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A new species of *Rhipidocladum* (Poaceae: Bambusoideae: Arthrostylidiinae) from Mexico

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Abstract

Mexico has a rich woody bamboo flora with over 52 species, 66% of which are endemic. Mexico represents the northern-most extent for many Neotropical bamboo genera such as the widespread *Rhipidocladum*, a genus with characteristic fan-like branching and variable synflorescence morphologies. Only four species of *Rhipidocladum* are known from Mexico: *R. bartlettii, R. martinezii, R. pittieri* and *R. racemiflorum*. Remarkably, the ranges of all four species overlap in the Mexican state of Chiapas. During field work in Chiapas, a flowering population of *Rhipidocladum* was discovered that had two glumes and retrorsely scabrous abaxial leaf surfaces, and lacked foliage leaf fimbriae. This combination of characters is unlike that of any known species in the genus. We conducted a comprehensive morphological study of specimens from this population and confirmed the existence of a new species of *Rhipidocladum*. We describe and illustrate the new taxon, discuss its diagnostic characters and provide an updated key to the species of *Rhipidocladum* distributed in Mexico. This taxonomic novelty increases the richness of the genus to 20 species and adds a new endemic woody bamboo to the flora of Mexico. The new species inhabits montane cloud forest, an important yet threatened vegetation type in Mexico.

Keywords: Bambuseae, Chiapas, cloud forest, Neotropics, woody bamboo

Introduction

Rhipidocladum McClure (1973: 101) is a genus of woody bamboo characterized by forming dense clumps of pachymorph rhizomes with short necks, with the culms erect at the base and self-supporting, but that begin arching in the middle; internodes are subequal and hollow with sparse patches of pith. The branch complement at each node is a fan-shaped cluster of numerous, small, subequal branches. The culm leaves are erect and triangular with a stiff to papery texture while the foliage leaves are linear to lanceolate and usually with conspicuous fimbriae at the sheath apex. The fimbriae vary from free with cylindrical bases to flattened with fused bases (Clark & Londoño 1991). The synflorescence axes can be zigzagged or straight, secund to racemiform, with spikelets comprising two, three or rarely five glumes, one or two sterile lemmas, two to twelve perfect florets, and a rachilla extension with a rudimentary floret. The fruit, in all species where it is known, is a basic caryopsis. The species of *Rhipidocladum*, like many woody bamboos, are semelparous plants with cycles of 7–20 years between flowering events (Clark & Londoño 1991, Triplett & Clark 2003, Judziewicz & Clark 2007, Guerreiro 2014).

Rhipidocladum consists of 19 species classified into two sections: section *Rhipidocladum* Clark & Londoño (1991: 1271) and section *Racemiflorum* Clark & Londoño (1991: 1275). Section *Rhipidocladum* is characterized by erect plants and self supporting culms with geniculate (zig-zag) synflorescence axes, basally fused foliage leaf fimbriae,

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lemmas with obtuse apices and abundant adaxial intercostal sclerenchyma in leaf cross-sections. This section includes three species: *R. arenicola* Tyrrell & Clark (2013: 58), *R. cordatum* Tyrrell & Clark (2013: 58), and *R. harmonicum* (Parodi 1944: 479) McClure (1973: 105).

Section *Racemiflorum* is characterized by plants with viny, scandent or climbing forms that include 16 species: *R. abregoense* Londoño & Clark (1998: 419), *R. ampliflorum* (McClure 1942: 167) McClure (1973: 105), *R. angustiflorum* (Stapf 1913: 268) McClure (1973: 105), *R. bartlettii* McClure (1973: 105), *R. clarkiae* R.W. Pohl (1985: 272), *R. martinezii* Davidse & Pohl (1992: 90), *R. maxonii* (Hitchcock 1927: 80) McClure (1973: 105), *R. neumannii* Sulekic, Rúgolo & Clark (1999: 317), *R. pacuarense* Pohl (1985: 273), *R. panamense* Pohl (1985: 275), *R. parviflorum* (Trinius 1835: 619) McClure (1973: 105), *R. pittieri* (Hackel 1903: 75) McClure (1973: 105), *R. prestoei* (Munro 1895: 186) McClure (1973: 106), *R. racemiflorum* (Steudel 1854: 336) McClure (1973: 106), *R. rubrofimbriatum* Tyrrell, Clark & Judz. (2013: 61), and *R. sibilans* Davidse, Judz. & Clark in Judziewicz *et al*. (1991: 84) (Clark & Londoño 1991, Londoño & Clark 1998, Tyrrell *et al*. 2012, Tyrrell & Clark 2013).

