



A new species and a new section of *Astragalus* (Fabaceae: Papilionoideae) from Mexico

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Abstract

We describe and illustrate *Astragalus sagitticarpus* A.E. Estrada, Villarreal & Encina (Fabaceae) as a new species from south-central Mexico. Its annual habit, free stipules, few leaves, small calyx teeth, and pendulous, persistent, stipitate, dorsoventrally compressed pod characterize this species. Added to other characteristics related to the other sections, but not in the same combination of them, such as habit, flower size, and union of the stipules allow recognizing a new section also.

Resumen

Se describe e ilustra a *Astragalus sagitticarpus* A.E. Estrada, Villarreal & Encina (Fabaceae) como una especie nueva del centro-sur de México. Esta especie se caracteriza por su hábito anual, estípulas libres, pocas hojas, dientes del cáliz pequeños y vaina pendulosa, persistente, estipitada, dorsoventralmente comprimida. Aunado a otras características relacionadas a otras secciones, pero no en la misma combinación de ellas, tales como hábito, tamaño de flor y unión de las estípulas permiten también reconocer una nueva sección.

Keywords: Leguminosae, section *Sagitticarpus*, south-central Mexico

Introduction

The diversity of *Astragalus* Linnaeus (1753: 755) in Mexico includes 29 sections, 25 sub-sections and 98 species of annual or perennial herbaceous plants. Nine of these species were described from 1976 to date (Barneby 1976, Barneby 1982, Villarreal & Carranza 1994; Estrada *et al.* 2005, Spelleneberg *et al.* 2014, Rzedowski & Rzedowski 2015, Estrada *et al.* 2016, Estrada *et al.* 2019). The 29 sections recognized by Barneby (1964) were separated mainly according their habit (annual or perennial), type of trichome (simple or dolabriliform), but also, the trichomes of similar size or trichomes of different size, the union of the stipules (free or connate/amplexicaul), inflation of pod (inflated, triquetrous or flattened), direction of the pod with respect to raceme (deflexed, spreading or ascending), presence or absence of stipe fruit, and presence or absence of gynophore. These morphological characteristics, coupled with particularities in the size and color of the flowers, allow classifying clearly, at least most of the species within the one of the eight sections found in southern Mexico proposed by Barneby (1964). The last 10 species of this genus discovered since 1976 until now have been included in one of these sections proposed by Barneby (1964) (Table 1). While continuing with the revision of herbarium materials (MEXU herbarium, Cd. México) of the genus *Astragalus*, as part of the ongoing project “*Astragalus* of Mexico”, a different specimen of this genus from Huitzilac, Morelos was found. Based on its morphology and with the use of specialized literature for the identification of *Astragalus* species of Mexico (Barneby 1964, McVaugh 1987, Estrada *et al.* 2005, Estrada *et al.* 2014), this new species does not fit in any

of the morphologically recognized infrageneric Barneby's (1964) classification, not only in those sections present in Mexico, but also in those existing in the adjacent region of the south of the United States of America.

Therefore, we here present a description of a new species together with a new section based on habit of the plant, stipules adherence; size of the inflorescences with respect to the leaves; size and shape of the calyx and its teeth; size, shape and compression type of the fruit, and number of ovules.



FIGURE 1. Holotype (MEXU 121925) of *Astragalus sagitticarpus*.

Material and methods

The botanical sample was examined by using a Carl Zeiss Stemi DV4 stereo dissecting microscope. The extinction risk category of IUCN (2017) was determined by estimating the area of occupation (AOO) and the extension of presence (EOO) with GeoCAT software (Bachman *et al.* 2011). The species distribution map was elaborated using the ArcMap 10.1 software (ESRI 2011).

Taxonomic treatment

Astragalus sect. *Sagitticarpus* A. E. Estrada, Villarreal & Encina, sect. nov.

