A taxonomic revision of the genus *Rothia* (Crotalarieae, Fabaceae)

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**Abstract.** *Rothia* Pers. is a genus of papilionoid legumes that consists of two species, *R. indica* (L.) Druce and *R. hirsuta* (Guill. & Perr.) Baker. The genus is a member of the tribe Crotalarieae and is widely distributed in Africa, Asia and Australia. Recent molecular systematic studies have shown the genus to be closely related to *Robynsiophyton* Wilczek and *Pearsonia* Dümmer; however, it is easily distinguished from these by its 10 small, rounded anthers and subequally lobed calyx (as opposed to the large, elongate anthers of *Pearsonia* or the 9 stamens of *Robynsiophyton*). These three genera share characters such as uniform anthers, straight styles and the presence of angelate esters of lupanine-type alkaloids. Leaf and fruit anatomy of *Rothia* and *Robynsiophyton* were also studied but revealed no informative differences. Both genera have dorsiventral leaves with mucilage cells in the epidermis and thin-walled fruits. A taxonomic revision of *Rothia* is presented, including a key to the species, correct nomenclature, descriptions, illustrations and distribution maps.

**Introduction**

The genus *Rothia* Pers. was described in 1806 and comprises two species, *R. hirsuta* (Guill. & Perr.) Baker and *R. indica* (L.) Druce. The species have been treated in several floristic studies (e.g. The Flora of Tropical Africa (Baker 1926), Flora of West Tropical Africa (Hepper 1958), Flora of East Africa (Milne-Redhead 1971), Flora Zambesiaca (Polhill 2003), A revised Handbook of the Flora of Ceylon (Rudd 1991)); however, no comprehensive revision of the genus exists. An Australian-endemic subspecies of *R. indica*, namely *R. indica* (L.) Druce subsp. *australis* A.E.Holland, was described by Holland (1997). It is morphologically distinct from the typical Asian subspecies.

The genus is a member of the Papilionoideae and is placed within the tribe Crotalarieae. The Crotalarieae form part of a monophyletic assemblage of tribes, the ‘core’ genistoid legumes (Crisp et al. 2000; Boatwright et al. 2008a), which comprises the Crotalarieae, Euchresteae, Genistaeae, Podalyrieae, Sophoreae (in part) and Thermopsisae. The Crotalarieae are subendemic to Africa, with a few species of *Crotalaria* L., *Lotononis* (DC.) Eckl. & Zeyh. and *Rothia* extending to other continents. A recent study of the tribe by Boatwright et al. (2008b), based on gene sequences (ITS and *rbcL*) and morphological data, showed *Rothia* to be in a well supported clade along with *Pearsonia* Dümmer and *Robynsiophyton* Wilczek, i.e. the *Pearsonia* clade. A sister relationship between *Robynsiophyton* and *Rothia* was strongly supported (Fig. 1). This confirmed hypotheses by Polhill (1976), Van Wyk (1991a) and Van Wyk and Schutte (1995) who suggested an affinity between these genera. The close relationship between *Pearsonia*, *Robynsiophyton* and *Rothia* is supported by three synapomorphies, i.e. uniform anthers, straight or down-curved styles and the presence of angelate esters of lupanine-type alkaloids. *Rothia* can be distinguished from *Pearsonia* and *Robynsiophyton* by its 10 small, rounded anthers and subequally lobed calyx.

In this paper we present a taxonomic account of *Rothia*, with illustrations, descriptions and distribution maps of the species. The results of anatomical studies of the leaves and fruits of *Rothia* and *Robynsiophyton* are also presented.

**Materials and methods**

**Morphology**

Morphological characters were assessed through the study of material from the following herbaria: BM, BOL, K, MEL, NBG (including SAM), PRE, S, UPS (abbreviations according to Holmgren et al. 1990). Drawings of reproductive features (all by JSB) were done by using a stereoscope (WILD M3Z) with a camera *lucida* attachment.

