



**Túlio Carmo
Conceição**

**O gênero *Ceratosanthes* Adans. (Cucurbitaceae
Juss.) no Brasil**

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Biologia Aplicada, realizada sob a orientação científica do Doutor Paulo Cardoso da Silveira, Professor Auxiliar do Departamento de Biologia da Universidade de Aveiro e coorientação da Doutora Vera Lúcia Gomes-Klein, Professora Associada do Instituto de Ciências Biológicas da Universidade Federal de Goiás.

Em memória a quem me ensinou a ter respeito e gosto pelas plantas, meu avo, e eterno professor, José Gonçalves do Carmo.

o júri

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palavras-chave

Análise de Componentes Principais, Distribuição Geográfica, Florística, Microscopia Eletrônica de Varredura, Neotropical, Pólen, Sinónimos, Taxonomia

resumo

O presente estudo teve como objetivo efetuar uma revisão taxonômica do gênero *Ceratosanthes* Adans. (Cucurbitaceae Juss.) no território brasileiro a fim de melhor definir as delimitações morfológicas assim como a distribuição geográfica e ampliar os estudos sobre a palinologia do grupo. Os espécimes estudados foram obtidos por meio de consultas às coleções de herbários nacionais e internacionais, além de expedições científicas ocorridas no período de 2010 e 2011. Todo o material estudado foi descrito e identificado por comparação com outras coleções ou espécimes tipo. Com base na revisão do gênero, são aqui apresentadas sete novas sinonímias, resultando em um total de cinco espécies para a flora brasileira. O estudo dos grãos de pólen indicou a forma dos grãos assim como dos muri e das columelas como elementos de valor taxonômico significativos. Apresenta-se neste trabalho pranchas ilustrativas, mapas de distribuição dos espécimes e eletromicrografias dos grãos de pólen além de uma chave analítica baseada nas características macro-morfológicas e uma outra apoiada nos estudos palinológicos.

keywords

Floristics, Geographic Distribution, Neotropical, Pollen, Principal Component Analysis, Scanning Electronic Microscopy, Synonyms, Taxonomy

abstract

This study aimed to review the genus *Ceratosanthes* Adans. (Cucurbitaceae Juss.) in the Brazilian territory in order to better define the morphological delimitations as well as the geographical distribution and expand the studies on the palynology of the genus. The specimens studied were obtained from collections held at national and international herbaria, and scientific expeditions that occurred between 2010 and 2011. All material studied was adequately described and identified by comparison with type specimens and other properly identified collections. Based on this review of the genus, seven new synonyms are presented, resulting in five species for the Brazilian flora. This study indicates pollen grain shape as well as muri and columellae as elements of significant taxonomic value. Furthermore, an analytical key based on macro-morphological characteristics, another key based on palynological studies, illustrations, distribution maps of specimens and electron micrographs of the pollen grains are presented.

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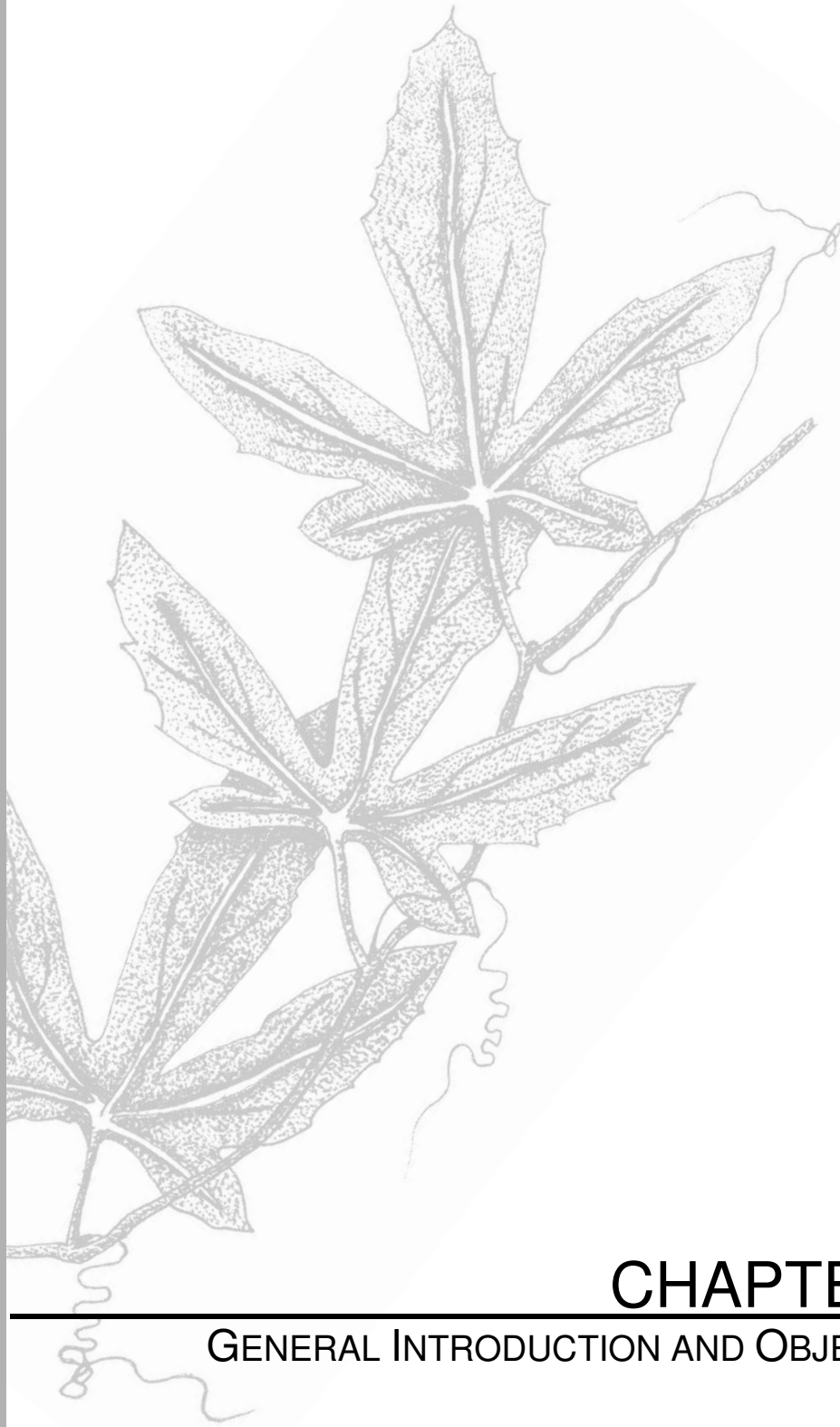
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*“Não te deixes destruir...
Ajuntando novas pedras e construindo novos poemas.
Recria tua vida, sempre, sempre.
Remove pedras e planta roseiras e faz doces.
Recomeça.
Faz de tua vida mesquinha um poema.
E viverás no coração dos jovens e na memória das gerações que hão de vir.
Esta fonte é para uso de todos os sedentos.
Toma a tua parte.
Vem a estas páginas e não entres seu uso aos que têm sede.”*

Aninha e suas Pedras
Cora Coralina - 1981

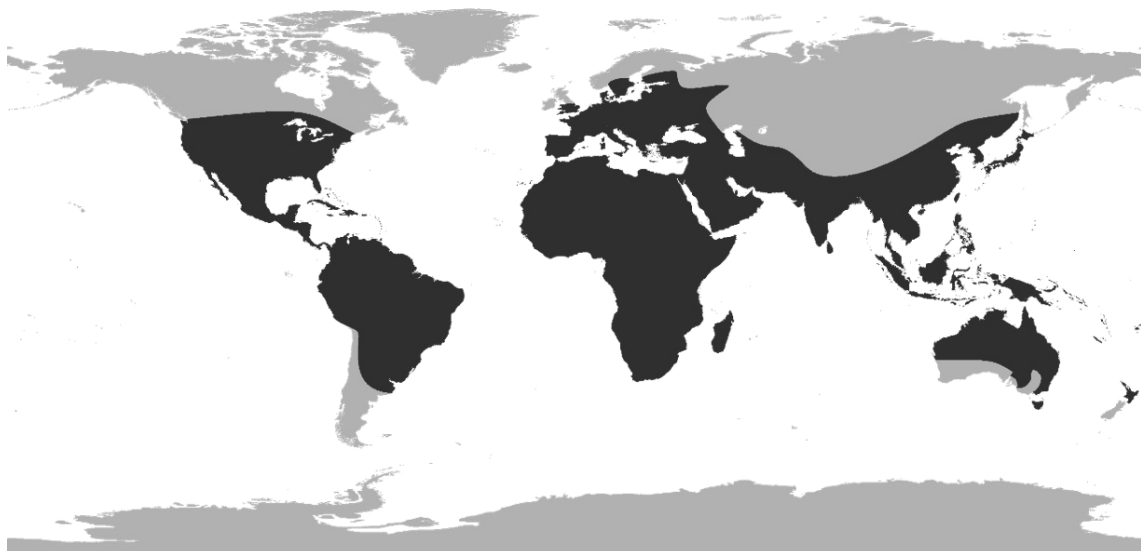


CHAPTER 1

GENERAL INTRODUCTION AND OBJECTIVES

INTRODUCTION

The Cucurbitaceae Juss., or vine crops family, is one of the most important botanical group with numerous domesticated species being extensively cultivated as source of food like vegetable sponges (*Luffa* Mill.), pumpkins and squashes (*Cucurbita* L.), cucumbers (*Cucumis* L.), melons, watermelons (*Citrullus* Schrad.), and others (Jeffrey 1978; Yang & Walters 1992; Pozner 1998). With 97 genera and 950 species, the family has four diversity hotspot regions in the world: Southeast Asia, West Africa, Madagascar and Mexico (Schaefer & Renner 2011a). In general, the species of Cucurbitaceae are frozen sensitive, this results in a wide distribution on tropical and subtropical regions of the world (Fig. 1.1). The few native species occurring in temperate regions spend the winter as seeds or tubers underground (Jeffrey 1980).



Stevens, 2012 - modified

Figure 1.1: Distribution of the family Cucurbitaceae Juss.

THE MORPHOLOGY OF CUCURBITACEAE JUSS.

The species of Cucurbitaceae are in general perennial or annual herbs or lianas often with presence of underground rootstocks or tuberose roots. In general, the leaves are simple, palmately lobed or palmately cleft, in spiral and stipulate with one or a branch of tendrils per node to anchor and support the stem. When bruised, the leaf blade or stem can have a very unpleasant smell (Burkill, 1985). The flowers develop in axillary inflorescences, under variable

structural types or solitary, usually whitish or yellowish, with some exceptions like *Gurania* that has vivid orange corollas (Jeffrey, 1984). The perianth is tubular with an hypanthium, the calix is imbricate with 5 sepals, free or connate at the base, and the corolla is apopetalous or simpetalous, greenish to white or vibrant yellow to orange color with membranaceous to fleshy petals. According to Schaefer & Renner 2011a, just a few species within Cucurbitaceae have an androdioecious or bisexual sexual system, while most taxa are 50% monoecious and 50% dioecious. Nevertheless, Pozner (1998) highlighted that, frequently, the juvenile monoecious species just present staminate flowers, being necessary some level of maturity for the simultaneous development of pistillate and staminate flowers. Therefore, this contributes to an erroneous simplification of the interpretation of the reproductive biology of these plants. The androecium is formed by 2, 3 or 5 stamens, alternipetalous, distinct or connate in the middle or at the margin of the hypanthium, often connate in two pairs or sometimes monadelphous as in *Sechium* P. Browne; anthers are typically basifixed or sometimes dorsifixed, with thecae longitudinally dehiscent. Jeffrey (1984) described the anthers of Cucurbitaceae as having a variable number of thecae, when 5, all of them are unilocular, if 3, one is unilocular and two are bilocular and if 2, all are bilocular. Pistillodium in general with 3 carpels, rarely 1 or 5, unilocular, 1 or 3 styles and 1 or 2 stigmas. Placentation usually is parietal, with anatropous, bitegmic ovules, generally ∞ . Fruits are variable, smooth, ridged, with a verrucose surface or covered by spines, indehiscent, less often operculate or valvately dehiscent as *Momordica charantia* L.; seeds frequently numerous, without endosperm and compressed, winged or enclosed by mucilage (Jeffrey 1984; Simpson 2006; Schaefer & Renner 2011b).

Diverse studies concerning pollen morphology, like Awasthi (1961); Marticorena (1963); Jeffrey (1964); Stafford & Sutton (1994); van der Ham *et al.* (1999, 2010), Pruesapan *et al.* (2007); Kouonon *et al.* (2009) and Lima & Miotto (2011). Have been published due the contribution of this discipline for the taxonomy of the group (Zienkiewicz, A. *et al.* 2012). Morphological characters of the pollen grains are significant to characterize some taxonomical ranks from subfamily, to tribe, genera and some groups of species. The classical division of Cucurbitaceae in the subfamilies Cucurbitoideae and Zanonioideae, for a while, was supported by the pollen morphology. However, Schaefer & Renner (2011a)

in a recent phylogenetic study indicated that all morphological characters used to characterize Zanonioideae, including the pollen grains, are not restricted to this subfamily, although, they continue to accept the classical circumscription of 15 tribes in Cucurbitaceae.

The pollen morphology in Cucurbitaceae is highly diversified in terms of size, ornamentation and number of apertures. The grains can be tectate to intectate, with variable ornamentation from reticulate (*Sicyos* L.), to striate (*Trichosanthes* L.) or echinate (*Cayaponia* Silva Manso) (Pruesapan & van der Ham 2005; Simpson 2006; Barth *et al.* 2007; Lima & Miotto 2011). In general, these species have large grains, but in a few groups like *Gurania* (Schltdl.) Cogn. and *Psiguria* Neck. ex Arn. have are very large. The tribe Coniandreae tends to have 3-colporate pollen, with some exceptions, like the genus *Ceratosanthes* that has 4-colporated or rarely 5-colporated grains.

THE SMALL AND OVERLOOKED GENUS *CERATOSANTHES* ADANS.

In Neotropics, the family Cucurbitaceae includes over 30 genera, among witch *Ceratosanthes* Adans. According with Schaefer & Renner (2011a) the genus is represented by four species in semi-arid plains and mountain slopes and roadsides. It is distributed between Central America to northern Argentina. The etymology of “*Ceratosanthes*” refers to Greek words “ceratos” (κερατος) and “anthos” (ανθος) that mean horned flowers (Fig. 1.2E).

The genus is composed by herbs with prostrate habit, with slender, striate and cylindrical stem and tuberous roots (Fig. 1.1C). The shape and indumentum of the leaves are very diverse and the occurrence of heterophylly is not rare in these species. The leaves are variable from simple to trifoliolate, three or four-lobate, palmately lobed, cleft, parted or divided, with glabrous, pubescent, puberulent or scabrous surface. The tendrils are simple and lateral to petiole. Male flowers in racemes or in simple umbellate inflorescences with glabrous or pubescent pedicels; hypanthium elongated, externally puberulent; sepals 5, triangular or widely triangular; corolla externally pubescent with five petals strongly bipartite in the apex. The androecium has three dorsifixed anthers inserted on the hypanthium and longitudinally dehiscent. Female flowers in smaller racemes or fasciculate inflorescences; perianth of the flowers as same as male. Pistil with elliptic ovary, two stigmas, each one bipartite and plumose.

The fruits are fleshy and ovoid (Fig.1.1F), red or orange when ripe, with 6 to 8 brownish subglobose seeds.