Species of *Rhipidocladum* are distributed in the Neotropics from northeastern Mexico and Trinidad to Argentina and central Brazil at elevations from near sea level up to 2800 m a.s.l. (Tyrrell & Clark 2013). Taxa are distributed in several biogeographic areas with no particular center of diversity: nine species in the Andes, eight species in Mexico and Central America, five species in the Guianas and the rest in Amazonian and Planaltine Brazil (Judziewicz & Clark 2007). In Mexico, the northernmost extent for the genus, four species (all section *Racemiflorum*) have been recorded: *R. bartlettii*, *R. martinezii*, *R. pittieri* and *R. racemiflorum*. These inhabit tropical rain forests, tropical seasonal forests, and montane cloud forests at elevations from 80 to 1700 m asl (Ruiz-Sanchez *et al*. 2015). Remarkably, in the state of Chiapas in southern Mexico the ranges for all four Mexican *Rhipidocladum* species overlap.

Phylogenetic analysis of arthrostylidioid bamboos (Arthrostylidiinae) demonstrated that *Rhipidocladum* is closely related to *Didymogonyx* (Clark & Londoño 1991: 1271) Tyrrell, Clark & Londoño (2012: 146), *Elytrostachys* McClure (1942: 173), and *Arthrostylidium* Ruprecht (1839: 27) (Tyrrell *et al*. 2012, 2018, Wysocki *et al*. 2015, Saarela *et al*. 2018). *Didymogonyx* was initially described as a section of *Rhipidocladum*; however, molecular phylogenetic analyses revealed that the latter genus was paraphyletic, and *Didymogonyx* was elevated to an independent genus (Tyrrell *et al*. 2012).

During field work in Chiapas, a flowering population of *Rhipidocladum* was vouchered that had a combination of floral and vegetative characters unlike those of any known species of *Rhipidocladum*. Comprehensive morphological study of specimens from this population confirmed the existence of a new *Rhipidocladum* species. Hence we describe and illustrate this new taxon, endemic to Mexico, and discuss the diagnostic characters among Mexican species of *Rhipidocladum*.

Rhipidocladum zoqueorum Ruiz-Sanchez, C.D. Tyrrell & Sosa *sp. nov.,* Figs. 1, 2

Type:—MEXICO. Chiapas: Ocozocoautla, camino al cerro Monterrey, 16°55’50’’ N, 93°35’38.6’’ W, 1180 m, 3 marzo 2018 (fl), *M. A. Domínguez Vazquez, H. Gómez Domínguez, A. E. Ortíz-Rodríguez 1300* (holotype: IBUG!, isotype: HEM!).

Diagnosis:—*Rhipidocladum zoqueorum* differs from *R. racemiflorum* by its longer lemmas 6.5–10 mm (vs. 5.5–7 mm), more widely spaced spikelets (5–20 mm apart vs. 3–6 mm apart), and bilateral (vs. secund) synflorescence form. It differs from all other Mexican species of *Rhipidocladum* in having scabrous (vs. glabrous or puberulent) glumes, lemmas and paleas.

