Taxonomic significance of vegetative and reproductive morphology in southern Africa

Rhynchosia sect. Rhynchosia (Fabaceae: Papilionoideae, Phaseoleae)

Abdulwakeel Ayokun-nun Ajao*, Annah Ntsamaeeng Moteetee

Department of Botany & Plant Biotechnology, APK Campus, University of Johannesburg, PO Box 524, Auckland Park, 2006, South Africa

*Corresponding author. E-mail: ajwak880@gmail.com

Abstract. Rhynchosia is the largest genus in the subtribe Cajaninae, tribe Phaseoleae. Due to the lack of a recent taxonomic revision in the genus, the species are poorly known and as a result, are difficult to identify. As part of our ongoing taxonomic studies on the genus in southern Africa, this paper presents a comparative study of vegetative and floral morphological variation in the 47 species currently recognised in the type section Rhynchosia in the region. This is with a view to provide useful diagnostic morphological characters that can be used to correctly identify species in the type section and in other sections. The study used morphological data from field observation, herbarium specimens, and literature. Stems, leaves, and floral structures were examined with a dissecting microscope. A stereoscope with a camera lucida attachment was used to draw the reproductive morphology. Although morphological characters seem to overlap between the sections, characters such as leaflets size, type of indumentum on leaflet surfaces, stipules shape, type and length of inflorescences, presence or absence of indumentum on standard petals, presence and absence of sculpturing on wing petals, as well as length of upper lobes of the calyx are useful in identifying species.

Keywords: subtribe Cajaninae, tribe Phaseoleae, Leguminosae, Taxonomy.

INTRODUCTION

The significance of morphological characters in the taxonomy of the genera belonging to the family Fabaceae has been stressed by many researchers (Moteetee and Van Wyk 2006; Boatwright et al. 2010; Le Roux et al. 2010; Santos et al. 2012; Jeewon et al. 2013; Borges et al. 2018). Morphology has not only been useful in the identification and description of species within the family Fabaceae but has also been employed in phylogenetic studies and to understand the evolutionary patterns of plant taxa (LPWG 2017; Pinto et al. 2018). However, not all morphological characters are useful, while others are known to be more consistent, delimitative, or informative (Manoko 2007). For example, a superior ovary with one locule, two to many
ovules arranged in two alternating rows on a single placenta, as well as marginal placentation are the most consistent characters that can be used to distinguish members of the family Fabaceae (Lewis et al. 2005).

The genus *Rhynchosia* Lour. belongs to the cosmopolitan family Fabaceae, tribe Phaseoleae, subtribe Cajaninae (Schrire 2005). It is the largest genus in its subtribe with a pantropical distribution and more than 230 species globally, ca. 55 in America, ca. 35 in Asia, ca. 69 in southern Africa, and ca. 64 in South Africa (Schrire 2005; Germishuizen 2006; Boatwright and Moteetee 2014; Ajao et al. 2018; Bezerra et al. 2019). Globally, it is found in America, Africa and Madagascar, Asia, and Australia. In Africa, its distribution ranges from West Africa (Ghana and Nigeria) to Tropical East Africa (Congo, Kenya, Tanzania, Uganda), Zambeziac region (Botswana, Caprivi Strip, Malawi, Mozambique, Zambia, and Zimbabwe), and southern Africa (eSwatini, Lesotho, Namibia, and South Africa). In South Africa, it is found in all the nine provinces (Ajao et al. in preparation).

Previously, the South African species of the genus were revised by Baker (1923) whereby 59 species were recognized and placed in five sections, namely: *Rhynchosia* sect. Arcyphylum (Elliott) Torr. & Gray., R. sect. Chrysosacias Bent., R. sect. Cyanospermum (Wight & Arnott) Benth., R. sect. Polytropia (Presl) Harv., and R. sect. Rhyynosia. However, *Rhynchosia* sect. Arcyphylum is not represented in Africa as it is native to North America, hence the segregation of the *R. densiflora* (Roth) DC. group from the section to avoid phytogeographical confusion (Jaca and Moteetee 2018). Therefore, *R. densiflora* complex is currently recognized as a distinct group pending the outcome of the phylogeny of the genus *Rhynchosia*. Even though reproductive characters are regarded to be more important than vegetative characters, the latter can also be used to provide a distinction between species. Both characters have been used to delineate members of the family Fabaceae. For example, genera of subtribe Cajaninae, namely, *Adenodolichos* Harms, *Bolusafra* Kuntze, *Cajanus* DC., *Dunbaria* Wight & Arn., *Eriosema* (DC.) G.Don, *Flemingia* Roxb. ex W.T. Aiton, *Paracalyx* Ali, and *Rhynchosia*, are generally distinguishable from other members of the tribe by the presence of bulbous-based hairs, capitate trichomes, secretory-base trichomes and vesicular glands (Moteetee and Van Wyk, 2006; de Vargas et al. 2018; de Vargas et al. 2019). Furthermore, within the subtribe, the genus *Adenodolichos* is identified by the presence of bracteoles (absent in all other genera), while the structure of the fruits is of diagnostic importance in separating the genera *Cajanus* and *Dunbaria*, where they are transversely grooved in *Cajanus* but not in *Dunbaria*. Expanded and papery calyx lobes after flowering is diagnostic of the species in the genus *Paracalyx* while the genus *Flemingia* is identified by the sub-digitate or rarely unifoliolate leaves. The genus *Eriosema* is distinguished from *Rhynchosia* by the following morphological characters: growth form or habit (subshrubs or erect, ascending, procumbent or prostrate, and never twining, vs. subshrubs or lianas/ erect, prostrate or twining), free or variably connate stipules (vs. always free stipules), absence of stipels (vs. stipels present in some species), hilum linear in shape (vs. hilum elliptical or oblong in shape), and funicle terminated attached to the hilum (vs. funicle centrally, subcentrally or occasionally terminally attached to the hilum) (Lackey 1981; Moteetee and Van Wyk, 2006; Cândido et al. 2019). A preliminary phylogenetic study in the genus by Manyelo (2014) revealed that the genus is not monophyletic as the other sections are embedded within the type section *Rhynchosia*.

In the ongoing taxonomic studies on the genus *Rhynchosia* in South Africa, reproductive and vegetative morphological characters have been successfully used to delineate species within groups, i.e. *R. densiflora* and *R. totta* groups and to revise *Rhynchosia* sect. *Chrysosacias*, R. sect. *Cyanospermum*, and R. sect. *Polytropia* (Moteetee et al. 2012; Moteetee et al. 2014; Moteetee and Le Roux 2016; Jaca and Moteetee 2018; Jaca et al. 2018). These morphological studies have also resulted in descriptions of a number of new species (Germishuizen 2011; Boatwright and Moteetee 2014; Moteetee et al. 2014; Ajao et al. 2018). The study here presented the morphological characters (reproductive and vegetative) of the species in the type section *Rhynchosia* in order to evaluate the characters that can be used to delineate species within the type section and between the other sections and group complexes.