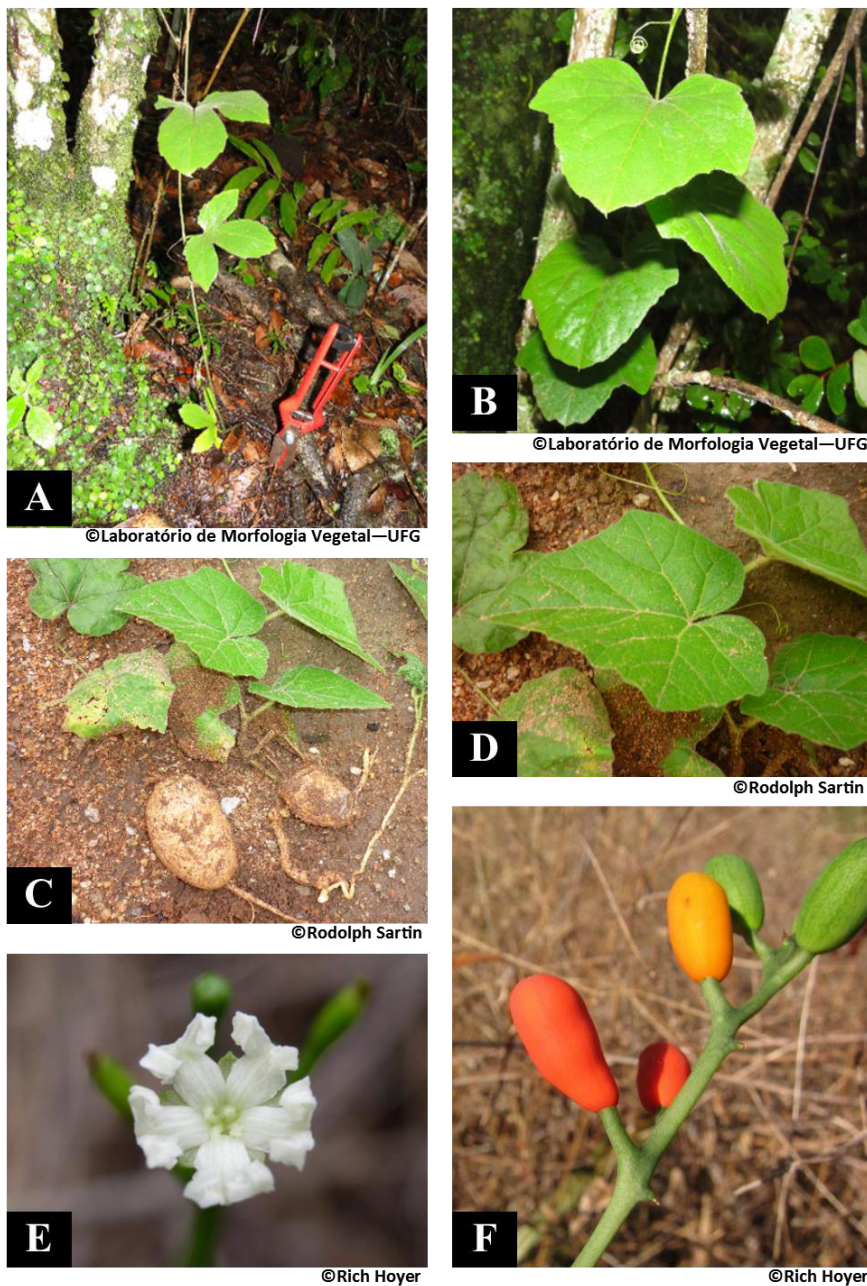


Figure 1.2: *Ceratosanthes tomentosa* Cogn. **A, B:** Habit; **C:** tuberous roots; **D:** leaf and tendrill; *Ceratosanthes hilariana* Cogn. **E:** Female flower detail; **F:** Fruits.

Burman (1756) was the first to mention a specimen of *Ceratosanthes* with the description and illustration of a specimen of *Trichosanthes* with bifid petals. With the creation of the binomial nomenclature, Linnaeus (1759) proposed, for these plants, the name *Trichosanthes palmata* (L). and Adanson (1763) was the first to mention the name “*Ceratosanthes*” separated of

"*Trichosanthes*". Persoon (1807) created the section *Ceratosanthes* and considered *Trichosanthes corniculata*, described by Lamarck (1783), as synonym of *Trichosanthes tuberosa*, published by Willdenow (1805). Sprengel in 1826 accepted the section *Ceratosanthes* as a genera publishing *T. tuberosa* as *Ceratosanthes tuberosa*. Few years later, Cogniaux, (1877) described seven new species to the genera. In 1878 he cites five species to the Brazilian flora, and later, in 1881, published *Ceratosanthes corniculata* (Lam.) Cogn. as the valid name to *C. tuberosa*. One more species was described by Cogniaux in 1888 and three others by Ridley in 1890. Later, The Geographic and Geologic Commission of São Paulo reports five species of *Ceratosanthes* occurring in the State of São Paulo in 1897. Cogniaux (1916) recognized a total of 15 species in the genus *Ceratosanthes* and in the next year, Urban (1918) considered *Trichosanthes palmata* L., *T. corniculata* Lamarck, *Ceratosanthes tuberosa* J.F.Gmel, *T. tuberosa* Willd. and *Ceratosanthes corniculata* (Lam.) Cogn. as synonymous of *Ceratosanthes palmata* (L.) Urb. Studying the *Ceratosanthes* occurrence in State of Rio Grande do Sul, Porto (1975) indicates *C. hilariana* as the only species in the region. Jeffrey (1978) recognized just five species of *Ceratosanthes* in a revision of Cucurbitaceae in New World; including, four well-known species and a new taxon not described, however, no mention is made to synonyms and to the geographical reference to the new species (Pozner 1998). Later, Jeffrey (1984), Jeffrey & Trujillo (1992) and Kearns (1998) indicate *Ceratosanthes palmata* as the only species occurring respectively in Suriname, Venezuela and Guayana Region in Venezuela. Pozner (1998) considered *C. diazzi* Lillo, *C. fiebrigii* Cogn. and *C. hassleri* Cogn. as synonym of *C. multiloba* Cogn. and mentioned this taxon and *C. hilariana* Cogn. as the two only species in Argentina.

The pollen of *Ceratosanthes* is not well-know with few studies restricted to *Ceratosanthes palmata* (Marticorena 1963; Jeffrey 1964) and *Ceratosanthes tomentosa* (Melhem 1966). The reticulate ornamentation and the 4-colporate configuration were described by Marticorena (1963) and based in those characters and other genera's descriptions Jeffrey (1964) included *Ceratosanthes* in the tribe *Melothriinae*, within which most genera share 3-porate and reticulate pollen, except *Ceratosanthes* that differs from the others by 4-colporate pollen grains (Marticorena 1963; Jeffrey 1964). Melhem (1966)

described the pollen of *C. tomentosa* and was the first to comment about the variation of numbers of colpi. In a recent classification, *Ceratosanthes* is included in the tribe *Coniandreae*, contrasting with most of the genera herein included by its 4-colporate instead of 3-colporate pollen (Schaefer & Renner, 2011b).

THESIS OBJECTIVES

So far, only Cogniaux (1916) analyzed the genus *Ceratosanthes* in its totality. The lack of studies has been filled up over the time by partial studies of the genus in floras and micro floras. Since the first description by Burman until now the flowers are used to delimitate the genera and only the leaves are useful to distinguish the species. The high diversity of leaf shapes in the genus, sometimes in the same specimen, results in erroneous or in indefinite identification. Other drawback due to the use of the leaves as taxonomical character is that they are frequently absent during or after the anthesis. This work endeavored to highlight new morphological and palynological elements of significant taxonomic value that can be used both for a better definition of species in Brazilian territory and to support future systematic studies within the family Cucurbitaceae.

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CHAPTER 2

A REVIEW OF THE GENUS *CERATOSANTHES* ADANS.
(CUCURBITACEAE JUSS.) IN BRAZIL

A REVIEW OF THE GENUS *CERATOSANTHES* ADANS. (CUCURBITACEAE JUSS.) IN BRAZIL

Resumo: O presente trabalho teve como objetivo revisar as espécies do gênero *Ceratosanthes* Adans. (Cucurbitaceae Juss.) encontradas no território brasileiro a fim de definir melhor as características morfológicas para cada uma das espécies ocorrentes e sua distribuição geográfica. Os espécimes estudados foram obtidos por meio de consultas às coleções dos herbários nacionais e internacionais, além de expedições científicas ocorridas no período de 2010 e 2011. Todo o material estudado foi descrito e identificado por meio de comparação com outras coleções ou espécimes tipos. Apresenta-se uma chave analítica para as cinco espécies ocorrentes no Brasil, assim como as descrições morfológicas, pranchas ilustrativas, mapas de distribuição e sete novas sinonímias.

Palavras chaves: Distribuição geográfica, florística, Neotropical, sinonímia, taxonomia

Abstract: The main objective of this study was to review the genus *Ceratosanthes* Adans. (Cucurbitaceae Juss.) in the Brazilian territory in order to characterize morphologically each occurring species and to define its geographic distribution. The specimens studied were obtained from collections of national and international herbaria and scientific expeditions occurring between 2010 and 2011. All material studied was adequately described and identified by comparison with type specimens and other properly identified collections. This paper presents an analytic key to all five species occurring in Brazil, along with morphological descriptions, illustrations and seven new synonyms.

Key word: Floristic, geographic distribution, Neotropical, synonyms, taxonomy,

INTRODUCTION

The family Cucurbitaceae Juss. includes about 97 genera and 950 species mostly distributed on tropical and subtropical regions of the world due to its sensitiveness to frozen temperatures (Jeffrey 1978; Nee 2007; Gomes-Costa & Alves 2012). The family is one of the most important sources of edible vegetables and several species have significant economic importance and are extensively cultivated such as vegetable sponges (*Luffa* Mill.), pumpkins and squashes (*Cucurbita* L.), cucumbers (*Cucumis* L.), melons, watermelons (*Citrullus* Schrad.), and others (Jeffrey 1978; Yang & Walters 1992, Pozner 1998; Schaefer & Renner 2011a). The Brazilian flora is estimated to contain 148 species and 30 genera of Cucurbitaceae among which *Ceratosanthes* Adans (Gomes-Klein *et al.* 2013). This genus comprising about five species characterized by the bipartite petals and has a Neotropical distribution occurring from Northeast of Argentina to South of Mexico, where one of the diversity centers of the family Cucurbitaceae is located, (Jeffrey 1984; Pozner 1998, Schaefer & Renner 2011b).

The first mention to a specimen of *Ceratosanthes* started early as 1756 when Burman described the bifid petals in a specimen of *Trichosanthes*. Later, Linnaeus (1759) described this species as *Trichosanthes palmata* L. and Adanson (1763) is the first to mention the name “*Ceratosanthes*” separated of “*Trichosanthes*”. In 1807, Persoon synonymizes *Trichosanthes corniculata*, described by Lamarck (1783), with *Trichosanthes tuberosa*, published by Willdenow (1805), and created the section *Ceratosanthes*. Sprengel in 1826 accepted the section *Ceratosanthes* as a genus publishing *T. tuberosa* as *Ceratosanthes tuberosa*. Based in leaf morphological characters, Cogniaux published in 1877 it's “*Diagnoses de Cucurbitacées*” on which he described seven new species of *Ceratosanthes*. Later, in 1881, he recognized five species on its account for *Flora brasiliensis*. Ridley (1890) published three other new species to the Brazilian flora as a result of his travel to the Archipelago of Fernando de Noronha, Pernambuco. Loefgren (1897) reported in the Bulletin of The Geographic and Geologic Commission of São Paulo five species of *Ceratosanthes* occurring in the State of São Paulo. Cogniaux (1916) recognized a total of 15 species in the genus *Ceratosanthes*. Urban (1918) considered

Thricosanthes palmata L., *T. corniculata* Lamarck, *Ceratosanthes tuberosa* J.F.Gmel, *T. tuberosa* Willd e *Ceratosanthes corniculata* (Lam.) Cogn. as synonymous of *Ceratosanthes palmata* (L.) Urb. Studying the occurrence of *Ceratosanthes* in the State of Rio Grande do Sul, Porto (1975) indicated *C. hilariana* as the only species in the region. Jeffrey (1978) recognized just five species of *Ceratosanthes* in a revision of Cucurbitaceae in the New World; including, four well-known species and a new taxon not determined. However, no mention is made to synonyms and to the geographical distribution of the new species (Pozner 1998). Later, Jeffrey (1984), Jeffrey & Trujillo (1992) and Kearns (1998) indicated *Ceratosanthes palmata* as the only species occurring respectively in Suriname, Venezuela and Guayana Region in Venezuela. Pozner (1998) considered *C. diazzi* Lillo, *C. fiebrigii* Cogn. and *C. hassleri* Cogn. as synonyms of *C. multiloba* Cog. and mentioned this taxon and *C. hilariana* Cogn. as the two only species in Argentina.

The aims of this study are to revise the morphology and taxonomy of the species of *Ceratosanthes* occurring in Brazil since the last study dates from 1916 and new material has been collected along the country and abroad providing new data and allowing us to revise morphological and nomenclatural relationships between the taxa.

METODOLOGY

This study is based mostly on specimens held at the following herbaria: BA, BM, BR, C, CAY, CEN, CEPEC, CETS, EAC, HB, HEPH, HJ, HST, HVASF, IBGE, IPA, K, LIL, MBM, NY, P, PEURFR, RB, S, SI, SP, SPF, UB, UEC and UFG according with Holmegren *et al.* (1990). Other specimens resulted from our own fieldwork in scientific expeditions between the years 2011 and 2012. The collected material was prepared according with the usual technics in botanic studies indicated in Bridson & Forman 1992. Later, the material was deposited in the UFG Herbarium. The identification of the studied specimens was based on comparison with type specimens and others previously identified by specialists and with literature pertaining to the genera like Cogniaux (1898), Pozner (1988) and Jeffrey & Trujillo (1992).

The morphologic terminology used in the descriptions of the species is based in Simpson (2006) and Souza & Lorenzi (2005). The measures were taken in wider parts of entire leaves, lobes and leaflets, the length of the petals does not include the bipartite portion of the apex and the tubular hypanthium.

Flowers of dry material were softened in boiling water with 1% of glycerin, and afterwards observed and measured using a stereoscope Olympus TL3[®]. Based in the descriptions of the species an analytic key was created. The distribution maps were plotted using the software DIVA-GIS 7.5 and all georeferencing data were based in information on the label of the specimens.

RESULTS AND DISCUSSION

SOME NOTES ABOUT *CERATOSANTHES* ADANS.

HABIT

The species within the genus *Ceratosanthes* are herbs with slender and striate stems, varying between climbing or prostrate habit according with the habitat. When in woods or edges of forest, the species have a stem with few ramifications and use the tendrils to anchor and grow towards light or next supporting plant. Species occurring in grazed areas usually have a prostrate, slender, more ramificated habit, with shorter internode regions. Furthermore, the branches can develop closer adopting a shrubby aspect, or be dispersed into different directions.

LEAVES

The leaves are always alternate and forming 90° with a solitary tendril in each node. The morphology of the leaves is diversified varying from entire, lobate or foliolate, and some species have heterophylly. The environmental conditions can affect directly the characters of the leaves. For example, *C. multiloba* displays a reduction of foliar area in drier regions. The indumentum is variable in glabrous, pubescent or scabrous. New leaves in *C. tomentosa* usually are pubescent and lose the trichomes over the time. During the anthesis of the flowers the species frequently are leave-less presenting only the inflorescence peduncle and tendrils.

INFLORESCENCE AND FLOWERS

The peduncle is axillar and longer in male than in female inflorescences. The flowers are organized between well-defined corymbs to racemes with flowers irregularly distributed, or racemelike fascicles. The male and female perianth are similar with tubular hypanthium with five greenish small fleshy sepals on the top of the tube, the corolla is white to greenish and has five long connate petals at the base. The exterior of the perianth is always covered by tector trichomes, and in *C. tomentosa* the density of indumentum is frequently puberulent or pubescent. Although here the species are described as monoecious or dioecious, the reproductive system in the species of *Ceratosanthes* still lacks considering that monoecious diclin species may develop pistillate flowers at the same time that the male flowers just when the species reach a specific maturity level, so to a concrete discussion about this, other studies supported by long term field observations are necessary.

FRUITS

The fruits are prolate ellipsoid berries, green with greenish strips and vivid red to orange when ripe, externally similar to fruits of *Coccina* spp. They usually have eight brownish and globose seeds per fruit and margin strongly boarded.

TAXONOMIC TREATMENT TO BRAZILIAN SPECIES OF *CERATOSANTHES* ADANS.:

***Ceratosanthes* Adans. Adans.**, Burm. *in* Plum. Pl. Amer. 1: tab 24. 1755; Fam. Pl. 2: 139, 535. 1763.; Juss. Gen. Plant. 396. 1789; Spreng. Anl. 2; Syst. Veget. 3:18; Schrad. *in* Linnaea 12:403; Arn. *in* Hook. J. Bot. 3:274; Roem. Syn. Mon. 2:16-93. 1846; Griseb. Fl. Brit. W. Ind. Isl. 289; Benth. & Hook. Gen. Plant. 1:833. 1867; Cogn. Diagn. Cucurb. Nouv. 2:29. 1877; Cogniaux *in* Engler, Pflanzenr. 4:275. 1916; Jeffrey *in* Brill, Flora Suriname. 5:462 – 463. 1984. Cat. Pl. Vasc. Argentina 3:19. 1998.

Type species: *Ceratosanthes palmata* (L.) Urb.

Climbing or prostrate herbs, with slender, striate and cylindrical stem. Leaves simple, trifoliolate, 3-4-lobate, palmately lobed, cleft, parted or divided, with glabrous, pubescent, puberulent or scabrous surface. Tendril simple and

lateral to petiole. Inflorescence with glabrous or pubescent peduncle, white or greenish flowers. Male flowers in racemes or in simple umbellate inflorescences; with glabrous or pubescent pedicels; hypanthium elongated, externally puberulent; sepals 5, triangular or widely triangular; corolla externally pubescent, petals 5, strongly bipartite in the apex. Anthers 3, dorsifixed, inserted on hypanthium, longitudinally dehiscent. Female flowers in smaller raceme or fasciculated inflorescences; flowers as same as male. Ovary ellipsoid, stigma 2, each bipartite and plumose. Fruits are globose to ellipsoide berries, red or orange when ripe, with 6 to 8 brown subglobose seeds.

General distribution: Neotropical distribution, five species in Brazil.