Description:—Culms 2–5 m long, erect and then strongly arching; internodes 14.5–24 cm long, 10–13 mm in diameter, hollow; walls 1–3 mm thick. Culm leaves unknown. Branch complements with 40–75 branchlets, branchlets 40–45 cm long, occasionally rebranching. Foliage leaves 3 per flowering branchlet; sheaths 30–45 mm long, abaxially glabrous, margins entire and without fimbriae; pseudopetioles 2–5 mm long, abaxially and adaxially glabrous, green; inner ligules 1–2 mm long, truncate; blades 8–13 cm long, 6–15 mm wide, L:W ratio 8.5–11, lanceolate, adaxially glabrous, abaxially retrorsely scabrous, base rounded, with a patch of hairs, apex acute, margins minutely serrate. Synflorescences 13–22.5 cm long, spicate, straight, bearing 13–21 spikelets spaced 5–20 mm apart. Spikelets 1.6–2.0 cm long, comprising 2 glumes, 2 fertile florets, and a 3.5–5 mm long rachilla extension with rudimentary floret. Lower glume 3–6 mm long, ovate-lanceolate, apex awned, awn ca. 2.5 mm, abaxially scabrous, adaxially glabrous,1-nerved; upper glume 3–6 mm long, ovate, apex awned, awn ca. 2 mm, abaxially scabrous, adaxially glabrous, 3-nerved. Lemma (6.5–) 8–10 mm long, 7–9-nerved, lanceolate, apex awned, awn 0.8–1 mm long, abaxially scabrous. Palea (6–) 8–9mm long, abaxially scabrous, green, sulcate, rounded, keels ciliate. Lodicules 3, the anterior pair ca. 0.8 mm long, posterior one ca. 0.5 mm long, ovate. Anthers unknown. Ovary ca. 1 mm long, amber. Caryopsis ca. 6 mm, immature, dark brown.