**MATERIALS AND METHODS**

This study was based on the examination of herbarium specimens housed in BNRH, JRAU, and PRE (herbarium acronyms according to Thiers 2019) as well as on morphological observations of *Rhynchosia* species on the field. Stems, leaves, and floral structures were examined, and images were taken with a dissecting microscope with a digital camera attachment (OLYMPUS SZX2-TR30 JAPAN). Flowers were rehydrated in boiling water for 4–5 min, dissected under a binocular stereomicroscope and mounted in glycerol on a microscope slide for observation. A stereoscope with a camera lucida attachment was used to draw the reproductive morphology.
Data on both vegetative and reproductive morphology were taken from a minimum of five specimens per species in five replicates on each specimen except for some species with few available specimens. Also, a minimum of five mature flowers was dissected for each species with the exception of the species with few specimens available. Information regarding other sections and groups in the genus Rhynchosia was gathered from previously published studies from South Africa (Moteetee et al. 2012; Moteetee et al. 2014; Moteetee and Le Roux 2016; Jaca and Moteetee, 2018; Jaca et al. 2018). The taxon (Rhynchosia sect. Rhynchosia) studied is predominantly distributed in South Africa with some of the species extended to other southern African countries such as Botswana, eSwatini, Lesotho, Namibia, and Zimbabwe. The terminology used in this study is in accordance with the morphological species concept, as adopted by Grear (1978) and Isely (1990).

RESULTS AND DISCUSSION

A comparison of morphological characters between the species studied is presented in Table 1. Author citations are included here and will not be repeated elsewhere.

Vegetative Morphology

Growth habit

Rhynchosia species in the type section Rhynchosia are perennial herbs or shrubs with trailing, climbing, prostrate or erect to sub-erect or woody to sub-woody stems. Out of a total of 47 species that are currently recognized in the type section, 18 have erect or sub-erect growth form, these include R. albissima, R. angulosa, R. bolusii, R. spectabilis, R. emarginata, R. pauciflora, R. sordia and R. sp. nov. (Ajao et al. in preparation). The remaining species such as R. caribaea, R. ciliata, R. fleckii, R. monophyla, and R. sublobata, have trailing, climbing, or prostrate stems (Table 1, Figure 1). However, stems are woody at the base in some climbing or trailing species such as R. capensis, R. coddii, R. fleckii, R. ovata as well as taxa in the R. totta complex group (R. totta var. totta, R. totta var. longicalyx, R. totta var. rigidula, R. totta var. venulosa) (Germishuizen 2011; Moteetee and Le Roux 2016). In sections Cyanospermum, Chrysoscias and Polytropa, stems are climbing, twining and trailing, whereas in the R. densiflora group they are twining, erect or prostrate (Moteetee et al. 2012; Moteetee et al. 2014; Jaca and Moteetee 2018; Jaca et al. 2018).

Indumentum

Stems are usually glabrescent to pubescent pilose to tomentose, velvety or villous with bulbous-based hairs and vesicular glands. Species such as R. albissima, R. argentea, R. clivorum, R. crassifolia, R. emarginata, R. spectabilis, and R. waterbergenensis have tomentose stems, in R. woodii and R. angulosa it is cano-pubescent or cano-pilose, while in R. sordida it is silky silvery-pilose and pilose in R. ovata. Taxa in the R. totta complex have stems that are usually glabrescent or pubescent with short hairs which are brownish or grey when young (Moteetee and Le Roux 2016). However, the stems are glandular in species such as R. adenodes, R. arida, R. bullata, R. capensis, and R. cooperi (Table 1). The indumentum type on the stems can be diagnostic as it can be used to distinguish between R. caribaea var. caribaea from R. caribaea var. picta in that it is pubescent in the former and tomentose in the latter.

Adaxial and abaxial surfaces of the leaves are usually glabrescent or pubescent to pilose or villous to velvety or tomentose, and glandular (yellow to orange or golden resin or dotted glands). Absence or presence of glands, and their distribution, can be of diagnostic importance in separating two morphologically similar species. For example, R. nitens shares tomentose stems and discolorous, silky silvery or velvet leaflets with R. galpinii. The former can be distinguished from the latter by the presence of glands on the surfaces, while they are absent in the latter. Rhynchosia adenodes can be easily confused with R. cooperi due to morphological similarities, i.e. having ovate-orbicular or subrhomboid leaflets, pubescent standard petals and axillary inflorescences with flowers arranged towards the apex. However, based on the distribution of glands, R. adenodes can be distinguished by its leaflets that are glandular on both surfaces while in R. cooperi they are glandular on abaxial surfaces only (Figure 2).

Leaf

Like most species in subtribe Cajaninae, the leaves of Rhynchosia sect. Rhynchosia are usually trifoliolate (Baker 1923), and rarely unifoliolate (e.g. R. waterbergenesis) or having both types (R. monophylla, R. nervosa, and R. totta var. totta). In Rhynchosia sect. Cyanospermum and sect. Chrysoscias, the leaves are trifoliolate and never unifoliolate, whereas sect. Polytropa have trifoliolate to simply or pedately bipinnate, bi-tri-jugate, paucijugate, or supra-decompound leaves with R. densiflora group (R. densiflora subsp. chrysadenia var. chrysadenia (Taub.) Verdc. and R. densiflora subsp. chrysadenia var.
| Species          | Habit                  | Leaflets shape                      | Stem indumentum                           | Inflorescence type | Inflorescence length (mm) | Number of flowers | Standard petal | Wing              | Fruits shape |
|------------------|------------------------|-------------------------------------|--------------------------------------------|--------------------|---------------------------|------------------|----------------|--------------------|--------------|
| R. adenodes Eckl. & Zey | Prostrate              | Ovate-orbicular or subrhomboid,     | Puberulous or sparsely pubescent and glandular | Axillary raceme     | 35–80(100)                | 2–7              | Pubescent and glandular | Glandular, with sculpturing | Oblong       |
| R. albissima Grand. | Erect sub-shrub        | Obovate, rhomboid or elliptic,      | Tomentose                                  | Axillary raceme     | 60–130                    | 10–10 or more     | Pubescent and glandular | Glandular, with sculpturing | Oblong-falcate |
| R. angulosa Schinz | Erect herb or shrublet | Elliptic                            | Cano-pilose or cano-pubescent             | Axillary raceme     | 30–80(120)                | 4–10              | Glabrous         | Glandular, without sculpturing | Oblong-elliptic |
| R. atropurpurea Germish | Twining or climbing    | Deltaid or rhomboid                 | Pubescent or pilose and glandular          | Axillary raceme     | 60–150                    | 7–13              | Glandular         | Glandular, with sculpturing | Oblong-falcate |
| R. argentea (Thunb.) Harv. | Climbing or creeping  | Ovate                              | Tomentose                                  | Axillary raceme     | 30–40                     | 4–6               | Pubescent and glandular | Glabrous, without sculpturing | Falcate      |
| R. arida Stirt. | Erect straggling       | Elliptic to ovate                   | Puberulous or glabrescent and glandular    | Axillary raceme     | ±15–40                     | 1 or 2            | Glabrous          | Glabrous, without sculpturing | Broadly oblong |
| R. bolusii Boatwr. & Moteetee | Erect or sub-erect (non-twinning) | Narrowly oblong to oblong          | Densely pilose to glabrescent and glandular | Axillary raceme     | 25–40(60)                | 1–2              | Glabrous          | Glabrous, without sculpturing | Oblong       |
| R. bullata Benth. ex Harv. | Erect                 | Oblong                             | Pubescent and glandular                    | Axillary raceme     | 25–40(60)                | 1–2              | Glabrous          | Glabrous, without sculpturing | Oblong       |
| Rhynchosia harmsiana Schlr. ex Zahlbr. var. buschelli Buttt Davy | Twining              | Rhomboid to deltoid or ovate-rhomboid | Villous, pubescent to pilose               | Axillary raceme     | 20–65                     | 4–10              | Glabrous          | Glabrous, with sculpturing | Oblong-falcate |
| R. calvescens Meikle | Twining               | Deltoind or rhomboid                | Sparsely pubescent                         | Axillary raceme     | 20–80(100)                | 3–8               | Glabrous          | Glabrous, without sculpturing | Falcate      |
| R. candida (Welw. Ex Hiern) | Erect               | Rhomboid or obovate-rhomboid        | Canescent-tomentose and glandular          | Axillary raceme     | 10–15                     | 2–4               | Pubescent and glandular | Glabrous, with sculpturing | Falcate      |
| R. capensis (Burn. F) Schinz | Climbing             | Oblong to oblong-lanceolate, or ovate | Glandular                                  | Axillary umbel      | 18–55(70)                 | 2–6               | Glabrous          | Glabrous, with sculpturing | Oblong-elliptic |
| R. caribaea (Jacq.) DC. var. caribaea | Twining             | Pubescent                           | Axillary raceme                            | 35–110              | 8–22 or more              | Glabrous          | Glabrous          | Glabrous, with sculpturing | Falcate  |
| Rhynchosia caribaea var. picta (E. Mey.) Baker f. | Twining or climbing | Deltaid or rhomboid                 | Tomentose                                  | Axillary raceme     | 60–80 (100)               | 8–12              | Pubescent         | Glabrous, with sculpturing | Fruit not seen |
| R. ciliata (Thunb.) Schinz | Prostrating         | Elliptic to oblong                  | Villous                                    | Axillary raceme     | 15–25                     | 1–2               | Glabrous          | Glabrous, without sculpturing | Oblong |

