A striking new species of *Rhipidocladum* (Poaceae: Bambusoideae: Bambuseae: Arthrostylidiinae) with single, terminal-spikelet synflorescences, endemic to Jalisco, Mexico

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Material and methods – This study was based on fieldwork, literature, and herbarium specimens review. Specimens collected were analysed and photographed during fieldwork. The conservation assessment is based on spatial analyses, following the IUCN guidelines and criteria.

Results – This is the first species in the genus *Rhipidocladum* that has synflorescences with only a single, terminal spikelet. *Rhipidocladum singuliflorum* occurs only in three localities in the municipality of Puerto Vallarta, Jalisco, Mexico. This species inhabits the canyon slopes of rivers in subdeciduous and tropical dry forests, at 6–150 m a.s.l. According to our IUCN assessment, this new species should be considered Critically Endangered.

Keywords

Arthrostylidiinae, *Rhipidocladum* sect. *Racemiflorum*, spicate synflorescence, tropical subdeciduous forest, woody bamboos

INTRODUCTION

*Rhipidocladum* McClure is one of eight genera of woody bamboo found in Mexico, and one of the four Mexican bamboo genera in subtribe Arthrostylidiinae (Ruiz-Sanchez et al. 2015). The genus has 21 described species, six of which are present in the country and three of which are endemic (Ruiz-Sanchez et al. 2019, 2021a, 2021b). Taxonomically, *Rhipidocladum* is classified into two sections: *Rhipidocladum* sect. *Rhipidocladum* and *R*. sect. *Racemiflorum* (Clark and Londoño 1991). *Rhipidocladum* sect. *Rhipidocladum* is characterized by robust culms with an apically arching or pendulous habit, basally fused fimbriae on the foliage sheath summit, a zigzagged synflorescence axis, and obtuse, unawned lemmas. Meanwhile, R. sect. *Racemiflorum* is characterized by plants with viny culms with a scandent or climbing habit, racemiform synflorescences with a straight (non-
Rhipidocladum\textsubscript{barbinode} Ruiz-Sanchez, C.D.Tyrrell & Sosa (endemic) (Ruiz-Sanchez et al. 2019, 2021b). The six species in Mexico are all classified within the \textit{R. sect. Racemiflorum} and include: \textit{Rhipidocladum barbinode} Ruiz-Sanchez, C.D.Tyrrell & Vigosa (endemic), \textit{R. bartlettii} McClure, \textit{R. martinezii} Davids & Pohl (endemic), \textit{R. pittieri} (Hack.) McClure, \textit{R. racemiflorum} (Steud.) McClure, and \textit{R. zoqueorum} Ruiz-Sanchez, C.D.Tyrrell & Sosa (endemic) (Ruiz-Sanchez et al. 2019, 2021b). Two species are known from the state of Jalisco: \textit{R. barbinode} and \textit{R. racemiflorum}. The first inhabits tropical dry forest and subdeciduous tropical forest glens, mainly in the southwestern part of the state at elevations of 500–1000 m a.s.l. The second inhabits tropical subdeciduous forest at the western edge of the state at elevations of 100–1000 m a.s.l. (Ruiz-Sanchez et al. 2021b) (Fig. 1). Until now, none of these species are found in sympatry. \textit{Rhipidocladum barbinode} has spicate synflorescences, bearing 3–7 spikelets spaced 5–7 mm apart, glumes are awned, and mucronate lemmas. Meanwhile, \textit{R. racemiflorum} has racemose inflorescences with 10–13 spikelets, glumes have awns, and the lemmas are aristate.

During our fieldwork carried out in Puerto Vallarta, Jalisco along the Palo Maria, El Nogalito, and El Pitillal rivers, we found a population of flowering bamboos that can be clearly assigned to \textit{Rhipidocladum}, but cannot be assigned to any known Mexican or American \textit{Rhipidocladum} species. This new species has synflorescences with only a single, terminal spikelet (compared to all other \textit{Rhipidocladum} species which have two to many spikelets). Further, these spikelets were strikingly wide for a \textit{Rhipidocladum} species with large, inflated lemmas. A few individual branchlets had spikelets bearing numerous (> 20) florets. In this study, we present a full description of this unusual new \textit{Rhipidocladum} species and provide a distribution map, illustrations, photographs, and a new key to the species of \textit{Rhipidocladum} in Mexico.