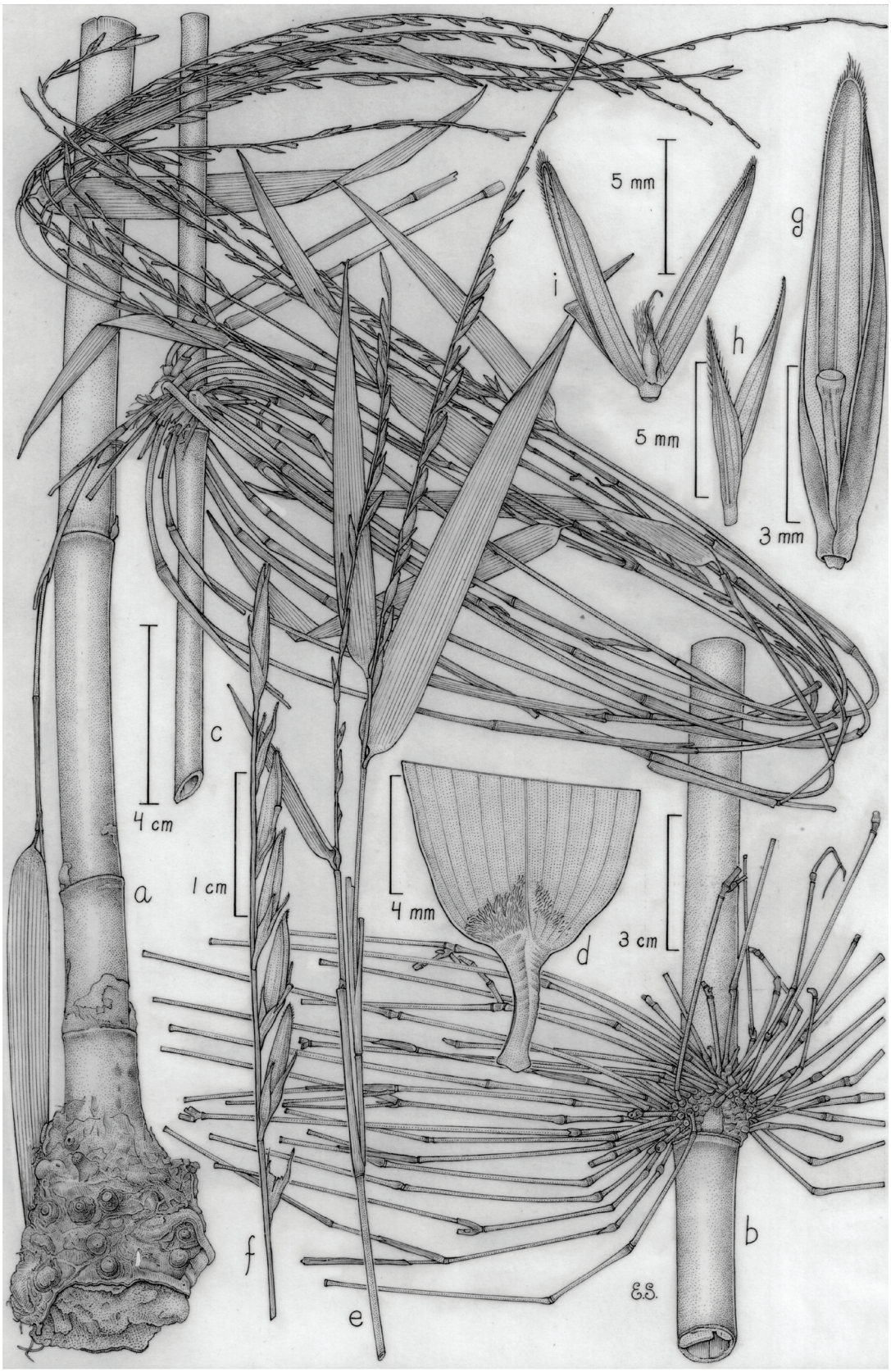

FIGURE 1. *Rhipidocladum zoqueorum*. a. Basal culm section showing a portion of the rhizome. b. Culm segment, showing the apsidate (fan-shaped) branch pattern and hollow culm. c. Culm segment showing flowering branches. d. Foliage leaf blade base, abaxial view, showing pseudopetiole and a patch of cilia. e. Branch segment showing foliage leaf complement and synflorescences. f. Synflorescence showing spikelets. g. Spikelet ventral view showing rachilla internode. h. Upper and lower glumes. i. Open spikelet showing lemma, palea and ovary. Drawing by Edmundo Saavedra based on *Domínguez Vazquez et al. 1300.*

