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Revisiting the taxonomy of *Exacum courtallense* (Gentianaceae) and recognizing *E. courtallense* var. *laxiflorum* at the species rank

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Abstract

Morphological, phenological and ecological evidences support the exclusion of *Exacum courtallense* var. *laxiflorum* Gamble (synonym: *E. courtallense* var. *bonaccordense* M. Mohanan) from *E. courtallense* Arn. resulting in the establishment of a new species *Exacum laxiflorum* (Gamble) Geethakumary, Deepu, Kissling & Pandurangan.

Keywords: *Exacum*, Kerala, Tamil Nadu, Taxonomy, Western Ghats

Introduction

The genus *Exacum* Linnaeus (1753: 112). (Gentianaceae, Exaceae) is a group of paleotropical plants that includes 77 taxa (POWO 2019) divided into two sections: sect. *Exacum* and sect. *Africana* (Klackenberg 1985). Recent biogeographical, karyological and molecular data support both sections (Yuan *et al.* 2005, Kissling *et al.* 2008, Kissling *et al.* 2009). Section *Exacum* (29 species, including saprophytes previously included in *Cotylanthera* Blume 1826: 707) is restricted to Asia and occurs mainly in India and Sri Lanka. Section *Africana* (48 species) is distributed in Madagascar, Socotra and the African mainland.

Exacum courtallense Arnott (1839:175) was described based on the collection of Robert Wight from Courtallum hills in India (Arnott 1839). Later, Gamble (1923) described a distinct variety: *E. courtallense* var. *laxiflorum* Gamble (1923: 873) based on the collection of Beddome from Travancore hills. The variety was distinguished by flowers in lax leafy cymes, leaves longer and more acuminate, and much nerved calyx-lobes, especially in the fruit. Another variety was added, *E. courtallense* var. *boneccordense* M. Mohanan (1994: 305; as “*boneccordensis*”) based on collections from Chemunji hills and Bonaccord. This new variety was distinguished from var. *laxiflorum* by solitary flowers with long pedicels and membranous leaves. All three varieties were synonymized under *E. courtallense* (Klackenberg 1985, Sasidharan 2004, Shahina and Nampy 2016).

For ten years, a systematic exploration of the genus *Exacum* in the Western Ghats allowed us to follow numerous *Exacum* species populations and revealed striking, non-overlapping, morphological and ecological differences between *E. courtallense* var. *courtallense* and *E. courtallense* var. *laxiflorum*. Furthermore, our thorough observations of the type locality of *E. courtallense* var. *boneccordense* show that this taxon is only a larger form of *E. courtallense* var. *laxiflorum*; both taxa have an overlapping habitat and readily hybridize. Based on those observations (detailed below), we deemed it necessary to erect *E. courtallense* var. *laxiflorum* to the rank of species (hereafter *E. laxiflorum*) and synonymize *E. courtallense* var. *boneccordense* with *E. laxiflorum*.

Material and method

Exacum courtallense and its varieties were observed and described from herbarium material, photography and living plants observed in the field (including type localities). All relevant material was examined in CMPR, KFRI, K, L, MH, P RHT, TBGT herbaria. Herbarium codes follow Theirs (2021 – continuously updated). For type specimens cited, barcode numbers of herbarium specimens, when available, are cited in after the herbarium code. The accession number, preceded by “Acc. No.” is cited for the specimen examined when the barcode number is not available. All specimens cited have been examined, unless indicated by “n.v.” (not seen) after the herbarium acronym. A preliminary extinction risk assessment of *E. laxiflorum* was made using the IUCN Red List Categories and Criteria (IUCN 2012).