**Anatomy**

Two or three samples per species of the leaves and fruits of *Rothia* and *Robynsiophyton* were studied. Dried material was first rehydrated and then fixed in formaldehyde : acetic acid : 96% alcohol : water (10 : 5 : 50 : 35; FAA) for 24 h. The method of Feder and O’Brien (1968) for embedding in glycol methacrylate (GMA) was used except that the final infiltration in GMA was done for a minimum of 5 days. Sections were stained according to the periodic acid Schiff/toluidine blue (PAS/TB) staining method and mounted. Photographs were taken with a JVC KY-F1030 digital camera.
**Results and discussion**

**Generic relationships**

In the study of Boatwright *et al.* (2008b), the *Pearsonia* clade is well separated from the ‘Cape’ group of the Crotalarieae (*Aspalathus* L., *Lebeckia* Thunb., *Rafnia* Thunb., *Spartidium* Pomel and *Wiborgia* Thunb.) and placed closer to *Lotononis*, a genus with which they share the lylonoid or zygomorphic calyx. However, the three genera of the *Pearsonia* clade possess a 17 base-pair deletion at positions 179–196 in the aligned ITS matrix and unique floral characters such as straight styles and uniform anthers. The *Crotalaria* clade (*Bolusia* Bentham, *Crotalaria* and *Lotononis* section *Euchlora* (Eckl. & Zeyh.) B.-E.van Wyk) is early diverging within the Crotalarieae and all members of this clade have strongly inflated pods (Boatwright *et al.* 2008b).

Van Wyk (2003) discussed the importance of chemical characters in genistoid legumes and mentioned that their distribution is not random, but in fact provides reliable information supporting phylogenetic relationships retrieved by studies of DNA sequence data. The *Pearsonia* clade is chemically distinct within the tribe Crotalarieae in having unique alkaloids (Van Wyk and Verdoorn 1990; Van Wyk 1991a, 2005; Van Wyk and Schutte 1995). *Pearsonia*, *Robynsiophyton* and *Rothia* produce tetracyclic quinolizidine alkaloids such as lupanine, together with anaglate esters such as lupanine-13α-angelate, cajanifoline, sessilifoline and pearsonine (Hussain *et al.* 1988; Van Wyk and Verdoorn 1989, 1991). These chemical characters are especially useful in distinguishing this clade from the morphologically similar genus *Lotononis* where pyrrolizidine and quinolizidine alkaloids are present but where no esters of lupanine-type alkaloids are found (Van Wyk 1991b). Also, some sections of *Lotononis* are cyanogenic, a trait which is unique within Crotalarieae (Van Wyk 1991b).

**Vegetative morphology and anatomy**

The species of *Rothia* are prostrate to procumbent or erect annuals. They share this life history with the monotypic African *Robynsiophyton*. This character lends support to the sister relationship found between these genera by Boatwright *et al.* (2008b) and distinguishes them from the closely related genus *Pearsonia* which consists of perennial herbs or shrubs.

The leaves of *Rothia* are digitately trifoliolate as in many of the Crotalarieae, and pubescent both adaxially and abaxially. *R. indica* subsp. *australis* has densely pubescent leaves with long whitish hairs that are more or less spreading. In contrast, the leaves of *R. indica* subsp. *indica* are moderately hairy with shorter, more or less appressed hairs. The stipules of *R. hirsuta* are linear to slightly falcate and single at each node, whereas those of *R. indica* are elliptic to lanceolate or ovate and invariably paired. Anatomical studies of the lamina (Fig. 2a, b) and petiole (Fig. 2c, d) revealed no informative differences between *R. hirsuta* and *R. indica*, or even between these and *Robynsiophyton* *vanderystii* Wilczek. The leaves are dorsiventral with mucilage cells present in the epidermis in both *Rothia* and *Robynsiophyton* (Fig. 2a, b). These cells are thought to contribute to the retention of water and reduction of transpiration, although their function has not been accurately ascertained (Gregory and Baas 1989).

**Reproductive morphology and anatomy**

Both species of *Rothia* have axillary racemes. *R. hirsuta* has up to seven flowers per raceme as opposed to *R. indica* where up to four flowers per raceme are found, although the flowers are often solitary or in pairs. Terminal racemes are found in most genera of the Crotalarieae (Polhill 1976) and they are either terminal or axillary in *Pearsonia* and strictly axillary in *Rothia* and *Robynsiophyton*. Bracts are present in *Rothia*, but bracteoles are lacking. Bracteoles are also absent in *Robynsiophyton* and most species of the genus *Lotononis*, but present in almost all *Pearsonia* species.

The flowers of *Rothia* and its relatives are relatively unspecialised compared with the rest of the Crotalarieae. *Rothia*, *Robynsiophyton* and *Pearsonia* have a ‘gullet’-type flower where the style is straight or down-curved and the anthers uniform and/or further reduced, as opposed to the more specialised and reflexed floral parts found in the other crotalaroid genera (Polhill 1976). In *Rothia* the two upper calyx lobes are larger than the other three lobes and distinctly falcate. The calyces of *Pearsonia* species have the upper sinus often shallower than the others or in some species the lateral sinus is the shallowest with the carinal lobe always narrower than the other lobes (Polhill 1974). *Robynsiophyton* differs from both these genera in having an equally lobed calyx (J. S. Boatwright and B.-E. van Wyk, unpubl. data).