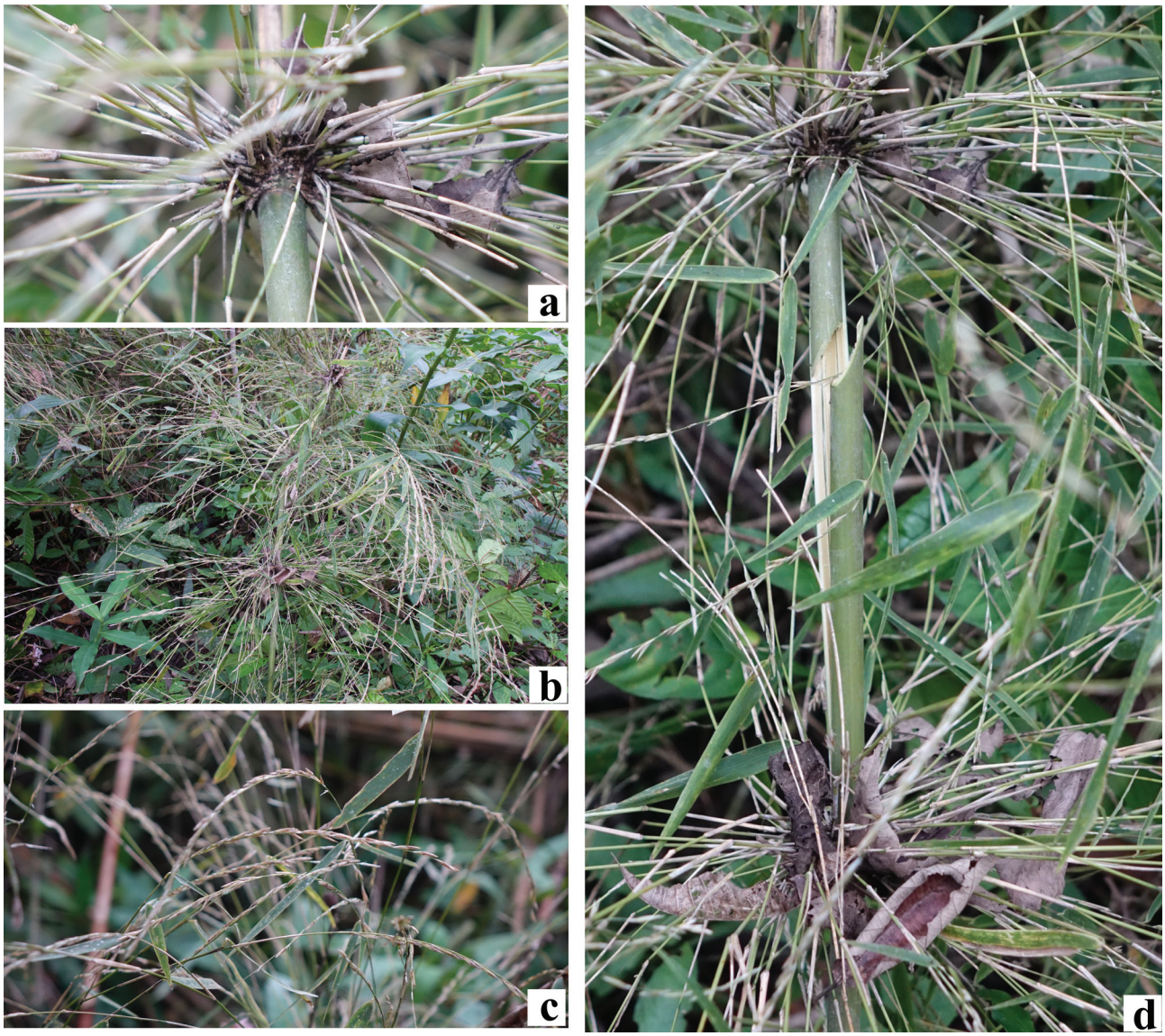

FIGURE 2. a. Mid-culm section showing branch complement. b. Mid-culm section showing flowering branches. c. Close-up of synflorescences with spikelets. d. Mid-culm section showing hollow culm and thin walls. Photos by Héctor Gómez-Domínguez.

Distribution and Habitat:—Known only from the type locality, located in the biosphere reserve El Ocote in Chiapas, Mexico. This species grows on karstic soils at 900–1200 m in the ecotone between tropical rain forest and montane cloud forest. It grows in association with *Clusia* Linnaeus (1753: 509) sp., *Oreopanax sanderianus* (Hemsley 1892: 718), and *Ardisia chiapensis* Brandegee (1924: 413). In the understory, species such as *Begonia nelumbonifolia* Schlechtendal & Chamisso in Fries (1830: 604), *Pitcairnia* L'Heritier (1789: 7) sp., *Sobralia macrantha* Lindley (1839: 29) and fern species were recorded. Similar Mexican *Rhipidocladum* species inhabit tropical rain forest (*R. bartlettii*), tropical subdeciduous forest (*R. racemiflorum*), or tropical dry forest (*R. pittieri*).

Similar species:—With regard to vegetative morphology, *Rhipidocladum zoqueorum* is most similar to *R. pittierii* and *R. bartlettii* in its foliage leaf size, but *R. zoqueorum* has more branches per node (45–75) than *R. barttletii* (20–40) or *R. pittieri* (24). *Rhipidocladum zoqueorum* has two glumes, similar to *R. racemiflorum* vs. three present in *R. bartlettii*, *R. martinezii,* and *R. pittieri*; however, *R. zoqueorum* has scabrous glumes, lemmas and paleas.

Etymology:—The specific epithet honors the Zoque, an ethnic group living in the area where this species grows in Chiapas and Oaxaca, Mexico.

Phenology:—The first known flowering specimens were collected in 1986 and we collected specimens again in flower in 2018. Most of the individuals collected from the type population were flowering, but a few were still sterile. We do not know if *R. zoqueorum* has periodic flowering but, if it does, we infer the flowering cycle to be about 32

years or less. A cycle of 16 years would be consistent with what has been reported for *R. pittieri* and *R. racemiflorum* (Pohl 1991). If an unrecorded flowering event occurred around 2002, it is possible *R. zoqueorum* also has a 16-year flowering cycle. Cycles of between 31 and 33 years, however, are known for some species of *Chusquea* and *Guadua* (Guerreiro 2014).

Additional Specimens Examined:—MEXICO. Chiapas: Ocozocoautla, camino al cerro Monterrey, 16°55'50"N, 93°35'38.6"W, 1180 m, 3 marzo 2018 (fl)**,** *H. Gómez Domínguez, A. E. Ortíz-Rodríguez and M. A. Domínguez Vazquez 3697* (IBUG), *3698* (HEM)*;* reserva ecológica "El Ocote", 14 Feb 1986 (fl), *J.J. Ortíz Díaz 965* (MO); Reserva El Ocote Callejon brecha al O adelante de la cassete aprox. 6 km, selva alta perennifolia, 10 marzo 1991 (fl, fr), *A. S. Ton 9616* (CAS); slope on the eastern edge of Selva del Ocote, Seasonal Evergreen Forest, 16°58'48"N, 93°34'12"W, 900 m, 25 Oct 1988, *D. E. Breedlove 70746* (CAS).