Type:—*Astragalus sagitticarpus* A. E. Estrada, Villarreal & Encina

Plant herbaceous, annual. Stipules free, leaflets elliptic, obovate-elliptic, oblong-elliptic, distally rounded or distally mucronulate. Inflorescences always longer than leaves, 1.7–5.7 cm long, the width of the peduncle remains the same in flower and fruit, floriferous axes 2–7 flowered. Pedicels and flowers suberect or ascending when young, reflexed with age. Calyx campanulate, basally inequilateral, gibbous dorsally at base, the teeth minute triangular, sometimes wider than long, always with dense black pubescence, contrasting with the tube color. Petals blue and white (at least dry), the banner recurved through 20°–35° when young, up to 90° with age (at least some flowers) from the vertical, the keel shorter than wings and banner. Ovary stipitate, glabrate. Ovules six. Pod pendulous, stipitate, persistent on the receptacle, elliptic to ovate-elliptic, straight, dorsoventrally compressed, gradually distally acute, ending in a short, straight beak, tan, ochre, light-brown or turning black with age, apically dehiscent, gradually narrowed at the base, ending in the stipe, the valves papery but stiff, glabrous, the septum complete. Seeds mitten shaped, olive to brown-reddish, opaque.

Etymology:—The name *Sagitticarpus* of this new section comes from the shape of the fruit, similar to an arrowhead. This new section is monospecific (monotypic). We added a dichotomous key in order to recognize and differentiate it from the other sections in Mexico (adapted from Barneby 1964). The key includes only those sections with free stipules.

Key to identify the different sections of *Astragalus* with free stipules present in Mexico.

1. Plants densely pubescent with short curly trichomes mixed with longer spirally twisted ones, appressed or spreading up to 2 mm long2
- Plant pubescent, but the trichomes shorter, none spirally twisted3
2. Stems prostrate or decumbent, usually shorter than the longest leaves; flowers ascending; pods humistrate with age, soon caducous sect. *Mollissimi*
- Stems erect, caulescent, the stems longer than longest leaves; flowers soon deflexed; pod erect, never humistrate, persistent sect. *Gigantei*
3. Annual; ovary (and pod) with 2 ovules only sect. *Microlobium*
- Annual or perennial; ovary (and pod) with 4 or more ovules4
4. Flowers red or purple; acaulescent plants5
- Flowers purple, blue, white, lilac, concolorous, or mixtures of these colors, but never completely red; caulescent plants6
5. Calyx tube shallowly campanulate, 2–4.5 mm long; banner 14 mm long or shorter; pubescence dolabriform sect. *Lotiflori*
- Calyx tube cylindrical or deeply campanulate, 6–10.5 mm long; banner 16–22 mm long; pubescence simple or dolabriform sect. *Argophylli*
6. Pod inflated, bladder-like of papyrus texture, stiffly so or papery-membranous, unilocular or bilocular7
- Pod triquetrous or dorsoventrally flattened, not bladderly inflated, narrow elliptic, linear-oblong, oblong-elliptic, oblique-obovate or subterete in cross section, bilocular 11
7. Flores very small, banner 5.5–6.5 mm long; pod small, up to 8 mm long, persistent sect. *Scalares*
- Flowers larger; pod larger or much larger, caducous8
8. Pod stipitate sect. *Trichopodi*
- Pod sessile9
9. Pod unilocular sect. *Inflati*
- Pod bilocular (at least below the apex, the beak10
10. Banner 7–9.5 mm long; pod 1 cm long or shorter, retuse in both extremes, minutely apiculate and bilocular at apex sect. *Diphaci*
- Banner 1 cm long or longer; pod 1.2 cm long or larger, the apex ending into a triangular unilocular beak sect. *Diphysi*
11. Peduncles dimorphic, the early ones very short, with only 1–2 flowers, the later ones, up to 7-flowered; the banner 5–5.5 mm long; pod pendulous, sessile, subunilocular, 6–10 mm long sect. *Quinqueflori*
- Peduncles homomorphic, if flowers as small, the root annual and pod larger; if the pod as small, the flowers much more numerous; pod fully bilocular 12

