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Mussaenda recurvata (Rubiaceae), a new species from southern Vietnam with observations on its heterostyly

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Abstract

Herein, *Mussaenda recurvata*, a new species from Hon Ba Nature Reserve, southern Vietnam, is described and illustrated. This species is morphologically similar to *M. longipetala*, distributed from southern China to northern Vietnam, in having recurved stipules and densely pilose and puberulent hairs throughout, but differs in its strongly recurved calyx lobes, a shorter corolla tube, and ovate corolla lobes. The species is morphologically heterostylous and it appears to be functionally dioecious. An updated key to *Mussaenda* species in Vietnam, Laos, and Cambodia is also provided.

Keywords: dioecy, distyly, heterostyly, Ixoroideae, Mussaendeae

Introduction

Mussaenda Burm. ex Linnaeus (1753: 177) (Rubiaceae, Ixoroideae, Mussaendeae) comprises approximately 135 species (Alejandro *et al.*, 2005), most of which occur in paleotropical regions (ca. 100 species in tropical Asia and ca. 35 species in mainland Africa). In habit, *Mussaenda* species are small trees, shrubs, scandent shrubs, or lianas. The genus is characterized by salverform shaped corollas, usually bifid stipules (Puff *et al.* 2005, Li *et al.* 2010), and by some peripheral flowers of an inflorescence having one, occasionally more, enlarged white, yellow, orange or red calycophylls (i.e., petaloid calyx lobes) (Claßen-Bockhoff 1996).

Pitard (1922–1924) recorded 23 species of *Mussaenda* from the French Indochina region, with 16 species from Vietnam. During our botanical explorations to study plant species diversity in Hon Ba Nature Reserve, Khanh Hoa Province, southern Vietnam, one undescribed species of *Mussaenda* was found. Here, we describe and illustrate this as a new species, *M. recurvata* Naiki, Tagane & Yahara.

Our field observations for the new species showed that it is morphologically heterostylous (distylous), with each individual having flowers with a long style and short stamens (long-styled flowers) or having flowers with a short style and long stamens (short-styled flowers). We describe and compare the floral characters of long- and short-styled flowers of *M. recurvata*.

Materials & Methods

Morphological examination of our newly collected materials from Hon Ba Nature Reserve, Khanh Hoa Province, southern Vietnam were compared with herbarium materials of *Mussaenda* from central to southern Vietnam and Laos deposited in the following institutions: Royal Botanic Gardens, Edinburgh, United Kingdom (E); Kyushu University, Fukuoka, Japan (FU); Kyoto University, Kyoto, Japan (KYO); Muséum National d’Histoire Naturelle, Paris, France

(P); and Vietnam Academy of Science and Technology, Ho Chi Minh, Vietnam (VNM), and surveyed morphological descriptions for *Mussaenda* species distributed in Vietnam, Laos and Cambodia in several literatures (Baker *et al.* 1921, Pitard 1922–24, Merrill 1938, Li 1943, Jayaweera 1963, Lin *et al.* 2011).

Meanwhile, the occurrence of heterostyly were determined examination of collected flowers from 12 short-styled and 10 long-styled individuals from the population of Hon Ba Nature Reserve. The following seven floral characters were measured for one flower per individual under a stereoscopic microscope (Armsystem AR-Z2-STL72, Tokyo, Japan; Fig. 1): stigma height (SH), anther height (AH), corolla diameter (CD), corolla tube length (TL), corolla tube diameter at base (TD), ovary length (OL) and ovary diameter (OD). Welch's *t*-test was performed for each floral character.