The most useful generic character to distinguish among *Pearsonia*, *Robynsiophyton* and *Rothia* is the androecium. These genera are unique within the Crotalarieae in having uniform anthers, as opposed to the dimorphic anthers found in other genera of the tribe with alternating basifixed and dorsifixed anthers (Polhill 1976). The anthers of *Pearsonia* are elongate and large, whereas in *Rothia* and *Robynsiophyton* they are small and rounded (Fig. 3). *Robynsiophyton* has a reduced number of stamens (9 rather than 10) and four anthers are infertile (Fig. 3). Although the generic concepts of *Rothia* and *Robynsiophyton* have been questioned by previous authors, the informative value of androecial characters (the main distinction among these three genera) at both tribal and generic level is usually closely correlated with relationships suggested by both molecular and morphological data (Polhill 1976; Boatwright *et al.* 2008b) and should be taken at face value as strong, sound generic apomorphies.
The pods of *Rothia hirsuta* are ovate to falcate and much shorter and fewer-seeded (up to 18 mm long with 25 seeds) than the linear pods of *R. indica* that are up to 55 mm long with 35 seeds. The pods of *Rothia* and *Robynsiophyton* are thin-walled and sclerified on the inner surface, with no apparent anatomical differences (Fig. 2e, f).

*Rothia indica* and *Robynsiophyton* have similar-sized seeds that are larger than those of *Rothia hirsuta* (J. S. Boatwright and B.-E. van Wyk, unpubl. data). The seeds of the latter are light brown with dark mottling and have a rugose surface, in contrast to the brown, smooth seeds of *Rothia indica* and *Robynsiophyton vanderystii*.

**Taxonomic treatment**

**Key to the genus Rothia**

1. Anthers dimorphic, styles upcurved.............................. other Crotalarieae
   Anthers uniform, styles straight or down-curved.................. 2
2. Perennial herbs or small shrubs, anthers large and elongate ... *Pearsonia*
   Annual herbs, anthers small and rounded............................. 3
3. Upper two calyx lobes larger than others (calyx subequally lobed), stamens 10, all fertile ......................................................... *Rothia*
   Upper two calyx lobes similar to others (calyx equally lobed), stamens nine, five fertile, four reduced and infertile .................. *Robynsiophyton


Type species: *R. trifoliata* (Roth) Pers. (= *Dillwynia trifoliata* Roth).

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**Diagnostic characters:** *Rothia* can be distinguished from *Robynsiophyton* in that the latter has an equally lobed calyx (in *Rothia* the upper two lobes are larger than the others) and in that there are 10 stamens with 10 fertile anthers in *Rothia* (in *Robynsiophyton* the stamens are reduced to nine and only five anthers are fertile). Furthermore, it differs from *Pearsonia* by its subequally lobed calyx and small, rounded anthers in contrast to the 'lotononoid' calyx (zygomorphic owing to the fusion of the upper and lateral lobes on either side) and large, elongate anthers of *Pearsonia*.

**Chromosome number:** A count of *n*=7 has been reported for *Rothia indica* (Goldblatt 1981; Bairiganjan and Patnaik 1989).

**Distribution:** The genus occurs in tropical Africa, Asia and Australia (Figs 5 and 7). It appears to have been well collected in areas for which regional floras have been compiled, e.g. the Flora of Tropical East Africa and Flora of West Tropical Africa.

**Key to the species of Rothia**

1. Stipules linear and single at each node, up to 7 flowers per inflorescence, pods ovate to falcate and up to 18 mm long, seeds light brown with dark mottling and a rugose surface, Africa and Madagascar....1. *R. hirsuta*

Stipules elliptic to lanceolate or ovate and paired at each node, up to 4 flowers per inflorescence, pods linear or slightly falcate and up to 55 mm long, seeds brown with a smooth surface, Asia and Australia .............................................................2. *R. indica*


[Note: according to Stafleu and Cowan (1983) the type material of *Perrottetia* is housed in P or G. No specimens were traced in G and we therefore designate the Paris specimen as lectotype.]