12. Pod declined or deflexed, sessile or elevated on a stipelike gynophore, the body very strongly dorsoventrally compressed, peltiform or shield-shaped, as broad as long or not much longersect. *Scutanei*
 - Pod ascending, spreading or deflexed, sessile or stipitate, sometimes shortly so, the body mostly lance-oblong, in profile, half-obovate, in any case triquetrous or compressed triquetrous, or the body subterete to dorsoventrally flattened, linear-oblong, elliptic, oblong-elliptic, ovate-elliptic to wide-elliptic to wide-oblong, twice to many times longer than wide.....13
13. Pod dorsoventrally flattened, somewhat bulged, persistent on the receptacle, the body elliptic, oblong-elliptic to ovate-elliptic, straight, dorsoventrally compressed, one to one and a half longer than wide.....sect. *Sagitticarpus*
 - Pod triquetrous and triangular in section or subterete, twice to many times longer than wide.....14
14. Pod stipitate15
 - Pod sessile16
15. Pod pendulous sect. *Miselli*
 - Pod incurved-ascending..... sect. *Reventi-Arrecti*
16. Pod deflexed; flowers very small, early deflexed, usually very numerous (15–65) sect. *Micranthi*
 - Pod ascending or loosely spreading; flowers either fewer or larger, ascending or loosely spreading sect. *Leptocarpus*

Astragalus sagitticarpus A.E. Estrada, Villarreal & Encina *spec. nov.* (Fig. 1 A–J)

Morphologically similar to *Astragalus strigulosus* Kunth (1823: 386) in the habit and stem size, but *A. sagitticarpus* having free stipules, flowers 2–7 per raceme, calyx 2.4–3 mm long, banner 8.2–8.6 mm long, wings 6.7–7 mm long, keel 6–6.5 mm long, only 6 ovules, and 6–7 mm long fruits.

Type:—MEXICO. Morelos (Municipio Huitzilac): Km 74 carretera (antigua) México-Cuernavaca, approx. 19°00'45"N, 99°15'55"W, elev. 2300 m, 10 Nov 1978, O. Téllez 526 (Holotype MEXU 1219252!) (Fig. 2).

