and *F. vestita* var. *nilgherensis* Baker (now *F. nilgherensis* (Baker) Wight ex Cooke). Two species, *F. gracilis* (Mukerjee) Ali and *F. rollae* (Billore & Hemadri) An.Kumar from the Western Ghats were added to this subgenus by Mukerjee (1953) and Billore & Hemadri (1982), respectively. Mattapha et al. (2017) recently described a new species, *F. sirindhorniae* Mattapha, Chantar & Suddee from Thailand. Prior to this discovery, the subg. *Rhynchosioides* was considered to be confined to the Indian subcontinent. It is now represented by seven species.

The Indo-Burmese region has been regarded as the centre of origin of *Flemingia* (Mukerjee 1953). Nonetheless, a taxonomic revision on the genus in the region is needed. The present investigation is a part of taxonomic revision of the genus for India (Lekhak et al. 2011, Gavade & Lekhak 2015, Gavade et al. 2016a, b, 2017). The key objectives of this study were: i) to revise the taxonomy of morphologically isolated *Flemingia* subg. *Rhynchosioides* in India; and ii) to assess the monophyly and affinities of the subgenus based on molecular phylogenetics. Consequently, all the studied taxa have been illustrated and described. Furthermore, we describe a new species and designate lectotypes for *F. gracilis*, *F. nilgherensis*, *F. tuberosa* and *F. vestita*. A taxonomic key for easy identification is provided and molecular phylogeny of the subgenus has been discussed.

## MATERIALS AND METHODS

### Plant materials

Field-trips and surveys were undertaken to different parts of the country during 2012–2017. All the species except *F. vestita* were collected from different regions of peninsular India. The voucher specimens for the collected species have been deposited in the Shivaji University Herbarium (SUK) at Kolhapur, India. Voucher details and GenBank accession numbers are provided in Table 1. Accession numbers of sequences downloaded from GenBank are listed in Table 2 and 3.

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**Table 1** *Flemingia* species, their collection localities, GPS coordinates, altitude, voucher specimens and GenBank accession numbers of markers.

Taxa	Collection localities	GPS coordinates	Altitude (in metres)	Voucher specimens	ITS	<i>matK</i>
<i>F. gracilis</i>	Morjai plateau, Kolhapur, Maharashtra	N16°30.920' E073°53.438'	962	S.K. Gavade 85	MK455091	MK453388
<i>F. mukerjeeana</i>	Kas plateau, Satara, Maharashtra	N17°43.621' E073°49.222'	1194	S.K. Gavade 104	MK455090	MK453392
<i>F. nilgheriensis</i>	Bababhudangiri hills, Chikmagalur, Karnataka	N13°25.545' E075°45.658'	1843	S.K. Gavade 146	MK455092	MK453389
<i>F. rollae</i>	Kalsubai hills, Ahmednagar, Maharashtra	N19°35.969' E073°42.831'	1563	S.K. Gavade & M.M. Lekhak 6	MK455093	MK453390
<i>F. tuberosa</i>	Hativale, Ratnagiri, Maharashtra	N16°35.831' E073°32.583'	204	S.K. Gavade 80	MK455087	MK453391
<i>F. vestita</i> (cultivated form)	Shillong, Meghalaya	N25°21.858' E091°44.797'	1593	S.K. Gavade 166	MK455088	MK453393
<i>F. vestita</i> (wild form)	Maintained in Botanic Garden, Shivaji University, Kolhapur, Maharashtra	N16°40.546' E074°15.337'	527	S.K. Gavade 167	MK455089	MK453394

**Table 2** List of taxa and GenBank accession numbers for the ITS dataset.

<i>Alysicarpus pubescens</i> var. <i>pubescens</i>	KT222205
<i>Alysicarpus pubescens</i> var. <i>vasavadae</i>	KT222206
<i>Alysicarpus vaginalis</i>	KT222211
<i>Alysicarpus vaginalis</i>	MF063692
<i>Cajanus scarabaeoides</i>	MF063725
<i>Dendrolobium lanceolatum</i>	AF467044
<i>Desmodium gangeticum</i>	KP092721
<i>Desmodium heterocarpon</i>	KP092723
<i>Desmodium laxiflorum</i>	KP092724
<i>Desmodium tortuosum</i>	KY968835
<i>Flemingia glutinosa</i>	FJ980289
<i>Flemingia lineata</i>	JX546293
<i>Flemingia macrophylla</i>	FJ980287
<i>Flemingia macrophylla</i>	JX546292
<i>Flemingia macrophylla</i>	KX277642
<i>Flemingia philippinensis</i>	JX546291
<i>Flemingia prostrata</i>	KP092725
<i>Flemingia strobilifera</i>	FJ839428
<i>Flemingia strobilifera</i>	JX546290
<i>Galactia glaucescens</i>	KJ402378
<i>Galactia remansoana</i>	KJ402379
<i>Mucuna pruriens</i>	KT696061
<i>Mucuna sloanei</i>	KT696070
<i>Rhynchosia minima</i>	KR734322
<i>Rhynchosia minima</i>	KR734336
<i>Rhynchosia viscosa</i>	KX689329
<i>Rhynchosia viscosa</i>	KX689330
<i>Rhynchosia viscosa</i>	KX689331

**Morphological observations and herbarium consultations**

The morphological analysis and description are based on observations made in the field and examination of live specimens maintained in the botanic garden at Kolhapur. Identity of the specimens was ascertained by consulting protologues and type specimens. We studied the specimens housed at ASSAM, BLAT, BSD, BSI, CAL, CALI, DD, JCB, MH and SUK. The third author examined specimens of A, BM, C, CAL, E, G, GH, K, L, LE, MH, US, W and WAG. The virtual herbarium of types and voucher specimens were also studied from JSTOR Plants and other herbaria (BM, E, K and N). Descriptions were made following the terminology Hickey & King (2000).

**DNA extraction**

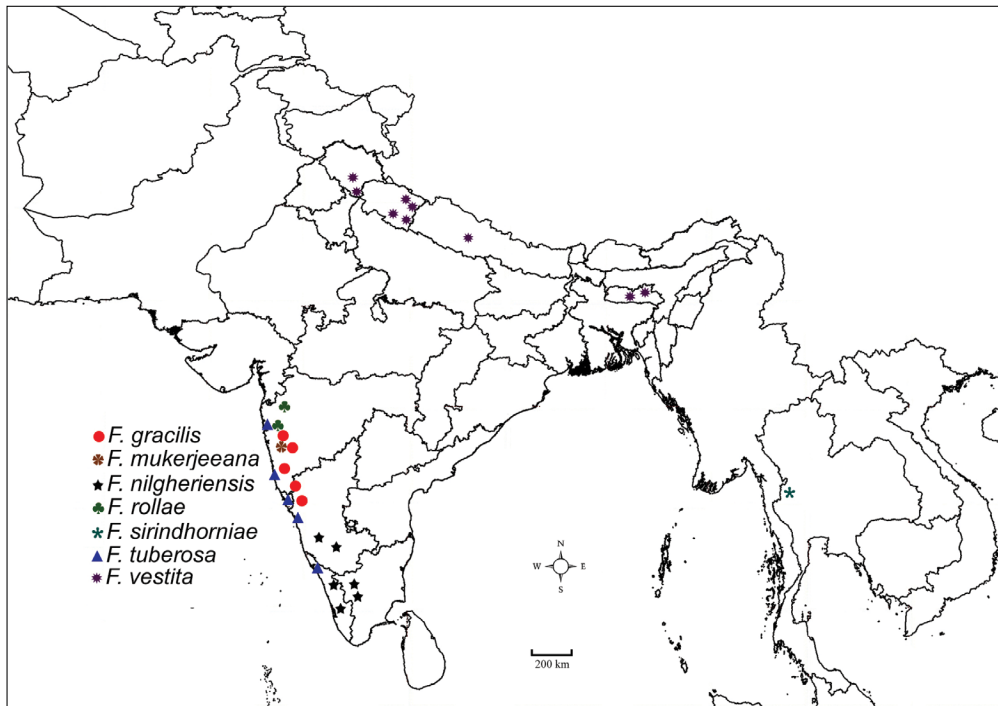
DNA extraction was done using the Qiagen PCR purification kit (Qiagen, Hilden, Germany) according to the manufacturer's instructions.

**Table 3** List of taxa and GenBank accession numbers for the *matK* dataset.

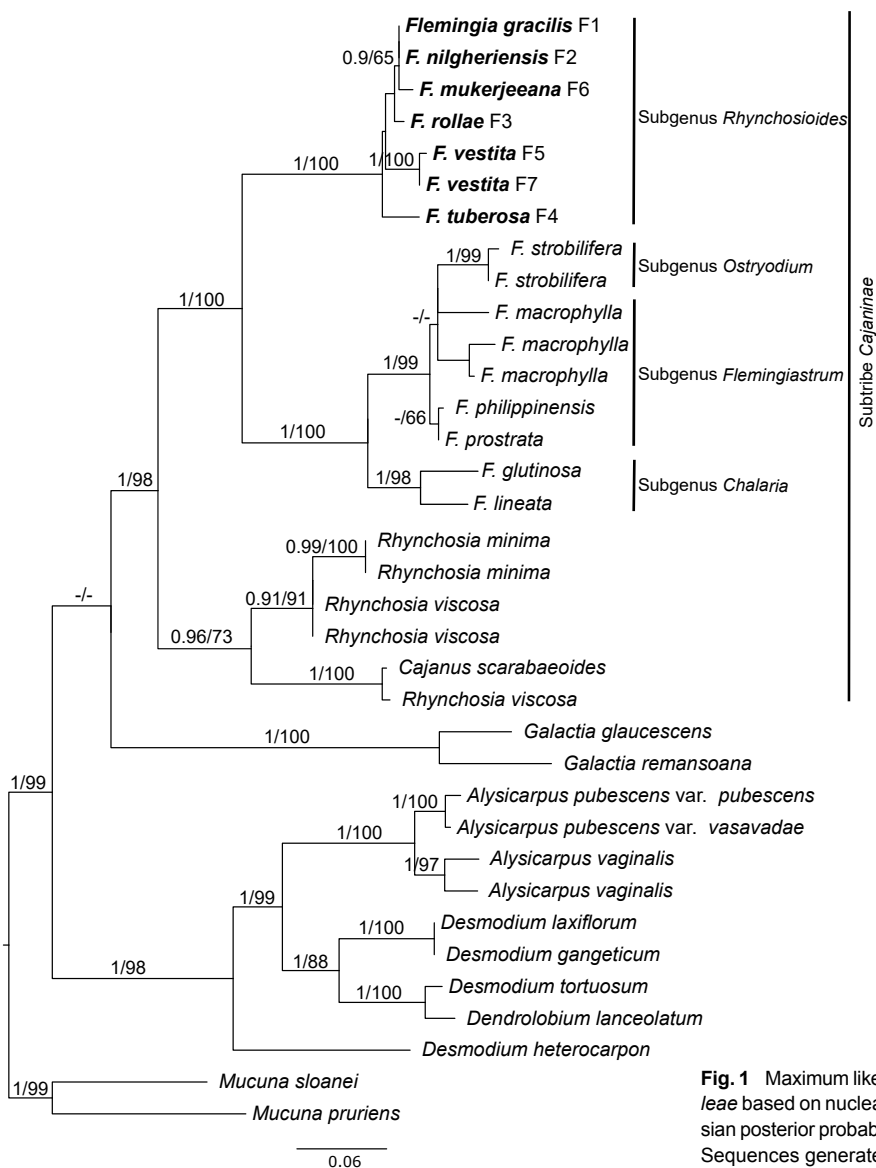
<i>Adenodolichos bussei</i>	KX213142
<i>Alysicarpus heyneanus</i> var. <i>ludens</i>	KT222214
<i>Apios americana</i>	EU717426
<i>Apios priceana</i>	KX213146
<i>Bolusafrax bituminosa</i>	EU717413
<i>Bolusafrax bituminosa</i>	KX213149
<i>Butea monosperma</i>	KX213150
<i>Butea superba</i>	KX213151
<i>Cajanus cajan</i>	JN228940
<i>Cajanus reticulatus</i>	KX213152
<i>Cajanus scarabaeoides</i>	KX213153
<i>Clitoria mexicana</i>	KX213157
<i>Clitoria ternatea</i>	KX213158
<i>Desmodium canadense</i>	HQ593266
<i>Desmodium floridanum</i>	EF549994
<i>Desmodium grahamii</i>	EU025904
<i>Desmodium nicaraguense</i>	JQ587598
<i>Desmodium psilocarpum</i>	AY386896
<i>Dunbaria longiracemosa</i>	AB925145
<i>Eriosema glabrum</i>	KX198118
<i>Eriosema heterophyllum</i>	KX198121
<i>Eriosema simplicifolium</i>	KX198123
<i>Eriosema stenophyllum</i>	KX988011
<i>Eriosema tacuarembense</i>	KX198125
<i>Flemingia macrophylla</i>	KF621101
<i>Flemingia parviflora</i>	KX213165
<i>Flemingia prostrata</i>	KP094092
<i>Flemingia rhodocarpa</i>	KX213166
<i>Flemingia stricta</i>	LC080898
<i>Flemingia strobilifera</i>	KX213167
<i>Galactia striata</i>	AF142704
<i>Galactia texana</i>	KC779625
<i>Galactia wrightii</i>	KC779632
<i>Galactia wrightii</i>	EU025894
<i>Nogra grahamii</i>	KX213177
<i>Phyllodium pulchellum</i>	HM049524
<i>Phyllodium vestitum</i>	AB924969
<i>Rhynchosia clivorum</i>	KX213231
<i>Rhynchosia edulis</i>	JQ587827
<i>Rhynchosia himalensis</i> var. <i>craibiana</i>	KF621104
<i>Rhynchosia monophylla</i>	KF147437
<i>Rhynchosia pyramidalis</i>	KJ594015
<i>Rhynchosia pyramidalis</i>	KJ594013