**TAXONOMIC TREATMENT**

\textit{Rhipidocladum singuliflorum} Ruiz-Sanchez & C.D.Tyrrell, \textit{sp. nov.}

urn:lsid:ipni.org:names:77308912-1 Fig 2, 3, 4

**Type.** MEXICO – Jalisco • Puerto Vallarta, Río Palo María; 20°33'8.76"N, 105°15'34"W; 6 m; 10 Dec. 2021; fl.; E. Ruiz-Sanchez, A.T. Nuño, A. Zabalgoitia, L.A. Monroy & L. Campos 722; holotype: IBUG; isotypes: MEXU, ZEA.

**Diagnosis.** \textit{Rhipidocladum singuliflorum} differs from \textit{R. barbinode} and \textit{R. racemiflorum} by having a single terminal spikelet. Meanwhile, \textit{R. barbinode} has a spicate synflorescence with 3–7 spikelets and \textit{R. racemiflorum} has a racemose synflorescence with 10–13 spikelets. \textit{R. singuliflorum} has efimbriate or poorly developed fimbriae on the foliage leaves, meanwhile, \textit{R. barbinode} and \textit{R. racemiflorum} bear fimbriae at the apex of the sheath of the foliage leaves.

**Description.** Culm height 3–10 m. Internodes smooth, uniform in colour, 9–33 cm long, 3–9 mm in diameter, hollow (pithy when young); walls 2–3 mm thick. Culm leaves 17–19 cm long; sheaths (6.5–)7.6–9(–9.9) cm long, abaxially glabrous, adaxially glabrous and shiny; blades erect, 9–10 cm long, abaxially sparsely pubescent at the base, adaxially glabrous, margins entire; fimbriae not seen. Branch complements at mid-culm nodes with (30–)41–87(–120) branchlets; branchlets (8–)113–30(–50) cm long, glabrous or pubescent. Foliage leaves 3–4 observed on flowering branchlets; sheaths 9–22 mm long, abaxially pubescent (occasionally glabrous); mostly efimbriate.
when fimbriate 0.2–0.8 mm long, white to stramineous; pseudopetioles 1.0–1.6 mm long, abaxially and adaxially pubescent; blades lanceolate to narrowly ovate with an attenuate apex, 32–75 mm long, 5–7 mm wide, abaxially and adaxially glabrous, without sparse patches of white cilia near the base on the abaxial side. Synflorescences 2.0–3.4 cm long, 0.9–10 mm wide, composed of a single spike, sometimes develop two spikelets, one of them with only two florets; rachis pubescent. Spikelets 2.0–3.4 cm long, comprising 2–4 glumes and (2–)4–5(–20) fertile florets, rachilla joints 3.5–4 mm long, glabrous. Glumes pubescent margins ciliate, awnless, lower glume, 3.2–5.8 mm long, 6–, 9–, 10-nerved, lanceolate; upper glume, 4.8–7.0 mm long, 11–, 13-nerved, lanceolate. Lemmas 8.8–12.0 mm long, 9–, 13-nerved, ovate and inflated, pubescent, apex rounded-obtuse and muticous. Palea 10.0–13.6 mm long, keels and sulcus pubescent, apex rounded-obtuse and muticous. Lodicules 3, abaxially glabrous, hyaline, margin ciliate apex fimbriate, the anterior pair 2.6–3.2 mm long, the posterior one 2.0–2.4 mm long. Anthers 3. Ovary 1.0–1.5 mm long, stigmas 2, plumose. Caryopsis 3.3–3.5 mm long, ellipsoid, pubescent with trichomes near base and apex, indented on hilum side, yellowish-golden.

**Distribution.** This species is only known from three localities in the municipality of Puerto Vallarta, Jalisco, Mexico in the Jalisciense-Tuito district of the Sierra Madre del Sur (Santiago-Alvarado et al. 2016) (Fig. 1).

**Habitat and ecology.** This species inhabits the slopes of humid canyons of creeks and rivers at 6–150 m a.s.l. The vegetation corresponds to subdeciduous and tropical dry forests with associated species, such as *Astronium graveolens* Jacq., *Bursera* spp., *Casearia arguta* Kunth, *Cecropia obtusifolia* Bertol., *Cudioscolus tepiquensis* (Cost. & Gall.) Lundell, *Croton schiedeanus* Schldl., *Cuapnia dentata* Moc. & Sesse, *Dendropanax arboreus* (L.) Decne. & Planch., *Euphorbia* spp., *Ficus* spp., *Guettarda elliptica* Sw., *Inga laurina* (Sw.) Willd., *Lonchocarpus* spp., *Luehea candida* Mart., *Lysiloma divaricatum* (Jacq.) Benth., *Ouratea madrensis* L.Riley, *Pseudobombax ellipticum* (Kunth) Dugand, and *Zygia conzattii* (Standl.) Britton & Rose, among others (Fig. 3A).