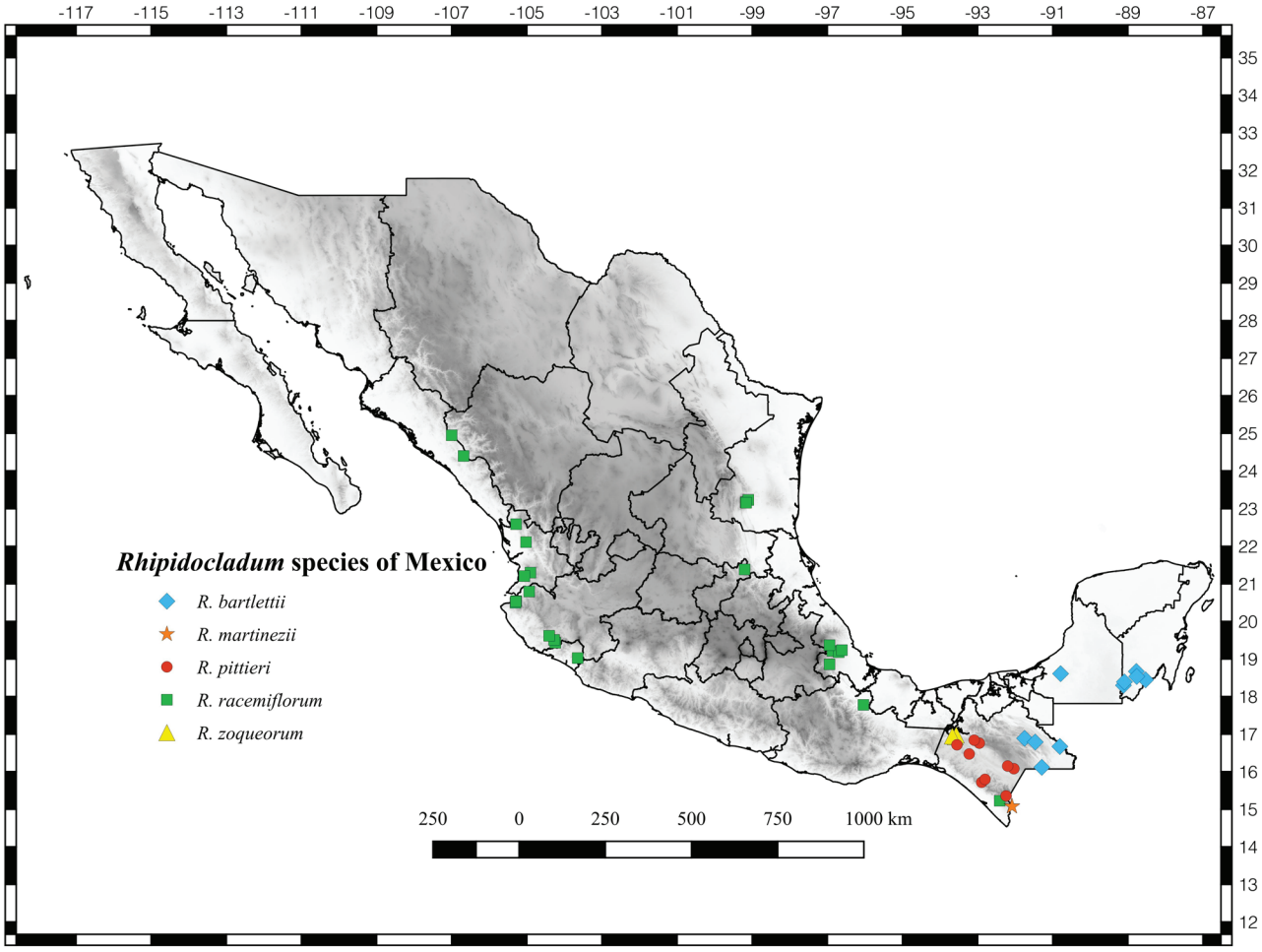

FIGURE 3. Geographical distribution of the species of *Rhipidocladum* in Mexico based on georeferenced localities of Ruiz-Sanchez *et al*. (In press).