[Note: Dümmer was based at K during his revision of *Lotononis*. However, the K isotype is a small piece taken from the specimen in Z (as annotated by Dümmer himself). The Z specimen is therefore chosen as lectotype.]
Small, pubescent, prostrate or semi-erect to procumbent herb. Branches 10–40 cm long, brown, sparsely hairy (pilose). Leaves with leaflets elliptic to oblanceolate, terminal leaflet 10–30 mm long, 3.5–12.0 mm wide, lateral leaflets 6–20 mm long, 2–7 mm wide; apex apiculate; base cuneate; petiole 3–13 mm long. Stipules linear to slightly falcate, 2–8 mm long, single. Inflorescence with 2–7 flowers; pedicel up to 1 mm long; bract 1.0–2.5 mm long. Flowers 4–8 mm long. Calyx 5–7 mm long; tube 1.5–2.0 mm long; lobes 3–4 mm long. Standard petal. Wing petal. Keel petal. Pistil. Flower in lateral view. Pod in lateral view. (i) Bract. (j) Anther. (k) Androecium. (l) Leaf in abaxial view. (m) Stipule. Voucher specimens. (a, c) Davey 173 (K). (b) Milne-Redhead & Taylor 11245 (K). (d, g, h, j, k) Greenway & Kanuri 14269 (K). (e) Jackson & Apejoye 413973 (K). (f) Hepper 1021 (K). (i) Polhill & Paulo 2089 (K). (l, m) Siame 162 (K). All scale bars represent 1 mm.

**Distribution and ecology:** widespread in the dry parts of tropical Africa from South Africa north to Eritrea and west up to Guinea (Fig. 5). Occurs on sandy loam or clay soils, often in grassland or forest openings. Common on sandy soils along watercourses or disturbed roadsides.

**Diagnostic characters:** the linear stipules are invariably single at each node in *Rothia hirsuta*, whereas they are paired and elliptic to ovate in *R. indica*. The inflorescences are more densely flowered (up to 7 flowers) in *R. hirsuta* than in *R. indica* where the flowers are often solitary or up to 4 per inflorescence. The linear pods of *R. indica* are three times longer (up to 55 mm) than the ovate pods of *R. hirsuta* that are only up to 18 mm long. In *R. hirsuta* the seeds are brown with dark mottling and have a rugose surface, whereas those of *R. indica* are brown (unmottled) with a smooth surface.

**Flowering period:** *R. hirsuta* flowers mainly from February to November, but flowering and fruiting specimens have been recorded throughout the year.
Selected specimens (150 specimens examined)

ERITREA: Bocos, Cheren, Pappi 2527, 10.xi.1902 (BM 2 sheets, K).


Lotus indicus Desr. in Lam., Encyc. 3: 606 (1759). Type: as for T. indica.


Small, pubescent, prostrate, herb. Branches up to 40 cm long, brown, either covered with dense, woolly hairs or sparsely hairy (pilo-se). Leaves with leaflets elliptic to obovate, terminal leaflet (7–)9–26 mm long, (2–)3–5 mm wide, lateral leaflets (5–)8–20 mm long, (1.5–)2.5–6.0 mm wide; apex obtuse or slightly acute; base cuneate; petiole 4–13 mm long. Stipules elliptic to lanceolate or ovate, 2–8–(10) mm long, paired. Inflorescence with flowers solitary or up to 4 per raceme; pedicel up to 2 mm long; bract 1–3 mm long. Flowers 5–8 mm long. Calyx 4–7 mm long; tube 1.5–4.0 mm long; lobes 1–4 mm long. Standard 4.0–6.5 mm long; claw 1.5–2.5 mm long; lamina 2.5–4.0 mm long, 2.0–2.5 mm wide. Wings 4.0–6.5 mm long; claw 2.0–2.5 mm long; lamina 2.5–4.5 mm long, 1.0–1.5 mm wide. Keel 4.0–6.5 mm long; claw 2.0–2.5 mm long; lamina 2.5–4.5 mm long, 1.0–1.5 mm wide. Pistil with ovary linear, 3.0–4.5 mm long, 0.5–1.0 mm wide with ±13–18 ovules; style 1.4–1.7 mm long. Pods linear or slightly falcate, (30–)35–55 mm long, 1.5–3.0 mm wide with up to ±35 seeds per pod. Seeds 1.3–1.8 mm long, 1.0–1.3 mm wide, mature seeds brown, surface smooth (Fig. 6).

Distribution and ecology: occurs in India, Sri Lanka, China, Vietnam, Malaysia and Australia (Fig. 7).

Diagnostic characters: the paired, ovate stipules, sparse inflorescences, long, linear pods and smooth, brown seeds distinguish Rothia indica from R. hirsuta.

Flowering period: flowering and fruiting all year round from January to December.