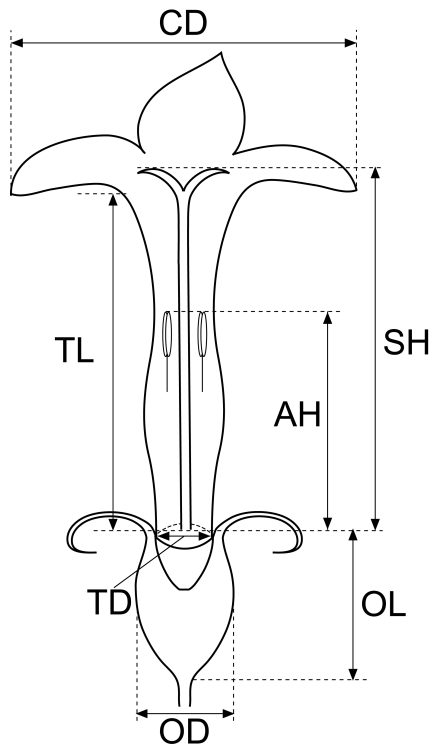


FIGURE 1. Schematic diagram of measurement floral parts of *Mussaenda recurvata* Naiki, Tagane & Yahara: stigma height (SH), anther height (AH), corolla diameter (CD), corolla tube length (TL), corolla tube diameter at base (TD), ovary length (OL) and ovary diameter (OD).

Result & Discussion

Taxonomy

Mussaenda recurvata Naiki, Tagane & Yahara, *sp. nov.* (Figs. 2 & 3)

Type:—VIETNAM. Mt. Hon Ba, Khanh Hoa Province, 221 m elev., 12°07'32.43"N, 109°00'27.42"E, 27 Nov. 2014 (fl.), A. Naiki, V. S. Dang, H. Toyama, S. Tagane, H. Nagamasu, H. Tran & C. J. Yang V2351 (holotype KYO!; isotype VNM!).

Diagnosis:—Similar to *Mussaenda longipetala* H. L. Li (1943: 373), distributed from southern China to northern Vietnam, in having recurved stipule and densely pilose and puberulent hairs throughout, but differing in its strongly recurved calyx lobes (vs. non-recurved in *M. longipetala*), a shorter corolla tube (18–26 mm long in *M. recurvata* vs. 28–32 mm long in *M. longipetala*), and ovate corolla lobes (vs. lanceolate in *M. longipetala*).

Shrubs, evergreen, scandent, 1.5–5 m tall; twigs terete, covered with both pilose (1.5–4.5 mm long) and densely puberulent (0.1–0.3 mm long) hairs on younger branches, most of the pilose hairs caducous but the puberulent hairs remaining on older branches. Stipules interpetiolar, deltoid, 5–8 × 3–5 mm [including lobes], recurved outward, apex bilobed, lobes narrowly triangular to linear, 3–4 × 1–1.5 mm, covered with densely pilose and puberulous hairs on both surfaces. Petiole 2–10 mm long, covered with both pilose and puberulous hairs. Leaves opposite blade elliptic or elliptic-lanceolate, 8–14 × 2.5–5 cm, chartaceous, base cuneate or attenuate into petiole, covered with both pilose and

