UNIVERSIDADE D
COIMBRA

Ana Maria Santos Coelho

POLYGALA L. IN ANGOLA

SEED MORPHOLOGY AND DISPERSAL MECHANISMS

Dissertation within the Master in Biodiversity and Plant Biotechnology supervised by Professor Doctor Maria de Fátima Matias Sales Machado and Professor Doctor Jorge Américo Rodrigues de Paiva and presented to the Department of Life Sciences of the Faculty of Sciences and Technology of the University of Coimbra.

July 2022

Faculty of Sciences and Technology
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Herbaria acronyms

Herbaria acronyms follow: Thiers, B. M. (continuously updated). Index Herbariorum. http://sweetgum.nybg.org/science/ih/.

European Herbaria:

BM – The Natural History Museum, London

BR – Meise Botanic Garden, Meise, Belgium

COI – University of Coimbra, Coimbra, Portugal

K – Royal Botanic Gardens Kew, London, U.K.

LISC – Instituto de Investigação Científica Tropical, Lisbon, Portugal

LISU – Museu Nacional de História Natural e da Ciência, Lisbon, Portugal

P – Muséum National d'Histoire Naturelle, Paris, France

African Herbaria:

LUA – Instituto de Investigação Agronómica, Huambo, Angola

LUAI – ex-Centro Nacional de Investigação Científica (CNIC), Luanda, Angola

Abstract

The seeds of *Polygala* L. are morphologically variable among taxa. Therefore, it is very interesting to study their potential for the taxonomy of the genus. Seed morphology in *Polygala* is often closely associated with the dispersal agent, being dispersal by ants (myrmecochory) the most studied. The main objective of this work is to test the hypothesis that seed characters in *Polygala* are of taxonomic importance at a specific level and that they allow for taxa identification.

This research focuses on the study of the morphology of the seeds of the 48 Angolan *Polygala*, and a total of 604 Angolan herbarium specimens were investigated. The seed descriptions are the most comprehensive so far in the literature of *Polygala*. The methodology for the descriptions considered taxa outside Angola with very different seed morphology so that it can be applied in the future to any taxon, establishing a precedent for any work of this kind. The 213 seeds were microphotographed using the binocular stereomicroscope Leica MZ 9.5 coupled with a microscope camera Leica MC190 HD. A total of 639 microphotographs were taken. For the seed measurements it was used the ANNOTATE software version 1.9.50. Information allowed the construction of an identification key to taxa using seed characters only.

Multivariate methods of analysis were carried out to identify the tendency for seeds and groups of taxa to cluster and to understand the characters that contribute to their separation: a Principal Component Analysis (PCA) performed with the five continuous variables assessed in this research and a Factorial Analysis of Mixed Data (FAMD) performed with all the variables assessed potentially involved in dispersal.

The statistical analyses support the big groups in the identification key and partially explained the difficulties in separating some of the Angolan taxa using seed characters only due to both some seed morphological variability within the same taxon and morphological similarity among some taxa. The detailed study of the seed morphological traits and the information on distribution and habitat and ecology establish the basis for the study of the relation between seed morphology and dispersal agents. For some cases it is possible to establish links between seed morphology and ecology, and consequently the possible dispersal agent.

Based on the results obtained for the Angolan sample here investigated, seed characters in *Polygala* are of taxonomic importance at a specific level and allow for the identification of most taxa.

Keywords: Polygalaceae; identification key; multivariate analyses; ecology; myrmecochory.

Resumo

As sementes de *Polygala* L. apresentam variação morfológica entre *taxa* sendo muito interessante estudar o potencial deste órgão para a taxonomia do género. A morfologia da semente de *Polygala* tem sido intimamente associada ao agente dispersor, sendo mais estudada a dispersão por formigas (mirmecocoria). O principal objetivo deste trabalho é testar a hipótese de que os caracteres da semente de *Polygala* têm importância taxonómica a nível específico podendo mesmo permitir a identificação dos *taxa*.

Esta investigação foca-se no estudo da morfologia das sementes dos 48 *taxa* de *Polygala* de Angola, e foram investigados 604 exemplares de herbário angolanos no total. Inclui as descrições mais completas de sementes de *Polygala* na literatura. A metodologia para as descrições considera *taxa* não angolanos, com morfologia da semente muito diferente para que possa ser aplicada a qualquer *taxon*, estabelecendo-se, assim, um precedente para qualquer trabalho futuro deste tipo. As 213 sementes foram microfotografadas utilizando uma lupa binocular Leica MZ 9.5 acoplada a uma câmara de microscópio Leica MC190 HD. Foram tiradas 639 microfotografias no total. Para as medições utilizou-se o software ANNOTATE 1.9.50. Esta informação permitiu a construção de uma chave de identificação dos *taxa* angolanos utilizando apenas caracteres da semente.

Foram utilizados métodos de análise multivariada para identificar a tendência para a formação de clusters de sementes e de *taxa* e quais os caracteres da semente que contribuem para a sua separação: uma Análise de Componentes Principais (PCA) realizada com as cinco variáveis contínuas avaliadas neste trabalho e uma Análise Fatorial de Dados Mistos (FAMD) realizada com todas as variáveis avaliadas potencialmente envolvidas na dispersão.

As análises estatísticas corroboram os grandes grupos da chave de identificação e explicam parcialmente as dificuldades em separar alguns *taxa* angolanos utilizando apenas caracteres da semente, devido a alguma variabilidade morfológica dentro do mesmo *taxon* e similaridade morfológica entre alguns *taxa*. O estudo detalhado da morfologia da semente e a informação da distribuição e de habitat e ecologia estabelecem a base para o estudo da relação entre a morfologia da semente e os agentes dispersores. Para alguns casos é possível estabelecer

ligações entre a morfologia da semente e a ecologia, e consequentemente o possível agente dispersor.

Com base nos resultados obtidos em *Polygala* de Angola, os caracteres da semente têm importância taxonómica a nível específico e permitem a identificação da maioria dos *taxa*.

Palavras-chave: Polygalaceae; chave de identificação; análises multivariadas; ecologia; mirmecocoria.

1. Introduction

1.1. Description of *Polygala* L.

Polygala, comprising *c.* 580 species (Pastore, 2018), is the largest genus in the Polygalaceae (order Fabales; APG IV, 2016). The genus is cosmopolitan (Paiva, 2015; Pastore, 2018) and it is divided in two subgenera, *Polygala* L. and *Chodatia* Paiva (Pastore, 2018). The plants are mainly herbs and shrublets and are heliophile, prefer open areas, developing in a wide range of habitats: from those that are xerophyte and grow in deserts and semideserts, especially shrublets and rhizomatous herbs, to those that are hygrophyte and grow in wetlands or temporarily wetlands in tropical and subtropical areas, mainly small herbs (Paiva, 1998, 2015). Some *Polygala* species have a great capacity to adapt to different ecological conditions (Levyns, 1955).

The **leaves** are alternate, exceptionally opposite, verticillate or in basal rosettes; mostly persistent; sessile or shortly petiolate; from linear to lanceolate or oblong-elliptic; mostly entire (Paiva, 1998). The **flower** (Fig. 1A-H) is very distinct, with: five sepals, three external generally green (two anterior similar, often free, and one superior, larger) and two internal (wing-sepals) larger and coloured; five petals: two upper, one lower (carina), keel-shaped, mostly with a polymorphic crest (fimbriate or pluri-lobed), and two lateral usually vestigial or absent; usually with eight stamens (sometimes six fertile and two staminodes), united into a tube (staminal tube); bilocular ovary, usually sessile, and bilobed stigma (Paiva, 1998, 2007). The **fruit** (Fig. 1I) is a bilocular capsule, with one seed in each locule; from obovoid to ellipsoid or sub-globose; usually compressed and winged; hairy or glabrous; stipitate or sessile, depending on the presence or absence of a gynophore, respectively (Paiva, 1998). The **seeds** are morphologically variable among taxa (Paiva, 1998). Therefore, it is very interesting to study the potential of this organ for the taxonomy of *Polygala*.

Figure 1. (A-H) Flower and (I) mature fruit of *Polygala myrtifolia* L. (A) Whole flower; (B) longitudinally dissected flower; (C) without the sepals; (D) external view of the external and the internal sepals; (E) lower petal (carina); (F) upper petals; (G) androecium, with the gynoecium inside; (H) gynoecium. 1 – carina; 2 – crest; 3 – internal sepal (wing-sepal); 4 – upper petal; 5 - posterior sepal; 6 – staminal tube; 7 – style; 8 – bilocular ovary; 9 – anterior sepals; 10 – stigma; 11 – capsule wing; 12 – the two locules with one seed in each. Images acquired in a HerbScan (with an inverted scanner). Bar = 1 mm.

1.2. Seed morphology in *Polygala* L.

Polygala seeds develop from an anatropous ovule (Verkerke & Bouman, 1980). The seed coat sculpture in scanning electron microscopy (SEM) alone proved to be difficult on taxa identification (Isaacs et al., 1993). Unicellular hairs that often cover the seed coat can be straight (Fig. 2B), or curving (Fig. 2D) or glochidiate (hook shaped; Fig. 2E) but the seed can also be glabrous (Fig. 2F). SEM revealed that some straight hairs have longitudinally striate surface while curving and glochidiate hairs have papillose surface (Paiva, 1998).

Seeds may also have structures generally named **elaiosomes**, an ecological term referring to the appendages that are attractive for ant dispersal (Lisci et al., 1996; Ridley, 1930; Sernander, 1906). Elaiosomes, found in 17% of all angiosperm families, are largely distributed in Fabales (Quillajaceae, Fabaceae, Surianaceae, and Polygalaceae; APG IV, 2016) (Lengyel et al., 2010). As such structures have variable ontogeny, final position, and morphology, and develop in very different plant groups, the terminology given to such structures has proliferated (Lisci et al., 1996).

In some *Polygala* there is an elaiosome at the proximal end of the seed that has been traditionally named **caruncle** (e.g. Paiva, 1998, 2016; Siebert et al., 2010; Fig. 2A-C), a term that refers usually only to the location of this seed appendage, near the hilum (Fig. 8C), the point of attachment of the seed to the funicle (Hickey & King, 2006). The funicle is localized between the caruncular ventral lobes (Verkerke & Bouman, 1980; Fig. 3). The investigation of the ontogeny of the caruncle revealed that it originates from the dermis of the outer integument (that develops into the seed coat or testa) surrounding the micropyle (Verkerke & Bouman, 1980; Fig. 8C). It is, therefore, exostomatic. Some authors also use the term caruncle to indicate the structure with such ontogenetic origin (Fernandes, 1972). Each of these three terms can be used for *Polygala* seeds in different contexts: ecological (elaiosome), morphological (caruncle) and ontogenetic (exostomatic). In this thesis I use the terms elaiosome and caruncle.

The earliest reference founded to the caruncle is by Gaertner (1788) for seeds of *P. vulgaris* L. In *Polygala*, the caruncle is a polymorphic structure (Chodat, 1893; Paiva, 1998), usually 3-lobed (Fig. 2A-C; Fig. 3C) with two ventral lobes turned to the inner side of the capsule and symmetrical plus a dorsal lobe at the opposite side of the raphe (Paiva, 1998; Fig. 3; Fig. 8). The caruncle can also be hairy or glabrous. Often, it has appendages that are elongations of the epidermis of the caruncular lobes (Paiva, 1998). The caruncular appendages vary from scarcely

developed (Fig. 2A) to extending almost to the distal end of the seed body (Fig. 2B) and even those of the two ventral lobes developing over the caruncle smooth portion (Fig. 2C) (Paiva, 1998; Paiva, 2007).

Some authors refer also in *Polygala* to a smaller elaiosome at the distal end of the seed (Ridley, 1930; Sernander, 1906), sometimes named chalazal region expansion, outgrowth, appendage or swelling (Adema, 1966; Verkerke, 1985). In this thesis I use the term chalazal region expansion.

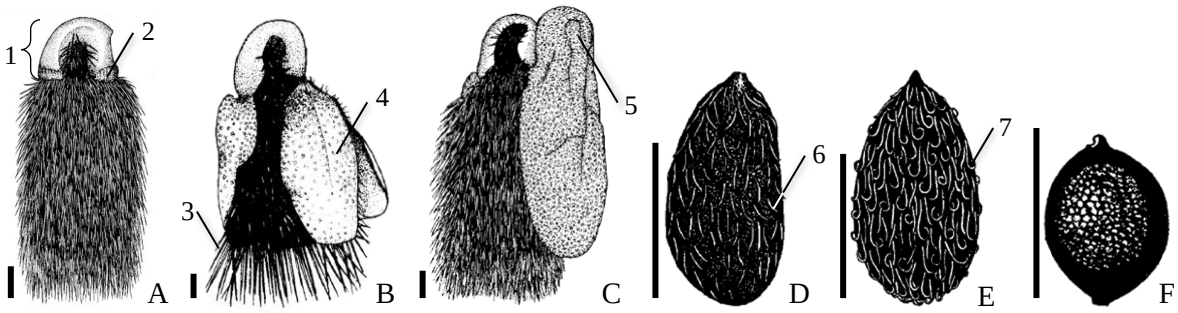

Figure 2. Some seed morphological variation in *Polygala*. (A) *P. kasikensis* Exell, *De Giorgi* s.n.– BR; (B) *P. effusa* Paiva & Thulin, *Bally* 9625– K; (C) *P. senensis* Klotzsch, *Phipps* 171– K; (D) *P. fernandesiana* Paiva, *Chapman* 65– K; (E) *P. sansibarensis* Gürke, *Holst* 2990– P; (F) *P. afra* Paiva, *Greenway & Polhill* 11666– K. 1 – caruncle; 2 – caruncular appendage scarcely developed; 3 – straight hairs; 4 – caruncular appendage extending almost to the distal end of the seed body; 5 – appendage of ventral lobe over the caruncle smooth portion; 6 – curved hairs; 7 – glochidiate hairs (Paiva, 1998, 2007). Bar = 0.5 mm.

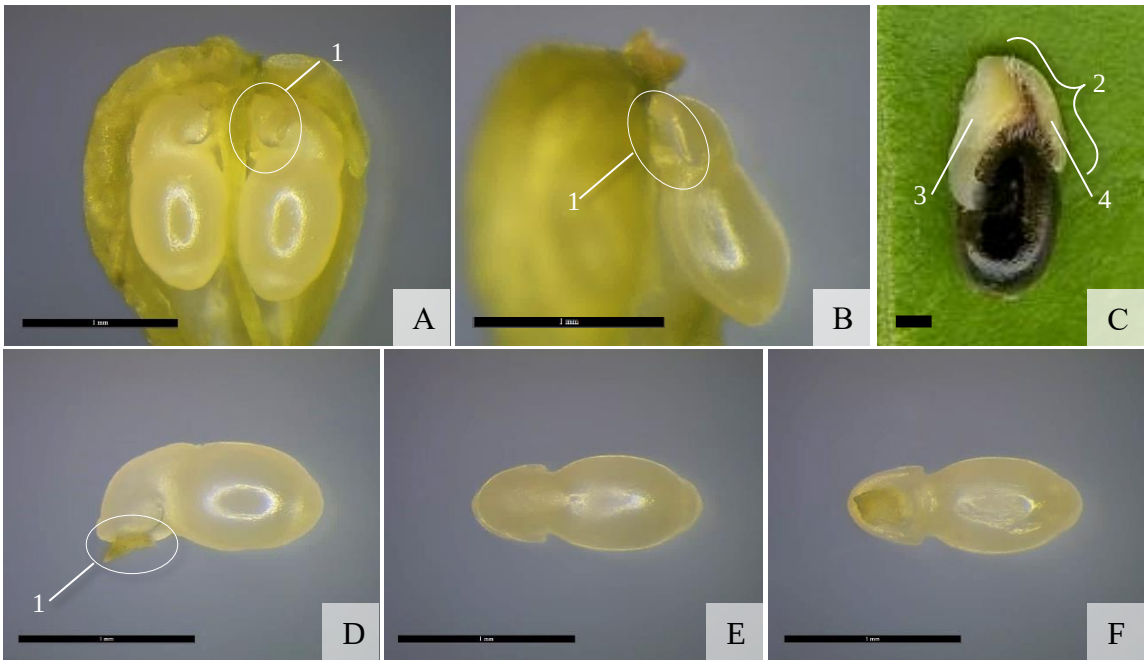

Figure 3. Seeds of *P. myrtifolia*. (A, B) Immature seeds attached to the immature capsule; (C) mature seed in lateral view (image acquired in a HerbScan - with an inverted scanner); immature seed in (D) lateral, (E) dorsal, and (F) ventral views. 1 – Funicle localized between the caruncular ventral lobes; 2 – caruncle; 3 – caruncular ventral lobe; 4 – caruncular dorsal lobe. Bar = 1 mm.

1.3. *Polygala* L. in Angola

All 48 taxa of *Polygala* in Angola are in subgen. *Polygala* (Paiva, 1998). Subgen. *Polygala* is cosmopolitan, plants are herbs, creepers, shrubs or trees, usually with membranous leaves. Flowers are solitary or axillar or in terminal inflorescences, with persistent external free sepals or the anterior ones joined, wing-sepals petaloid and persistent (exceptionally deciduous), upper petals joined to the staminal tube, generally with crested keel. The capsule is generally symmetrical and aptera or winged. Seeds have caruncle, exceptionally without, and can be hairy or glabrous (Paiva, 1998).

Polygala subgen. *Polygala* is divided into 11 sections, some divided into subsections. The Angolan taxa are in five sections, three of which divided into subsections (Paiva, 1998; Table 1)

Table 1. Subgeneric classification of the 48 Angolan *Polygala* (Paiva, 1998).

Section	Subsection	Taxon in Angola
Timutua DC.	———	*P. africana* Chodat
		P. capillaris E.Mey. subsp. *capillaris*
		P. spicata Chodat
Leptaleae (Chodat) Paiva	———	*P. myriantha* Chodat
Blepharidium DC.	*Blepharidium*	*P. erioptera* DC.
	Asiaticae (Chodat) Paiva	*P. myrtillopsis* Welw. *ex* Oliv.
	Sphenopterae (Chodat) Paiva	*P. sphenoptera* Fresen.
	Arenariae (Chodat) Paiva	*P. albida* Schinz subsp. *albida*
		P. albida Schinz subsp. *stanleyana* (Chodat) Paiva
		P. arenaria Willd.
		P. melilotoides Chodat
		P. welwitschii Chodat subsp. *pygmaea* (Gürke) Paiva
		P. welwitschii Chodat subsp. *welwitschii*
	Sativae Paiva	*P. angolensis* Chodat
		P. britteniana Chodat
		P. ganguelensis Exell & Mendonça
		P. gomesiana Welw. *ex* Oliv.
		P. macrostigma Chodat
		P. mendoncae E.M.A. Petit
		P. nambalensis Gürke
		P. oliverana Exell & Mendonça [*oliverana* in the protologue]
		P. paludicola Gürke
		P. usafuensis Gürke
		P. youngii Exell
Tetrasepalae (Chodat) Paiva	*Tetrasepalae*	*P. antunesii* Gürke
		P. laxifolia Exell
		P. luenensis Paiva

		P. mossamedensis Paiva
		P. resendeana Paiva
		P. rivularis Gürke
		P. schinziana Chodat
		P. stenopetala Klotzsch subsp. *casuarina* (Chodat) Paiva
	Ecristatae Paiva	*P. fragilis* Paiva
		P. petitiana A.Rich. subsp. *petitiana* var. *petitiana*
		P. xanthina Chodat
	Hexandriae Paiva	*P. acicularis* Oliv.
		P. arenicola Gürke
		P. baumii Gürke
		P. dewevrei Exell
		P. gossweileri Exell & Mendonça
		P. huillensis Welw. *ex* Oliv.
		P. kalaxariensis Schinz
		P. nematophylla Exell
		P. poggei Gürke
		P. robusta Gürke
Megatropis Paiva	*Megatropis*	*P. guerichiana* Engl.
	Heterolophus Paiva	*P. leptophylla* Burch. var. *leptophylla*
		P. pallida E.Mey. *ex* Harv.

The information on ecology of each of these taxa on herbarium specimens is poor and various terms seem to be used with no uniform criterion, a problem much discussed by Mengist (2019).

1.4. Seed dispersal mechanisms in *Polygala* L.

Most of the dispersal mechanisms put forward for *Polygala* have not been demonstrated in the field and were inferred based only on the morphology of diaspores (Castro et al., 2010). Paiva (1998) associated the presence of glochidiate and curving hairs with papillose surface on seeds without caruncle to dispersal by birds (ornitochory) present in the wetlands where some of such plants grow, since these hairs can adhere to the feathers of migratory aquatic birds that disperse them to greater distances. Glochidiate hairs are referred to as specialized to epizoochory – dispersal of propagules by adhesion to the body surface of animals (Gorb & Gorb, 2002; Sorensen, 1986). Also, the absence of caruncle in some *Polygala* would be associated with the absence of ants in wetlands (Paiva, 1998). Furthermore, glabrous seeds without caruncle do not have auxiliar structures to the dispersal and grow, in fact, in small areas (Paiva, 1998). Seeds with coloured caruncle would be associated with dispersal by the birds attracted by the colour (Paiva, 1998).

Nevertheless, some experiments and observations have been carried out revealing important information for the study of the dispersal mechanisms in *Polygala*, mainly about ant dispersal of seeds – myrmecochory (e.g. Castro et al., 2010; Lack & Kay, 1987; Oostermeijer, 1989).

A dispersal mechanism performed in two steps (diplochory) was observed in *P. vulgaris*, the type of the genus: first, it occurs the anemochoric dispersal of the membranous mature capsule, laterally compressed and alate, as it is blown off the plant and dispersed by the wind falling to the ground, opening and exposing the seeds; then it occurs de second step, the myrmecochoric dispersal of the seeds by ants that mutilate the elaiosome (Paiva, 1998; Ulbrich, 1928; Verkerke, 1985).

The elaiosome (meaning "oil-body") is a structure with nutritive reserves, generally lipids, sometimes also starch or proteins, it attracts ants that benefit from these resources (Sernander, 1906), being very important in ant seed dispersal (e.g. Castro et al., 2010). Some authors pointed to a relation between bigger-sized elaiosomes and an increase of its attractiveness to ants in studies including *Polygala* (e.g. Oostermeijer, 1989). Ants collect not only complete seeds with the elaiosome, but also some seeds with fragmented or removed elaiosome even when complete seeds are present (Castro et al., 2010; Lack & Kay, 1987; Oostermeijer, 1989), probably because ants form a "search image" for the seed morphology of the taxon (Lack & Kay, 1987).

The transport of the seeds of *P. vulgaris* by ants may be facilitated by the presence of hairs, given that ants have difficulties in handling hairless seeds in a favourable position to transport them to the entrance of the nest (Oostermeijer, 1989). After eating or mutilating the elaiosome ants eject the remaining seed from the nests, therefore, germination occurs nearby (Lack & Kay, 1987). The presence of structures with a thick wall separating the elaiosome from the seed body forces ants to consume only the elaiosome, rejecting the remaining seed (Bresinsky, 1963 in Verkerke, 1985), this ready for normal germination.

It can, then, be concluded that seed morphology in *Polygala* is often closely associated with the dispersal agent. Seed dispersal has many consequences for the ecology (Nagendra, 2020) and evolution (Bello & Barreto, 2021) of plants.

The investigation of myrmecochory is a very broad issue that seems to be more complex than the mere relation species to species (animal/plant). Generally, it is recognised that seed dispersal by ants plays an important role in shaping vegetation community structure (Del Toro et al., 2012). Still, it has also been observed a variation of ant diversity along altitudinal gradients (Bernadou et al., 2015; Del Toro & Ribbons, 2019), that it is related to ecological factors, such as habitat characteristics and temperature (Bernadou et al., 2015).

1.5. Objectives

The main objective of this work is to test the hypothesis that seed characters in *Polygala* are of taxonomic importance at a specific level and that they allow for taxa identification.

The objectives in detail are:

- To investigate the seed morphology of the Angolan taxa of *Polygala*;
- To microphotograph in different positions the seeds of the Angolan taxa;
- To describe in detail the seeds of the Angolan taxa;
- To construct an identification key for the Angolan taxa of *Polygala* using seed characters only;
- To establish the basis for the investigation on the relation between seed morphology and dispersal agents in Angolan *Polygala*.

2. Materials and Methods

2.1. Plant material

The Angolan sample here investigated represents only *c*. 8.3% of the overall *Polygala*, but it is geographically and ecologically significant. Angola is a good case study because it consists in an ecologically variable territory, comprising an extensive central plateau, mostly savannah ecosystem, surrounded by different ecological units: Zambesi basin (east), the Namib desert (southwest) and tropical forest (north) (White, 1983).

The seeds of each of the 48 Angolan taxa included in *Polygala* subgen. *Polygala* were searched and investigated. Most of the seed material used in this research was from the seed collection of Jorge Paiva (Fig. 4A-B). This collection covers most of the *Polygala* taxa worldwide, extracted from many herbaria. Seeds are stored in small paper envelopes, each with the citation of the original herbarium specimen (Fig. 4B).

The material used from Paiva's collection was originally from European herbaria (BM, COI, LISC, LISU, K) and also from Africa (LUA, LUAI). Seed material of each taxon is very variable, (0-)1 – >10. Therefore, it was established to study five seeds *per* taxon, a number that covered most taxa. For the taxa not represented in the collection or those with 1-4 mature seeds only, material was searched and extracted from the specimens of COI, LUA and LUAI (loans already at COI), and LISC (loan requested) (Fig. 4C-F).

The total of Angolan herbarium specimens investigated was 604 (Table 2).

Nevertheless, there were taxa for which there was not, or not enough, Angolan material. For these, it was searched and extracted material from countries as close as possible to Angola in the collection of Paiva and in the COI collection.

After all this material search, the remaining problems were (Table A1): no seeds of *P. poggei* were found; the single immature seed of *P. gossweileri* found was partially described and included in the key; five Angolan endemics (see 3.2. Seed descriptions and microphotographs. Distribution and ecology) had less than five mature seeds to work with; two other species also had less than five seeds.

The total of seeds studied was 213, from 127 specimens (Table A1).

The information on the labels of all the Angolan herbarium specimens investigated and of those specimens previously seen by Paiva was used for collecting the distribution of the taxa in

Angola. The information of total distribution, and habitat and ecology was mainly retrieved from Paiva (1998). Difficulties arose on transferring into English the ecological terms in Portuguese and Spanish. The names of the Angolan provinces follow the Getty Thesaurus of Geographic Names (The J. Paul Getty Trust, 2017).

Figure 4. Material of *Polygala*. (A, B) Seed collection of Jorge Paiva; Angolan herbarium specimens (C) in COI, (D) from LISC, and (E) LUA and LUAI; (F) extracting seeds from specimens.

Table 2. Number of Angolan specimens investigated *per* herbarium.

Herbarium	Specimens
COI	309
LISC	75
LUA	124
LUAI	96
Total	604

2.2. Taxonomy

When the seeds studied seemed to be morphologically quite different within the same taxon or very similar between different taxa, it was imperative to check the identification of the respective herbarium specimen from which the seeds were extracted. Identifications were confirmed against type specimens housed at the Herbarium of the University of Coimbra and all those available online in JSTOR, Global Plants (https://plants.jstor.org/). To find the types it was necessary to search in the taxonomic literature for the taxa protologues and the citation of the specimens originally studied, also in Figueiredo et al. (2013). The information for the protologues was searched mainly in the online database POWO (Plants of the World Online, http://www.plantsoftheworldonline.org/). The identification keys in Paiva (1998) were also critically important at this stage of the research. The African Plant Database (http://www.ville-ge.ch/musinfo/bd/cjb/africa/recherche.php?langue=an) and IPNI (International Plant Names Index, https://www.ipni.org/) were also consulted.

Images of specimens at The Natural History Museum were requested to clarify the identity of the original material of some seeds in Paiva's collection.

2.3. Microphotography

The five seeds of each taxon were microphotographed using a binocular stereo microscope Leica MZ9.5 coupled with a microscope camera Leica MC190 HD with a 10 megapixel CMOS (complementary metal oxide semiconductor, electronic chip that converts photons to electrons for digital processing used to create images in cameras; TechTarget Inc., 2018) sensor (Fig. 5A). It was also used the software for widefield imaging LAS (Leica Application Suite) Live Z Image Builder that assembles images from the entire focal range into a single image (Leica Microsystems, 2011b; Fig. 6). To even out the lighting on the material to be photographed and improve quality, it was adapted to this stereo microscope the LED Ringlight Fit of the binocular stereo microscope Leica S9E (Fig 5A).

For the microphotography background, it was used a standard Grey Card for photography. Each seed was placed on an inverted glass Petri dish, this placed on the Grey Card (Fig. 5B-C). It was made a white balance for greys.

The acquisition mode selected was "Image Builder" (Fig. 6B) and the following camera settings were pre-adjusted, occasionally re-adjusted during photography, to optimize the quality of image acquisition (Leica Microsystems, 2011a, 2021).

In **Acquire > Camera > Exposure Adjust** (Fig. 6C):

- exposure (time the camera sensing elements are exposed to the material) set to 10,5 ms;
- gain (brilliance of the image) set to 1,4 x;
- saturation (colour intensity of the image) set to 90,00;
- gamma (contrast range) set to 0,60.

In **Acquire > Camera > Processing**:

- sharpening set to low (Fig. 6D).

In **Acquire > MZ9.5 > Zoom Drive (Manual) 60.0x**, the objective magnification was always adapted to the seed size (Fig. 6E).

For building the image capture mode "Extending in Z axis" was selected (Fig. 6B).

Each seed was photographed with a resolution of 1000 dpi (dots per inch) in three different views: lateral, dorsal, and ventral (Fig. 5D; Fig. 8). A total of 639 microphotographs were taken.