KEY TO SPECIES OF *CERATOSANTHES* ADANS. IN BRAZIL

1. Blade glabrous, subglabrous or rarely sparsely scabrous
 2. Coriaceous leaves..... **4- *C. rupicola***
 2. Membranous leaves
 3. Leaves with 3 to 5 lobes with margin or apex laciniate or irregular
..... **2- *C. multiloba***
 3. Leaves with 3 leaflets, 3 lobes entire or lateral lobes constricted or deeply bilobate with margin entire or sometimes sparsely dentate **3- *C. palmata***
1. Blade puberulent or pubescent to scabrous
 4. Stem glabrous or rarely pubescent, petiole glabrous **1- *C. hilariana***
 4. Stem and petiole pubescent or puberulent..... **5- *C. tomentosa***

SPECIMENS DESCRIPTIONS

1 – *Ceratosanthes hilariana* Cogn. Diagn. Cucurb. Nouv. 2:31-33. 1877; Cogn. in Mart., Fl. Bras. 6(4):67-68. t.18. 1878; Cogn. in DC. Mon. Phan. 3:722-723. 1881; in Engler, Pflanzenr. fig. 56 E-L, 243-244. 1916; Cat. Pl. Vasc. Rep. Argentina 3:19. 1998. **Typus:** “In Brasilia: Province de Goyas”, A. De Saint-Hilaire, cat. C¹, n^o. 777 bis (Sintypus P!); campos, prés de Meia ponte, prov. De Goyaz, id., cat C¹, n^o. 726, O (Sintypus P!); prov. De Minas-Geraes, id., cat B¹, n^o.1959 (Sintypus P!); campos, prés Poso alto, id., cat C¹, n^o. 981bis, (Sintypus P!); ad Lagoa Santa, Eug. Warming, 21 mart. 1864 (Sintypus C!).

= *Ceratosanthes parviflora* Cogn. in Bull. Acad. Belg. 3(16):242. 1888. Pflanzenr. 243. 1916. *Syn. nov.* **Typus:** Brazil, "prov. S. Catharina ad Blumenau", 02/X/1886, *Schenck 293* (Holotypus BR!).

Monoecious climbing herbs; stem sparsely branched, cylindrical, glabrous rarely pubescent. Leaves, 6.60 – 7.63 x 5.91 – 7.98 cm, deeply 3 lobed, or rather cordiforme with 3 lobes not so deeply divided; leaf blade puberulent to scabrous; petiole 1.00 – 1.37 cm, glabrous; leaf base cordate; sinus 0.96 – 1.46 cm deep x 1.71 – 2.57 cm; central lobe 5.26 – 6.14 x 3.17 – 3.74 cm, obovate, acuminate, crenate-dentate; lateral lobes 3.33 – 4.07 x 2.05 – 2.33 cm, margin crenate-dentate, apex acuminate to acute. Tendrils simple, glabrous, delicate. Male peduncle 7.30 – 10.60 cm, 6 – 9 flowers, glabrous; flowers 1.90 – 2.00 cm, pedicel approx. 0.5 cm, puberulent; hypanthium 1.20 – 1.40 cm long, calix with 5 sepals, ca. 1.00 x 1.00 mm, widely ovate to ovate, ciliate, acute; corolla with 5 petals ca. 2.00 x 1.50 mm, oblong, connate at the base, externally puberulent. Anther ca. 2.00 x 1.00 mm. Female peduncle 1.50 – 11.78 cm, with 3 – 13 flowers, glabrous, flowers approx. 1.70 cm; pedicels approx. 3.0 mm, puberulent; hypanthium and perianth identical to male flowers. Ovary 0.50 – 0.60 x ca. 1.00 mm, narrowly ellipsoid, puberulent; style approx. 5.0 mm long, stigma bifid and plumose. Fruit a globose berry, ca. 1.00 x 1.00 cm, one or two per branch; seeds approx. 8 per fruit, globose, ca. 4.00 x 4.00 mm, brown, bordered.

- *Comments:* *Ceratosanthes hilariana* is distinguishable from the other species by its strongly crenate-dentate or just dentate leaf margins, frequently with scabrous surface and central lobe obovate, oblance-ovate to widely elliptic. In this study, *C. parviflora* is considered as synonym of *C. hilariana* for sharing the crenate-dentate margin and scabrous surface. This is supported, also, by the geographic distribution of *C. hilariana* that is well distributed on Southeast and South regions of Brazil where the type material of *C. parviflora* was collected.

- *Material examined:* **Brazil. Goiás:** Campinaçu, região da Fazenda Praia Grande, 06/X/1995, fl. masc., Walter *et al.* 2674 (CEN); Goiânia, cercado da EMBRAPA, *s.d.*, fl. masc., Gomes-Klein & Lorenzi 4000 (UFG); Pirenópolis, Serra dos Pireneus, lado esquerdo da estrada para o topo da Serra,

24/XI/1994, Gomes-Klein & Nakajima 2611 (UFG); *loc. id.*, entrada da mata na base dos Três Picos, 01/II/2013, Gomes-Klein *et al.* 7707 (UFG); **Mato Grosso:** Garapú, 01/X/1964, Irwin, H.S. & Soderstrom *s.n.* (MBM 65406); **Minas Gerais:** Belo Horizonte, *leg. ign. s.n.* (RB); Caeté, XI/1915, fl. fem., Hoehne 6090 (R); *loc. id.* XI/1915, fl. masc., Hoehne 6092 (R); **São Paulo:** Capão Bonito, ± no Km 14 da rodovia C.Bonito-Itapeva, 9/XII/1966, fr. Mattos & Mattos 14878 (SP); Mogi-guaçu, Martinho Prado, Reserva Biológica da Fazenda Campininha, 22/IX/1980, fl. masc., Mantovani 1076 (SP); *loc. id.* 47 – 47°15'W, 22°10' – 22°20'S, 24/IX/1980, fl. masc., Custódio Filho 340 (SP); Pirassununga, Emas, 14/IX/1946, fl. masc. *et fl. fem.*, Kuhlmann 3186 (SP); *loc. id.* Km 221 da Rod. Anhanguera, 07/X/1975, fl. masc., Leitão Filho, Semir & Martins 1521 (UEC); *loc. id.*, Salto de Emas, Academia da Força Aérea Brasileira 23/IX/1980, fl. masc. Barros 410 (SP); *loc. id.* 23/IX/1980, fr., Forero *et al.* 8337, 8358 (SP); Porto Ferreira, 23/X/1954, fr., Wasicky *s.n.* (SPF and UFG).

- *Additional material:* **Argentina. Formosa:** *loc. ignot.*, 1915, fl. fem., Jørgensen 2774 (SI); **Misiones:** *loc. ignot.*, fl. masc., Bonpland 1906 (BA); Caingúas, Valle del Arroyo Cuña Pirú, 20/IX/1999, fl. masc. *et fl. fem.*, Biganzoli *et al.* 528 (SI); **Paraguay. Concepcion:** *loc. ignot.*, 1901-1902, fl. masc., Hassler 7185 (P).



Figure 2.1: Geographic distribution of *Ceratosanthes hilariana* Cogn.

2 – *Ceratosanthes multiloba* Cogn. Diagn. Cucurb. Nouv. 2:29. 1877; Cogn. in Mart., Fl. Bras. 6(4):68. 1878; Comm. Geogr. Geol. E. S. Paulo 14(3):70-71. 1897; Cogn., in Engler, Pflanzenr. fig.56 a-d., 244-245. 1916; Cat. Pl. Vasc. Rep. Argentina 3:19. 1998. **Typus:** In Brasilia, Sello, n. 3214 (Sintypus B†; photo F!); S. Joano Baptista, Pohl 520 (Sintypus W); prov. St-Paulo and Rio, 1861-1862, J.Weir 316 (Sintypus K!).

= *Ceratosanthes hassleri* Cogn. Bull. Herb. Boiss. 2(3):925. 1903; Chod & Bassl 212; Cogn., in Engler, Pflanzenr. 245-246. 1916. **Typus:** Paraguay, “bey Vaqueria Capibary”, 08/1898-99, Hassler 4382 (Holotypus S!).

= *Ceratosanthes fiebrigii* Cogn. in Engler, Pflanzenr. 242. 1916. **Typus:** Paraguay, Fiebrig 4865 (Sintypus B†; photo F!); Fiebrig 5346 (Sintypus B†).

= *Ceratosanthes diazii* Lillo. Resena fitogeog. de la prov. de Tucuman, Actas de la primera Reunion Nac. de la Soc. Arg. de Cienc. Nat. 212. 1916.: Lilloa 4:58. 1939. **Typus:** Argentina, Tucumán, Diaz 12901 (Lectotypus LIL!); Argentina, Tucumán, (Paratypus LIL!).

Monoecious climbing herbs; stem sparsely branched, cylindrical, glabrous. Leaves 6.34 – 10.30 x 4.99 – 11.01 cm, 3-4 or 5 lobed or decomposed; leaf blade membranous, glabrous or puberulent to scabrous; petiole 1.15 – 4.89 cm, glabrous; leaf base straight or cordate; sinus 1.72 - 3.11 deep x 2.30 – 5.84 cm; central lobe 3.82 – 8.50 cm x 2.26 – 4.14 cm, oblong, lanceolate or oblanceolate, margin entire or sparsely lobed, apex acute, rounded, obtuse, retuse or 2-3 lobed; lateral lobes asymmetric 3.50 – 7.00 x 1.98 – 7.33 cm, apex acute, obtuse or rounded, frequently mucronate. Tendril simple, glabrous, delicate. Male peduncle 6.05 – 22.73 cm, with 10 - 20 flowers, glabrous on the base and puberulent on the apex; flowers 0.95 – 1.44 cm; pedicel 0.30 – 0.60 cm long, puberulent; hypanthium approx. 1.00 cm; calix with 5 sepals 1.25 – 1.75 x 1.12 – 1.37 mm broad, ovate, ciliate, acute; corolla 5 petals approx. 4.00 x 2.00 mm, oblong, connate at the base, externally puberulent. Anther approx. 2.00 x 0.80 mm. Female peduncle 0.58 – 1.21 cm, with 1 – 7 flowers, glabrous or subglabrous, flowers 0.58 – 1.21 cm; pedicel 1.20 – 3.90 mm, puberulent; hypanthium and perianth identical to of male flowers. Ovary 0.44 – 1.21 x 0.10 – 0.63 cm, narrowly ellipsoid or ellipsoid, puberulent. Fruit a globose berry, 0.97 – 1.27 x 0.42 – 0.73 cm, one or two per branch; seed approx. 4 per fruit, orbiculate, approx. 4.00 x 4.00 mm, brown, bordered.

- *Comments:* *Ceratosanthes multiloba* is well delimited by its leaf lobes deeply subdivided varying in its number, width and depth. All this variation results in different leaf patterns that may correlate with environmental factors, like reduced leaves in arid regions. When the lobes in *C. multiloba* are entire or with few divisions, the species can share similarities with *C. tomentosa*, being

differentiated by the glabrous petiole and adaxial surface of the leaves in *C. multiloba*.

- *Material examined*: **Brazil. Bahia**: Santo Sé, Serra do Campo Largo, 29/II/2010, fr., Araújo *et al.* 1500 (HVASF); **Mato Grosso**: 12°49'S, 51°46'W, 21/X/1968, fl. masc., Harley, Castro & Ferreira 10739 (UB, K); Barra do Garças, 15°53'S, 52°15'W, 15/X/1964, fl. fem. *et fr.*, Irwin & Soderstrom 6879 (R, NY); Corumbá, Fazenda Marzilândia, 05/X/1953, fl. masc., Pereira, Egler & Graziela 193 (RB); Garapú, 13°12'S, 52°34'W, 01/X/1964, fl. masc., Irwin & Soderstrom 6540 (R, NY); Lago Leo, Acampamento da Expedição Inglesa, 11/X/1968, fl. masc., Sidney & Onishi 1420 (UB); **Minas Gerais**: Paraopeba, Horto Florestal, 15/XI/1958, fl. masc., Heringer *s.n.* (UB 27957); **Paraná**: Arapoti, Chapadão Santo Antônio, 11/X/1968, fl. masc., Hatschbach 19986 (MBM); Guarapuáva, Colônia São Judas Tadeu 30/V/1991, fl. fem. *et fr.*, Silva & Hatschbach 1031 (MBM); *loc. id.*, 18/IX/1996, fl. fem., Hatschbach *et al.* 65308 (MBM, SPF); Sengés, 07/X/1971, fl. masc., Hatschbach 27136 (MBM, HB); *loc. id.*, na beira da rodoviária entre Jaguariaiva e Itararé, 28/X/2007, fl. masc., Ulmann *et al. s.n.* (MBM 349543); Via Dutra, 14/IX/1967, fl. masc., Haas 2 (MBM); **Pernambuco**: Buíque, Vale de Catimbau, Trilha do Dragão, 12/II/2006, fl. fem., Miranda & Oliveira 5650 (HST); **Rio Grande do Sul**: São Francisco de Assis, 05/XI/1973, fl. masc., Dobereiner & Tokarnia 1046 (RB); **São Paulo**: Botucatu, “à margem da rodovia municipal, estrada do Roberto, que liga Vitoriana ao Rio Bonito Campo e Náutica, a ± 5 Km de Vitoriana, Fazenda Gold Farm”, 04/II/1986, fl. masc., Bicudo, Campos & Amaral 471 (UEC); Iperó, 10/XI/1936, fl. masc., Hoehne & Gehrt *s.n.* (SP 36750); Pirassununga, Cerrado da Cachoeira de Emas, 25/IX/1945, fl. fem., *leg. ign. s.n.* (SPF 66875); *loc. id.* estrada Pirassununga-Emas, 23/IX/1980, fl. masc. Forero *et al.* 8272 (SP); *loc. id.*, 25/IX/1945, fl. fem., *leg. ign. s.n.* (SPF 66875); *loc. id.* 10/X/1992, fl. masc., Slatino M.L.F. *et al.* 115 (SPF); *loc. id.*, 10/X/1992, Salatino, M.L.F. *et al.* 152 (SPF); *loc. id.*, Cerrado de Emas 47°30'W, 22°02'S, 08/IX/1994, fl. masc., Aragaki & Batalha 115 (SP); *loc. id.*, 27/X/1994, fl. fem. *et fr.*, Batalha 222 (SP).
- *Additional material*: **Argentina. Chaqueña**: *loc. ignot.*, X-XII/1930, fl. masc., Schulz 72 (SI); **Formosa**: *loc. ignot.*, 1915, fl. masc., Jørgensen 2781 (SI);

Misiones: San Ignacio, 27°15'S, 55°32'W, 21/IX/2000, fl. masc., Múlgura de Romero *et al.* 2179 (SI); **Santa Cruz:** Deseado, Tres Cerros, 08/XI/1936, fl. masc., Burkart 8093 (SI); **Tucumán:** Burroyau, Cerro del Campos, 05/XII/1928, fl. fem. *et fr.*, Venturi 7719 (SI); *loc. id.*, El Puestito, 14/XI/1928, fl. fem., Venturi 7497 (SI); Leales, Chañar Pozo, XI/1919, fl. masc., Venturi 668 (SI); **Paraguay.** *loc. ignot.:* Puerto Yataybá, 14 – 15/IX/1928, fl. masc., Daguerre *s.n.* (BA 281015); **Uruguay.** *loc. ignot.*, n.d., fl. masc., Felippone 4281 (SI); **Venezuela.** **Lara:** Barquisimeto, 26/I/1946, fl. masc., Tamayo 2615 (SI).



Figure 2.2: Geographic distribution of *Ceratosanthes multiloba* Cogn.

3 – *Ceratosanthes palmata* (L.) Urb. in Fedde, Rep. 15:323. 1918; Jeffrey & Trujillo in Flora da Venezuela 5(1):39. 1992. **Typus:** Plate in Burm., Pl. Amer. 1: tab. 24. 1756.

= *Tricosanthes palmata* L. Syst. Nat. ed. 10. 2:1278. 1759. **Typus:** Plate in Burm., Pl. Amer. 1:tab.24. 1756 (Iconotypus!).

= *Ceratosanthes tuberosa* J.F.Gmel. Syst. Nat.:102. 1792; Spreng Syst. Veg. 3:18. 1826; Descourt. Fl. Antill. 8:23 t.538. 1829; Schrad. in Linnaea 12:403. 1838; Roem. Syn. Mon. fasc.2:93.1846; Griseb. Fl. Brit. W. Ind. Isl.:289. 1860; Cogn. Diagn. Cucurb. Nouv. 2:28. 1877. **Typus:** *In insulis Antillarum! Venezuela!* (Holotypus P!).

= *Anguria fructu parvo, florum segmentis ramosis* Plum. Cat. 3. 1703.

= *Trichosanthes foliis palmatis integerrimis, florum p&alis bicornibus* Plum. Pl. Amer. ed Burm. 1:12. t.24. 1755.

= *Trichosanthes tuberosa* Willd., Sp. Pl. 4:601. 1805; Sims, Bot. Mag. t.2703. **Typus:** *Habitat in India occidentali.*

= *Trichosanthes corniculata* Lam. Encycl. 1:191. 1783; Ser. in DC. Prodr. 3:315. 1828.