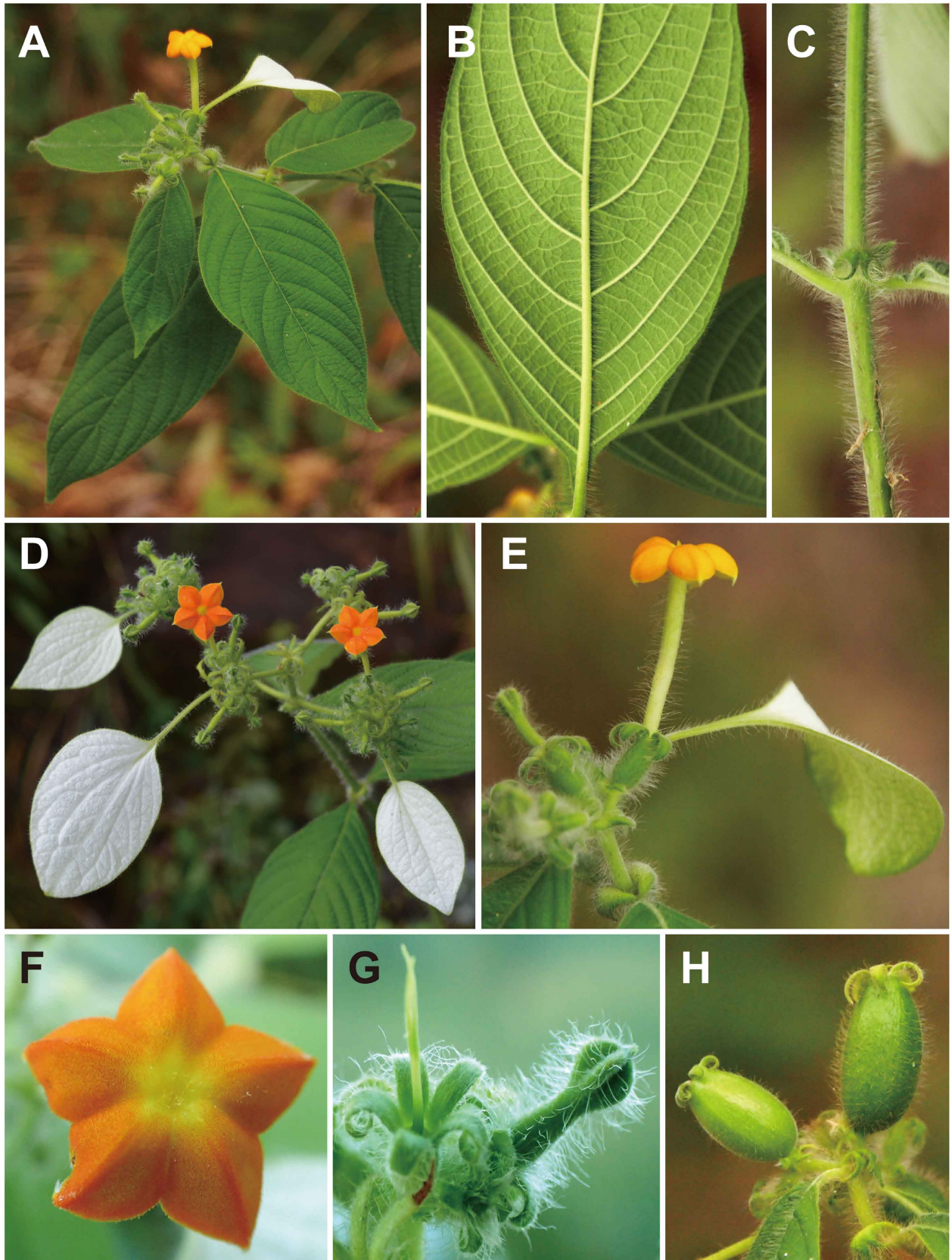


FIGURE 2. *Mussaenda recurvata* Naiki, Tagane & Yahara: **A. & D.** flowering branches, **B.** portion of abaxial surface of leaf, **C.** stem and stipule, **E.** long-styled flower, **F.** top view of short-styled flower, **G.** short-styled flower with corolla removed showing calyx and pistil (left) and flower bud (right), **H.** young fruits. Photos: **A–C, E & H** on 19 Feb. 2014, **D** on 21 Nov. 2014, **F & G** on 27 Nov. 2014 in Hon Ba Nature Reserve, Khanh Hoa Province, southern Vietnam.