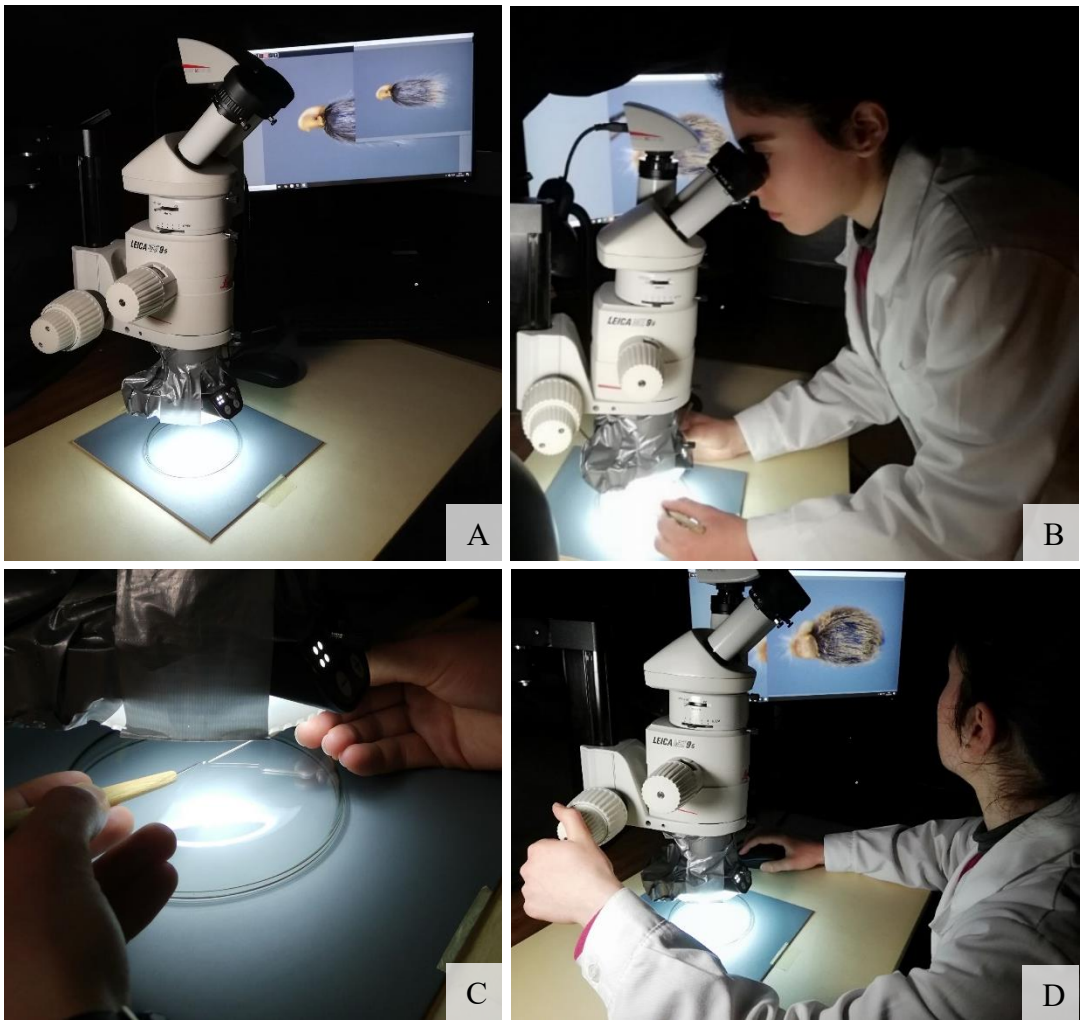

Figure 5. Microphotography. (A) Leica equipment; (B, C) manipulating the seed placed on an inverted glass Petri dish, this placed on the Grey Card for photography; (D) microphotography in the different views.

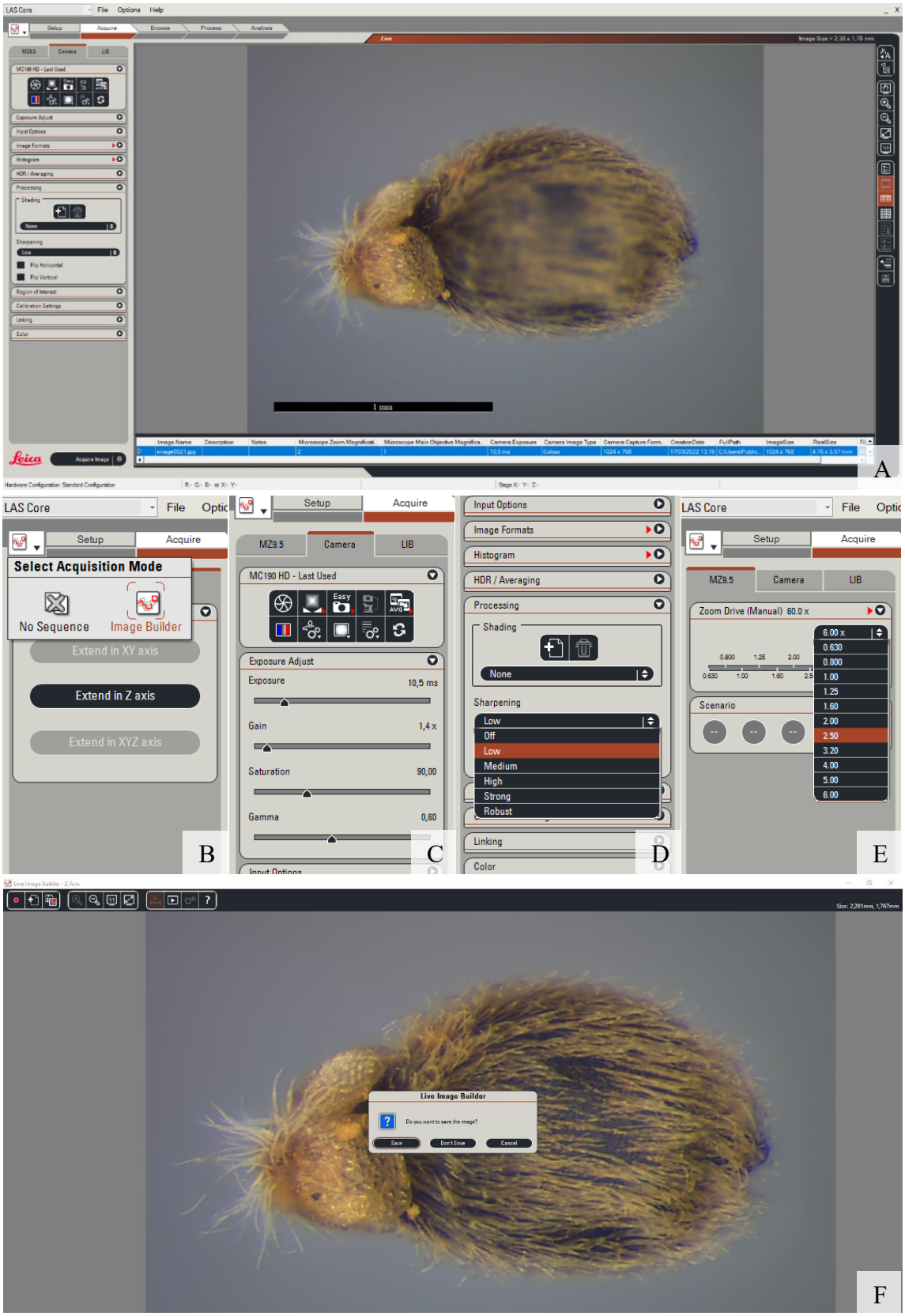

Figure 6. Leica Application Suite. (A) Application view screen; (B) selecting acquisition and capture modes; adjusting (C) exposure, gain, saturation, and gamma, (D) sharpening, and (E) objective magnification; (F) application view screen showing the Live Z Image Builder.

2.4. Seed measurements

Seed measurements were taken using the ANNOTATE software version 1.9.50 developed by ReColNat, *Réseau des Collections Naturalistes*, at the Muséum National d'Histoire Naturelle, Paris [*RECOLNAT (ANR-11-INBS-0004)*]. It annotates measurements directly on natural sciences images.

The seeds of each taxon were measured on the microphotographs using the length tool of the software, always calibrating the measurement scale with the 1 mm scale in each microphotograph (Fig. 7).

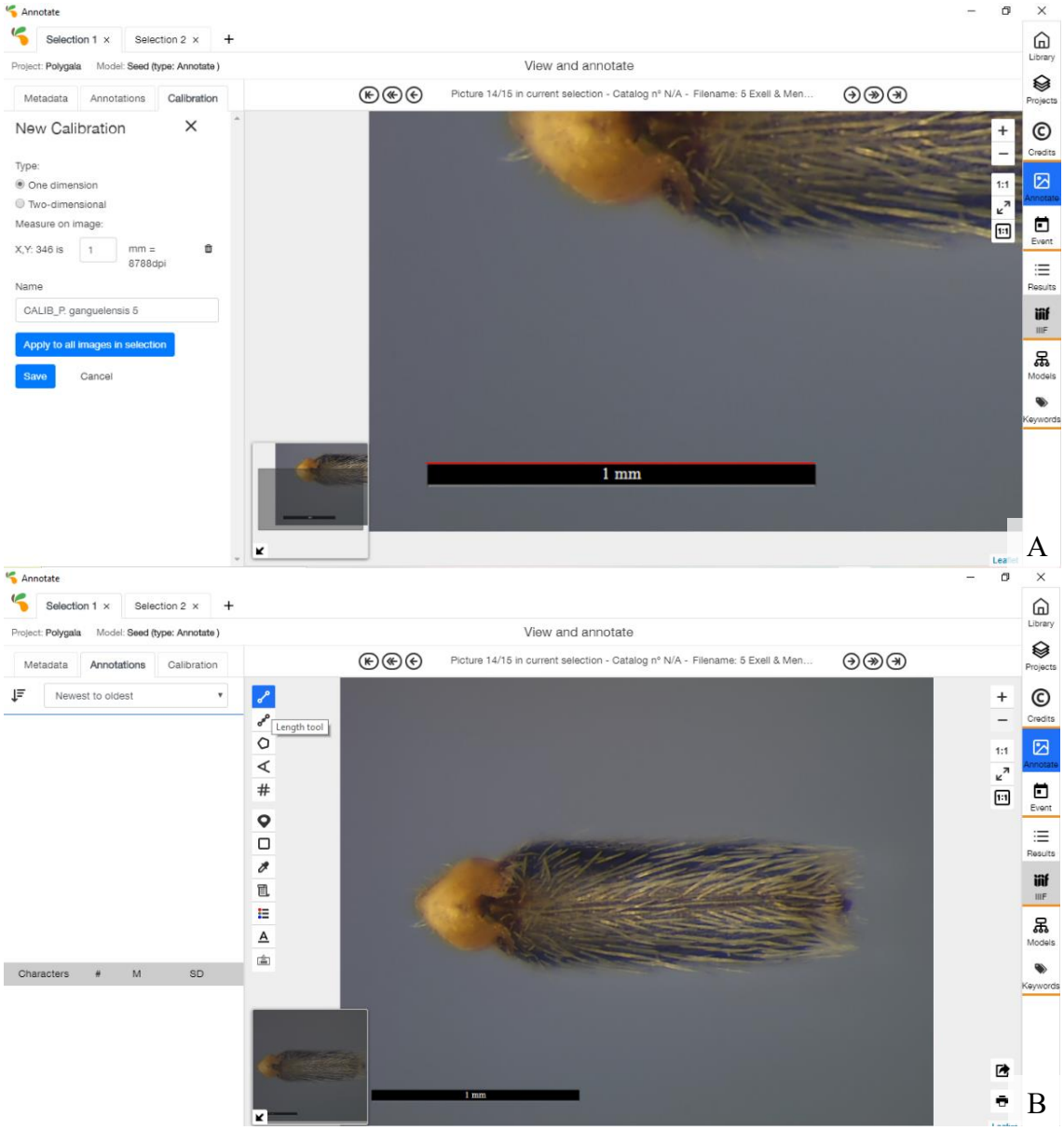

Figure 7. Annotate view screen. (A) Calibration (red line); (B) the length tool for measurements on the top left is selected.

2.5. Identification key to taxa and seed descriptions

The seed characters described and used in the identification key are in Table 3. Seed general morphology is illustrated in Figure 8.

These seed descriptions are the most comprehensive so far in the literature of *Polygala*. The methodology for the descriptions considered taxa outside Angola with very different seed morphology and can be applied in the future to any taxon, being established here a precedent for any future work of this kind.

Table 3. Seed characters and character states used in the descriptions, identification key, and statistical analyses. In grey are those referred to in the literature as potentially involved in dispersal; these traits were used in the statistical analyses. The codes of the variables (characters) and the numerical classification of the categories (character states) used are also provided.

Characters			Character states		Literature
Seed body	SB1	Length in lateral view	X-Y mm		Bas et al. (2007); Mattana et al. (2010); Paiva (1998)
	SB2	Width at mid-length in lateral view	X-Y mm		
	SB3	Width at mid-length in dorsal/ventral view	X-Y mm		
	SB4	Compression	1	laterally not compressed	Paiva (1998); Ulbrich (1928); Verkerke (1985)
			2	laterally slightly compressed	
			3	laterally strongly compressed	
	SB5	Shape in lateral view	1	obtriangular	Harper et al. (1970); Paiva (1998)
			2	subobtriangular	
			3	elliptic	
			4	subcircular	
	SB6	Surface cover	0	glabrous	Oostermeijer (1989); Paiva (1998)
			1	hairy	
	SB7	Hair density	1	scattered	
			2	dense	
	SB8	Hair posture	1	straight	
			2	± curving	
			3	glochidiate	
	SB9		1	not exceeding the distal end	

		Hair length after distal end of seed body	2	shortly exceeding the distal end	
			3	largely exceeding the distal end	
Chalazal region	CR1	Hairiness	0	without tuft of hairs	Sernander (1906); Ridley (1930)
			1	with narrow tuft of hairs	
			2	with wide tuft of hairs	
	CR2	Expansion presence	0	absent	
			1	present	
	CR3	Expansion shape	1	minute	
			2	short	
			3	long ± terete	
			4	long flattened	
Caruncle	C1	Presence	0	absent	Castro et al. (2010); Oostermeijer (1989); Paiva (1998); Ridley (1930)
			1	present	
	C2	Smooth portion maximum length in lateral view	X-Y mm		Bas et al. (2007); Mattana et al. (2010); Oostermeijer (1989); Paiva (1998)
	C3	Smooth portion maximum width in lateral view	X-Y mm		
	C4	Surface cover	0	glabrous	Oostermeijer (1989)
			1	hairy	
	C5	Ventral view shape	1	very narrow	Bas et al. (2007); Mattana et al. (2010); Oostermeijer (1989); Paiva (1998)
			2	wide	
	Ventral lobes fusion in ventral view		not fused in a single structure		———
			± fused in a single structure		
	Relation between length of dorsal and ventral lobes in lateral view		similar		———
			dorsal longer than ventral		
	Dorsal lobe shape in dorsal view		inconspicuous		———
			circular		
			clavate		
			elliptic		
			linear		
			ovate		

			obovate		
			sub-rectangular		
	Ventral lobes shape in lateral view		dolabriform towards apex		———
			globose but very narrow at apex		
			globose and wide at apex		
			not dolabriform nor globose		
	Relation between length of ventral and dorsal lobes appendages (at apex only)		similar		———
			ventral longer than dorsal		
	C6	Appendages development on ventral lobes	0	inconspicuous	Mattana et al. (2010); Oostermeijer (1989); Paiva (1998)
			1	short rim	
			2	long rim	
			3	very large and inflated	
	Appendages localization on ventral lobes		at lobe apex only		———
			at lobe apex and decurrent		
			at lobe apex, decurrent and joining		
	Ventral lobes apex shape, including appendages, in lateral view		not auriculate		———
			clearly auriculate		
	Funicular gap shape		minute		———
			narrow		
			± circular		
			wide		

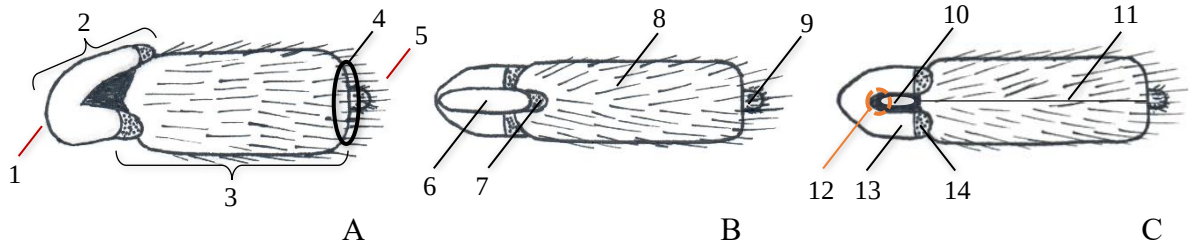

Figure 8. Seed general morphology. (A) Lateral, (B) dorsal, and (C) ventral views. 1 – Proximal end of the seed; 2 – caruncle; 3 – seed body; 4 – chalazal region; 5 – distal end of the seed; 6 – caruncular dorsal lobe; 7 – appendage of the dorsal lobe; 8 – hair; 9 – chalazal region expansion; 10 – hilum; 11 – raphe; 12 – micropyle; 13 – caruncular ventral lobe; 14 – appendage of ventral lobe.

Methodology followed to describe some **characters**:

- **Length of the seed body** was measured in lateral view (Fig. 9B).
- **Lateral and dorsal/ventral widths of the seed body** were measured at the seed body mid-length in lateral (Fig. 9B) and dorsal/ventral views (Fig. 9C-D), respectively.
- **Maximum length and width of the caruncle smooth portion** were measured in lateral view showing one ventral lobe and the dorsal lobe (Fig. 9A). The smooth portion did **not** include the caruncular appendages, these starting where texture and/or colour changes. The reason for not including the appendages lies not in the structure of the Angolan taxa, but in instances in which the appendages develop over the caruncle smooth portion and extend almost to the distal end of the seed body, such as in *P. senensis* from East Africa from Somalia to South Africa (Fig. 2C).

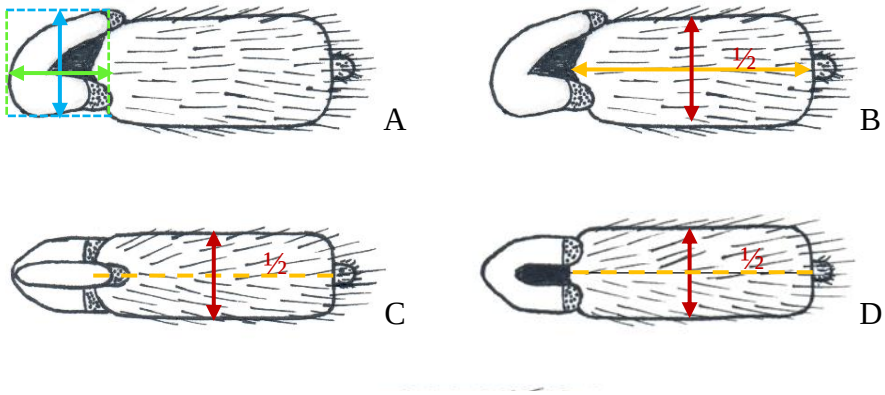

Figure 9. Measurements taken on seeds. Measurements of (A) caruncle smooth potion in lateral view, (B) seed body in lateral view, (C) seed body in dorsal view, and (D) seed body in ventral view. ↔ – Maximum length; ↕ – maximum width; ↔ – length; ↕ ½ – width at mid-length, the same in dorsal and ventral views; ¦--- --- – auxiliar lines.

- **Compression of the seed body** was considered (1) laterally strongly compressed when the width of the seed body at mid-length in dorsal/ventral view was *circa* half of the width at mid-length in lateral view; (2) laterally slightly compressed when the width in dorsal/ventral view was more than half of the width in lateral view; (3) not compressed when the width of the seed body in dorsal/ventral view was similar to the width at mid-length in lateral view.

- **Shape of the seed body in lateral view** is illustrated in Figure 10.

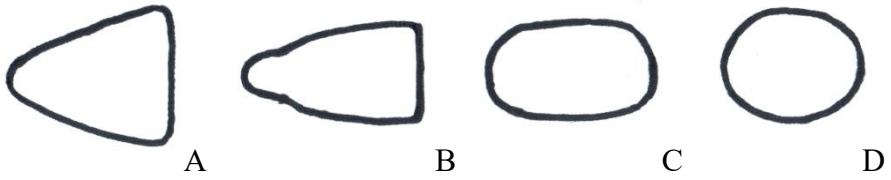

Figure 10. Shape of the seed body in lateral view. (A) Obtriangular; (B) subobtriangular; (C) elliptic; (D) subcircular.

- **Hair density on the seed body** has taken into account that seeds may lose some hairs by friction as they are stored in paper envelopes.
- **Hair length after the distal end of the seed body** was largely exceeding the distal end of the seed body when exceeded *circa* or more than half of the length of the seed body, and shortly exceeding the distal end when exceeded less than half of the length of the seed body.
- **Hairiness of the chalazal region** and **shape of the chalazal region expansion** are illustrated in Figures 11 and 12, respectively.

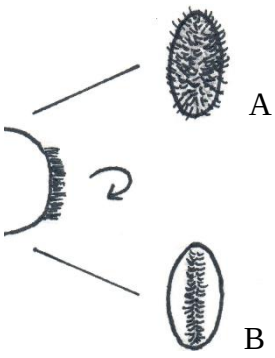

Figure 11. Hairiness of the chalazal region. (A) Wide tuft of hairs; (B) narrow tuft of hairs.

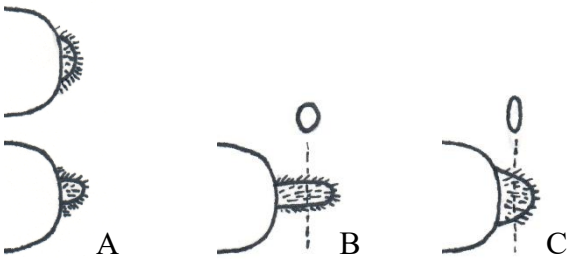

Figure 12. Shape of the chalazal region expansion. (A) Short; (B) long ± terete; (C) long flattened.

- **Fusion of the caruncular ventral lobes in ventral view** was described as ± fused in a single structure if there was not a space or depression between them in ventral view.
- **Shape of the caruncular dorsal lobe in dorsal view** is illustrated in Figure 13. The term inconspicuous was used when the dorsal lobe was not clearly visible in dorsal view.

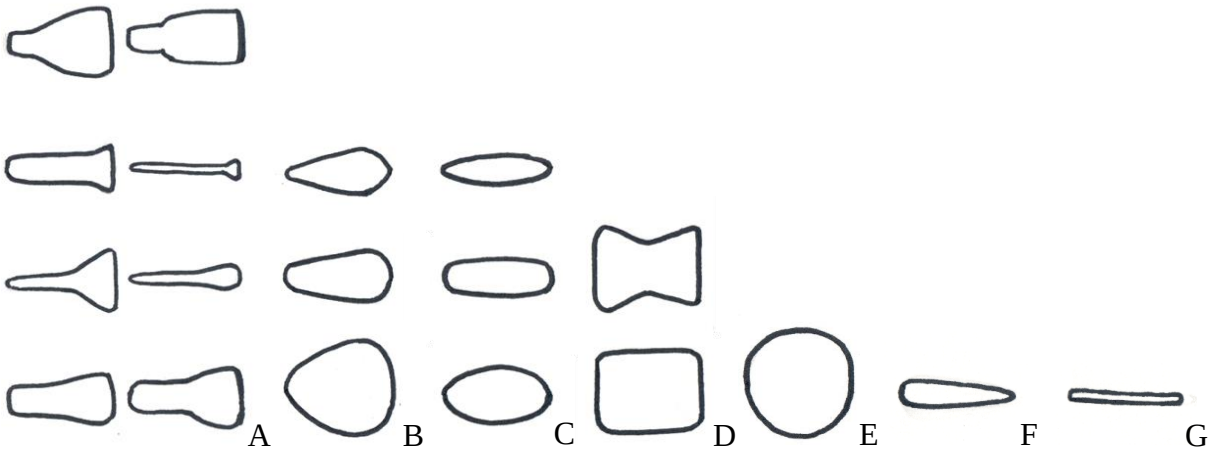

Figure 13. Shape of the caruncular dorsal lobe in dorsal view. (A) Clavate; (B) obovate; (C) elliptic; (D) sub-rectangular; (E) circular; (F) ovate; (G) linear.

- **Shape of the caruncular ventral lobes in lateral view** is illustrated in Figure 14. Other morphologies are less clear and were not referred to.

Figure 14. Shape of the caruncular ventral lobes in lateral view. (A) Dolabriform towards apex; (B) globose but very narrow at apex; (C) globose and wide at apex.

- **Relation between the length of the appendages of the caruncular ventral and dorsal lobes** was described at lobe apex only and is better seen in lateral view.

- **Development of the appendages of the caruncular ventral lobes** is easily seen in lateral view. The term inconspicuous was used when the caruncular appendages were not clearly visible. When the length of the appendages of the ventral lobes was roughly the same or longer than the ventral lobes it was considered that they form long rims, unless they are very large and inflated. Appendages of *P. welwitschii* subsp. *pygmaea* and *P. arenaria* form long rims, but their appendages were probably inflated, this deduced from the comparison with the texture of the very large and inflated appendages of *P. melilotoides* and *P. welwitschii* subsp. *welwitschii*. As it was not observed any seed of *P. welwitschii* subsp. *pygmaea* and *P. arenaria* with caruncular appendages inflated, it was always considered that they form long rims.

- **Localization of the appendages on the caruncular ventral lobes** at apex plus decurrent and joining was indicated (arrow) in some microphotograps at the seed descriptions.

- **Shape of the apex of the caruncular ventral lobes, including the appendages, in lateral view** clearly auriculate is illustrated in Figure 15.

Figure 15. Shape of the apex of the caruncular ventral lobes, including appendages, clearly auriculate in lateral view.

- **Shape of the caruncle funicular gap** refers to the gap between the two ventral lobes (Fig. 16) and would reflect the shape of the transversal section of the funicle (Fig. 3).

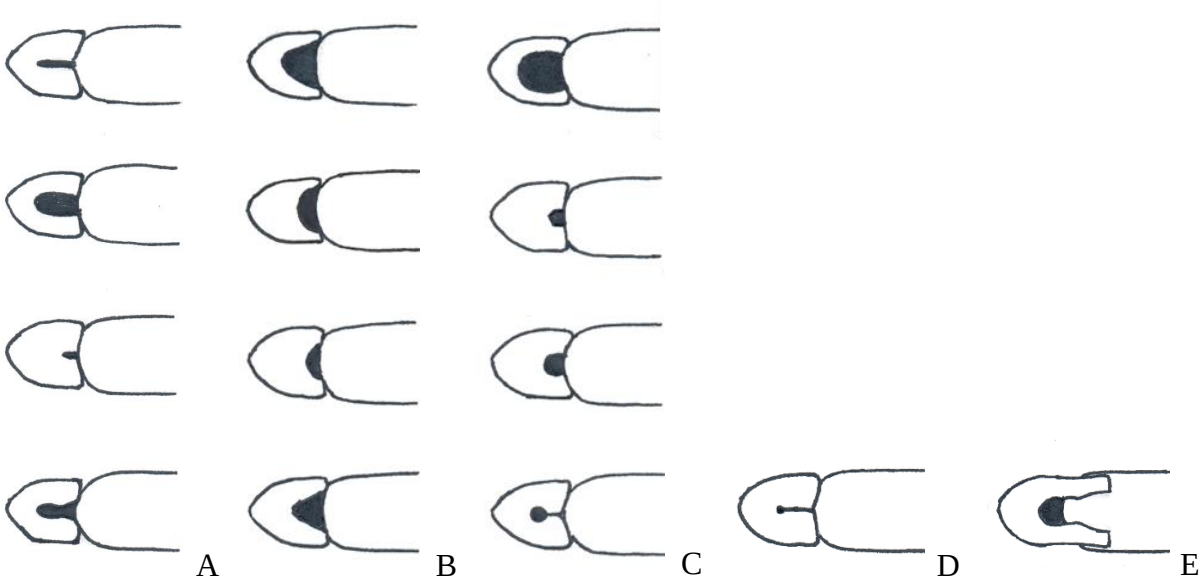

Figure 16. Shape of the caruncle funicular gap in ventral view. (A) Narrow; (B) wide; (C) ± circular; (D) minute; (E) shape of funicular gap is independent from the fact that sometimes the caruncle expands over the seed body.

2.6. Statistical analyses

Multivariate methods of analysis were carried out to identify the tendency for seeds and groups of taxa to cluster and to understand the characters that contribute to their separation. First, a Principal Component Analysis (PCA) was performed with the five continuous variables assessed here (characters SB1-SB3 and C2-C3; Table 3) using the STATISTICA software version 7.0 (StatSoft Inc., 2004). Second, a Factorial Analysis of Mixed Data (FAMD) was performed with the five continuous variables (characters SB1-SB3 and C2-C3; Table 3) and 13 out of the 21 categorical variables assessed (characters SB4-SB9, CR1-CR3, C1, and C4-C6; Table 3) using R software version 4.0.2 (R Core Team., 2015) and the packages "FactoMineR" (Husson et al., 2020) and "factoextra" (Kassambara & Mundt, 2020).

The characters selected for the statistical analyses are those referred to in the literature as potentially involved in seed dispersal. The categorical variables were coded, and the respective

categories were numerically classified from “zero” (when the structure is absent or not clearly visible) or “one” to subsequent numbers, depending on the number of categories within each variable (Table 3). When structures such as, seed body hairs, caruncle or chalazal region expansion are absent, all associated characters were numerically classified as “zero”.

Two of the 48 Angolan taxa were not included in the analyses, namely, *P. gossweileri*, because of the poorly developed seed material and the resulting gaps in the information, and *P poggei*, because there was no seed material available. The multivariate analyses were carried out with the information of 212 seeds (cases) from 46 taxa (Table A2).

3. Results

3.1. Identification key to taxa

The identification key of the Angolan taxa of *Polygala* was constructed using seed characters only (Table 3). Such seed characters are in the taxa descriptions in the next subsection (3.2. Seed descriptions and microphotographs. Distribution and ecology).

P. poggei of which there is no seed material is not in the key; *P. gossweileri* is included due to its partial description.