(Continued)
| Species                  | Habit                      | Leaflets shape                  | Stem indumentum     | Inflorescence type      | Inflorescence length (mm) | Number of flowers | Standard petal             | Wing                      | Fruits shape |
|-------------------------|----------------------------|---------------------------------|---------------------|-------------------------|----------------------------|--------------------|--------------------------|---------------------------|---------------|
| *R. clivorum* S. Moore  | Erect                      | Ovate-elliptic or ovate-lanceolate | Tomentose           | Axillary raceme         | 60–100 (140)               | 5–10 or more       | Glabrous, with sculpturing | Oblong        |
| *R. codii* Germish.     | Trailing                   | Narrowly elliptic to broadly ovate | Densely pubescent   | Axillary raceme         | 10–25                      | 2–5                | Glabrous, without sculpturing | Oblong falcate |
| *R. cooperi* (Harv. ex Baker f.) Burtt Davy | Climbing and twinning Trailing and proccumbent | Ovate or suborbicular | Pubescent and glandular | Axillary raceme         | 80–170 (200)           | 10–20              | Glabrous, with sculpturing | Not seen      |
| *R. crassifolia* Benth. ex Harv. | Erect                      | Ovate or suborbicular | Tomentose           | Axillary raceme         | 150–230 (280)             | 10–22              | Pubescent and glandular   | Fruits falcate |
| *R. emarginata* Germish. | Erect                      | Ovate or broadly obovate        | Tomentose and glandular | Axillary raceme         | 20–70                     | 3–5                | Glabrous, without sculpturing | Falcate       |
| *R. fleckii* Schinz     | Climbing, semi-erect       | Ovate to obovate or elliptic to sub-rhomboid | Pubescent to tomentose and glandular | Axillary raceme         | 10–25                     | 2–4                | Glabrous, without sculpturing | Oblong        |
| *R. galpinii* Baker f. | Erect or sub-erect         | Ovate to obovate or elliptic to sub-rhomboid | Tomentose or velvety | Axillary umbel          | 15–40                     | 2–4                | Pubescent, with sculpturing | Oblong        |
| *R. grandifolia* Steud. | Prostrate                  | Ovate to suborbicular           | Pubescent           | Axillary raceme         | 70–120                    | 7–10               | Glabrous, without sculpturing | Fruit not seen |
| *R. harveyi* Baker f.  | Prostrate or climbing      | Orbicular-rhomboid to deltoid   | Velvety             | Axillary raceme         | 10–20 (40)                | 2–4                | Glabrous, without sculpturing | Oblong        |
| *R. hirsuta* Eckl. & Zeyh. | Twining or trailing        | Ovate-suborbicular              | Pubescent           | Axillary raceme         | 100–170 (190)            | 6–13               | Pubescent, without sculpturing | Oblong falcate |
| *R. holosericea* Schinz | Trailing                   | Orbicular to orbicular-ovate    | Pubescent to pilose | Axillary raceme         | 40–170                    | 3–10               | Glabrous, without sculpturing | Oblong falcate |
| *R. komatiensis* Harms  | Erect                      | Ovate or ovate-orbicular        | Tomentose           | Axillary umbel          | 15–25 (40)                | 1–2 or 4–10        | Pubescent and glandular    | Glabrous, without sculpturing |
| *R. minima* (L.) DC. var. minima Meikle | Climbing                  | Rhomboid, ovate or suborbicular | Glabrous to velvety | Axillary raceme         | 20–180                    | Many flowered up to 24 | Puberulous to pubescent and glandular | Semi-falcate or falcate |
| *R. minima* (L.) DC. var. glandularis Mothogoane and Moteetee | Prostrate                  | Rhomboid-deltoid or ovate or suborbicular | Glabrous to velvety | Axillary raceme         | 40–150                    | Many flowered          | Puberulous to pubescent and glandular | Oblong |
| *R. minima* (L.) DC. var. magniflora Mothogoane and Moteetee | Twining and prostrate      | Rhomboid-deltoid or ovate or suborbicular | Glabrous to velvety | Axillary raceme         | 30–150 (250)            | Many flowered          | Puberulous to pubescent and glandular | Oblong obovate |
| **(Continued)**         |                            |                                 |                     |                         |                            |                    |                          |                           |