**Polymerase chain reaction (PCR) amplification and sequencing**

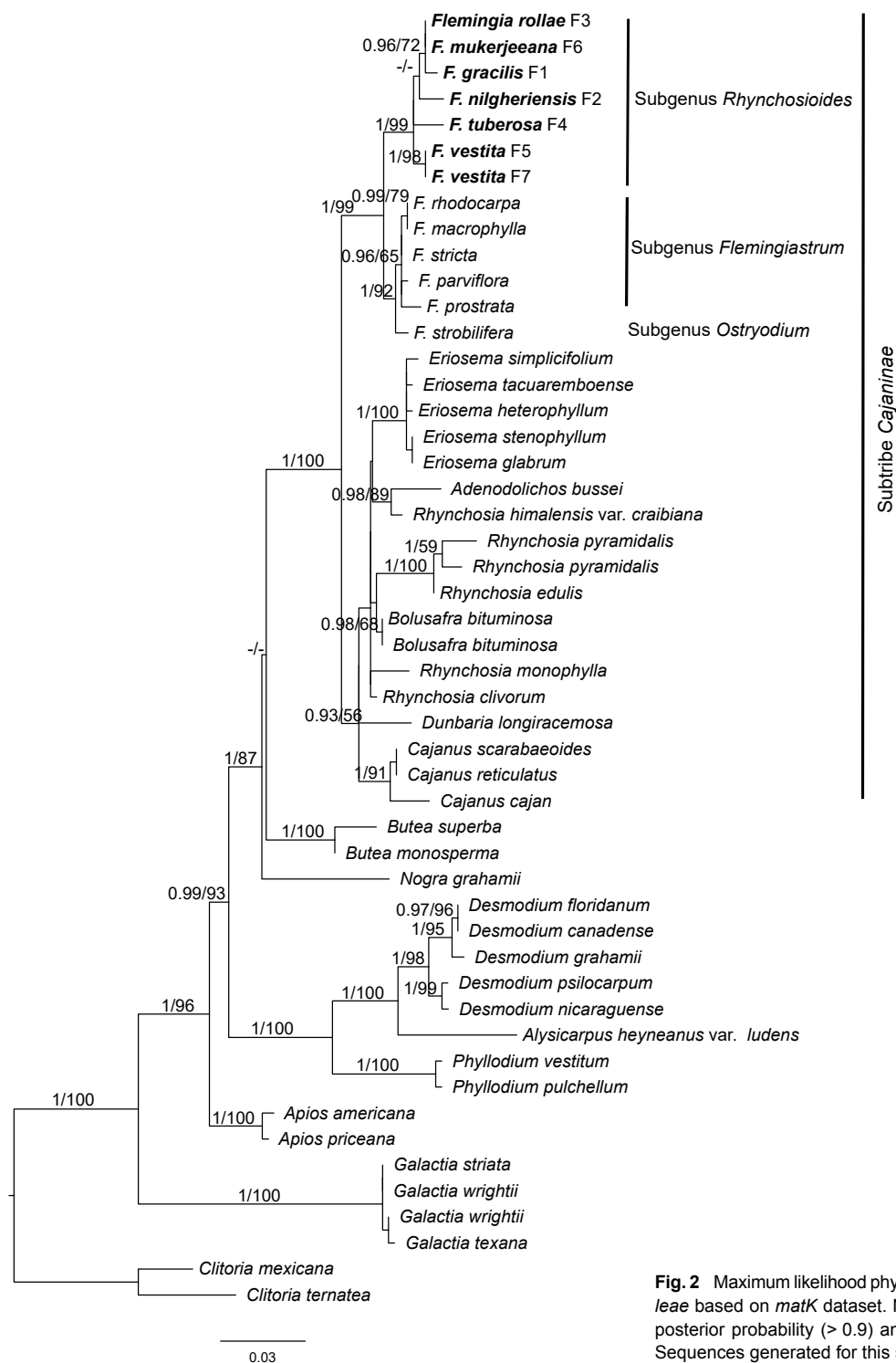
The nuclear ribosomal internal transcribed spacer (ITS) was amplified using primers ITS4 and ITS5 (White et al. 1990). The partial chloroplast maturase K (*matK*) was amplified using primers 1210F (Egan & Crandall 2008) and 1932R (Hu et al. 2000) as described in Egan et al. (2016). PCR reactions were



**Map 1** Geographical distribution of species of *Flemingia* subg. *Rhynchosioides*.



**Fig. 1** Maximum likelihood phylogram of selected species from tribe *Phaseoleae* based on nuclear ITS dataset. Numbers above branches indicate Bayesian posterior probability (> 0.9) and Maximum likelihood bootstraps (> 50 %). Sequences generated for this study are indicated in **bold**.



**Fig. 2** Maximum likelihood phylogram of selected species from tribe *Phaseoleae* based on *matK* dataset. Numbers above branches indicate Bayesian posterior probability (> 0.9) and Maximum likelihood bootstraps (> 50 %). Sequences generated for this study are indicated in **bold**.

carried out in 25  $\mu$ l volume using the 2 $\times$  DreamTaq Green PCR master mix (Thermo Fisher Scientific, USA). Each PCR reaction consisted of 12.5  $\mu$ l 2 $\times$  DreamTaq Green PCR master mix, 10 pmol of each primer and about 10–200 ng of DNA as template. The PCR program consisted of an initial denaturation at 95  $^{\circ}$ C for 2 mins, followed by 40 cycles of 95  $^{\circ}$ C for 15 sec, 57  $^{\circ}$ C for 30 sec and 72  $^{\circ}$ C for 55 sec each and followed by a final extension at 72  $^{\circ}$ C for 5 mins. PCR products were checked on 1 % agarose gels stained with GelRed (Biotium, CA, USA). PCR product purification and Sanger sequencing was done by Eurofins India Pvt. Ltd. (Bangalore, India).

### Phylogenetic analyses

Sequences were aligned using the MUSCLE algorithm using Aliview v. 1.20 (Larsson 2014). Tree building was performed

using the maximum likelihood algorithm as implemented in FastTree using Aliview. The best model of sequence evolution was found to be GTR+I+G and GTR+G for the ITS and *matK* regions respectively using jModeltest v. 2.1.10 (Darriba et al. 2012) under the Akaike information criterion (AIC). Bayesian phylogeny and statistical support of the nodes were obtained using MrBayes v. 3.2.6 (Ronquist et al. 2012). 1 million generations of the MCMC run was conducted and the first 25 % of the trees were discarded as the burn-in. Before the burn-in phase the convergence of the parameters was checked using Tracer v. 1.6 (Rambaut & Drummond 2007). One hundred maximum likelihood bootstrap replicates were performed in RAXML v. 8.2.4 (Stamatakis 2014) using the rapid bootstrapping option. Trees were visualized using Figtree v. 1.4.2 (Rambaut 2012).

**Table 4** Comparison of morphological attributes across *Flemingia* subg. *Rhynchosioides*.

Attributes	<i>F. gracilis</i>	<i>F. mukerjeeana</i>	<i>F. nilgheriensis</i>	<i>F. rollae</i>	<i>F. sirindhorniae</i>	<i>F. tuberosa</i>	<i>F. vestita</i>
Habit	decumbent herbs	decumbent herbs	decumbent herbs	erect herbs	erect herbs	trailing herbs	decumbent herbs
Leaflets	lanceolate or linear-lanceolate, 1–2.2 by 1–1.2 cm	ovate to linear-lanceolate, 2.5–4.5 by 1.5–2.2 cm	obovate to lanceolate, 1.5–3 by 0.7–1.6 cm	ovate to elliptic lanceolate, 2.5–4.8 by 1.2–3 cm	obovate to ovate, rarely elliptic, frequently lanceolate, 2–7 by 0.5–5 cm	narrowly linear-lanceolate or oblong, 5–7 by 1–1.5 cm	obovate to rounded, 4–4.8 by 3–4.2 cm
Petiole	longer than leaflets, 1.5–6 cm long	longer than leaflets, 3–7 cm long	shorter than leaflets, 0.7–1.5 cm long	shorter than leaflets, 1.3–2.2 cm long	shorter than leaflets, 1–3 cm long	shorter than leaflets, 4–6 cm long	longer than leaflets, 4.5–6.5 cm long
Stipule	caducous	persistent	persistent	persistent	persistent	caducous	caducous
Bract	caducous, acute	persistent, acute	persistent, acuminate	persistent, acuminate	persistent, acute-acuminate	caducous, acute	caducous, acuminate
Inflorescence	3–8-flowered, head	15–30-flowered, head	12–25-flowered, head	15–25-flowered, head	4–7-flowered, head	1–2-flowered, raceme	3–6-flowered, head
Pod	1-seeded, calyx-lobes slightly larger	1-seeded, calyx-lobes twice the length of pod	1-seeded, calyx-lobes twice the length of pod	1-seeded, calyx-lobes twice the length of pod	1–2-seeded, calyx-lobes twice the length of pod	2-seeded, calyx-lobes slightly larger	1-seeded, calyx-lobes twice the length of pod

## RESULTS

### Taxonomy

Species of the subg. *Rhynchosioides* are tuberous herbs distributed in Peninsular India, Indian Himalayas (North eastern and western), Nepal and Thailand (Map 1). All taxa except *F. tuberosa* are confined to high altitude (> 900 m to 2 100 m asl) plateaus. *Flemingia tuberosa* grows on low altitude plateaus (200 m asl) usually along the coastal regions of the states of Goa, Maharashtra, Karnataka and Kerala. *Flemingia sirindhorniae*, a newly described species from Thailand grows on limestone mountains (Mattapha et al. 2017). *Flemingia tuberosa* bears solitary or geminate flowers in a raceme while others have a head type of inflorescence with a long and stout peduncle (Fig. 3). Circumscriptions of the subgenus by Baker (1876) and Mukerjee (1953) characterized the species as trailing herbs with minute and caducous bracts. However, in the present studies we have noticed that *F. rollae* and *F. sirindhorniae* are erect herbs. Similarly, bracts are persistent in *F. mukerjeeana*, *F. nilgheriensis*, *F. rollae* and *F. sirindhorniae*. Consequently, the characters of the section have been amended to include species with erect habit and persistent bracts.

A thorough morphological analysis of the species (based on live and herbarium specimens) revealed that the subgenus is homogeneous except for *F. tuberosa*. *Flemingia tuberosa* differs from the remaining species in the characters listed in Table 4. Table 4 presents a comparative morphological account of all the known species of the section. A new species has been recognized from the high altitude lateritic plateau ecosystems from northern Western Ghats. The new species shows affinities towards *F. gracilis* and *F. nilgheriensis* (Table 4).

### Molecular phylogeny

To test the monophyly of *Flemingia* subg. *Rhynchosioides*, genera from the tribe *Phaseoleae* Bronn ex DC. were used. *Flemingia* was found to be monophyletic within the clade containing subtribe *Cajaninae* Benth. based on both nuclear and plastid DNA phylograms. Subg. *Rhynchosioides* also showed monophyly within *Flemingia* with good Bayesian inference (BI) and Maximum likelihood (ML) support (Fig. 1, 2) in both datasets. Subg. *Rhynchosioides* showed sister relationship with other subgenera of *Flemingia* namely, *Flemingiastrum*, *Ostrydium* and *Chalaria* (Fig. 1, 2) in both the datasets.

Though *Flemingia* subg. *Rhynchosioides* was found to be monophyletic in both datasets, the relationships among the species were not well resolved. *Flemingia gracilis*, *F. mukerjeeana*, *F. nilgheriensis* and *F. rollae* showed a close relationship but this relationship was not well supported by BI and ML. These four species occur on high elevation plateaus in the Western Ghats; this specific ecological character might be reason for this relationship. The relationship between North/North Eastern Indian species, *F. vestita* was not well resolved in the *matK* dataset (Fig. 2), but it was sister to the Western Ghats clade in the ITS dataset, though without statistical support (Fig. 1). *Flemingia tuberosa* was not well resolved in the *matK* dataset, however it was distantly related to all other species in the subgenus in the ITS dataset (Fig. 1) and this relationship was not supported.