1. Seeds without caruncle ..…….....……..…... 2
   Seeds with caruncle ……... 4

2. Seed body with glochidiate hairs …….. 1. *P. africana*
   Seed body with ± curving, but not glochidiate hairs ……. 3

3. Seed body 0.6-0.8 x 0.4-0.5 mm in lateral view, 0.4-0.5 mm wide in dorsal/ventral view; hairs shortly exceeding the distal end of the seed body; chalazal region with a minute expansion ……...……...……..... 2. *P. spicata*
   Seed body *c.* 0.8-1.1 x 0.5 mm in lateral view, *c.* 0.5 mm wide in dorsal/ventral view; hairs not or shortly exceeding the distal end of the seed body; chalazal region with or without a minute expansion …..……...… 3. *P. capillaris* subsp. *capillaris*

4. Seed body glabrous ……..…...……...….. 4. *P. melilotoides*
   Seed body hairy ……...…….……..……. 5

5. Hairs largely exceeding the distal end of the seed body [exceeding *c.* ½ or more the length of the seed body] ..…….……...……...……..... 6
   Hairs not or shortly exceeding the distal end of the seed body [exceeding less than ½ the length of the seed body] …….…..... 12

6. Seeds laterally strongly compressed [width in dorsal/ventral view *c.* ½ the width in lateral view] ……. 5. *P. oliverana*
Seeds laterally slightly compressed [width in dorsal/ventral view more than ½ the width in lateral view] ……..……...…..…….……..…..……... 7

7. Chalazal region with a wide tuft of hairs (Fig. 11A) …..……..… 6. *P. albida* subsp. *albida*
Chalazal region without tuft of hairs ..……...……...……..... 8

8. Chalazal region with a long ± terete hairy expansion (Fig. 12B) ..…….……..… 9
Chalazal region with a short hairy expansion (Fig. 12A) ……...……..……... 10

9. Caruncle very narrow or wide in ventral view, smooth portion 1.0-1.2 x 0.7-1.0 mm in lateral view; funicular gap narrow (Fig. 16A); seed body 2.1-2.7 x 1.1-1.4 mm in lateral view, 0.9-1.1 mm wide in dorsal/ventral view …..... 7. *P. nambalensis*
Caruncle wide in ventral view, smooth portion *c.* 1.0-1.1 x 0.9 mm in lateral view; funicular gap ± circular (Fig. 16C); seed body *c.* 2.5-2.6 x 1.3 mm in lateral view, *c.* 0.8 mm wide in dorsal/ventral view …….……..…….……...… 8. *P. britteniana*

10. Appendages of caruncular ventral lobes at apex only; caruncle funicular gap ± circular; funicular gap wide when appendages of caruncular ventral lobes are at lobe apex plus decurrent and joining …….…..…… 9. *P. usafuensis*
Appendages of caruncular ventral lobes are at lobe apex plus decurrent and joining; funicular gap ± circular 11

11. Seed body 3.0-3.4 x 2.0-2.1 mm in lateral view; caruncle smooth portion *c.* 0.8 x 1.2-1.4 mm in lateral view ……..……...……. 10. *P. macrostigma*
Seed body 2.6-2.9 x 1.6-1.7 mm in lateral view; caruncle smooth portion 0.6-0.7 x 1.0-1.1 mm in lateral view ……..…..…. 11. *P. mendoncae*

12. Caruncle very narrow in ventral view; seed body obtriangular in lateral view (Fig. 10A) … ……..... 12. *P. pallida*
Caruncle wide in ventral view; seed body elliptic (Fig. 10C) or subcircular (Fig. 10D) in lateral view or sometimes subobtriangular (in *P. guerichiana*; Fig. 10B) ……..... 13

13. Appendages of caruncular ventral lobes very large and inflated ……
……..……..……. 13. *P. welwitschii* subsp. *welwitschii*
Appendages of caruncular ventral lobes inconspicuous or forming short or long rims, not inflated …….. 14

14. Appendages of ventral lobes at lobe apex only ……..…….....……... 15
Appendages of ventral lobes at lobe apex and are decurrent, often joining …...…..…..... 33

15. Seed body hairs scattered; caruncle glabrous ……..…. 14. *P. paludicola*
Seed body hairs scattered; caruncle hairy ……...……... 16
Seed body hairs dense; caruncle hairy …….……...…….….. 22

16. Seed body hairs straight ……..…… 15. *P. ganguelensis*
Seed body hairs ± curving ……...……...……... 17

17. Appendages of caruncular ventral lobes form long rims at lobe apex …….…..... 18
Appendages of caruncular ventral lobes form short rims at lobe apex …….…. 19

18. Seeds laterally strongly compressed [width in dorsal/ventral view *c.* ½ the width in lateral view] ……...……...……..... 16. *P. angolensis*
Seeds laterally not compressed or slightly compressed [width in dorsal/ventral view more than ½ the width in lateral view] .....……..…….....….. 17. *P. myriantha*

19. Caruncle smooth portion 0.8-1.2 x 0.9-1.5 mm in lateral view ……...….. 18. *P. luenensis*
Caruncle smooth portion 0.3-0.5 x 0.6-0.8 mm in lateral view ……...…….. 20

20. Apex of caruncular ventral lobes clearly auriculate (including the appendages) in lateral view (Fig. 15) ……...……...… 19. *P. dewevrei*
Apex of caruncular ventral lobes not auriculate (including the appendages) in lateral view …….…….. 21

21. Seed body 2.1-2.8 x 1.3-1.6 mm in lateral view, 0.6-1.0 mm wide in dorsal/ventral view; caruncle smooth portion *c.* 0.5 x 0.6-0.8 mm in lateral view……..…... 20. *P. antunesii*
Seed body 1.7-2.0 x 0.9-1.0 mm in lateral view, 0.8-1.1 mm wide in dorsal/ventral view; caruncle smooth portion *c.* 0.3-0.4 x 0.6 mm in lateral view ……..……..... 21. *P. rivularis*

22. Appendages of caruncular ventral lobes forming long rims at apex ..……...…... 23
Appendages of caruncular ventral lobes inconspicuous or forming short rims at apex 25

23. Chalazal region with a wide tuft of hairs (Fig. 11A); seed body *c.* 2.5 x 1.9 mm in lateral view ...……...……...……..... 22. *P. myrtillopsis*
Chalazal region without tuft of hairs; seed body 1.1-2.2 x 0.8-1.2 mm in lateral view 24

24. Seed body *c.* 1.1 x 0.8 mm in lateral view ……...……. 14. *P. paludicola*
Seed body 2.0-2.2 x 1.1-1.2 mm in lateral view ...……..… 23. *P. fragilis*

25. Chalazal region with a narrow tuft of hairs (Fig. 11B) ……..…….. 24. *P. schinziana*
Chalazal region without tuft of hairs ……...…….. 26

26. Seeds laterally strongly compressed [width in dorsal/ventral view *c.* ½ the width in lateral view] ……..... 25. *P. resendeana*
Seeds laterally slightly compressed [width in dorsal/ventral view more than ½ the width in lateral view] ……..……...……...… 27

27. Seed body 1.5-2.1 x 0.8-1.2 mm in lateral view …… 28
Seed body 2.4-4.6 x 1.1-2.4 mm in lateral view ……..……..……. 29

28. Caruncular dorsal lobe obovate in dorsal view (Fig. 13B) …...…… 26. *P. youngii*
Caruncular dorsal lobe clavate (Fig. 13A) or elliptic in dorsal view (Fig. 13C) ……..
……..……..…..… 27. *P. petitiana* subsp. *petitiana* var. *petitiana*; 28. *P. gossweileri*

29. Apex of caruncular ventral lobes clearly auriculate (including the appendages) in lateral view (Fig. 15) ……...……..… 29. *P. arenicola*; 30. *P. baumii*; 31. *P. huillensis*; 32. *P. kalaxariensis*; 33. *P. nematophylla*; 34. *P. robusta*
Apex of caruncular ventral lobes not auriculate (including the appendages) in lateral view ……... 30

30. Seed body 0.8-1.2 mm wide at mid-length in dorsal/ventral view ……..... 31
Seed body 1.3-1.6 mm wide at mid-length in dorsal/ventral view …….…..…. 32

31. Caruncle smooth portion 0.8-1.2 x 1.0-1.3 mm in lateral view, ventral lobes globose but very narrow at apex in lateral view (Fig. 14B); caruncle funicular gap wide (Fig. 11B); seed body 3.0-3.5 x 1.6-1.8 mm in lateral view, 0.9-1.2 mm wide in dorsal/ventral view ...……..… 35. *P. acicularis*
Caruncle smooth portion 0.6-0.8 x 0.9-1.0 mm in lateral view, ventral lobes globose and wide at apex in lateral view (Fig. 14C); caruncle funicular gap ± circular (Fig. 16C); seed body 2.7-3.1 x 1.3-1.6 mm in lateral view, 0.8-1.0 mm wide in dorsal/ventral view; …….……..… 36. *P. xanthina*
Caruncle smooth portion 0.8-1.0 x 0.8-0.9 mm in lateral view, ventral lobes dolabriform towards apex in lateral view (Fig. 14A); caruncle funicular gap narrow (Fig. 16A), occasionally ± circular (Fig. 16C); seed body 3.0-3.8 x 1.5-1.7 mm in lateral view, *c.* 0.9 mm wide in dorsal/ventral view …...…...……... 37. *P. mossamedensis*

32. Seed body 3.3-4.6 x 2.0-2.4 mm in lateral view; hairs ± curving or straight; chalazal region with or without a minute expansion; caruncle smooth portion 0.9-1.0 x 1.1-1.3 mm in lateral view ……..…..... 38. *P. stenopetala* subsp. *casuarina*
Seed body 3.2-4.1 x 1.7-2.2 mm in lateral view; hairs straight; chalazal region without a minute expansion; caruncle smooth portion 0.8-1.3 x 1.1-1.4 mm in lateral view ……. ……..... 39. *P. laxifolia*

33. Caruncular dorsal lobe longer than ventral lobes in lateral view ……..…….....… 34
Caruncular dorsal and ventral lobes ± the same length in lateral view ……..... 35

34. Seed body 3.2-3.6 x 1.3-1.6 mm in lateral view; caruncle smooth portion 1.3-1.4 x 1.1-1.4 mm in lateral view; chalazal region with a long flattened hairy expansion (Fig. 12C), ocasionally short …..……..…….…….…… 40. *P. guerichiana*
Seed body 2.9-3.1 x 1.1-1.4 mm in lateral view; caruncle smooth portion 1.3-1.6 x 0.9-1.0 mm in lateral view; chalazal region with a short hairy expansion (Fig. 12A) …….
…….…. 41. *P. leptophylla* var. *leptophylla*

35. Caruncle glabrous …..……..…….……. 42. *P. gomesiana*
Caruncle hairy ……...… 36

36. Chalazal region without tuft of hairs ……..……...……... 37
Chalazal region with a wide tuft of hairs (Fig. 11A) .....…...……...…….…… 38

37. Caruncle smooth portion 0.4-0.5 x 0.4-0.5 mm in lateral view, dorsal lobe clavate in dorsal view (Fig. 13A); seed body 1.3-1.7 x 0.7-0.9 mm in lateral view, 0.6-0.7 mm wide in dorsal/ventral view …..……..…… 43. *P. welwitschii subsp. pygmaea*
Caruncle smooth portion 0.2-0.3 x 0.1-0.4 mm in lateral view, dorsal lobe inconspicuous or ovate in dorsal view (Fig. 13F); seed body 0.9-1.4 x 0.4-0.6 mm in lateral view, *c.* 0.4 wide in dorsal/ventral view .....…….....…….……...…. 17. *P. myriantha*

38. Caruncle funicular gap ± circular (Fig. 16C) ……...…..... 44. *P. albida* subsp. *stanleyana*
Caruncle funicular gap narrow (Fig. 16A) or wide (Fig. 16B) …..…….....……..… 39

39. Appendages of caruncular ventral lobes form short rims ...……..... 45. *P. erioptera*
Appendages of caruncular ventral lobes form long rims (occasionally short in *P. sphenoptera*) ……..…..... 40

40. Seed body 1.6-1.9 x 0.9-1.0 mm in lateral view, 0.7-0.8 mm wide in dorsal/ventral view; caruncle smooth portion 0.4-0.5 x 0.5-0.6 mm in lateral view; funicular gap narrow (Fig. 16A) ……...……..…. 46. *P. arenaria*
Seed body 2.1-2.5 x 1.3-1.7 mm in lateral view, 0.7-1.0 mm wide in dorsal/ventral view; caruncle smooth portion 0.4-0.7 x 0.8-0.9 mm in lateral view; funicular gap wide (Fig. 16B) …….…….....……. 47. *P. sphenoptera*

3.2. Seed descriptions and microphotographs. Distribution and ecology

General and detailed seed description of each Angolan taxon of *Polygala* using the morphological characters indicated in Table 3 is provided, together with seed microphotographs in lateral, dorsal, and ventral views (Figs. 17-63). To clarify particular morphological terms, see Figures 8-16. Distribution and habitat and ecology of each taxon are also indicated.

1. *P. africana* Chodat

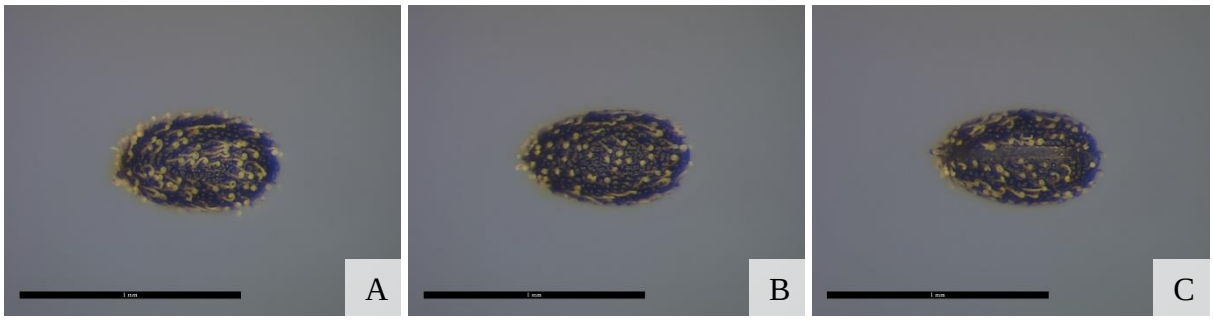

Figure 17. Seed of *P. africana*. (A) Lateral, (B) dorsal, and (C) ventral views (*Silva* 2480–COI00100970, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally not compressed, elliptic or subcircular in lateral view, hairy, caruncle absent.

Detailed description of seed morphology

Seed body 0.6-0.7 x 0.4-0.5 mm in lateral view, 0.4-0.5 mm wide in dorsal/ventral view. Hairs glochidiate, scattered, not exceeding the distal end of the seed body.

Distribution. Tropical Africa, south of the Equator.

Angola: Kwanza Norte, Kwanza Sul, Bié, Huambo, Benguela, Huíla, and Cunene.

Habitat and ecology. Wetland, including wet grassland; up to 2000 m.

2. *P. spicata* Chodat

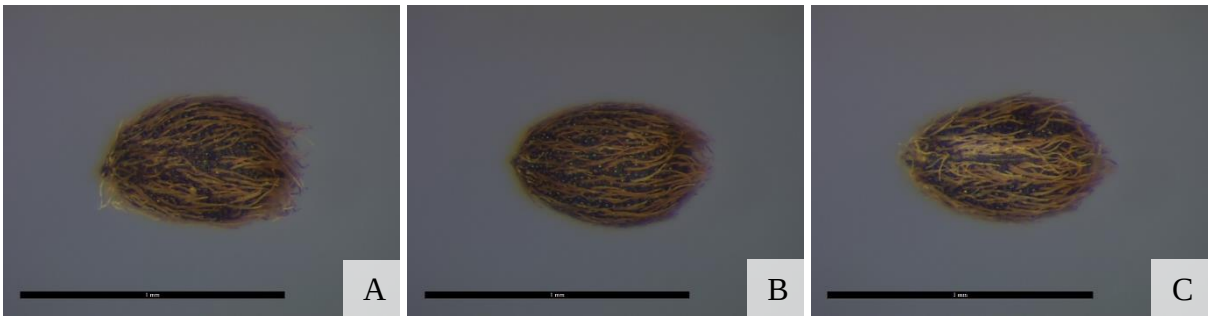

Figure 18. Seed of *P. spicata*. (A) Lateral, (B) dorsal, and (C) ventral views (*Carrisso & Mendonça* 540– BM, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally not compressed, elliptic or subcircular in lateral view, hairy, chalazal region with a minute expansion, caruncle absent.

Detailed description of seed morphology

Seed body 0.6-0.8 x 0.4-0.5 mm in lateral view, 0.4-0.5 mm wide in dorsal/ventral view. Hairs ± curving, dense, shortly exceeding the distal end of the seed body.

Distribution. Southeast and centre of tropical and subtropical Africa.

Angola: Lunda Norte, Lunda Sul, Moxico, Bié, Huambo, Benguela, Huíla, and Kuando Kubango.

Habitat and ecology. Wet grassland; 1000-2000 m.

3. *P. capillaris* E.Mey. subsp. *capillaris*

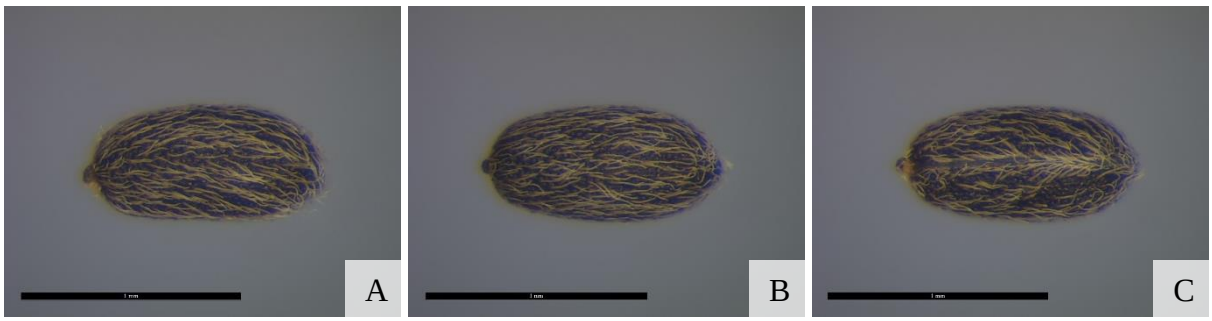

Figure 19. Seed of *P. capillaris* subsp. *capillaris*. (A) Lateral, (B) dorsal, and (C) ventral views (*Milne-Redhead* 4000– BM, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally not compressed, elliptic or subcircular in lateral view, hairy, chalazal region with or without a minute expansion, caruncle absent.

Detailed description of seed morphology

Seed body c. 0.8-1.1 x 0.5 mm in lateral view, *c.* 0.5 mm wide in dorsal/ventral view. Hairs ± curving, dense, not or shortly exceeding the distal end of the seed body.

Distribution. Tropical and subtropical Africa, and Madagascar.
Angola: Zaire, Malanje, Moxico, Bié, Huíla, and Kuando Kubango.

Habitat and ecology. Wetland; 0-1800 m.

4. *P. melilotoides* Chodat

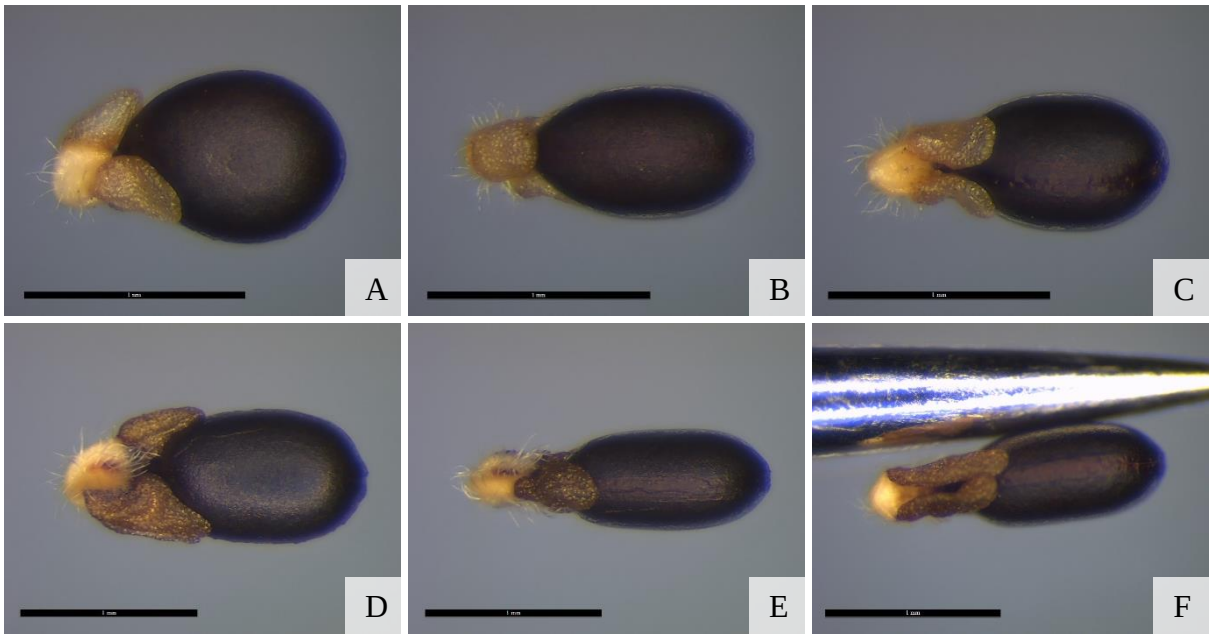

Figure 20. Seeds of *P. melilotoides* have very variable morphology. (A, D) Lateral, (B, E) dorsal, and (C, F) ventral views (A-C: *Exell & Mendonça* 310– COI00100969, Angola; D-F: *Exell & Mendonça* 556– BM001173011, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic or subcircular in lateral view, glabrous, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 0.9-1.2 x 0.7-0.8 mm in lateral view, 0.5-0.6 mm wide in dorsal/ventral view. *Caruncle* hairy, wide in ventral view; smooth portion 0.2-0.4 x 0.2-0.3 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe inconspicuous to elliptic in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes very large and inflated at lobe apex only or also decurrent. Funicular gap narrow or ± circular.

Distribution. Tropical Africa, south of the Equator and north of the Tropic of Capricorn. Angola: Malanje and Lunda Sul.

Habitat and ecology. Grassland, savannah, and open woodland; ruderal; loose sandy soil; 800-2000 m.

5. *P. oliverana* Exell & Mendonça

Figure 21. Seed of *P. oliverana*. (A) Lateral, (B) dorsal, and (C) ventral views (*Welwitsch* 1018– LISU, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally strongly compressed, elliptic in lateral view, hairy, chalazal region with a short hairy expansion, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 1.8-2.0 x 1.1-1.2 mm in lateral view, 0.6-0.7 mm wide in dorsal/ventral view. Hairs straight or ± curving, dense, largely exceeding the distal end of the seed body.

Caruncle hairy**,** wide in ventral view; smooth portion 0.5-0.6 x 0.7-0.8 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view; ventral lobes dolabriform towards apex in lateral view. Appendages of ventral and dorsal lobes similar in length to appendages of ventral lobes longer; appendages of ventral lobes form short to long rims at lobe apex only. Funicular gap ± circular.

Distribution. Angolan endemic: Malanje.

Habitat and ecology. Wet grassland.

6. *P. albida* Schinz subsp. *albida*

Figure 22. Seeds *P. albida* subsp. *albida*. (A) Lateral, (B) dorsal, and (C) ventral views (*Exell & Mendonça* 1921– COI00103133, Angola). ↑ – joining of the appendages of ventral lobes. Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with a wide tuft of hairs, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 1.7-2.3 x 1.2-1.5 mm in lateral view, 0.8-1.0 mm wide in dorsal/ventral view. Hairs straight, dense, largely exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.4-0.6 x 0.7-0.9 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view. Appendages of ventral and dorsal lobes similar in length to appendages of ventral lobes longer; appendages of ventral lobes form short to long rims at lobe apex and are decurrent, often joining. Funicular gap ± circular, occasionally narrow.

Distribution. Tropical Africa.

Angola: Kwanza Norte, Bié, Huambo, Benguela, Huíla, Kuando Kubango, Cunene.

Habitat and ecology. Woodland; cultivated ground and roadside; 900-1800 m.

7. *P. nambalensis* Gürke

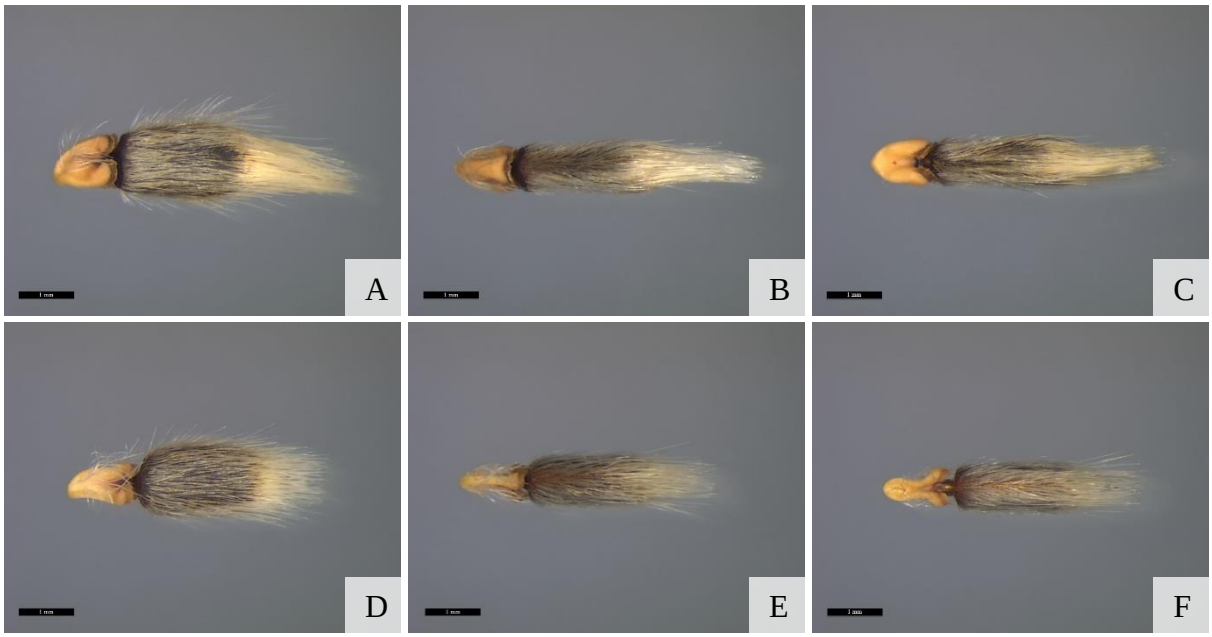

Figure 23. Seeds of *P. nambalensis*. (A, D) Lateral, (B) dorsal, and (C, E) ventral views with wide and very narrow caruncle (A-C: *Exell & Mendonça* 814– COI00103154, Angola; D-F: *Gossweiler* 11600– COI00067245, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with a long ± terete hairy expansion, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.1-2.7 x 1.1-1.4 mm in lateral view, 0.9-1.1 mm wide in dorsal/ventral view. Hairs straight, dense, largely exceeding the distal end of the seed body.

Caruncle hairy, very narrow or wide in ventral view; smooth portion 1.0-1.2 x 0.7-1.0 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view; ventral lobes dolabriform towards apex in lateral view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only Funicular gap narrow.

Distribution. South of tropical Africa: Democratic Republic of the Congo, Zambia, and Angola.

Angola: Lunda Norte, Lunda Sul, Bié, Benguela, Huíla, Kuando Kubango, Cunene.

Habitat and ecology. Open and xerophyte woodland, and grassland, sometimes wet; 1000-2200 m.

8. *P. britteniana* Chodat

Figure 24. Seed of *P. britteniana*. (A) Lateral, (B) dorsal, and (C) ventral views (*Scott-Elliot* 8256– K, Zambia). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with a long ± terete hairy expansion, caruncle 3-lobed. The material observed was almost all black and could have been burnt.

Detailed description of seed morphology

Seed body c. 2.5-2.6 x 1.3 mm in lateral view, *c.* 0.8 mm wide in dorsal/ventral view. Hairs straight, dense, largely exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion *c.* 1.0-1.1 x 0.9 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view; ventral lobes dolabriform towards apex in lateral view. Appendages of ventral and dorsal lobes inconspicuous or similar in length then those of ventral lobes form short rims at lobe apex only. Funicular gap ± circular.

Distribution. Tropical Africa: Zambia and Angola.

Angola: Huambo.

Habitat and ecology. Savannah and open woodland, with possibility of fire; 700-1700 m.