= *Ceratosanthes corniculata* (Lam.) Cogn. in DC. Mon. Phan. 3:724. 1881; Cogn. in Engler, Pflanzenr.: 242-243. 1916. **Typus:** *In insul. Martinica, Plée* (Sintypus P!; Isosintypus B†); Duperrey (Sintypus P!); *in ins. Grenada, Wulschlaegel sec. Griseb. l. c.* (Sintypus P!); *in ins. Trinitatis, Cruger n. 7* (Sintypus P!); *in Venezuela prope caracas, Plée* (Sintypus P!); *ad Porto Cabello prov. Carabobo, Linden n. 1611* (Sintypus P!).

= *Ceratosanthes gracilis* Cogn. Diagn. Cucurb. Nouv. 2:33-34. 1877; in Engler, Pflanzenr. 244. 1916. **Syn. nov.** **Typus:** “*In Columbia: prope Santa Martha*”, 08/1844, J. Goudot (Holotypus P!).

= *Ceratosanthes latiloba* Cogn. Diagn. Cucurb. Nouv. 2:33. 1877; Cogn. in DC. Mon. Phan. (3):723. 1881; Cogn., in Engler, Pflanzenr.:241-242.1916. **Syn. nov.**

Typus: “*In Venezuela. – Caracas*”, 1830, Joseph Vargas 228 (Sintypus FI, G); “*Valle Del Aragua, Palmar & Matheo*”, 18/05/1840, E. Otto 799 (Sintypus B†, photo FI), “*bei Biscaina*”, Fendler 500 (Sintypus GOET).

= *Ceratosanthes latiloba* var. *acutiloba* Cogn. Diagn. Cucurb. Nouv. 2:33. 1877; Cogn. in DC. Mon. Phan. (3):724.1881; Cogn., in Engler, Pflanzenr. 241-242. 1916. **Typus:** “*Prope coloniam Tovar*”, 1856-1857, Fendler 495 (Holotypus K!).

= *Ceratosanthes trifoliata* Cogn. Diagn. Cucurb. Nouv. 2: 34-35. 1877; Cogniaux in Mart., Fl. Bras. 6(4):68-69. 1878; Cogniaux in De Candolle, A.L.P.P. & Candolle, A. C. Pç. de Monogr. Phan. 3:726. 1881; Cogniaux in Engler, Pflanzenr. 246. 1916. *Syn. nov.* **Typus:** *In Brasilia* (Sintypus herb. Deless); *prope Crato, prov. Ceara, Brasilia tropica, novemb.* 1838, Gardner, n. 1628 (Sintypus K! and BM!); *Serra de Ararisse, prov. Ceara, septemb.* 1838, Gardner, n. 1627 (Sintypus BR).

= *Ceratosanthes cuneata* Ridl. In J. Linn. Soc., Bot. 27:38. 1890; in Engler, Pflanzenr. 244. 1916. *Syn. nov.* **Typus:** Brazil, “*Insel Fernando Noronha*”, Ridley, Lea & Ramage 52 (Lectotypus BM!).

= *Ceratosanthes angustiloba* Ridl. In J. Linn. Soc., Bot. 27: 38.1890; Cogn. in Engler, Pflanzenr. 246. 1916. *Syn. nov.* **Typus:** “*Insel Fernando Noronha*”, Ridley (holotypus not designated).

Dioecious climbing herbs; stem sparsely branched, cylindrical, glabrous. Leaves, 5.94 – 15.00 x 6.70 – 13.21 cm, trifoliolate or deeply trilobate; leaf blade membranous, glabrous; petiole 1.68 – 3.28 cm, glabrous; leaf base straight or cordate; sinus 1.25 – 1.75 x 0.69 – 4.34 cm; central leaflet or lobe 4.22 – 7.89 x 1.40 – 4.30 cm, lanceolate, lance-ovate, oblanceolate, margin entire, sparsely dentate or crenate, apex acute mucronulate; lateral leaflet or lobes asymmetric, shorter than central, 3.95 – 6.50 x 1.67 – 6.62 cm, constricted or strongly bilobate, 3.95 – 6.50 x 1.67 – 6.62 cm, apex acute or obtuse, submucronate. Tendril simple, glabrous, robust. Male peduncle aprox. 17.65 cm, with 10 flowers, glabrous to puberulent; flowers 2.19 – 2.52 cm; pedicel 0.51 - 0.58 cm, glabrous; hypanthium 1.22 – 1.68 cm; calix with five

sepals 1.0 – 2.0 x ca. 1.5 mm, widely ovate, ciliate, acute; corolla five petals ca. 4.00 x 1.5 – 2.00 mm, oblong, connate at the base, externally puberulent. Anther ca. 3.00 x ca. 1.00 mm. Female peduncle ca. 6.5 cm, with 2 – 4 flowers, glabrous to puberulent; flowers 1.2 – 1.5 cm, pedicel 0.48 – 0.52 cm., glabrous; hypanthium and perianth similar to male flowers; ovary 0.30 – 0.40 x 0.30 – 0.50 cm, narrow ellipsoid or ellipsoid, puberulent; Fruits a globose to ellipsoid berry, 1.10 – 1.15 x ca.. 0.70 cm, five to six seeds per fruit, orbiculate, 4.00 x 4.00 mm, brownish.

- *Comments*: The foliar morphology of *Ceratosanthes palmata* is highly variable, except for its entire or sparsely dentate margins. When the lobes are entire and lanceolate this species has some similarities with *C. tomentosa* from which it can easily be distinguished by the glabrous surface and sparsely dentate margins while *C. tomentosa*, usually has pubescent or scabrous petioles. In this study *Ceratosanthes gracilis* is considered as synonym of *C. palmata*. This proposal is based in the pattern of the leaves of the type material of *C. gracilis*, which is the same presented by Cruger 7 (P), i.e. the stronger trilobate shape, lateral lobes with crenate margin and a central lobe rhombic to widely ovate in shape with crenate margins. This leaf pattern is similar to *C. hilariana* but both species can be distinguished by the wider lobes and crenate-dentate margins in *C. hilariana*. Although the typus specimen of *C. angustiloba* was not observed, based in the descriptions of Ridley (1890), we adopted this species as a synonym of *C. palmata* by the trifoliolate pattern similar to *C. trifoliolata*.

- *Material examined*: **Brazil. Bahia**: Rio de Contas, ca. 6.5 Km da cidade, na estrada que liga Rio de Contas à Livramento de Nossa Senhora, 29/XI/2003, Amorim *et al.* 3892 (CEPEC); São Bento das Lajes, Escola Agrícola, 20/III/1925, fl. masc., Pickel 873 (IPA); **Ceará**: Brejo Santo, Chapada do Araripe, Torres de TV, 11/I/2010, fr., Fontana *et al.* 6289 (HVASF, UFG); Meruoca, Sítio Santo Antônio, Serra da Neruoca, 09/III/1981, fl. masc., Fernandes & Nunes *s.n.* (EAC 9928); **Goiás**: Campos Belos, 30/X/2000, fl. masc., Aparecida da Silva *et al.* 4601 (IBGE); **Mato Grosso**: *loc. ignot.*, 26/X/1968, fl. masc., Harley *et al.* 10848 (UB, K); Aquidauana, Fazenda Santa

Cruz, 17/VII/1969, fl. masc., Hatschbach & Guimarães 21930 (MBM); **Paraná:** Campo Mourão 20/X/1974, fl. masc., Hatschbach 32912 (MBM, SPF, P, HB); **Pernambuco:** Gravatá, Serra da Russa em frente à polícia rodoviária 28/IV/1993, fl. masc., Miranda *et al.* 719 (HST); Ilha de Fernando de Noronha, Alagados, 19/VI/2003, Miranda *s.n.* (HST 11790); Petrolândia, Novo Mundo, 07/III/2004, Silva 303 (PEUFR); **Piauí:** Várzea Grande, S. Raimundo Nonato, 06/II/1984, Emperaire 230 (RB); **Rio Grande do Norte:** Natal, Parque das Dunas, 05°46'00"S, 38°13'00"S, 16/II/1981, fl. fem. *et fr.*, Projeto Parque das Dunas 276 (R); **Santa Catarina:** Urubici, Morro Parapente, 9/II/2007, Hatschbach & Ribas 79842 (MBM)

- *Additional material:* **Grenada: Santa Martha.** VIII/1844, fl. masc., Goudot *s.n.* (P 5622529); **Trinidad and Tobago: Arima.** XI/1861, Cruger 7 (P); **Venezuela: Margarita.** *loc. ignot., n.d.*, fl. fem., *leg. ign. s.n.* (P 5622516); **French Guiana:** 54°4'W, 2°39'N, 31/VIII/1987, fl. masc., Granville *et al.* 9892 (P); Inselbergs de la haute Wanapi, 53°49'2"W, 2°31'0"N, 19/IV/2004, fl. masc., Granville, Crozier & Sarthou 16080 (CAY, P); **Martinique.** *loc. ignot.*, 1825, fl. masc., Vuperr. *s.n.* (P 5622513); *loc. ignot.*, VII/1820, fl. fem. *et fr.*, Bleé *s.n.* (P 5622512); Sainte-Anne, 1870, fl. masc., Hahn 1332 (P); **Miranda:** Los Teques, 19/III/1946, fl. masc., Burkart 16027 (SI).



Figure 2.3: Geographic distribution of *Ceratosanthes palmata* (L.) Urb.

4 – *Ceratosanthes rupicola* Ridl. J. Linn. Soc., Bot. 27:38. 1890; Cogn., in Engler, Pflanzenr. 246. 1916. **Typus:** “Insel Fernando Noronha, auf Felsen”, 09/1891, Ridley, Lea & Ramage 53 (Lectotypus K!).

Dioecious; climbing herbs; stem branched, cylindrical, glabrous. Leaf, 5.5 – 7.5 x 4.5 – 13.0 cm, trifoliolate; leaflets coriaceous, glabrous; central leaflet entire 4.8 – 7.5 x 3.0 – 4.1 cm, obovate, mucronate; lateral leaflet entire 6.0 – 6.5 x 2.5 – 3.0 cm, oblong, mucronate; petiole 1.0 – 3.0 cm long, glabrous; petiole 1.68 – 3.28 cm long, glabrous; leaf base straight or cordate; sinus 1.15 – 1.33 deep x 2.41 – 2.59 cm; central leaflet or lobe 4.22 – 7.89 x 1.40 – 4.30 cm, obovate, margin entire or sparsely dentate, apex acute mucronulate; lateral

leaflet asymmetric 3.95 – 6.50 x 1.67 – 6.62 cm, oblong, apex rounded or obtuse. Tendril simple, glabrous, robust. Male peduncle 3.50 – 13.10 cm, with 5 – 18 flowers, glabrous to puberulent; flowers 1.09 – 1.33 cm; pedicel 0.15 - 0.32 cm long, glabrous; hypanthium ca. 2.00 cm; calix with five sepals 0.56 – 1.0 x ca. 1.5 mm, widely ovate, ciliate, acute; corolla five petals ca. 4.00 x 2.00 mm oblong, connate at the base, externally puberulent. Anther approx. 3.00 mm. Female peduncle 6.56 – 10.76 cm, with 5 – 10 flowers, glabrous to puberulent; flowers 1.30 – 1.53 cm, pedicel 0.2 – 0.3 cm., glabrous; hypanthium and perianth identical to male flowers. Ovary ca. 0.40 x ca. 0.10 cm, narrow ellipsoid, puberulent. Fruit a globose berry, 0.56 – 1.10 x 0.51 – 0.80 cm, seeds ca. 4 per fruit, globose, ca. 4.00 mm x 4.00 mm broad, brownish, bordered.

- *Comments:* Jeffrey (2004) does not list this species in his paper and consider it as a synonym of *C. hilariana*. Although this information is not published, the author left a note written in the syntypus of *C. rupicola*, Ridley, Lea & Ramage 53 (K) with this synonymy and a reference to his study about New World Cucurbitaceae (2004) where a list of *Ceratosanthes* species is provided. However, we consider that the scabrous surface and the crenulate-dentate margin of the blade in *C. hilariana* contrast with the glabrous blade and entire margin of *C. rupicola* delimiting both species as different taxa. The distribution map indicates that *C. rupicola* is endemic to Archipelago of Fernando de Noronha, while, *C. hilariana* is well distributed in South and Southeast regions of Brazil and Northeast of Argentina.

- *Material examined:* **Brazil. Pernambuco:** Arquipélago de Fernando de Noronha, Ilha da Rata, 01/VI/1993, Miranda *et al.* 864 (HST); *loc. id.*, Ilha Fernando de Noronha, Ponta da Sapata, próximo ao farol, 26/IX/2000, fl. masc., fl. fem. *et fr.*, Miranda 3732 (HST); *loc. id.*, 17/X/2003, fl. masc., Miranda 4226 (HST).

5 – *Ceratosanthes tomentosa* Cogn. Diagn. Cucurb. Nouv. 2:29. 1877; Cogn. *in* Mart., Fl. Bras. 6(4):66-67. 1878; Cogn. *in* DC. Mon. Phan. (3):720. 1881; Cogn., *in* Engler, Pflanzenr. 241. 1916. *Syn. nov.* **Typus:** “*In Brasilia – a Ad Lagoa Santa*”, 21 Septembr. 1864, Eug. Warming (Holotypus C!).

= *Ceratosanthes tomentosa* var. *subnuda* Cogn. Diagn. Cucurb. Nouv. 2:29. 1877; Cogn. in Mart., Fl. Bras.6(4):67. 1878; Cogn. in DC. 1:721. 1881; Cogn., in Engler, Pflanzenr. 241. 1916. **Typus:** Ad Lagoa Santa, octobr. 1864, Eug. Warming (Sintypus C!); S. Ignacio, Sello n. 2110, 2145 (Sintypi B†, photo F!); *Ipannema, decembre* 1819, Sello 2119 (Sintypus B†); *prov. Minas-Geraes, ann.* 1845, Widgren, n. 714 (Sintypus BR!).

= *Ceratosanthes warmingii* Cogn. Diagn. Cucurb. Nouv. 2:35. 1877; Cogn. in Mart., Fl. Bras.6(4):67. 1878; Mém. Couronnés Mém. Savants Étrangers Acad. Roy. Sci. Bruxelles (4)28. 1878; Cogn. in DC. Mon. Phan. (3):721. 1881. Cogn., in Engler, Pflanzenr. 241. 1916. *Syn. nov.* **Typus:** “*In Brasilia: ad Lagoa Santa, in virgultis sepibus, ubi scandens; corolla alba; flor.*” octob.-novemb., 1863, Warming, 24 octobre (Holotypus C!, Isotypus BR!).

Dioecious plants; climbing herbs; stem branched, cylindrical, puberulent or pubescent. Leaves, 3.6 – 13.5 x 3.75 – 11.5 cm, trilobite, palmately divided or sometimes entire sagitate, reniforms or wide ovate; leaf blade pubescent or puberulent when juvenill; when leaves entire base reniform to sagitate with sinus, 0.75 – 2.5 cm deep x 1.0 – 2.0 cm; petiole 0.5 – 3.0 cm, pubescent, puberulent when juvenile or rarely estrigulose when mature leaf; margin entire or sparsely denteate; apex acute, obtuse or rounded, mucronate; when blade lobed, central lobe 2.75 – 9.5 x 0.35 – 5.0 cm, oblanceolate to lanceolate, apex acute to rounded, mucronate, margin entire sparsely dentate; lateral lobes asymmetric, 2.25 – 9.0 x 2.5 – 4.8 cm; apex obtuse to rounded. Tendrils simple, glabrous, robust. Male peduncle 10.5 – 14.0 cm, with 4 – 12 flowers, puberulent or pubescent; flowers 1.5 – 2.0 cm long., pedicel 3.0 – 5.0 mm., puberulent, hypanthium 0.9 – 2.22 cm, calix with five sepals, 1.0 – 1.5 x ca. 1.0 mm, lance-ovate, ciliate, acute; corolla with five petals, 2.0 – 2.2 x 1.0 – 2.0 mm, oblong, connate at the base, externally puberulent. Anther ca. 2.0 x 0.8 mm. Female peduncle 1.0 – 13.0 cm, with 3 – 12 flowers, puberulent or pubescent; flowers 1.0 – 2.0 cm, pedicel 2.5 – 3.0 mm, puberulent or pubescent; hypanthium and perianth identical to male flowers. Ovary 2.5 – 7.5 x 1.0 – 3.0 mm, narrowly ellipsoid to puberulent; style ca. 8.0 mm. Stigma bifid and plumose. Fruit a

ellipsoid berry, glabrous, 1.5 – 2.6 x 1.0 – 1.5 cm, two or six per branch; seeds two or six per fruit, orbiculate, ca. 4.0 x 4.0 mm, brown, bordered.