Discussion

Rhipidocladum section *Racemiflorum* is characterized by racemiform synflorescence, 2(–3) glumes that are usually aristate, 1 sterile lemma, 2 or 3 florets, and one rudimentary floret (Clark & Londoño 1991). We assign *Rhipidocladum zoqueorum* to this section because it has a racemiform synflorescence, two aristate glumes and two florets per spikelet with a terminal rudimentary floret.

All the specimens of *Rhipidocladum zoqueorum* we have seen lack foliage leaf fimbriae, whereas all other species of *Rhipidocladum* section *Racemiflorum* are known to have fimbriae (Clark & Londoño 1991). Fimbriae are terete to flattened linear structures that arise from the summit of the leaf sheaths. When fimbriae are present on the culm leaves, they are also typically present in the same pattern on the foliage leaves (Clark & Cortés 2004). Culm and foliage leaf fimbriae are delicate and can to be lost due to abrasion or physical degradation, thus older plants have a greater

chance of not presenting fimbriae even if they were originally present. When bamboos lose their fimbriae there is usually a basal scar or small remnants on the sheath. This is not the case in *R. zoqueorum*, as we did not observe any scars or fimbriae remnants on the reviewed specimens. It is possible that this species may lose its fimbriae early in development, but we have described it as efimbriate based on the available evidence.

The addition of *Rhipidocladum zoqueorum* raises the richness of Mexican woody bamboos to 53 species and the number of endemic Mexican woody bamboos to 36 (68%; Ruiz-Sanchez *et al*. 2015, 2017, 2018, Ruiz-Sanchez & Castro-Castro 2016). Globally, the addition of *R. zoqueorum* increases the genus to 20 species and raises the richness of Mesoamerican *Rhipidocladum* to nine species (Tyrrell & Clark 2013).

Rhipidocladum zoqueorum and *R. martinezii* are the only two species of *Rhipidocladum* that are endemic to Mexico and, coincidentally, are also the only two that inhabit montane cloud forest (Ruiz-Sanchez *et al*. 2015). The montane cloud forest is the most important vegetation type in Mexico for woody bamboo diversification. Almost 50% of the total bamboo diversity in Mexico is found this type of forest. With the description of *R. zoqueorum* the number of Mexican woody bamboos inhabiting montane cloud forest increases to 26 (Ruiz-Sanchez *et al*. 2015, 2018).

Alarmingly, cloud forests are one of the most threatened vegetation types in Mexico (Rzedowski 1996, Aldrich *et al*. 2000, Luna-Vega *et al*. 2000). They occupy less than 50% of their former total area (Sánchez-Ramos & Dirzo 2014), which poses a grave threat to the woody bamboos restricted to this habitat type. The conservation status of this new bamboo species has yet to be formally assessed; however, the type locality (the only known location for the species) is within the limits of Selva El Ocote, a UNESCO biosphere reserve. Governmental protection with the international recognition of its habitat will help to buffer this species from threats.

Table 1. Comparison of morphological characters among the species of *Rhipidocladum* in Mexico.