## TAXONOMIC TREATMENT

### *Flemingia* subg. *Rhynchosioides*

*Flemingia* subg. *Rhynchosioides* Baker

Type. *F. vestita* Benth. ex Baker (1876) 230.

Trailing or erect herbs with herbaceous roots, leaves digitately trifoliolate, bracts minute, caducous or persistent, inflorescences terminal heads (capitula) or (axillary or terminal) racemes.





**Fig. 3** Inflorescence of the species *Flemingia* subg. *Rhynchosioides*. a. *F. gracilis*; b. *F. mukerjeeana*; c. *F. nilgheriensis*; d. *F. rollae*; e. *F. tuberosa*; f. *F. vestita*. Note that all species except *F. tuberosa* have a head (capitulum). — Scale bars = 5 mm.

**Key to the species of subgenus *Rhynchosioides***

- 1. Pods 2-seeded, inflorescence a raceme, with 2–3 flowers; . . . . . 5. *F. tuberosa*
- 1. Pods 1-seeded, inflorescence a head, with 4–25 flowers . . . . . 2
- 2. Plants erect herbs . . . . . 3
- 2. Plants decumbent herbs . . . . . 4
- 3. Inflorescence 15–25-flowered . . . . . 4. *F. rollae*
- 3. Inflorescence 4–7-flowered . . . . . *F. sirindhorniae*
- 4. Leaves rather close; petioles shorter than leaflet . . . . . 3. *F. nilgheriensis*
- 4. Leaves distantly placed; petioles longer than leaflet . . . . 5
- 5. Leaflets obovate to rounded . . . . . 6. *F. vestita*
- 5. Leaflets ovate to linear-lanceolate . . . . . 6

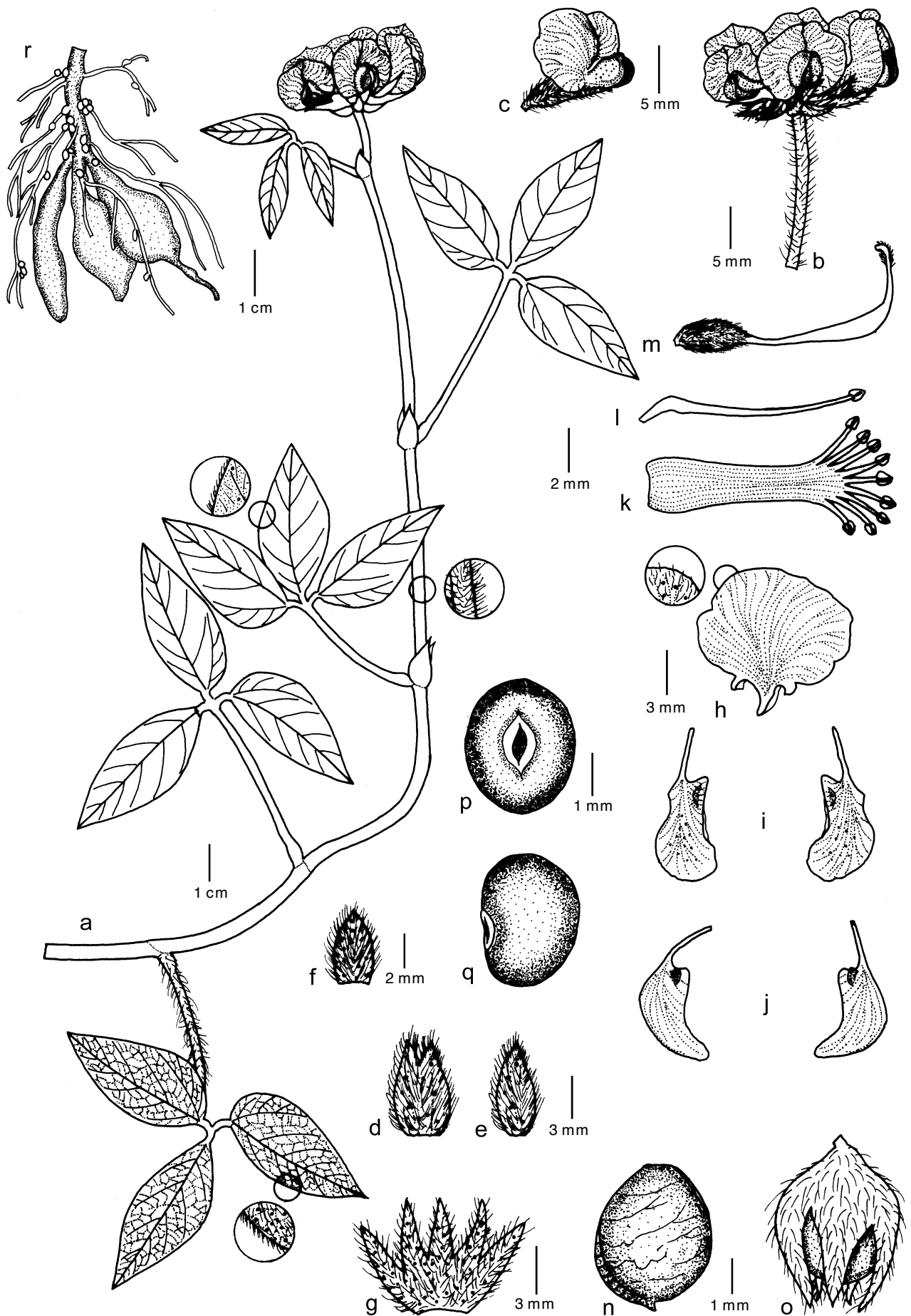
- 6. Stem slender; stipules and bracts caducous . . . . . 1. *F. gracilis*
- 6. Stem robust; stipules and bracts persistent . . . . . 2. *F. mukerjeeana*

**1. *Flemingia gracilis* (Mukerjee) Ali — Fig. 4, 5**

*Flemingia gracilis* (Mukerjee) Ali (1966) 78. — *Maughania gracilis* Mukerjee (as *Moghania*) (1953) 22. — *Lepidocoma gracilis* (Mukerjee) M.R. Almeida (1998) 103. — Type: Bell 4347 (lecto, here designated, BLAT (accession number 89413)), India, Karnataka, Uttar Kannada, Castle rock, Sept. 1918).

*Etymology.* The specific epithet '*gracilis*' refers to its slender stem.

Decumbent herbs, 20–30 cm long with branched stem; *roots* tuberous, ovoid, elongate, 1–2 in cluster; underground. *Stems* 1.5–2 mm diam, terete, sparsely hairy with brown silky antrorse hairs, gland-dotted. *Leaves* 2–6.5 cm long; *stipules* 2, 5–6



**Fig. 4** *Flemingia gracilis* (Mukerjee) Ali. a. Habit; b. inflorescence; c. flower; d. fused stipule; e. free stipule; f. bract; g. calyx, dorsal view; h. standard; i. wing petals; j. keel petals; k. fused androecium; l. free stamen; m. gynoecium; n. fruit without calyx; o. fruit included within the calyx; p. seed, dorsal view; q. seed, lateral view; r. tuberous root (all: Gavade 85, SUK). — Drawing by Sandip Gavade.



by 3–4 mm, ovate, acute, fused, basifixed, caducous, many-nerved, gland-dotted, densely hairy; hairs antrorse; *petioles* 1.5–6 cm long, hairy, gland-dotted. *Leaflets* 1.5–2.2 by 1–1.2 cm, lanceolate or linear-lanceolate, middle leaflet cuneate at base, lateral leaflets asymmetrical or oblique at base, hairy on adaxial surface, abaxially gland-dotted, margin ciliate; glands orange-red; *petiolules* 1–2 mm long, hairy. *Inflorescences* terminal heads, 3–8-flowered; *peduncles* 0.5–5 cm long. *Flowers* 1.2–1.3 cm long, pedicellate, bracteate; *pedicel* 1–2 mm long, hairy; *bracts* 4–5 by 2.5–3 mm, ovate, acute, caducous, many-nerved, gland-dotted, densely hairy; hairs antrorse. *Calyx* 6–7 mm long, hairy, gland-dotted on outer surface, hairs antrorse; *calyx tube* 2.5–3 mm long, campanulate, hairy, gland-dotted; *calyx teeth* 5, equal, 3–4 by 1–1.5 mm, lanceolate, acute, connate for 1/2 of their length, many-nerved. *Corolla* purple; *standard* 11–12 by 9–10 mm, obovate, retuse at apex, clawed with 2 auricles at base, hairy, gland-dotted on outer surface towards apex; claw 2 mm long; auricles  $\leq$  1 mm long; *wings* 9–10 by 4–4.5 mm, oblong, hairy with claw and auricle; gland-dotted on outer surface; *claw* 4 mm long, auricles  $<$  1 mm long; *keel petals* 7–7.5 by 2–2.5 cm, slightly falcate, with claw and auricle, hairy, gland-dotted on outer surface, fused for half of its length at lower side; claw 4 mm long, auricle less than 1 mm. *Stamens* 10, diadelphous (9+1); staminal tube 7–7.5 by 1–1.5 mm; *anthers* uniform, less than 1 mm, basifixed; *filaments* of united stamens 2.5–3 mm long, that of free stamen 6–7 mm long. *Ovary* 1.8 by 1 mm, sub-sessile, hairy, gland-dotted; *ovules* 1–2; *style* 6–7 mm long, glabrous, swollen at middle; *stigma* capitate, hairy. *Fruit* a pod, 6–7 by 4–4.5 mm, 1-seeded,



Fig. 5 Lectotype of *Flemingia gracilis* (Mukerjee) Ali. [Reproduced with the kind permission of authorities of Blatter herbarium (BLAT), Mumbai.]

included within the calyx, beaked, turgid, glabrous; *beak* less than 1 mm long. *Seeds* 3 by 2 by 2 mm, brown, ellipsoid, hilum less than 1 mm long, position  $\pm$  central.

Flowering & Fruiting — September to October.

Distribution — Maharashtra, Karnataka; endemic.

Habitat & Ecology — *Flemingia gracilis* grows on high altitude plateaus of northern Western Ghats of Maharashtra and Karnataka. It occupies rocky crevices and plains at an altitude of c. 800–1300 m asl. It grows in association with *Crinum* spp., *Indigofera dalzellii* T.Cooke, *Lepidagathis clavata* Dalzell, *Merremia rhynchorrhiza* Hallier f., *Rhaphicarpa longiflora* Benth., *Rotala densiflora* (Roth) Koehne, *R. malampuzhensis* R.V.Nair ex C.D.K.Cook, *Senecio bombayensis* N.P.Balacr., *Smithia hirsuta* Dalzell, *Strobilanthes sessilis* Nees and *Utricularia purascens* J.Graham.

*Additional specimens examined.* INDIA, Karnataka, Belgaum District, Sada plateau, 14 Oct. 2016, Gavade & Lekhak 147 (SUK). — Maharashtra, Kolhapur District, Morjai Plateau, 27 July 2008, Lekhak 114 (SUK); *ibid.*, 2 Aug. 2015, Gavade 85 (SUK); *ibid.*, 18 Oct. 2015, Gavade 108 (SUK); Pune District, Khandala, Echo point, 14 Sept. 1942, Santapau 949 (BLAT, DD); Lonavla, Sakarpathat Plateau, 29 Sept. 1964, Reddi 100923 (BSI); Raigad District, Matheran, Porcupine point, 24 Sept. 1976, Kothari 147387 (BSI); Ratnagiri District, Gothane plateau, Nalawade & Gurav s.n. (SUK); *ibid.*, 20 Oct. 2014, S.K. Gavade s.n. (SUK); Satara District, Chalkewadi plateau, 17 Aug. 2010, Lekhak 330 (SUK); 7 Oct. 2014, Gavade & Joshi 3 (SUK); near Kas village, 26 Sept. 2015, Gavade 103 (SUK); Sindhudurg District, Amboli, Chaukul Road, 12 Aug. 1971, Kulkarni 131606 (BSD).

Nomenclatural notes — Mukerjee (1953) described *F. gracilis* based on the collections made by Bell and Santapau. He clearly mentioned that the type specimen 'Bell 4347' is housed at CAL. However, we could not trace the type at CAL. A duplicate (isotype) of the type 'Bell 4347' was located at BLAT. In the absence of the holotype this has been designated as lectotype here.