Plant annual herb (according to specimen label, not root available), caulescent. **Stems** branched at base or near it, suberect, curved, weak, up to 30 cm long, 1–1.3 mm diameter, green to green-brown, subglabrate or with scattered, appressed to sub-appressed, straight, white, 0.2–0.3 mm long trichomes, with few leaves, at least 3–8 leaves per stem, so the stems obvious and conspicuous, not hidden by foliage; **stipules** free, straight or basally oblique, 3–10 × 1–1.3 mm, triangular to triangular-lanceolate, white, green or with a green widened green strip along the midvein, the lower ones adaxially ciliate, abaxially glabrate or less densely pubescent, the upper ones more densely ciliate. **Leaves** odd-pinnate, alternate, 3.6–6.5 cm long, the petiole 0.5–1.3 mm long; leaflets (15–)17–19, (2)4–5(–6–5) × (1–)2–2.5(–2.9) mm, elliptic, obovate-elliptic, oblong-elliptic, distally rounded or ending in a minute mucro, basally rounded or gradually narrowed, bicolored, light-green and pilose or scattered pilose with 2.5–5 mm long, straight, white trichomes, more densely so in young leaves, sometimes the trichomes more densely so along the midvein and edges adaxially, dark-green, glabrous or rarely with very few scattered, straight, white trichomes. **Inflorescences** axillar, the flowers arranged in racemes, always longer than leaves, peduncles weak, thin, 1.7–5.7 cm long in flower, lengthening up to 7.2 cm long, straight or curved, ascending, pubescent as stems, its width remaining the same in flower and fruit; floriferous axes 2–9 mm long, lengthening up to 1 cm with age, invested with white and black, straight, appressed to sub-appressed 0.2–0.3 mm long trichomes; flowers (2–)3–5(–7) per raceme, ascending when young and remaining so until open or belatedly semi deflexed but not completely pendulous; bracts persistent, 0.5–1.5 mm long, triangular, lanceolate to oblong-lanceolate, white, translucent to subdiaphanous, adaxially and marginally ciliate, invested with white and black mixed, 0.2–0.3 mm long trichomes, abaxially glabrate or rarely with few trichomes; pedicels 0.3–0.8 mm long, suberect and straight in young flowers, resupinate with age, so the fruits are pendulous, strigulose pubescent, mostly with black trichomes, on times mixed with few white trichomes; bractlets absent. **Flowers** up to 8 mm long, blue (according to sample label information), turning purple, at least on the keel tip; calyx 2.4–3 mm, narrow to wide campanulate, inequilateral, somewhat gibbous dorsally at base; the tube 2.2–2.5 × 1.5–1.9 mm, always densely strigulose with black, straight trichomes, very rarely with some few, appressed to sub-appressed; white, sparsely trichomes present, the teeth 0.3–0.5 mm long, triangular, sometimes (0.57 mm wide) wider than long, always densely strigulose with black trichomes, thence, the teeth almost with black colored, and strongly contrasting with the less black colored tube; petals turning white or purple with age; the banner 8.2–8.6 × 4.3–4.5 mm, sessile, elliptic, elliptic-ovate to obovate, apically rounded to truncate-rounded, narrowing gradually to the base, folded longitudinally in the middle, the margins also folded backward, bent backward from the keel, distally curved 20°–35° from the vertical; wings 6.7–7 mm long, the claw 2.9–3.1, the blade 4–4.1 × 2.5–2.9 mm, oblong, oblique and rounded distally, auriculate; keel 6–6.5 mm long, the claw 2.9–3 mm, the blade 3.5–3.6 × 1.3–1.5 mm, half-obovate, incurved, apically rounded but distally triangular-rounded; stamens 10, diadelphous, 9 fused by their filaments into a white sheath, 4.7–5.5 mm long, the free portion 1.3–2.1 mm long, enfolding the ovary, the vexillar stamen 6.6–6.8 mm long, free; anthers elliptic, sub-spherical 0.3 × 0.1 mm, yellow; ovary stipitate, stipe 1–1.3 mm long; ovary 3–3.5 mm long, slightly widened, style 2.5 mm long, incurved, ending in a minute terminal stigma; ovule 6. **Pod** pendulous, stipitate, stipe 2.2–2.5 mm long, persistent on the receptacle, the body elliptic, oblong-elliptic to ovate-elliptic, straight, dorsoventrally compressed, 6–7 × 4–4.5 × 0.6–0.8 mm, distally gradually acute, ending in a short, straight, 0.6–1 mm on beak, tan, ochre, light-brown or even,

turning black with age, apically dehiscent, basally gradually narrowing, ending in the stipe, the valves papery but stiff, glabrous, the sept complete, 0.4–0.5 mm wide; seeds 1.2–1.6 × 1.1–1.2 mm, mitten shaped, olive, orange-olive to brown-reddish, opaque.