Taxonomic significance of vegetative and reproductive morphology in southern Africa *Rhynchosia* sect. *Rhynchosia*
| Species                     | Habit                      | Leaflets shape                     | Stem indumentum | Inflorescence type | Inflorescence length (mm) | Number of flowers | Standard petal | Wing                           | Fruits shape                  |
|-----------------------------|----------------------------|------------------------------------|------------------|--------------------|--------------------------|-------------------|----------------|--------------------------------|-------------------------------|
| *R. minima* (L.) DC. var. *memnonia* (Del.) Meikle | Prostrate                  | Rhomboid-ovate or suborbicular     | Densely velvety  | Axillary raceme     | 30–130                  | Many flowered     | Puberulous to pubescent and glandular | Glabrous, without sculpturing | Oblong                        |
| *R. minima* (L.) DC. var. *prostrata* (Harv.) Meikle | Prostrate                  | Rhomboid-ovate or suborbicular     | Glabrous to velvety | Axillary raceme     | 20–130                  | Many flowered     | Puberulous to pubescent and glandular | Glandular, without sculpturing | Oblong                        |
| *R. monophylla* Schltr.    | Trailing or twinning       | Ovate or ovate-elliptic to elliptic-oblong or sub-rhomboidal, Broadly ovate to cordate-ovate or ovate-elliptic or suborbicular | Pubescent and sometimes glandular | Axillary raceme | 15–25                    | 1–3               | Glabrous                  | Glabrous, with sculpturing  | Elliptic                       |
| *R. nervosa* Benth. & Harv | Prostrate or twinning      | Ovate to ovate-elliptic or suborbicular | Silky silvery or velvety to tomentose. | Axillary raceme | 62–135(210)             | 3–10              | Glabrous                  | Glabrous, with sculpturing  | Oblong-falcate                 |
| *R. nitens* Benth.         | Erect                      | Oblong to linear or oblong-linear lanceolate-elliptic | Tomentose and glandular | Axillary raceme | 35–80                    | 1                 | Glabrous                  | Glabrous, with sculpturing  | Oblong                        |
| *R. pedunculata* le Roux & Moteete | Prostrate                 | Sub- or orbiculate or rhomboe- orbicular | Pubescent-glabescent | Axillary raceme | (30) 45–125            | (1)2–4            | Glabrous                  | Glabrous, without sculpturing | Oblong-elliptic                |
| *R. pentheri* Schltr. ex Zahlbr var. *pentheri* | Prostrate                 | Sub- or orbiculate or rhomboe- orbicular | Pubescent or puberulous and glandular | Axillary raceme | 120–170(240)           | 8–10              | Glabrous sometimes glandular | Glabrous, or sometimes glandular with sculpturing | Oblong-falcate or falcate |
| *R. pentheri* Schltr. ex Zahlbr var. *hutchinsoniana* Burtt Davy | Prostrate                 | Sub- or orbiculate or rhomboe- orbicular | Pubescent and glandular | Axillary raceme | 145–210(242)           | 8–20              | Glabrous                  | Glabrous, with sculpturing  | Oblong-falcate                 |
| *R. reptabunda* N.E.Br.    | Climbing                   | Ovate suborbicular                 | Stems densely pubescent or pilose | Axillary raceme | 70–100(130)            | 4–9               | Glabrous                  | Glabrous, without sculpturing | Oblong-falcate                |
| *R. resinosa* (Hochst. ex A.Rich.) Baker | Climbing                   | Deltoid or rhomboid                | Puberulous and glandular | Axillary raceme | 60–150                  | 6–12              | Glabrous                  | Glabrous, with sculpturing  | Oblong                        |
| *R. schlechteri* Baker f.  | Sub-erect                  | Ovate                             | Glandular and Pubescent | Axillary raceme | 30–80 (100)            | 2–6               | Glabrous                  | Glabrous, without sculpturing | Oblong                        |
| *R. sordida* (E. Mey.) Schinz | Erect                     | Elliptic to elliptic-oblong or oblanceolate | Silky silvery to pilose | Axillary raceme | 5–15(30)               | 1–5               | Glabrous                  | Glabrous, without sculpturing | Oblong                        |

(Continued)
| Species | Habit | Leaflets shape | Stem indumentum | Inflorescence type | Inflorescence length (mm) | Number of flowers | Standard petal | Wing | Fruits shape |
|---------|-------|----------------|------------------|--------------------|--------------------------|------------------|----------------|------|--------------|
| *R. spectabilis* Schinz | Erect | Ovate or ovate-orbicular or orbicular | Canescent-tomentose | Axillary umbel | 18-30 | 2-5 | Pubescent and glandular | Glabrous, with sculpturing | Oblong |
| *R. sublobata* Schumach.) Meikle | Trailing, creeping or climbing | Deltoid or rhomboid | Pubescent or pilose | Axillary raceme | 90–180 (260) | 10–17 or more | Pubescent | Glabrous, with sculpturing | Oblong-falcate and inflated |
| *R. thormcroftii* (Baker f.) Burtt Davy | Twinning, climbing or trailing | Deltoid or rhomboid-ovate | Stem pubescent or pilose and glandular | Axillary raceme | 30–80 (100) | 3–10 | Glabrous | Glabrous, without sculpturing | Oblong |
| *R. tota* (Thunb.) DC. var. tota | Twinning or climbing, semi-erect | Puberulous or Glabrescent | Axillary raceme | 10–40 | 1–3 | Glabrous | Glabrous, without sculpturing | Narrowly oblong |
| *R. tota* var. longicalyx Moteetee & le Roux | Twinning or climbing, semi-erect | Ovate to lanceolate | Puberulous or glabrescent | Axillary raceme | 18–55 | 2–5 | Glabrous | Glabrous, without sculpturing | Narrowly oblong |
| *R. tota* var. rigidula (DC.) Moteetee & le Roux | Twinning or climbing, semi-erect | Lanceolate to elliptic | Puberulous or glabrescent | Axillary raceme | 13–16 | 1–3 | Glabrous | Glabrous, without sculpturing | Narrowly oblong |
| *R. tota* var. venulosa (Hiern) Verdc. | Twinning or climbing, semi-erect | Lanceolate | Puberulous or glabrescent | Axillary raceme | 23–40 | 2–4 | Glabrous | Glabrous, without sculpturing | Narrowly oblong |
| *R. villosa* (Meisn.) Druce | Prostrate | Ovate to cordate-ovate or orbicular | Villous to tomentose | Axillary raceme | 100–200(250) | 12–24 | Glabrous | Glabrous, with sculpturing | Oblong-falcate |
| *R. vendae* Stirt. | Climbing | Rhomboid | Puberulous or sparsely pubescent | Axillary raceme | 110–160 | 8–14 | Pubescent and sometimes glandular | Glabrous, with sculpturing | Oblong-falcate |
| *R. waterbergensis* Ajao, Boatwr. & Moteetee | Erect | Ovate or orbicular-ovate | Canescent-tomentose | Axillary raceme | 25–60 | 4–8 | Pubescent and glandular | Glabrous, with sculpturing | Fruit not seen |
| *R. woodi* Schinz i | Erect | Oblate or ovate | Cano-pubescent | Axillary raceme | 30–60 (80) | 5–10 | Glabrous | Glabrous, with sculpturing | Oblong |
| *R. sp. nov.* | Erect | Linear-lanceolate to oblong-lanceolate | Pubescent and glandular | Axillary raceme | (25–)30–42 | 1 | Glabrous | Glabrous, without sculpturing | Oblong to broadly-oblong |
connata (Baker f.) Jaca & Moteetee) having unifoliolate or trifoliolate leaves (Moteetee et al. 2012; Moteetee et al. 2014; Jaca and Moteetee 2018; Jaca et al. 2018). In this regard, the latter group is closely allied to the type section. In addition, the leaflet shape varies greatly in R. sect. Rhynchosia from oblong, linear to narrowly or broadly elliptic, ovate, obovate, obcordate, lanceolate, rhomboid and deltoid or sub-orbicular. The leaflets are linear to narrowly linear, or linear-lanceolate and lanceolate to oblong-lanceolate in R. sect. Chrysoscias, they are broadly elliptic to ovate or cordate in R. sect. Cynospermum and lanceolate to linear-lanceolate, or elliptic to elliptic-lanceolate in R. sect. in R. sect. Polytropia. The presence of lanceolate to linear-lanceolate leaflets in both R. sect. Polytropia and R. sect. Chrysoscias suggests they are morphologically related. Furthermore, they are elliptic-ovate, rhomboidal to rhomboidal-ovate or almost round in Rhynchosia densiflora group. Leaf size can be as small 5–10 × 2–5 mm as in R. bullata and can be as big 45–150 (220) × 37–140 (230) mm in R. villosa. Leaf margins are usually entire but sometimes revolute in species such as R. bullata, R. capensis, R. pauciflora, and R. sp. nov. as well as species belonging to R. sect. Chrysoscias (Jaca et al. 2018). Leaf venation usually reticulate to cross-venulate, apices acute to mucronate or apiculate, acuminate or emarginate, bases rounded to oblique or cordate or cuneate.