Results

Exacum laxiflorum morphologically differs from *E. courtallense* (table 1) by much-branched erect somewhat ascending herbs (*vs* low bushy habit, dichotomously branched from the base), narrowly elliptic to lanceolate, long acuminate, chartaceous leaves (*vs* orbicular to lanceolate, succulent leaves with scarious margins), flowers appearing as terminal or axillary dichasial lax cymes (*vs* terminal 5-flowered cyme or rarely solitary from the terminal axis), pedicels bent towards one side in fruit (*vs* always straight pedicels), calyx wings abruptly narrowing towards the base (*vs* rounded calyx wings which become sub-cordate in fruit), blue to purplish corolla lobes (*vs* deep blue), anthers are slightly curved with a convex back face (*vs* not curved and with a flat back face), ellipsoid ovary (*vs* oblong), ovate capsule (*vs* oblong-ovate).

Furthermore, *E. courtallense* had a narrow habitat specificity and occurred along rocky outcrops, often in open montane grasslands. The presence of *E. courtallense* was favoured by the presence of rock formation and a low percentage of vegetation coverage with a high slope and direct influence of wind; while *E. laxiflorum* inhabits forest grassland margins to semi-evergreen forests.

Finally, *E. courtallense* and *E. laxiflorum* differ in their phenology, with almost no overlap. The former is primarily a winter species, and the latter being a monsoon one.

Taxonomical treatments

Exacum courtallense Arnott (1839: 175).

Type:—INDIA. Tamil Nadu: Tirunelveli District, Courtallum hills, August 1835, *Wight 1835. 553* (lectotype E [barcode E00001507, image], designated by Klackenberg (1985: 66); isolectotypes E [barcode E00001508, image], NY [barcode NY00297601, image]).

Perennial *herbs*, to 30 cm tall; low, bushy, dichotomously branched from the base (older plants occasionally diffuse). *Stem* terete at the base, sharply 4-angular at medio-distal portion; young branches 4-lineolate; internodes 4–45 mm long. *Leaves* opposite, sessile, orbicular (when young) to lanceolate, 10–45 × 7–23 mm, succulent, glabrous, green, base cuneate, stem-clasping, margin scarious, apex acute to obtuse, (1–)3–5 veined, secondary veins diverging from base of the lamina, abaxially prominent. Inflorescence terminal, 5-flowered cyme, rarely solitary from terminal axis; peduncles 15–20 mm long; pedicels 8–15 mm long, slightly enlarging in fruit (10–20 mm), straight. *Calyx* 5-lobed; tube about half the length of the calyx, campanulate, 3–4 mm long; lobes 6–7 mm long, overlapping at the base in fruit, tapering to a long point at the apex, winged; wings *ca.* 2 mm broad, rounded or in fruit subcordate at the base, accrescent in fruit with prominent veins. *Corolla* tube *ca.* 6 mm long, green; lobes 5, obovate, 11–13 × 6–7 mm, obtuse to acute at apex, long persistent in fruit but eventually deciduous, blue to deep blue. *Stamens* 5, 8–9 mm long; filaments *ca.* 3 mm, as long as the anther, attached at the distal portion of the corolla throat; anthers bottle-shaped with a long narrow neck, *ca.* 6 mm long, base cordate, opening by apical pores that later widen to slits to the base, without papilla. *Ovary* oblong, *ca.* 5 mm long; style 10–12 mm long, curved; stigma capitate. *Capsule* oblong-ovate, *ca.* 7 × 3 mm, dehiscent septically, 2-valved; fruiting pedicel straight; style persistent. *Seeds* many, irregularly rhomboid, angular, with shallowly sunken sides (Fig. 1).

TABLE 1. Diagnostic characters of *Exacum courtallense* and *E. laxiflorum*.