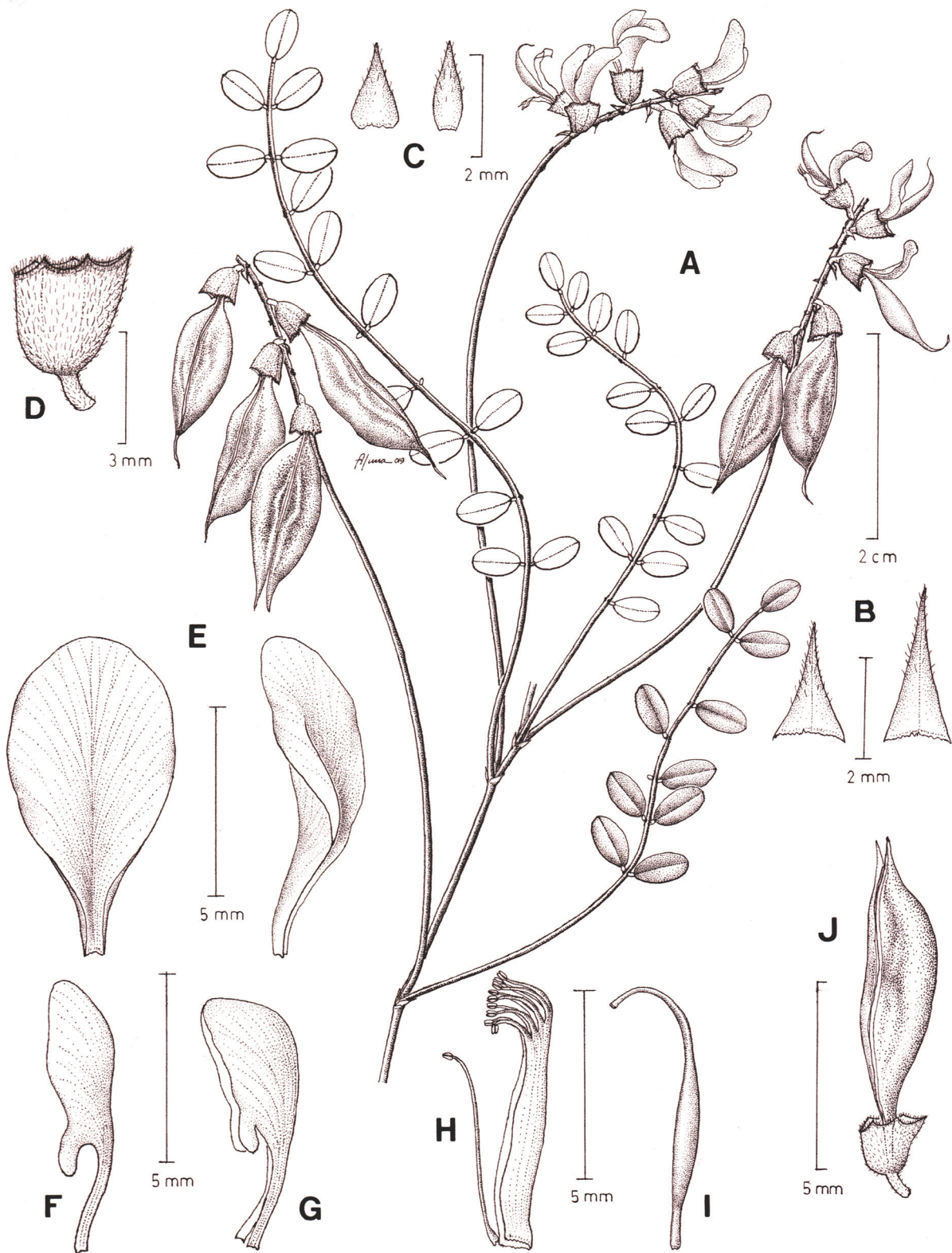


FIGURE 2. *Astragalus sagitticarpus*, A) Whole plant showing leaves, inflorescences, flowers and fruits. B) Stipules. C) Bracts. D) Calyx. E) Banner front view (left) and profile (right). F) Wing. G) Keel. H) Stamens. I) Ovary. J) Fruit.

Distribution and habitat:—As currently known, there is only one specimens existent of *Astragalus sagitticarpus* collected in the type locality near to the highway Cuernavaca-Mexico, growing in pine forest stands (Fig. 3).