Petiole and petiolule length is usually varied among the species, petioles are 1–63 mm long while petiolules are 2–30 mm long, and they are both usually pubescent to tomentose or pilose and glandular. Petiole length is of diagnostic importance in separating the different sections, for example, it is much longer in R. sect. Cynospermum (up to 140 mm long), and much shorter in R. sect. Chrysoscias, (2.2–8.6 mm long), while R. sect. Polytropia and R. densiflora group range between the two

Figure 1. Growth habit of some Rhynchosia sect. Rhynchosia species. (A) Sub-erect stems of R. schlechteri (B). Erect stem of R. sordida. (C) Trailing stem of R. sublobata. (D) Erect stem of R. albissima. (E) Climbing stem of R. fleckii. (F) Trailing stem of R. monophylla. Photo by Pieter Mier (A), John Burrows (B), Mothogoane (D), Abdulwakeel Ajao (C,E,F).
Taxonomic significance of vegetative and reproductive morphology in southern Africa *Rhynchosia* sect. *Rhynchosia*

(Moteetee et al. 2012, Moteetee et al. 2014; Jaca & Moteetee, 2018; Jaca et al., 2018). Within the sections, petiole length can sometimes be of diagnostic value, most especially in *R*. sect. *Rhynchosia* and *R*. sect. *Chrysoscias*. In *R*. sect. *Rhynchosia*, *R*. nitens, and *R*. galpinii are morphologically similar in having tomentose stems, discolorous, silky silvery or velvety leaflets, and pubescent standard petals. But the former can be distinguished from the latter in the longer petiole ((3)7–15(19) mm vs. 1–6 mm)). In *R*. sect. *Chrysoscias*, *R*. leucoscia with much longer petioles (8–20 mm) can be distinguished from the other species in having shorter petioles, for example, *R*. angustifolia (2.2–4.5 mm), *R*. chrysoscia (3.5–7.8 mm), and *R*. microscia (3.0–) 4.3–8.6 mm) (Jaca et al. 2018).

**Figure 2.** Variation in indumentum type and distribution on the leaflets of *Rhynchosia* sect. *Rhynchosia* species. (A,B) Adaxial and abaxial leaflet surfaces of *R*. adenodes. (C,D) Adaxial and abaxial leaflet surfaces of *R*. cooperi. (E,F) Adaxial and abaxial leaflet surfaces of *R*. nitens. (G,H) Adaxial and abaxial leaflet surfaces of *R*. galpini. Voucher specimens: (A,B) Grobbelaar 1345 (PRE); (C,D) Pienaar 557 (PRE); (E,F) Bester 4429 (PRE); (G,H) Pott 5315 (PRE).

**Figure 3.** Variation in stipules shape in *Rhynchosia* sect. *Rhynchosia* species. (A) Deltoid shaped stipule in *R*. calvescens. (B) Narrow lanceolate stipule in *R*. caribaea var. caribaea. (C) Large oblong-ovate with aristate or caudate apex in *R*. clivorum. (D) Long oblong-lanceolate or oblong-ovate in *R*. reptabunda. Voucher specimens: (A) Acoks 20080 (PRE); (B) Wells 4216 (PRE); (C) Klein 197 (PRE); (D) Ellan-Puttick 168 PRE).

Stipules are persistent, deciduous or caducous, pubescent or pilose to tomentose and glandular. They are quite varied in shape and can sometimes be useful in separating two morphologically similar species such as *R*. calvescens and *R*. caribaea which both have deltoid or rhomboid leaflets. However, the former can be identified by its deltoid stipules as opposed to lanceolate in the latter. *Rhynchosia clivorum* can also be identified by its large (7–13 × 4–6 mm), oblong-ovate stipules with aristate or caudate apex (Figure 3C). Stipule shape can also be used to some extent to distinguish different sections, for example in *R*. sect. *Cyanospermum* stipules are elliptic-lanceolate while in *R*. sect. *Polytropia*, they are ovate, but in *R*. sect. *Chrysoscias* the shape is quite variable. Within the latter section, *Rhynchosia leucoscia* and *R*. angustifolia are morphologically related in that they both have broad oblong stipules while *R*. chrysoscia and *R*. microscia have ovate-lanceolate stipules (Moteetee et al. 2012, Moteetee et al. 2014; Jaca et al. 2018). Stipels are usually absent in members of subtribe Cajaninae.
ever, there are few exceptions in some taxa of Rhynchosia sect. Rhynchosia (namely, R. adenodes, R. cooperi, and R. pentheri var. pentheri) where minute, caducous linear-lanceolate stipels occur. The presence of linear-lanceolate stipels was also reported in R. sect. Cyanospermum (Moteetee et al. 2012).

Reproductive Morphology

Inflorescence

In Rhynchosia sect. Rhynchosia flowers are usually arranged in axillary or terminal racemes or umbels (Wood and Key 2009). However, sometimes inflorescences are in axillary racemes but arranged towards the apex or summit as in R. adenodes and R. cooperi (Figure 4B). The inflorescence length ranges from 5 to 200 (280) mm, bears 1 to many flowers and can also be branched or unbranched. The inflorescence in R. sect. Cyanospermum, R. sect. Polytropia, and the R. densiflora group is an axillary raceme, while R. sect Chrysosclias has axillary umbels or solitary to sub-solitary flowers. On the other hand, the inflorescence is occasionally branched in R. sect. Cyanospermum (Moteetee et al. 2012; Moteetee et al. 2014; Jaca and Moteetee, 2018; Jaca et al. 2018). The branching pattern as well as the length of the inflorescences can sometimes be of diagnostic importance within in R. sect. Rhynchosia. For example, R. caribaea var. caribaea and R. caribaea var. picta can be separated from other species in southern Africa with deltoid, rhomboid, or ovate-rhomboid leaflets such as R. burchelli, R. atropurpurea, R. calvescens, R. sublobata, and R. thorncroftii, by their branched inflorescences.

The peduncle is usually glabrescent to pubescent or pilose to tomentose in the genus (Ajao et al. in preparation). Regarding the usefulness of inflorescence length in species delimitation, R. sordida is a species that is similar to R. angulosa in that the leaflets are elliptic. Rhynchosia sordida can be distinguished from the latter by the inflorescence that is usually shorter than the leaflets (5–15(30) mm) versus inflorescence that is longer than the leaflets (30–80(120) mm) in R. angulosa. Therefore, species in the type section of Rhynchosia can be grouped into two groups based on the length of inflorescences. Species such as R. cilliata, R. nitens, R. sordida, R. spectabilis, and R. komatiensis etc. have inflorescences that are shorter than the leaflets while species such as R. angulosa, R. atropurpurea, R. caribaea, R. clivorum, R. holosericea, and R. sublobata have inflorescences that are longer than the leaflets (Figure 4).

Flowers are usually pedicellate and yellow in all the species in the genus. To some extent, the number of flow-
erers per inflorescence could be used to separate identical species in the genus. In the type section, for example, R. ovata is morphologically similar to R. reptabunda in that the stems are pilose, the leaflets are ovate or suborbicular and the bracts are persistent. However, R. ovata can be distinguished by its shorter inflorescence (35–60 mm long) with fewer flowers (2–4-flowered), whereas in R. reptabunda the inflorescence is 70–100(130) mm long and 4–9-flowered. Another example is found between R. bolusii and R. capensis which are similar in leaflet shape, but the former can be identified by its 1- or 2-flowered inflorescences vs. 1–6-flowered in the latter (Boatwright and Moteetee 2014). In Rhynchosia sect. Polytropia, R. ferulaefolia is similar to R. pinnata in having a non-twinning habit and clustered inflorescences, but they can be distinguished based on the number of flowers, i.e. 5–12 in the former and 5–8 in the latter (Moteetee et al. 2014).