Characters	<i>E. courtallense</i>	<i>E. laxiflorum</i>
Habit	Low bushy herbs, dichotomously branched from base, 10–30 cm tall	Much branched erect somewhat ascending herbs, 15–152 cm tall
Stem	Terete at the base, angular above, young branches 4-lineolate	Terete at the base, angular above, young branches 4-lineolate
Internode	4–45 mm long	10–95 mm long
Leaves	Orbicular to lanceolate, 10–45 × 7–23 mm, base cuneate, apex acute to obtuse, sessile, stem-clasping, (1–)3–5 nerved, succulent, margin scariosus, veins diverging from the base of the lamina not reaching to the apex	Narrowly elliptic to lanceolate, 15–88 × 5–20 mm, attenuate at base, subsessile, long acuminate at apex, 3-nerved, chartaceous, margin not scariosus, veins diverging from the base of the lamina reaching to the apex
Flowers	Terminal, 5-flowered cyme, or rarely solitary from the terminal axis	Terminal or axillary, dichasial lax cymes, rarely solitary at terminal axils
Peduncle	15–20 mm long	15–55 mm long
Pedicels	8–15 mm long, slightly enlarging in fruit (10–20 mm), straight	6–25 mm long, enlarging in fruit (10–30 mm), bent towards one side
Calyx	Wings rounded, sub-cordate in fruit, accrescent in fruit	Wings abruptly narrowing towards the base, accrescent in fruit
Corolla	Lobes obovate, 11–13 × 6–7 mm, obtuse to acute at the apex, blue to deep blue	Lobes broadly obovate to oblong, 8–11 × 5–12 mm, sub-acute at the apex, blue towards purplish
Anthers	ca. 6 mm long, bottle-shaped with a long narrow neck, not curved and with a flat back face	5–5.5 mm long, bottle-shaped with a long narrow neck, slightly curved with a convex back face
Ovary	Oblong	Ellipsoid
Fruiting pedicel	Straight	Slightly bent towards one side
Capsule	Oblong ovate	Ovoid

Phenology:—Flowering and fruiting were observed from September to February.

Chromosome number:— $2n=68$ (Mallikarjuna *et al.* 1987)

Distribution and Habitat:—Occurs in the rocky outcrops, mostly in high altitude grasslands in the southern Western Ghats of Kerala and Tamil Nadu.

Specimens examined:—INDIA. Tamil Nadu, Tirunelveli District, Courtallum hills, 1836, *Wight 1836.552* (MH). Kerala, Thiruvananthapuram District, Ponnudi, ± 793 m, 7 December 2014, *Geethakumary 83197* (TBGT); *ibid.*, 18 October 2015, *Geethakumary 84385* (TBGT); *ibid.*, 12 January 2015, *Geethakumary 84743* (TBGT); *ibid.*, 7 December 2015, *Deepu Sivadas 78878* (TBGT); *ibid.*, 10 January 2016, *Geethakumary 84794* (TBGT).

Note:—The specimen NY00297601 is likely to be the material studied by Arnott as this material reached NY from Arnott's collection.