Notes: two subspecies can be recognised based predominantly on their geographical distribution, size and pubescence of vegetative and reproductive parts.
2a. *Rothia indica* (L.) Druce subsp. *indica*

Leaves with terminal leaflet (7–)10–26 long, (2–)4–8 mm wide, lateral leaflets (5–)8–20 mm long, (1.5–)3.0–6.0 mm wide; petiole 5–13 mm long. Stipules elliptic to lanceolate, 2–8(–10) mm long. Calyx 5.0–6.5 mm long; tube 2–4 mm long; lobes 1–3 mm long. Standard 4.0–6.5 mm long; claw 1.5–2.0 mm long; lamina 2.5–4.0 mm long, 1.0–1.5 mm wide. Keel 4–6 mm long; claw 2.0–2.5 mm long; lamina 2.5–4.0 mm long, 1.0–1.5 mm wide. Pistil with ovary 3–4 mm long, 0.5–0.7 mm wide with ±14–18 ovules; style 1.4–1.6 mm long. Pods (–33)35–55 mm long, (1.5–)2.0–3.0 mm wide with up to ±35 seeds per pod. Seeds 1.3–1.6 mm long, 1.0–1.3 mm wide.

*Distribution and ecology*: collections from India, Sri Lanka, Vietnam and Malaysia were studied (Fig. 7); this subspecies has also been recorded from China (Chen and Li 1997) and the specimens cited by these authors were included on the map. It favours sandy soils, grassy slopes or moist open fields. Common in disturbed areas such as roadsides.

**Selected specimens** (33 specimens examined)

INDIA: Chinglepul, Barber 55, 10.i.1899 (K); Bombay (Mumbai), Dolzell s.n., iv.1878 (K); Ganjam district, Chennai, Gamble 13771, ii.1884 (K); Bengaluru, Gough 162, Dec 1937 (K); Tinneveli, Tamil Nadu, Matthews 16388, 26.i.1979 (BM); Denkanikotta, Dharmapuri, Denkanikotta Rest House, Matthew RHT 24647, 15.xi.1979 (K); Kodaikanal, Dindigul, Law’s Ghat Rd, Matthew RHT 51949, 4.xii.1987 (K); Mysore, Minso 607, x.1837 (K); Hassan, Mysore, Belvathally, Ramamooorthy 1956, 13.xii.1971 (K); 70 km N of Munnar, Palani hills, Tamilnadu, Van der Maesen 3453, 20.i.1979 (K). VIETNAM: Tourane (now Da Nang), Clemens & Clemens 4294, v–vii.1927 (BM). SRI LANKA: Ruhuna NP, Block 1 near Buttawa Bungalow, Cooray & Balakrishnan 69010909R, 9.vi.1969 (BM);
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Fig. 7. Known geographical distribution of *Rothia indica* subsp. *indica* (triangles) and *R. indica* subsp. *australis* (dots). Specimens cited in Chen and Li (1997) from China are represented by stars.

Trincomalee, near China Bay Airport, Rudd & Balakrishnan 3134, 24. ii.1970 (K); Hambantota, Yala, Fagerlind 1695, 1.1974 (S).

**MALAYSIA:** Pulau Pinang, Fagerlind 1695 thanked for.

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**References**


Baker EG (1926) ‘The Leguminosae of tropical Africa. 1’. (Erasmus Press: Ghent, Belgium)


**Type:** Queensland, Gregory South District, Site 195, Warlus 1, 7 Aug. 1971, Boyland 4016; holo BRI (photo seen).

Leaves with terminal leaflet 9–15 mm long, 3–5 mm wide, lateral leaflets 9–12 mm long, 2.5–4.0 mm wide; petiole 4–8 mm long. Stipules elliptic to ovate, 2–5 mm long. Inflorescence with flowers solitary or 2 per raceme. Calyx 4–7 mm long; tube 1.5–3.0 mm long; lobes 3.5–4.0 mm long. Standard 4.0–6.5 mm long; claw 1.5–2.0 mm long; lamina 2.5–4.0 mm long, 2.0–2.5 mm wide. Wings 4.0–6.5 mm long; claw 2.0–2.5 mm long; lamina 2.5–4.5 mm long, 1.0–1.5 mm wide. Keel 4.0–6.5 mm long; claw 2.0–2.5 mm long; lamina 2.5–4.5 mm long, 1.0–1.5 mm wide. Pistil with ovary 4.0–4.5 mm long, 0.6–1.0 mm wide with ±13–17 ovules; style 1.5–1.7 mm long. Pods (30–)35–45 mm long, 1.5–2.0 mm wide with up to ±30 seeds per pod. Seeds 1.5–1.8 mm long, 1.2–1.3 mm wide.

**Distribution and ecology:** Restricted to Australia where it occurs on sandy hills and flats (Fig. 7).

**Specimens examined**


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