Bracts and bracteoles

In Rhynchosia sect. Rhynchosia bracts are usually lanceolate to ovate, deciduous or caducous to persistent, 1–6 × 0.2–3.0 mm, pilose or pubescent and glandular; bracteoles are absent. The absence of bracteoles is one of the diagnostic characters that separate the genus Rhynchosia and other genera in the subtribe Cajaninae (namely, Bolusafra, Cajanus, Dunbaria, Eriosema, Flemina, and Paracalyx) from the genus Adenodolichos (Moteetee and Van Wyk 2006).

Flower structure

The calyx is generally bilabiate in all the species in the genus, with unequal lips and lanceolate to acuminate, broadly lanceolate or obtuse lobes. The calyx tube is 1–6 mm long, the upper lobes are usually the shortest and are always connate almost to the apex, sometimes halfway and rarely below halfway, 0.3–13 mm long, the lateral lobes are 1.5–18 mm long while the carinal lobe is usually longer than the other lobes (2–21 mm long). The length of lobes, as well as the extent of connation of the upper calyx lobes, can be of diagnostic value within the type section and the R. densiflora group. A noteworthy example in the type section is found between R. sordida and R. angulosa which share elliptic leaflets as well as an erect habit. However, R. sordida can be distinguished by its much longer upper calyx lobes (6–10 mm) when compared to those of R. angulosa (1–3 mm) (Figure 5). In the R. densiflora group, the upper lobes of the calyx are connate less than halfway to almost entirely, these character states are useful to separate the species in the complex. In R. densiflora
Figure 4. Variation in inflorescence type and length in *Rhynosia* sect. *Rhynosia* species. (A) Umbel inflorescence shorter than the leaflets in *R. spectabilis*. (B) Axillary inflorescence arranged towards the apex in *R. cooperi*. (C) Axillary inflorescence with flowers with purplish keel petals in *R. atropurpurea*. (D) Axillary inflorescence longer than the leaflets in *R. angulosa*. (D) Inflorescences shorter than the leaflets in *R. sordida*. (F) Axillary inflorescence in *R. sublobata*. Voucher specimens: (A) Bester 11418 (JRAU); (B) Stirton 8107 (PRE). Photo by John Burrows (C,D,E), Abdulwakel Ajao (F).
subsp. *chrysadenia* var. *chrysadenia*, they are connate up to halfway while in *R. densiflora* subsp. *chrysadenia* var. *connata* they are connate more than halfway and sometimes to the apex (Jaca and Moteetee 2018). *Rhynchosia sect. Cyanospermum* and *R. sect. Polytropia* have upper calyx lobes connate to the apex while in *R. sect. Chrysochias*, they are somewhat connate at the base.

Calyx indumentum varies from glabrescent to pubescent or pilose, villous to tomentose and glandular in the type section (Figure 5), it is pubescent or pilose and glandular-punctate in the *R. densiflora* group, pubescent, glandular-dotted in *R. sect. Polytropia* and entirely velvety canescent or sometimes brownish pubescent at base in *R. sect. Cyanospermum* (Moteetee et al. 2012; Moteetee et al. 2014; Jaca and Moteetee 2018; Jaca et al. 2018).

**Standard petals**

Species in the type section have standard petals that are persistent, yellowish, purplish to brownish or brown-maroon veined, with or without callosities, 5–18 × 4–21 mm, claw (0.5) 1–3 mm. It also varies in shape from ovate to obovate or cordate to orbicular or elliptic in the type section, suborbicular in *R. sect. Cyanospermum* and *R. sect. Polytropia*, ovate to broadly obovate in *R. sect. Chrysochias* and elliptic to oblong in *R. densiflora* group (Moteetee et al. 2012; Moteetee et al. 2014; Jaca and Moteetee 2018; Jaca et al. 2018).

In terms of indumentum, the standard petals are glabrous and eglandular in all the sections and the *R. densiflora* group, with the exception of *R. sect. Rhynchosia* in which the standard petals are glabrous to pubescent or glandular. The indumentum on the standard petals is of great taxonomic importance as it can be used to separate morphologically similar species in this section. For example, *R. sublobata* and *R. caribaea* are similar in having deltoid or rhomboid leaflets, but the former can be differentiated by pubescent standard petals compared to glabrous in the latter. Also, *R. caribaea* var. *picta* can be differentiated from *R. caribaea* var. *caribaea* by its pubescent standard petals. Other species with pubescent and glandular standard petals in the type section are *R.*
adenodes, R. argentea, R. cooperi, R. crassifolia, R. galpinii, R. hirsuta, R. nitens, R. komatiensis, R. resinosa, R. spectabilis, R. vendae R. waterbergensis. In addition, Rhynchosia pentheri var. pentheri is occasionally glandular (Figure 6). Despite the absence of indumentum on standard petals in R. sect. Chrysocasias, its size is of diagnostic value. The standard petal is larger in R. leucoscias (10.0–15.5 × 7.0–15.0 mm) when compared to R. microscias (8–11 × 6–9 mm) and R. leucoscias (9.5–13.0 × 7.5–12.5 mm) (Jaca et al. 2018).

Wing petals

Oblong wings that are usually spurred at the base, 3–13 × 0.5–5.5 mm with linear claw 1–5 mm long is typical of the genus Rhynchosia. However, size, absence or presence of glands and surface sculpturing are of diagnostic importance. Wings are usually shorter than the keels in most of the species in the type section except in species such as R. clivorum R. cooperii, R. ovata, R. resinosa that have wings that are sometimes the same length as keel or even slightly longer than the keels as in R. argentea. Interestingly, in R. sect. Chrysocasias, the wing petals are equal to or longer than the keel petals in all species except in R. microscias, where they are slightly shorter than the keel. This character thereby separated R. microscias from the remaining species in the section (Jaca et al. 2018). Furthermore, the wings are generally longer than keels in R. pinnata and R. smithiana in R. sect. Polytropia (Moteetee et al. 2014). Most of the species in the genus have glabrous wings with the exception of R. adenodes, R. albissima, R. atropurpurea, R. bullata, and sometimes R. pentheri var. pentheri (all in the type section), which have glandular wings. Surface sculpturing can either be present or absent in the species in the type section and can be used to separate identical species. For example, R. komatiensis and R. spectabilis with similar ovate-orbicular or ovate leaflets, are distinguishable by the presence of sculpturing on the wings of R. spectabilis. Furthermore, R. pauciflora and R. sp. nov. are similar in having erect habit, linear or oblong leaflets and 1-flowered inflorescence. However, the former is separated from the latter by the presence of sculpturing on wing petals (Figure 7). The presence of surface sculpturing on the wing petals is also of taxonomic value in R. sect. Polytropia as it is used to distinguished R. ferulaefolia (where it is absent) from R. pinnata and R. smithiana (Moteetee et al. 2014). However, it is absent in R. sect. Chrysocasias, R. sect. Cyanospermum, and the R. densiflora group.

Keel petals

Keel petals are uniform in shape in the genus Rhynchosia, they are usually yellow, veined, pocketed, rostrate or boat-shaped, 5–15 × 2–9 mm, with a claw, 1–5 mm long. They are usually larger than the wings with the exception of those mentioned in the previous section and smaller than the standard petals. However, in R. atropurpurea the keels are almost the same length as the standard petals and entirely purplish colour, hence the specific name atropurpurea (Figures 4C & 8). The colour of the keels in R. atropurpurea is the most important character to distinguish it from the remaining species in the genus.

