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Senna (Cassiinae, Leguminosae) in Paraguay: synopsis, occurrence, ecological role and ethnobotany

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RÉSUMÉ

MARAZZI, B., R. H. FORTUNATO, P. K. ENDRESS & R. SPICHIGER (2006). Le genre Senna (Cassiinae, Leguminosae) au Paraguay: synopsis, répartition, rôle écologique et ethnobotanique. *Candollea* 61: 315-329. En anglais, résumés français et anglais.

Senna (Cassiinae, Leguminosae) est un genre qui compte env. 350 espèces, distribuées principalement dans les tropiques et en Amérique tempérée. Les auteurs reconnaissent 23 espèces pour le Paraguay. Une d'entre elles, *S. macranthera*, est nouvelle pour le Paraguay. La distribution des espèces est discutée. Celles-ci sont largement répandues au Paraguay. Néanmoins, on peut qualifier quatre espèces de peu fréquentes (moins de trois localités) et trois autres de rares. Leur statut de conservation est discuté par les auteurs. Le rôle écologique des espèces de *Senna* est aussi analysé, celles-ci offrant du pollen aux abeilles et du nectar extrafloral aux fourmis. Les aspects ethnobotaniques et l'utilisation ornementale de ces espèces sont passés en revue par les auteurs. Les clés de détermination publiées dans les révisions récentes du genre étant construites autour des relations systématiques entre les espèces de *Senna*, les auteurs présentent une nouvelle clé de détermination des espèces de ce genre au Paraguay, basée sur un critère pratique. Des notes discutant des problèmes potentiels de détermination accompagnent cette clé.

ABSTRACT

MARAZZI, B., R. H. FORTUNATO, P. K. ENDRESS & R. SPICHIGER (2006). Senna (Cassiinae, Leguminosae) in Paraguay: synopsis, occurrence, ecological role and ethnobotany. *Candollea* 61: 315-329. In English, French and English abstracts.

Senna (Cassiinae, Leguminosae) is a large and diverse genus of about 350 species mainly distributed in the Tropics and in temperate America. We recognized 23 species for Paraguay, one of them, *S. macranthera*, is new for Paraguay. Most species are widely distributed in Paraguay and are common ruderals of roadsides. However, four species, *S. leiophylla*, *S. rugosa*, *S. spiniflora*, and *S. splendida*, are known from less than three localities, and at least three other species are also rare. The unclear conservation status of these species is especially due to habitat disruption by human activities, but also to the patterns of distribution of the species, to naturalization from cultivated plants, and perhaps to recent speciation. *Senna* species play an ecological role by offering pollen to traplining bees, and extrafloral nectar to ants. Although no *Senna* species is economically important in Paraguay, some species were mentioned by ethnobotanists to be used by man, and others are cultivated as ornamentals. The keys found in the most recent revision of the genus show systematic relationships between the *Senna* species, but are not a suitable identification tool. Thus, in addition to discuss the distribution, conservation status, ecologic role and aspects of ethnobotany and ornamental plants, the present study includes a new practical determination key for the *Senna* species in Paraguay with notes discussing potential identification problems.

KEY-WORDS: LEGUMINOSAE – CASSIINAE – Senna – Conservation – Ethnobotany – Floristics Ornamentals – Systematics – Paraguay

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Introduction

Senna Mill. *(Leguminosae, Cassiinae)* is a large and diverse genus with attractive yellow flowers, which was formerly part of *Cassia* L. together with *Chamaecrista* Moench. The separation of *Cassia* s.l. into *Cassia* s.str., *Chamaecrista* and *Senna* (IRWIN & BARNEBY, 1981, 1982) has been confirmed by morphological studies (e.g. ENDRESS, 1994; TUCKER, 1996) and molecular phylogenetic studies (e.g. BRUNEAU & al., 2001; HERENDEEN & al., 2003; MARAZZI & al., 2006). *Senna* includes approximately 350 species distributed worldwide almost throughout the Neotropics and widespread in tropical Africa, Madagascar, and Australia, but less so in SE-Asia and the Pacific Islands (IRWIN & BARNEBY, 1982; RANDELL & BARLOW, 1998). Approximately 80% of *Senna* species occur in the American continent and these were grouped into 6 sections and 35 series by IRWIN & BARNEBY (1982).

The classification proposed by IRWIN & BARNEBY (1982) has been widely adopted also in taxonomic treatments of *Senna* in other continents (e.g. RANDELL, 1988, 1989, 1990; SINGH, 2001), and reflects IRWIN & BARNEBY's (1982) interpretations of morphological evolution and phylogenetic relationships within the genus. Although these interpretations and also most of the sectional delimitations (except section *Psilorhegma*) were not supported by recent molecular phylogenetic work on *Senna* (MARAZZI & al., 2006), the keys and species descriptions by IRWIN & BARNEBY (1982) offer a large amount of information collected during many years of dedication to this group.

Species of *Senna* are used for their medicinal properties (especially as a purge) and are appreciated as ornamentals since a long time, owing to their showy yellow flowers (COLLADON, 1816; PARODI, 1934; BURKART, 1943; DIMITRI & RIAL ALBERTI, 1954; IRWIN & BARNEBY, 1982; LUCKOW, 1996). The specialized buzz-pollinated flowers, but also the extrafloral nectaries of numerous *Senna* species are highly interesting features of the genus (see also MARAZZI & al., 2006). Both have ecological roles, since the flowers provide pollen to their pollinators, and the extrafloral nectaries produce nectar, which is appreciated by ants.

The presence of *Senna* in Paraguay was already documented more than a century ago. MORONG & BRITTON (1892) recognized 15 Paraguayan *Cassia* s.l. species, 11 of which correspond to *Senna* species according to IRWIN & BARNEBY (1982), including a new species, *Senna* (*Cassia*) *morongii*. In the beginning of the 20th century, additional *Senna* species were collected by Emil Hassler and Teodoro Rojas during their expeditions to Paraguay.

The aim of the present study is to provide an account of the genus *Senna* in Paraguay. In particular we focus on (i) the geographic distribution and conservation needs, (ii) the potential ecologic role, (ii) aspects of ethnobotany considering also ornamental species, and (iv) a new determination key for the *Senna* species in Paraguay, which mostly bases on vegetative traits and includes notes on potential identification problems.