9. *P. usafuensis* Gürke

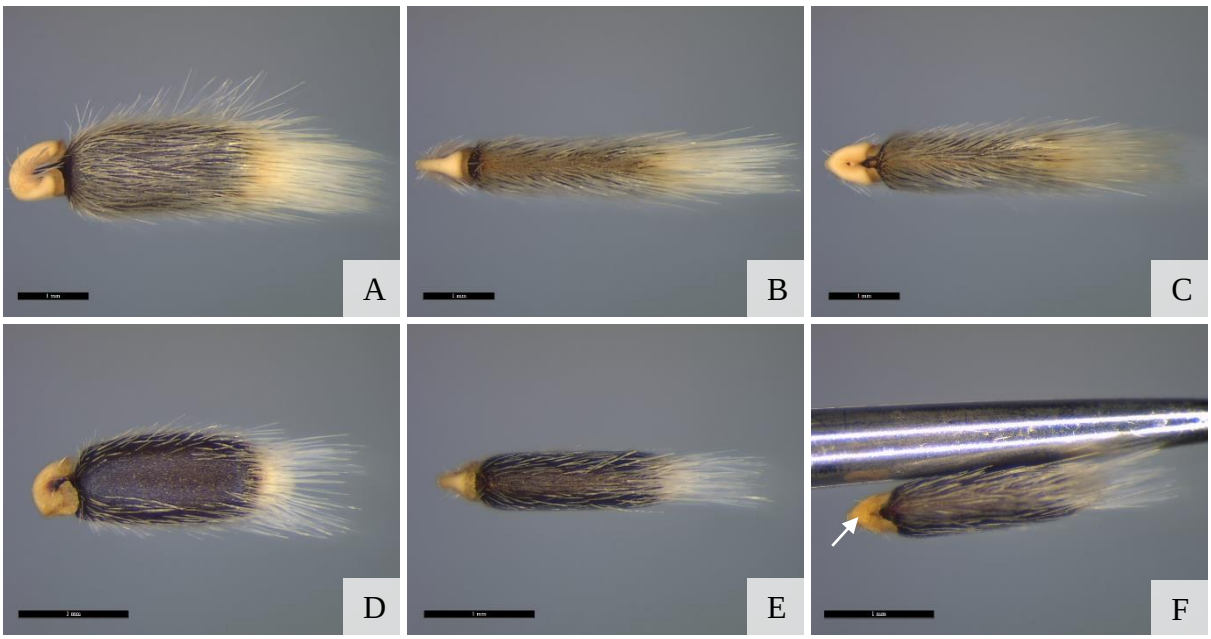

Figure 25. Seeds of *P. usafuensis* have very variable morphology. (A, D) Lateral, (B, E) dorsal, and (C, F) ventral views (A-C: *Henriques* 63– LUAI, Angola; D-F: *Exell & Mendonça* 1724– COI00103205, Angola). ↑ – joining of the appendages of ventral lobes. Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with a short hairy expansion, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 1.7-2.8 x 0.8-1.3 mm in lateral view, 0.5-0.9 mm wide in dorsal/ventral view. Hairs straight, scattered to dense, largely exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.3-0.7 x 0.5-0.9 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view; ventral lobes dolabriform towards apex, or not, in lateral view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only to also decurrent and joining. Funicular gap ± circular or wide.

Distribution. Tropical Africa: Zambia and Angola.

Angola: Huambo.

Habitat and ecology. Savannah and open woodland, with possibility of fire; 700-1700 m.

10. *P. macrostigma* Chodat

Figure 26. Seed of *P. macrostigma*. (A) Lateral, (B) dorsal, and (C) ventral views (*Lopes, Silva* & *Murta* 3696– COI00103149, Angola). ↑ – joining of the appendages of ventral lobes. Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with a short hairy expansion, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 3.0-3.4 x 2.0-2.1 mm in lateral view, 1.0-1.3 mm wide in dorsal/ventral view. Hairs straight, dense, largely exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion *c.* 0.8 x 1.2-1.4 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex plus decurrent and joining. Funicular gap ± circular.

Distribution. Tropical Africa.

Angola: Uíge, Malanje, Kwanza Norte, Kwanza Sul, Huambo, and Benguela.

Habitat and ecology. Savannah, open woodland, and wetland; 600-2500 m.

11. *P. mendoncae* E.M.A. Petit

Figure 27. Seed of *P. mendoncae*. (A) Lateral, (B) dorsal, and (C) ventral views (*Exell & Mendonça* 1458– COI00005656, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with a short hairy expansion, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.6-2.9 x 1.6-1.7 mm in lateral view, 1.0-1.2 mm wide in dorsal/ventral view. Hairs straight, dense, largely exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.6-0.7 x 1.0-1.1 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex plus decurrent and joining. Funicular gap ± circular.

Distribution. South of tropical Africa: Democratic Republic of the Congo, Zambia, and Angola.

Angola: Lunda Sul, Moxico, Bié, and Huambo.

Habitat and ecology. Deciduous woodland; 1000-1500 m.

12. *P. pallida* E.Mey. *ex* Harv.

Figure 28. Seed of *P. pallida*. (A) Lateral, (B) dorsal, and (C) ventral views (*Correia* 365– LUAI, Angola). ↑ – joining of the appendages of ventral lobes. Bar = 1 mm.

General description of seed morphology

Seeds laterally strongly compressed, obtriangular in lateral view, hairy, chalazal region with a minute expansion, caruncle with dorsal lobe very long and rooted ventrally, ventral lobes very small.

Detailed description of seed morphology

Seed body 1.4-1.6 x 0.8-1.0 mm in lateral view, 0.4-0.5 mm wide in dorsal/ventral view. Hairs straight, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, very narrow in ventral view; smooth portion 0.3-0.4 x 0.3-0.4 mm in lateral view. Dorsal lobe longer than ventral lobes in lateral view, linear in dorsal view. Appendage of dorsal lobe inconspicuous; appendages of ventral lobes form short rims at lobe apex plus decurrent and joining. Funicular gap ± circular.

Distribution. Southwest of Africa: Angola, Namibia, and South Africa (northwest of Cape). Angola: Namibe.

Habitat and ecology. Desert sandy plain.

13. *P. welwitschii* Chodat subsp. *welwitschii*

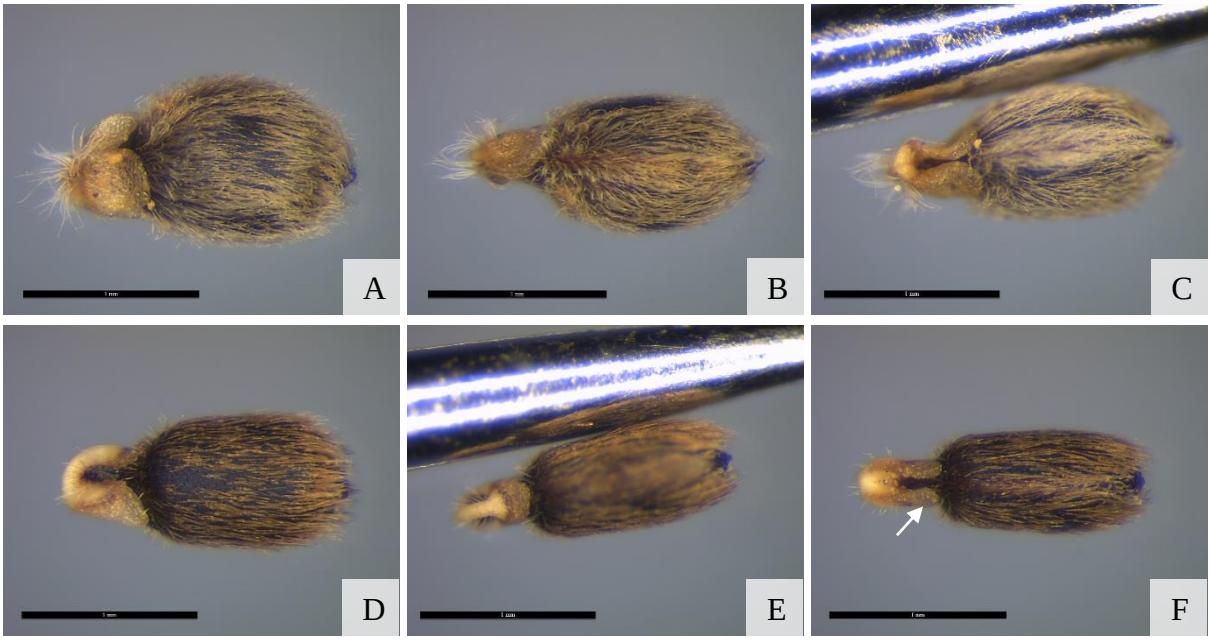

Figure 29. Seeds of *P. welwitschii* subsp. *welwitschii* have very variable morphology. (A, D) Lateral, (B, E) dorsal, and (C, F) ventral views (A-C: *Welwitsch* 1013– BM001173009, Angola; D-F: *Exell & Mendonça* 105– COI00103172, Angola). ↑ – caruncular appendage previously inflated. Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic or subcircular in lateral view, hairy, chalazal region with a minute expansion, occasionally without, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 1.1-1.5 x 0.7-1.1 mm in lateral view, 0.6-0.8 mm wide in dorsal/ventral view. Hairs straight or ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide smooth portion 0.1-0.4 x 0.3-0.5 mm in lateral view; caruncle in ventral view. Dorsal and ventral lobes ± the same length in lateral view, sometimes minute; dorsal lobe inconspicuous or clavate in dorsal view. Appendages of ventral and dorsal lobes similar in length to appendages of ventral lobes longer; appendages of ventral lobes very large and inflated at lobe apex only or also decurrent. Funicular gap narrow.

Distribution. Angolan endemic: Malanje, Kwanza Norte, Kwanza Sul, and Lunda Sul.

Habitat and ecology. Grassland; 1000-1200 m.

14. *P. paludicola* Gürke

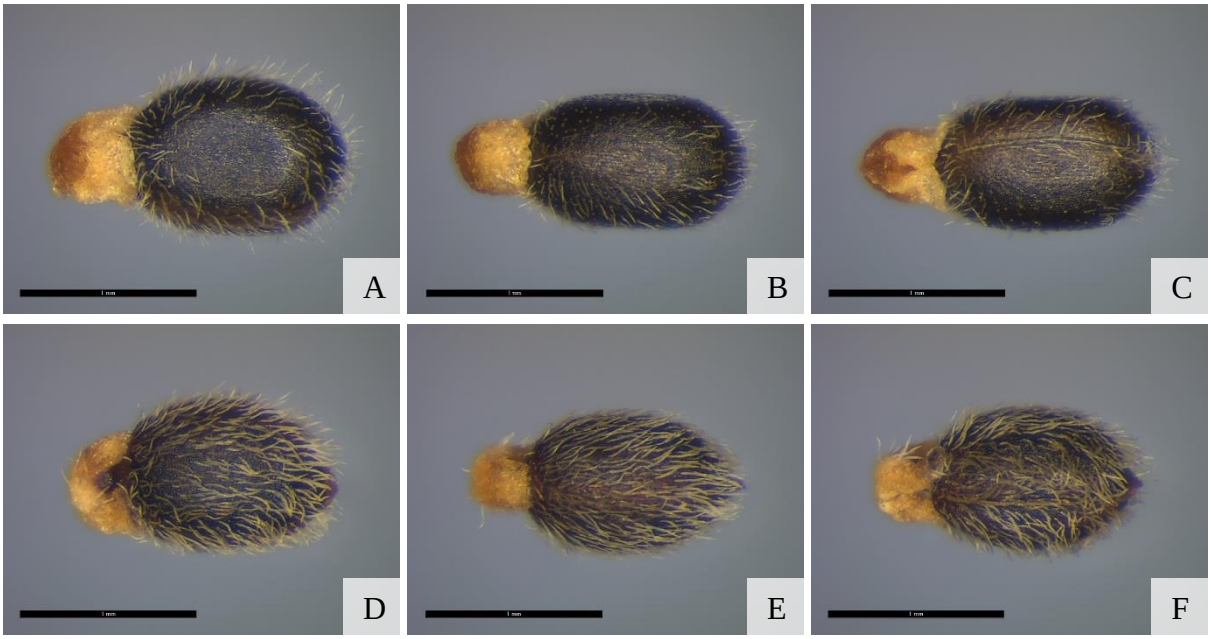

Figure 30. Seeds of *P. paludicola* have very variable morphology. (A, D) Lateral, (B, E) dorsal, and (C, F) ventral views (A-C: *Silva* 1962– COI00103156, Angola; D-F: *Gossweiler* 2783 *p.p.*– BM001173012, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally not compressed to slightly compressed, elliptic or subcircular in lateral view, hairy, chalazal region with or without a minute expansion, caruncle 3-lobed, sometimes the two ventral lobes ± fused in a single structure.

Detailed description of seed morphology

Seed body 1.0-1.3 x 0.8-0.9 mm in lateral view, 0.6-0.8 mm wide in dorsal/ventral view. Hairs ± curving, scattered to dense, shortly exceeding the distal end of the seed body.

Caruncle glabrous or hairy, smooth portion 0.1-0.3 x 0.2-0.4 mm in lateral view; caruncle wide in ventral view. Dorsal and ventral lobes ± the same length in lateral view, sometimes minute; dorsal lobe inconspicuous or obovate in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form long rims at lobe apex only. Funicular gap minute or wide.

Distribution. South of tropical Africa: Democratic Republic of the Congo, Zambia, and Angola.

Angola: Malanje, Lunda Sul, Moxico, Bié, Huambo, Benguela, Kuando Kubango, and Namibe.

Habitat and ecology. Wet grassland; 1000-1800 m.

15. *P. ganguelensis* Exell & Mendonça

Figure 31. Seed of *P. ganguelensis*. (A) Lateral, (B) dorsal, and (C) ventral views (*Mendes* 2103–LISC098057, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with a minute expansion, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 1.6-1.7 x 1.0-1.1 mm in lateral view, 0.6-0.7 mm wide in dorsal/ventral view. Hairs straight, scattered, shortly exceeding the distal end of the seed body.

Caruncle hairy**,** wide in ventral view; smooth portion 0.2-0.4 x 0.5-0.6 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short to long rims at lobe apex only. Funicular gap ± circular.

Distribution. Southwest of tropical Africa: Cameroon, Gabon, Zambia, and Angola.

Angola: Kwanza Norte, Bié, Benguela, Moxico, Huíla, and Kuando Kubango.

Habitat and ecology. Wet grassland; 1000-1500 m.

16. *P. angolensis* Chodat

Figure 32. Seed of *P. angolensis*. (A) Lateral, (B) dorsal, and (C) ventral views (*Dekindt* 255– BM, Angola). Bar = 1 mm.

General description of seed morphology

Seed laterally strongly compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body c. 1.7 x 1.1 mm in lateral view, *c.* 0.6 mm wide in dorsal/ventral view. Hairs ± curving, scattered, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion *c.* 0.3 x 0.5 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe obovate in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form long rims at lobe apex only. Funicular gap wide.

Distribution. Angolan endemic: Huíla and Bié.

Habitat and ecology. Wet meadow; 1700-1850 m.

17. *P. myriantha* Chodat

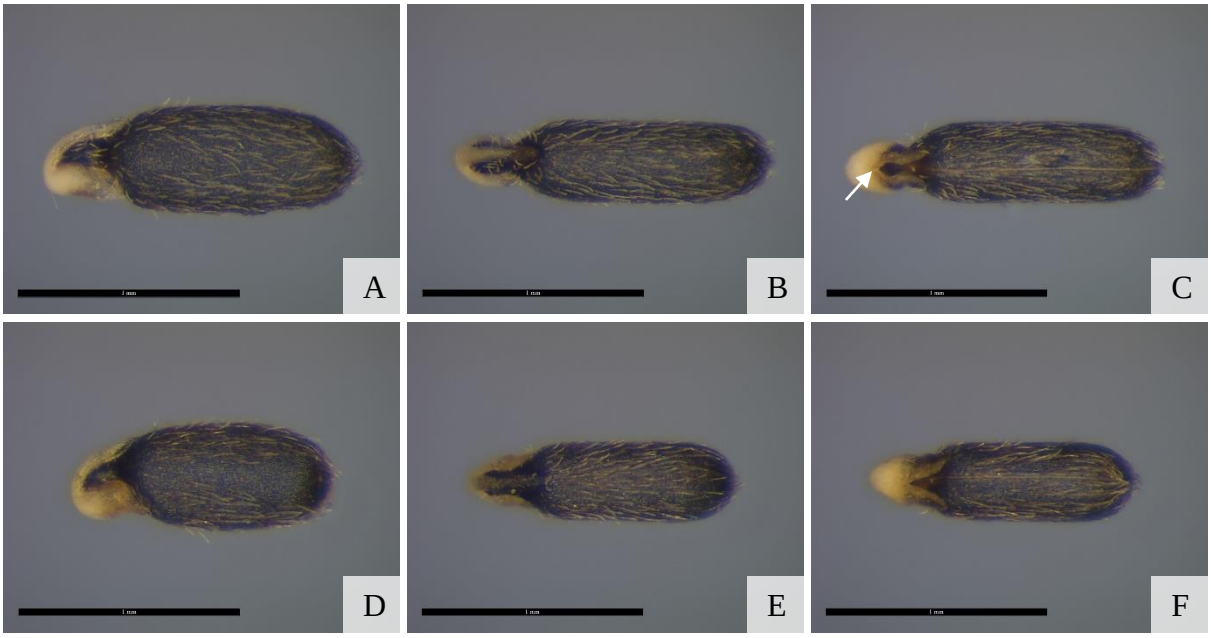

Figure 33. Seeds of *P. myriantha* have very variable morphology. (A, D) Lateral, (B, E) dorsal, and (C, F) ventral views (A-C: *Monteiro & Murta* 1854– COI00103153, Angola; D-F: *Nolde* 730– BM, Angola). ↑ – joining of the appendages of ventral lobes. Bar = 1 mm.

General description of seed morphology

Seeds laterally not compressed to slightly compressed, elliptic in lateral view, hairy, chalazal region with a minute expansion, caruncle 3-lobed, sometimes the two ventral lobes ± fused in a single structure.

Detailed description of seed morphology

Seed body 0.9-1.4 x 0.4-0.6 mm in lateral view, *c.* 0.4 wide in dorsal/ventral view. Hairs ± curving, scattered, not exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.2-0.3 x 0.1-0.4 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe inconspicuous or ovate in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form long rims at lobe apex only or also decurrent and joining. Funicular gap narrow or wide.

Distribution. Tropical Africa.

Angola: Malanje, Lunda Sul, Bié, Huambo, Huíla, and Cunene.

Habitat and ecology. Savannah and open woodland.

18. *P. luenensis* Paiva

Figure 34. Seed of *P. luenensis*. (A) Lateral, (B) dorsal, and (C) ventral views (*Gossweiler* 3601–BM001173010, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally not compressed to slightly compressed, elliptic in lateral view, hairy, caruncle 3-lobed, sometimes the two ventral lobes ± fused in a single structure.

Detailed description of seed morphology

Seed body 2.1-2.8 x 1.3-1.6 mm in lateral view, 0.7-1.3 mm wide in dorsal/ventral view. Hairs ± curving, scattered, not or shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.8-1.2 x 0.9-1.5 mm in lateral view. Dorsal and ventral lobes ± the same length or dorsal lobe longer in lateral view; dorsal lobe obovate, occasionally elliptic, in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only. Funicular gap wide.

Distribution. Angolan endemic: Moxico and Bié.

Habitat and ecology. Grassland; 1000-1250 m.

19. *P. dewevrei* Exell

Figure 35. Seed of *P. dewevrei*. (A) Lateral, (B) dorsal, and (C) ventral views (*Monteiro & Murta* 1777– COI00103216, Angola). ↑ – Funicular gap ± circular. Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed or occasionally strongly compressed, elliptic in lateral view, hairy, caruncle 3-lobed, sometimes the two ventral lobes ± fused in a single structure.

Detailed description of seed morphology

Seed body 1.8-2.2 x 1.1-1.3 mm in lateral view, 0.5-0.9 mm wide in dorsal/ventral view. Hairs ± curving, scattered, not or shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.4-0.5 x 0.6-0.7 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe obovate or elliptic in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only; apex of ventral lobes together with appendages are clearly auriculate in lateral view. Funicular gap minute to ± circular or wide.

Distribution. South of tropical Africa: Democratic Republic of the Congo, Zambia, and Angola.

Angola: Lunda Sul, Moxico, and Bié.

Habitat and ecology. Termite mound and wetland; 1000-1400 m.

20. *P. antunesii* Gürke

Figure 36. Seed of *P. antunesii*. (A) Lateral, (B) dorsal, and (C) ventral views (*Humbert* 16536– BM, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed to strongly compressed, elliptic in lateral view, hairy, caruncle 3-lobed, sometimes the two ventral lobes ± fused in a single structure.

Detailed description of seed morphology

Seed body 2.1-2.8 x 1.3-1.6 mm in lateral view, 0.6-1.0 mm wide in dorsal/ventral view. Hairs ± curving, scattered, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion *c.* 0.5 x 0.6-0.8 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe elliptic in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only. Funicular gap ± circular to wide.

Distribution. Angolan endemic: Benguela and Huíla.

Habitat and ecology. Xerophytic shrubland and woodland; 1700-2000 m.

21. *P. rivularis* Gürke

Figure 37. Seed of *P. rivularis*. (A) Lateral, (B) dorsal, and (C) ventral views (*Silva* 3489–COI00103218, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed or occasionally not compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 1.7-2.0 x 0.9-1.0 mm in lateral view, 0.8-1.1 mm wide in dorsal/ventral view. Hairs ± curving, scattered, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion *c.* 0.3-0.4 x 0.6 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe elliptic in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only. Funicular gap wide.

Distribution. Tropical Africa: Democratic Republic of the Congo, Zambia, and Angola. Angola: Lunda Sul, Moxico, Bié, Kwanza Sul, Huambo, Huíla, and Kuando Kubango.

Habitat and ecology. Wetland; 1000-1700 m.

22. *P. myrtillopsis* Welw. *ex* Oliv.

Figure 38. Seed of *P. myrtillopsis*. (A) Lateral, (B) dorsal, and (C) ventral views (*Welwitsch* 1029–LISU, Angola). Bar = 1 mm.

General description of seed morphology

Seed laterally strongly compressed, elliptic in lateral view, hairy, chalazal region with a wide tuft of hairs, caruncle 3-lobed, the two ventral lobes ± fused in a single structure.

Detailed description of seed morphology

Seed body c. 2.5 x 1.9 mm in lateral view, *c.* 0.8 mm wide in dorsal/ventral view. Hairs ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view, smooth portion *c.* 0.8 x 1.1 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view. Appendages of ventral lobes longer than dorsal; appendages of ventral lobes form long rims at lobe apex only. Funicular gap ± circular.

Distribution. Tropical Africa: Democratic Republic of the Congo and Angola.
Angola: Benguela and Huíla.

Habitat and ecology. Savannah; up to 1800 m.

23. *P. fragilis* Paiva

Figure 39. Seed of *P. fragilis*. (A) Lateral, (B) dorsal, and (C) ventral views (*Drummond & Cookson* 6490– K, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed or occasionally not compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.0-2.2 x 1.1-1.2 mm in lateral view, 0.7-1.1 mm wide in dorsal/ventral view. Hairs ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion *c.* 0.2-0.3 x 0.5 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe obovate to circular in dorsal view. Appendages of ventral lobes longer than dorsal; appendages of ventral lobes form long rims at lobe apex only. Funicular gap ± circular to wide.

Distribution. Southwest of tropical Africa: Zambia and Angola.

Angola: Moxico and Bié.

Habitat and ecology. Wet grassland; 1100-1300 m.

24. *P. schinziana* Chodat

Figure 40. Seed of *P. schinziana*. (A) Lateral, (B) dorsal, and (C) ventral views (*Brummitt, Chisumpa & Polhill* 14265– K, Zambia). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed to strongly compressed, elliptic in lateral view, hairy, chalazal region with a narrow tuft of hairs, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 3.1-3.4 x 1.7-1.9 mm in lateral view, 0.8-1.1 mm wide in dorsal/ventral view. Hairs ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy**,** wide in ventral view; smooth portion 0.9-1.1 x 0.8-0.9 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe linear or clavate in dorsal view; ventral lobes dolabriform towards apex in lateral view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only. Funicular gap narrow.

Distribution. Southeast of tropical Africa.

Angola: Bié and Kuando Kubango.

Habitat and ecology. Steppe; 900-1200 m.

25. *P. resendeana* Paiva

Figure 41. Seed of *P. resendeana*. (A) Lateral, (B) dorsal, and (C) ventral views (*Teixeira & Andrade* 8000a– LISC, Angola). Bar = 1 mm.

General description of seed morphology

Seed laterally strongly compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body c. 2.4 x 1.5 mm in lateral view, *c.* 0.8 mm wide in dorsal/ventral view. Hairs straight, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion *c.* 0.9 x 1.1 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only; apex of ventral lobes together with appendages are clearly auriculate in lateral view. Funicular gap ± circular.

Distribution. Angolan endemic: Huambo.

Habitat and ecology. Shrubby grassland; 1600-1700 m.

26. *P. youngii* Exell

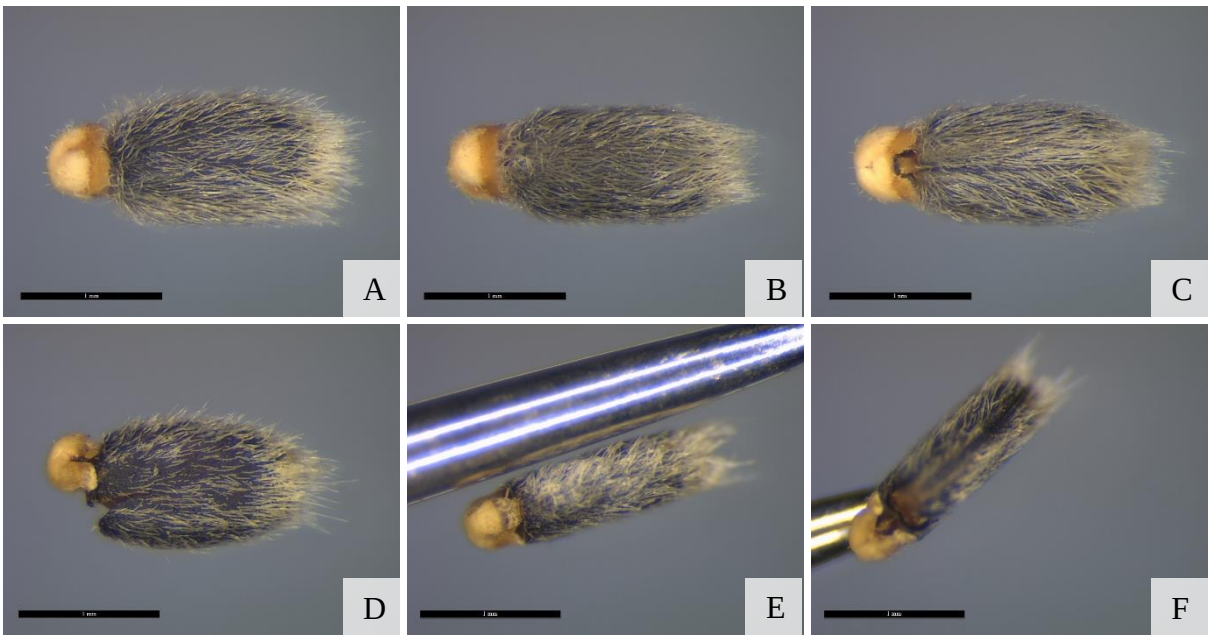

Figure 42. Seeds of *P. youngii*. (A, D) Lateral, (B, E) dorsal, and (C, F) ventral views (A-C: *Brummitt, Chisumpa & Polhill* 13987– COI00103264, Zambia; D-F: *Young* 1163– BM, Angola). Material from Angola differs, but very little, from that of Zambia. Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, caruncle 3-lobed, sometimes the two ventral lobes ± fused in a single structure.

Detailed description of seed morphology

Seed body 1.5-1.7 x 0.8-1.0 mm in lateral view, 0.5-0.8 mm wide in dorsal/ventral view. Hairs ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.2-0.3 x 0.4-0.5 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe obovate in dorsal view; ventral lobes globose and wide at apex in lateral view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only. Funicular gap ± circular.

Distribution. Centre of tropical Africa: Democratic Republic of the Congo, Zambia, and Angola.

Angola: Lunda Sul.

Habitat and ecology. Wet grassland; 1200-1350 m.

27. *P. petitiana* A.Rich. subsp. *petitiana* var. *petitiana*

Figure 43. Seed of *P. petitiana* subsp. *petitiana* var. *petitiana*. (A) Lateral, (B) dorsal, and (C) ventral views (*Gomes & Silva* 2786– COI00103157, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with or without a minute expansion, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 1.8-2.1 x 1.0-1.2 mm in lateral view, 0.6-0.8 mm wide in dorsal/ventral view. Hairs straight or ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy**,** smooth portion 0.5-0.7 x 0.6-0.7 mm in lateral view; caruncle wide in ventral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate or elliptic in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only. Funicular gap ± circular.

Distribution. Widespread throughout tropical Africa.

Angola: Kwanza Norte, Bié, Huambo, and Kuando Kubango.

Habitat and ecology. Very variable, from grassland and wetland to savannah and open woodland; 0-2100 m.

28. *P. gossweileri* Exell & Mendonça

Figure 44. Immature seed of *P. gossweileri*. (A) Lateral, (B) dorsal, and (C) ventral views (*Moreno* & *Lopes* 352– COI00103263, Angola). Bar = 1 mm.

General description of seed morphology (one seed available and immature, therefore the description is not as comprehensive as the other taxa)
Seeds laterally not compressed (cylindrical in Exell, 1960: 336), hairy, caruncle 3-lobed.

Detailed description of seed morphology
Seed body 2 x 0.8 mm (from Exell, 1960: 336) in lateral view. Hairs dense, shortly exceeding the distal end of the seed body.
Caruncle 0.7 mm (from Exell, 1960: 336), hairy, wide in ventral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe elliptic in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only; apex of ventral lobes together with appendages are clearly auriculate in lateral view. Funicular gap wide.

Distribution. Tropical Africa: Tanzania, Malawi, Zambia, and Angola.
Angola: Moxico, Bié, and Huíla.

Habitat and ecology. Grassland and wetland edges; 950-1650 m.

29-34. Taxa that key out together and are all included in section *Tetrasepalae* (Chodat) Paiva subsect. *Hexandrae* Paiva.

29. *P. arenicola* Gürke

Figure 45. Seed of *P. arenicola*. (A) Lateral, (B) dorsal, and (C) ventral views (*Young* 1382– BM, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.4-2.7 x 1.1-1.4 mm in lateral view, 0.8-1.1 mm wide in dorsal/ventral view. Hairs ± curving, dense, not or shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.8-1.0 x 0.9-1.1 mm in lateral view. Dorsal and ventral lobes ± the same length, occasionally dorsal lobe longer in lateral view; dorsal lobe elliptic or obovate in dorsal view. Appendages of ventral and dorsal lobes similar in length, sometimes of dorsal lobe inconspicuous; appendages of ventral lobes form short rims at lobe apex only; apex of ventral lobes together with appendages are clearly auriculate in lateral view. Funicular gap ± circular.