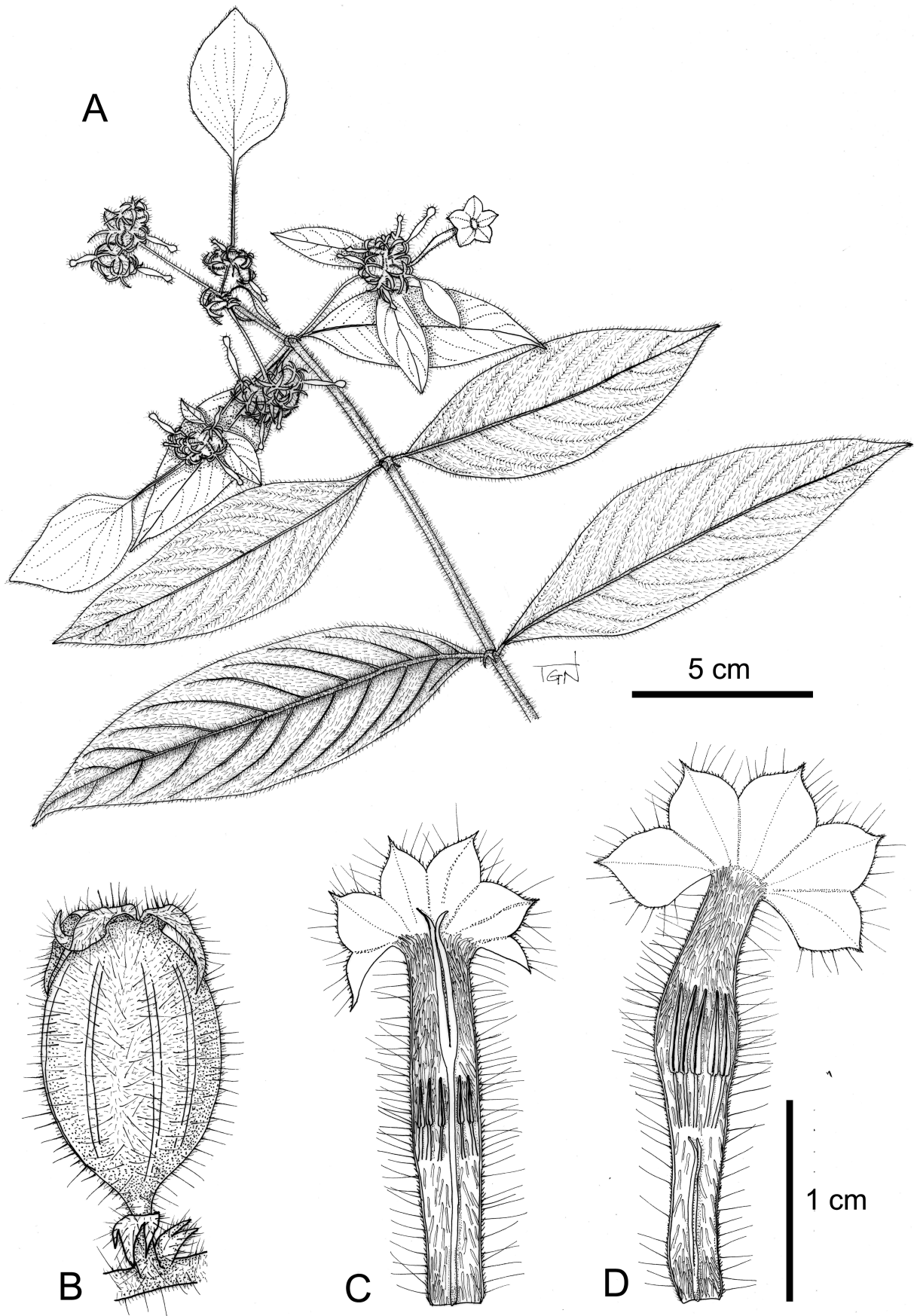


FIGURE 3. *Mussaenda recurvata* Naiki, Tagane & Yahara: **A.** Flowering branch, **B.** fruit, **C.** cross section of long-styled flower, **D.** cross section of short-styled flower. Drawn by S. Tagane from *Toyama et al. V1946* (FU).