Material and methods

The present work is in part based on the diploma thesis of the first author (see MARAZZI, 2002). The initial preliminary list of *Senna* species of Paraguay had been provided by C. Lambelet (collaborator of the Project 'Flora del Paraguay' at G), who in 1996 recorded the species cited for Paraguay in the revision of IRWIN & BARNEBY (1982) and listed them together with Paraguayan specimens at G.

Specimens from the following herbaria were studied: BAB, BAF, CTES, FCQ, G, LIL, MO, NY, PY, SI, Z, and from the collections of B. Marazzi and R. Fortunato. The specimens studied are not listed in this publication because of its non-taxonomic focus.

The measurements of all organs used in our artificial key are based on the herbarium specimens from Paraguay studied by the first author, except for *S. leiophylla*, *S. morongii* (in part), and *S. rugosa* with insufficient material. In these cases, the sources of information are from IRWIN & BARNEBY (1982). Leaflet size used in the artificial key is referred to the blade (the pulvinulus is excluded).

Results

In the present study, all 22 species out of the four sections reported for Paraguay by IRWIN & BARNEBY (1982), are confirmed, and a further species, *S. macranthera*, represented by more recent collections, is added (see Table 1). The presence of *S. oblongifolia* and *S. bicapsularis* (MORONG & BRITTON, 1892; BERNARDI, 1984) in Paraguay is doubtful, as all reports are based on incorrectly determined specimens of *S. pendula*, but we did not see the two specimens cited by DEGEN & MERELES (1996). The presence of *S. chacoënsis* in Paraguay, reported only by DEGEN & MERELES (1996), remains unclear, since we did not see any specimen of this species.

Table 1. – Sections, series and species of *Senna* in Paraguay (after IRWIN & BARNEBY, 1982).

Section	Series	Species
Chamaefistula	*Sapindifoliae*	*Senna silvestris* (Vell.) H. S. Irwin & Barneby
	Bacillares	*S. macranthera** (Collad.) H. S. Irwin & Barneby
		S. rugosa (G. Don) H. S. Irwin & Barneby
		S. splendida (Vogel) H. S. Irwin & Barneby
	Laxiflorae	*S. velutina* (Vogel) H. S. Irwin & Barneby
	Trigonelloideae	*S. leiophylla* (Vogel) H. S. Irwin & Barneby
		S. mucronifera (Benth.) H. S. Irwin & Barneby
		S. obtusifolia (L.) H. S. Irwin & Barneby
		S. pilifera (Vogel) H. S. Irwin & Barneby
	Coluteoideae	*S. corymbosa* (Lam.) H. S. Irwin & Barneby
		S. hilariana (Benth.) H. S. Irwin & Barneby
		S. morongii (Britton) H. S. Irwin & Barneby
		S. pendula (Willd.) H. S. Irwin & Barneby
	Basiglandulosae	*S. cernua* (Balbis) H. S. Irwin & Barneby
		S. hirsuta (L.) H. S. Irwin & Barneby
		S. occidentalis (L.) Link
		S. scabriuscula (Vogel) H. S. Irwin & Barneby
Senna	*Pictae*	*S. alata* (L.) Roxb.
	Aculeatae	*S. aculeata* (Benth.) H. S. Irwin & Barneby
Paradictyon	–	*S. paradictyon* (Vogel) H. S. Irwin & Barneby
Peiranisia	*Chlorocladae*	*S. chloroclada* (Harms) H. S. Irwin & Barneby
	Aphyllae	*S. spiniflora* (Burkart) H. S. Irwin & Barneby
	Excelsae	*S. spectabilis* (DC.) H. S. Irwin & Barneby

* Species added in the present study, and not cited for Paraguay by IRWIN & BARNEBY (1982).

Geographic distribution and conservation needs

The amount of collected plant material in herbaria may be used to evaluate the conservation status of species. According to our results, *Senna* species occur in almost all departments of Paraguay except Ñeembucú (see Table 2). The *Senna*-richest departments are Amabay and Cordillera with 12 species each, followed by Central and Concepción with 10 species each, Boquerón, Caaguazú, and Canindeyú with nine species, Guairá with eight species, Alto Paraná and Paraguarí with seven species, and the remaining San Pedro, Presidente (Pte.) Hayes, Alto Paraguay, Chaco, Misiones, Caazapá, Nueva Asunción, and Itapúa with six or less species (Table 2).

Table 2. – Departments (Departamentos) of Paraguay where *Senna* species occur according to this study, number (#) and names of species of *Senna* in each department (see Table 1 for complete species names). [!]: conservation status unclear.

Departments	#	Species
Alto Paraguay	4	*S. aculeata*, *S. chloroclada*, *S. morongii*, *S. pilifera*
Alto Paraná	7	*S. alata*, *S. hilariana*, *S. hirsuta*, *S. obtusifolia*, *S. paradictyon*, *S. pilifera*, *S. spectabilis*
Amambay	12	*S. alata*, *S. cernua*, *S. hilariana*, *S. hirsuta*, *S. mucronifera*, *S. occidentalis*, *S. paradictyon*, *S. pendula*, *S. pilifera*, *S. rugosa* [!], *S. silvestris* [!], *S. velutina* [!]
Boquerón	9	*S. aculeata*, *S. chloroclada*, *S. corymbosa*, *S. morongii*, *S. obtusifolia*, *S. occidentalis*, *S. pendula*, *S. pilifera*, *S. spiniflora* [!]
Caaguazú	9	*S. alata*, *S. cernua*, *S. hilariana*, *S. macranthera* [!], *S. mucronifera*, *S. obtusifolia*, *S. occidentalis*, *S. paradictyon*, *S. pilifera*
Caazapá	2	*S. mucronifera*, *S. occidentalis*
Canindeyú	9	*S. alata*, *S. hilariana*, *S. macranthera* [!], *S. mucronifera*, *S. obtusifolia*, *S. paradictyon*, *S. pendula*, *S. pilifera*, *S. silvestris* [!]
Central	10	*S. aculeata*, *S. alata*, *S. corymbosa*, *S. hirsuta*, *S. obtusifolia*, *S. occidentalis*, *S. pendula*, *S. pilifera*, *S. scabriuscula*, *S. spectabilis*
Chaco	4	*S. alata*, *S. chloroclada*, *S. morongii*, *S. pendula*
Concepción	10	*S. aculeata*, *S. alata*, *S. hirsuta*, *S. morongii*, *S. paradictyon*, *S. pendula*, *S. pilifera*, *S. spectabilis*, *S. splendida* [!], *S. velutina* [!]
Cordillera	12	*S. aculeata*, *S. alata*, *S. cernua*, *S. corymbosa*, *S. hirsuta*, *S. obtusifolia*, *S. occidentalis*, *S. paradictyon*, *S. pendula*, *S. pilifera*, *S. scabriuscula*, *S. silvestris* [!]
Guairá	8	*S. alata*, *S. cernua*, *S. corymbosa*, *S. mucronifera*, *S. obtusifolia*, *S. occidentalis*, *S. pendula*, *S. leiophylla* [!]
Itapúa	1	*S. pilifera*
Misiones	3	*S. hirsuta*, *S. morongii*, *S. pilifera*
Nueva Asunción	2	*S. chloroclada*, *S. scabriuscula*
Paraguarí	7	*S. alata*, *S. hirsuta*, *S. obtusifolia*, *S. pendula*, *S. pilifera*, *S. scabriuscula*, *S. silvestris* [!]
Pte. Hayes	5	*S. aculeata*, *S. chloroclada*, *S. corymbosa*, *S. morongii*, *S. pendula*
San Pedro	6	*S. alata*, *S. hirsuta*, *S. macranthera* [!], *S. paradictyon*, *S. pilifera*, *S. silvestris* [!]