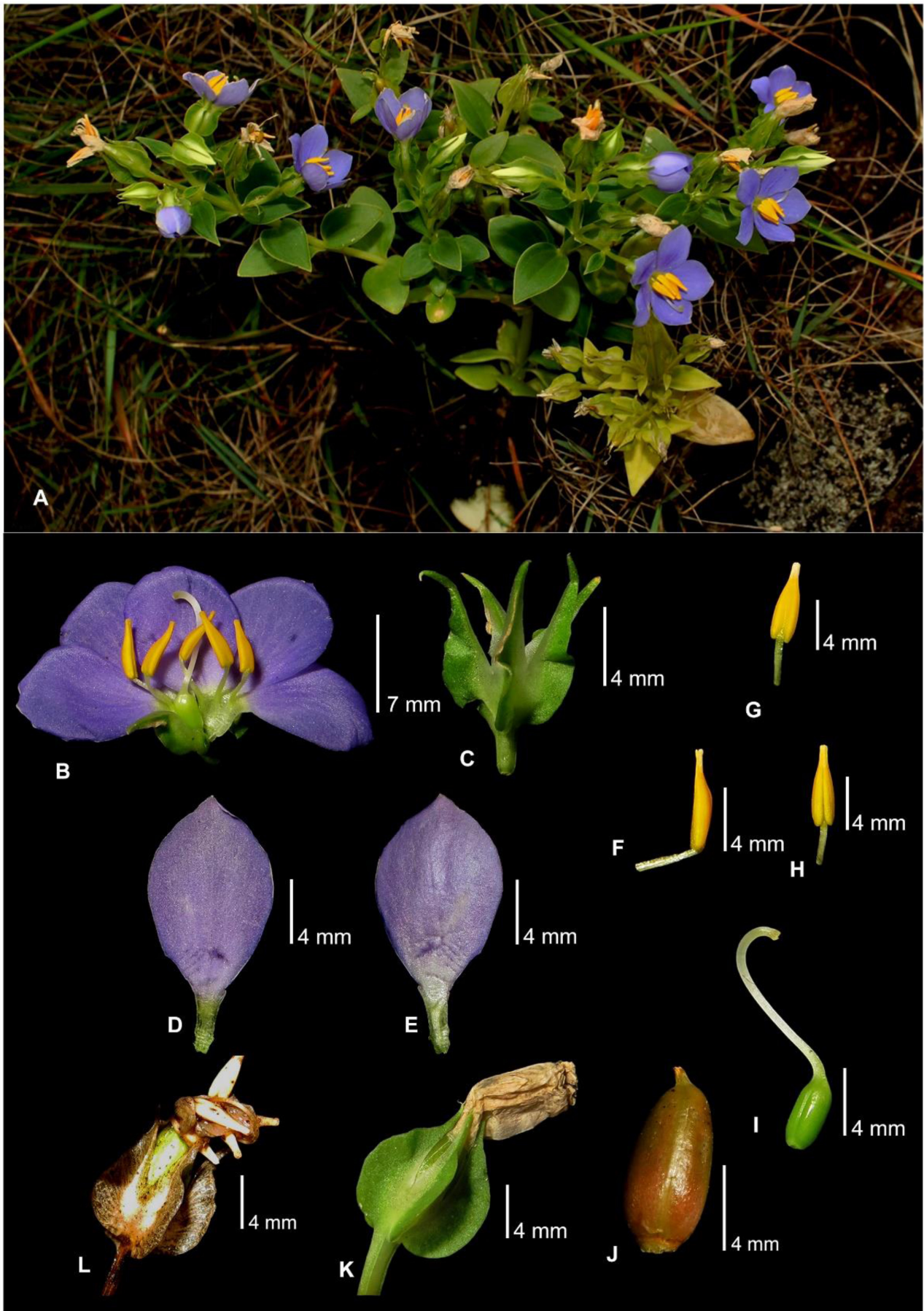


FIGURE 1. *Exacum courtallense* Arnott. **A.** Habit; **B.** Flower split open; **C.** Calyx; **D–E.** Petal; **F–H.** Stamen; **I.** Pistil; **J.** Fruit; **K.** Young fruiting calyx; **L.** Dry fruiting calyx.