puberulous (0.3–0.5 mm long) hairs on both sides, especially denser on the midrib and secondary veins, apex acute or acuminate; midrib and secondary veins flat adaxially, prominent abaxially; secondary veins 9–13 pairs, ascending at an angle of 50–70° from midrib, curved to the margin. Inflorescences terminal and sometimes also in axils of uppermost leaves in a branch, cymose, usually regularly dichotomous, sometimes secondary axis poorly elongating; peduncles 1–3.5 cm long; secondary axis up to 1.5 cm long, bracts lanceolate or narrowly triangular, 1.5–3.5 mm long, sometimes slightly bilobed. Flowers sessile or pedicellate; pedicel up to 2 mm long, covered with both pilose and puberulous hairs, calyx tube urceolate, 2.5–4 × 2–3 mm in short-styled flowers, 3–6 × 2.5–3.5 mm in long-styled flowers, densely covered with both pilose and puberulous hairs; calyx lobes 5, narrowly triangular, 4.5–15 × 1–2 mm, apex acute, covered with puberulous hairs on both sides and pilose at the margin, strongly recurved; one calyx-lobe of some outer flowers per inflorescence enlarged and petaloid, white on upper surface, pale green on lower surface, blade ovate or elliptic, both sparsely pilose and densely puberulous on both sides, chartaceous, 17–65 × 7–54 mm, base acute to cuneate, apex acute to acuminate, stipe 8–35 mm long; corolla salverform, 9–15 mm in diam., corolla tube pale green, 18–26 mm long in short-styled flowers, 18.5–22.5 mm long in long-styled flowers, 1–1.5 mm in diam. at base, ca. 2.5 mm in diam. at the widest part [anther-inserted part] in both long- and short-styled flowers, outside covered with both pilose and puberulous hairs, upper 2/3 to 3/4 part of inside densely covered with upward yellow pilose hairs, and the remaining part sparsely so; lobes 5, reduplicate-valvate in bud, orange-yellow to orange on upper surface, pale orange on lower surface, ovate, 5–7 × 4–5.5 mm, basal 1/4–2/5 portion fused with adjacent lobes, cuspidate, cusp 0.5–0.7 mm long; stamens 5, inserted in middle to upper part of the corolla tube, included; filaments adnate to the tube, 9.5–15.5 mm long in short-styled flowers, 7.5–11 mm long in long-styled flowers; anthers dorsifixed, narrowly oblong, 4.5–6.5 mm long in short-styled flowers, narrowly lanceolate 2.5–4.5 mm long in long-styled flowers, pollen absent in the anthers of long-styled flowers; ovary 2-celled, ovules numerous in each cell; style 5–10 mm long in short-styled flowers, 10–14 mm long in long-styled flowers; stigmas 2-lobed, lobes linear, 6–8.5 mm long, included in short-styled flowers, 8–12.5 mm long, slightly exserted in long-styled flowers. Fruits green when young, baccate, ellipsoid, 15–19 mm long, 10–11 mm in diam., covered with both pilose and puberulous hairs, with strongly recurved calyx lobes persistent. Seeds dark brown, numerous, lenticular, ca. 0.5 × 0.3 mm, ca. 0.1 mm thick; testa foveolate.

Other specimens examined:—VIETNAM, Mt. Hon Ba, Khanh Hoa Province, 622 m elev, 12°06'40.06"N, 108°58'58.75"E, 19 February 2014 (fl., fr.), *Toyama et al. V799* (FU, VNM); Khanh Hoa Province, 877 m elev, 12°13'29.23"N, 108°46'46.62"E, 21 November 2014 (fl., fr.), *Toyama et al. V1946* (FU, VNM); Nhatrang, Phu Khanh Province [current Khanh Hoa Province], 22 January 1923 (fl.), *Poilane 5399* (E, P).

Distribution:—Vietnam (so far known only from Khanh Hoa Province). *Mussaenda recurvata* is occasional at forest margins and is easily found along roadsides in Hon Ba Nature Reserve and surrounding areas in Khanh Hoa Province, at 200–900 m elev.

Phenology:—Flowering and fruiting specimens were collected in February and November.

Etymology:—The species epithet “*recurvata*” refers to its strongly recurved stipules and calyx lobes.

Conservation status:—Least Concern (LC) (IUCN 2012). We propose the status of *M. recurvata* as LC because the species is not rare and was easily found along roadsides exposed by some disturbances for maintenance.

Heterostyly in *Mussaenda recurvata*

Mean values (\pm SD) of seven floral characters are shown in Table 1. Stigma height (SH) of long-styled flowers and anther height (AH) of short-styled flowers were significantly longer than those of the opposite type of flowers. Ovary length (OL) and diameter (OD) were significantly larger in long-styled flowers than in short-styled ones. There were no significant differences in corolla tube length (TL), corolla diameter (CD), and tube base diameter (TD).

There was little overlap between stigma height of long-styled flowers and anther height of short-styled ones, and between anther height of long-styled flowers and stigma height of short-styled ones (Fig. 4).

Mussaenda recurvata is morphologically heterostylous (distylous), but at least functionally gynodioecious, as long-styled flowers are female with anthers that lack pollen grains and short-styled flowers are morphologically hermaphroditic. However, it is likely that short-styled individuals are male, as no fruit set was observed in the inflorescences of short-styled individuals. In contrast, there were several fruits seen in long-styled flowers during our field observations in November 2014. *Mussaenda recurvata* is considered a functionally dioecious plant, a characteristic known from some other *Mussaenda* species (Naiki & Kato 1999, Li *et al.* 2010).