Many species of *Senna* have been copiously collected in Paraguay, likely because they are widespread. Some are weeds and ruderals, notably *S. obtusifolia* and *S. occidentalis* (IRWIN & BARNEBY, 1982), and/or commonly occur in open secondary vegetation, e.g., *S. spectabilis* (B. Marazzi, pers. obs.). This may explain why *Senna* species have, to our knowledge, not been reported in the literature on Paraguayan vegetation, although *S. paradictyon* and *S. hilariana* typically occur in Paraguayan campo, and *S. paradictyon* also in cerrado vegetation, for example (IRWIN & BARNEBY, 1982; R. Vanni, pers. comm.). *Senna paradictyon* seems to be particularly well adapted to its habitat, since it is the only species of the genus having a xylopodium. This feature may represent an adaptation to fire that is an important ecological factor in cerrado vegetation (RATTER & al., 1997).

We consider the absence of *Senna* species in the departments of Ñeembucú likely due to deficient sampling, since we actually expect at least weedy *Senna* species to occur there.

Although most *Senna* species have been copiously collected and seem to be widely distributed in Paraguay, there are seven little collected species, *S. leiophylla, S. macranthera, S. rugosa, S. spiniflora, S. silvestris, S. splendida*, and *S. velutina*, whose distribution appears to be more restricted. In the list on endangered plants of Paraguay *S. silvestris, S. splendida*, and *S. velutina* are considered to be "vulnerable" and *S. spiniflora* to be "rare" (BERTONI & al., 1994). We consider the conservation status of these seven little collected species as unclear, and discuss it in the following paragraphs.

The seven species belong to different biogeographical regions: most species are from E-Paraguay, whereas *S. spiniflora* is from W-Paraguay (see geographical distribution of the species in Table 3). In E-Paraguay the degree of human interference and especially the disruption of the habitats is higher than in W-Paraguay (SPICHIGER & al., 1992; BERTONI & al., 1994), making the reconstruction of the original vegetation and flora difficult (SPICHIGER & al., 1992). As an example, *S. leiophylla* is apparently rare and local in campo vegetation, known only from scattered localities in SE-Paraguay, NE-Argentina and the Jucuí valley of Brazil (IRWIN & BARNEBY, 1982). However, many *Senna* species occur in secondary vegetation; therefore, they may not only represent "survivors" of former considerably larger communities that were reduced by human activities. A possible scenario may be that these *Senna* species took advantage of extensively exploited secondary vegetation like campos and cerrados. According to THE ALTERNATIVE NGO (1992), cerrados in Brazil were exploited by aboriginal peoples for 15'000 years. For instance, *S. rugosa, S. silvestris, S. splendida*, and *S. velutina* are mostly Brazilian species of cerrado vegetation, and Paraguay is situated in the extreme south-western extension of their range of distribution and at the southern limit of the cerrados. Thus, in Paraguay these *Senna* species could have been maintained and expanded by human activities. However, since a few years an increasing number of these areas is being transformed into soybean monocultures (ALTSTATT & al., 2003; B. Marazzi, pers. obs.; R. Vanni, pers. comm.). Thus, now human interference additionally affects the "naturally" scattered presence of these *Senna* species in Paraguay. In the following, the conservation status of each of the little collected *Senna* species is presented.

Senna leiophylla – The geographic distribution of *S. leiophylla* in Paraguay is enigmatic, since we found only one Paraguayan herbarium specimen of *S. leiophylla* collected in Guairá (*P. Jörgensen 3592;* LIL), and the species is additionally reported only from scattered localities in NE-Argentina and the Jucuí valley of Brazil (IRWIN & BARNEBY, 1982).

Senna macranthera – The here newly reported *S. macranthera* is typically Brazilian and includes many varieties. It is represented in Paraguay by *S. macranthera* var. *nervosa*, of which there are only few herbarium specimens of non-cultivated but many of cultivated individuals. IRWIN & BARNEBY (1982) do not report this species for Paraguay, but to our knowledge it is commonly cultivated for its attractive flowers, as in other adjacent countries, such as Argentina (observation by B. Marazzi and R. Fortunato), and may have escaped.

Table 3. – Geographical distribution (departments) and flowering time (months) of species of *Senna* in Paraguay (see Table 1 for complete species names). [!]: conservation status unclear. *: flowering time according to IRWIN & BARNEBY (1982).