## 2. *Flemingia mukerjeeana* S.K. Gavade, Survesw., Maesen & Lekhak, *sp. nov.* — Fig. 6, 7

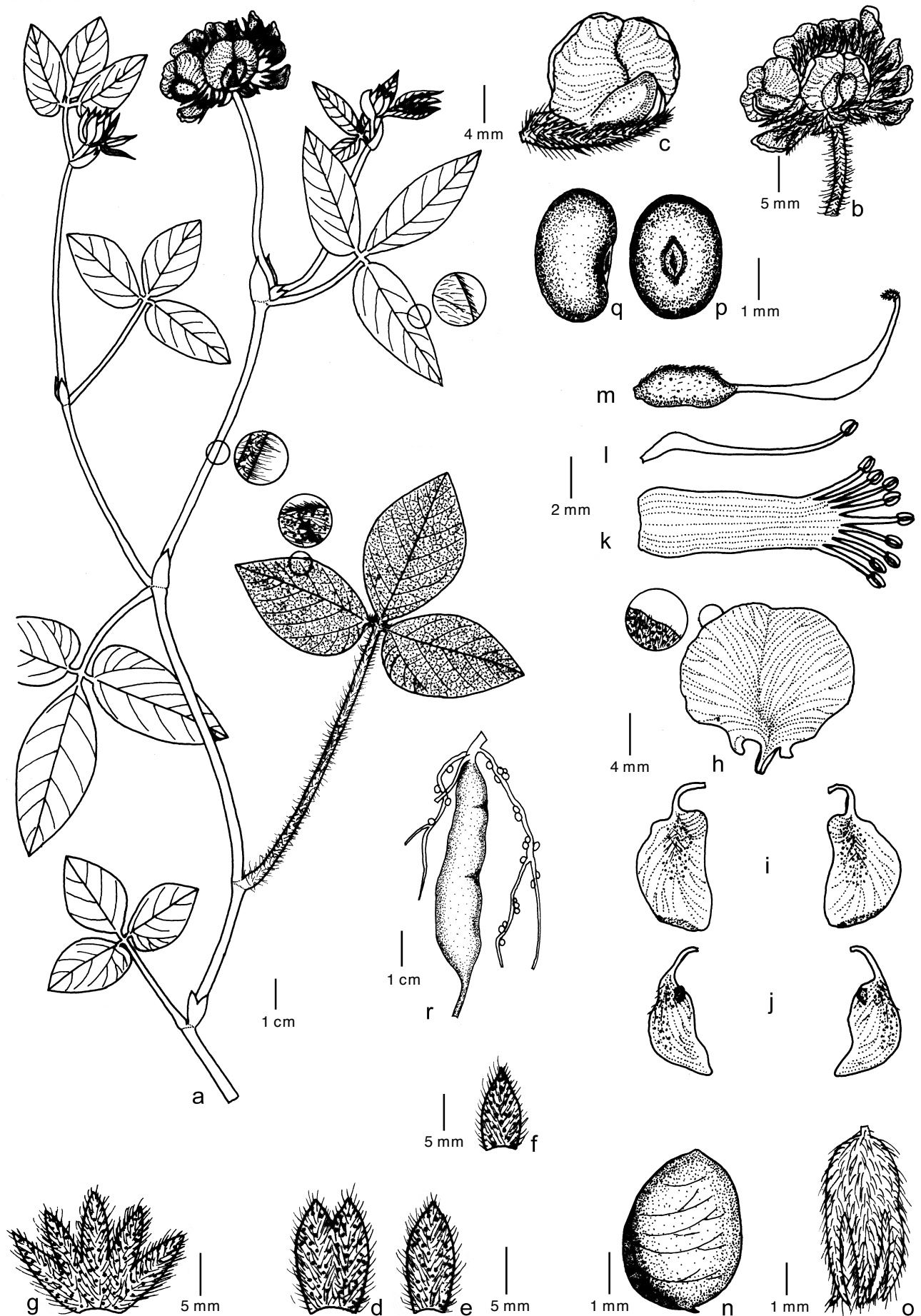
*Flemingia mukerjeeana* differs from *F. gracilis* and *F. nilgheriensis* by its robust habit; long petiole, ovate to linear-lanceolate leaflets 2.5–4.5 by 1.5–2.2 cm, stipule persistent.

*Type.* India, Maharashtra, Satara District, Kas plateau, 12 Sept. 2017, Gavade 200 (holo CAL; iso BSI, MH, SUK).

*Etymology.* The species is named after Dr. Susil Kumar Mukerjee (1909–1997), former Curator and Keeper of the Central National Herbarium (then Calcutta) for his contributions in the field of plant taxonomy. He also provided a synopsis of the genus *Flemingia* for India and Burma in 1953.

*Decumbent herbs*, 20–45 cm long with branched stem; *roots* tuberous, elongate, 2–3 in cluster, underground; *stems* 2–3 mm diam, terete, densely hairy with long brown, silky antrorse hairs, gland-dotted. *Leaves* 6–11 cm long; *stipules* 10–10.5 by 4–5 mm, ovate, acute, fused, splitting at maturity, basifixed, persistent, many-nerved, gland-dotted, densely hairy; hairs antrorse; *petioles* 3–7 cm long, densely pubescent with brown silky hairs, gland-dotted; *leaflets* 2.5–4.5 by 1.5–2.2 cm, ovate to linear-lanceolate, middle leaflet cuneate at base, lateral leaflets asymmetrical or oblique at base, hairy on both surfaces, abaxially gland-dotted, margin hairy; glands orange-red; *petiolules* 1–2 mm long, pubescent. *Inflorescences* terminal heads, 15–30-flowered; *peduncles* 1–8 cm long; *Flowers* 1.2–1.5 cm long, pedicellate, bracteate; *pedicels* 1–2 mm long, hairy; *bracts* 10–12 by 4–5 mm, ovate, acute, persistent, many-nerved, gland-dotted, densely hairy; hairs antrorse. *Calyx* 9–13 mm long, hairy, hairs brown silky, gland-dotted on outer surface; hairs brown, silky, antrorse; *calyx tube* 3–3.5 mm long, campanulate, hairy, gland-dotted; *calyx teeth* 5, equal, 7–8 by 2–2.5 mm, linear to lanceolate, acute, connate for 1/3 of its length, many-nerved. *Corolla* purple; *standard* 1.1–1.2 by 1.1–1.2 cm,





**Fig. 6** *Flemingia mukerjeeana* S.K.Gavade, Survesw., Maesen & Lekhak. a. Habit; b. inflorescence; c. flower; d. fused stipule; e. free stipule; f. bract; g. calyx, dorsal view; h. standard; i. wing petals; j. keel petals; k. fused androecium; l. free stamen; m. gynoeceum; n. fruit without calyx; o. fruit included within the calyx; p. seed, dorsal view; q. seed, lateral view; r. tuberous root (all: Gavade 200, SUK). — Drawing by Sandip Gavade.

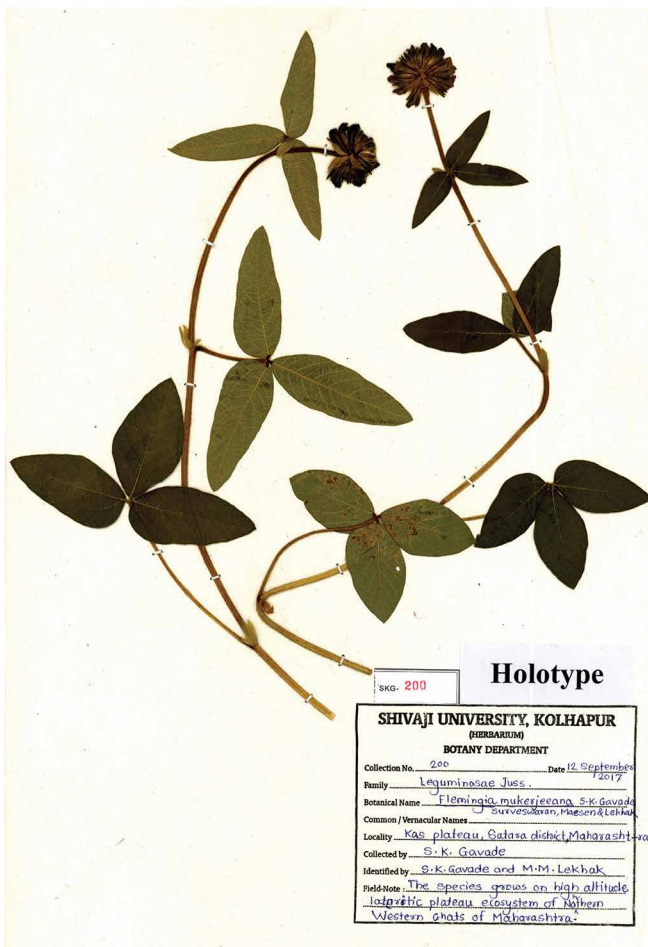


Fig. 7 Holotype of *Flemingia mukerjeeana* S.K. Gavade, Survesw., Maesen & Lekhak.

rounded, retuse at apex, hairy, gland-dotted on outer surface, clawed with 2 auricles at base; wings 10–11 by 5–6 mm, oblong, pubescent, gland-dotted on outer surface, with claw and auricle, claw 3 mm long, auricles c. 1 mm long; keel petals 8–8.5 by 3–3.5 mm, slightly falcate, hairy, gland-dotted on outer surface, with claw and auricle, fused 1/2 of its length at lower side, claw 4 mm long, auricle less than 1 mm. Stamens 10, diadelphous (9+1); staminal tube 6–7 by 1.5–2 mm; anthers uniform, < 1 mm, basifixed; filaments of fused stamens 3–4 mm long, that of free stamen 7–8 mm long. Ovary 2–2.5 by 1–1.5 mm, sub-sessile, hairy, gland-dotted; ovules 2; style 6–8 mm long, glabrous, swollen at middle; stigma, capitate, hairy. Fruit a pod, 11–12 by 3–4 mm, 1-seeded, included within the calyx, beaked, turgid, glabrous; beak less than 1 mm long. Seeds 3 by 2 by 2 mm, brown, ellipsoid, hilum less than 1 mm long, position ± central.

Flowering & Fruiting — October to November.

Distribution — Maharashtra (Kaas plateau and Chalkewadi plateau, Satara District); endemic. This species is restricted to the type locality.

Habitat & Ecology — *Flemingia mukerjeeana* grows on a high altitude lateritic plateau in the northern Western Ghats of Maharashtra. It occurs at an altitude of c. 1100–1200 m asl. The common associates of the species are *Cyanotis fasciculata* (B. Heyne ex Roth) Schult. f., *Drosera indica* L., *Flemingia gracilis* (Mukerjee) Ali, *Habenaria heyneana* Lindl., *Hitchenia caulina* (J. Graham) Baker, *Impatiens lawii* Hook. f. & Thomson, *Iphigenia stellata* Blatt., *Memecylon umbellatum* Burm. f., *Murdannia lanuginosa* G. Brückn., *Rhamphicarpa longiflora* Wight ex Benth., *Strobilanthes sessilis* Nees.

*Additional specimens examined.* INDIA, Maharashtra, Bombay, s.d., Dalzell s.n. (DD); Satara District, Chalkewadi plateau, 17 Aug. 2010, Lekhak 330 (SUK); Kas plateau, 16 Oct. 2014, Gavade 5 (SUK); ibid., 26 Sept. 2015, Gavade 104 (SUK); ibid., 22 Oct. 2015, Gavade 110 (SUK); ibid., 5 Oct. 2016, Gavade 145 (SUK); ibid., 19 Nov. 2016, Gavade 150 (SUK).

### 3. *Flemingia nilgheriensis* (Baker) Wight ex T. Cooke — Fig. 8, 9

*Flemingia nilgheriensis* (Baker) Wight ex T. Cooke (1902) 393.

*Flemingia procumbens* Wight (1846) 9, nom. illeg., non Roxb. (1832) 338.