TABLE 1. Measurements of seven floral characters between flowers from long- and short-styled plants of *Mussaenda recurvata* in a population of the Hon Ba Nature Reserve, Khanh Hoa Province, Vietnam.

Floral characters (mm)	Long-styled	Short-styled	<i>t</i>
	Mean ± SD	Mean ± SD	
1. Stigma height (SH)	22.9 ± 2.10	8.25 ± 0.87	18.7**
2. Anther height (AH)	11.8 ± 1.58	17.5 ± 1.59	8.97**
3. Corolla tube length (TL)	20.7 ± 1.50	22.1 ± 2.22	1.56 ^{ns}
4. Corolla diameter (CD)	12.9 ± 2.00	13.3 ± 1.42	0.59 ^{ns}
5. Diameter at the base of corolla tube (TD)	1.33 ± 0.12	1.36 ± 0.15	0.38 ^{ns}
6. Ovary length (OL)	4.44 ± 0.95	3.38 ± 0.53	3.57*
7. Ovary diameter (OD)	3.05 ± 0.30	2.27 ± 0.33	6.44**

Sample sizes were 10 flowers from long-styled and 12 from short-styled individuals.

t: value of Welch's *t*-test, ns: not significant between two floral morphs. **p*<0.01, ***p*<0.00001.

Key to *Mussaenda* species in Vietnam, Laos and Cambodia. Characters used in the key are based on Baker *et al.* (1921), Pitard (1922–24), Merrill (1938), Li (1943), Jayaweera (1963), and Lin *et al.* (2011).

1. Young shoots glabrous..... 2.
- Young shoots hairy..... 4.
2. Flowers sessile or pedicellate; pedicel up to 1 mm long if present..... *M. dranensis* Wernham
- Flowers pedicellate; pedicel 1–5 mm long..... 3.
3. Corolla lobes ovate 4–5 mm long; corolla tube 22–24 mm long..... *M. erosa* Champ. ex Benth.
- Corolla lobes oblong 6 mm long; corolla tube 25–30 mm long..... *M. glabra* Vahl
4. Upper surface of leaf blades completely or almost glabrous..... 5.
- Upper surface of leaf blades hairy..... 8.
5. Lower surface of leaf blades glabrous..... *M. thorelii* Pit.
- Lower surface of leaf blades hairy..... 6.
6. Petioles 1–5 mm long; calyx tubes 1.5–2 mm long; calyx lobes linear..... *M. hoensis* Pierre ex Pit.
- Petioles more than 5 mm long; calyx tubes 3–4 mm long; calyx lobes lanceolate or oblong..... 7.
7. Leaf blades oblong–elliptic, 5–16 × 2.5–8 cm; petiole 5–15 mm long..... *M. bonii* Pit.
- Leaf blades broadly elliptic, 12–20 × 6–9 cm; petiole 15–25 mm long..... *M. aptera* Pit.
8. Upper surface of leaf blades densely hairy..... 9.
- Upper surface of leaf blades sparsely hairy..... 13.
9. Apex of leaf blades cuspidate; inflorescences sessile; calyx tubes cylindrical ca. 10 mm long..... *M. hilaris* Pierre ex Pit.
- Apex of leaf blades acute or acuminate; inflorescences peduncled; calyx tubes less than 5 mm long..... 10.
10. Leaves sessile or sometimes petiolate; petioles up to 2 mm long; base of leaf blades cordate..... *M. sanderiana* Ridl.
- Leaves petiolate; petioles more than 2 mm long; base of leaf blades cuneate, rounded or attenuate..... 11.
11. Older branches glabrous; petioles 10–25 mm long; stipules 8–10 mm long..... *M. saigonensis* Pierre ex Pit.
- Older branches pilose and/or puberulent; petioles 2–10 mm long; stipules 5–8 mm long..... 12.
12. Calyx lobes non–recurved; corolla tubes 28–32 mm long; corolla lobes lanceolate, ca. 12 mm long..... *M. longipetala* H. L. Li
- Calyx lobes strongly recurved; corolla tubes 18–26 mm long; corolla lobes ovate, 5–7 mm long..... *M. recurvata* Naiki, Tagane & Yahara
13. Stipules ovate..... *M. macrophylla* Wall.
- Stipules linear, lanceolate or triangular..... 14.
14. Inflorescences capitate to subcapitate; flowers mostly or all sessile, or pedicellate..... 15.
- Inflorescences branched; flowers pedicellate..... 18.
15. Petioles 1–2 cm long; corolla tubes 3–3.5 cm long..... *M. densiflora* H. L. Li
- Petioles less than 1 cm long; corolla tubes less than 3 cm long..... 16.
16. Calyx tubes 1–1.5 mm; calyx lobes ca. 10 mm long..... *M. subsessilis* Pierre ex Pit.
- Calyx tubes more than 1.5 mm; calyx lobes 2–6 mm long..... 17.
17. Young shoots and lower surface of leaf blades sparsely pubescent; corolla lobes ovate; fruit ellipsoid 10–12 × 4–6 mm..... *M. divaricata* Hutch.
- Young shoots and lower surface of leaf blades strigillose; corolla lobes oblong–lanceolate to lanceolate; fruit subglobose 8–10 × 6–7.5 mm..... *M. pubescens* Dryand.
18. Petioles 1–2.5 cm long; corolla tubes ca. 15 mm long..... *M. dinhensis* Pierre ex Pit.
- Petioles less than 1 cm long; corolla tubes more than 15 mm long..... 19.
19. Corolla tubes 16–18 mm long..... *M. chevalieri* Pit.
- Corolla tubes more than 20 mm long..... 20.
20. Stipules ca. 8 mm long; calyx lobes ca. 4 mm long..... *M. squiresii* Merr.
- Stipules less than 7 mm long; calyx lobes less than 3 mm long..... 21.
21. Secondary veins of leaf blade 8–10 pairs; fruits oblong–ellipsoid, 18 mm long..... *M. hossei* Craib
- Secondary veins of leaf blade 6–8 pairs; fruits subglobose or ellipsoid, 6–10 mm long..... 22.
22. Leaf blades 4–9 × 1.5–4.5 cm, hispid–tomentose on lower surface; petioles 3–8 cm long..... *M. cambodiana* Pierre ex Pit.
- Leaf blades 8.5–15 × 3–5 cm, sparsely strigillose on lower surface; petioles 8–10 cm long..... *M. frondosa* L.