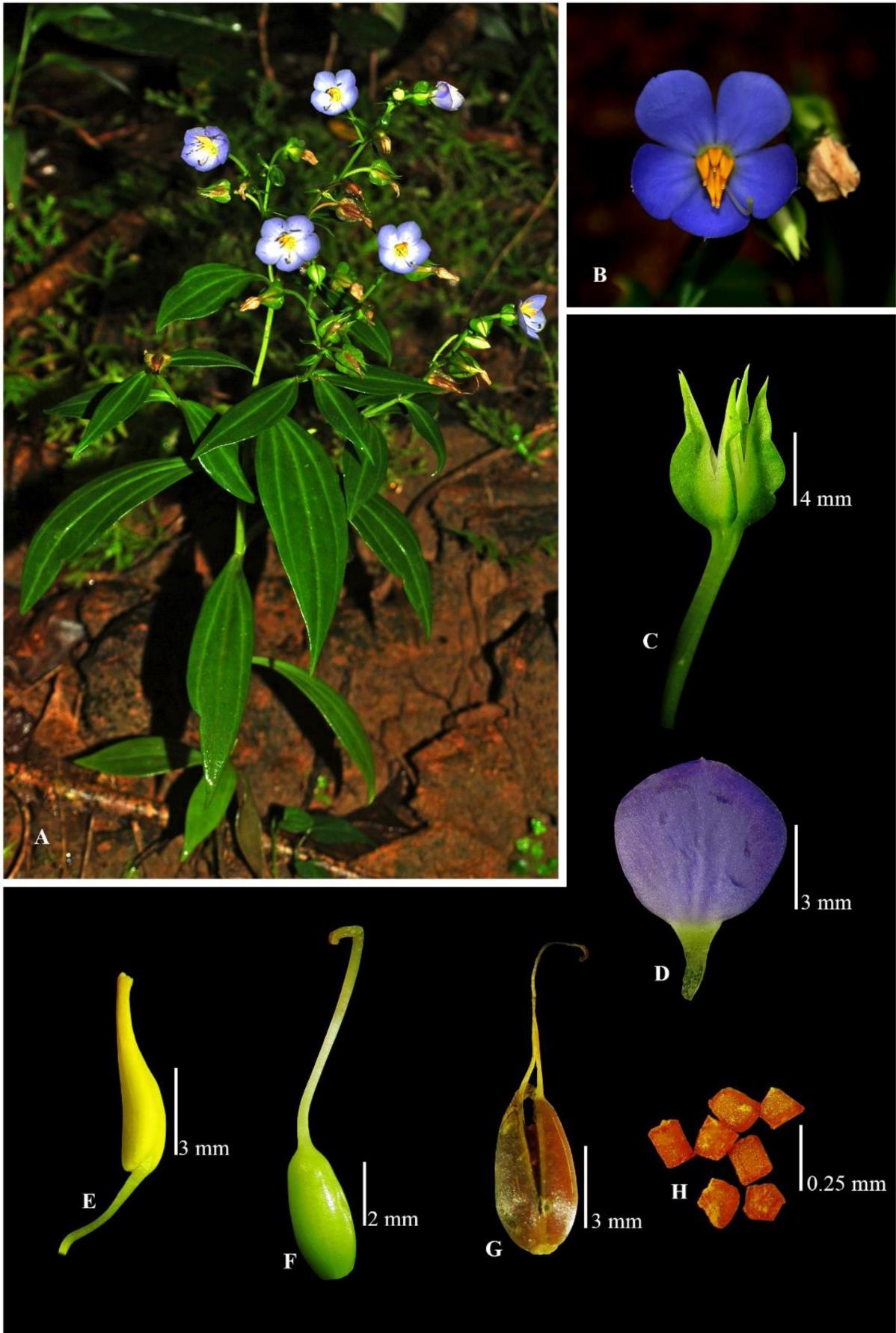


FIGURE 2. *Exacum laxiflorum* (Gamble) Geethakumary, Deepu, Kissling & Pandurangan A. Habit; B. Flower; C. Calyx; D. Petal; E. Stamen; F. Pistil; G. Mature fruit split open; H. Seeds.

Exacum laxiflorum (Gamble) Geethakumary, Deepu, Kissling & Pandurangan, *comb. et stat. nov.*

Exacum courtallense var. *laxiflorum* Gamble (1923: 873).

Type:—INDIA. Travancore, 1873, *Beddome s.n.* (lectotype MH [barcode MH00002366], designated by Henry & Swaminathan (1983: 458); isolectotype K [barcode K000759944]).

Exacum courtallense var. *boneccordense* M. Mohanan in M. Mohanan & A.N. Henry (1994: 305, as “*boneccordensis*”).

Type:—INDIA. Kerala, Thiruvananthapuram district, Bonaccord, *s. d.*, M. Mohanan 63225 (holotype CAL n.v.; isotype MH n.v.).