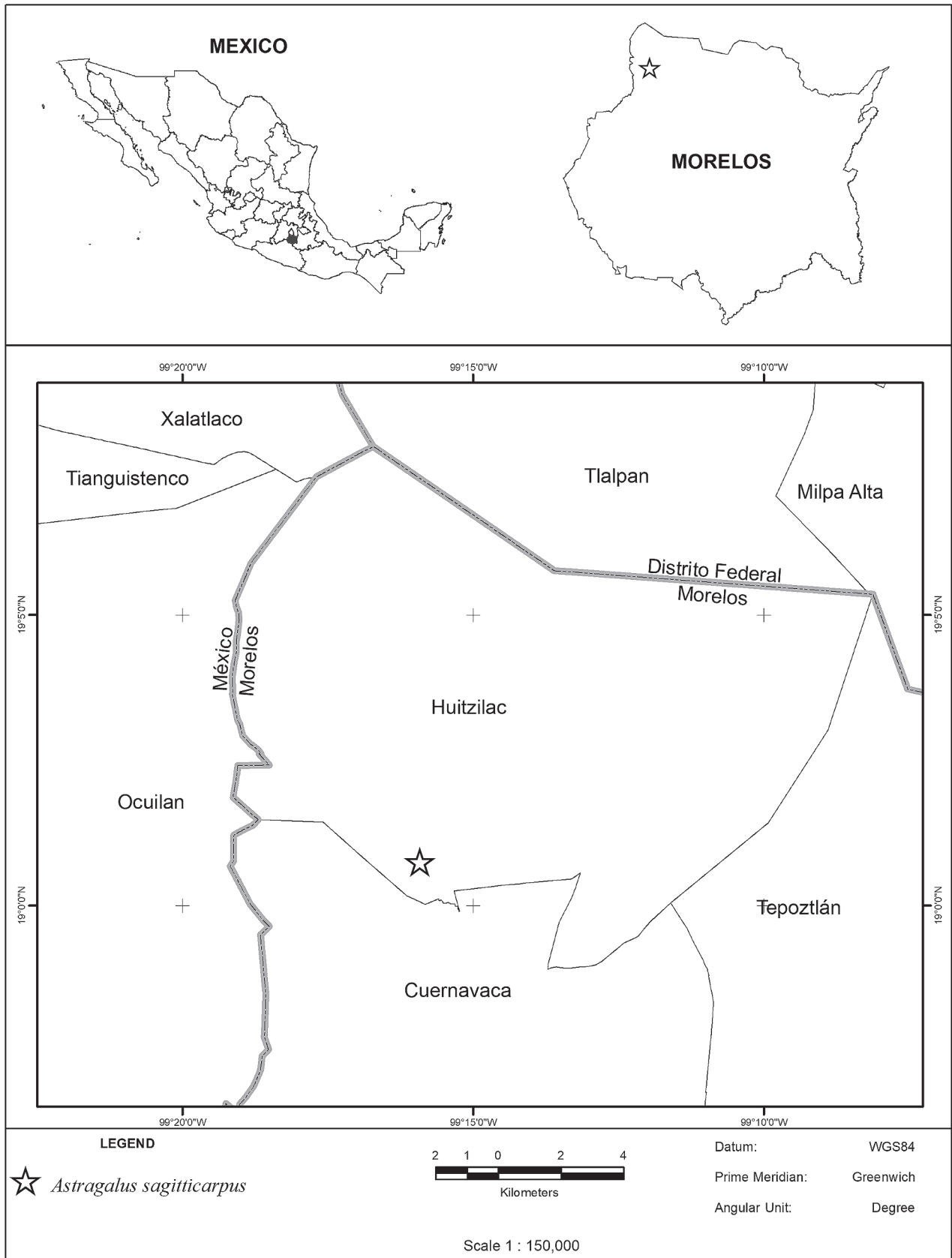


FIGURE 3. Distribution of *Astragalus sagitticarpus* in Morelos, Mexico.

Etymology:—The name of the species refers to the characteristic shape of the fruit, which resembles an arrowhead, flattened dorsoventrally, elliptical to oval, straight, basally gradually narrowing, ending in a stipe, distally gradually acute, ending in a short, straight beak.

TABLE 1. The eight sections of *Astragalus*, species that encompasses each and that are distributed in the central and southern portion of Mexico.