- *Comments:* *Ceratosanthes tomentosa* is well defined by the pubescent stem, tendril, petiole and leaves when those parts are relative young. Over the time, parts of the plant become glabrous losing the trichomes, except on petiole where the indumentum is observed even in older fragments. Some specimens have a scabrous leaf surface like *C. hilariana* and some individuals of *C. palmata*. However, the pubescent petiole and entire or sparsely dentate margin in *C. tomentosa* allow us to distinguish it from the crenate-dentate or crenate margins of leaves in *C. hilariana* and *C. palmata*, respectively.

- *Material examined:* **Brazil.** *loc. ignot.*, n.d., fl. masc., Simart *s.n.* (P 5622510); *Loc. id.*, 1907, fl. fem., Glaziou *s.n.* (P 5622507); **Goiás:** *loc. ignot.*, “ca. 6 Km of Piranhas”, 24/VI/1966, fl. masc., Irwin, Souza & Grear 17698 (RB, NY, UB); *loc. ingot.*, Doada pela EMBRAPA-GO, 06/IX/1994, *v.s.c.*, fl. fem., Costa & Klein 39 (UFG); Campos Belos, estrada de terra para Divinópolis de Goiás, a 43 Km do entroncamento com a GO 118, 16/VIII/1990, fl. fem., Cavalcanti *et al.* 725 (SP); Caiapônia, BR 158, 41 Km de Barra do Garças, 12/X/1998, Gomes-Klein *et al.* 3503 (RB, UFG); Goiânia, 23/I/1996, Costa *s.n.* (UFG); *loc. id.*, 04/VI/1996, fl. fem *et fr.*, Costa *s.n.* (UFG); *loc. id.*, Mansões do Campus, área loteada, 16°33'34.2"S, 49°12'12.5"W, 07/XI/2005, Gomes-Klein *et al.* 4013 (UFG); Goianira, Fazenda Louzandira, a 2 Km da margem esquerda do Rio Meia Ponte, 21/III/1970, fl. fem., Rizzo & Barbosa 4873 (UFG); Goiás, Serra do Bromodo, 08/IX/1996, Gomes-Klein, Costa & Gomes 3183 (UFG), *loc. id.* 08/IX/1996, Gomes-Klein, Costa & Gomes 3184 (UFG); Mineiros, Parque Nacional das Emas, próximo à nascente do Rio Glória, 03/XII/1994, Gomes-Klein *et al.* 2632 (UFG), *loc id.* 03/XII/1994, Gomes-Klein *et al.* 2633 (UFG); Pirenópolis, Serra dos Pireneus, saída da Serra, 26/IX/1987, Skorupa, Werneck & Silveira 204 (CEN); *loc. id.*, Mata na base dos Três Picos, 08/VIII/2012, fr., Gomes-Klein & Conceição 7707 (UFG); Serranópolis, 28/IX/2004, fl. fem. *et fr.*, Souza *et al.* 1181 (HJ, UFG); *loc. id.*, 28/IX/2005, fl. masc., Souza *et al.* 2628 (HJ, UFG); **Mato Grosso:** Barra do Garças, 15°53'S, 52°15'W, 15/X/1964, fl. masc., Irwin & Soderstrom 6878 (HB, NY); Três Lagoas, 20°48'57"S,

51°43'26"W, ± 9.4 Km da MS 395, 13/X/1998, fl. masc., Amaral, Medonça & Dias 61 (BOTU); **Minas Gerais:** Juíz de Fora, 25/V/1996, fl. masc., Krieger *s.n.* (SP); Paracatú, 22/X/1989, fl. masc., Salles *et al.* 1462 (HEPH); **São Paulo:** *loc. ignot.*, à margem da rodovia sem pavimentação que liga Vitoriana ao Rio Bonito, 24/X/1985, fl. masc., Amaral *et al.* 76 (UEC); Araraquara, 11/IX/1908, fl. masc., Loefgren 864 (SP); Mogy-mirim, 06/X/1931, fl. masc., Hoehne *s.n.* (SP 28344, UFG); Itararé, perto da ponte do Rio Itararé, X/1965, fr., Mattos & Moura *s.n.* (SP 101715); **Tocantins:** Arráias, na rodovia para Paranã, 10/I/1991, fl. masc., Hatschbach & Silva 56032 (MBM).



Figure 2.4: Geographic distribution of *Ceratosanthes tomentosa* Cogn (●) and *Ceratosanthes rupicola* Ridl. (▲)

CONCLUDING REMARKS

The genus *Ceratosanthes* Adans. is a Neotropical genus of Cucurbitaceae that comprises five species in the Brazilian territory. The geographic distribution of examined material allows us to observe a high frequency in Brazilian West-Center and Southeast regions, Caribbean Archipelagos and Northeast of Argentina. The species are climber or prostrate herbs with simple tendrils and simple entire, lobate or foliolate leaves. This work recognized the flowers and fruits as characters without taxonomic value at the species level due to similar morphology among them. We highlighted the importance of the leaves and petiole indumentum as a valid taxonomic element and indicated seven synonyms, one to *C. hilariana*, other one to *C. tomentosa* and five to *C. palmata*. Although the morphology of the leaves is the most important taxonomical character, its use presents several difficulties: the specimens frequently lose their leaves during or after the anthesis; or they might present simultaneous different leaf patterns. Both situations contribute to a difficult correct identification of the taxa. Further studies with pollen morphology, leaf architecture or molecular analyses might allow new information to the taxonomy of the genus.

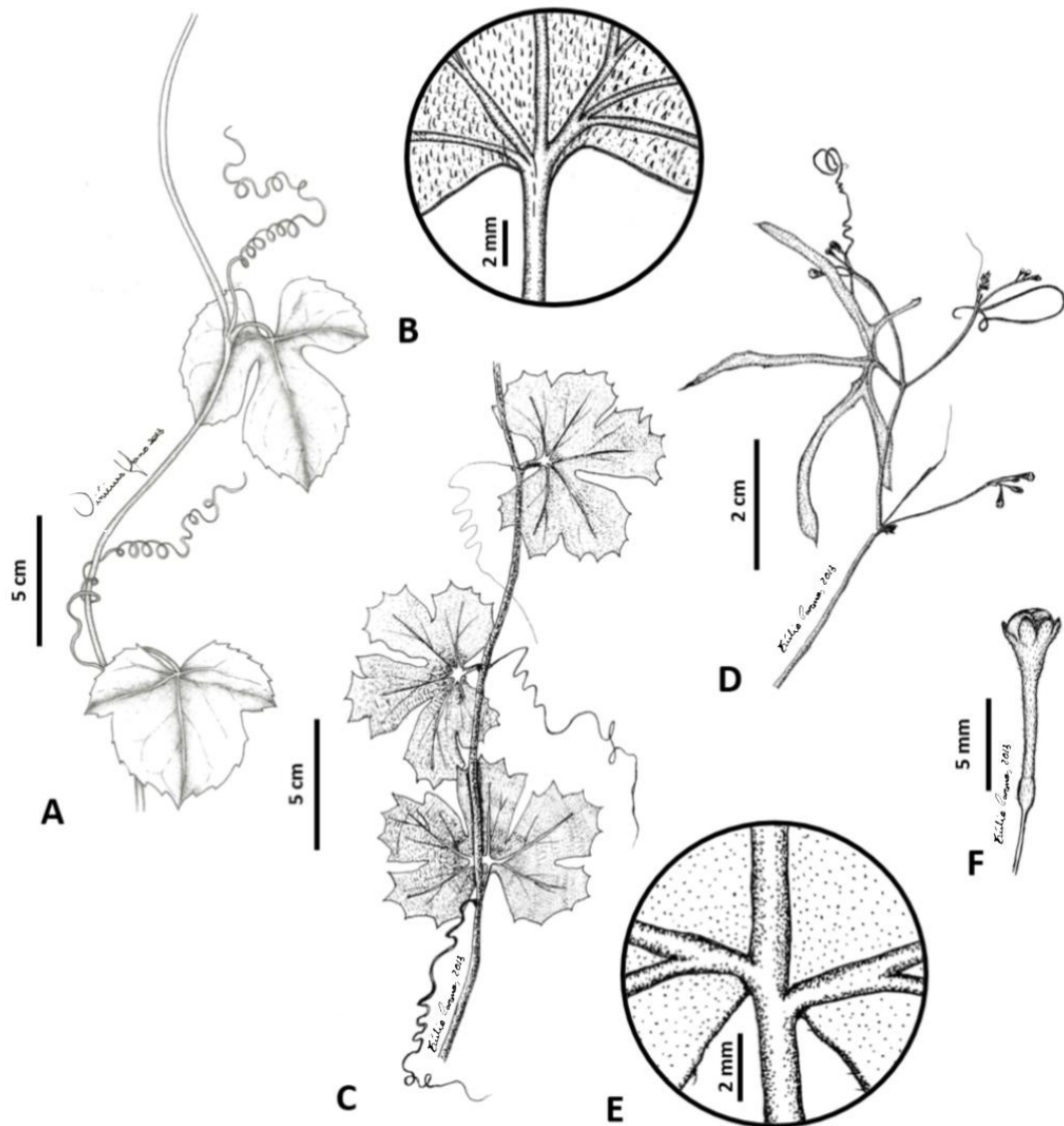


Figure 2.5: *Ceratosanthes hilariana* Cogn., **A:** Habit, **B:** Petiole detail; *Ceratosanthes multiloba* Cogn. **C, D:** Habit, **E:** Petiole detail, **F:** male flower bud.; Material: **A, B:** Gomes-Klein & Nakajima 2611 (UFG); **C:** Doberiner & Tokarnia 1046 (RB); **D:** Romero *et al.* 2179 (SI); **E, F:** Hatschbach *et al.* 65308 (SPF).

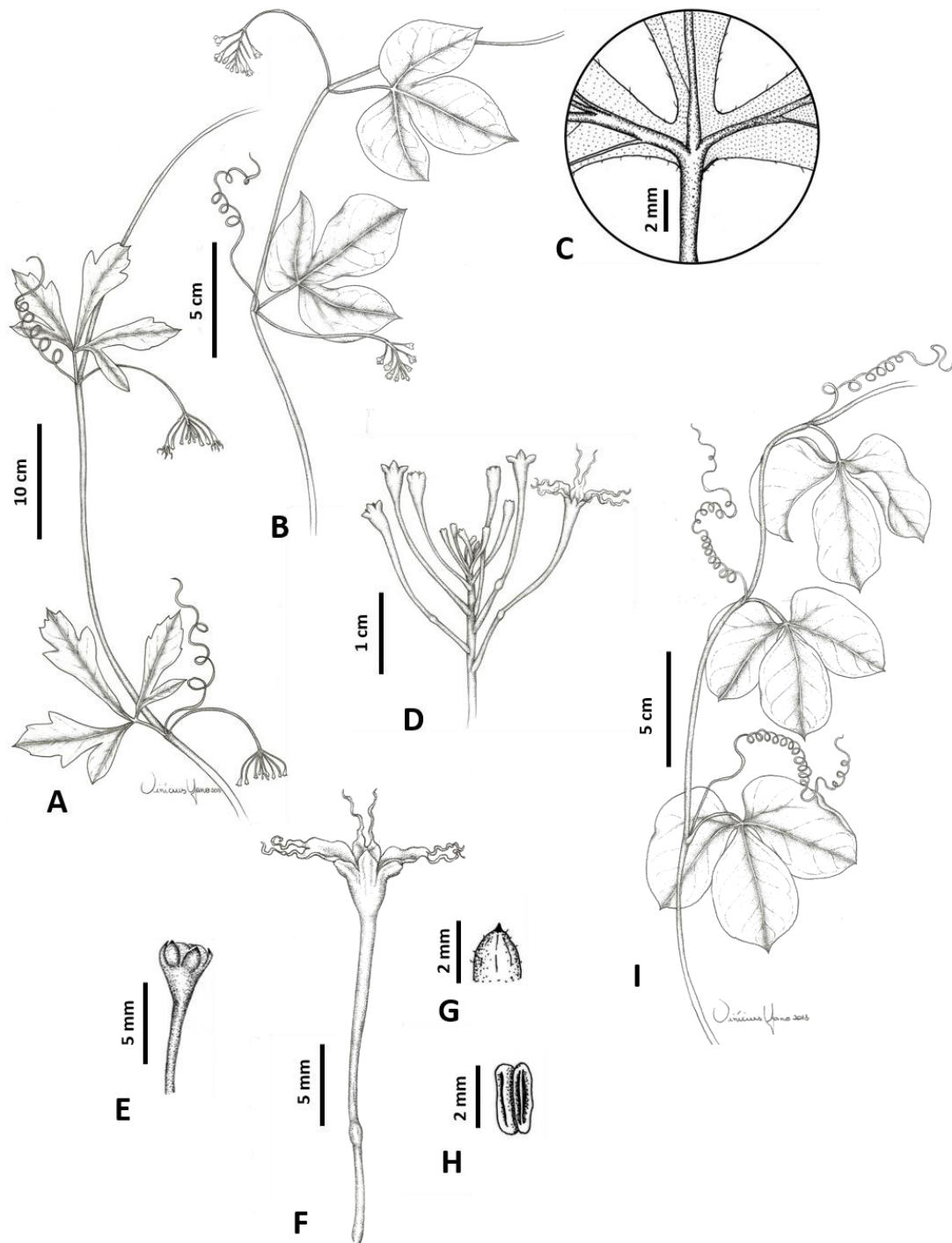


Figure 2.6: *Ceratosanthes palmata* (L.) Urb., **A, B:** Habit, **C:** Petiole detail, **D:** Male inflorescence, **E:** Male flower bud, **F:** Male flower, **G:** Sepal, **H:** Anthers; *Ceratosanthes rupicola* Ridl. **I:** Habit. Material: **A, C, D, E, F, G, H:** Pickel 873 (IPA); **B:** Miranda 3222 (HST); **I:** Miranda 864 (HST).

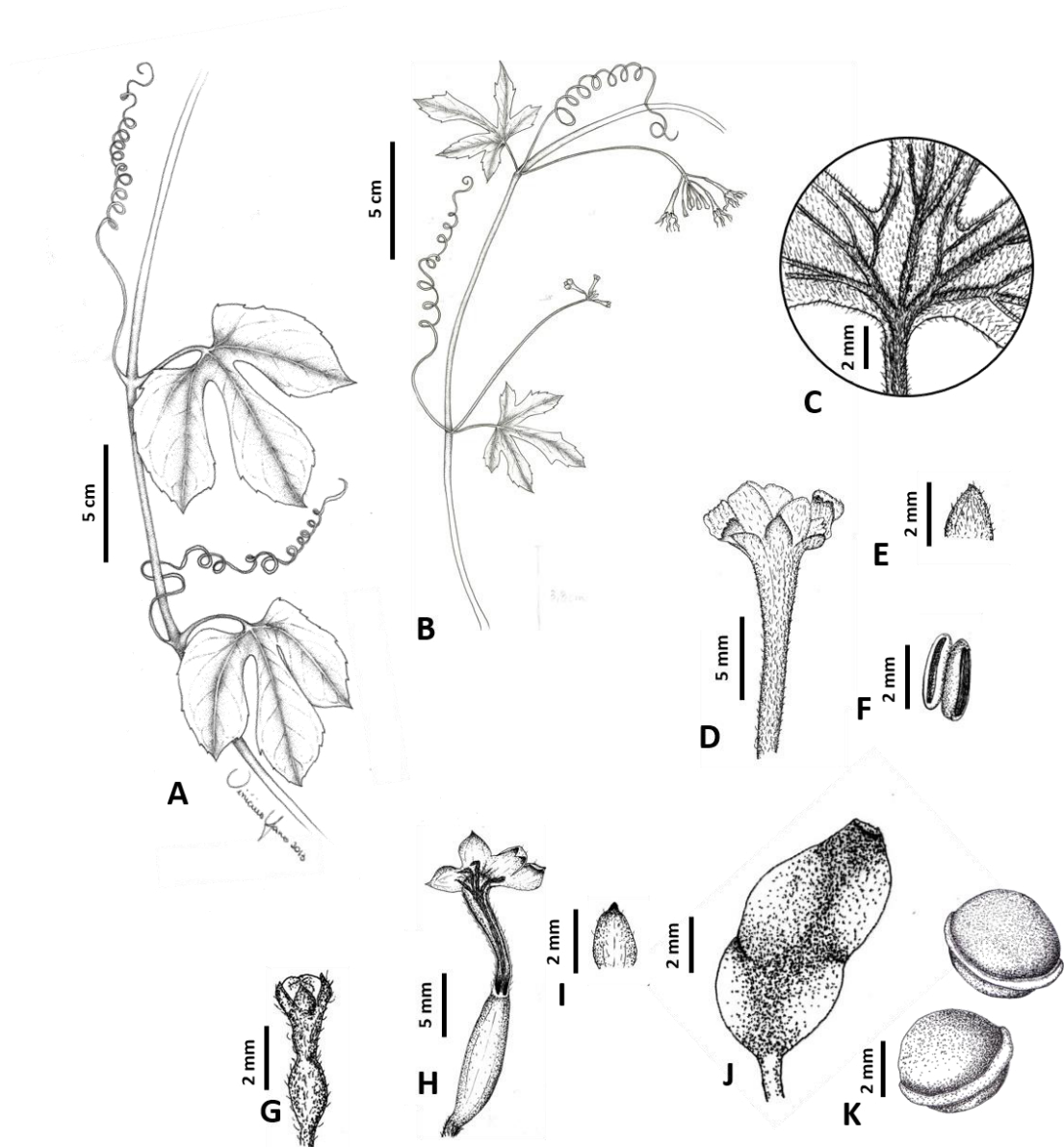


Figure 2.7: *Ceratosanthes tomentosa* Cogn. **A, B:** Habit, **C:** Petiole detail, **D:** Male flower, **E:** male flower sepal, **F:** anthers, **G:** Female flower bud, **H:** Female flower, detail of the hypanthium, sepals and pistil, **I:** Female flower sepal, **J:** Fruit, **K:** seeds. Material: **A:** Gomes-Klein *et al.* 3503 (UFG); **B:** Salles *et al.* 1462 (HEPH); **C:** Gomes-Klein *et al.* 4013 (UFG); **D, E, F:** Souza *et al.* 2628 (HJ); **G, H, I, J, K:** Souza *et al.* 1181 (HJ).