Herbs, 15–152 cm tall. Stems much branched, terete at the base, sharply 4-angular above, young branches 4-lineolate, internodes 10–95 mm. *Leaves* opposite, subsessile, narrowly elliptic to lanceolate, 15–88 × 5–20 mm, chartaceous, glabrous, green, base attenuate, petiolate, apex long acuminate, 3–veined (midvein with one secondary vein on each side), tips recurved, veins diverging from the base of the lamina reaching to the apex prominent. Inflorescence terminal or axillary dichasial lax cymes, rarely solitary from terminal axis; peduncles 15–55 mm long; pedicels 6–25 mm long, enlarging in fruit (10–30 mm), bent towards one side. *Calyx* 5-lobed; tube campanulate, 2–3 mm long; lobes 5–7 mm long acuminate at apex, winged; wings 2–3 mm broad, wings narrowing at the apex, abruptly narrowing to base, accrescent in fruit, with prominent veins. *Corolla* tube 3–4 mm long, green; lobes 5, broadly obovate-oblong, 8–11 × 5–12 mm, subacute at apex, long persistent in fruit with prominent nerves but eventually deciduous, blue towards purplish. *Stamens* 5, 6.5–9.5 mm long; filaments *ca.* 4 mm long, attached at distal portion of the corolla tube; anthers bottle-shaped with long narrow neck, 5–5.5 mm long, slightly curved with the convex back face, base cordate, opening by apical pores that later widen to slits to the base, without papilla. *Ovary* ellipsoid, *ca.* 4 mm long; style 9–10 mm long, curved, persistent; stigma capitate. *Capsule* ovoid, 6–9 × 3–4 mm, dehiscent septicidally, 2-valved; style persistent. *Seeds* many, irregularly rhomboid, angular, with shallowly sunken sides (Fig. 2).

Note:—We searched for the type specimens of *Exacum courtallense* var. *boneccordense* in both CAL and MH, and we were unable to locate them. However, for this study, specimens collected from the type locality matching the drawing in the protologue were used for logical conclusions.

Phenology:—Flowering and fruiting were observed from July to December.

Chromosome number:— $2n=68$ (Mallikarjuna *et al.* 1987)

Distribution and Habitat:—Occurs in the evergreen and semi-evergreen forests of the Southern Western Ghats in Kerala and Tamil Nadu. This species has a wider distribution than *E. courtallense* and is recorded from many districts in Kerala.

Conservation status:—Based on the information from field surveys and herbarium data, the species is known from 13 subpopulations. Some of these subpopulations are under stress due to a decline in the quality of habitat. The species is annual, and it is observed to have undergone a reduction of over 50% over a period of 10 years due to a decline in area of occupancy (AOO) and quality of habitat, as evident by the fact that some subpopulations seen in the past are currently not present. Some subpopulations occur along the trek paths and wall cuttings along the roads, which are subjected to annual clearing, posing a threat to these subpopulations. Based on the available population information, the AOO of the species is not expected to be greater than 500 km². Given the species has a low AOO, suffered population decline over the past, and the continuing threat due to the decline in habitat quality, the species is assessed as Endangered [EN A2ac; B2b(ii, iv, v)].

Specimens examined:—INDIA. Kerala, Ernakulam District, Bhoothathankettu, 22 September 2012, *Geethakumary 70936* (TBGT). Idukki District, Kulamavu, 7 July 1984, *C.N. Mohanan 82012* (MH); Thiruvananthapuram District, Travancore hills, 26 December 1821, *R. H. Beddome s.n.* (MH); Travancore, 1873, *R. H. Beddome s.n.* (MH); Neyyar Dam, *K. Rajappan, s.n.* (UCT); Forest near Bonaccord, 500 m, 1 October 1973, *J. Joseph 44484* (MH); Bonaccord, 600 m, 22 March 1978, *M. Mohanan 54736* (MH); *ibid.*, + 575 m, 3 August 1978, *M. Mohanan 58523* (MH); *ibid.*, 700 m, 18 May 1991, *N. Mohanan 10818* (TBGT); *ibid.*, 30 October 1992, *E S Santhoshkumar & M. A. Jabbar 14727* (TBGT); *ibid.*, ± 600 m, *Geethakumary 53681* (TBGT); *ibid.*, 11 December 2014, *Geethakumary 80885* (TBGT); *ibid.*, + 700m, 11 December 2014, *Geethakumary 80885* (TBGT); *ibid.*, 12 August 2011, *Geethakumary 67929* (TBGT); *ibid.*, 16 November 2011, *Geethakumary 69883* (TBGT); Athirumala, 11 December 2014, *Geethakumary 80887* (TBGT); *ibid.*, 1100 m, 12 October 1988, *N. Mohanan 4215* (CALI, TBGT); Meenmutty, 500 m, 6 November 1990, *N. Mohanan 10147* (TBGT); Chemunji, 900 m, 5 February 1991, *N. Mohanan 10325* (TBGT); Karamanayar, 700 m, 30 July 1991, *N. Mohanan 10704* (TBGT); Near Karamana River, 660 m, 26 September 1995, *C.S.K. & S. A. K. 24359* (TBGT); near Karamanayar, *s.d.*, *Geethakumary 63693* (TBGT); Agasthiyamala MPCA, 27 April 1994, *N. Mohanan & T. Shaju 2055* (TBGT); Cement cana, 800 m, 14 August 2001, *NWFP team 46630* (TBGT); Way to Koviltherimala, 16 November 2011, *Geethakumary 69884* (TBGT); *ibid.*, *Geethakumary 69886* (TBGT); Chemunji, 16 November 2011, *Geethakumary 69888* (TBGT). TAMILNADU: Kanyakumari District, Way to Muthukuzhivayal,