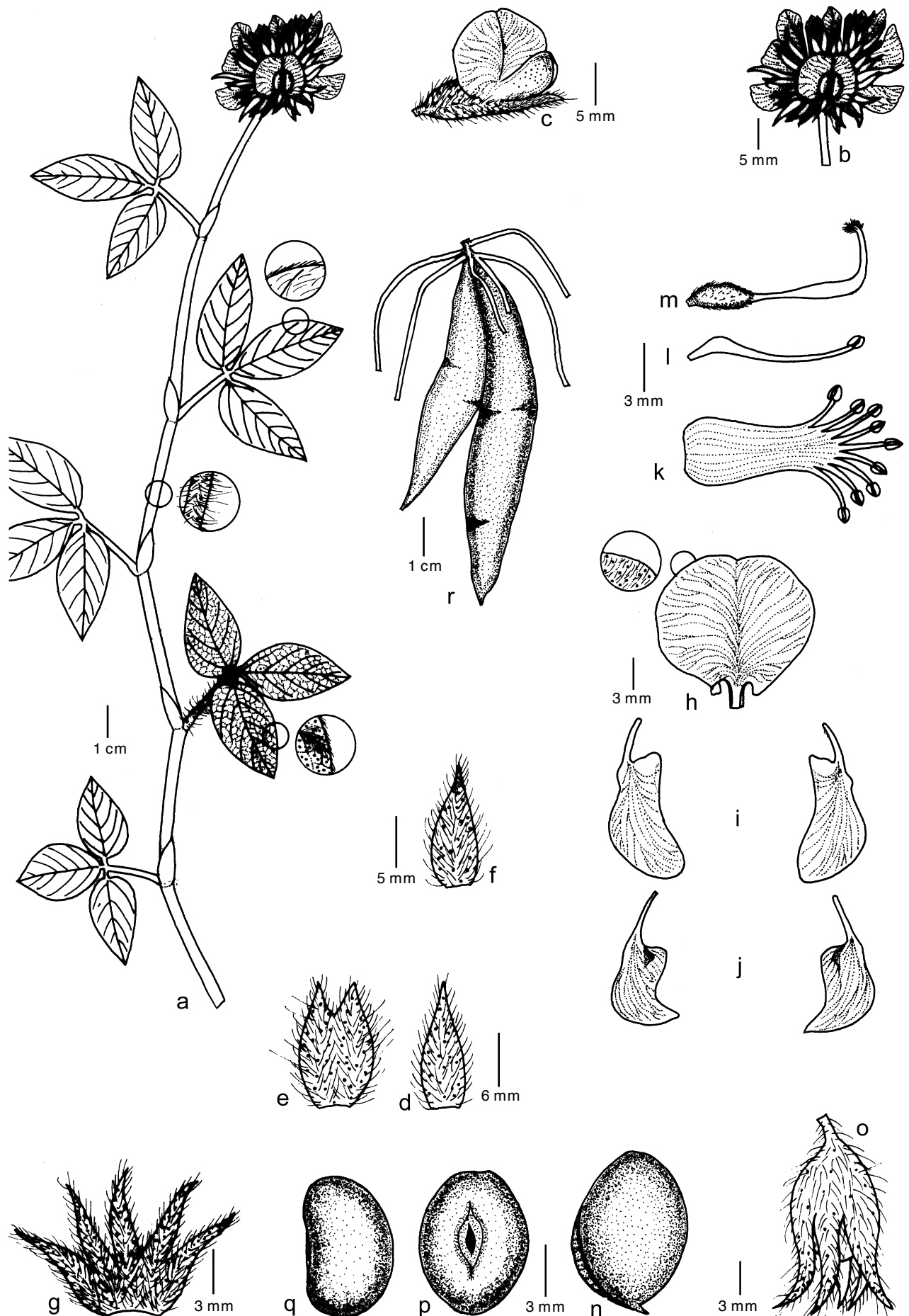
*Flemingia vestita* Benth. ex Baker var. *nilgheriensis* Baker (1876) 230. — *Maughania nilgheriensis* (Baker) H.L. Li (1944) 227. — Type: Wight (lecto E (E00157790), here designated; isolecto BM (BM001209605), E (E00157789)), India, Tamil Nadu, Nilgiri District, Pykara, s.d.

*Etymology.* The specific epithet '*nilgheriensis*' refers to the Nilgiri hills (Nilgiri District), Tamil Nadu, where Pykara is the type location.

*Decumbent herbs*, 20–30 cm long with branched stem; roots tuberous, elongate, 2–3 in cluster, underground; stems 2–2.5 mm diam, terete, densely hairy with long brown, silky, antrorse hairs, gland-dotted. Leaves 2.5–4.5 cm long; stipules 2, 9–14 by 3–4 mm, ovate, acuminate, fused, splitting at maturity, basifixed, persistent, many-nerved, gland-dotted, densely hairy; hairs antrorse; petioles 0.7–1.5 cm long, densely hairy, gland-dotted; leaflets 1.5–3 by 0.7–1.6 cm, obovate to lanceolate, middle leaflet cuneate at base, lateral leaflets asymmetrical or oblique at base, densely hairy on both surfaces, abaxially gland-dotted, margin ciliate; glands orange-red; petiolules 1–2 mm long, pubescent. Inflorescences terminal heads, 12–25-flowered; peduncles 1–4 cm long. Flowers 1.1–1.2 cm long, pedicellate, bracteate; pedicel 1–1.5 mm long, hairy; bracts 8–12 by 2.5–4 mm, lanceolate, acuminate, persistent, many-nerved,



Fig. 8 Lectotype of *Flemingia nilgheriensis* (Baker) Wight ex T. Cooke (E00157790). [Reproduced with the kind permission of the Board of Trustees, Royal Botanic Garden, Edinburgh.]



**Fig. 9** *Flemingia nilgheriensis* (Baker) Wight ex T.Cooke. a. Habit; b. inflorescence; c. flower; d. fused stipule; e. free stipule; f. bract; g. calyx, dorsal view; h. standard; i. wing petals; j. keel petals; k. fused androecium; l. free stamen; m. gynoecium; n. fruit without calyx; o. fruit included within the calyx; p. seed, dorsal view; q. seed, lateral view; r. tuberous root (all: Gavade 146, SUK). — Drawing by Sandip Gavade.

gland-dotted, densely hairy; hairs antrorse. *Calyx* 9–10 mm long, hairy, gland-dotted on outer surface; hairs antrorse; *calyx tube* 2.5–3 mm long, campanulate, hairy, gland-dotted; *calyx teeth* 5, subequal, 6.5–7 by 1.5–2 mm, linear to lanceolate, acuminate, connate for 1/3 of its length, many-nerved. *Corolla* purple; *standard* 11–12 by 10–11 mm, obovate to round, retuse at apex, hairy, gland-dotted on outer surface, with claw and auricle, claw 2 mm long, auricled; auricles 2; *wings* 11–11.5 by 4–4.5 mm, oblong, pubescent, gland-dotted on outer surface, claw 3 mm long, auricles c. 1 mm long; *keel petals* 8–9 by 3–3.5 mm, slightly falcate, hairy, gland-dotted on outer surface, with claw and auricle, fused 1/2 of its length at lower side; *claw* 4 mm long, auricle less than 1 mm long. *Stamens* 10, diadelphous (9+1); *staminal tube* 5–5.5 by 1–1.5 mm; *anthers* uniform, less than 1 mm, basifixed; *filaments* of fused stamens 3–3.5 mm long, that of free stamen 7–8 mm long. *Ovary* 1.5–2 by 1–1.5 mm, sub-sessile, hairy, gland-dotted; *ovules* 2; *style* 7–8 mm long, glabrous, swollen at middle; *stigma* capitate, hairy. *Fruit* a pod, 11–12 by 4–5 mm, 1-seeded, included within calyx, beaked, turgid, glabrous; beak less than 1 mm long. *Seeds* 3 by 1.5 by 2 mm, black, ellipsoid, hilum less than 1 mm long, position ± central.

Flowering & Fruiting — September to October.

Distribution — Karnataka, Kerala, Tamil Nadu; endemic.

Habitat & Ecology — *Flemingia nilgheriensis* grows on hill slopes and plateaus of southern Western Ghats of Karnataka and Kerala. It occurs at an altitude of c. 800–1800 m asl. It grows in association with *Arundinella* spp., *Chlorophytum malabaricum* Baker, *Crotalaria nana* Burm.f., *Desmodiastrum racemosum* (Benth.) A.Pramanik & Thoth., *Jansenella griffithiana* (Müll.Hal.) Bor, *Leucas stelligera* Wall., *Pleocaulus ritchei* (C.B. Clarke) Bremek., *Satyrium nepalense* D. Don, *Smithia blanda* Wall. ex Wight & Arn. and *Vigna vexillata* (L.) A. Rich.

*Additional specimens examined.* INDIA, **Concan**, s.d. and month 1860, *Stocks* s.n. (A, BM, C, OXF, P, US). — **Karnataka**, Chikkamagaluru District, Baba Budangiri Hills, 12 Oct. 2016, *Gavade 146* (SUK); *ibid.*, Oct. 1890, *Talbot 2352* (BSI); *ibid.*, s.d., *Talbot 3242* (BSI); Hassan District, Vanagur, 4 Sept. 1969, *Saldanha 17836* (JCB); Brahmagiri hills, without day Dec. 1907, without collector *103448* (BSI); *ibid.*, without collector s.n. (BSI); Kodagu District, Dodda Abbey falls, 25 Oct. 1964, *Raghavan 103914* (BSI). — **Kerala**, Alappuzha District, Kallumala, 6 Oct. 1997, *Biju 36507* (TBGT); Palakkad District, Kundipurha dam site, 6 Nov. 1976, *Vajravelu 48862* (CAL); Silent Valley National Park, dam site, 18 Oct. 1982, *Sabu 10844* (CALI); Trivandrum District, on the way to Poovar, 27 July 1998, *Biju 38292* (TBGT). — **Tamil Nadu**, Coimbatore District, Anaimalai hills, s.d., without collector *15572* (MH); Kolanar, 14 Nov. 1980, *Chandrabose 57758* (MH); Nilgiris District, Pykara, 28 Aug. 1970, *Sharma 35860* (MH); *ibid.*, 14 Sept. 1918, without collector, s.n. (MH); *ibid.*, Sept. 1905, without collector s.n. (MH); *ibid.*, 18 Oct. 1981, *Ansari 77714* (CAL); *ibid.*, *Vajravelu 77714* (MH); *ibid.*, 18 Nov. 1928, *Mariana & Raju 18456* (MH); *ibid.*, Nov. 1883, without collector s.n. (MH); Southern bank of Pykara river, 12 Sept. 1930, *Narayanaswami 4263* (MH).

Taxonomic note — *Flemingia nilgheriensis* was considered a variety of *F. vestita*, i.e., *F. vestita* var. *nilgheriensis* by Baker (1876). Cooke (1902) restored it to the rank of species, and we agree.

Nomenclatural notes — *Flemingia nilgheriensis* was originally described by Wight (1846) as *F. procumbens* from Pykara, Nilgiri hills. This name was already used by Roxburgh for an altogether different plant. According to Cooke (1902), Wight realized his mistake and corrected the error and added the name *F. neilgherrensensis* on a slip which is attached with the type specimen in K, but we have not been able to confirm the existence of this specimen. In search of the type specimens we could trace three specimens (two at E and one at BM). Among these three specimens, the specimen E00157790 is complete, bears 3–4 flowering twigs and matches well with the protologue. Therefore, this specimen is designated here as a lectotype. The duplicates of this specimen BM001209605 and E00157789 constitute isolectotypes.

#### 4. *Flemingia rollae* (Billore & Hemadri) An.Kumar — Fig. 10

*Flemingia rollae* (Billore & Hemadri) An.Kumar (1983) 232. — *Maughania rollae* Billore & Hemadri (1982) 617. — *Lepidocoma rollae* (Billore & Hemadri) M.R.Almeida (1998) 104. — Type: *Patwardhan 1200* (lectotype BSI designated by Gavade et al. (2016a)), India, Maharashtra, Ahmednagar District, Kalsubai hills, 13 Oct. 1907.

*Etymology.* Specific epithet '*rollae*' honours Dr. Rolla Sheshagiri Rao, Botanical Survey of India, Western Regional Centre (Pune), for his valuable contribution towards the advancement of studies in Indian taxonomy.

*Erect herbs*, 20–45 cm long with branched stem; *roots* tuberous, elongate, 2–3 in cluster, underground; *stems* 3–4 mm diam, terete, densely hairy with white, silky antrorse hairs, gland-dotted. *Leaves* 4.5–9 cm long; *stipules* 2, 12–18 by 4–5 mm, ovate to lanceolate, acuminate, fused, splitting at maturity, basifixed, persistent, many-nerved, gland-dotted, densely hairy; hairs antrorse; *petioles* 1.3–2.2 cm long, pubescent with white silky hairs, gland-dotted; *leaflets* 2.5–4.8 by 1.2–3 cm, ovate to elliptic lanceolate, middle leaflet cuneate at base, lateral leaflets asymmetrical or oblique at base, hairy on both surfaces, abaxially gland-dotted, margin ciliate; glands orange-red; *petiolules* 1–2 mm long, hairy. *Inflorescences* terminal heads, 15–25-flowered; peduncle 1–4 cm. *Flowers* 1.3–1.4 cm long, pedicellate, bracteate; *pedicels* 2–3 mm long; *bracts* 1.1–1.2 by 0.3–0.4 cm, ovate to lanceolate, acuminate, persistent, many-nerved, gland-dotted, densely hairy; hairs antrorse. *Calyx* 1.2–1.3 cm long, hairy, gland-dotted on outer surface; hairs antrorse; *calyx tube* 4–5 mm long, campanulate, hairy, gland-dotted; *calyx teeth* 5, equal, 7–8 by 2 mm, linear-lanceolate, acute, connate for 1/3 of its length, many-nerved. *Corolla* purple; *standards* 1.2–1.3 by 1.1–1.2 cm, obovate to orbicular, retuse at apex, hairy, gland-dotted on outer surface towards apex, clawed with 2 auricles at base, claw 2 mm long, auricles ≤ 1 mm long; *wings* 11–12 by 4–5 mm, oblong, hairy, gland-dotted on outer surface, with claw and auricle; claw 4 mm long, auricles c. 1 mm long; *keel petals* 10 by 3 mm, slightly falcate, hairy, gland-dotted on outer surface, with claw and auricle, fused half of its length at lower side, claw 4 mm long, auricle less than 1 mm. *Stamens* 10, diadelphous (9+1); *staminal tube* 7–8 by 1.5–2 mm; *anthers* uniform, less than 1 mm, basifixed; *filaments* of united stamens 3–4 mm long, that of free stamens 7–8 mm long. *Ovary* 2–2.5 by 1–1.5 mm, sub-sessile, hairy, gland-dotted; *ovules* 1–2; *style* 7–8 mm long, glabrous, swollen at middle; *stigma*, capitate, hairy. *Fruit* a pod, 1.2–1.4 by 0.4–0.5 cm, 1-seeded, included within the calyx, beaked, turgid, glabrous; beak less than 1 mm long. *Seeds* 4 by 2 by 2 mm, brown, ellipsoid, hilum less than 1 mm long, position ± central.