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CHAPTER 3

POLLEN MORPHOLOGY OF *CERATOSANTHES ADANS.*
(CUCURBITACEAE JUSS.) IN BRAZIL

POLLEN MORPHOLOGY OF *CERATOSANTHES* ADANS. (CUCURBITACEAE JUSS.) IN BRAZIL.**Resumo**

Neste trabalho foi estudada a morfologia polínica de cinco espécies de *Ceratosanthes* Adans., (Cucurbitaceae) em microscopia eletrônica de varredura (MEV) e microscopia óptica (MO). As espécies do gênero apresentam pólen de tamanho médio a grande, com ornamentação reticulada e predominantemente 4-colporados ou raramente 5-colporados. Os caracteres morfológicos foram usados para calcular o intervalo de confiança ($p=0.05$) e para uma análise de componentes principais (PCA). Os resultados indicam a forma dos grãos e dos muri como elementos de valor taxonômico. São ainda apresentadas imagens de microscopia eletrônica e uma chave dicotômica para as espécies estudadas.

Palavras-chave: Análise de componentes principais, Microscopia eletrônica de varredura, Neotropical, Ornamentação, Taxonomia

Abstract

In this paper the pollen morphology of five species of *Ceratosanthes* Adans. (Cucurbitaceae) was studied through scanning electronic microscopy (SEM) and light microscopy (LM). The genus has pollen grains with size varying between medium to large, with reticulate ornamentation and in general, 4-colporated, rarely 5-colporated. For each morphological character we calculated the confidence interval ($p=0.05$) and using the whole dataset we plotted a principal component analysis (PCA). The results showed that the shape of the grains and of the muri are the characters of greater taxonomical value. Scanning electronic images and a dichotomous key to the studied species are also presented.

Key words: Principal component analysis, Neotropical, Ornamentation, Taxonomy, Scanning electronic microscopy

INTRODUCTION

Cucurbitaceae Juss. is an important food source and several species are economically significant to some tropical countries being widely cultivated as crops around the world as cucumbers, pumpkins and squashes, melons, watermelons and sponges. The Cucurbitaceae family is a medium-size plant family, including about 300 genera with a wide distribution in tropical and subtropical regions. It includes annual or perennial herbs, vines or lianas (Souza & Lorenzi 2005). Schaffer & Renner (2011a) indicates four different diversity points to the family: Southeast Asia, West Africa, Madagascar and Mexico. In Neotropical region 30 native genera are recognized. *Ceratosanthes* Adans. is distinguishable from the other genera by its strongly bipartite petals. This taxon comprises five species in Brazil: *C. hilariana* Cogn., *C. multiloba* Cogn., *C. palmata* (L.) Urb., *C. rupicola* Ridl. and *C. tomentosa* Cogn..

So far, only *Ceratosanthes palmata* (Marticorena 1963) and *Ceratosanthes tomentosa* (Melhem 1966) were studied palynologically. The reticulate ornamentation and the 4-colporate configuration were described by Marticorena (1963) and based in those and other characters, Jeffrey (1964) included *Ceratosanthes* in the tribe *Melothriinae*. However, while the pollen of the other representatives of this tribe is also reticulate, they have 3-porate pollen instead of the 4-colporate presented by *Ceratosanthes* (Marticorena 1963; Jeffrey 1964). Melhem (1966) described the pollen of *C. tomentosa* and was the first to comment about the variation of number of colpi. The actual position of *Ceratosanthes* in *Coniandreae* tribe is supported by the reticular ornamentation, though contrasted by the 3-colporate pollen of the other genera in the tribe (Schaefer & Renner 2011b).

The aim of this paper is to contribute to a better knowledge of the genus *Ceratosanthes*, by providing and analyzing descriptions and images of pollen grains, in order to better understand the taxonomical delimitation of the species occurring in Brazil, and promoting further studies about the phylogenetic relationships among *Ceratosanthes* and the other genera within the tribe *Coniandreae*.

METHODOLOGY

In this study, male flowers of five *Ceratosanthes* species were obtained from herbarium vouchers, held in the following institutions: CEN, HST, IPA, SPF and UFG. The samples were submitted to the acetolysis method according to Erdtman (1960).

Slides for light microscopy (LM) were pretreated using t-butanol, mounted with silicon oil and sealed with nail varnish. The following characters were measured in thirty pollen grains: Polar axis (P), equatorial diameter (E), colpi width (CW), mesocolpium width (MW), endoaperture width (EA), apocolpium (A) and exine thickness in optical section.

For scanning electron microscopy (SEM), acetolized samples were mounted on metallic stubs and coated with golden/palladium film at high vacuum. The samples were observed with a Jeol JSM 5400 (Jeol Ltd, Tokyo, Japan) SEM, operating at 10 kV. The SEM images were analysed using the ImageJ program (public domain) to observe and measure muri thickness (M) and lumina diameter (L). The PAST software (Hammer, Ø., Harper, D.A.T., Ryan, P.D. 2001) were used to calculate the mean (\bar{X}), standard variation (S), standard variation of the mean ($S\bar{x}$), coefficient of variability percent (CV), confidence interval (CI) and to apply a principal component analyses (PCA).

The terminology used follows Punt (2007) and Hesse *et al.* (2009). When used two different specimens to the same species, they are differentiated by (*).

EXAMINED MATERIAL:

Ceratosanthes hilariana Cogn. **Brazil. Goiás:** Goiânia, Embrapa. n.d., Gomes-Klein & Lorenzi *s.n.* (UFG); Campinaçu, Região da Faz. Praia Grande, 06/X/1995, *fl. masc.*, Walter, M.T. *et al.* 2674 (CEN)*

Ceratosanthes multiloba Cogn. **Brazil. Paraná:** *loc. id.*, 18/IX/1996, *fl. fem.*, Hatschbach *et al.* 65308 (SPF)*. **São Paulo:** Pirassununga, Cerrado de Emas, 29/VIII/1992, Salatino *et al.* 115 (SPF)

Ceratosanthes palmata (L.) Urb. **Brazil. Bahia:** São Bento das Lajes, Escola Agrícola, 20/III/1925, *fl. masc.*, Pickel *s.n.* (IPA).

Ceratosanthes rupicola Ridl. **Brazil. Pernambuco:** Ilha de Fernando de Noronha, Ponta da Sapata, 21/IX/2001, *fl. masc.* Miranda, A.M. 3884 (HST).

Ceratosanthes tomentosa Cogn. **Brazil. Goiás:** Mineiros, Parque Nacional das Emas, 03/XII/1994, Gomes-Klein, V. L. 2633 (UFG)*; **Goiás:** Serranópolis, Sudoeste de Goiás, 28/IX/2005, Souza, L. F *et al.* 2628 (HJ)

RESULT AND DISCUSSION

All measures of morphological characters are summarized in Table 3.1, 3.2, 3.3, and 3.4.

This is the first study of the pollen morphology of three (*C. hilariana*, *C. multiloba* and *C. rupicola*) of the five species of *Ceratosanthes* recognized for Brazil.

The mean length of the polar axis varied from 42.71 μm in *C. multiloba* to 57.13 μm in *C. palmata*, while the mean equatorial diameter varied from 44.27 μm in *C. multiloba* to 52.49 μm in *C. hilariana**. The arithmetic mean of the ratio P/E indicates the presence of three different shapes for the pollen grains of *Ceratosanthes* (Tab.3.1): the grains of *C. hilariana*, *C. multiloba*, *C. rupicola* and *C. tomentosa* are oblate spheroidal while in *C. palmata* they are subprolate. Comparing with other studies, the results obtained for *C. palmata* are according with Marticorena (1963) that observed the same grains shape in *C. corniculata* (= *C. palmata*), although the values of P and E were lower than here described. Melhem (1966) indicated polar and equatorial means similar to the values here observed for *Ceratosanthes tomentosa*, whereas the second sample (*) of this species showed a higher mean of polar and equatorial axes and presents a ratio referent to prolate spheroidal grains.

Although cited by Schaefer & Renner (2011) that *Ceratosanthes* pollen grains are (3)-4 colpi, in this work we observed them to be 4-(5)-colpi. The 5-colpi grains were occasionally observed in *C. hilariana*, *C. multiloba* and *C. tomentosa*, and were frequent in *C. rupicola* (Tab.3.2). The colpi and endoaperture width of *C. palmata* were not possible to measure through light microscope since the colpi width was less than 1 μm , and the endoaperture was covered by a margo. The high value of the coefficient of variation to colpi width (Tab.3.2) in *C. rupicola* – 47.63%, *C. tomentosa* and *C. tomentosa** (34.60%, 32.75%*), *C. multiloba** (30.17%) indicates a wide variation among the pollen grains of this species. The apocolpium side was not measured in *C. palmata* due to the low number of grains observed in polar view. This is due to the subprolate shape that results in a tendency for the grains to

repose on slides in equatorial view. The measure of the apocolpium side (Tab.3.3) reached a high coefficient of variability (35.28%) in *C. rupicola*, due to a significant presence of 5-colporated pollen grains.

Though all species share a reticulate pattern of ornamentation, the muri and lumina are variable: polyhedral lumina with irregular and thick muri, are present in *C. rupicola* (Fig.3.2I) and rounded lumina with thicker muri in *C. hilariana* (Fig.3.2A, B), *C. palmata* (Fig.3.2F, G) and in both specimens of *C. tomentosa* (Fig.3.2K, L). In the samples of *C. multiloba* it is possible to observe both patterns of lumina, and irregular thickness of the muri. The muri joined mostly at different levels in *C. hilariana* and *C. tomentosa*, and, in general, at the same level in *C. multiloba*, *C. palmata* and *C. rupicola*. We only succeed to observe fractures showing the exine structure in *C. multiloba* (Fig.3.2E), *C. palmata* (Fig.3.2H) and *C. rupicola* (Fig.3.2J). In those samples, a columellate and simplecolumellate infratectum is visible in *C. palmata* and *C. rupicola*, whereas a duplicolumellate muri with sparse columellae fused or in “Y” with presence of free-columellae (Fig.3.2C, D) in *C. multiloba*.

The divergence between the values of polar axis and equatorial diameter here presented and the ones described by Marticorena (1963), and also of the different colpi number reported by Schaefer & Renner (2011), could be explained by variation in chromosome number according to Pringle & Murray (1992) and Coutinho *et al.* (2011) or by distinct environmental conditions.

A PCA based on palynological characters is presented in Figure 3.3 and the percentage of variance for the axis and the factor coordinates of the variables along the three first components are described in Table 3.5. The first three axes accounted for 89.67% of the total variation. The first represents 42.71% of variation and had a negative loading to equatorial diameter, colpi width, mesocolpia width and lumina, and a high positive loading to Polar axis and the ratio P/E. The second component explains 36.71% of variation, and has negative loadings to the ratio P/E and Muri thickness. The third axis, reaching just 10.25% of variation, has negative loading to Apocolpium, Exine thickness, and Lumina diameter. Pollen grains of *C. palmata* are well separated by the first component due the P/E ratio of the subprolate grain shape.

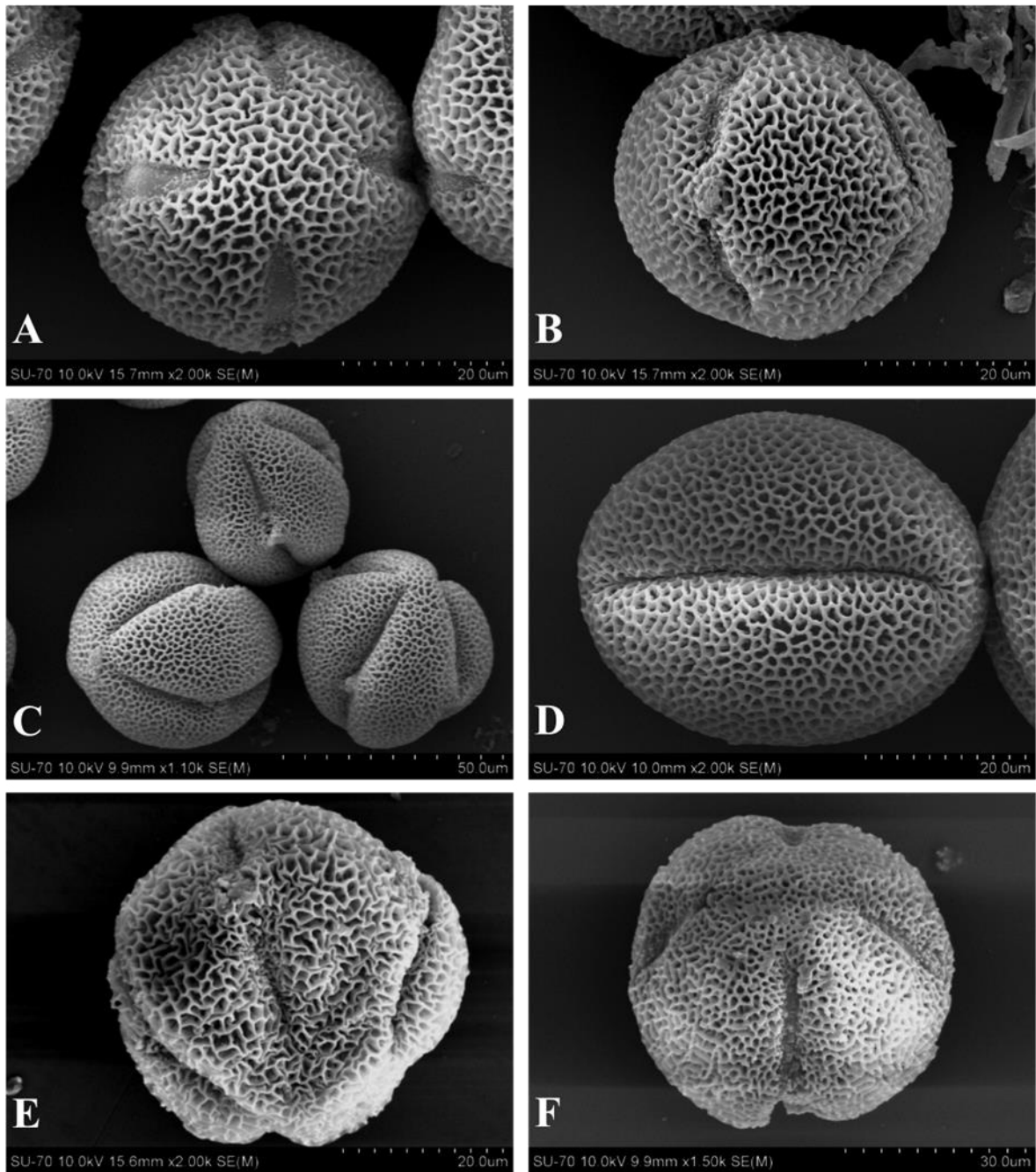


Figure 3.1: Micrographs of pollen grains (SEM): *Ceratosanthes multiloba*, **A** – polar view, **B** – equatorial view; *Ceratosanthes palmata*, **C** – polar oblique view, **D** – equatorial view; *Ceratosanthes rupicola*, **E** – polar oblique view; *Ceratosanthes tomentosa**, **F** – polar oblique view.