Species	Geographical distribution	Flowering time
S. aculeata	Alto Paraguay, Boquerón, Central, Concepción, Cordillera, Pte. Hayes	I-XII (mostly IV-VIII)
S. alata	Alto Paraná, Amambay, Caaguazú, Canindeyú, Central, Chaco, Concepción, Cordillera, Guairá, Paraguarí, San Pedro	IX-III
S. cernua	Amambay, Caaguazú, Cordillera, Guairá	VIII-IV
S. chloroclada	Alto Paraguay, Boquerón, Chaco, Nueva Asunción, Pte. Hayes	IX-VI
S. corymbosa	Boquerón, Central, Cordillera, Guairá, Pte. Hayes	XI-V
S. hilariana	Alto Paraná, Amambay, Caaguazú, Canindeyú	IX-III
S. hirsuta	Alto Paraná, Amambay, Central, Concepción, Cordillera, Misiones, Paraguarí, San Pedro	XI-III
S. leiophylla [!]	Guairá	I-IV*
S. macranthera [!]	Caaguazú, Canindeyú, San Pedro	(XII-)I-IV*
S. morongii	Alto Paraguay, Boquerón, Chaco, Concepción, Misiones, Pte. Hayes	X-V
S. mucronifera	Amambay, Caaguazú, Caazapá, Canindeyú, Guairá	XI-III
S. obtusifolia	Alto Paraná, Boquerón, Caaguazú, Canindeyú, Central, Cordillera, Guairá, Paraguarí	X-IV
S. occidentalis	Cordillera, Guairá, Caaguazú, Caazapá, Central, Amambay, Boqueron	XII-V
S. paradictyon	Alto Paraná, Amambay, Caaguazú, Canindeyú, Concepción, Cordillera, San Pedro	XI-III
S. pendula	Amambay, Boquerón, Canindeyú, Central, Chaco, Concepción, Cordillera, Guairá, Paraguarí, Pte. Hayes	IX-V
S. pilifera	Alto Paraguay, Alto Paraná, Amambay, Boquerón, Caaguazú, Canindeyú, Central, Concepción, Cordillera, Itapúa, Misiones, Paraguarí, San Pedro	X-IV
S. rugosa [!]	Amambay	X-VI
S. scabriuscula	Central, Cordillera, Nueva Asunción, Paraguarí	X-III
S. silvestris [!]	Amambay, Canindeyú, Cordillera, Paraguarí, San Pedro	XI-III
S. spectabilis	Alto Paraná, Central, Concepción	I-IV
S. spiniflora [!]	Boquerón	IX
S. splendida [!]	Concepción	I-III
S. velutina [!]	Amambay, Concepción	II-IV

Senna rugosa – The presence of *S. rugosa* in Paraguay is confirmed by a number of old specimens of 1907–1908 (*E. Hassler 10504;* BAF, G; and *E. Hassler 10504a;* G) and one of 1974 (*A. Schinini 8983;* G), which were all collected in Amambay. Habitat disruption by man seems to be the main cause of the unclear conservation status of *S. rugosa*.

Senna silvestris – The species is considered "vulnerable" in Paraguay by BERTONI & al. (1994). Two varieties are confirmed to occur in Paraguay: *S. silvestris* var. *guaranitica*, which appears to be common, and var. *unifaria*, which has apparently been collected only by E. Hassler during 1901-1902 (*E. Hassler 8017* and *8017a;* G!) and 1912-1913 (*E. Hassler 10953;* G). The two varieties have, therefore, each a different conservation status. Interestingly, these varieties have different patterns of distribution in Paraguay: var. *guaranitica* is distributed in the South-Est, whereas var. *unifaria* is restricted to the extreme central Est (IRWIN & BARNEBY, 1982). Both become weedy in roadside thickets (IRWIN & BARNEBY, 1982), but apparently only the often collected *S. silvestris* var. *guaranitica* could take advantage from the human activities in SE-Paraguay (which notably increased in the last decades, e.g. BERTONI & al., 1994), whereas var. *unifaria* has probably disappeared from its restricted area in Paraguay.

Senna spiniflora – Previously only reported in Paraguay from few localities of the Chaco region in W-Paraguay (BURKART, 1946; BRAVO, 1978), *S. spiniflora* was more recently reported also from a locality in northern Argentina, where the specimens slightly differ from those of Paraguay in having the calyx externally glabrous, instead of pubescent (FORTUNATO, 1984). Because the dryer W-Paraguay is less affected by man than the densely populated E-Paraguay (BERTONI & al., 1994), the conservation status of *S. spiniflora* is probably different from that of the *Senna* species of E-Paraguay. *Senna spiniflora* is very similar to the Argentinean *S. chacoënsis*, with which herbarium material is often confused, and whose area apparently is adjacent to that of *S. spiniflora*. Because of the morphological similarity and distribution pattern, *S. spiniflora* may have resulted from a recent speciation event, but (still) has a narrow distribution unlike its potential sister *S. chacoënsis*.

Senna splendida – We could find only one Paraguayan herbarium specimen of *S. splendida* var. *splendida* collected in 1912/1913 (*E. Hassler 11050;* G, BAF), which was also examined by IRWIN & BARNEBY (1982) and BERNARDI (1984). MORONG & BRITTON (1892) cite another Paraguayan specimen (*T. Morong 426;* as *Cassia splendida*) collected between 1888 and 1890 near Caballero, probably in the department of Amambay. As for *S. rugosa*, the unclear conservation status of *S. splendida* may be especially due to habitat disruption by man.

Senna velutina – Ascribed to the category of "vulnerable" species (BERTONI & al., 1994), *S. velutina* is apparently a little collected species in Paraguay. We examined only one recent herbarium specimen from 1980 (*L. Bernardi 20587;* G) and four other specimens dated 1912/1913 (*E. Hassler 10993* and *10993a, 11601* and *11601a;* G). Furthermore, it seems that the species was collected in Paraguay only in Amambay (BERNARDI, 1984; Table 3). In contrast, it is widely distributed in Brazil, extending also into Bolivia (IRWIN & BARNEBY, 1982). The unclear conservation status of *S. velutina* may also be especially due to habitat disruption.

In conclusion, the conservation status of *S. leiophylla* and *S. splendida* are apparently the most unclear, since these species have not been recently collected in Paraguay, and their presence is confirmed by only one specimen each. Moreover, the presence of *S. rugosa*, *S. splendida* and *S. velutina* seems to be restricted to the department of Amambay. Because since a few decades the human activities in eastern Paraguay strongly negatively affected the cerrado vegetation, in which these species typically occur, it is unclear whether these species are still present in Paraguay. The same is also true for *S. silvestris* var. *unifaria*. Furthermore, the human interference may also affect other still "non-endangered" species, such as *S. paradictyon* and *S. hilariana*, that also commonly occur in cerrados and other extensively exploited secondary vegetations. Therefore, on the one hand collecting expeditions are needed to evaluate whether the little collected species still occur in Paraguay. On the other hand conservation and management strategies should be urgently conceived to preserve their habitats, bearing in mind the ecological role that *Senna* species play (see next section).