Figure 7. Variation in wing petals indumentum in Rhynchosia sect. Rhynchosia species. (A) Glandular with sculpturing in R. adenode. (B) Glabrous without sculpturing in R. calvescens. (C) Glabrous without sculpturing and narrow in R. thorncroftii. (D) Glabrous with sculpturing in R. villosa. Voucher specimens: (A) Grobbelaar 1345 (PRE); (B) Steyn 75 (PRE); (C) Dlamini 3060 (PRE); (D) Tyson 3085 (PRE). Scale bar 1 mm. Drawn by Abdulwakeel Ajao.

Figure 8. Variation in keel petals size in Rhynchosia sect. Rhynchosia species. (A) R. atropurpurea. (B) R. arida. (C) R. nitens. (D) R. ovata. Voucher specimens: (A) Nkoane 33 (PRE); (B) Van wyk 3029 (JRAU); (C) Lansdell 16078 (PRE); (D) Acocks 12979 (PRE). Scale bar 1mm. Drawn by Abdulwakeel Ajao.
Androecium

Stamens are uniform in the genus, and usually dia-
delphous with nine filaments fused and vexillary sta-
men free to the base. Anthers are also uniform, mono-
morphic, dorsifixed and somewhat dehiscent (Figures
9A-B).

Gynoecium

Ovaries are elliptic-oblong to oblong-lanceolate, ses-
sile to subsessile or stipitate, puberulous or pubescent
to pilose or glandular in *Rhynchosia* sect. *Rhynchosia*.
However, they are narrowly oblong and sub sessile in
other sections but vary in terms of indumentum as it is
densely silky-villous and glandular-punctate in the *R.*
densiflora group and pubescent in *R.* sect. *Chryso-
siaceae*, *R.* sect. *Cyanospermum*, and *R.* sect. *Polytropia* (Motee-
tee et al. 2012; Moteetee et al. 2014; Jaca and Moteetee
2018; Jaca et al. 2018). Styles are usually glabrous but
sometimes pubescent to pilose or glandular most es-
specially at the lower part. In the type section, it is usual-
ly 4–18 mm long and the variation in length can be of
diagnostic importance. For example, *R.* atropurpurea
can be distinguished from *R.* calvescens by a longer style
(13–15 mm) as opposed to the shorter style (7–10 mm)
in *R.* calvescens (Figures 9C-D).

Fruits

The shape, size, and type of indumentum on the
surface of the fruits vary greatly in the genus, but it can
sometimes be of diagnostic importance. In the type sec-
tion, fruits are 1–2-seeded, oblong to elliptic or falcate,
10–42 × 3–13 mm, compressed or inflated, stiped, gla-
brescent to pubescent or pilose to tomentose and gland-
ular. It is important to note fruits of most species in
this section are compressed and sometimes inflated as
seen in *R.* sublobata (Figure 10F). In *R.* sect. *Cyanosper-
um*, the fruits are narrowly oblong, 2-seeded, 15–20
× 5–6 mm, densely velvety canescent or rusty-brown
pubescent. However, they are oblong, broadly-oblong to
ovoid, and 1–2-seeded in *R.* sect. *Chryso-
CONCLUSIONS

In this study, we investigated the reproductive and vegetative characters that can be used to delineate species within *Rhynchosia* sect. *Rhynchosia* and between the different sections in the genus *Rhynchosia* in southern Africa. The type section seems to be more variable, which might be due to the higher number of the species (47) as well as wider distribution in southern Africa when compared to the other sections. Within *Rhynchosia* sect. *Rhynchosia*, both vegetative and reproductive characters appear to be useful in the grouping of the species. These characters include growth habit, leaflet shape and indumentum as well as inflorescence length and type (branched or not), extent of connation of upper lobes of the calyx, indumentum on standard petals as well as presence or absence of surface sculpturing on the wing petals. However, structures such as stamen, pistil and keel petals are of lower taxonomic value as they tend to be similar within the section as well as between the sections. All the sections and the *R. densiflora* group overlap in terms of leaflet structure in that they all have either trifoliolate or unifoliolate leaflets with the exception of *R. sect. Polytropia* in which the leaves are trifoliolate to simply or pedately bipinnate, bi-tri-jugate, pauci-cias petals which are consistently absent in presence or absence of surface sculpturing on the keel petals. However, structures such as stamen, pistil and keel petals are of lower taxonomic value as they tend to be similar within the section as well as between the sections. All the sections and the *R. densiflora* group overlap in terms of leaflet structure in that they all have either trifoliolate or unifoliolate leaflets with the exception of *R. sect. Polytropia* in which the leaves are trifoliolate to simply or pedately bipinnate, bi-tri-jugate, pauci-jugate, or supra-decompound. *Rhynchosia* sect. *Chrysos- cias* and *R. sect. Polytropia* are morphologically related in that they both exclusively have lanceolate to linear-lanceolate leaflets. It is worth mentioning that these two sections are restricted to the Eastern and Western Cape Provinces (South Africa).

Flowers can either be solitary, sub-solitary (e.g., *R. sect. Chrysos- cias*) on in axillary inflorescences which are either racemes or umbels. Reproductive morphological characters are more variable in the type section when compared to other sections. Standard petals indumentum varies from being glabrous to pubescent or glandular in the type section, but they are consistently glabrous and eglandular in all other sections including *R. densiflora* group. Although, *R. sect. Rhynchosia* and *R. sect. Polytropia* appear to be related when it comes to the presence or absence of surface sculpturing on the keel petals which are consistently absent in *R. sect. Arcypsyllum*, *R. sect. Cyanospermum*, and *R. sect. cyanospermum* group. However, *R. sect. Arcypsyllum* is close to *R. sect. Cyano- spermum* in the twinning growth habit and the many-flowered inflorescences which occur in dense subsessile axillary raceme. Morphologically, there are a number of overlapping characters between the sections, but we are not oblivious of the fact that Baker’s sectional classification is natural. Hence the reason phylogenetic relationships were also investigated between the sections in the genus in this study to determine whether Baker’s sectional classification will be upheld when using a combination of morphological and DNA sequencing data.

ACKNOWLEDGMENTS

This work is based on the research supported in part by the National Research Foundation of South Africa for the Grant number 76177. The authors thank the University of Johannesburg for logistical and financial support. Mr Ajao A.A. appreciates the International Association for Plant taxonomy for the award of the Dan Nicolson Research Grant in Plant Systematics in 2017. Our profound gratitude to the curators and staff of PRE and BNRH herbaria for making the specimens available to study.

REFERENCES

Ajao AA, Boatwright JS, Motetee AN. 2018. *Rhynchosia waterbergensis* (Cajaninae, Phaseoleae, Fabaceae), a new unifoliolate species from Waterberg, South Africa. Phytotaxa 382 (2): 234–238. Doi: http://dx.doi.org/10.11646/phytotaxa.382.2.9

Ajao AA, Boatwright JS, Motetee AN. In preparation. Taxonomic synopsis of *Rhynchosia* section *Rhynchosia* (Leguminosae: Papilionoideae, Phaseoleae) in southern Africa with a description of a new species.

Baker EG. 1923. Revision of South African species of *Rhynchosia*. Bothalia 1: 113–138.

Bezerra LMDPA, Candido ES, Vargas WD, Servilha JH, Monteiro TC, Perez APF. 2019. O gênero *Rhynchosia* (Leguminosae, Papilionoideae, Phaseoleae) no Brasil [The genus *Rhynchosia* (Leguminosae, Papilionoideae, Phaseoleae) in Brazil]. Rodriguésia 70 : 1–21. http://dx.doi.org/10.1590/2175-7860201970058. Português.