Characters	*R. zoqueorum*	*R. bartlettii*	*R. martinezii*	*R. pittieri*	*R. racemiflorum*
Height (m)	2–5	3–10	5–12	5–10	>10
Culm diam. (mm)	10–13	4–5(–13)	8–16	5	3–10
Internode length (cm)	14.5–24	29	24	17.5	19–25
# branchlets per node	45–75	20–40	100–200	24–30	30–80
Branchlet length (cm)	40–45	20–40	10–30	about 38	13–20
Foliage leaves per branchlet	3	3–5	2–5	1–3	3–5
Foliage leaf sheath length (mm)	30–45	21–30	ca. 16	28–40	15–20
Fimbriae length (mm)	absent	2.5–4.0	1.5–2.5	>1.5	3–5
Pseudopetiole length (mm)	2–5	2–3	1.0–1.3	2.0–2.5	1.0–1.5
Foliage leaf blade length (cm)	8–13	8.5–13.0	4–8	6–10	2.5–5.0
Foliage leaf blade width (mm)	6–15	6–11	2.5–3.5	6–9	2–4
Foliage leaf blade length:width ratio	8.5–11	10–14	16–23	10–11	12–13
Foliage leaf blade abaxial vestiture	retrorsely scabrous, pubescent near base	glabrous	pubescent near base	glabrous, pubescent near base	pubescent near base
Foliage leaf blade adaxial vestiture	glabrous	scabrid	glabrous	glabrous	glabrous
Synflorescence length (cm)	13–22.5	10–17	2.5–4.5	8–13	3.5–5
# spikelets per synflorescence	13–21	15–20	2–4	9–17	10–13
Spikelet spacing (mm)	5–20	5–12	8–15	6–11	3–6
Synflorescence form	bilateral	bilateral	bilateral	secund	secund
Spikelet length (cm)	1.6–2.0	1.5–2.0	2.5–3.0	1.7–2.0	1.3
# glumes	2	3	3	3	2
# florets	2	1–2	2–4	4	2
First glume abaxial vestiture	scabrous	glabrous	puberulent to scabrous	glabrous	glabrous or puberulent
First glume length (mm)	3–6	2.5	2.5–7	2	2.5–3
First glume awn length (mm)	2–2.5	0.5	2–3	1.5–2.5	1.0–1.5
First glume abaxial vestiture	scabrous	glabrous	puberulent to scabrous	glabrous	puberulent
Second glume length (mm)	4–7	3	6–11	3.5–4	4–5
Third glume length (mm)	--	4.5	12–15	6–7	--
Lemma abaxial vestiture	scabrous	glabrous	puberulent	glabrous	pubescent
Lemma length (mm)	(6.5–)8–10	8	12–16	10–11	5.5–7
Palea length (mm)	(6–)8–9	8.5–9.0	9.5–10	9.5–10.5	6–7
Palea abaxial vestiture	scabrous	glabrous	glabrous	glabrous	glabrous

Key to the species of *Rhipidocladum* in Mexico

1. Plants with flowers (in reproductive condition) 2
-- Plants without flowers (vegetative condition) 6
2. Spikelets with 3 glumes (the first sometimes small and acicular) 3
-- Spikelets with 2 glumes (more or less similarly shaped) 5
3. Mid-culm nodes with more than 100 subequal branchlets; leaves linear-lanceolate (ratio of length to width 16–23) ... *R. martinezii*
-- Mid-culm nodes with fewer than 50 subequal branchlets; leaves lanceolate (ratio of length to width 10–14) 4
4. Glumes puberulent to scabrous; leaves adaxially scabrid, abaxially glabrous; sheath margins ciliolate; pseudopetioles scabrous ..... *R. bartlettii*
-- Glumes glabrous; leaves adaxially glabrous, abaxially with a patch of hairs near the base; sheath margins entire; pseudopetioles glabrousq ..... *R. pittieri*
5. Glumes scabrous; lemmas 6.5–10 mm long; synflorescences with spikelets spaced 5–20 mm apart, arising bilaterally ..... *R. zoqueorum*
-- Glumes glabrous to puberulent; lemmas 5–7 mm long; synflorescences with spikelets spaced 3–6 mm apart, secund ..... *R. racemiflorum*
6. Leaves narrowly lanceolate, 15 or more times longer than wide (blades at least 4 cm long) ..... *R. martinezii*
-- Leaves lanceolate, less than 15 times as long as wide (blade lengths various, 2.5–13 cm long) 7
7. Leaves abaxially retrorsely scabrous, fimbriae absent ..... *R. zoqueorum*
-- Leaves abaxially glabrous, fimbriae present or absent 8
8. Leaf blades shorter than 5.5 cm and narrower than 5 mm wide; pseudopetioles less than 2 mm long; foliage leaf sheaths less than or equal to 2 cm long ..... *R. racemiflorum*
-- Leaf blades longer than or equal to 5.5 cm and wider than 5.5 mm; pseudopetioles more than 2 mm long; foliage leaf sheaths more than 2 cm long 9
9. Leaves adaxially scabrid, abaxially glabrous; sheath margins ciliolate; pseudopetioles scabrous ..... *R. bartlettii*
-- Leaves adaxially glabrous, abaxially with a patch of hairs near the base; sheath margins entire; pseudopetioles glabrous ..... *R. pittieri*

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