Distribution. Tropical Africa: Democratic Republic of the Congo, Zambia, and Angola. Angola: Kwanza Norte, Lunda Sul, Moxico, Bié, and Kuando Kubango.

Habitat and ecology. Savannah, woodland edges, and wetland; 900-1350 m.

30. *P. baumii* Gürke

Figure 46. Seed of *P. baumii*. (A) Lateral, (B) dorsal, and (C) ventral views (*Machado* VI-54-149–LISC098020, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.7-3.4 x 1.3-1.9 mm in lateral view, 0.8-1.3 mm wide in dorsal/ventral view. Hairs straight or ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.9-1.0 x 1.0-1.2 mm in lateral view; Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe obovate or elliptic in dorsal view. Appendages of ventral and dorsal lobes inconspicuous or similar in length then those of ventral lobes form short rims at lobe apex only; apex of ventral lobes together with appendages are clearly auriculate in lateral view. Funicular gap ± circular to wide.

Distribution. South of tropical Africa: Democratic Republic of the Congo, Zambia, and Angola.

Angola: Lunda Sul, Bié, Benguela, Huíla, and Kuando Kubango.

Habitat and ecology. Deciduous woodland and savannah on sandy soil; 110-1500 m.

31. *P. huillensis* Welw. *ex* Oliv.

Figure 47. Seed of *P. huillensis*. (A) Lateral, (B) dorsal, and (C) ventral views (*Santos* 39– LUAI, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.6-3.1 x 1.3-1.5 mm in lateral view; 0.9-1.2 mm wide in dorsal/ventral view. Hairs ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.8-1.0 x 0.9-1.0 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe obovate or elliptic in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only; apex of ventral lobes together with appendages are clearly auriculate in lateral view. Funicular gap ± circular.

Distribution. Angolan endemic: Huíla.

Habitat and ecology. Grassland and xerophytic shrubland.

32. *P. kalaxariensis* Schinz

Figure 48. Seed of *P. kalaxariensis*. (A) Lateral, (B) dorsal, and (C) ventral views (*Correia* 1459–LUAI, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.6-4.0 x 1.3-1.8 mm in lateral view, 1.0-1.5 mm wide in dorsal/ventral view. Hairs ± curving, dense, not exceeding the distal end of the seed body, occasionally shortly exceeding. *Caruncle* hairy**,** wide in ventral view; smooth portion 0.9-1.1 x 1.0-1.3 mm in lateral view. Dorsal and ventral lobes ± the same length or dorsal lobe longer in lateral view; dorsal lobe elliptic or obovate in dorsal view. Appendages of ventral and dorsal lobes inconspicuous or similar in length then those of ventral lobes form short rims at lobe apex only; apex of ventral lobes together with appendages are clearly auriculate in lateral view. Funicular gap ± circular or wide.

Distribution. Tropical Africa: Democratic Republic of the Congo, Zambia, Zimbabwe, Angola, and Namibia.

Angola: Moxico, Bié, Benguela, Huíla, Kuando Kubango, and Cunene.

Habitat and ecology. Grassland on sandy soil; 1150-2400 m.

33. *P. nematophylla* Exell

Figure 49. Seed of P. *nematophylla*. (A) Lateral, (B) dorsal, and (C) ventral views (*Mendes* 3010a–LISC098160, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 3.4-4.0 x 1.4-2.0 mm in lateral view, 1.4-1.6 mm wide in dorsal/ventral view. Hairs ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy**,** wide in ventral view; smooth portion 1.2-1.4 x 1.2-1.4 mm in lateral view. Dorsal lobe longer than ventral lobes in lateral view, obovate in dorsal view. Appendages of ventral and dorsal lobes similar in length, sometimes of dorsal lobe inconspicuous; appendages of ventral lobes form short rims at lobe apex only; apex of ventral lobes together with appendages are clearly auriculate in lateral view. Funicular gap ± circular.

Distribution. South of tropical Africa: Zambia, Angola, and Namibia.

Angola: Bié, Benguela, Huíla, and Kuando Kubango.

Habitat and ecology. Grassland; 900-1350 m**.**

34. *P. robusta* Gürke

Figure 50. Seed of *P. robusta*. (A) Lateral, (B) dorsal, and (C) ventral views (*Devred* 2981– K, Zaire). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 3.7-4.5 x 1.8-2.2 mm in lateral view, 1.4-1.8 mm wide in dorsal/ventral view. Hairs ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy**,** wide in ventral view; smooth portion 1.4-1.6 x 1.4-1.7 mm in lateral view. Dorsal and ventral lobes ± the same length or dorsal lobe longer in lateral view, elliptic or obovate in dorsal view. Appendages of ventral and dorsal lobes inconspicuous or similar in length then those of ventral lobes form short rims at lobe apex only; apex of ventral lobes together with appendages are clearly auriculate in lateral view. Funicular gap narrow or ± circular.

Distribution. Southwest of tropical Africa: Zambia and Angola.

Angola: Lunda Sul, Bié, and Kuando Kubango.

Habitat and ecology. Savannah and gallery woodland; 1250-1750 m

35. *P. acicularis* Oliv.

Figure 51. Seed of *P. acicularis*. (A) Lateral, (B) dorsal, and (C) ventral views (*Monteiro & Murta* 185– LUAI, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 3.0-3.5 x 1.6-1.8 mm in lateral view, 0.9-1.2 mm wide in dorsal/ventral view. Hairs ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.8-1.2 x 1.0-1.3 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe obovate in dorsal view; ventral lobes globose but very narrow at apex in lateral view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only. Funicular gap wide.

Distribution. Tropical Africa.

Angola: Cabinda.

Habitat and ecology. Grassland, savannah, and wetland edges; 350-1600 m.

36. *P. xanthina* Chodat

Figure 52. Seed of *P. xanthina*. (A) Lateral, (B) dorsal, and (C) ventral views (*Robinson* 5090– LISC, Zambia). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.7-3.1 x 1.3-1.6 mm in lateral view, 0.8-1.0 mm wide in dorsal/ventral view. Hairs straight or ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.6-0.8 x 0.9-1.0 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate or obovate in dorsal view; ventral lobes globose and wide at apex in lateral view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only. Funicular gap ± circular.

Distribution. East and centre of tropical Africa.

Angola: Malanje.

Habitat and ecology. Grassland and savannah; 1000-1750 m.

37. *P. mossamedensis* Paiva

Figure 53. Seed of *P. mossamedensis*. (A) Lateral, (B) dorsal, and (C) ventral views (*Santos* 1050–COI00067248, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with a minute expansion, occasionally without, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 3.0-3.8 x 1.5-1.7 mm in lateral view, *c.* 0.9 mm wide in dorsal/ventral view. Hairs straight or ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy**,** smooth portion 0.8-1.0 x 0.8-0.9 mm in lateral view; caruncle wide in ventral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe obovate or clavate in dorsal view; ventral lobes dolabriform towards apex in lateral view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only. Funicular gap narrow, occasionally ± circular.

Distribution. Angolan endemic: Namibe.

Habitat and ecology. Rocky steppe of shrubs and shrublets; 400-500 m.

38. *P. stenopetala* Klotzsch subsp. *casuarina* (Chodat) Paiva

Figure 54. Seed of *P. stenopetala* subsp. *casuarina*. (A) Lateral, (B) dorsal, and (C) ventral views (*Exell & Mendonça* 1678– BM, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with or without a minute expansion, caruncle 3-lobed, sometimes the two ventral lobes ± fused in a single structure.

Detailed description of seed morphology

Seed body 3.3-4.6 x 2.0-2.4 mm in lateral view; 1.3-1.6 mm wide in dorsal/ventral view. Hairs straight or ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.9-1.0 x 1.1-1.3 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate or obovate in dorsal view; ventral lobes globose and wide at apex in lateral view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex only. Funicular gap wide.

Distribution. Angolan endemic: Malanje, Kwanza Norte, Lunda Sul, Bié, Huambo, Benguela, Huíla, Kuando Kubango, and Cunene.

Habitat and ecology. Grassland and xerophytic shrubland; 1100-2200 m.

39. *P. laxifolia* Exell

Figure 55. Seed of *P. laxifolia*. (A) Lateral, (B) dorsal, and (C) ventral views (*Exell & Mendonça* 2082–COI00103146, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, caruncle 3-lobed, sometimes the two ventral lobes ± fused in a single structure.

Detailed description of seed morphology

Seed body 3.2-4.1 x 1.7-2.2 mm in lateral view; 1.3-1.5 mm wide in dorsal/ventral view. Hairs straight, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.8-1.3 x 1.1-1.4 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe obovate in dorsal view; ventral lobes globose and wide at apex in lateral view. Appendages of ventral and dorsal lobes inconspicuous or similar in length then those of ventral lobes form short rims at lobe apex only. Funicular gap wide.

Distribution. Angolan endemic: Huíla and Namibe.

Habitat and ecology. Xerophytic shrubland; 1700-2000 m.

40. *P. guerichiana* Engl.

Figure 56. Seed of *P. guerichiana*. (A) Lateral, (B) dorsal, and (C) ventral views (*Correia* 226– LUAI, Angola). ↑ – joining of the appendages of ventral lobes. Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed to strongly compressed, subobtriangular or elliptic in lateral view, hairy, chalazal region with a long and flattened hairy expansion, sometimes glochidiate, occasionally short, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 3.2-3.6 x 1.3-1.6 mm in lateral view, 0.6-0.8 mm wide in dorsal/ventral view. Hairs straight, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 1.3-1.4 x 1.1-1.4 mm in lateral view. Dorsal lobe longer than ventral lobes in lateral view, linear or ovate in dorsal view. Appendages of ventral lobes longer than dorsal, sometimes of dorsal lobe inconspicuous; appendages of ventral lobes form long rims at lobe apex plus decurrent and joining. Funicular gap ± circular.

Distribution. Southwest of Africa. Angola and Namibia.

Angola: Namibe.

Habitat and ecology. Rocky steppe of shrubs and succulents; 500-800 m.

41. *P. leptophylla* Burch. var. *leptophylla*

Figure 57. Seed of *P. leptophylla* var. *leptophylla*. (A) Lateral, (B) dorsal, and (C) ventral views (*Teixeira et al.* 12919– LUA, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed to strongly compressed, elliptic in lateral view, hairy, chalazal region with a short hairy expansion, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.9-3.1 x 1.1-1.4 mm in lateral view, 0.6-0.8 mm wide in dorsal/ventral view. Hairs straight or ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 1.3-1.6 x 0.9-1.0 mm in lateral view. Dorsal lobe longer than ventral lobes in lateral view, linear in dorsal view. Appendages of ventral lobes longer than dorsal, sometimes of dorsal lobe inconspicuous; appendages of ventral lobes form long rims at lobe apex plus decurrent and joining. Funicular gap narrow or ± circular.

Distribution. Southwest of Africa (Namaqualand and Kalahari). Angola, Namibia, Botswana, and South Africa.

Angola: Namibe.

Habitat and ecology. Steppe; up to 1500 m.

42. *P. gomesiana* Welw. *ex* Oliv.

Figure 58. Seed of *P. gomesiana*. (A) Lateral, (B) dorsal, and (C) ventral views (*Teixeira et al.* 12222–LUA, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly or occasionally strongly compressed, elliptic in lateral view, hairy, chalazal region with a minute expansion, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.0-2.2 x 1.4-1.6 mm in lateral view, 0.7-1.2 mm wide in dorsal/ventral view. Hairs straight, dense, shortly exceeding the distal end of the seed body.

Caruncle glabrous**,** wide in ventral view; smooth portion 0.4-0.5 x 0.6-0.7 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe sub-rectangular in dorsal view. Appendages of ventral and dorsal lobes inconspicuous or similar in length then those of ventral lobes form short rims at lobe apex and are decurrent, sometimes joining. Funicular gap ± circular, occasionally wide.

Distribution. Southwest of tropical Africa. Zambia and Angola.

Angola: Kwanza Norte, Kwanza Sul, Lunda Sul, Moxico, Bié, Huambo, Huíla, and Kuando Kubango.

Habitat and ecology. Wet grassland; 900-1500 m.

43. *P. welwitschii* Chodat subsp. *pygmaea* (Gürke) Paiva

Figure 59. Seed of *P. welwitschii* subsp. *pygmaea* (A) Lateral, (B) dorsal, and (C) ventral views (*Exell & Mendonça* 2019– COI00103167, Angola). ↑ – caruncular appendage probably previously inflated. Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with a minute expansion, occasionally without, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 1.3-1.7 x 0.7-0.9 mm in lateral view, 0.6-0.7 mm wide in dorsal/ventral view. Hairs straight or ± curving, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.4-0.5 x 0.4-0.5 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form long rims at lobe apex and are decurrent, probably inflated. Funicular gap narrow to wide.

Distribution. Tropical Africa, south of the Equator.

Angola: Lunda Sul, Bié, Huambo, Benguela, and Huíla.

Habitat and ecology. Wet grassland and savannah; 900-2000 m.

44. *P. albida* Schinz subsp. *stanleyana* (Chodat) Paiva

Figure 60. Seed of *P. albida* subsp. *stanleyana*. (A) Lateral, (B) dorsal, and (C) ventral views (*Silva* 2657– COI00103136, Angola). ↑ – joining of the appendages of ventral lobes. Bar = 1 mm.

General description of seed morphology

Seeds laterally strongly compressed, elliptic in lateral view, hairy, chalazal region with a wide tuft of hairs, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 1.8-1.9 x 1.0-1.3 mm in lateral view, 0.5-0.7 mm wide in dorsal/ventral view. Hairs straight, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.3-0.5 x 0.6-0.8 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view. Appendages of ventral and dorsal lobes similar in length to appendages of ventral lobes longer; appendages of ventral lobes form short to long rims at lobe apex and are decurrent, often joining. Funicular gap ± circular.

Distribution. Tropical Africa, south of the Tropic of Cancer.

Angola: Uíge, Malanje, Kwanza Norte, Lunda Sul, Bié, Huambo, Benguela, and Huíla.

Habitat and ecology. Grassland, savannah, and open woodland; ruderal; 0-2000 m.

45. *P. erioptera* DC.

Figure 61. Seed of *P. erioptera*. (A) Lateral, (B) dorsal, and (C) ventral views (*Exell & Mendonça* 2379– BM, Angola). Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed to strongly compressed, elliptic in lateral view, hairy, chalazal region with a wide tuft of hairs, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.2-2.5 x 1.1-1.3 mm in lateral view, 0.6-0.7 mm wide in dorsal/ventral view. Hairs straight, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.6-0.7 x 0.5-0.7 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view. Appendages of ventral and dorsal lobes similar in length; appendages of ventral lobes form short rims at lobe apex and are decurrent, sometimes joining. Funicular gap narrow or wide.

Distribution. Widespread throughout tropical and subtropical Africa, Arabian Peninsula, and tropical Asia.

Angola: Malanje, Kwanza Norte, Kwanza Sul, Luanda, Huambo, Benguela, Huíla, Cunene, and Namibe.

Habitat and ecology. Steppe, grassland, open bushland, and woodland; ruderal and weed; rocky ground; 0-2000 m.

46. *P. arenaria* Wild.

Figure 62. Seed of *P. arenaria*. (A) Lateral, (B) dorsal, and (C) ventral views (*Rocha* 93– LISC098000, Angola). ↑ – caruncular appendage probably previously inflated. Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with a wide tuft of hairs, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 1.6-1.9 x 0.9-1.0 mm in lateral view, 0.7-0.8 mm wide in dorsal/ventral view. Hairs straight, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.4-0.5 x 0.5-0.6 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate in dorsal view. Appendages of ventral lobes longer than dorsal; appendages of ventral lobes form long rims at lobe apex plus decurrent and joining, probably inflated. Funicular gap narrow.

Distribution. Widespread throughout tropical Africa.

Angola: Malanje and Kwanza Norte.

Habitat and ecology. Savannah and woodland; cultivated ground and roadside; 0-1700 m.

47. *P. sphenoptera* Fresen

Figure 63. Seed of *P. sphenoptera*. (A) Lateral, (B) dorsal, and (C) ventral views (*Antunes* s.n.–COI00103219, Angola). ↑ – joining of the appendages of ventral lobes. Bar = 1 mm.

General description of seed morphology

Seeds laterally slightly compressed, elliptic in lateral view, hairy, chalazal region with a wide tuft of hairs, caruncle 3-lobed.

Detailed description of seed morphology

Seed body 2.1-2.5 x 1.3-1.7 mm in lateral view, 0.7-1.0 mm wide in dorsal/ventral view. Hairs straight, dense, shortly exceeding the distal end of the seed body.

Caruncle hairy, wide in ventral view; smooth portion 0.4-0.7 x 0.8-0.9 mm in lateral view. Dorsal and ventral lobes ± the same length in lateral view; dorsal lobe clavate, occasionally elliptic, in dorsal view. Appendages of ventral lobes longer than dorsal, occasionally similar in length; appendages of ventral lobes form long rims, occasionally short, at lobe apex and are decurrent, often joining. Funicular gap wide.

Distribution. Tropical Africa. East Africa (from Ethiopia to Transvaal) to southwest of Africa. Angola: Uíge, Kwanza Norte, Huíla.

Habitat and ecology. Evergreen bushland, grassland, and wooded grassland; 0-2600 m.

48. *P. poggei* Gürke

No seed material available.

Distribution. South of tropical Africa. Democratic Republic of the Congo and Angola. Angola: Lunda.

Habitat and ecology. Mountain shrubby grassland; 1300-1750 m.

3.3. Statistical analyses

PRINCIPAL COMPONENT ANALYSIS

PCA carried out with the 212 seeds (Table A2) and the five continuous variables (Table 3) produced the results given in Table 4, Figures 64-65, and Tables A3-A4. The first two components were plotted for both the variables (Fig. 64) and the cases (Fig. 65). The first three components account for 97.4% of the total variation of the original dataset. The first component explains 86.7% of the total variation and has high negative loading for the five variables (Fig. 64). The second component explains 7.4% of the total variance, having positive loading for variables SB2 and SB3 and negative loading for the remaining variables, SB3 having the highest loading and C2 having the lowest loading (Fig. 64).

Table 4. Results of PCA on the five continuous variables of 212 seeds of 46 taxa of Angolan *Polygala*. Eigenvalues, percentage of variance explained by each component and cumulative percentage along the three first components.

	Eigenvalue	**% total variance**	**Cumulative %**
Component 1	4.333805	86.7	86.7
Component 2	0.369842	7.4	94.1
Component 3	0.164051	3.3	97.4

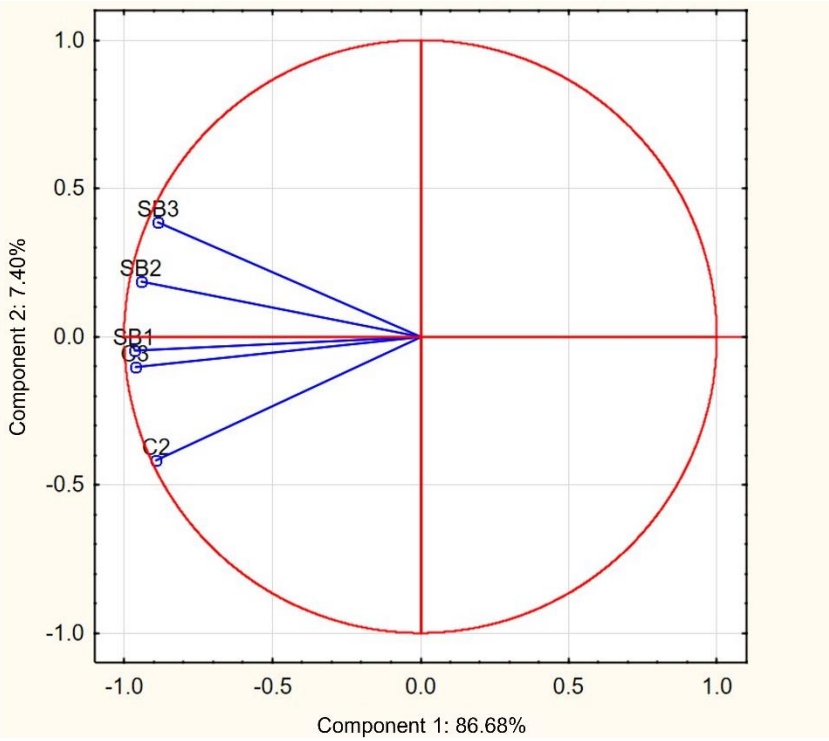

Figure 64. Projection and loading of the five continuous variables (the characters in Table 3) along the axes of the first two components (Table A3). SB1 – length of the seed body in lateral view; SB2 – width of the seed body in lateral view; SB3 – width of the seed body in dorsal/ventral views; C2 – length of the caruncle smooth portion in lateral view; C3 – width of the caruncle smooth portion in lateral view.

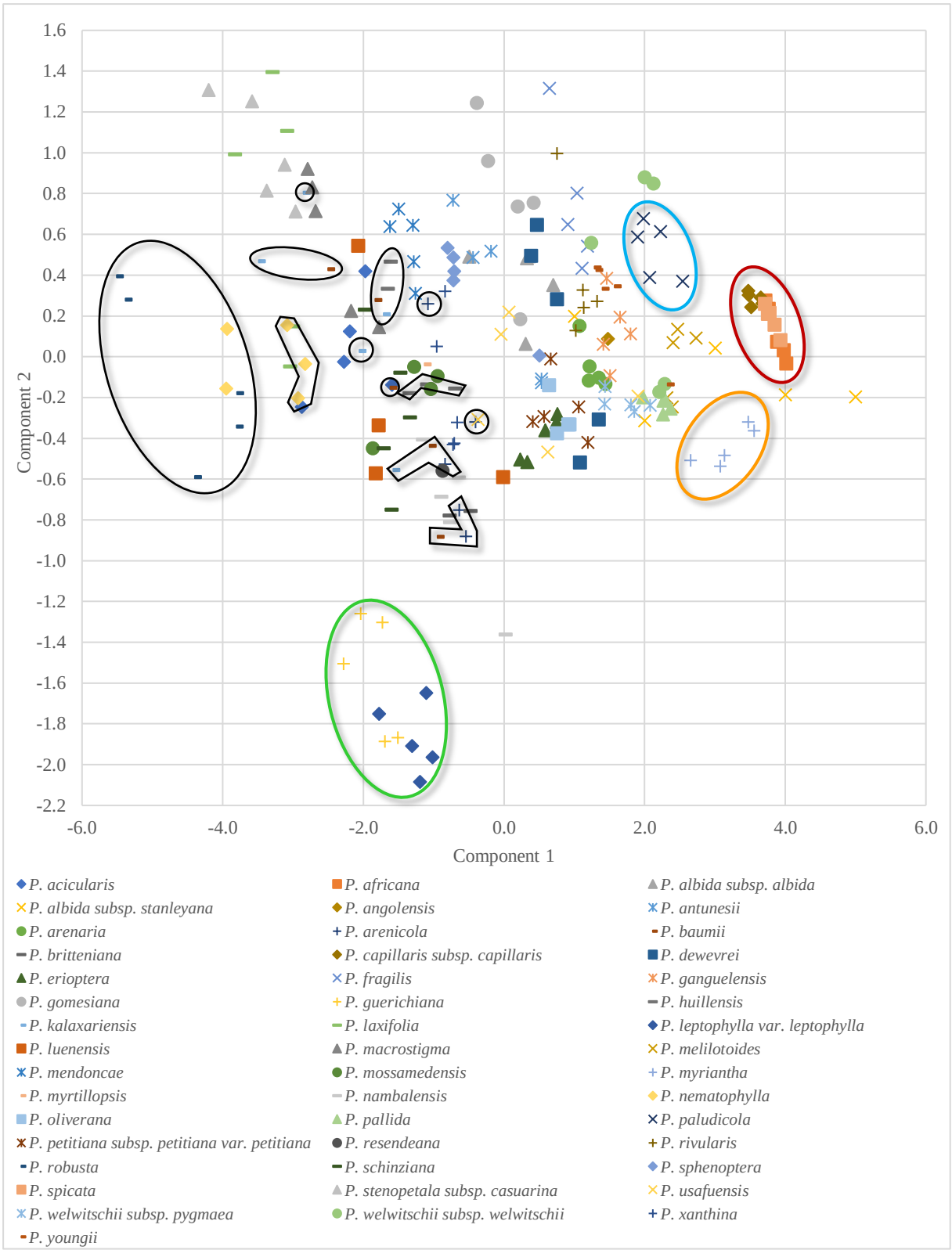

Figure 65. Scatterplot of the first two components from PCA performed with the five continuous variables (Table 3) of 212 seeds of 46 taxa of Angolan *Polygala* (for details of the taxa studied see Table A4) indicated by different symbols. Coloured closed lines indicate clusters referred to in the text; black closed lines indicate six taxa that key out simultaneously and are very similar.

Overall, the scatterplot of the cases on the first two components shows a gradient in size of the structures (i.e., size of the seed body and caruncle smooth portion) mainly along the axis of the first component from right-hand side indicating lack of structures (indicated as 0 mm) or small structures to the left-hand side indicating bigger structures (Fig. 65).

Also, seeds of some taxa tend to form some groups. For example, *P. africana*, *P. capillaris* subsp. *capillaris*, and *P. spicata* form a cluster (red closed line, Fig. 65) on the right-hand side of the graph separated along the axis of the first component. These taxa are among the taxa with the smallest seeds and the seeds lack a caruncle (indicated as 0 mm).

P. guerichiana and *P. leptophylla* var. *leptophylla* form a cluster (green closed line, Fig. 2) on the lower side of the graph separated along the axis of the second component, although this component explains a low percentage of variance. These taxa tend to have higher C2 values (i.e., higher length of the caruncle smooth portion in lateral view) and lower SB3 values (i.e., lower width of the seed body in dorsal/ventral views) (Fig. 64).

All seeds of *P. paludicola* form a cluster (blue closed line, Fig. 65) on the right-hand side of the graph. The same for *P. myriantha* (orange closed line, Fig. 65). *P. paludicola* and *P. myriantha* are separated from each other only along the axis of the second component indicating that *P. paludicola* tend to have lower C2 values and higher SB3 values (Fig. 64), while *P. myriantha* tend to have the opposite pattern, i.e., higher C2 values and lower SB3 values (Fig. 64) (although the axis of the second component explains a low percentage of variance).

The points of all the other taxa overlap, and separation is not possible. It is interesting to note that the six taxa that key out simultaneously (see 3.1. Key to taxa: 29. *P. arenicola*; 30. *P. baumii*; 31. *P. huillensis*; 32. *P. kalaxariensis*; 33. *P. nematophylla*; 34. *P. robusta*), although not clustering together (black closed lines, Fig. 65), they all have negative values along the axis of the first component. For these taxa, there tends to be a gradient from the largest seeds (e.g., *P. robusta*) to the intermediate-sized ones.

FACTORIAL ANALYSIS OF MIXED DATA

FAMD carried out with the 212 seeds (Table A2) and all the variables assessed potentially involved in dispersal (Table 3) produced the results given in Table 5, Figures 66-67, and Tables A5-A7. Figures 66 and 67 show the plots of the first two components for the variables and the cases. The first three components account for 47.1% of the total variation of the original dataset (Table 5). The first component explains 22.5% of the total variation and has high loading for variables such as SB1, SB2, C3 and, to a less extent, C1, C2, and C5 (Fig. 66). The second component explains 14.5% and has high loading for variables such as SB6-SB9 and C6 (Fig. 66).

Table 5. Results of FAMD on the five continuous variables and 13 categorical variables of 212 seeds of 46 taxa of Angolan *Polygala*. Eigenvalues, percentage of variance explained by each component and cumulative percentage along the three first components.

	Eigenvalue	**% total variance**	**Cumulative %**
Component 1	7.418418	22.5	22.5
Component 2	4.801318	14.5	37.0
Component 3	3.333141	10.1	47.1

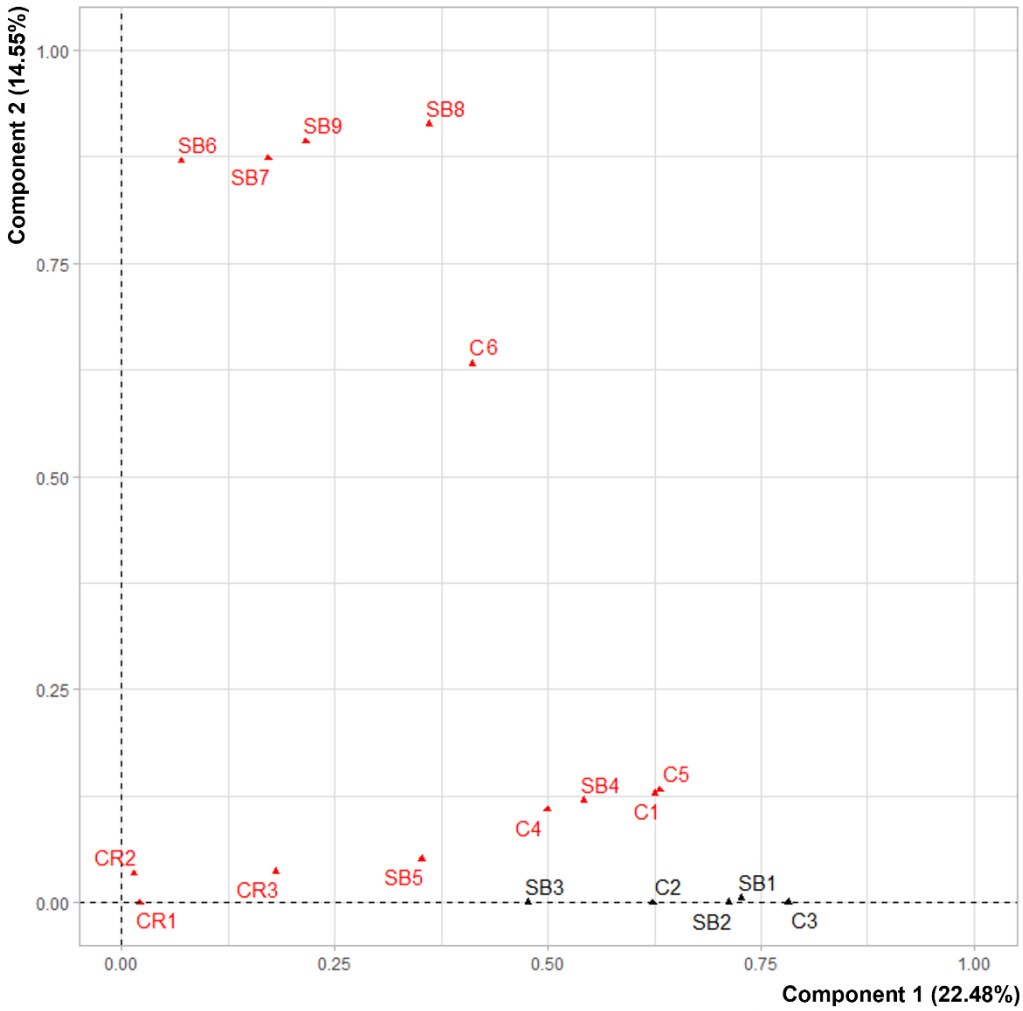

Figure 66. Projection and loading of all the variables potentially involved in dispersal (the characters in grey in Table 3) along the axes of the first two components (Table A5). The five continuous variables (in black): SB1 – length of the seed body in lateral view, SB2 – width of the seed body in lateral view, SB3 – width of the seed body in dorsal/ventral views, C2 – length of the caruncle smooth portion in lateral view, C3 – width of the caruncle smooth portion in lateral view; the 13 categorical variables (in red): SB4 – compression of the seed body, SB5 – shape of the seed body in lateral view, SB6 – cover on seed body surface, SB7 – hair density on the seed body, SB8 – hair posture on the seed body, SB9 – hair length after the distal end of the seed body, CR1 – hairiness of the chalazal region, CR2 – presence of chalazal region expansion, CR3 – shape of the chalazal region expansion, C1 – presence of caruncle, C4 – cover on caruncle surface, C5 – shape of the caruncle in ventral view, C6 – development of the appendages of the caruncular ventral lobes.