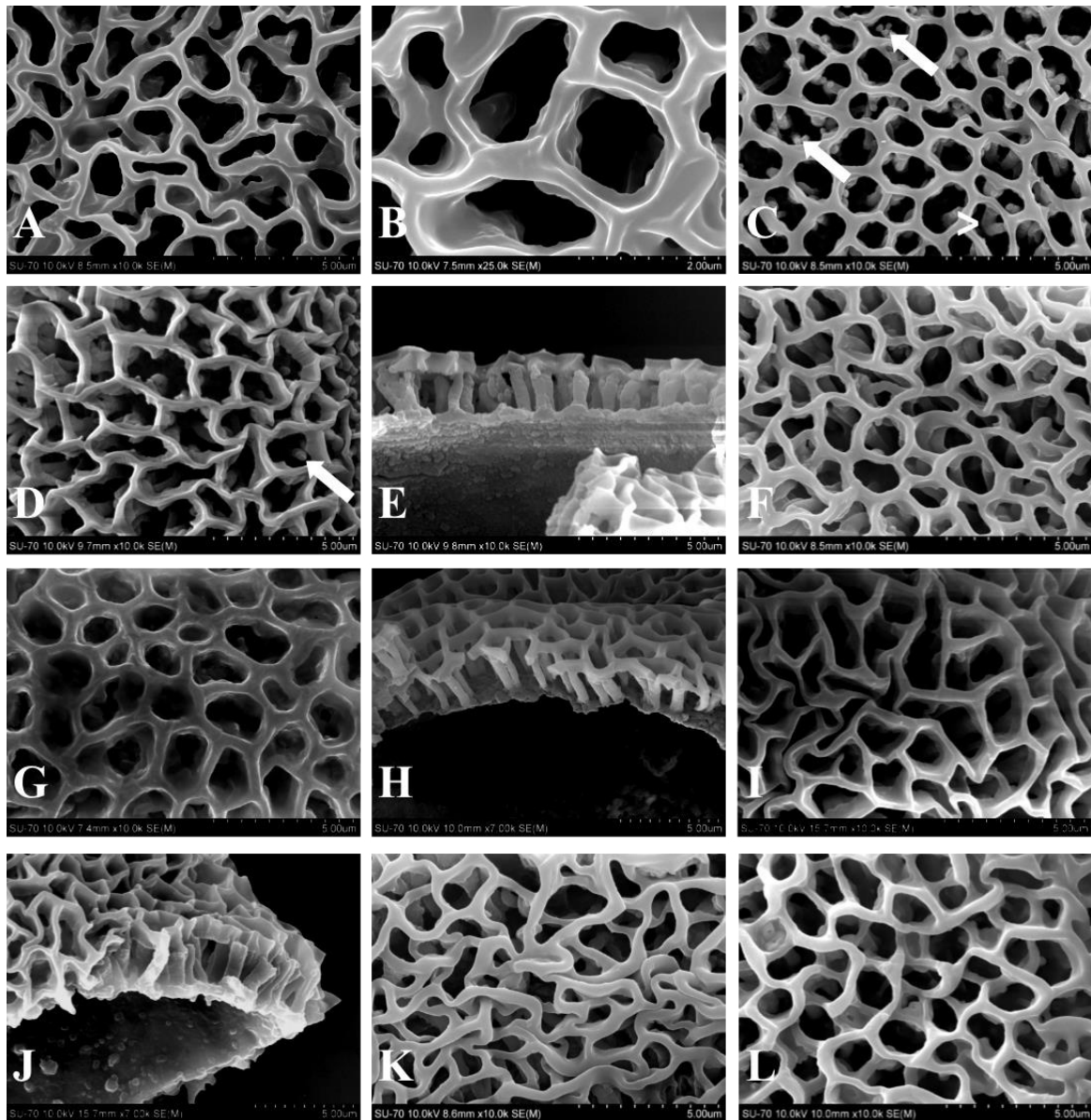


Figure 3.2: Detail of exine ornamentation (SEM): *Ceratosanthes hilariana*, Gomes-Klein, V.L. & Lorenzi, *s.n.* (UFG), **A** - reticulum organization, **B** - detail of lumina and muri; *Ceratosanthes multiloba*, Salatino, M.L.F.; Salatino, A. & Mayworm, M.A.S. 152 (SPF), **C**, **D** - reticulum organization, long sign indicates free-standing columellae, short sign indicates fused columellae, **E** - exine structure; *Ceratosanthes palmata*, Pickel, *s.n.* (IPA), **F** - polar oblique view., **G** - reticulum organization, **H** - exine structure; *Ceratosanthes rupicola*, Miranda, A.M. 3884 (HST), **I** - reticulum organization, **J** - polar oblique view and exine structure; *Ceratosanthes tomentosa**, **K** - reticulum organization; *Ceratosanthes tomentosa*, **L** - reticulum organization.

Table 3.1: Measures of Polar axis (P) and Equatorial diameter (E) of *Ceratosanthes* species. (\bar{X}) mean; ($S_{\bar{X}}$) mean deviation; (S) sample deviation; (V) coefficient of variation; (CI) confidence interval; (OS) oblate spheroidal; (SP) subprolate; (PS) prolate spheroidal; n=30.

Species	$P_{\mu m}$				$E_{\mu m}$				P/E	
	$\bar{X} \pm S_{\bar{X}}$	S	V%	CI _{95%}	$\bar{X} \pm S_{\bar{X}}$	S	V%	CI _{95%}	\bar{X}	Shape
<i>C. hilariana</i>	45,31 ± 1,56	1,93	4,25	44,59 - 46,03	47,42 ± 1,33	1,82	3,85	46,74 - 48,11	0,96	OS
<i>C. hilariana</i> *	47,32 ± 1,77	2,41	5,09	46,42 - 48,22	52,49 ± 2,08	3,01	5,74	51,36 - 53,61	0,90	OS
<i>C. multiloba</i>	42,71 ± 1,81	2,23	5,23	41,87 - 43,54	44,27 ± 1,69	2,11	4,77	43,48 - 45,06	0,97	OS
<i>C. multiloba</i> *	45,52 ± 2,17	2,74	6,02	44,49 - 46,54	46,45 ± 1,85	2,29	4,93	45,60 - 47,31	0,98	OS
<i>C. palmata</i>	57,13 ± 1,47	2,10	3,67	56,35 - 57,91	46,11 ± 2,29	2,76	5,99	45,08 - 47,14	1,24	SP
<i>C. rupicola</i>	49,64 ± 3,08	3,86	7,78	48,20 - 51,08	51,76 ± 1,53	2,25	4,34	50,92 - 52,60	0,96	OS
<i>C. tomentosa</i>	45,66 ± 2,05	2,54	5,56	44,71 - 46,60	47,01 ± 2,79	3,57	7,58	45,68 - 48,34	0,98	OS
<i>C. tomentosa</i> *	55,09 ± 1,84	2,37	4,31	54,20 - 55,97	50,75 ± 3,15	3,72	7,33	49,36 - 52,14	1,09	PS

Table 3.2: Measures of colpus width (CW), endoaperture (EA) and number of colpi (CN) of the studied species of *Ceratosanthes*. (\bar{X}) mean; ($S_{\bar{X}}$) mean deviation; (S) sample deviation; (V) variation; (CI) confidence interval; n=30.

Species	CN	$CW_{\mu m}$				$EA_{\mu m}$			
		$\bar{X} \pm S_{\bar{X}}$	S	V%	CI _{95%}	$\bar{X} \pm S_{\bar{X}}$	S	V%	CI _{95%}
<i>C. hilariana</i>	4 (5)	2,74 ± 0,57	0,64	23,35	2,50 - 2,98	7,38 ± 1,11	1,45	19,69	6,84 - 7,93
<i>C. hilariana</i> *	4(5)	3,12 ± 0,35	0,61	19,57	2,89 - 3,35	8,25 ± 1,53	1,85	22,43	7,56 - 8,94
<i>C. multiloba</i>	4	2,46 ± 0,55	0,64	25,98	2,22 - 2,70	7,56 ± 1,46	1,87	24,76	6,86 - 8,26
<i>C. multiloba</i> *	4(5)	2,01 ± 0,39	0,61	30,17	1,78 - 2,24	7,42 ± 1,74	2,08	27,97	6,64 - 8,19
<i>C. palmata</i>	4								
<i>C. rupicola</i>	4-5	1,59 ± 0,67	0,76	47,63	1,31 - 1,88	10,43 ± 1,09	1,63	15,59	9,83 - 11,04
<i>C. tomentosa</i>	4(5)	2,29 ± 0,67	0,79	34,60	1,99 - 2,58	10,02 ± 0,97	1,30	12,93	9,54 - 10,50
<i>C. tomentosa</i> *	4(5)	3,12 ± 0,76	1,02	32,75	2,74 - 3,50	9,91 ± 1,34	1,74	17,58	9,26 - 10,57

Table 3.3 Measures of mesocolpe width (MW), apocolpium (A) of the studied species of *Ceratosanthes*. (\bar{X}) mean; ($S_{\bar{x}}$) mean deviation; (S) sample deviation; (V) variation; (CI) confidence interval; n=30.

Species	MW				A			
	$\bar{X} \pm S_{\bar{x}}$	S	V%	CI _{95%}	$\bar{X} \pm S_{\bar{x}}$	S	V%	CI _{95%}
<i>C. hilariana</i>	25,65 ± 1,55	1,86	7,25	24,96 - 26,35	214,04 ± 34,37	44,38	20,74	197,47 - 230,61
<i>C. hilariana</i> *	29,33 ± 2,43	2,97	10,13	28,22 - 30,44	220,18 ± 43,54	52,38	23,79	200,62 - 239,74
<i>C. multiloba</i>	23,46 ± 2,17	2,78	11,85	22,42 - 24,49	195,30 ± 48,86	60,94	31,20	172,54 - 218,05
<i>C. multiloba</i> *	25,10 ± 2,48	3,03	12,06	23,97 - 26,23	215,56 ± 37,67	48,09	22,31	197,61 - 233,52
<i>C. palmata</i>	24,68 ± 1,66	2,02	8,20	23,93 - 25,44	-	-	-	-
<i>C. rupicola</i>	26,00 ± 2,70	3,96	15,22	24,52 - 27,48	253,89 ± 71,29	89,58	35,28	220,44 - 287,34
<i>C. tomentosa</i>	26,55 ± 1,78	2,48	9,36	25,63 - 27,48	174,14 ± 45,36	54,83	31,49	153,66 - 194,61
<i>C. tomentosa</i> *	26,42 ± 3,63	4,67	17,68	24,67 - 28,16	249,1 ± 51,02	66,52	26,71	224,23 - 273,91

Table 3.4: Measures of muri thickness and lumina diameter for the studied species of *Ceratosanthes*. (\bar{X}) mean; ($S_{\bar{x}}$) mean deviation; (S) sample deviation; (V) variation; (CI) confidence interval; n=15.

Species	Muri				Lumina			
	$\bar{X} \pm S_{\bar{x}}$	S	V%	CI _{95%}	$\bar{X} \pm S_{\bar{x}}$	S	V%	CI _{95%}
<i>C. hilariana</i>	0,29 ± 0,04	0,05	18,53	0,26 - 0,32	1,63 ± 0,36	0,49	29,96	1,36 - 1,90
<i>C. hilariana</i> *	0,35 ± 0,05	0,06	16,38	0,31 - 0,38	1,82 ± 0,37	0,44	24,26	1,57 - 2,06
<i>C. multiloba</i>	0,45 ± 0,13	0,15	33,58	0,36 - 0,53	1,84 ± 0,29	0,42	22,78	1,61 - 2,07
<i>C. multiloba</i> *	0,30 ± 0,07	0,09	31,11	0,25 - 0,36	2,41 ± 0,37	0,46	18,91	2,16 - 2,66
<i>C. palmata</i>	0,44 ± 0,08	0,09	20,42	0,39 - 0,49	1,93 ± 0,24	0,37	19,07	1,72 - 2,13
<i>C. rupicola</i>	0,33 ± 0,06	0,07	21,72	0,29 - 0,37	2,34 ± 0,68	0,79	33,89	1,90 - 2,78
<i>C. tomentosa</i>	0,34 ± 0,08	0,10	29,31	0,29 - 0,40	1,54 ± 0,15	0,20	12,74	1,43 - 1,65
<i>C. tomentosa</i> *	0,45 ± 0,11	0,13	28,95	0,38 - 0,52	1,66 ± 0,26	0,36	21,74	1,46 - 1,86

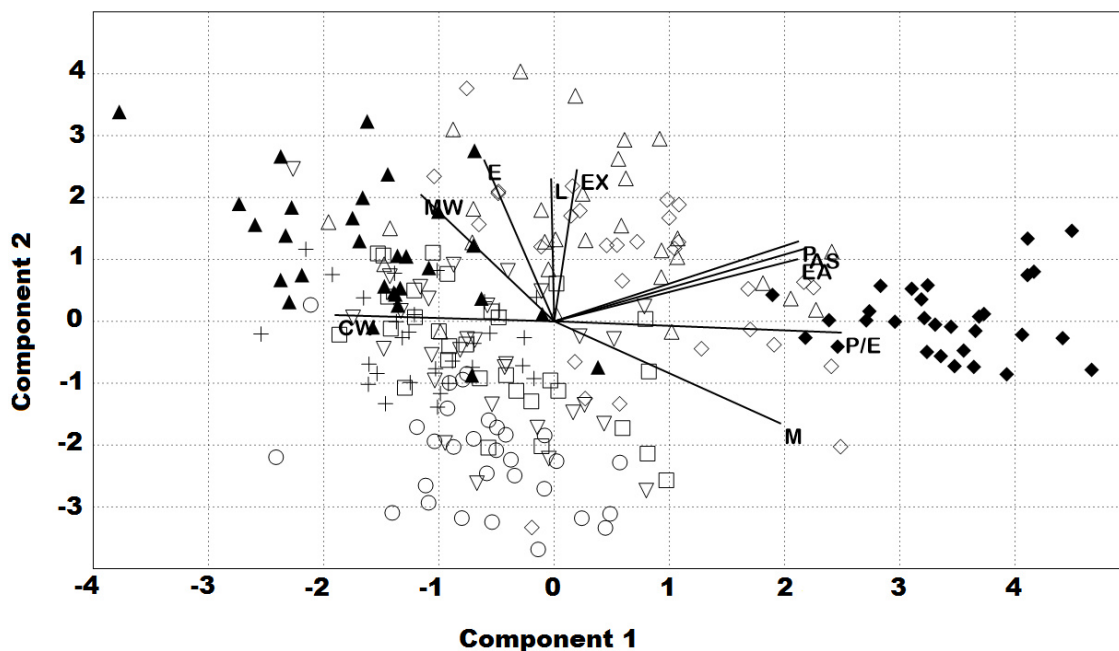


Figure 3.3: Biplot of principal component analyses (PCA) for *Ceratosanthes* species with pollen grains metrics variables, samples ordinated according with first and second component. (+ = *C. hilariana*; ▲ = *C. hilariana**; ○ = *C. multiloba*; □ = *C. multiloba**; ◆ = *C. palmata*; △ = *C. rupicula*; ▽ = *C. tomentosa*; ◇ = *C. tomentosa**; for legend for variables see legend in Table 5).

Table 3.5: Principal component analyses for *Ceratosanthes* species with ten variables. P= Polar Axis; E= Equatorial diameter; EA= Endoaperture; CW= Colpi width; MW= Mesocolpe width; A= Apocolpium; EX= Exine.

Axis	Eigen value	Variance%	Variables									
			P	E	P/E	EA	CW	MW	A	EX	Muri	Lumina
1	4,27	42,71	0,81	-0,23	0,95	0,81	-0,73	-0,44	0,83	0,08	0,75	-0,01
2	3,67	36,71	0,46	0,93	-0,06	0,36	0,04	0,73	0,42	0,87	-0,59	0,82
3	1,02	10,25	0,33	0,20	0,22	0,12	0,63	0,39	-0,01	-0,30	0,16	-0,38

DICHOTOMOUS PALYNOLOGICAL KEY FOR *CERATOSANTHES* SPECIES:

- 1- Pollen grains with 4-5 colpi **4 - *C. rupicola***
 1- Pollen grains with 4(5) colpi **2**
 2- Pollen grains subprolate **3 - *C. palmata***
 2- Pollen grains oblate spheroidal or prolate spheroidal **3**
 3- Numerous free-standing columellae **2 - *C. multiloba***
 3- Few or no free-standing columellae **4**
 4- Muri joined mostly at different level **5 - *C. tomentosa***
 4- Muri joined mostly at the same level **1 - *C. hilariana***

POLLEN DESCRIPTION

GENERAL DESCRIPTION

Pollen medium size to large, P= 38.48 – 62.40 μm ; E= 38.48 – 62.40 μm , oblate spheroidal to subprolate, P/E= 0.77 – 1.38, radially symmetric, isopolar and stephanoaperturate. Colpi 4(5), 1.04 – 5.20 μm width; endoaperture 4.16 – 15.60 μm wide; mesocolpus 15.60 – 36.40 μm width and apocolpium 83.20 – 432.64 μm^2 . Exine 2.08 – 6.24 μm thickness, ornamentation reticulate; muri 0.16 – 0.71 μm thickness; lumina rounded to polyhedral with 0.55 – 3.84 μm diameter; tectum 0.63 – 1.65 μm , columellae 1.10 – 2.12 x 0.43 – 0.73; nexine 0.27 – 0.50.

1- *Ceratosanthes hilariana* Cogn. Diagn. Cucurb. Nouv. 2: 31 – 33.1877.