Pollination biology, extrafloral nectaries and ecological role

Flowers of *Senna* are nectarless and offer pollen to their pollinators, usually large female bees of different genera, e.g. *Xylocopa*, *Centris*, and Euglossini, which collect pollen to feed their progeny (DELGADO SALINAS & SOUSA SANCHEZ, 1977; DULBERGER, 1981; GOTTSBERGER & SILBERBAUER-GOTTSBERGER, 1988). The fertile stamens are poricidal and are differentiated into one set of four shorter stamens providing "food pollen", which bees extract by buzzing (BUCHMANN, 1974), and another set of two or three longer stamens depositing their "pollinating pollen" on the bee's body (e.g. IRWIN & BARNEBY, 1982). Many *Senna* species are enantiostylous, with the gynoecium deflected either to the left or to the right. In this way, the stigma may touch the bee's side where the pollen of the long abaxial stamens was not groomed, and the gynoecium may not be damaged by the buzzing bee (DULBERGER, 1981; IRWIN & BARNEBY, 1982; GOTTSBERGER & SILBERBAUER-GOTTSBERGER, 1988).

The large bees visiting *Senna* flowers are trapliners (JANZEN, 1974). In general, trapliners pollinate flowers of species with widely spaced individuals or only few flowers at a time. Thus, traplining bees may fly several kilometers along their "foraging" route. Many *Senna* species occur in a scattered pattern and have only few flowers per inflorescence open at a time, e.g. *S. leiophylla*, *S. pendula*, *S. pilifera*, *S. rugosa*, *S. silvestris*, *S. splendida*, and *S. velutina* (IRWIN & BARNEBY, 1982; B. Marazzi, pers. obs.). In addition, blooming *Senna* species are available over several months (see flowering times in Table 3). A study by CARVALHO & OLIVEIRA (2003) shows that *S. silvestris* is self-sterile, and traplining bees are thus important to promote cross pollination. The availability through the year of *Senna* or other pollen flowers likely is important for the existence of such animals. Vice versa, according to JANZEN (1974) traplining plays an important role in the context of conservation of tropical organisms, since it shows that large areas may be necessary even for small organisms.

Numerous species of *Senna* produce extrafloral nectar. The extrafloral nectaries on the leaves and rarely also on the pedicels are visited by ants, which feed on the nectar, likely forming a protective opportunistic ant-plant interaction (mutualism) against herbivores. Recent work in tropical forest ecosystems suggests a key role of these rewards in shaping the nutritional ecology of tree-dwelling ants and the importance of this kind of mutualisms in structuring entire canopy arthropod communities (HEIL & MCKEY, 2003). Among the 243 eudicots surveyed for the presence of ant-defended plants in a Panamanian forest, there is also a *Senna* species, *S. fruticosa* (as *Cassia fruticosa*), for which ants were confirmed to harvest the nectar (SCHUPP & FEENER, 1991). In contrast, no *Senna* species is reported by OLIVEIRA & BRANDÃO (1991) and by OLIVEIRA & FREITAS (2004) in similar studies in Brazilian cerrado vegetation (in which plants with extrafloral nectaries represent a considerable proportion of the total vegetation), although IRWIN & BARNEBY (1982) mention many *Senna* species in this vegetation.

Among the 17 Paraguayan *Senna* species with extrafloral nectaries, six occur in cerrado vegetation: *S. macranthera*, *S. mucronifera*, *S. pilifera*, *S. rugosa*, *S. splendida* and *S. velutina* (IRWIN & BARNEBY, 1982). *S. velutina* additionally possess extrafloral nectaries on pedicels. Ants were observed by the first author on *S. pendula* and *S. morongii* (common along rivers, temporary lakes or ponds), *S. chloroclada* (in open brush lands of the Chaco region), and *S. hirsuta*, *S. obtusifolia* and *S. occidentalis* (usually on roadsides, in cultivated and disturbed land). They may all play a similar ecological role.

As discussed in the previous section, *S. rugosa*, *S. splendida* and *S. velutina* are rare in Paraguay, and there are also other Paraguayan *Senna* species lacking extrafloral nectaries among the endangered plants. Since habitat disruption is rapidly increasing in Paraguay (e.g. ALTSTATT & al., 2003; ROLÓN, 2004) a decrease in number of plants exploited by trapliners or ants may have an influence on other biological interactions. Conversely, the absence of such specialized pollinators may hamper the reproduction of the plant species which depend on them.

Ethnobotany and ornamental species

A few *Senna* species are mentioned among the many medicinal and otherwise useful plants in Paraguay (e.g. ARENAS, 1981, 2003), and others are reported in a compilation of the woody Paraguayan plants, but do not have any economic importance (BERNARDI, 1984). These species were formerly known only by their common names, almost always in Guarani or sometimes in Lengua-Maskoy (both are languages of the native peoples).

Natives peoples in Paraguay have been using species of *Senna* especially as medicinal plants. Stems and leaves of *S. chloroclada* seem to have been applied against smallpox (ARENAS, 1981). The species is called "Youhan yaamit" in Lengua-Maskoy, which means "the plant of the Tapesua" (Tapesua is a bee species; ARENAS, 1981), or "Pichana" (ARENAS, 2003). *Senna occidentalis* is known as "Taperyva" or "Taperyva hû", which means "black fruit of the abandoned village" in Guarani (R. Martini, pers. comm.). Its root and the base of stems are used to abort (ARENAS, 1981), against liver diseases, and the toasted seeds are used for a drink similar to coffee (GONZALES TORRES, 1996). According to the herbarium label of *J. E. Montes 10955* (CTES) collected in Paraguay in 1951, also the seeds of *S. hirsuta* are probably used as coffee substitute, as the common name of the species "Cafe-Güri" suggests. In contrast, Benedict (Benjamin) Balansa noted on a herbarium specimen collected in 1876 (*B. Balansa 1412;* BAF, G) that the decoction of the leaves of *S. paradictyon* seems to be a poison.

Species of *Senna* in Paraguay may also be used for other purposes, as they are in the adjacent Argentinean central Chaco. Toba and Wichí natives cover the walls of their warestores ("trojes" in Spanish), in which they conserve food, with plants of *S. occidentalis* and *S. morongii*, and the Toba use *S. occidentalis* also to cover the walls of their ranches (ARENAS, 2003).

Owing to their attractive yellow flowers, several *Senna* species, such as *S. alata*, *S. macranthera*, and *S. spectabilis* are commonly cultivated as ornamentals. Specimens of *S. spectabilis* var. *excelsa* in the wild in Paraguay most likely are derived from cultivated specimens (B. Marazzi, pers. obs.), since this variety is typical of the drier Brazilian Caatinga vegetation (IRWIN & BARNEBY, 1982). Flowering specimens of *S. pilifera* were observed to grow close to houses (B. Marazzi, pers. obs.). Because of its particularly showy flowers, *S. splendida* certainly would also merit to be cultivated as an ornamental plant (BERNARDI, 1984).