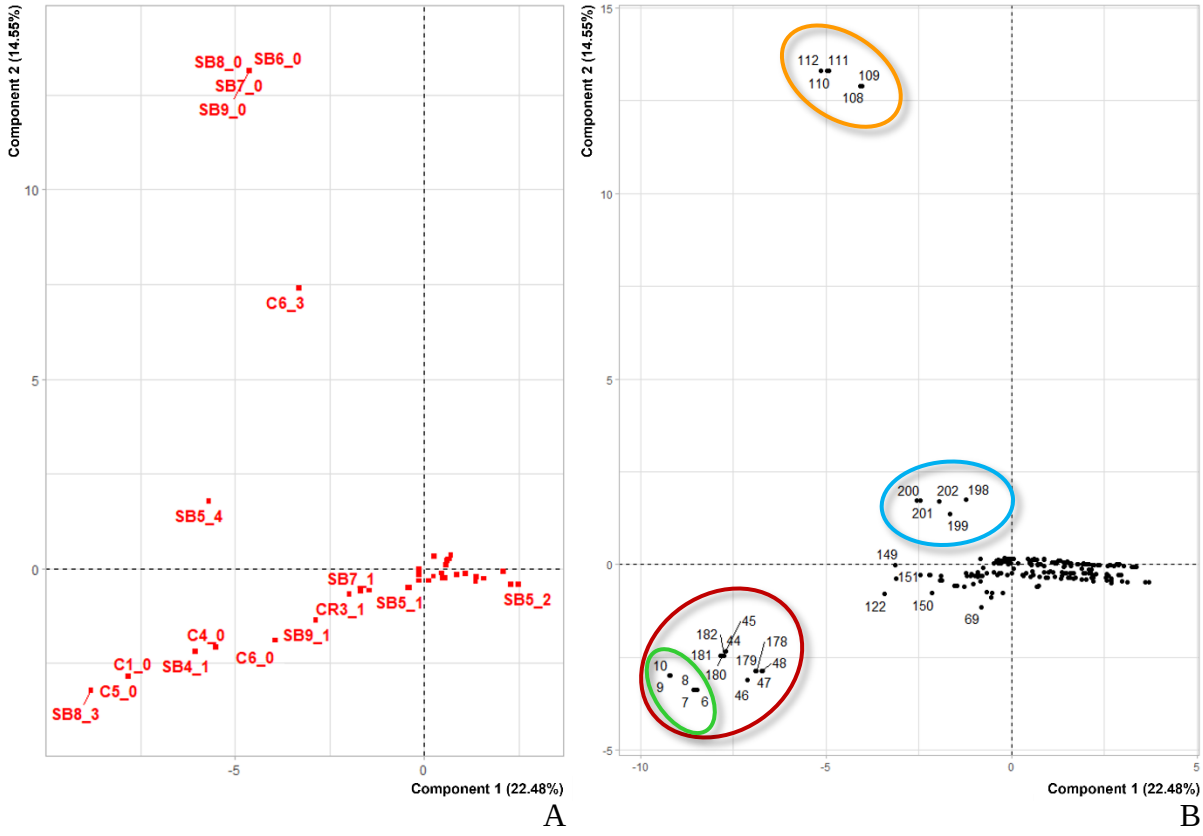

Figure 67. Scatterplots of the first two components from FAMD performed with all the variables potentially involved in dispersal (Table 3) of 212 seeds of 46 taxa of Angolan *Polygala* (taxa ID is provided in Table A7). (A) Projection of the categories of categorical variables (Table A6); (B) Projection of the cases (Table A7). Coloured closed lines indicate clusters referred to in the text.

The scatterplot of the cases on the first two components tend to form some groups of seeds of certain taxa (Fig. 67), described thereafter.

P. africana (6-10), *P. capillaris* subsp. *capillaris* (44-48), and *P. spicata* (178-182) form a cluster (red closed line, Fig. 67B) on the lower left corner of the graph separated along both axes, of the first and the second components. These taxa tend to group together because they fall in in the character state classified as “zero” for the character C1 referring to the absence of caruncle, particular of these taxa, (as well as for the related characters, e.g., C5) and in the character state classified as “one” for the character SB4, i.e., seeds laterally not compressed (Fig. 67). These taxa are also among those with the smallest seed body tending to have lower SB1 and SB2 values, those with highest loading in the axis of the first component (Fig. 66). Within this cluster, all seeds of *P. africana* tend to form a small cluster (green closed line, Fig.

67B), separated by the influence of the character state classified as “three” (i.e., glochidiate hairs) for the character SB8 (Fig. 67), unique of this taxon, whereas the points of *P. capillaris* subsp. *capillaris* and *P. spicata* are mixed.

The cases 108-112, all those referring to *P. melilotoides*, form a cluster (orange closed line, Fig. 67B) separated along the axis of the second component. This taxon can be easily separated from all the other taxa as it presents the character state classified as “zero” for the character SB6 referring to glabrous seed body (as well as for all the related characters – SB7-SB9) (Fig. 67), with high loading in the second component. This taxon is also separated by presenting the character state classified as “three” for the character C6 (i.e., very large and inflated appendages on ventral lobes), also with high loading in the second component. This is between the cases of this taxon and those of *P. welwitschii* subsp. *welwitschii* (198-202) contributing also for the additional cluster of its seeds (blue closed line, Fig. 67B) separated along the axis of the second component from all the other taxa, as these are the only two taxa with this trait.

Finally, the remaining cases form a big cluster almost without variation along the axis of the second component and forming a *continuum* along the axis of the first component (Fig. 67B).

4. Discussion

The multivariate analyses point to some interesting points connecting all aspects of the research, seed morphology and characters used in the identification key, distribution, and ecology of taxa.

The PCA for the five continuous variables in general shows a gradient in seed size. The seed cluster *P. africana* - *P. capillaris* subsp. *capillaris* - *P. spicata* obtained in the PCA is also separated from all the other taxa in FAMD for all the variables assessed potentially involved in dispersal. This reflects both the fact that their seed body is among the smallest and the absence of caruncle restricted in Angola to these three taxa, all in section *Timutua* (Table 1). In the FAMD the cluster of all seeds of *P. melilotoides* is in accordance with its unique trait, the glabrous seed body. Therefore, in the FAMD are defined the big groups of the identification key, these based in the following characters (see 3.1. Identification key to taxa: steps 1 and 4): presence of caruncle and cover on seed body surface. Also, the step 2 of the identification key based on hair posture on the seed body is represented in the FAMD: within the above-mentioned taxa without caruncle, all seeds of *P. africana* cluster as it is the only taxon with glochidiate hairs.

The segregation of the pair *P. welwitschii* subsp. *welwitschii* and *P. melilotoides* based in the very large and inflated caruncular appendages in the FAMD emphasises such character state shared only by these taxa. This trait is probably present in two other taxa (*P. arenaria* and *P. welwitschii* subsp. *pygmaea*), as noted in their descriptions. More material would be necessary to assess the consistency of such character.

The big cluster obtained in the FAMD plus the overlapping points in the PCA, partially explain the difficulties in separating some of the Angolan taxa using seed characters only. This is due to morphological variability within the same taxon and morphological similarity among some taxa. Such overlapping in the PCA highlights the difficulty to distinguish most of the taxa based on measurements only. It is noteworthy that the six taxa that key out simultaneously (see 3.1. Identification key to taxa: 29. *P. arenicola*; 30. *P. baumii*; 31. *P. huillensis*; 32. *P. kalaxariensis*; 33. *P. nematophylla*; 34. *P. robusta*) form in the PCA a gradient from the largest seeds (e.g., *P. robusta*) to the intermediate-sized ones. The similarities in seed morphology may reflect similar selective pressures over dispersal structures among these taxa. In addition to the very similar seed morphology, these taxa have very similar vegetative, fruit and flower characters and they are all included in section *Tetrasepalae* (Chodat) Paiva subsect. *Hexandrae* Paiva. They all have a restrict distribution, in countries nearby Angola, except *P. huillensis* that is an Angolan endemic (see 3.2. Seed descriptions and microphotographs. Distribution and ecology). A

common ancestor of wide distribution in the past could have originated these present-day species if its range was broken and the various parts originated new taxa by reproductive isolation.

There are also some taxa pairs separated in the identification key that have particularly similar seed morphology. For such taxa pairs, listed in Table 6, some vegetative characters and characters of capsule, and/or flower can be added to help taxa distinction/identification. It is noteworthy the difficulty in distinguishing two Angolan endemics growing in xerophytic habitats, 38. *P. stenopetala* subsp. *casuarina* and 39. *P. laxifolia*, even using these additional characters.

Table 6. Additional vegetative, fruit, and flower characters added to help identification in some taxa pairs. Characters used are in Paiva (1998). Taxa are preceded by the number in the identification key.

Taxa pairs with similar morphology	
2. *P. spicata*	**3. *P. capillaris* subsp. *capillaris***
Flowers always in dense racemes, pedicels generally up to 0.5 mm, wing-sepals (2.0)2.5-3.0 x 1.0-1.5 mm	Flowers in scattered or dense racemes, pedicels 0.5-1.0 mm, wing-sepals 1.5-2.0 x 0.7-1.0 mm
7. *P. nambalensis*	**8. *P. britteniana***
Much leafy herb; inflorescence branched, dense flowered; wing-sepals 6.0-7.0 x 3.5-5.0 mm	Little leafy herb; inflorescence not branched, scattered flowered; wing-sepals 7.5-8.0(9.0) x 5.0-6.0 mm
10. *P. macrostigma*	**11. *P. mendoncae***
Bracts caudate (ovate base and filiform apex)	Bracts ovate to lanceolate, not caudate
19. *P. antunesii*	**20. *P. rivularis***
Leaves 1.0-3.0 mm large, linear to linear-lanceolate	Leaves less than 1.0 mm large, filiform to linear
38. *P. stenopetala* subsp. *casuarina*	**39. *P. laxifolia***
Rachis, sepals, and capsule generally glabrous; wing-sepals 7.5-8.5 x 5.0-6.0 mm	Rachis, sepals, and capsule densely pubescent; wing-sepals 7.0-10.0 x 4.0-6.0 mm
40. *P. guerichiana*	**41. *P. leptophylla* var. *leptophylla***
Wing-sepals 5.5-15.0 mm wide, lower petal crest 2.5-5.0 mm long; capsule wing *c.* 1.0 mm wide	Wing-sepals up to 5.5 mm wide, lower petal crest *c.* 1.0 mm long; capsule wing up to 0.5 mm wide
46. *P. arenaria*	**47. *P. sphenoptera***
Flowers dense in terminal racemes	Flowers scattered in lateral racemes

Despite the difficulties, it was possible to construct an identification key to taxa because: (1) in spite of the morphological variability within taxa there are constant seed characters, sometimes unique in the sample (e.g., glabrous seed body in *P. melilotoides*); (2) other characters than those potentially involved in dispersal and used in the statistical analyses were included in the identification key; (3) some characters were used repeatedly in the identification key, due to the similarities among taxa in some characters.

This detailed study of the seed morphological traits and the information on the distribution and habitat and ecology, establish a basis for the investigation on the relation between seed morphology and dispersal agents. Thus, it is worth to highlight the information thereafter.

The statistical analyses, based on the seed characters potentially involved in dispersal, show separation of groups of taxa with distinct characters, mainly related to the presence of caruncle, an elaiosome important for myrmecochory (e.g. Castro et al., 2010; Paiva, 1998; Ridley, 1930). Additionally, seed hairs are important for facilitating the transport by ants attracted by the elaiosome (e.g. Oostermeijer, 1989). Although without seed body hairs, seeds of *P. melilotoides* have hairy elaiosome. Similarly, to the species with hairs in the seed body, this hairy elaiosome of *P. melilotoides* may facilitate the transport by ants to the nest. Ants would be initially attracted by the very large and inflated appendages. The glabrous seed body might be particularly advantageous on the loose sandy soil where these plants grow and through the unstable structure of such sandy nests (Paiva, 1998). Interestingly, the habitats of the three taxa separated based on the absence of caruncle (*P. africana*, *P. capillaris* subsp. *capillaris*, and *P. spicata*) are wetlands. In these habitats, ants are not expected to be present (Paiva, 1998) and, thus, there was no selective pressure for elaiosome traits and other dispersal characters might have played key roles in seed dispersal. These habitats and the absence of caruncle linked to the ± curving hairs and glochidiate hairs are closely associated to dispersal by birds (Paiva, 1998), glochidiate hairs having a general specialization for epizoochory (Gorb & Gorb, 2002; Sorensen, 1986). In this group of taxa, either the mutualistic interaction with ants has been lost and new dispersal interaction have been established, with subsequent new seed characters development, or the current dispersal characters evolved from a common ancestor without adaptations to myrmecochory.

Similarly to the caruncle, the chalazal region expansion is also referred to in the literature as an elaiosome by Ridley (1930) and Sernander (1906). In *Polygala*, these structures may be advantageous and may be selected under certain ecological scenarios where ants are present. However, the presence of chalazal region expansion is not constant within the same taxon, sometimes being only vestigial. This structure is also morphologically very different from the caruncle and needs to be studied in more detail in the future.

The seed morphology of the Angolan taxa described in this thesis, including the morphological variability within taxa and similarities among taxa, may be closely related to the habitat and ecology.

Although it is possible to establish links for some cases between seed morphology and ecology, and consequently the possible dispersal agent, a reliable analysis of the correlation between seed morphology and ecology based only on the currently available data does not seem to be feasible at the present state of knowledge. The ecological information on the labels of the herbarium specimens is often vague and further ecological studies are necessary to better understand the dispersal mechanisms in the Angolan *Polygala* and then to discuss possible evolutionary mechanisms.

5. Conclusions and future work

Based on the results obtained for the Angolan sample here investigated, seed characters in *Polygala* are of taxonomic importance at a specific level and allow for the identification of most taxa. It was possible to construct an identification key using seed characters only, although some taxa were particularly difficult or even impossible to distinguish, this is partially explained by the statistical analyses.

In the future it will be important to try to access more material in the field, mainly for those taxa with lack of seed material and those with seeds probably with very large and inflated caruncular appendages.

To establish further connections between seed morphology and the dispersal agents, fieldwork is necessary. It will be important to follow the behaviour and interaction of the dispersal agents with the seeds of each taxon, including the study of the fruit, to assess the dispersal mechanisms involved, and, also, to analyse the relation between the seed morphology and the habitat and ecology in the Angolan field.

Furthermore, for particular groups of taxa it will be important to do scanning electron microscopy and molecular investigation, especially for those six taxa that key out together to access differences between them.

Also, to do a chemical analysis of the caruncle smooth portion, the caruncular appendages, and the chalazal region expansion, to access similarities and differences that could be related to dispersal.

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7. Appendix

Table A1. Herbarium specimens from which seeds were collected for the investigation. Most material used was from Angola. When necessary neighbouring countries were investigated.

Taxon	Herbarium specimen	Country	Seed total
P. acicularis Oliv.	*Monteiro & Murta* 185– LUAI	Angola	2
	Muerillon 995– K	Cameroon	1
	Dalziel 89– K	Nigeria	2
	Hepper 1369– K		
P. africana Chodat	*Exell & Mendonça* 2609– COI00103131	Angola	5
	Silva 2480– COI00100970		
	Silva 3524– COI00103130		
	Welwitsch 1010– BM		
P. albida Schinz subsp. *albida*	*Carrisso & Sousa* 72– COI00103134	Angola	5
	Exell & Mendonça 1921– COI00103133		
	Exell & Mendonça 2468– BM		
	Silva 2586– COI00103132		
P. albida Schinz subsp. *stanleyana* (Chodat) Paiva	*Exell & Mendonça 1469– COI00103138*	Angola	5
	Gossweiler 11133– COI00005979		
	Gossweiler & Borges 14176– COI00005980		
	Silva 2657– COI00103136		
P. angolensis Chodat	*Dekindt* 255– BM	Angola	1
P. antunesii Gürke	*Exell & Mendonça* 3005– COI00103139	Angola	5
	Humbert 16536– BM		
	Hundt 890– COI00103140		
P. arenaria Wild.	*Rocha* 93– LISC098000	Angola	3
	de Kruif 469– COI00092300	Ivory Coast	2
P. arenicola Gürke	*Young* 1382– BM	Angola	5
	Exell & Mendonça 1206– COI00103214		
	Gossweiler 3698– COI00005382		
P. baumii Gürke	*Gossweiler* 3734– COI00005974	Angola	5
	Gossweiler 3734– LISC098017		
	Machado VI-54-149– LISC098020		

	Teixeira & Andrade 5314– LUA		
P. britteniana Chodat	*Scott-Elliot* 8256– K	Zambia	2
P. capillaris E.Mey. subsp. *capillaris*	*Chaves* s.n.– COI00103141	Angola	5
	Milne-Redhead 4000– BM		
P. dewevrei Exell	*Exell & Mendonça* 1659– COI00103142	Angola	5
	Gossweiler 11844– BM		
	Monteiro & Murta 1777– COI00103216		
P. erioptera DC.	*Exell & Mendonça* 2379– BM	Angola	5
	Gossweiler 9767– COI00005966		
	Silva 1790– COI00103143		
P. fragilis Paiva	*Drummond & Cookson* 6490– K	Angola	2
	Mendes 2919– LISC		
	Drummond & Cookson 6505– BM	Zambia	3
	Drummond & Cookson 6505– K		
P. ganguelensis Exell & Mendonça	*Gossweiler* 3150– BM	Angola	5
	Mendes 2103– LISC098057		
P. gomesiana Welw. *ex* Oliv.	*Baum* 371– COI00103217	Angola	5
	Teixeira 3440– COI00103144		
	Teixeira et al. 12222– LUA		
P. gossweileri Exell & Mendonça	*Moreno & Lopes* 352– COI00103263	Angola	1 (immature)
P. guerichiana Engl.	*Correia* 226– LUAI	Angola	5
	Mendes 3961– LISC		
P. huillensis Welw. *ex* Oliv.	*Mendes* 332– LISC	Angola	5
	Mendes 332– LUAI		
	Santos 39– LUAI		
	Santos 117– LUAI		
P. kalaxariensis Schinz	*Couto* 210– LUAI	Angola	5
	Correia 1459– LUAI		
	Gossweiler 3123– COI00005961		
	Teixeira & Almeida 5691– LUA		

P. laxifolia Exell	*Exell & Mendonça* 2082– COI00103146	Angola	5
	Teixeira 2735– COI00103145		
P. leptophylla Burch. var. *leptophylla*	*Castro* 139– COI00103147	Angola	5
	Teixeira et al. 12919– LUA		
P. luenensis Paiva	*Exell & Mendonça* 1594– COI00005653	Angola	4
	Gossweiler 3601– BM001173010		
P. macrostigma Chodat	*Forst* 126– LUA	Angola	5
	Lopes, Silva & Murta 3696– COI00103148		
	Lopes, Silva & Murta 3696– COI00103149		
P. melilotoides Chodat	*Exell & Mendonça* 310– COI00100969	Angola	5
	Exell & Mendonça 556– BM001173011		
	Exell & Mendonça 1240– COI00103150		
P. mendoncae E.M.A. Petit	*Exell & Mendonça* 1458– COI00005656	Angola	5
	Gossweiler 11781– BM		
P. mossamedensis Paiva	*Kers* 3644– LISC098132,	Angola	4
	Santos 1050– COI00067248		
	Teixeira 2223– LISC?		
P. myriantha Chodat	*Gossweiler* 3114– COI00005953	Angola	5
	Monteiro & Murta 1854– COI00103153		
	Nolde 730– BM		
P. myrtillopsis Welw. *ex* Oliv.	*Welwitsch* 1029– LISU	Angola	1
P. nambalensis Gürke	*Exell & Mendonça* 814– COI00103154	Angola	5
	Gossweiler 11600– COI00067245		
	Santos & Barroso 2958– LUAI		
P. nematophylla Exell	*Mendes* 2893– LISC098158	Angola	5
	Mendes 3010a– LISC098160		
P. oliverana Exell & Mendonça	*Welwitsch* 1018– LISU	Angola	4
P. pallida E.Mey. *ex* Harv.	*Correia* 365– COI00103155	Angola	5
	Correia 365– LUAI		

	Pearson 2200– K		
P. paludicola Gürke	*Gossweiler* 2783 *p.p.*– BM001173012	Angola	5
	Silva 1962– COI00103156		
	Silva 3495– BM		
P. petitiana A.Rich. subsp. *petitiana* var. *petitiana*	*Exell & Mendonça* 1698– COI00103158	Angola	5
	Gomes & Silva 2786– COI00103157		
	Silva 1949– COI00103159		
P. poggei Gürke	No material available		
P. resendeana Paiva	*Teixeira & Andrade* 8000a– LISC	Angola	1
P. rivularis Gürke	*Exell & Mendonça* 1389– COI00103160	Angola	5
	Silva 1963– COI00103161		
	Silva 3489– COI00103218		
P. robusta Gürke	*Gossweiler* 2851– LISC098180	Angola	3
	Devred 2981– K	Democratic Republic of the Congo	2
P. schinziana Chodat	*Brummitt, Chisumpa & Polhill* 14265– K	Zambia	5
	Luwiika, Harder & Zimba 370– COI00098237		
P. sphenoptera Fresen.	*Antunes* s.n.– COI00103219	Angola	5
	Gossweiler s.n.– LUA		
	Santos 233– LUAI		
P. spicata Chodat	*Baum* 315– BM, Angola	Angola	5
	Carrisso & Mendonça 540– BM		
	Milne-Redhead 4145– BM		
P. stenopetala Klotzsch subsp. *casuarina* (Chodat) Paiva	*Exell & Mendonça* 224– COI00103162	Angola	5
	Exell & Mendonça 1678– BM		
P. usafuensis Gürke	*Exell & Mendonça* 1724– COI00103205	Angola	5
	Henriques 63– LUAI		
	Silva 2587– COI00103208		
	Teixeira & Andrade 7295– LUA		
	Exell & Mendonça 2019– COI00103167	Angola	5

P. welwitschii Chodat subsp. *pygmaea* (Gürke) Paiva	*Pritchard* 323– COI00103166		
	Teixeira 3590– COI00103168		
P. welwitschii Chodat subsp. *welwitschii*	*Barbosa & Correia* 8863– LUAI	Angola	5
	Exell & Mendonça 105– COI00103172		
	Exell & Mendonça 203– COI00103171		
	Welwitsch 1013– BM001173009		
P. xanthina Chodat	*Lewalle* 932– K	Burundi	2
	Robinson 5090– LISC	Zambia	3
P. youngii Exell	*Young* 1163– BM	Angola	1 (broken)
	Brummitt, Chisumpa & Polhill 13987– COI00103264	Zambia	4
Total	127	7	213

Table A2. Dataset used for the statistical analyses using 212 seeds (cases) of 46 taxa of Angolan *Polygala*, with the codes (ID) of both the cases and all the variables used, and the numerical classification of the categories for FAMD.

	Variables	Length of the seed body in lateral view (mm)	Width of the seed body in lateral view (mm)	Width of the seed body in dorsal/ventral views (mm)	Compression of the seed body	Shape of the seed body in lateral view	Cover on seed body surface	Hair density on the seed body	Hair posture on the seed body	Hair length after the distal end of the seed body	Hairiness of the chalazal region	Presence of chalazal region expansion	Shape of the chalazal region expansion	Presence of caruncle	Length of the caruncle smooth portion in lateral view (mm)	Width of the caruncle smooth portion in lateral view (mm)	Cover on caruncle surface	Shape of the caruncle in ventral view	Development of the appendages of the caruncular ventral lobes
Cases	**ID**	SB1	SB2	SB3	SB4	SB5	SB6	SB7	SB8	SB9	CR1	CR2	CR3	C1	C2	C3	C4	C5	C6
P. acicularis Oliv.	1	3.47	1.64	0.91	2	3	1	2	2	2	0	0	0	1	0.81	1.04	1	2	1
P. acicularis Oliv.	2	3.52	1.83	1.05	2	3	1	2	2	2	0	0	0	1	0.88	1.13	1	2	1
P. acicularis Oliv.	3	3.41	1.76	1.22	2	3	1	2	2	2	0	0	0	1	1.24	1.28	1	2	1
P. acicularis Oliv.	4	3.38	1.70	1.15	2	3	1	2	2	2	0	0	0	1	1.05	1.10	1	2	1
P. acicularis Oliv.	5	3.01	1.81	1.17	2	3	1	2	2	2	0	0	0	1	0.90	1.02	1	2	1
P. africana Chodat	6	0.73	0.42	0.42	1	3	1	1	3	1	0	0	0	0	0	0	0	0	0
P. africana Chodat	7	0.67	0.38	0.38	1	3	1	1	3	1	0	0	0	0	0	0	0	0	0
P. africana Chodat	8	0.63	0.41	0.40	1	3	1	1	3	1	0	0	0	0	0	0	0	0	0
P. africana Chodat	9	0.70	0.47	0.48	1	4	1	1	3	1	0	0	0	0	0	0	0	0	0
P. africana Chodat	10	0.71	0.50	0.49	1	4	1	1	3	1	0	0	0	0	0	0	0	0	0
P. albida Schinz subsp. *albida*	11	1.76	1.27	0.93	2	3	1	2	1	3	2	0	0	1	0.48	0.74	1	2	2
P. albida Schinz subsp. *albida*	12	1.74	1.19	0.84	2	3	1	2	1	3	2	0	0	1	0.44	0.67	1	2	1

P. albida Schinz subsp. *albida*	13	2.25	1.50	0.99	2	3	1	2	1	3	2	0	0	1	0.59	0.87	1	2	2
P. albida Schinz subsp. *albida*	14	1.75	1.27	0.92	2	3	1	2	1	3	2	0	0	1	0.46	0.80	1	2	1
P. albida Schinz subsp. *albida*	15	1.79	1.19	0.87	2	3	1	2	1	3	2	0	0	1	0.61	0.79	1	2	1
P. albida Schinz subsp. *stanleyana* (Chodat) Paiva	16	1.81	1.24	0.64	3	3	1	2	1	2	2	0	0	1	0.33	0.56	1	2	2
P. albida Schinz subsp. *stanleyana* (Chodat) Paiva	17	1.48	1.02	0.48	3	3	1	2	1	2	2	0	0	1	0.35	0.60	1	2	2
P. albida Schinz subsp. *stanleyana* (Chodat) Paiva	18	1.83	1.30	0.67	3	3	1	2	1	2	2	0	0	1	0.42	0.80	1	2	1
P. albida Schinz subsp. *stanleyana* (Chodat) Paiva	19	1.81	1.32	0.59	3	3	1	2	1	2	2	0	0	1	0.46	0.82	1	2	1
P. albida Schinz subsp. *stanleyana* (Chodat) Paiva	20	1.94	1.09	0.62	3	3	1	2	1	2	2	0	0	1	0.41	0.79	1	2	2
P. angolensis Chodat	21	1.73	1.08	0.62	3	3	1	1	2	2	0	0	0	1	0.33	0.48	1	2	2
P. antunesii Gürke	22	2.76	1.49	0.88	2	3	1	1	2	2	0	0	0	1	0.47	0.64	1	2	1
P. antunesii Gürke	23	2.76	1.58	1.04	2	3	1	1	2	2	0	0	0	1	0.52	0.78	1	2	1
P. antunesii Gürke	24	2.73	1.48	0.94	2	3	1	1	2	2	0	0	0	1	0.53	0.75	1	2	1
P. antunesii Gürke	25	2.11	1.38	0.62	3	3	1	1	2	2	0	0	0	1	0.49	0.70	1	2	1
P. antunesii Gürke	26	2.21	1.28	0.65	3	3	1	1	2	2	0	0	0	1	0.49	0.71	1	2	1
P. arenaria Wild.	27	1.82	0.93	0.68	2	3	1	2	1	2	2	0	0	1	0.44	0.51	1	2	2
P. arenaria Wild.	28	1.87	0.96	0.69	2	3	1	2	1	2	2	0	0	1	0.46	0.55	1	2	2
P. arenaria Wild.	29	1.87	1.00	0.77	2	3	1	2	1	2	2	0	0	1	0.41	0.58	1	2	2