Pollen medium size to large, P= 46.31 (41.6 – 53.04) μm ; E= 49.95 (42.64 – 62.4) μm , oblate spheroidal, P/E= 0.93, radially symmetric, isopolar and stephanoaperturate. Colpi 4(5), 2.93 (2.08 – 4.16) μm width; endoaperture 7.82 (5.2 – 12.48) μm wide; mesocolpus 27.50 (22.88 – 36.4) μm width and apocolpium 217.11 (97.35 – 318.24) μm^2 . Exine 3.12 – 6.24 μm thickness, ornamentation reticulate; muri 0.32 (0.22 – 0.44) μm thickness; lumina mostly rounded 0.65 – 2.77 μm diameter.

2- *Ceratosanthes multiloba* Cogn. Diagn. Cucurb. Nouv. 2: 29.1877.

Pollen medium size to large, P= 44.11 (38.48 – 52.0) μm ; E= 45.63 (40.56 –

52.00) μm , oblate spheroidal, $P/E = 0.97$, radially symmetric, isopolar and stephanoaperturate. Colpi 4(5), 2.24 (1.04 – 4.16) μm width; endoaperture 7.49 (4.16 – 12.48) μm wide; mesocolpus 24.28 (18.72 – 31.2) μm width and apocolpium 205.43 (83.20 – 330.97) μm^2 . Exine 3.12 – 5.20 μm thickness, ornamentation reticulate; muri 0.38 (0.16 – 0.68) μm thickness; lumina rounded to polyhedral 0.55 – 3.12 μm diameter. Presence of free-standing columellae.

3- *Ceratosanthes palmata* (L.) Urb. in Fedde, Rep. 15:323. 1918.

Pollen medium size to large, $P = 53.04 - 62.40 \mu\text{m}$; $E = 39.52 - 49.92 \mu\text{m}$, subprolate, $P/E = 1.24$, radially symmetric, isopolar and stephanoaperturate. Colpi 4, with less than 1 μm width; mesocolpus 24.68 (1.04 – 1.04) μm width. Exine 3.12 – 5.20 μm thickness, ornamentation reticulate; muri 0.43 (0.032 – 0.60) μm thickness; lumina rounded 0.55 – 3.12 μm diameter. Most of the pollen grains lie in polar view due the subprolate shape, thus it hinders the measure of the apocolpium. Although the colpi width is less than 1 μm , the margo is visible and covers the endoaperture.

4- *Ceratosanthes rupicola* Ridl. J. Linn. Soc., Bot. 27:38.1890.

Pollen medium size to large, $P = 41.6 - 58.24 \mu\text{m}$; $E = 46.80 - 56.16 \mu\text{m}$, oblate spheroidal, $P/E = 0.95$, radially symmetric, isopolar and stephanoaperturate. Colpi 4-5, 1.60 (1.04 – 3.12) μm width; endoaperture 10.44 (7.28 – 15.60) μm wide and apocolpium 253.89 (108.16 – 408.98) μm^2 . Exine 4.16 – 6.24 μm thickness, ornamentation reticulate; muri with irregular thickness, 0.33 (0.22 – 0.45) μm ; lumina polyhedral with 1.45 – 3.84 μm diameter.

5- *Ceratosanthes tomentosa* Cogn. Diagn. Cucurb. Nouv. 2:29.1877.

Pollen medium size to large, $P = 41.6 - 59.28 \mu\text{m}$; $E = 38.48 - 57.20 \mu\text{m}$, oblate spheroidal to prolate spheroidal, $P/E = 1.03$, radially symmetric, isopolar and stephanoaperturate. Colpi 4(5), 2.70 (1.04 – 5.20) μm width; endoaperture 9.97 (5.2 – 12.48) μm wide and apocolpium 211.60 (97.34 – 432.64) μm^2 . Exine 2.08 – 5.20 μm thickness, ornamentation reticulate; muri 0.40 (0.17 – 0.71) μm thickness; lumina rounded and irregular 0.88 – 2.39 μm diameter. Muri joined in different levels.

CONCLUSION

The pollen grains in *Ceratosanthes* are medium size to large, radially symmetric, isopolar, 4(5) stephanoaperturate. The reticulate ornamentation here observed is similar to the ornamentation pattern of the tribe *Coniandreae*. Although flower morphology is very uniform and do not provide support to delimitation of the taxa, this work evidences a pollen heterogeneity among different species and highlights the taxonomic importance of the grain shape, columellae, muri and lumina features.

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CHAPTER 4

FINAL CONCLUSIONS

FINAL CONCLUSION

After Cogniaux 1916, this thesis is the first review, that deals with the Brazilian species of *Ceratosanthes* Adans. on its totality, focusing on the morphological and palynological characters. Based on an exhaustive bibliographic review and thorough analyses of loans provided by national and international herbaria, the results here indicate a total of five species in Brazil, and suggested seven new synonyms, one for *Ceratosanthes hilariana* Cogn., other for *C. tomentosa* Cogn. and five new to *C. palmata* (L.) Urb. In spite of the detailed morphological study here presented, the information about the sexual system of the species still lacks consistent field observations. Thus, further studies are necessary, dedicated to continuous observations throughout different reproductive seasons to elucidate the apparently dioecious state of some species.

The endemic distribution of *Ceratosanthes rupicola* Ridl. in the Archipelago of Fernando de Noronha cited by Gomes-Klein & Santana 2009 reinforces the importance to preserve the natural landscape and resource of the archipelago.

The frequent deciduous condition of the species during anthesis has been a problem for the identification of the specimens since the leaves still are the main important character for intraspecific delimitation.

The pollen study here presented has shown that some pollen characters have significant taxonomic value like the grain shape, ornamentation and sculpture. The dichotomous key, based on palynological characters, here presented can be used as an additional tool for the identification of the various specimens held under *Ceratosanthes* sp. in herbaria collections, particularly when they present flowers but no leaves.

The author hopes that the new information brought by this thesis will be a useful contribution to the knowledge of the Brazilian flora and to encourage new studies about the phylogenetic relationships among the species of *Ceratosanthes* and with other genus in the tribe *Coniandreae*, considering the few information available about the phylogenetic hierarchy among the genera in the tribe.

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CHAPTER 5

APPENDICES

Appendix 5.1: List of Exsiccata

***Ceratosanthes hilariana* Cogn.**

leg. ign. s.n. (RB)
 Barros 410, 23/IX/1980 (SP);
 Custódio Filho 340, 24/IX/1980 (SP)
 Forero *et al.* 8337, 23/IX/1980 (SP)
 Forero *et al.* 8358, 23/IX/1980 (SP);
 Gomes-Klein & Lorenzi *s.n.* (UFG)
 Gomes-Klein & Nakajima 2611, 24/XI/1994 (UFG)
 Gomes-Klein *et al.* 7707, 01/II/2013 (UFG)
 Hoehne 6090, XI/1915 (R)
 Hoehne 6092, XI/1915 (R)
 Irwin, H.S. & Soderstrom *s.n.*, 01/X/1964 (MBM 65406);
 Kuhlmann 3186, 14/IX/1946 (SP)
 Mantovani 1076, 22/IX/1980 (SP)
 Mattos & Mattos 14878, 9/XII/1966 (SP)
 Semir & Martins 1521, 07/X/1975 (UEC)
 Walter *et al.* 2674, 6/X/1995 (CEN);
 Wasicky *s.n.* 23/X/1954 (SPF, UFG)
 Biganzoli *et al.* 528, 20/IX/1999 (SI)
 Bonpland, 1906, *s.d.* (BA)
 Hassler 7185, 1901-1902 (P)
 Jørgensen 2774, 1915 (SI)

***Ceratosanthes multiloba* Cogn.**

leg. ign. s.n., 25/IX/1945 (SPF 66875)
leg. ign. s.n., 25/IX/1945 (SPF 66875)
 Aragaki & Batalha 115, 08/IX/1994 (SP)
 Araújo *et al.*, 1500, 29/II/2010 (HVASF)
 Batalha 222, 27/X/1994 (SP).
 Bicudo, Campos & Amaral 471, 04/II/1986 (UEC)
 Dobreiner & Tokarnia 1046, 05/XI/1973 (RB)
 Forero *et al.* 8272, 23/IX/1980 (SP)
 Haas 2, 14/IX/1967 (MBM)
 Harley, Castro & Ferreira, 21/X/1968 10739 (UB, K);
 Hatschbach 19986, 11/X/1968 (MBM)
 Hatschbach 27136, 07/X/1971 (MBM)
 Hatschbach *et al.* 65308, 18/IX/1996 (MBM, SPF)
 Heringer *s.n.*, 15/XI/1958 (UB 27957)
 Hoehne & Gehrt *s.n.*, 10/XI/1936 (SP 36750)
 Irwin *et Soderstrom* 6540, 01/X/1964 (R, NY)
 Irwin *et Soderstrom* 6879, 15/X/1964 (R, NY);
 Miranda & Oliveira 5650, 12/II/2006 (HST)
 Pereira, Egler & Graziela 193, 05/X/1953 (RB)

Salatino, M.L.F. *et al.* 152, 10/X/1992 (SPF)
 Sidney & Onishi 1420, 11/X/1968 (UB)
 Silva & Hatschbach 1031, 30/V/1991 (MBM)
 Slatino, M.L.F. *et al.* 115, 10/X/1992 (SPF)
 Uhlmann *et al. s.n.*, 28/X/2007 (MBM 349543)
 Burkart 8093, 08/XI/1936 (SI)
 Daguerre *s.n.*, 14 – 15/IX/1928 (BA 281015)
 Felippone 4281, *n.d.* (SI)
 Jørgensen 2781, 1915 (SI)
 Múlgura de Romero *et al.* 2179, 21/IX/2000 (SI)
 Schulz 72, X-XII/1930 (SI)
 Tamayo 2615, 26/I/1946 (SI)
 Venturi 668, XI/1919 (SI)
 Venturi 7497, 14/XI/1928 (SI)
 Venturi 7719, 05/XII/1928 (SI)

Ceratosanthes palmata

Amorim *et al.* 3892, 29/XI/2003 (CEPEC)
 Aparecida da Silva *et al.* 4601, 30/X/2000 (IBGE)
 Bleé *s.n.*, VII/1820 (P 5622512)
 Burkart 16027, 19/III/1946 (SI).
 Cruger 7, XI/1861 (P)
 Empereire 230, 06/II/1984 (RB)
 Fernandes *et Nunes s.n.*, 09/III/1981 (EAC)
 Fontana *et al.* 6289, 11/I/2010 (HVASF, UFG)
 Goudot *s.n.*, VIII/1844 (P 5622529)
 Granville *et al.* 9892, 31/VIII/1987 (P)
 Granville, Crozier *et Sarthou* 16080, 19/IV/2004 (CAY, P)
 Hahn 1332, 1870 (P)
 Harley *et al.* 10848, 26/X/1968 (UB, K)
 Hatschbach 32912, 20/X/1974 (MBM, SPF, P)
 Hatschbach *et Guimarães* 21930, 17/VII/1969 (MBM)
 Hatschbach *et Ribas* 79842, 9/II/2007 (MBM)
leg. ign. s.n., *n.d.* (P 5622516)
 Miranda *et al.* 719, 28/IV/1993 (HST)
 Miranda *s.n.*, 19/VI/2003 (HST 11790)
 Pickel 873, 20/III/1925 (IPA)
 Projeto Parque das Dunas 276, 16/I/1981 (R)
 Silva 303, 07/III/2004 (PEUFR)
 Vuperr. *s.n.*, 1825 (P 5622513)

***Ceratosanthes rupicola* Ridl.**

Miranda *et al.* 864, 01/VI/1993 (HST)

Miranda 3732, 26/IX/2000 (HST)

Miranda 4226, 17/X/2003 (HST)

***Ceratosanthes tomentosa* Cogn.**

Amaral *et al.* 76, 24/X/1985 (UEC)

Amaral, Medonça & Dias 61, 13/X/1998 (BOTU)

Cavalcanti *et al.* 725, 16/VIII/1990 (SP)

Costa *et Klein* 39, v.s.c., 06/IX/1994 (UFG)

Costa *s.n.*, 04/VI/1996 (UFG)

Costa *s.n.*, 23/II/1996 (UFG)

Glaziou *s.n.*, 1907 (P)

Gomes-Klein & Conceição 7707, 08/VIII/2012 (UFG)

Gomes-Klein *et al.* 2632, 03/XII/1994 (UFG)

Gomes-Klein *et al.* 2633, 03/XII/1994 (UFG)

Gomes-Klein *et al.* 3503, 12/X/1998 (RB, UFG)

Gomes-Klein *et al.* 4013, 07/XI/2005 (UFG)

Gomes-Klein, Costa & Gomes 3183, 08/IX/1996 (UFG)

Gomes-Klein, Costa & Gomes 3184, 08/IX/1996 (UFG)

Hatschbach & Silva 56032, 10/II/1991 (MBM)

Hoehne *s.n.*, 06/X/1931 (SP, UFG)

Irwin & Soderstrom 6878, 15/X/1964 (HB, NY)

Irwin, Souza & Grear 17698, 24/VI/1966 (RB, NY, UB)

Krieger *s.n.*, 25/V/1996 (SP)

Loefgren 864, 11/IX/1908 (SP)

Mattos & Moura *s.n.*, X/1965 (SP)

Rizzo *et Barbosa* 4873, 21/III/1970 (UFG)

Salles *et al.* 1462, 22/X/1989 (HEPH)

Simart *s.n.*, s.d. (P)

Skorupa, Werneck & Silveira 204, 26/IX/1987 (CEN)

Souza *et al.* 1181, 28/IX/2004 (HJ, UFG)

Souza *et al.* 2628, 28/IX/2005 (HJ, UFG)

Appendix 5.2: Abbreviations

µm = micrometer

Actas de la primera Reunion Nac. de la Soc.

Arg. de Cienc. Nat. = Actas de la primeira reunion Nacional de la Sociedad Argentina de Ciencias Naturales

Arn. = George Arnott Walker Arnott

Benth. = George Bentham

Bot. Mag. = Botanical Magazine

Bull. Acad. Roy. Sci. Belgique = Bulletins de l'Academie Royale des Sciences, des Lettres et des Beaux Arts de Belgique

Bull. Herb. Boiss. = Bulletin de l'Herbier

Boissier

Burm. = Johannes Burman

ca. = *circa*

Cat. = Catalogue plantarum americanarum / catalogue

Cat. Pl. Vasc. Argentina

cm = centimeter

Cogn. = Célestin Alfred Cogniaux

Comm. Geogr. Geol. E. S. Paulo =

Comissão Geográfica e Geologica do Estado de São Paulo

DC. = De Candolle

Descourt. = Michel Étienne Descourtilz

Diagn. Cucurb. Nouv. = Diagnoses des Cucurbitacées Nouvelles et Observations sur les Especies Critiques

Encycl. = Encyclopedie Methodique.

Botanique

et al. = *et alii* / *et aliorum*

Fam. Pl. = Familles des Plantes

fasc. = fasciculum

Fl. Antill. = Flore des Antilles

Fl. Bras. = Flora Brasiliensis

Fl. Brit. W. Ind. Isl. = Flora of the British West Indian Islan

fl. fem. = *flores foeminei*

fl. masc. = *flores masculi*

fr. = *fructu*

Gen. Plant. = Genera Plantarum (Jussieu) or Genera Plantarum ad exemplaria imprimis in herbariis Kewensibus

Griseb. = August Heinrich Rudolf Grisebach

Hook. = William Jackson Hooker

J. Bot. = Journal of Botany

J. F. Gmel. = Johann Friedrich Gmelin

Juss. = Antoine Laurent de Jussieu

Lam. = Jean-Baptiste Pierre Antoine de Monet de Lamarck

leg. ign. = *legit ignotus*

Linn. Soc., Bot. = Journal of the Linnean Society. Botany

loc. id. = *loco idem*

loc. ingot. = *locus ignotus*

Mart. = Carl (Karl) Friedrich Philipp von Martius
Mém. Couronnés Mém. Savants Étrangers
Acad. Roy. Sci. Bruxelles = Mémoires Couronnées et Mémoires des Savants Étrangers. Academie Royale des Sciences et Belles-Lettres de Bruxelles
mm = millimeter
Mon. Phan. = Monographiæ Phanerogamarum
N = North
n.d. = no date
Pflanzenr. = Das Pflanzenreich
Pl. Amer. = Plantarum Americanarum
Plum. = Charles Plumier
Prodr. = Prodrömus
prov. = province
Rep = Repertorium novarum specierum regni vegetabilis

Resena fitogeog. de la prov. de Tucuman = Resenha fitogeographica de la provincia de Tucuman
Roem. = Johann Jakob Roemer
s.n. = *sine numero*
S = South
Schrad. = Heinrich Adolph Schrader
Ser. = Nicolas Charles Seringe
Sp. Pl. = Species Plantarum
Spreng = Curt (Kurt, Curtius) Polycarp Joachim Sprengel
Syn. Mon = Familiarum Naturalium Regni Vegetabilis Synopses Monographicae
Syn. nov. = Synonymum novum
Syst. Nat. = Systema Naturae
Syst. Veg = Systema vegetabilium
v.s.c. = *vidi siccam cultam*
W = West
Willd. = Carl Ludwig Willdenow