± 1000 m, 31 August 1976, *A.N. Henry 48174* (MH); Thovazha hill, *s.d.*, *Narayana Iyer s.n.* (TBGT); Tirunelveli District, Mahendragiri, 18 September 1916, *s.coll. 13249* (MH).

Key to *Exacum* species in the Western Ghats

1.	Flowers 4-merous	2
-	Flowers 5-merous	8
2.	Calyx lobes without wings	3
-	Calyx lobes with prominent wings	4
3.	Flowers subsessile; calyx wings without prominent veins	<i>E. sessile</i> Linnaeus (1753: 112)
-	Flowers pedicellate; calyx wings with prominent veins	<i>E. lawii</i> C.B. Clarke (1885: 98)
4.	Leaves 3-veined (midvein with one secondary vein on each side)	<i>E. pedunculatum</i> Linnaeus (1753: 112)
-	Leaves 5-veined (midvein with two secondary veins on each side)	5
5.	Anthers oblong	6
-	Anthers linear	7
6.	Leaves with a distinct petiole; calyx wings truncate	<i>E. petiolare</i> Grisebach (1845: 46)
-	Leaves sessile; calyx wings cordate	<i>E. pumilum</i> Grisebach (1845: 46)
7.	Calyx lobes cuspidate with broad rounded dorsal wing; anthers curved	<i>E. tetragonum</i> Roxburgh (1832: 398)
-	Calyx lobes acuminate with a narrow dorsal wing; anthers straight	<i>E. grande</i> Klackenberg (1985: 43)
8.	Dorsal side of the anther with a papilla present near the apex	9
-	Dorsal side of the anther without a papilla	14
9.	Leaves petiolate or ± sessile	10
-	Leaves amplexicaul or semiamplexicaul	12
10.	Perennial herbs; anthers oblong	<i>E. idukkianum</i> Geethakumary <i>et al.</i> (2016a: 226)
-	Annual herbs; anthers linear	11
11.	Stem 4-angled, winged; fruiting pedicel drooping	<i>E. wightianum</i> Arnott (1839: 176)
-	Stem 4-lineolate, not winged; fruiting pedicel not drooping	<i>E. klackenbergii</i> Gopalan (2002: 271)
12.	Style shorter than anthers	<i>E. keralense</i> Geethakumary <i>et al.</i> (2016b: 429)
-	Style longer than anther	13
13.	Leaves ovate, papilla in the dorsal side of anther distinct	<i>E. atropurpureum</i> Beddome (1874: 24)
-	Leaves elliptic, papilla in the dorsal side of anther indistinct	<i>E. anamallayanum</i> Beddome (1874: 33)
14.	Succulent herbs with a pincushion habit	15
-	Slightly to much-branched ascending herbs	<i>E. laxiflorum</i>
15.	Flowers solitary, long-pedicellate	<i>E. travancoricum</i> Beddome (1874: 24)
-	Flowers in multiflorous cymes, short-pedicellate	<i>E. courtallense</i>

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