Flowering & Fruiting — October to November.

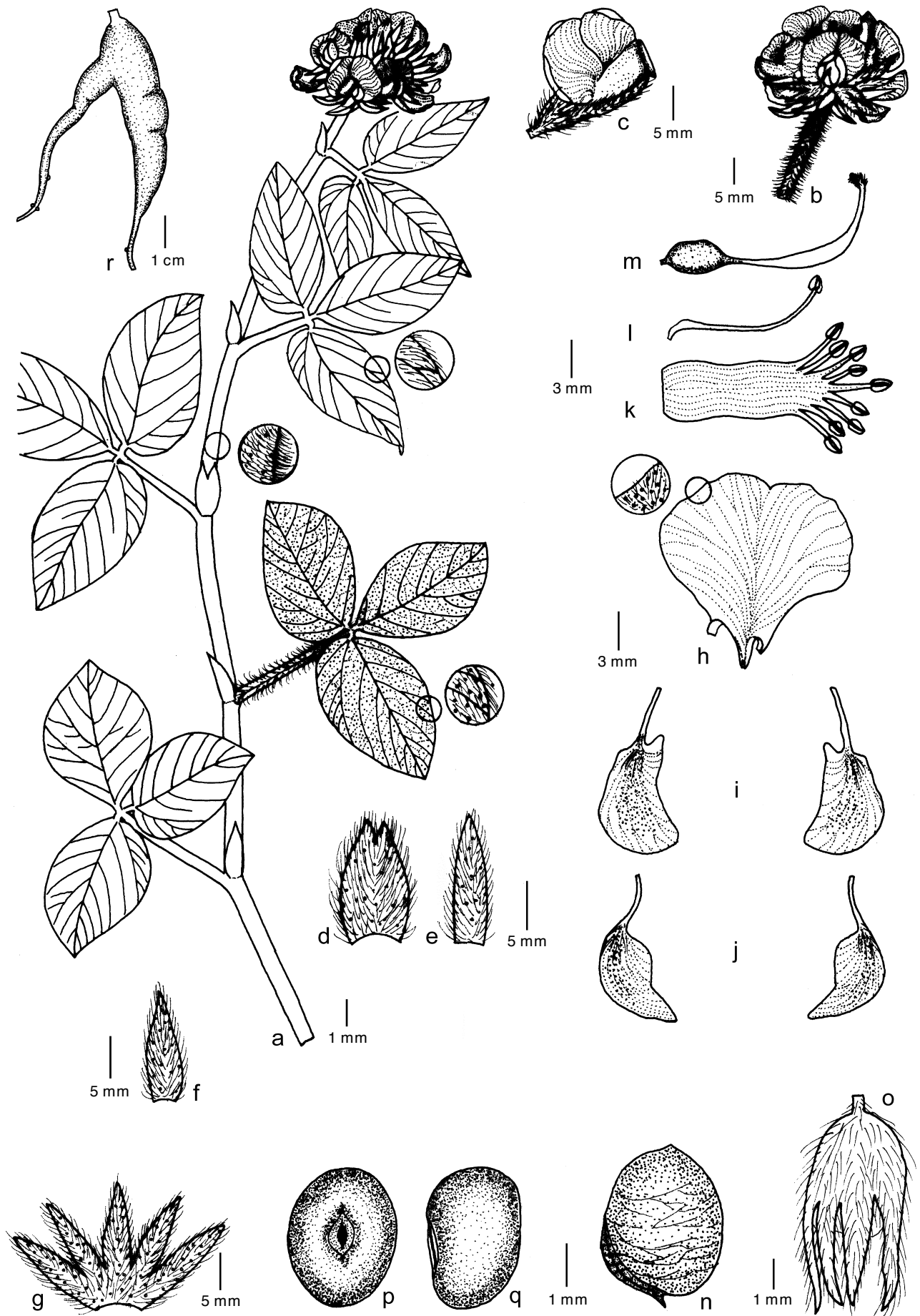
Distribution — Maharashtra (Harishchandragad and Kalsubai hills, Ahmednagar District and Torana fort, Pune District); endemic.

Habitat & Ecology — *Flemingia rollae* is found to grow on high altitude plateaus of northern Western Ghats of Maharashtra. It occurs on hill slopes, rocky crevices and plains at an altitude of c. 700–1600 m asl. It grows in association with species, such as *Adelocaryum* spp., *Adenoon indicum* Dalzell, *Barleria sepalosa* C.B. Clarke, *Ceropegia sahyadrica* Ansari & B.G.Kulk., *Chlorophytum glaucum* Dalzell, *Delphinium malabaricum* (Huth) Munz, *Echinops echinatus* Roxb., *Neuracanthus* spp., *Pleocaulus ritchei* (C.B. Clarke) Bremek.

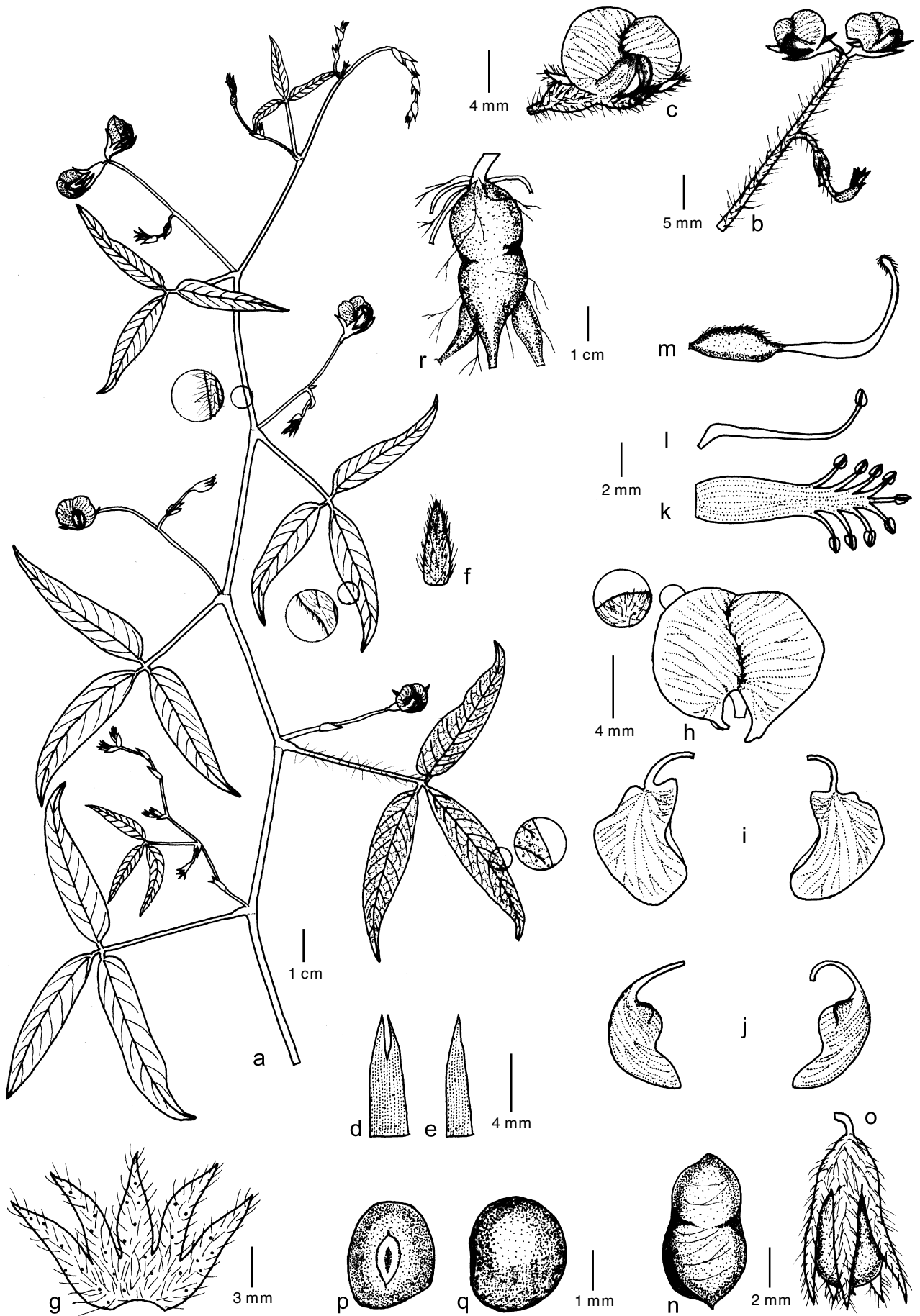
*Additional specimens examined.* INDIA, **Maharashtra**, Ahmednagar District, Panshet Forests, Kalsubai Hills, near Bari, 3 Oct. 2014, *Gavade & Lekhak 6* (SUK); Harishchandragad, near Pachnai, 4 Oct. 2014, *Gavade & Lekhak* s.n. (SUK); Pune District, Torna fort, 26 Sept. 2015, *Nandikar & Giranje 1403* (SUK).

Nomenclatural notes — See Gavade et al. (2016a).





**Fig. 10** *Flemingia rollae* (Billore & Hemadri) An.Kumar. a. Habit; b. inflorescence; c. flower; d. fused stipule; e. free stipule; f. bract; g. calyx, dorsal view; h. standard; i. wing petals; j. keel petals; k. fused androecium; l. free stamen; m. gynoecium; n. fruit without calyx; o. fruit included within the calyx; p. seed, dorsal view; q. seed, lateral view; r. tuberous root (all: Gavade & Lekhak 6, SUK). — Drawing by Sandip Gavade.



**Fig. 11** *Flemingia tuberosa* Dalzell. a. Habit; b. inflorescence; c. flower; d. fused stipule; e. free stipule; f. bract; g. calyx, dorsal view; h. standard; i. wing petals; j. keel petals; k. fused androecium; l. free stamen; m. gynoeceum; n. fruit without calyx; o. fruit included within the calyx; p. seed, dorsal view; q. seed, lateral view; r. tuberous root (all: Gavade 80, SUK). — Drawing by Sandip Gavade.

### 5. *Flemingia tuberosa* Dalzell — Fig. 11, 12

*Flemingia tuberosa* Dalzell (1850) 34. — *Maughania tuberosa* (Dalzell) Kuntze (1891) 199. — Type: India, Maharashtra, Bombay, Malvan, s.d., Dalzell s.n. (lecto K (K001328006), here designated; isolecto K (K001328004), DD).

*Etymology.* Specific epithet 'tuberosa' refers to its tuberous roots.