SECTION	Species
Inflati A. Gray A. Gray (1864: 213)	<i>A. wootonii</i> E. Sheld (1894: 138)
Leptocarpi M. E. Jones (1923: 266)	<i>A. nuttallianus</i> DC. (1825: 289)
Miselli Barneby (1964: 438)	<i>A. ervoides</i> Hook & Arn. (1840: 417)
Hypoleuci Barneby (1964: 1099)	<i>A. hypoleucus</i> S. Schauer (1847: 747)
Mollissimi A. Gray (1864:195)	<i>A. helleri</i> Fenzl (1861: 56)
	<i>A. mollissimus</i> A. Gray (1827: 178)
Scutanei Barneby (1964: 1127)	<i>A. scutaneus</i> Barneby (1956: 502)
Micranthi A. Gray (1864: 198)	<i>A. hartwegii</i> Benth. (1839: 10)
	<i>A. oxvrrhynchus</i> Hemsl. (1880: 265)
Strigulosi M.E. Jones (1923: 184)	<i>A. cenorrhynchus</i> Barneby (1982: 78)
	<i>A. esperanzae</i> M.E. Jones (1923: 277)
	<i>A. guanajuatensis</i> Rzedowski & Rzedowski (2015: 2)
	<i>A. guatemalensis</i> Hemsl. (1880: 266)
	<i>A. hidalgensis</i> Barneby (1964: 175)
	<i>A. hintoni</i> Barneby (1964: 157)
	<i>A. jaliscensis</i> (Rydb.) Barneby(1964: 167)
	<i>A. lyonnetii</i> Barneby (1964: 161)
	<i>A. micranthus</i> Desv. (1814: 78)
	<i>A. potosinus</i> Barneby (1964: 165)
	<i>A. pueblae</i> M.E. Jones (1912: 35)
	<i>A. radicans</i> Hornem (1815: 708)
	<i>A. strigosus</i> Kutnh (1823: 386)
	<i>A. tioides</i> Barneby (1964: 171)
	<i>A. tolucanus</i> Robinson & Seaton (1893: 104)
	<i>A. zacatecanus</i> Barneby (1964: 167)

Phenology:—With only one specimens of this new species, we can at least approximate dates of flowering and fruiting. The sample shows several stages of flower and fruit development, there are developed but still closed flowers, developed and open flowers, young fruits with presence and absence of petals, closed developed fruits with developing seeds and, open developed fruits with mature seeds. Therefore, based on the phenological conditions of this specimen, flowering apparently occurs from late September to early December, and fruiting is likely from early October to late December.

Conservation status:—To date, the new species has only one known locality. Its habitat is currently affected by intense human activity and, according the GeoCAT algorithm (Bachman *et al.* 2011) based on the extent of occurrence (EOO) and the area of occupancy (AOO), which in this case is 4 km² and the default cell width of 2 km, as recommended by the IUCN Red list guidelines (IUCN 2017). Following such criteria *Astragalus sagitticarpus* is placed in the category critically endangered (CR), criterion B2ab (iii). It is therefore, considered to be facing an extremely high risk of extinction in the wild. In the near future one or several excursions could be made in order to explore this area carefully and try to locate, within the access possibilities, this species, since there is only one sample stored in the scientific collections (MEXU).

Discussion

From the 29 sections and 25 subsections of this genus present in Mexico (Barneby 1964), only eight of them reaches the south states of Tropic of Cancer (Table 1).

TABLE 2. Particular morphological characteristics of each section.

SECTION	Particular morphological characters
Inflati	Pods bladderly inflated with papery texture
Leptocarpi	Pods triquetrous
Miselli	Perennial; calyx campanulate but not inequilateral or gibbous dorsally at base; ovary with 7–37 ovules
Hypoleuci	Amplexicaul and connate stipules, and dolabriform pubescence
Mollissimi	Two types of pubescence, one consisting of short, curly and entangled trichomes, the other one, consisting of spirally twisted, straight to sinuous and appressed hairs; large flowers, racemes with abundant flowers (7–45)
Scutanei	Pod sessile, strongly obcompressed and shield shaped
Micranthi	Perennial; stipules free; racemes dense and long, open; flowers early reflexed; pod sessile, reflexed, linear to lanceolate, trigonous to sharply triquetrous
Strigulosi	Perennial; at least the lowest stipules fully amplexicaul and connate; racemes with horizontal to reflexed flowers with age; banner 4.5–15 mm long; pod pendulous, stipitate or sessile, almost always persistent in the receptacle, dorsoventrally to subtrigonus (no sharply compressed, triquetrous) compressed, straight, decurved or incurved pods, and 4–24 ovules

All of these sections together include 25 species. These sections show several particular morphological characteristic by which they can be differentiated from each other (Table 2). According to the morphological characters used to discriminate the different sections of *Astragalus* by Barneby (1964), the most striking differences among groups are the stipules adherence, shape and size of the pod, flower size, and type of pubescence.