Boatwright JS, Tilney PM, Van Wyk BE. 2010. Taxonomy of *Wiborgiella* (Crotalariaeae, Fabaceae), a genus endemic to the greater Cape Region of South Africa. Systematic Botany 35(2): 325–340.

Boatwright JS, Motetee AN. 2014. *Rhynchosia bolusii* (Phaseoleae, Fabaceae), a new species from Western Cape Province of South Africa. Phytotaxa 161(2): 169–172. doi: http://dx.doi.org/10.11646/phyto- taxa.161.2.9.

Borges LM, Marazzi B, Lewis GP. 2018. Shaping knowledge on legume morphology. *Botanical Journal of the Linnean Society* 187: 1–4. DOI: https://doi.org/10.1093/botlinnean/boy010.
Candido ES, De Vargas W, Bezerra LMDPA, Mansano VDF, Vatanparast M, Lewis GP, Tozzi AMG-DA, Fortuna-Perez AP. 2019. Taxonomic Synopsis of *Eriosema* (Leguminosae: Papilionoideae, Phaseoleae) in Brazil. *Phytotaxa* 416 (2): 91–137. doi: http://dx.doi.org/10.11646/phytotaxa.416.2.1.

De Vargas W, Machado SR, Lewis GP, Candido ES, Vatanparast M, Fortuna-Perez AP. 2018. Revisiting the leaflet secretory structures in subtribe Cajaninae Benth. (Leguminosae, Phaseoleae). *International Journal of Plant Sciences*. 179(9):697–711.

De Vargas W, Fortuna-Perez AP, Lewis GP, Piva TC, Vatanparast M, Machado SR. 2019. Ultrastructure and secretion of glandular trichomes in species of subtribe Cajaninae Benth. (Leguminosae, Phaseoleae). *Protoplasma* 256(2):431–45.

Germishuizen G. 2006. *Rhynchosia* In: Germishuizen G, Meyer NL, Steenkamp Y, Keith M. (eds.) A checklist of South African plants. South African Biodiversity Network Report no. 41, SABONET Pretoria; p. 488–490.

Germishuizen G. 2011. Fabaceae: a new species of *Rhynchosia* from the northern provinces of South Africa. *Bothalia* 41(2): 319–321. doi: https://doi.org/10.4102/abc.v41i2.72

Grear JW. 1978. A revision of the New World species of *Rhynchosia* (Leguminosae-Faboideae). *Memoirs of the New York Botanical Garden* 31:1–168.

Isely D. 1990. Vascular flora of the southeastern United States, Leguminosae (Fabaceae) Volume 3, Part 2. The University of North Carolina Press, Chapel Hill, North Carolina, p. 277.

Jaca TP, Moteetee AN. 2018. Taxonomic notes on the *Rhynchosia densiflora* group (Phaseoleae, Fabaceae) in South Africa and its segregation from *Rhynchosia* section *Arcrophyllum* *Bothalia* 48 (1):1–10. DOI: https://doi.org/10.4102/abc.v48i1.2305

Jaca TP, Botwright JS, Moteetee AN. 2018. Taxonomic studies of the genus *Rhynchosia* Lour. (Phaseoleae, Fabaceae) in South Africa: A review of section *Chrysosias*. *South African Journal of Botany* 117:119–133.

Jeewon R, Liew EC, Simpson JA, Hodgkiss JJ, Hyde KD. 2003. Phylogenetic significance of morphological characters in the taxonomy of *Pestalotiopsis* species. Molecular Phylogenetics and Evolution 27(3): 372–383. doi: https://doi.org/10.1016/S1055-7903(03)00010-1.

Lackey JA. 1981. Tribe 10. Phaseoleae. In: Polhill RM, Raven PH. (Eds.), *Advances in Legume Systematics*. Royal Botanic Gardens Kew, Richmond U.K. 1: 301–327.

Le Roux MM, Van Wyk BE, Botwright JS, Tilney PM. 2010. The systematic significance of morphological and anatomical variation in fruits of Crotalaria and related genera of tribe Crotalarieae (Fabaceae). *Botanical Journal of the Linnean Society* 165(1): 84–106.

Lewis G, Schrire B, Mackinder B, Lock M. (eds.). 2005. Legumes of the World. Royal Botanic Gardens Kew, Richmond U.K.

LPWG. 2017. A new subfamily classification of the Leguminosae based on a taxonomically comprehensive phylogeny. *Taxon* 66: 44–77. doi: https://doi.org/10.12705/661.3

Manoko MLK. 2007. Systematics analysis and morphological characters and the value in the taxonomy of *Solanum* L. section *Solanum*, in: A systematic study of African *Solanum* L. section *Solanum* (Solanaceae). PhD. Thesis. Radboud University Nijmengen, Netherlands.

Manyelo TS. 2014. A phylogenetic study of South African species of *Rhynchosia* (Phaseoleae, Fabaceae) [Masters thesis]. University of Johannesburg. Retrieved from https://ujdigspace.uj.ac.za (Accessed: 26/07/2018).

Moteetee AN, Le Roux MM. 2016. The *Rhynchosia totta* complex (Phaseoleae, Fabaceae) in Southern Africa, including the description of a new variety and new species. *Bothalia* 46(1): 1–19. doi: https://doi.org/10.4102/abc.v46i1.2041.

Moteetee AN, Van Wyk BE. 2006. A revision of the genus *Bolusafra* (tribe Phaseoleae, Fabaceae). *South African Journal of Botany* 72(4): 604–608.

Moteetee AN, Boatwright JS, and Jaca TP. 2012. A review of *Rhynchosia* section *Cyanospermum* (Phaseoleae, Fabaceae) in South Africa. *South African Journal of Botany* 81:124–127. doi: https://doi.org/10.1016/j.sajb.2012.06.007.

Moteetee AN, Boatwright JS, Jaca TP. 2014. A review of *Rhynchosia* section *Polypotlia* (Phaseoleae, Fabaceae) and a new species from the Western Cape Province, South Africa. *Systematic Botany* 39(4): 1127–1131. doi: https://doi.org/10.1600/036364414X683859.

Pinto R, Lusa M, Mansano V, Tozzi A. 2018. Morphoanatomy of the leaflets of the *Hymenaea* clade (Fabaceae, Detarioideae) reveals their potential for taxonomic and phylogenetic studies. *Botanical Journal of the Linnean Society* 187: 87–98. doi:https://doi.org/10.1093/botlinnean/boy007

Santos RC, Pires JI, Correa RX. 2012. Morphological characterization of leaf, flower, fruit and seed traits among Brazilian *Theobroma* L. species. *Genetic Resources and Crop Evolution* 59(3): 327–345. doi: https://doi.org/10.1007/s10722-011-9685-6

Schrire BD. 2005. Tribe Phaseoleae. In: Lewis G, Schrire BD, Mackinder B, Lock M. (eds.) *Legumes of the World*. Royal Botanic Gardens Kew, Richmond p. 393–429.
Silva N, de Oliveira Arruda R, Alves F, Sartori AL. 2018. Leaflet anatomy of the Dipterygeae clade (Fabaceae, Papilionoideae): evolutionary implications and systematics. Botanical Journal of the Linnean Society 187: 99–117. doi: https://doi.org/10.1093/botlinnean/boy009.

Thiers B. 2019. Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. Available from http://sweetgum.nybg.org/ih/ (accessed: 30 June 2019).

Woods M, Key J. 2009. The genus Rhynchosia (Fabaceae) in Alabama. Phytologia 91(1):3–17.