P. arenaria Wild.	30	1.80	0.93	0.72	2	3	1	2	1	2	2	0	0	1	0.44	0.58	1	2	2
P. arenaria Wild.	31	1.60	0.89	0.67	2	3	1	2	1	2	2	0	0	1	0.42	0.59	1	2	2
P. arenicola Gürke	32	2.35	1.10	0.95	2	3	1	2	2	1	0	0	0	1	0.83	0.93	1	2	1
P. arenicola Gürke	33	2.68	1.39	1.13	2	3	1	2	2	1	0	0	0	1	0.82	0.90	1	2	1
P. arenicola Gürke	34	2.64	1.31	0.87	2	3	1	2	2	1	0	0	0	1	0.90	1.02	1	2	1
P. arenicola Gürke	35	2.57	1.22	0.80	2	3	1	2	2	2	0	0	0	1	0.91	1.03	1	2	1
P. arenicola Gürke	36	2.52	1.05	0.83	2	3	1	2	2	2	0	0	0	1	0.95	1.05	1	2	1
P. baumii Gürke	37	3.21	1.48	1.03	2	3	1	2	1	2	0	0	0	1	0.90	1.09	1	2	1
P. baumii Gürke	38	2.92	1.40	1.32	2	3	1	2	2	2	0	0	0	1	1.00	1.03	1	2	1
P. baumii Gürke	39	2.79	1.28	0.77	2	3	1	2	1	2	0	0	0	1	0.93	1.16	1	2	1
P. baumii Gürke	40	3.40	1.94	1.20	2	3	1	2	2	2	0	0	0	1	0.94	1.11	1	2	1
P. baumii Gürke	41	2.69	1.27	0.97	2	3	1	2	2	2	0	0	0	1	0.94	1.06	1	2	0
P. britteniana Chodat	42	2.56	1.32	0.84	2	3	1	2	1	3	0	1	3	1	1.05	0.89	1	2	1
P. britteniana Chodat	43	2.48	1.28	0.78	2	3	1	2	1	3	0	1	3	1	0.96	0.86	1	2	0
P. capillaris E.Mey. subsp. *capillaris*	44	0.81	0.49	0.49	1	4	1	2	2	1	0	0	0	0	0.00	0.00	0	0	0
P. capillaris E.Mey. subsp. *capillaris*	45	0.80	0.50	0.50	1	4	1	2	2	1	0	0	0	0	0.00	0.00	0	0	0
P. capillaris E.Mey. subsp. *capillaris*	46	1.10	0.50	0.49	1	3	1	2	2	2	0	1	1	0	0.00	0.00	0	0	0
P. capillaris E.Mey. subsp. *capillaris*	47	1.06	0.52	0.52	1	3	1	2	2	1	0	1	1	0	0.00	0.00	0	0	0
P. capillaris E.Mey. subsp. *capillaris*	48	1.07	0.52	0.51	1	3	1	2	2	2	0	1	1	0	0.00	0.00	0	0	0
P. dewevrei Exell	49	1.78	1.08	0.51	3	3	1	1	2	1	0	0	0	1	0.38	0.65	1	2	1
P. dewevrei Exell	50	2.06	1.22	0.92	2	3	1	1	2	1	0	0	0	1	0.36	0.68	1	2	1
P. dewevrei Exell	51	1.90	0.98	0.58	2	3	1	1	2	2	0	0	0	1	0.53	0.69	1	2	1
P. dewevrei Exell	52	2.18	1.22	0.90	2	3	1	1	2	1	0	0	0	1	0.42	0.67	1	2	1
P. dewevrei Exell	53	2.08	1.10	0.81	2	3	1	1	2	2	0	0	0	1	0.40	0.63	1	2	1

P. erioptera DC.	54	2.50	1.28	0.61	3	3	1	2	1	2	2	0	0	1	0.67	0.64	1	2	1
P. erioptera DC.	55	2.47	1.21	0.69	3	3	1	2	1	2	2	0	0	1	0.73	0.65	1	2	1
P. erioptera DC.	56	2.29	1.11	0.67	2	3	1	2	1	2	2	0	0	1	0.60	0.52	1	2	1
P. erioptera DC.	57	2.24	1.12	0.67	2	3	1	2	1	2	2	0	0	1	0.58	0.54	1	2	1
P. erioptera DC.	58	2.24	1.24	0.63	3	3	1	2	1	2	2	0	0	1	0.61	0.60	1	2	1
P. fragilis Paiva	59	1.96	1.19	0.73	2	3	1	2	2	2	0	0	0	1	0.23	0.49	1	2	2
P. fragilis Paiva	60	2.11	1.15	0.72	2	3	1	2	2	2	0	0	0	1	0.25	0.52	1	2	2
P. fragilis Paiva	61	2.16	1.14	1.11	1	3	1	2	2	2	0	0	0	1	0.22	0.46	1	2	2
P. fragilis Paiva	62	2.11	1.20	0.82	2	3	1	2	2	2	0	0	0	1	0.19	0.47	1	2	2
P. fragilis Paiva	63	2.13	1.21	0.81	2	3	1	2	2	2	0	0	0	1	0.26	0.51	1	2	2
P. ganguelensis Exell & Mendonça	64	1.67	0.98	0.60	2	3	1	1	1	2	0	1	1	1	0.35	0.57	1	2	1
P. ganguelensis Exell & Mendonça	65	1.69	1.02	0.64	2	3	1	1	1	2	0	1	1	1	0.32	0.59	1	2	1
P. ganguelensis Exell & Mendonça	66	1.68	1.11	0.68	2	3	1	1	1	2	0	1	1	1	0.24	0.50	1	2	2
P. ganguelensis Exell & Mendonça	67	1.61	1.02	0.63	2	3	1	1	1	2	0	1	1	1	0.26	0.49	1	2	2
P. ganguelensis Exell & Mendonça	68	1.60	0.98	0.59	2	3	1	1	1	2	0	1	1	1	0.25	0.46	1	2	2
P. gomesiana Welw. *ex* Oliv.	69	2.22	1.57	1.15	2	3	1	2	1	2	0	1	1	1	0.42	0.70	0	2	0
P. gomesiana Welw. *ex* Oliv.	70	2.04	1.39	0.98	2	3	1	2	1	2	0	1	1	1	0.47	0.60	0	2	1
P. gomesiana Welw. *ex* Oliv.	71	1.97	1.55	0.72	3	3	1	2	1	2	0	1	1	1	0.51	0.73	0	2	1
P. gomesiana Welw. *ex* Oliv.	72	2.00	1.37	0.92	2	3	1	2	1	2	0	1	1	1	0.38	0.60	0	2	1
P. gomesiana Welw. *ex* Oliv.	73	2.16	1.50	1.07	2	3	1	2	1	2	0	1	1	1	0.46	0.71	0	2	1

P. guerichiana Engl.	74	3.22	1.51	0.76	3	2	1	2	1	2	0	1	2	1	1.23	1.17	1	2	2
P. guerichiana Engl.	75	3.25	1.37	0.61	3	3	1	2	1	2	0	1	4	1	1.31	1.20	1	2	2
P. guerichiana Engl.	76	3.54	1.33	0.67	3	3	1	2	1	2	0	1	4	1	1.38	1.13	1	2	2
P. guerichiana Engl.	77	3.59	1.45	0.83	2	2	1	2	1	2	0	1	4	1	1.23	1.24	1	2	2
P. guerichiana Engl.	78	3.46	1.55	0.79	3	2	1	2	1	2	0	1	4	1	1.34	1.36	1	2	2
P. huillensis Welw. *ex* Oliv.	79	2.98	1.53	0.89	2	3	1	2	2	2	0	0	0	1	0.78	0.98	1	2	1
P. huillensis Welw. *ex* Oliv.	80	2.63	1.30	0.94	2	3	1	2	2	2	0	0	0	1	0.79	0.93	1	2	1
P. huillensis Welw. *ex* Oliv.	81	3.07	1.53	1.20	2	3	1	2	2	2	0	0	0	1	0.80	0.99	1	2	1
P. huillensis Welw. *ex* Oliv.	82	3.05	1.52	1.19	2	3	1	2	2	2	0	0	0	1	0.86	1.00	1	2	1
P. huillensis Welw. *ex* Oliv.	83	2.89	1.37	1.07	2	3	1	2	2	2	0	0	0	1	0.96	0.99	1	2	1
P. kalaxariensis Schinz	84	4.03	1.82	1.47	2	3	1	2	2	1	0	0	0	1	1.12	1.29	1	2	1
P. kalaxariensis Schinz	85	3.05	1.34	1.01	2	3	1	2	2	1	0	0	0	1	1.05	1.13	1	2	0
P. kalaxariensis Schinz	86	3.49	1.77	1.47	2	3	1	2	2	1	0	0	0	1	0.96	1.18	1	2	1
P. kalaxariensis Schinz	87	2.95	1.57	1.16	2	3	1	2	2	1	0	0	0	1	0.91	1.04	1	2	1
P. kalaxariensis Schinz	88	2.63	1.48	1.26	2	3	1	2	2	2	0	0	0	1	1.05	1.30	1	2	1
P. laxifolia Exell	89	3.17	1.72	1.39	2	3	1	2	1	2	0	0	0	1	1.19	1.37	1	2	0
P. laxifolia Exell	90	3.34	2.16	1.62	2	3	1	2	1	2	0	0	0	1	1.15	1.37	1	2	0
P. laxifolia Exell	91	3.19	1.77	1.33	2	3	1	2	1	2	0	0	0	1	1.25	1.37	1	2	0
P. laxifolia Exell	92	4.13	2.04	1.53	2	3	1	2	1	2	0	0	0	1	0.78	1.13	1	2	1
P. laxifolia Exell	93	3.90	2.10	1.40	2	3	1	2	1	2	0	0	0	1	0.83	1.11	1	2	1
P. leptophylla Burch. var. *leptophylla*	94	2.90	1.28	0.74	2	3	1	2	1	2	0	1	2	1	1.55	0.89	1	2	2
P. leptophylla Burch. var. *leptophylla*	95	2.93	1.11	0.68	2	3	1	2	1	2	0	1	2	1	1.42	0.97	1	2	2

P. leptophylla Burch. var. *leptophylla*	96	3.01	1.32	0.61	3	3	1	2	1	2	0	1	2	1	1.50	0.91	1	2	2
P. leptophylla Burch. var. *leptophylla*	97	3.02	1.29	0.68	3	3	1	2	1	2	0	1	2	1	1.31	0.95	1	2	2
P. leptophylla Burch. var. *leptophylla*	98	3.08	1.35	0.83	2	3	1	2	1	2	0	1	2	1	1.55	1.04	1	2	2
P. luenensis Paiva	99	2.76	1.56	1.34	2	3	1	1	2	1	0	0	0	1	0.89	1.24	1	2	1
P. luenensis Paiva	100	2.06	1.19	0.74	2	3	1	1	2	1	0	0	0	1	0.78	0.94	1	2	1
P. luenensis Paiva	101	2.15	1.36	1.17	2	3	1	1	2	2	0	0	0	1	1.09	1.45	1	2	1
P. luenensis Paiva	102	2.22	1.26	1.16	1	3	1	1	2	2	0	0	0	1	1.16	1.49	1	2	1
P. macrostigma Chodat	103	3.00	1.95	1.01	2	3	1	2	1	3	0	1	2	1	0.79	1.36	1	2	1
P. macrostigma Chodat	104	3.34	1.99	1.28	2	3	1	2	1	3	0	1	2	1	0.77	1.34	1	2	1
P. macrostigma Chodat	105	3.38	2.02	1.30	2	3	1	2	1	3	0	1	2	1	0.75	1.35	1	2	1
P. macrostigma Chodat	106	3.18	2.05	1.22	2	3	1	2	1	3	0	1	2	1	0.79	1.37	1	2	1
P. macrostigma Chodat	107	3.02	1.74	1.02	2	3	1	2	1	3	0	1	2	1	0.81	1.17	1	2	1
P. melilotoides Chodat	108	1.04	0.79	0.61	2	4	0	0	0	0	0	0	0	1	0.26	0.27	1	2	3
P. melilotoides Chodat	109	1.04	0.80	0.60	2	4	0	0	0	0	0	0	0	1	0.28	0.31	1	2	3
P. melilotoides Chodat	110	1.15	0.71	0.56	2	3	0	0	0	0	0	0	0	1	0.37	0.32	1	2	3
P. melilotoides Chodat	111	0.92	0.78	0.54	2	4	0	0	0	0	0	0	0	1	0.21	0.24	1	2	3
P. melilotoides Chodat	112	1.22	0.76	0.57	2	3	0	0	0	0	0	0	0	1	0.38	0.29	1	2	3
P. mendoncae E.M.A. Petit	113	2.64	1.67	1.17	2	3	1	2	1	3	0	1	2	1	0.66	1.12	1	2	1
P. mendoncae E.M.A. Petit	114	2.69	1.56	1.11	2	3	1	2	1	3	0	1	2	1	0.71	1.04	1	2	1
P. mendoncae E.M.A. Petit	115	2.63	1.59	1.14	2	3	1	2	1	3	0	1	2	1	0.65	1.07	1	2	1
P. mendoncae E.M.A. Petit	116	2.69	1.68	1.18	2	3	1	2	1	3	0	1	2	1	0.72	1.13	1	2	1
P. mendoncae E.M.A. Petit	117	2.90	1.69	0.95	2	3	1	2	1	3	0	1	2	1	0.64	1.07	1	2	1

P. mossamedensis Paiva	118	3.76	1.64	0.93	2	3	1	2	1	2	0	1	1	1	1.03	0.92	1	2	1
P. mossamedensis Paiva	119	3.15	1.72	0.92	2	3	1	2	2	2	0	0	0	1	0.89	0.76	1	2	1
P. mossamedensis Paiva	120	3.12	1.54	0.90	2	3	1	2	1	2	0	1	1	1	0.85	0.79	1	2	1
P. mossamedensis Paiva	121	3.03	1.55	0.88	2	3	1	2	2	2	0	1	1	1	0.79	0.82	1	2	1
P. myriantha Chodat	122	1.43	0.59	0.40	2	3	1	1	2	2	0	1	1	1	0.25	0.38	1	2	2
P. myriantha Chodat	123	0.92	0.44	0.36	1	3	1	1	2	2	0	1	1	1	0.15	0.11	1	2	2
P. myriantha Chodat	124	0.95	0.48	0.37	2	3	1	1	2	2	0	1	1	1	0.15	0.12	1	2	2
P. myriantha Chodat	125	1.13	0.47	0.37	2	3	1	1	2	2	0	1	1	1	0.21	0.33	1	2	2
P. myriantha Chodat	126	1.12	0.49	0.37	2	3	1	1	2	2	0	1	1	1	0.20	0.28	1	2	2
P. myrtillopsis Welw. *ex* Oliv.	127	2.45	1.90	0.79	3	3	1	2	2	2	2	0	0	1	0.76	1.05	1	2	2
P. nambalensis Gürke	128	2.69	1.31	0.82	2	3	1	2	1	3	0	1	3	1	1.04	0.87	1	2	1
P. nambalensis Gürke	129	2.52	1.34	0.88	2	3	1	2	1	3	0	1	3	1	1.04	0.95	1	2	1
P. nambalensis Gürke	130	2.28	1.33	0.92	2	3	1	2	1	3	0	1	3	1	1.09	0.76	1	1	1
P. nambalensis Gürke	131	2.14	1.07	0.68	2	3	1	2	1	3	0	1	3	1	1.16	0.71	1	1	1
P. nambalensis Gürke	132	2.30	1.36	1.08	2	3	1	2	1	3	0	1	3	1	1.15	0.91	1	1	1
P. nematophylla Exell	133	3.56	1.43	1.40	2	3	1	2	2	2	0	0	0	1	1.19	1.30	1	2	1
P. nematophylla Exell	134	3.36	1.45	1.40	2	3	1	2	2	2	0	0	0	1	1.29	1.36	1	2	1
P. nematophylla Exell	135	3.97	1.98	1.38	2	3	1	2	2	2	0	0	0	1	1.41	1.41	1	2	1
P. nematophylla Exell	136	3.78	1.88	1.55	2	3	1	2	2	2	0	0	0	1	1.43	1.35	1	2	1
P. nematophylla Exell	137	3.73	1.82	1.32	2	3	1	2	2	2	0	0	0	1	1.15	1.23	1	2	1
P. oliverana Exell & Mendonça	138	1.82	1.15	0.59	3	3	1	2	2	3	0	1	2	1	0.50	0.72	1	2	1
P. oliverana Exell & Mendonça	139	1.85	1.17	0.62	3	3	1	2	1	3	0	1	2	1	0.56	0.75	1	2	1

P. oliverana Exell & Mendonça	140	1.81	1.12	0.62	3	3	1	2	1	3	0	1	2	1	0.53	0.70	1	2	2
P. oliverana Exell & Mendonça	141	2.01	1.24	0.66	3	3	1	2	2	3	0	1	2	1	0.50	0.72	1	2	1
P. pallida E.Mey. *ex* Harv.	142	1.52	0.90	0.43	3	1	1	2	1	2	0	1	1	1	0.29	0.33	1	1	1
P. pallida E.Mey. *ex* Harv.	143	1.40	0.89	0.43	3	1	1	2	1	2	0	1	1	1	0.28	0.31	1	1	1
P. pallida E.Mey. *ex* Harv.	144	1.40	0.91	0.45	3	1	1	2	1	2	0	1	1	1	0.28	0.35	1	1	1
P. pallida E.Mey. *ex* Harv.	145	1.58	0.95	0.51	3	1	1	2	1	2	0	1	1	1	0.35	0.35	1	1	1
P. pallida E.Mey. *ex* Harv.	146	1.49	0.82	0.50	3	1	1	2	1	2	0	1	1	1	0.31	0.29	1	1	1
P. paludicola Gürke	147	1.01	0.80	0.61	2	4	1	1	2	2	0	0	0	1	0.11	0.35	0	2	2
P. paludicola Gürke	148	1.22	0.90	0.78	2	3	1	1	2	2	0	0	0	1	0.20	0.43	0	2	2
P. paludicola Gürke	149	1.25	0.89	0.78	2	3	1	1	2	2	0	0	0	1	0.15	0.40	0	2	2
P. paludicola Gürke	150	1.13	0.80	0.74	1	3	1	2	2	2	0	1	1	1	0.23	0.43	1	2	2
P. paludicola Gürke	151	1.14	0.86	0.79	1	4	1	2	2	2	0	1	1	1	0.25	0.17	1	2	2
P. petitiana A.Rich. subsp. *petitiana* var. *petitiana*	152	1.86	1.06	0.64	2	3	1	2	2	2	0	1	1	1	0.50	0.61	1	2	1
P. petitiana A.Rich. subsp. *petitiana* var. *petitiana*	153	2.02	1.11	0.78	2	3	1	2	2	2	0	1	1	1	0.54	0.63	1	2	1
P. petitiana A.Rich. subsp. *petitiana* var. *petitiana*	154	1.81	0.98	0.61	2	3	1	2	2	2	0	0	0	1	0.54	0.59	1	2	1
P. petitiana A.Rich. subsp. *petitiana* var. *petitiana*	155	2.13	1.05	0.81	2	3	1	2	1	2	0	0	0	1	0.72	0.65	1	2	1

P. petitiana A.Rich. subsp. *petitiana* var. *petitiana*	156	2.01	1.15	0.72	2	3	1	2	1	2	0	0	0	1	0.64	0.66	1	2	1
P. resendeana Paiva	157	2.41	1.48	0.78	3	3	1	2	1	2	0	0	0	1	0.86	1.14	1	2	1
P. rivularis Gürke	158	1.95	1.01	1.07	1	3	1	1	2	2	0	0	0	1	0.29	0.56	1	2	1
P. rivularis Gürke	159	1.92	1.04	0.75	2	3	1	1	2	2	0	0	0	1	0.41	0.59	1	2	1
P. rivularis Gürke	160	1.86	0.95	0.82	2	3	1	1	2	2	0	0	0	1	0.35	0.58	1	2	1
P. rivularis Gürke	161	1.68	0.92	0.79	2	3	1	1	2	2	0	0	0	1	0.35	0.55	1	2	1
P. rivularis Gürke	162	1.73	0.93	0.82	2	3	1	1	2	2	0	0	0	1	0.39	0.61	1	2	1
P. robusta Gürke	163	4.41	2.22	1.79	2	3	1	2	2	2	0	0	0	1	1.60	1.66	1	2	0
P. robusta Gürke	164	4.54	2.13	1.74	2	3	1	2	2	2	0	0	0	1	1.56	1.67	1	2	0
P. robusta Gürke	165	3.88	1.80	1.46	2	3	1	2	2	2	0	0	0	1	1.62	1.69	1	2	0
P. robusta Gürke	166	3.71	1.80	1.46	2	3	1	2	2	2	0	0	0	1	1.46	1.41	1	2	1
P. robusta Gürke	167	3.88	1.85	1.36	2	3	1	2	2	2	0	0	0	1	1.44	1.43	1	2	1
P. schinziana Chodat	168	3.14	1.69	0.99	2	3	1	2	2	2	1	0	0	1	0.97	0.80	1	2	1
P. schinziana Chodat	169	3.17	1.74	0.85	3	3	1	2	2	2	1	0	0	1	0.94	0.82	1	2	1
P. schinziana Chodat	170	3.22	1.90	1.10	2	3	1	2	2	2	1	0	0	1	0.99	0.86	1	2	1
P. schinziana Chodat	171	3.28	1.85	0.84	3	3	1	2	2	2	1	0	0	1	1.03	0.92	1	2	1
P. schinziana Chodat	172	3.39	1.73	0.79	3	3	1	2	2	2	1	0	0	1	1.10	0.88	1	2	1
P. sphenoptera Fresen	173	2.47	1.60	0.99	2	3	1	2	1	2	2	0	0	1	0.63	0.84	1	2	2
P. sphenoptera Fresen	174	2.49	1.66	0.99	2	3	1	2	1	2	2	0	0	1	0.62	0.86	1	2	2
P. sphenoptera Fresen	175	2.48	1.63	0.96	2	3	1	2	1	2	2	0	0	1	0.68	0.80	1	2	2
P. sphenoptera Fresen	176	2.45	1.61	0.97	2	3	1	2	1	2	2	0	0	1	0.65	0.84	1	2	2
P. sphenoptera Fresen	177	2.14	1.31	0.67	2	3	1	2	1	2	2	0	0	1	0.44	0.76	1	2	1
P. spicata Chodat	178	0.65	0.47	0.44	1	4	1	2	2	2	0	1	1	0	0.00	0.00	0	0	0
P. spicata Chodat	179	0.76	0.48	0.49	1	3	1	2	2	2	0	1	1	0	0.00	0.00	0	0	0
P. spicata Chodat	180	0.75	0.47	0.47	1	3	1	2	2	2	0	1	1	0	0.00	0.00	0	0	0
P. spicata Chodat	181	0.64	0.42	0.42	1	4	1	2	2	2	0	1	1	0	0.00	0.00	0	0	0

P. spicata Chodat	182	0.71	0.47	0.47	1	4	1	2	2	2	0	1	1	0	0.00	0.00	0	0	0
P. stenopetala Klotzsch subsp. *casuarina* (Chodat) Paiva	183	4.28	2.08	1.56	2	3	1	2	2	2	0	1	1	1	0.91	1.12	1	2	1
P. stenopetala Klotzsch subsp. *casuarina* (Chodat) Paiva	184	4.63	2.38	1.53	2	3	1	2	2	2	0	1	1	1	0.91	1.26	1	2	1
P. stenopetala Klotzsch subsp. *casuarina* (Chodat) Paiva	185	3.36	2.05	1.33	2	3	1	2	1	2	0	0	0	1	0.94	1.27	1	2	1
P. stenopetala Klotzsch subsp. *casuarina* (Chodat) Paiva	186	3.33	2.04	1.46	2	3	1	2	1	2	0	0	0	1	0.97	1.24	1	2	1
P. stenopetala Klotzsch subsp. *casuarina* (Chodat) Paiva	187	4.10	2.20	1.33	2	3	1	2	2	2	0	1	1	1	0.93	1.17	1	2	1
P. usafuensis Gürke	188	2.84	1.27	0.79	2	3	1	2	1	3	0	1	2	1	0.69	0.86	1	2	1
P. usafuensis Gürke	189	2.19	1.23	0.90	2	3	1	2	1	3	0	1	2	1	0.55	0.80	1	2	1
P. usafuensis Gürke	190	2.29	1.28	0.86	2	3	1	2	1	3	0	1	2	1	0.57	0.84	1	2	1
P. usafuensis Gürke	191	2.20	1.07	0.64	2	3	1	1	1	3	0	1	2	1	0.58	0.75	1	2	1
P. usafuensis Gürke	192	1.73	0.83	0.53	2	3	1	1	1	3	0	1	2	1	0.28	0.49	1	2	1
P. welwitschii Chodat subsp. *pygmaea* (Gürke) Paiva	193	1.68	0.87	0.67	2	3	1	2	2	2	0	0	0	1	0.48	0.53	1	2	2
P. welwitschii Chodat subsp. *pygmaea* (Gürke) Paiva	194	1.43	0.82	0.60	2	3	1	2	1	2	0	1	1	1	0.39	0.53	1	2	2
P. welwitschii Chodat subsp. *pygmaea* (Gürke) Paiva	195	1.27	0.74	0.60	2	3	1	2	2	2	0	1	1	1	0.39	0.44	1	2	2

P. welwitschii Chodat subsp. *pygmaea* (Gürke) Paiva	196	1.50	0.84	0.57	2	3	1	2	2	2	0	1	1	1	0.39	0.48	1	2	2
P. welwitschii Chodat subsp. *pygmaea* (Gürke) Paiva	197	1.69	0.86	0.69	2	3	1	2	1	2	0	1	1	1	0.45	0.53	1	2	2
P. welwitschii Chodat subsp. *welwitschii*	198	1.23	0.93	0.79	2	4	1	2	2	2	0	1	1	1	0.11	0.28	1	2	3
P. welwitschii Chodat subsp. *welwitschii*	199	1.26	0.94	0.83	2	4	1	2	2	2	0	1	1	1	0.14	0.29	1	2	3
P. welwitschii Chodat subsp. *welwitschii*	200	1.14	0.72	0.60	2	3	1	2	1	2	0	0	0	1	0.35	0.44	1	2	3
P. welwitschii Chodat subsp. *welwitschii*	201	1.19	0.76	0.58	2	3	1	2	1	2	0	1	1	1	0.34	0.35	1	2	3
P. welwitschii Chodat subsp. *welwitschii*	202	1.45	1.14	0.83	2	4	1	2	2	2	0	1	1	1	0.35	0.48	1	2	3
P. xanthina Chodat	203	2.70	1.40	0.81	2	3	1	2	2	2	0	0	0	1	0.82	0.96	1	2	1
P. xanthina Chodat	204	2.69	1.31	0.86	2	3	1	2	2	2	0	0	0	1	0.78	0.97	1	2	1
P. xanthina Chodat	205	2.69	1.39	0.81	2	3	1	2	2	2	0	0	0	1	0.81	0.97	1	2	1
P. xanthina Chodat	206	2.87	1.51	0.96	2	3	1	2	1	2	0	0	0	1	0.62	0.89	1	2	1
P. xanthina Chodat	207	3.11	1.64	0.81	2	3	1	2	1	2	0	0	0	1	0.62	0.95	1	2	1
P. youngii Exell	208	1.46	0.79	0.49	2	3	1	2	2	2	0	0	0	1	0.22	0.39	1	2	1
P. youngii Exell	209	1.74	0.96	0.83	2	3	1	2	2	2	0	0	0	1	0.33	0.49	1	2	1
P. youngii Exell	210	1.70	0.92	0.83	2	3	1	2	2	2	0	0	0	1	0.31	0.54	1	2	1
P. youngii Exell	211	1.52	0.86	0.79	2	3	1	2	2	2	0	0	0	1	0.30	0.51	1	2	1
P. youngii Exell	212	1.56	0.95	0.79	2	3	1	2	2	2	0	0	0	1	0.34	0.52	1	2	1

Table A3. Results of PCA on the five continuous variables of 212 seeds of 46 taxa of Angolan *Polygala*. Codes of each variable (ID) and the respective coordinates along the axes of the three first components.

ID	Component 1	Component 2	Component 3
SB1	-0,966961	-0,047231	0,153541
SB2	-0,942891	0,184880	0,248319
SB3	-0,886720	0,385942	-0,246507
C2	-0,892958	-0,417174	-0,121177
C3	-0,962342	-0,102203	-0,058001

Table A4. Results of PCA on the five continuous variables of 212 seeds (cases) of 46 taxa of Angolan *Polygala*. Coordinates of each case along the axes of the three first components.