Identification key for the *Senna* species in Paraguay

Species of *Senna* are best distinguished from species of the other Cassiinae, *Cassia* s.str. and *Chamaecrista*, using floral characters (IRWIN & BARNEBY, 1981, 1982): in *Cassia* s.str. the filaments of the three abaxial stamens are sigmoidally curved and many times longer than their anthers, while the filaments of all stamens of *Senna* (and *Chamaecrista*) are straight or simply incurved and are either shorter than or not over twice as long as their anther. The pedicel of *Senna* flowers does not bear bracteoles (except in *S. paradictyon*), whereas the pedicel of *Chamaecrista* flowers bears two bracteoles above or at the middle and that of *Cassia* s.str. at or near the base.

Many floral features, including number of fertile stamens, stamen orientation, and corolla symmetry, were also used to distinguish the sections and series of the American *Senna* species (IRWIN & BARNEBY, 1982). For instance, IRWIN & BARNEBY's (1982) classification of *Senna* reflects their interpretation of phylogenetic relationships and evolutionary trends in morphology within the genus. Because the key to the sections is mainly based on floral traits, including three-dimensional features, the identification of herbarium specimens and non-flowering specimens may be difficult.

The present study provides a new artificial key for the *Senna* species in Paraguay, which uses a number of vegetative characters and a combination of both vegetative and floral characters, allowing the identification of herbarium specimens and, in part, also of non-flowering specimens. Furthermore, in five notes accompanying our key, we briefly address 1) distinctions between the

Paraguayan *S. spiniflora* and *S. chacoënsis*, whose presence in Paraguay is unclear, and discuss repeatedly encountered identification errors: 2) between *S. cernua*, *S. hirsuta*, *S. occidentalis*, and *S. scabriuscula*, 3) between *S. mucronifera* and *S. obtusifolia*; 4) between *S. corymbosa* and *S. pendula*; and 5) between *S. pendula* and other species that do not occur in Paraguay.

The genus *Senna* Mill. (partly based on Irwin & Barneby, 1982)

Herbs, shrubs, treelets and trees, lacking bacterial root nodules. Leaves with 1 to many pairs of leaflets, or highly reduced. Stipules from minute to oblanceolate and broad blades, persistent or caducous. Extrafloral nectaries, when present, globose, ovoid, pyriform, cylindric, fusiform, or stipitate, at the base or at mid-length of the petiole, or between one or more pair(s) of leaflets; rarely a nectary on pedicel. Inflorescence usually a many-flowered compound raceme, or sometimes a simple raceme or the lateral racemes only 2- (occasionally 1- or 3-) flowered. Calyx spiral, sepals predominantly graded from short to longer along the spiral. Aestivation of corolla cochlear-ascending; corolla yellow, either monosymmetric or asymmetric (one of the two lower petals highly concave or strongly modified in shape). Standard (vexillar) petal obovate or emarginate or obcordate. Androecium of all Paraguayan species with (6-)7 fertile stamens and 3 sterile adaxial stamens (referred to as staminodes). Fertile stamens often modified into two heteromorphic sets of 4 shorter middle and of (2-)3 longer abaxial stamens; anthers basifixed, beakless or variably beaked. Gynoecium usually arched, either in the plane of symmetry of the flower (median) or deflected alternatively to the left and to the right (enantiostylous), glabrous or variably hairy. Pod usually flat, angulated or terete. Seeds usually free, mostly 1-seriate.

Artificial key for the *Senna* species of Paraguay (partly based on features described by Irwin & Barneby, 1982)

1. Extrafloral nectaries present, at base of petiole or between pair(s) of leaflets (Figs. 1A-C) 7
1a. Extrafloral nectaries absent, or plant leafless 2
2. Prickles on stems present, 2-3 mm long. Apex of leaflets spiny..... ***S. aculeata***
2a. Prickles on stems absent. Apex of leaflets not spiny 3
3. Plant leafless at anthesis, branchlets spine-tipped. Standard petal not emarginate (Fig. 2B) ..... ***S. spiniflora***[1]
3a. Plant with leaves at anthesis. Branchlets not spine-tipped. Standard petal emarginate..... 4
4. Plant herbaceous, with xylopodium, not more than 1 m tall at anthesis. Leaflet pairs 5 or less..... ***S. paradictyon***
4a. Shrub or tree, more than 1 m tall at anthesis. Leaflet pairs 6 or more 5
5. Largest leaflets obovate and broadly oblong, more than 3.5 cm wide, the distal pair obovate (Fig. 3A). Candelabriform compound raceme; pedicels always shorter than 1 cm..... ***S. alata***
5a. Largest leaflets ovate lanceolate-acuminate or elliptic obtuse, up to 3.5 cm wide, the distal pair broadest near or above mid-length (Fig. 3A). Inflorescence otherwise; pedicels longer than 1 cm..... 6
6. Longest sepal more than 7 mm long. Corolla monosymmetric; lower petals similar in shape to other petals (Fig. 4A). Pairs of leaflets 6-11 ..... ***S. silvestris***
6a. Longest sepal shorter than 6 mm long. Corolla asymmetric; one lower petal completely different from other petals (Fig. 4B). Pairs of leaflets 10-19 ..... ***S. spectabilis***
7. Pairs of leaflets 1-2 and up to 1.7 cm long; or pairs exactly 2 in the whole plant and 4.5 cm long or more 8
7a. Pairs of leaflets 2-3 or more, if exactly 2 then each 2.5-4.3 cm long..... 12

8. Stems chlorophyllous. Leaflets up to 1.7 cm long and up to 1 cm wide. Lower petals of different form than upper petals, surrounding the stamens and the gynoecium (Fig. 5) ..... ***S. chloroclada***

8a. Stems not chlorophyllous. Leaflets more than 1.7 cm long and more than 1 cm wide. Lower petals concave and similar in shape to upper petals (Fig. 4A) 9

9. Petiole up to 1.2 cm. Sepals up to 1 cm long. Shrub hairy throughout or almost so, with hairs shorter than 0.7 mm ..... ***S. rugosa***

9a. Petiole 1.5 cm long or longer, if shorter then stems and foliage variably pubescent with hairs up to 4.5 mm 10