Phylogenetic (Sanderson 1991) and molecular studies (Sanderson & Doyle 1993) have tested the monophily of a large group of species belonging to sections and subsections of *Astragalus* distributed in North America and Mexico, including those with many species, such as the sect. *Argophylli* A. Gray (1864: 209).

Molecular studies have shown a close relationship between species belonging to different sections with similar distribution (Sanderson & Dolye 1993), an example of this close relationship is presented by the sect. *Leptocarpi*, and the sect. *Humillimi* M. E. Jones (1923: 68), which are distributed in the south of the United States and the north of Mexico.

Unfortunately, to date, there is no detailed molecular study with the total species of all sections in Mexico and North America; so, the following will be to conduct molecular studies to elucidate the complexes of species that still appear to be certainly subjective.

The species of this new section shows no trace of amplexicaul or connate stipules in its scarce leaves along the stems. Coupled with this, some other morphological specialization affinities, such as persistent stipitate and apically dehiscent fruits, few flowers per raceme, extended or reflexed flowers, calyx with campanulate tube, and regularly graduated petals could indicate a close relationship with sect. *Strigulosi*, however, there are several striking differences such as the growth habit (annual vs. perennial) and stipules adherence (free vs. connate or amplexicaul) between it and sect. *Sagitticarpi*.

The most conspicuous characteristic of the new species is the annual habit. Physognomically, the plant show weak stems, 1–1.3 mm diameter, compared to the ones of the species of sect. *Strigulosi* (at least, the double of the diameter). The lack of amplexicaul or connate stipules in sect. *Sagitticarpi*, are small and almost inconspicuous, and the inflorescences are always longer than leaves, and always, the length is positively correlated in young and old growth for both structures, the young inflorescences are always longer than young leaves, the same relationship occurs when both are mature, and also, the width of the peduncle remains the same in flower and fruit.

Also, something very distinctive in *A. sagitticarpus* is its campanulate but basally asymmetric calyx, its union to the pedicel is unequal, being dorsally gibbous, similar to those of *A. hartweggi* and *A. goldmani* (from the sect. *Micranthi*, with triquetrous pods). The calyx teeth are relatively small compared to the length of the tube, the teeth-tube ratio is approximately 1:4–1:8 respectively and, frequently, the teeth of *A. sagitticarpus* are inconspicuous, if we compare it with sect. *Strigulosi* species, only one variant of *A. guatemalensis* has similar characteristics in the size of the teeth, *A. guatemalensis* var. *brevidentatus*. However, the latter can be easily differentiated by its pink-purple or yellow petals, with longer banner, 9–11.4 mm long.

The size and shape of the pod, and its position (sessile-elevated) with respect to the receptacle could suggest a closer relationship of *A. sagitticarpus* with the group of sect. *Strigulosi* species that have stipitate, persistent and dorsoventrally flattened pods, however the species with these features in southern Mexico (*A. tolucanus*, *A.*

guatemalensis, *A. longissimus* (M.E. Jones) Barneby (1964: 183), *A. potosinus*, *A. zacatecanus*, *A. jaliscensis*, *A. pennellianus*, *A. strigulosus*, and *A. tioides*) are perennial with connate basal stipules, more ovules, ranging 10–24, with exception of *A. tolucanus* (5–)8–14, and longer (10–38 mm long) fruits. The distribution of the *A. sagitticarpus* follows the same pattern of the several species of the sect. *Strigulosi*, since many of them are found in restricted areas, high altitudes, and one or several adjacent plant communities such as *A. radicans*, *A. lyonnetii* Barneby (1964: 161), *A. tolucanus*, *A. longissimus*, *A. pueblae*, *A. hidalgensis*, *A. zacatecanus*, *A. regiomontanus* Barneby (1964: 168), *A. hintoni*, *A. legionensis* Barneby (1964: 155), and *A. tioides*.

Other national (ANSM, BCMEX, CFNL, CIIDIR, IBUG, IEB, USON) and international (CAS, MEXU, NYBG, SD, TEX-LL, US) herbaria were reviewed, and the presence of this species has not been registered in any of them.

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