*Trailing herbs*, 30–90 cm long with branched stem; *roots* tuberous, oblong, 2–3 in cluster, underground; *stems* 2–3 mm diam, terete, sparsely hairy with brown silky antrorse hairs, gland-dotted. *Leaves* 9–13 cm long, stipulate, petiolate; *stipules* 6–8 by 2–4 mm, caducous, lanceolate, acute, basifixed, many-nerved, hairy; hairs antrorse; *petioles* 4–6 cm long, sparsely hairy, gland-dotted; *leaflets* 3, 5–7 by 1–1.5 cm, narrowly linear-lanceolate or oblong, middle leaflet shortly attenuate at base, lateral leaflets asymmetrical or oblique at base, hairy on both surfaces, abaxially gland-dotted, margin ciliate; *glands* orange-red; *petiolules* 1–2 mm long, sparsely hairy. *Inflorescences* axillary or terminal racemes with 2–3 solitary or geminate flowers; *peduncles* 3–6 cm long. *Flowers* 1–1.2 cm long, pedicellate, bracteate; *pedicels* 1–2 mm long, hairy; *bracts* caducous, 4.5–5.5 by 2–2.5 mm, ovate, acute, caducous, many-nerved, gland-dotted, densely hairy; hairs antrorse. *Calyx* 8–10 mm long, hairy, gland-dotted on outer surface; hairs antrorse; *calyx tube* 2–3 mm long, campanulate, hairy, gland-dotted; *calyx teeth* 5, equal, 6–7 by 1–2 mm, lanceolate, acuminate, connate



**Fig. 12** Lectotype of *Flemingia tuberosa* Dalzell. [Reproduced with the kind permission of the Board of Trustees, Royal Botanic Gardens, Kew.]

for 1/3 of their length, many-nerved. *Corolla* purple; *standards* 8–9 by 8–9 mm, rounded to obovate, retuse at apex, hairy, gland-dotted on outer surface towards apex, clawed with 2 auricles at base; claw 2 mm long; auricles  $\leq$  1 mm long; *wings* 8–9 by 4–4.5 mm, oblong, hairy, gland-dotted on outer surface with claw and auricle, claw 2 mm long, auricles  $<$  1 mm long; *keels* 7–8 by 2–2.5 mm, slightly falcate, hairy, gland-dotted on outer surface, with claw and auricle, fused half of its length at lower side, claw 2 mm long, auricle less than 1 mm long. *Stamens* 10, diadelphous (9+1); *staminal tube* 3–4 by 1 mm; *anthers* uniform, less than 1 mm, basifixed; *filaments* of united stamens 2.5–3 mm long, that of free stamens 6–7 mm long. *Ovary* 2 by 1 mm, sub-sessile, hairy, gland-dotted; *ovules* 2; *style* 4–5 mm long, glabrous, swollen at middle; *stigma* capitate, hairy. *Fruit* a pod, 5–6 by 2–2.5 mm, 2-seeded, exceeding the calyx, beaked, turgid, glabrous, septate between seeds; *beak* less than 1 mm long. *Seeds* 3 by 3 by 2 mm, brown, rounded, hilum less than 1 mm long, position  $\pm$  central.

Flowering & Fruiting — August to September.

Distribution — Goa, Gujarat, Karnataka, Kerala and Maharashtra; endemic.

*Habitat & Ecology* — *Flemingia tuberosa* is found to grow on low altitude plateaus of northern Western Ghats of Goa, Kerala, Maharashtra and Karnataka. It occurs on plateaus, rocky crevices and plains at an altitude of c. 150–200 m asl. It grows in association with *Ceropegia attenuata* Hook., *Chamaesyce concanensis* (Janarth. & S.R.Yadav) V.S. Raju, *Chlorophytum laxum* R.Br., *Dipcadi concanense* Baker, *Elaeocharis* spp., *Galactia tenuiflora* var. *minor* Baker, *Glyphochloa forficulata* (C.E.C.Fisch.) Clayton, *Habenaria grandifloriformis* Blatt. & McCann, *Impatiens minor* (DC.) S.M.Almeida, *Indigofera dalzellii* Cooke, *Theriophonum dalzellii* Schott.

*Additional specimens examined.* INDIA, **Dadra**, 29 Sept. 1963, Ansari 93818 (BSI). — **Goa**, North Goa District, Mopa Village, 8 Aug. 2015, Gavade & Lekhak 88 (SUK). — **Maharashtra**, Mumbai Suburban District, Borivali National Park, 13 July 1956, Herbert 1757 (BLAT); *ibid.*, 14 Sept. 1956, Herbert 2252 (BLAT); *ibid.*, 18 Sept. 1956, Herbert 2320 (BLAT); *ibid.*, Herbert 2321 (BLAT); *ibid.*, Herbert 2322 (BLAT); Quarry hill, Malad, 6 Sept. 1956, Shah 7435 (BLAT); Ratnagiri District, near Dapoli, Aug. 1922, Geland 358 (BLAT); Hativale, 17 Oct. 2014, Chandore & Borude s.n. (SUK); *ibid.*, 17 July 2015, Gavade 80 (SUK); *ibid.*, 3 Aug. 2015, Gavade 87 (SUK); *ibid.*, 20 Sept. 2016, Gavade 144 (SUK); Sindhudurg District, Nandos, 6 Aug. 1971, Rao 131510A (BSI); Thane District, Sativali forest, 21 Aug. 1903, Ryan 1164 (BSI); *ibid.*, 20 June 1903, Ryan 920 (BSI); *ibid.*, 29 Sept. 1903, Ryan 1484 (BSI). — **Karnataka**, Uttar Kannada, 5 Sept. 1884, Talbot 975 (BSI).

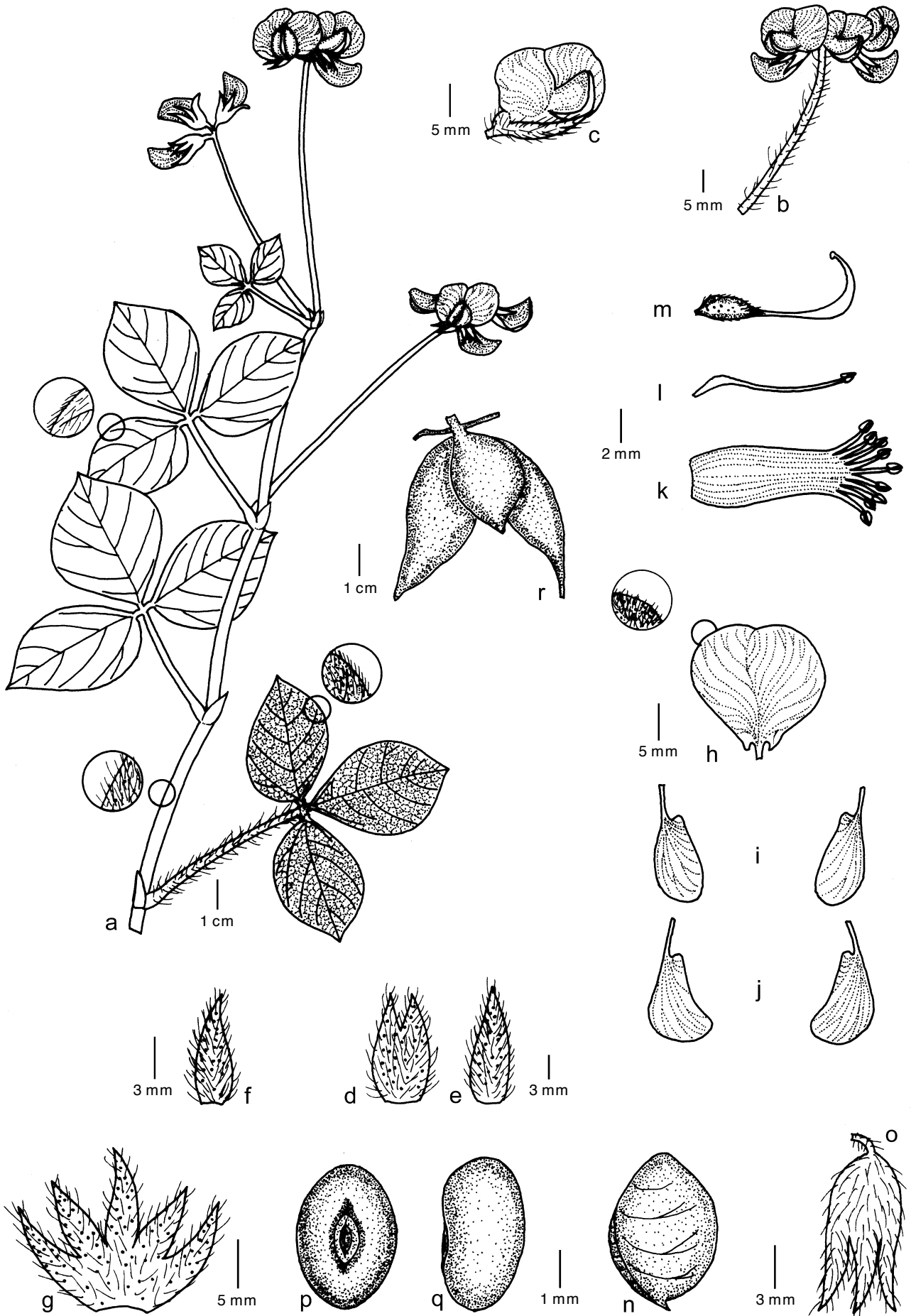
*Nomenclatural notes* — *Flemingia tuberosa* was described by Dalzell from Malvan (Bombay presidency). The protologue bears no information on the type. In search of the type specimen we could trace some specimens at DD and K (K001328006, K001328006). Among these, a single specimen from K (K001328006), which is complete and matches well with the protologue, has been designated here as a lectotype.

### 6. *Flemingia vestita* Benth. ex Baker — Fig. 13, 14

*Flemingia vestita* Benth. ex Baker (1876) 230. — *Maughania vestita* (Benth. ex Baker) Kuntze (1891) 199. — *Lepidocoma vestita* (Benth. ex Baker) M.R. Almeida (1998) 105. — Type: *Blinkworth s.n.*, s.d., *Wallich Cat. Number 5545*, (lecto K-W (K001121248), here designated; isolecto CAL (CAL0000067596), G), India, Kumaon.

*Etymology.* The specific epithet 'vestita' refers to its stem clothed with hairs.

*Decumbent herbs*, 45–60 cm long branched stem; *roots* tuberous, ovoid or elongate, 2–3 in cluster, underground; *stems* 3–4 mm diam, terete, densely hairy with grey, antrorse hairs, gland-dotted. *Leaves* 8–11 cm long; *stipules* caducous, 12–15 by 4–6 mm, ovate to lanceolate, acuminate, fused, splitting at maturity, basifixed, persistent, many-nerved, gland-dotted, densely



**Fig. 13** *Flemingia vestita* Benth. ex Baker. a. Habit; b. inflorescence; c. flower; d. fused stipule; e. free stipule; f. bract; g. calyx, dorsal view; h. standard; i. wing petals; j. keel petals; k. fused androecium; l. free stamen; m. gynoeceum; n. fruit without calyx; o. fruit included within the calyx; p. seed, dorsal view; q. seed, lateral view; r. tuberous root (all: Gavade 167, SUK). — Drawing by Sandip Gavade.



hairy; hairs antrorse; *petioles* 4.5–6.5 cm long, sparsely hairy, gland-dotted; *leaflets* 4–4.8 by 3–4.2 cm, obovate to round, middle leaflet cuneate at base, lateral leaflets asymmetrical or oblique at base, hairy on both surfaces, abaxially gland-dotted, margin ciliate; glands orange-red; *petiolules* 1.8–2 mm long, hairy. *Inflorescences* terminal heads, 3–6-flowered; *peduncles* 3–6 cm long. *Flowers* 1.5–1.7 cm long, pedicellate, bracteate; *pedicels* 2–3 mm long, hairy; *bracts* 6–7 by 2.5–3 mm, ovate to lanceolate, acuminate, caducous, many-nerved, gland-dotted, densely hairy; hairs antrorse. *Calyx* 10–11.5 mm long, hairy, gland-dotted on outer surface; *calyx tube* 5–6.5 mm long, campanulate, hairy, gland-dotted; *calyx teeth* 5, subequal, 5.5–6.5 by 2.2–3 mm, linear to lanceolate, acuminate, connate for 1/2 of their length, many-nerved. *Corolla* reddish pink; *standard* 1.4–1.5 by 1.5–1.6 cm, cordate to round, retuse at apex, hairy, gland-dotted on outer surface, towards apex, clawed with 2 auricles; claw 2–2.5 mm long, auricles  $\leq$  1 mm long; *wings* 12–13 by 3.5–4 mm, oblong, with claw and auricle, claw 4–4.5 mm long, auricles c. 1 mm long; *keel petals* 13–14 by 3.5–4 mm, slightly falcate, hairy, gland-dotted on outer surface, with claw and auricle, fused half of its length at lower side, claw 5–5.5 mm long, auricles  $<$  1 mm long. *Stamens* 10, diadelphous (9+1); *staminal tube* 9–10 by 1 mm; *anthers* uniform, less than 1 mm, basifixed; *filaments* of fused stamens 4–4.5 mm long, that of free stamen 10–11 mm long. *Ovary* 2–2.5 by 1 mm, sub-sessile, hairy, gland-dotted; *ovules* 2; *style* 8–8.5 mm long, glabrous, swollen at middle; *stigma* capitate, hairy. *Fruit* a pod, (9–)12–13 by 4–5 mm, 1-seeded, included within calyx, beaked, turgid, glabrous; *beak* less than 1 mm long. *Seeds* 4.5 by 2.5 by 2.5 mm, black, ellipsoid, hilum less than 1 mm long, position  $\pm$  central.

Flowering & Fruiting — October to December.