10. Shrubs. Extrafloral nectary cylindric or fusiform (Figs. 7A, B)..... 11

10a. Tree or treelets; ornamental and naturalized. Extrafloral nectary globose, ovoid, or pyriform (Figs. 7D-F) ..... ***S. macranthera***

11. Shrub erect, glabrous. Longest leaflets 5-8.7 cm long. Longest sepal 1.3-2.3 cm long. Pod 0.8-1.3 cm wide..... ***S. splendida***

11a. Shrub usually decumbent, variably pubescent with hairs up to 2-4.5 mm. Longest leaflets 1.7-5.3 cm long. Longest sepal 0.7-1.2 cm long. Pod 0.25-0.4 cm wide..... ***S. pilifera***

12. Extrafloral nectary at base of petiole (Fig. 1A).....13

12a. Extrafloral nectary(s) between pair(s) of leaflets (Figs. 1B, C) 16

13. Largest leaflets 0.8-1.5 cm wide, 4-6 times longer than wide; 5-8 pairs of leaflets. Petiole 0.7-2.2 cm long ..... ***S. scabriuscula***[2]

13a. Largest leaflets more than 1.5 cm wide, if narrower then 2.8-4 times longer than wide and not more than 6 pairs of leaflets. Petiole usually longer, up to 5.3 cm.....14

14. Leaflets of distal pair broadest above or near mid-length (Fig. 3B). Filament of the two long lateral abaxial stamens 8-9 mm long. Pod 17.5-35 cm long and 0.25-0.3 cm wide; the stipe 4-5 mm long..... ***S. cernua***[2]

14a. Leaflets of distal pair broadest below or near mid-length (Fig. 3A). Filament of the two long lateral abaxial stamens up to 8 mm long. Pod and stipe otherwise.....15

15. Floral bracts 8-15 mm long, longer as and partially enclosing the bud (Fig. 6). Style 3.5-4 mm long. Pod linear, 9-12.5 cm long and 0.5-0.8 cm wide..... ***S. occidentalis***[2]

15a. Floral bracts up to 2.5 mm long, shorter or as long as the bud. Style 2-3 mm long. Pod curved or sigmoidally twisted, 10.5-25 cm long and 0.3-0.5 cm wide ..... ***S. hirsuta***[2]

16. Stems and leaflets densely hairy, hairs more than 0.45 mm long 17

16a. Stems and leaflets glabrous or nearly so 19

17. Leaflets of distal pair obovate (Fig. 3B), leaflets mucronate. Pairs of leaflets 2-3. Beak of the two long abaxial stamens 1.5-3 mm long ..... ***S. mucronifera***[3]

17a. Leaflets of distal pair broader above mid-length or ovate (Fig. 3A), leaflets not mucronate. Leaflets either more than 1.7 cm wide or, if narrower, 3-5 times longer than wide, and longest petal up to 1.3 cm. Pairs of leaflets 3-5. Beak of the two long abaxial stamens up to 1 mm 18

18. Extrafloral nectary present on pedicel. Largest leaflets more than 1.7 cm wide. Indument giving an orange-brownish color to the plant. Pod 10-23.5 cm long and 0.3-0.4 cm wide..... ***S. velutina***

18a. Extrafloral nectary absent on pedicel. Largest leaflets less than 1.4 cm wide. Indument giving a whitish color to the plant. Pod 4-9 cm long and 0.6-0.9 cm wide ..... ***S. morongii***

19. Extrafloral nectaries cylindric, fusiform or stipitate with an ovoid or pyriform head (Figs. 7A-C), between proximal and usually also next pair of leaflets (Fig. 1C) 20

19a. Extrafloral nectary globose, ovoid, or pyriform (Figs. 7D-F), only between proximal pair of leaflets (Fig. 1B) 21

20. Herb. Leaflets of distal pair obovate (Fig. 3B), 1.6-2.5 times longer than wide. Inflorescence usually 2-(sometimes 1- or 3-)flowered. Pod flat and curved, 7.5-15 cm long and 0.25-0.6 cm wide ..... ***S. obtusifolia***[3]

20a. Shrub or treelet. Leaflets of distal pairs ovate or lanceolate-ovate (Fig. 3A), 3.5-5.6 times longer than wide. Inflorescence usually 4- or more flowered. Pod otherwise, 7.5-12 cm long and 0.6-0.9 cm wide ..... ***S. corymbosa***[4]

21. Largest leaflets 1.3-2.7 cm long and 0.35-0.7 cm wide, 4-5 times longer than wide. 3-8 pairs of leaflets (but usually more than 5) ..... ***S. hilariana***

21a. Largest leaflets more than 1.8 cm long and 0.9 cm wide; 2-6 pairs of leaflets (mostly with 2-3 or 4-5 pairs, rarely 6) 22

22. Pairs of leaflets 2-3, largest leaflet 3.5-9 cm long and 1.6-3.7 cm wide. Inflorescence 2-(sometimes 1-)flowered. Beak of the two long abaxial stamens ca. 2 mm long. Pod 0.45-0.5 cm wide ..... ***S. leiophylla***

22a. Pairs of leaflets mostly 4-5, but also some leaves with 2, 3 or 6 pairs. Largest leaflets 1.8-5 cm long and 0.9-2 cm wide. Inflorescence usually more than 4-flowered. Beak of the two long abaxial stamens shorter than 1 mm. Pod 0.9-1.6 cm wide ..... ***S. pendula***[4,5]

Notes

[1] *Senna spiniflora* may be confused with the closely related *S. chacoënsis*. Stems and sepals are glabrous in *S. chacoënsis*, whereas they are finely hairy in *S. spiniflora* (Bravo, 1978). Although Degen & Mereles (1996) reported two specimens of *S. chacoënsis* collected in Boquerón, we could not confirm the presence of this species in Paraguay.

[2] *Senna cernua*, *S. hirsuta*, *S. occidentalis* and *S. scabriuscula* were sometimes confused with each other, suggesting that the species are apparently similar. However, we rather think that the specimens were determined without a key, because the key of Irwin & Barneby (1982) does not allow errors in their identification.

[3] *Senna mucronifera* was often erroneously identified as *S. obtusifolia*. The leaves of *S. mucronifera* are thicker, with more conspicuous venation, the flowers are larger and more showy, and the mature fruits are usually longer than those of *S. obtusifolia*.