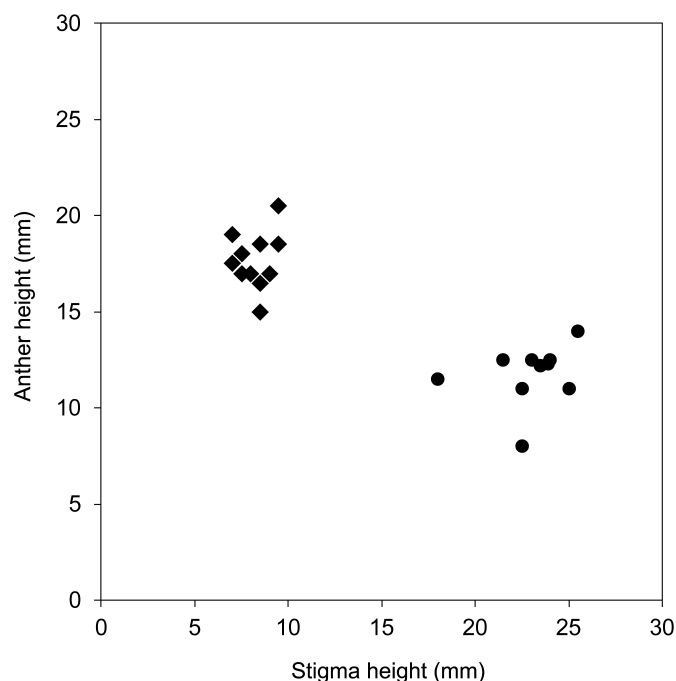


FIGURE 4: Relationship between stigma height and anther height of one flower for each individual of *Mussaenda recurvata* Naiki, Tagane & Yahara in a population of the Hon Ba Nature Reserve, Khanh Hoa Province, Vietnam. Circle: long-styled flowers, diamond: short-styled flowers.

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