Fig. 14 Lectotype of *Flemingia vestita* Benth. ex Baker. [Reproduced with the kind permission of the Board of Trustees, Royal Botanic Gardens, Kew.]

Distribution — Himachal Pradesh, Meghalaya and Uttarakhand. Nepal.

Habitat & Ecology — *Flemingia vestita* grows on the slopes of mountains. It occurs at high altitude of c. (1600–)1800–2100 m asl.

*Additional specimens examined.* INDIA, without day Sept. 1964, *Brandis* 3823 (DD); *ibid.*, *Schlich* 139 (BM, OXF); N.W. Himalayas, *Royle s.n.* (CAL, LE). — **Himachal Pradesh**, Chamba District, Dalhousie, 22 Sept. 1874, *Clarke* 22901 F (E); Kangra District, McLeodganj, 28 Aug. 2017, *Bhatia* (SUK); Shimla District, Pulbaha, 19 Aug. 1940, *Raizada* 14261 (DD); Shali, 17 Aug. 1884, *Drummond* 2510 (DD); Shimla, s.d., *Drummond* 2518 (DD); Elysian Hill, Simla, 13 Aug. 1877, *Gamble* 4718 A (MH); *ibid.*, B (CAL, GH); *ibid.*, *Gamble* 4813b (DD); Chota Simla, 2 Aug. 1877, *Gamble* 4813A (MH); near Taradevi, 18 Aug. 1889, *Duthie* 8768 (DD); Hoya Khud, Simla, 1866, *Johnson s.n.* (CAL); Simla, Oct. 1907, *Meebold* 8700 (CAL); Chall, Banjani village, 14 May 1945, *Ram* (DD, MH); Jagu Road, 6 Aug. 1940, *Raizada* 10099 (DD); Pulbaha, Giri Road, 9 Aug. 1940, *Raizada* 14261 (DD); *ibid.*, *Royle* 63/243 (DD); *ibid.*, *Royle* 63/255 (DD); Simla, Sept. without year, *Schlich* 139 (BM, OXF); Simla, Oct. 1928, *Wall* 421 (S); *ibid.*, 18 Aug. 1889, *Duthie* 8768 (DD); *ibid.*, 6 Aug. 1940, *Raizada* 10099 (DD); Sirmour District, 6 Aug. 1986, *Karki* 82221 (BSD); Solan District, Banjani, 14 May 1905, *Ram s.n.* (DD); 25 km to Kalka, before Dharampur, 15 Oct. 1977, *Van der Maesen* 2955 (ICRISAT, WAG); Shalai, N.W. Himalayas, 31 Aug. 1889, *Watt* 9585 (E); Simla s.d., *Watt s.n.* (OXF). — **Jammu and Kashmir**, Pagaway, 14 Aug. 1884, *Drummond* 2519 (DD). — **Meghalaya**, East Khasi Hills District, s.d., without collector *s.n.* (ASSAM); without precise locality, 19 Oct. 1867, *Clarke* 5721 (CAL); *ibid.*, Aug. 1874, *Kurz* 68 (A, CAL); Shillong, 13 Aug. 1885, *Clarke* 40296 A (CAL); Lailankote, 26 Sept. 1886, *Clarke* 45555 B (CAL); *ibid.*, C (BM); *ibid.*, E (US); Shillong, Bishop's Fall, 8 Oct. 1890, *Collett s.n.* (BM); Dum pep, Khasi hills, 13 Oct. 1910, *Hooper* 34685 (CAL); Khasi Hills, Nov. 1873, *Mann s.n.* (ASSAM, CAL, DD, MH); Khasia, s.d., *Hooker & Thomson s.n.* (BM, MH, US); Khasi hills, Dec. 1897, *Prain* 1823 (CAL); Kanital, Aug. 1899, *Ramsukh s.n.* (DD); Shillong, s.d., *Kanjilal* 7235 (ASSAM). — **Uttarakhand**, Almora District, Almora to Kalmatia, 2 Oct. 1957, *Rao* 4726 (BSB); Gairar, 17 Oct. 1975, *Vohra* 57991 (BSD); Kukuchina, 8 Oct. 1975, *Wadhwa* 57529 (BSD); Panuwanaula, 30 Sept. 1900, *Khan* 24336 A (DD); Chamoli District, 4 Sept. 1889, *Hajara* 87620 (BSD); Ansuva, 5 Oct. 1970, *Naithani* 42028 (BSD); Bhyundar, 15 Aug. 1963, *Bhattacharyya* 29332 (BSD); Champawat District, Abbott Mount, 23 Sept. 2002, *Karki* 98606 (BSD); Bagargad, 27 Sept. 1963, *Bhattacharyya* 30884 (BSD); on the way to Wan, Sept. 1993, *Balvin* 77140 (BSD); Lohajung, Sept. 1993, *Baloni* 73634 (BSD); Dehradun District, Chakrata, 24 Sept. 1943, *Raizada* 18294 (DD); *ibid.*, 18 Oct. 1946, *Raizada s.n.* (DD); Kandar village, Jaunsar, N.W. Provinces, Sept. 1890, *Keshavanand* 232 (OXF); Landour, Oct. 1945, *Raizada s.n.* (DD); 10 Sept. 1948, *Fleming* 738 (DD); Mussoorie, s.d., *Duthie s.n.* (DD); Mussoorie, Chamars Khud, Aug. 1915, *Anderson* 30 (E); Tehri Road, Landour, Mussoorie, 11 Aug. 1934, *Stewart* 14311 (A); Jabberkhet, Landour, Mussoorie, 18 Aug. 1934, *Stewart* 15613 (A); *ibid.*, 14 Sept. 1927, *Gupta s.n.* (DD); *ibid.*, Oct. 1945, *Raizada s.n.* (DD); *ibid.*, Aug. 1957, *Rau* 3311 (BSD); *ibid.*, July 1877, *Duthie* 140 (DD); *ibid.*, Sept. 1877, *Duthie* 145 (CAL); *ibid.*, Sept. 1878, *Duthie s.n.* (DD); Benog, 8 Sept. 1960, *Saxena* 1165 (DD); Benog, 18 Aug. 1961, *Saxena* 2155b (DD); *ibid.*, 1869, *King s.n.* (CAL); on the way to Landour, 21 Sept. 1877, *Duthie* 1540 (DD); Hardwar District, Rajpur, 19 Sept. 1970, *Vaid s.n.* (DD); Nainital District, Ayarpatta, 15 Aug. 1937, *Champion* 7703 (DD); Chana above Nainital, s.d., *Hume s.n.* (CAL); Pithoragarh District, Chulkot, 20 July 1951, *Thomas* 20857 (DD); Nagling, 5 Sept. 1900, *Duthie* 24336 (K); Nongling, Dharma valley, 5 Sept. 1900, *Khan* 24336 (DD); Milankuti, 12 Sept. 1983, *Baloni* 75002 (BSD); on the way to Sirkha, Sept. 1986, *Baludi* 83218 (BSD); on the way to Patalthor, 18 Sept. 1983, *Balvin* 75294 (BSD); Pithoragarh, 26 Sept. 1975, *Arora* 56541 (BSD); Pauri Garhwal District, on the way to Khirsu to Pouri, 18 Sept. 1975, *Rao* 56335 (BSD); Ranisi, 11 Sept. 1972, *Naithani* 3687 (DD); Rudraprayag District, Madhyamaheshwar, 13 Sept. 1997, *Pundir* 91970 (BSD); Tehri Garhwal District, Sept. 1881, *Duthie s.n.* (DD); Rangalgarh, 26 Sept. 1954, *Bahni* 21459 (DD); Reeh, 8 Aug. 1978, *Goal* 64279 (BSD); *ibid.*, 22 Sept. 1979, *Goal* 67979 (BSD); Garhwal, s.d., *King s.n.* (CAL).

Taxonomic note — Baker (1876) reported one variety under *F. vestita*, i.e., *F. vestita* var. *nilgheriensis*. Subsequent researchers (Cooke 1902, Gamble 1928, Sanjappa 1992, Kothari 2001) treated this as the distinct species *F. nilgheriensis*. We agree with them. Almeida (1998) reported *F. vestita* as *Lepidocoma vestita* (Benth. ex Baker) M.R. Almeida in his Flora of Maharashtra; however, field surveys and herbarium consultations reveal that this species has not been collected from Maharashtra so far.

Nomenclatural note — The binomial *Dolichos vestitus* Graham was proposed by Graham in the Wallich catalogue. Graham omitted to validate the name (Wallich 1828). Baker (1876) validated Graham's name and proposed a new combination *Flemingia vestita* in Hooker's Flora of British India. However, Baker (1876) did not mention any specific sheet as the type in the protologue but he cited the specimen with *Wallich catalogue number 5545*. In search of the type we could locate three sheets, one each at K (K-W, K001121248), CAL (0000067596) and G. All these match well with the description given in the protologue and can be considered as original material. In order to fix the application of the binomial *Flemingia vestita* we herewith designate K (K001121248) from the Wallich collection as lectotype.

## DISCUSSION

Baker (1876) split *Flemingia* into five subgenera, viz. *Chalaria*, *Flemingiastrum*, *Lepidocoma*, *Ostryodum* and *Rhynchosioides*. The characters used to delimit these subgenera were habit (erect shrub or trailing herb), nature of leaves (digitately trifoliolate or unifoliolate), inflorescence (racemes/panicles or heads) and bracts (small/large or caducous/persistent). The subg. *Rhynchosioides* occupies an isolated position within the genus as the component species are herbaceous and usually possess a capitate head. The inclusion of *F. tuberosa* within the subg. *Rhynchosioides* makes it a heterogeneous assemblage. *Flemingia tuberosa* bears racemose inflorescences in contrast to the capitate heads that are characteristic of the subgenus. The presence of usually 2-seeded pod (as against 1-seeded pod) and pink colour corolla (as against blue/purple/red corolla) further indicate that the species may not belong to subg. *Rhynchosioides*. Furthermore, the ecology of the species is entirely different from those of subg. *Rhynchosioides*. *Flemingia tuberosa* is confined to the low altitude lateritic plateau ecosystems (< 200 m asl) that form a part of the western coast of India. Other species of subg. *Rhynchosioides* including the newly described *F. sirindhorniae* are restricted either to the high altitude lateritic plateaus or mountains ( $\geq 900$  m asl). *Flemingia gracilis*, *F. mukerjeeana*, *F. nilgheriensis* and *F. rollae* are a part of the flora of the Western Ghats whereas *F. vestita* occupies an altogether distinct geographical zone, i.e., North Eastern and North Western Himalayas of India and Nepal. The edapho-climatic regimes of high and low altitude lateritic plateaus or mountains differ drastically. For instance, the amount of rainfall varies greatly in these ecosystems. It is 1500–2000 mm in coastal plateaus and 5000–6000 mm at higher altitudes, mainly during the monsoon season (Gadgil 2002). Joshi & Janarthanam (2004) found out that the ephemeral vegetation of plateaus in northern Western Ghats is closely linked to the rainfall patterns. Considering these facts it is obvious that the ecological niches exploited by *F. tuberosa* and the rest of the species of subg. *Rhynchosioides* are altogether different. Thus, one of the reasons for the evolution of distinct morphology in *F. tuberosa* could be the niche divergence. Another possibility could be an independent or allotropic origin of *F. tuberosa*.

Though molecular sequences have been generated from *Flemingia* species, it was mainly used for validation of medicinal plants (Wu et al. 2013) or DNA barcoding (Liu et al. 2015). Egan et al. (2016) included only three species of *Flemingia* (*F. rhodocarpa* Baker (syn. of *F. grahamiana*), *F. parviflora* Benth. and *F. strobilifera*) in their study of the genus *Pueraria* DC. *Flemingia* was nested within the clade *Cajaninae* along with *Cajanus* DC., *Bolusafra* Kuntze, *Eriosema* (DC.) G. Don, *Rhynchosia* Lour. and *Adenodolichos* Harms. Our study has shown the monophyly of *Flemingia* by including 16 species within its range. Our sampling of subg. *Rhynchosioides* is nearly complete except

for the recently described *F. sirindhorniae*. In the ITS dataset, *F. tuberosa* comes out a separate species with respect to the other species (Fig. 1). Based on the distinct occurrence in the ITS phylogenetic tree as well as morphological and altitudinal differences we suggest that *F. tuberosa* could be placed in a separate subgenus other than *Rhynchosioides*. However, creating a monotypic subgenus does not really improve the taxonomy of the genus and hence *F. tuberosa* has been retained in the subgenus. The subgenus comprises herbaceous plants and occurrence of its members in elevated rocky plateaus especially offers clues to the choice of this habitat where the soil is shallow and hence a tree-like habit is not possible.

The relationships among different subgenera in this genus need to be resolved only with complete sampling of the species in this complex. Furthermore, in future studies involving better sampling it would be interesting to study the phylogenetic position of the species such as *F. grahamiana* which occurs in both Asia and Africa.

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