[4] Without flowers, *S. corymbosa* can be confused with *S. pendula* var. *paludicola*. Identification problems occur, as recognized also by Randell (1988), when specimens without flowers have three pairs of leaflets. For those herbarium specimens in which flowers are present, Irwin & Barneby (1982) and Randell (1988) consider the median abaxial stamen a significant character to clearly distinguish *S. corymbosa* from *S. pendula*. It produces pollen in *S. corymbosa* but not in *S. pendula* (and other species). Searching for an unequivocal vegetative identification character, we noticed that the extrafloral nectary in *S. corymbosa* is stipitate with an ovoid or pyriform head, whereas in *S. pendula* it is sessile, globose or ovoid, confirmed by the description of Irwin & Barneby (1982).

[5] *Senna pendula* may be confused with *S. bicapsularis* and *S. oblongifolia*, whose distribution does not include Paraguay according to Irwin & Barneby (1982). However, apparently two specimens of *S. bicapsularis* were found in Boquerón by Degen & Mereles (1996), but they were not examined in this study. *Senna bicapsularis* is easily distinguished from *S. pendula* by its pedicel only up to 5 mm long, whereas it is more than 8 and up to 37 mm long in *S. pendula* (Irwin & Barneby, 1982). *Senna oblongifolia* is distinguished by having only one nectary on the pulvinus or, more commonly, on the petiole (Irwin & Barneby, 1982). However, in some specimens the nectary is next to one or between two leaflets, which are much smaller than the other leaflets (Irwin & Barneby, 1982). These smaller leaflets in *S. oblongifolia* likely are the cause for the confusion with *S. pendula*, which has the extrafloral nectaries between the (normal) leaflets.

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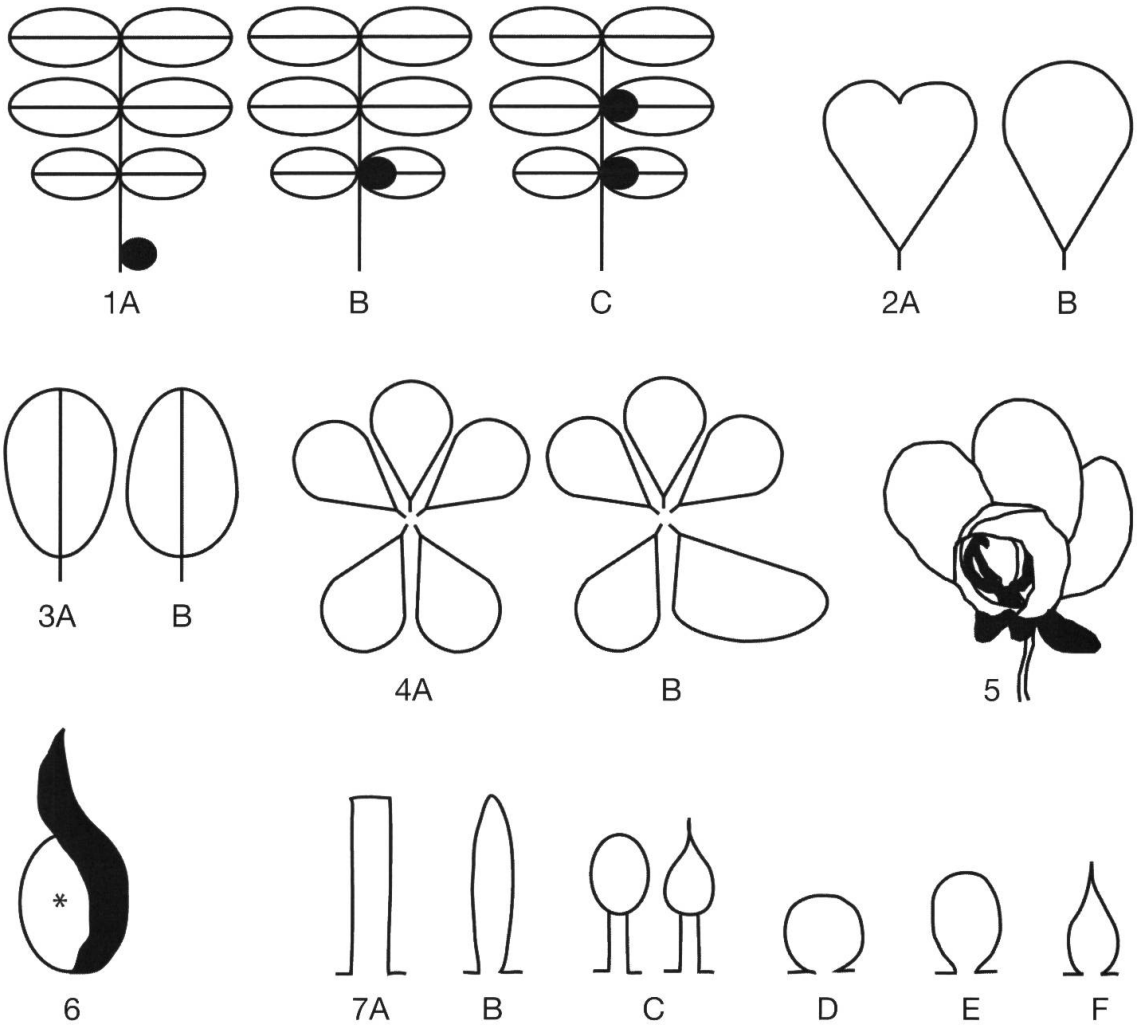

Figures 1-7. – Schematic figures to the key for *Senna* in Paraguay.
1. *Extrafloral nectarines.* **A:** at base of petiole; **B:** only between leaflets of first pair; **C:** additionally between leaflets of second pair.
2. *Standard petal.* **A:** emarginate; **B:** not emarginate.
3. *Distal pair of leaflets.* **A:** broadest near or below mid-length (e.g. ovate); **B:** broadest near or above mid-length (e.g. obovate).
4. *Corolla.* **A:** lower petals similar to the three upper petals (e.g. *S. silvestris*); **B:** one lower petal strongly oblique, different from all other petals (e.g. *S. spectabilis*).
5. Flower of *S. chloroclada*. Corolla asymmetrical, the two lower petals surrounding the stamens and the gynoecium (sepals, stamens and gynoecium are in black).
6. Floral bract of *S. occidentalis*, partially enclosing the bud (asterisk indicates the bud).
7. *Extrafloral nectary.* **A:** cylindric; **B:** fusiform; **C:** stipitate with an ovoid or pyriform head; **D:** globose; **E:** ovoid; **F:** pyriform.