Cases	Component 1	Component 2	Component 3
P. acicularis	-1.59482	-0.13628	0.68231
P. acicularis	-2.19746	0.12487	0.60318
P. acicularis	-2.87506	-0.24550	-0.20917
P. acicularis	-2.27890	-0.02496	0.04418
P. acicularis	-1.97371	0.41910	0.14616
P. africana	3.88325	0.07371	-0.20143
P. africana	4.01177	-0.03274	-0.20248
P. africana	3.97306	0.03346	-0.21723
P. africana	3.76246	0.23671	-0.26419
P. africana	3.71214	0.27768	-0.23792
P. albida subsp. *albida*	0.35363	0.49475	-0.23460
P. albida subsp. *albida*	0.70017	0.35182	-0.11871
P. albida subsp. *albida*	-0.49499	0.49211	0.04248
P. albida subsp. *albida*	0.32276	0.48317	-0.22585
P. albida subsp. *albida*	0.30546	0.06462	-0.33042
P. albida subsp. *stanleyana*	1.14345	0.19976	0.50589
P. albida subsp. *stanleyana*	1.69664	-0.31200	0.34982
P. albida subsp. *stanleyana*	0.64497	0.04301	0.38178
P. albida subsp. *stanleyana*	0.67978	-0.18655	0.52456
P. albida subsp. *stanleyana*	0.89947	-0.19579	0.24440
P. angolensis	1.47424	0.08802	0.31730
P. antunesii	-0.18764	0.51823	0.63838
P. antunesii	-0.72701	0.76870	0.35421
P. antunesii	-0.44230	0.48804	0.40543
P. antunesii	0.53224	-0.10742	0.69613
P. antunesii	0.53063	-0.12723	0.53360
P. arenaria	1.34483	-0.10164	-0.07016
P. arenaria	1.20461	-0.11600	-0.05699
P. arenaria	1.06887	0.15265	-0.13481

P. arenaria	1.21531	-0.04659	-0.18472
P. arenaria	1.43941	-0.13174	-0.21299
P. arenicola	-0.40575	-0.31945	-0.60035
P. arenicola	-1.08244	0.26134	-0.39730
P. arenicola	-0.84330	-0.52544	-0.10922
P. arenicola	-0.63834	-0.75027	-0.13572
P. arenicola	-0.54543	-0.87940	-0.49329
P. baumii	-1.62074	-0.15142	0.02139
P. baumii	-1.83258	0.27808	-0.84777
P. baumii	-0.94825	-0.88113	0.03782
P. baumii	-2.50169	0.43084	0.36857
P. baumii	-1.05889	-0.43474	-0.39013
P. britteniana	-0.77722	-0.77703	-0.13336
P. britteniana	-0.47731	-0.75516	-0.02375
P. capillaris subsp. *capillaris*	3.67118	0.26213	-0.21007
P. capillaris subsp. *capillaris*	3.65188	0.29089	-0.22028
P. capillaris subsp. *capillaris*	3.51193	0.24421	-0.07452
P. capillaris subsp. *capillaris*	3.46955	0.32437	-0.12340
P. capillaris subsp. *capillaris*	3.47847	0.30258	-0.09913
P. dewevrei	1.34610	-0.30667	0.45850
P. dewevrei	0.46682	0.64653	-0.04651
P. dewevrei	1.08020	-0.51656	0.09997
P. dewevrei	0.38046	0.49508	0.00242
P. dewevrei	0.75216	0.28359	0.00243
P. erioptera	0.32715	-0.51634	0.62570
P. erioptera	0.22608	-0.50305	0.30529
P. erioptera	0.74602	-0.31818	0.27553
P. erioptera	0.75902	-0.28106	0.27630
P. erioptera	0.58661	-0.35903	0.48041
P. fragilis	1.18350	0.54353	0.41904
P. fragilis	1.10465	0.43429	0.41959
P. fragilis	0.64551	1.31720	-0.31158
P. fragilis	1.03676	0.80377	0.35281
P. fragilis	0.90680	0.64983	0.32779
P. ganguelensis	1.50787	-0.09198	0.14344
P. ganguelensis	1.40840	0.06103	0.14293
P. ganguelensis	1.45779	0.38556	0.27846
P. ganguelensis	1.64773	0.19400	0.21167
P. ganguelensis	1.79720	0.11356	0.25020
P. gomesiana	-0.39043	1.24576	-0.00197
P. gomesiana	0.19307	0.73703	0.01027
P. gomesiana	0.22974	0.18478	0.64945
P. gomesiana	0.41585	0.75638	0.15365
P. gomesiana	-0.22972	0.96127	0.00129

P. guerichiana	-1.72962	-1.30119	0.33155
P. guerichiana	-1.51119	-1.86647	0.37714
P. guerichiana	-1.69484	-1.88415	0.29517
P. guerichiana	-2.03921	-1.25862	0.23585
P. guerichiana	-2.28218	-1.50359	0.27494
P. huillensis	-1.09694	-0.13487	0.40740
P. huillensis	-0.69985	-0.15598	-0.15182
P. huillensis	-1.61219	0.46739	-0.19593
P. huillensis	-1.65423	0.33324	-0.24719
P. huillensis	-1.34386	-0.17708	-0.35573
P. kalaxariensis	-3.48918	0.46927	-0.28024
P. kalaxariensis	-1.57494	-0.55352	-0.32999
P. kalaxariensis	-2.85592	0.80488	-0.41553
P. kalaxariensis	-1.71442	0.21015	-0.21107
P. kalaxariensis	-2.05888	0.02955	-0.87396
P. laxifolia	-3.00264	0.15034	-0.70280
P. laxifolia	-3.82656	0.99281	-0.44489
P. laxifolia	-3.04531	-0.04575	-0.54892
P. laxifolia	-3.29493	1.39624	0.26563
P. laxifolia	-3.08663	1.10801	0.48426
P. leptophylla var. *leptophylla*	-1.30973	-1.90695	-0.22301
P. leptophylla var. *leptophylla*	-1.01951	-1.96377	-0.26054
P. leptophylla var. *leptophylla*	-1.19497	-2.08296	0.17050
P. leptophylla var. *leptophylla*	-1.10988	-1.64741	0.12034
P. leptophylla var. *leptophylla*	-1.78036	-1.75037	-0.28539
P. luenensis	-2.07660	0.54397	-0.72496
P. luenensis	-0.01323	-0.58939	-0.13989
P. luenensis	-1.78379	-0.33544	-1.14864
P. luenensis	-1.82523	-0.57032	-1.30727
P. macrostigma	-2.17635	0.22498	0.61694
P. macrostigma	-2.72624	0.83203	0.29607
P. macrostigma	-2.79635	0.92157	0.32621
P. macrostigma	-2.67952	0.71442	0.40762
P. macrostigma	-1.77738	0.14582	0.36539
P. melilotoides	2.46990	0.13632	-0.22878
P. melilotoides	2.40421	0.07045	-0.22452
P. melilotoides	2.38822	-0.24520	-0.29609
P. melilotoides	2.73005	0.09252	-0.10384
P. melilotoides	2.31136	-0.19969	-0.21302
P. mendoncae	-1.49867	0.72441	-0.06179
P. mendoncae	-1.28433	0.46626	-0.08303
P. mendoncae	-1.29784	0.64571	-0.09214
P. mendoncae	-1.62551	0.64005	-0.09576
P. mendoncae	-1.26253	0.31179	0.55042

P. mossamedensis	-1.86608	-0.44718	0.64234
P. mossamedensis	-1.27967	-0.04876	0.68390
P. mossamedensis	-1.04195	-0.15740	0.47759
P. mossamedensis	-0.94906	-0.09396	0.52818
P. myriantha	2.65177	-0.50654	0.04197
P. myriantha	3.55589	-0.36107	-0.12697
P. myriantha	3.47298	-0.31919	-0.08197
P. myriantha	3.07539	-0.53640	-0.14348
P. myriantha	3.13027	-0.48263	-0.09354
P. myrtillopsis	-1.13045	-0.03674	0.89514
P. nambalensis	-0.77079	-0.81107	-0.03787
P. nambalensis	-0.89449	-0.68472	-0.21697
P. nambalensis	-0.64420	-0.59123	-0.37925
P. nambalensis	0.01883	-1.36191	-0.35570
P. nambalensis	-1.15431	-0.40589	-0.75057
P. nematophylla	-2.83227	-0.03387	-0.94106
P. nematophylla	-2.93000	-0.20153	-1.09428
P. nematophylla	-3.95452	-0.15544	-0.16274
P. nematophylla	-3.94195	0.13853	-0.71697
P. nematophylla	-3.08520	0.15529	-0.10524
P. oliverana	0.92733	-0.33153	0.29675
P. oliverana	0.74840	-0.37403	0.22091
P. oliverana	0.91294	-0.33191	0.17499
P. oliverana	0.63803	-0.13861	0.36230
P. pallida	2.25813	-0.28286	0.44341
P. pallida	2.36480	-0.25357	0.39401
P. pallida	2.26818	-0.21514	0.36717
P. pallida	1.97436	-0.19803	0.32562
P. pallida	2.28441	-0.20668	0.17765
P. paludicola	2.54139	0.37020	-0.14391
P. paludicola	1.89822	0.58751	-0.35405
P. paludicola	1.98303	0.67735	-0.30677
P. paludicola	2.07202	0.39002	-0.47457
P. paludicola	2.22325	0.61396	-0.40532
P. petitiana subsp. *petitiana* var. *petitiana*	1.06133	-0.24526	0.12737
P. petitiana subsp. *petitiana* var. *petitiana*	0.66353	-0.00889	-0.05389
P. petitiana subsp. *petitiana* var. *petitiana*	1.19288	-0.41990	0.03150
P. petitiana subsp. *petitiana* var. *petitiana*	0.40893	-0.31690	-0.29532
P. petitiana subsp. *petitiana* var. *petitiana*	0.56762	-0.29148	0.03214
P. resendeana	-0.87535	-0.55865	0.19969
P. rivularis	0.74945	0.99662	-0.59165
P. rivularis	1.01784	0.13002	-0.02121
P. rivularis	1.12046	0.32695	-0.26442
P. rivularis	1.32198	0.27173	-0.31067

P. rivularis	1.12894	0.24207	-0.38822
P. robusta	-5.50925	0.39551	-0.69978
P. robusta	-5.38106	0.28173	-0.64497
P. robusta	-4.39501	-0.58992	-0.87572
P. robusta	-3.80059	-0.17744	-0.72284
P. robusta	-3.80156	-0.34065	-0.37296
P. schinziana	-1.47590	-0.07782	0.42198
P. schinziana	-1.33800	-0.29546	0.80103
P. schinziana	-1.98274	0.23129	0.49251
P. schinziana	-1.71122	-0.44804	0.91697
P. schinziana	-1.60071	-0.74928	0.85688
P. sphenoptera	-0.71910	0.48684	0.25613
P. sphenoptera	-0.80474	0.53551	0.34895
P. sphenoptera	-0.71947	0.37510	0.33982
P. sphenoptera	-0.71272	0.41912	0.28688
P. sphenoptera	0.50161	0.00619	0.52545
P. spicata	3.84432	0.15727	-0.20484
P. spicata	3.70723	0.25946	-0.24507
P. spicata	3.75084	0.21148	-0.22317
P. spicata	3.92945	0.08143	-0.23914
P. spicata	3.77137	0.21492	-0.23992
P. stenopetala subsp. *casuarina*	-3.58406	1.25384	0.23024
P. stenopetala subsp. *casuarina*	-4.20018	1.30925	0.80684
P. stenopetala subsp. *casuarina*	-2.96903	0.71356	0.18623
P. stenopetala subsp. *casuarina*	-3.12246	0.94248	-0.11284
P. stenopetala subsp. *casuarina*	-3.37441	0.81524	0.75156
P. usafuensis	-0.37420	-0.30578	0.29633
P. usafuensis	0.06931	0.22023	-0.12536
P. usafuensis	-0.04710	0.11085	0.03723
P. usafuensis	0.62284	-0.46642	0.17182
P. usafuensis	1.90224	-0.19253	0.18064
P. welwitschii subsp. *pygmaea*	1.42595	-0.23012	-0.23057
P. welwitschii subsp. *pygmaea*	1.80173	-0.23458	-0.19726
P. welwitschii subsp. *pygmaea*	2.07438	-0.23751	-0.34341
P. welwitschii subsp. *pygmaea*	1.84689	-0.26774	-0.06112
P. welwitschii subsp. *pygmaea*	1.43550	-0.14427	-0.25798
P. welwitschii subsp. *welwitschii*	2.12422	0.84904	-0.20450
P. welwitschii subsp. *welwitschii*	1.99790	0.88101	-0.28447
P. welwitschii subsp. *welwitschii*	2.20508	-0.17121	-0.39585
P. welwitschii subsp. *welwitschii*	2.28426	-0.13315	-0.23773
P. welwitschii subsp. *welwitschii*	1.23908	0.55887	-0.15231
P. xanthina	-0.72518	-0.42926	0.24528
P. xanthina	-0.66561	-0.32171	0.04069
P. xanthina	-0.71081	-0.42244	0.23087

P. xanthina	-0.83778	0.32257	0.34651
P. xanthina	-0.95686	0.05253	0.90863
P. youngii	2.32278	-0.13391	0.17380
P. youngii	1.28671	0.43876	-0.27236
P. youngii	1.31066	0.42716	-0.34876
P. youngii	1.56816	0.34738	-0.40955
P. youngii	1.39906	0.33323	-0.30017

Table A5. Results of FAMD on the five continuous variables and 13 categorical variables of 212 seeds of 46 taxa of Angolan *Polygala*. Codes of each variable (ID) and the respective coordinates along the axes of the three first components.

ID	Component 1	Component 2	Component 3
SB1	0.7268	5.31E-03	0.085355
SB2	0.712527	4.78E-04	0.068007
SB3	0.476838	9.64E-04	0.23064
C2	0.623037	7.67E-05	0.038405
C3	0.782039	6.99E-04	0.067864
SB4	0.542695	1.20E-01	0.192571
SB5	0.352153	5.15E-02	0.303621
SB6	0.069788	8.69E-01	0.004434
SB7	0.171736	8.73E-01	0.016941
SB8	0.36065	9.13E-01	0.379133
SB9	0.215988	8.93E-01	0.275402
CR1	0.021514	2.82E-04	0.026192
CR2	0.013808	3.40E-02	0.498222
CR3	0.180582	3.69E-02	0.506108
C1	0.62595	1.28E-01	0.06321
C4	0.49928	1.10E-01	0.032184
C5	0.631358	1.33E-01	0.352784
C6	0.411674	6.32E-01	0.192068

Table A6. Results of FAMD on 212 seeds of 46 taxa of Angolan *Polygala*. Numerical classification of the categories of categorical variables (ID) and the respective coordinates along the axes of the three first components.

ID	Component 1	Component 2	Component 3
SB4_1	-6.04659	-2.19846	1.167145
SB4_2	0.702443	0.344648	0.209431
SB4_3	0.484621	-0.25111	-1.74546
SB5_1	-1.45396	-0.57839	-6.11516

SB5_2	2.4792	-0.43001	-2.23513
SB5_3	0.45104	-0.11913	0.135374
SB5_4	-5.69429	1.779842	0.779706
SB6_0	-4.62964	13.14511	0.782188
SB6_1	0.111827	-0.31751	-0.01889
SB7_0	-4.62964	13.14511	0.782188
SB7_1	-1.68644	-0.58616	0.4033
SB7_2	0.542551	-0.25317	-0.12002
SB8_0	-4.62964	13.14511	0.782188
SB8_1	0.866454	-0.15832	-1.18468
SB8_2	-0.1322	-0.32144	0.838631
SB8_3	-8.80421	-3.22561	3.375319
SB9_0	-4.62964	13.14511	0.782188
SB9_1	-2.8691	-1.35858	2.40947
SB9_2	0.242803	-0.20522	-0.02417
SB9_3	1.375901	-0.21097	-1.559
CR1_0	-0.1395	-0.01162	0.029972
CR1_1	2.093196	-0.07433	1.533242
CR1_2	0.568581	0.095153	-0.50351
CR2_0	0.25419	0.321055	1.023467
CR2_1	-0.40298	-0.50899	-1.62257
CR3_0	0.25419	0.321055	1.023467
CR3_1	-1.97817	-0.67443	-1.49609
CR3_2	1.571652	-0.2669	-1.57398
CR3_3	1.358871	-0.34052	-2.38271
CR3_4	2.286894	-0.41429	-2.05053
C1_0	-7.80931	-2.84622	1.663441
C1_1	0.594618	0.216717	-0.12666
C4_0	-5.51689	-2.08005	0.93889
C4_1	0.671368	0.253128	-0.11426
C5_0	-7.80931	-2.84622	1.663441
C5_1	-0.41538	-0.50014	-5.08033
C5_2	0.637369	0.24706	0.083022
C6_0	-3.93905	-1.91409	1.761077
C6_1	1.086213	-0.1423	0.089539
C6_2	-0.12959	-0.16162	-1.06494
C6_3	-3.29935	7.400531	-0.21516

Table A7. Results of FAMD on the five continuous variables and 13 categorical variables of 212 seeds (cases) of 46 taxa of Angolan *Polygala*. Coordinates of each case, and the respective code (ID), along the axes of the three first components.

Cases	ID	Component 1	Component 2	Component 3
P. acicularis	1	1.796491	0.004372	1.439721
P. acicularis	2	2.193308	-0.0119	1.6849
P. acicularis	3	2.637219	-0.02253	1.943215
P. acicularis	4	2.235137	-0.00923	1.739356
P. acicularis	5	2.024954	0.004967	1.657059
P. africana	6	-8.48142	-3.38434	3.288015
P. africana	7	-8.56423	-3.37933	3.229466
P. africana	8	-8.53998	-3.37948	3.249612
P. africana	9	-9.23432	-2.99168	3.544594
P. africana	10	-9.20111	-2.9932	3.564908
P. albida subsp. *albida*	11	0.618683	0.15203	-0.54001
P. albida subsp. *albida*	12	0.870083	0.141817	-0.38896
P. albida subsp. *albida*	13	0.886385	0.143317	-0.41466
P. albida subsp. *albida*	14	0.682227	0.13863	-0.7416
P. albida subsp. *albida*	15	1.255924	0.107318	-0.44925
P. albida subsp. *stanleyana*	16	0.498279	0.027414	-0.71921
P. albida subsp. *stanleyana*	17	0.484598	0.030412	-0.76754
P. albida subsp. *stanleyana*	18	-0.008	0.035314	-1.22795
P. albida subsp. *stanleyana*	19	-0.36492	0.058562	-1.47759
P. albida subsp. *stanleyana*	20	0.16539	0.026903	-1.16487
P. angolensis	21	-0.76421	-0.0802	-0.4175
P. antunesii	22	0.532934	-0.01804	1.155651
P. antunesii	23	0.885389	-0.03248	1.3896
P. antunesii	24	0.702064	-0.02356	1.256126
P. antunesii	25	0.047009	-0.10554	0.2193
P. antunesii	26	0.04404	-0.10866	0.233997
P. arenaria	27	-0.12394	0.164708	-0.69529
P. arenaria	28	-0.02861	0.160258	-0.64769
P. arenaria	29	0.055578	0.155161	-0.56745
P. arenaria	30	-0.0385	0.161385	-0.63819
P. arenaria	31	-0.18446	0.171904	-0.73197
P. arenicola	32	0.559856	-0.18083	1.793668
P. arenicola	33	0.999092	-0.20703	2.090076
P. arenicola	34	0.869734	-0.1961	1.896632
P. arenicola	35	1.157916	0.051622	1.070082
P. arenicola	36	1.090758	0.054926	1.049748
P. baumii	37	0.747375	-0.33217	1.776305
P. baumii	38	1.935479	0.043503	0.881311
P. baumii	39	1.510313	0.073256	0.549104

P. baumii	40	1.909111	0.009329	1.667797
P. baumii	41	2.382809	-0.01701	1.839035
P. britteniana	42	0.716589	-0.58761	-1.37462
P. britteniana	43	1.591547	-0.22711	-1.76116
P. capillaris subsp. *capillaris*	44	-7.7041	-2.32244	2.6613
P. capillaris subsp. *capillaris*	45	-7.69207	-2.32276	2.671505
P. capillaris subsp. *capillaris*	46	-7.13203	-3.10947	0.998475
P. capillaris subsp. *capillaris*	47	-6.73806	-2.86886	0.242778
P. capillaris subsp. *capillaris*	48	-6.71746	-2.86915	0.261416
P. dewevrei	49	-0.3348	-0.22829	1.692858
P. dewevrei	50	-0.27448	-0.23207	1.709298
P. dewevrei	51	-0.91518	-0.3189	0.648555
P. dewevrei	52	-0.29391	0.037225	0.609668
P. dewevrei	53	-0.0988	0.020252	0.823591
P. erioptera	54	0.448121	0.145826	-0.1682
P. erioptera	55	0.44009	0.147017	-0.17181
P. erioptera	56	0.714403	0.008465	-0.65056
P. erioptera	57	0.773506	0.006508	-0.58933
P. erioptera	58	0.535021	0.019882	-0.72342
P. fragilis	59	-0.83889	-0.45488	0.784187
P. fragilis	60	-0.24884	0.097781	0.161132
P. fragilis	61	-0.19384	0.092498	0.182404
P. fragilis	62	-0.16035	0.088835	0.251049
P. fragilis	63	-0.06985	0.086382	0.282921
P. ganguelensis	64	-0.84433	-0.29591	-1.66361
P. ganguelensis	65	-0.78051	-0.29976	-1.61289
P. ganguelensis	66	-0.98444	-0.30373	-1.95163
P. ganguelensis	67	-1.10848	-0.29663	-2.03533
P. ganguelensis	68	-1.20649	-0.29244	-2.09881
P. gomesiana	69	-0.82317	-1.14585	-0.16674
P. gomesiana	70	-0.52633	-0.75548	-0.93045
P. gomesiana	71	-0.67056	-0.74983	-1.02067
P. gomesiana	72	-0.24581	-0.76998	-0.75688
P. gomesiana	73	-0.54543	-0.87293	-1.6441
P. guerichiana	74	2.211757	-0.43892	-2.44011
P. guerichiana	75	2.540638	-0.36327	-1.86394
P. guerichiana	76	2.685204	-0.48783	-2.40133
P. guerichiana	77	1.903508	-0.39749	-2.01021
P. guerichiana	78	2.018225	-0.40859	-1.92665
P. huillensis	79	1.459117	0.028066	1.26907
P. huillensis	80	1.181187	0.045354	1.159267
P. huillensis	81	1.773195	0.009712	1.563731
P. huillensis	82	1.803048	0.010228	1.568156
P. huillensis	83	1.604921	0.024487	1.409606

P. kalaxariensis	84	0.675389	-0.59243	2.68368
P. kalaxariensis	85	2.605629	-0.29778	2.991552
P. kalaxariensis	86	2.173285	-0.27168	2.795429
P. kalaxariensis	87	1.429539	-0.2278	2.299205
P. kalaxariensis	88	2.078781	0.012056	1.703761
P. laxifolia	89	2.16432	-0.35808	1.949554
P. laxifolia	90	2.700061	-0.3848	2.31326
P. laxifolia	91	2.200445	-0.35776	1.933581
P. laxifolia	92	3.018148	-0.0267	1.645267
P. laxifolia	93	2.891904	-0.01339	1.517282
P. leptophylla var. *leptophylla*	94	1.674886	-0.22657	-1.30878
P. leptophylla var. *leptophylla*	95	1.486142	-0.22216	-1.41709
P. leptophylla var. *leptophylla*	96	1.988683	-0.24371	-1.12021
P. leptophylla var. *leptophylla*	97	1.583427	-0.34965	-1.98187
P. leptophylla var. *leptophylla*	98	1.518876	-0.35195	-1.96575
P. luenensis	99	1.360457	-0.3044	2.644259
P. luenensis	100	0.018727	-0.23153	1.736317
P. luenensis	101	0.726112	-0.56918	2.016254
P. luenensis	102	1.606361	-0.03773	1.724282
P. macrostigma	103	2.568812	-0.26245	-0.98273
P. macrostigma	104	2.910053	-0.28772	-0.68733
P. macrostigma	105	2.955826	-0.29093	-0.65473
P. macrostigma	106	2.886849	-0.28152	-0.73169
P. macrostigma	107	2.289507	-0.25311	-1.10418
P. melilotoides	108	-4.08118	12.90532	0.678252
P. melilotoides	109	-4.03083	12.90196	0.70739
P. melilotoides	110	-4.97133	13.30338	0.873524
P. melilotoides	111	-4.92434	13.30217	0.888306
P. melilotoides	112	-5.14052	13.31275	0.763465
P. mendoncae	113	2.081887	-0.24145	-1.12318
P. mendoncae	114	1.939929	-0.23597	-1.2186
P. mendoncae	115	1.946967	-0.23618	-1.19848
P. mendoncae	116	2.167016	-0.24491	-1.08239
P. mendoncae	117	1.94522	-0.23942	-1.28574
P. mossamedensis	118	1.573978	0.021806	1.336159
P. mossamedensis	119	1.71894	-0.35196	-0.63301
P. mossamedensis	120	1.159735	-0.3188	-0.90216
P. mossamedensis	121	0.965604	-0.34908	-0.33037
P. myriantha	122	-3.4313	-0.79593	-1.85862
P. myriantha	123	-1.90423	-0.29981	-1.84469
P. myriantha	124	-2.46586	-0.26906	-2.11512
P. myriantha	125	-2.19013	-0.28263	-1.99265
P. myriantha	126	-2.22871	-0.28106	-2.00904
P. myrtillopsis	127	1.401368	-0.06404	0.13709

P. nambalensis	128	1.346681	-0.37273	-3.32424
P. nambalensis	129	0.921021	-0.34951	-3.6426
P. nambalensis	130	1.679074	-0.38694	-3.10003
P. nambalensis	131	1.588614	-0.23	-1.76889
P. nambalensis	132	1.668573	-0.22974	-1.70745
P. nematophylla	133	2.585401	-0.02905	2.011901
P. nematophylla	134	2.65387	-0.02502	2.032266
P. nematophylla	135	3.35577	-0.06148	2.347912
P. nematophylla	136	3.325365	-0.05848	2.412505
P. nematophylla	137	2.766858	-0.03791	2.063744
P. oliverana	138	0.577405	-0.28663	-2.65591
P. oliverana	139	0.323896	-0.31609	-2.11419
P. oliverana	140	0.512529	-0.32843	-1.9901
P. oliverana	141	0.30007	-0.28616	-3.05237
P. pallida	142	-1.46904	-0.57848	-6.13709
P. pallida	143	-1.5419	-0.57311	-6.17174
P. pallida	144	-1.47727	-0.57575	-6.13301
P. pallida	145	-1.28489	-0.58682	-6.01683
P. pallida	146	-1.49673	-0.57778	-6.11714
P. paludicola	147	-1.87703	-0.42376	0.420937
P. paludicola	148	-1.93554	-0.4232	0.398345
P. paludicola	149	-3.12501	-0.00685	0.342425
P. paludicola	150	-2.15566	-0.77117	-1.38989
P. paludicola	151	-3.09991	-0.37182	-1.22228
P. petitiana subsp. *petitiana* var. *petitiana*	152	0.568876	0.11903	0.146093
P. petitiana subsp. *petitiana* var. *petitiana*	153	0.472924	0.125873	0.061388
P. petitiana subsp. *petitiana* var. *petitiana*	154	-0.07627	0.111513	0.42856
P. petitiana subsp. *petitiana* var. *petitiana*	155	-0.37877	-0.274	-1.06345
P. petitiana subsp. *petitiana* var. *petitiana*	156	-0.12428	-0.28863	-0.8787
P. resendeana	157	1.431949	-0.04054	-0.05679
P. rivularis	158	-1.0391	-0.51145	1.22879
P. rivularis	159	-0.27361	0.031484	0.711288
P. rivularis	160	-0.35211	0.033396	0.712046
P. rivularis	161	-0.48625	0.04306	0.633117
P. rivularis	162	-0.35695	0.037304	0.704357
P. robusta	163	3.694604	-0.48115	3.506557
P. robusta	164	3.612848	-0.48145	3.449447
P. robusta	165	2.975047	-0.43767	3.004295
P. robusta	166	3.241082	-0.05202	2.325871
P. robusta	167	3.253998	-0.05517	2.287421
P. schinziana	168	2.000929	0.004463	1.872876

P. schinziana	169	2.335453	-0.01053	2.079217
P. schinziana	170	1.895096	-0.11563	1.185612
P. schinziana	171	2.153069	-0.12577	1.29384
P. schinziana	172	2.081434	-0.12419	1.234665
P. sphenoptera	173	0.623254	0.140889	-0.08383
P. sphenoptera	174	1.254699	0.098651	0.082789
P. sphenoptera	175	1.313853	0.096015	0.110704
P. sphenoptera	176	1.257321	0.099746	0.067083
P. sphenoptera	177	1.252748	0.099894	0.07055
P. spicata	178	-6.8702	-2.85587	0.17594
P. spicata	179	-6.89755	-2.85434	0.153493
P. spicata	180	-7.78576	-2.45373	0.302987
P. spicata	181	-7.84159	-2.45128	0.267413
P. spicata	182	-7.73981	-2.45735	0.339713
P. stenopetala subsp. *casuarina*	183	2.825351	0.004833	1.433183
P. stenopetala subsp. *casuarina*	184	2.913512	0.000712	1.534681
P. stenopetala subsp. *casuarina*	185	2.686331	-0.44974	0.799857
P. stenopetala subsp. *casuarina*	186	3.11384	-0.47248	0.985985
P. stenopetala subsp. *casuarina*	187	2.573234	-0.43684	0.631196
P. usafuensis	188	0.387858	-0.24364	-1.86036
P. usafuensis	189	-0.47619	-0.20452	-2.29543
P. usafuensis	190	1.351298	-0.21404	-1.63739
P. usafuensis	191	1.036794	-0.19103	-1.73018
P. usafuensis	192	1.121796	-0.19544	-1.71063
P. welwitschii subsp. *pygmaea*	193	-0.40758	0.114471	0.036812
P. welwitschii subsp. *pygmaea*	194	-0.90926	-0.21722	-2.26597
P. welwitschii subsp. *pygmaea*	195	-0.6713	-0.23254	-2.11223
P. welwitschii subsp. *pygmaea*	196	-1.23198	-0.24065	-1.74681
P. welwitschii subsp. *pygmaea*	197	-1.07254	-0.25127	-1.68453
P. welwitschii subsp. *welwitschii*	198	-1.22371	1.754203	-0.58957
P. welwitschii subsp. *welwitschii*	199	-1.66714	1.37508	-2.1707
P. welwitschii subsp. *welwitschii*	200	-2.54629	1.725917	-1.21303
P. welwitschii subsp. *welwitschii*	201	-2.46489	1.722093	-1.15782
P. welwitschii subsp. *welwitschii*	202	-1.94329	1.702453	-0.93142
P. xanthina	203	1.407341	0.0677	0.620258
P. xanthina	204	1.51E+00	6.10E-02	0.597184
P. xanthina	205	1.21E+00	4.53E-02	1.110647
P. xanthina	206	1.17E+00	4.55E-02	1.115683
P. xanthina	207	1.21E+00	4.57E-02	1.106579
P. youngii	208	-8.36E-01	1.44E-01	0.039224
P. youngii	209	-1.68E-01	1.09E-01	0.507075
P. youngii	210	-1.83E-01	1.11E-01	0.499914
P. youngii	211	-3.54E-01	1.21E-01	0.399736
P. youngii	212	-2.39E-01	1.17E-01	0.450891