**Etymology.** Latin singulus, solitary, and florurn, flowered, alluding to usual occurrence of single, terminal spikelet in synflorescence (Figs 2A, 3D–F). The use of -florum instead of -spiculum is preferred here [cf., *R. racemiflorum*]

**Preliminary IUCN conservation assessment.** Critically endangered: CR B1ab(iii). *Rhipidocladum singuliflorum* is known from three localities that are separated by no more than 14 km. Using GeoCAT, the Extent of Occurrence (EOO) was calculated to be 10.6 km², and the Area of Occupancy to be 12 km², based on 2 × 2 km cells. The three localities are canyons that are not suitable for agriculture.

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**Figure 1. A.** Geographical distribution of the species of *Rhipidocladum* in Mexico based on georeferenced localities of herbarium specimens (Ruiz-Sánchez et al. 2019, 2020, 2021b). **B.** Close up to the geographical distribution of *R. singuliflorum* (red stars) and *R. racemiflorum* (black circles) in western Jalisco.
or grazing, and are often used for recreation with one of them (El Nogalito) currently under management by an ecotourism centre. The localities, however, are adjacent to the Carretera Pacifico (Carretera Federal 200), the major west coast highway, and potentially in the path of the planned series of “via corta” highway expansions. A preliminary category of Critically endangered: CR B1ab(iii) is proposed following the IUCN (IUCN Standards and Petitions Committee 2022) criteria.

**Key to the species of Rhipidocladum in Mexico**

| 1. Plants with spikelets (reproductive stage) | 2. Plants without spikelets (vegetative stage) | 3. Spikelets with 3 glumes (the first sometimes small and acicular) | 4. Mid-culm nodes with more than 100 subequal branchlets; foliage leaves linear-lanceolate (ratio of length to width 16–23) | 5. Glumes puberulent to scabrous; foliage leaves adaxially scabrid, abaxially glabrous; sheath margins ciliolate; pseudopetioles glabrous | 6. Glumes scabrous; lemmas 6.5–10 mm long; synflorescences with spikelets on both sides, spaced 5–20 mm apart | 7. Synflorescences 2.5–9 cm long, with 3–7 spikelets spaced 5–7 mm apart; glumes awnless | 8. Foliage leaf blades narrowly lanceolate to linear, 4–8 cm long, ratio of length to width 16–23 | 9. Foliage leaf blades abaxially retrorsely scabrous, fimbriae absent on the sheath summit | 10. Foliage leaf blades sheaths with a copious band of hairs near the base | 11. Foliage 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 | 12. Culms appearing solid or, if hollow, the wall thickness at mid-culm half or more the diameter of the lumen | 13. Foliage leaves adaxially scabrid, abaxially glabrous; sheath margins ciliolate; pseudopetioles scabrous |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Planta con escasos | Planta sin escasos | Espiga con 3 glumas (la primera a veces pequeña y acicular) | Nudos medioculares con más de 100 ramas subiguales; hojas foliares lineales-lanceoladas (proporción de longitud a anchura 16–23) | Glumas puberulentos a escamosos; hojas foliares adaxialmente escamadas, abaxialmente glabras; bordes de las espatulas enteros; estípulas glabras | Espiga con 6.5–10 mm; sinflorescencias con espinas en ambos lados, a 5–20 mm apartadas | Sinflorescencias 2.5–9 cm de longitud, con 3–7 espinas a 5–7 mm apartadas; glumas sin espinas | Hojas foliares estrechamente lanceoladas a lineares, 4–8 cm de longitud, proporción de longitud a anchura 16–23 | Hojas foliares abaxialmente retrorsamente escamosas, fimbrias ausentes en la cima de las espatulas | Hojas foliares estrechamente lanceoladas con bandas de espinas cerca de la base | Hojas foliares más cortas de 5.5 cm y más estrechas de 5 mm de anchura; estípulas más cortas de 2 mm; hojas foliares no más de 2 cm de longitud | Culmos aparentemente sólidos o, si huecos, la pared de la mitad inferior de los culmos o más del diámetro del lumen | Hojas foliares adaxialmente escamadas, abaxialmente glabras; bordes de las espatulas enteros; estípulas escamosas |

**Additional specimens examined.** MEXICO — Jalisco • Puerto Vallarta, 4 km al SE de Playa Grande, subiendo por el Río Pitillal (2.4 km en línea recta); 20°38’14”N, 105°10’14”W; 120 m; 18 Feb. 2022; fl.; A.T. Carrillo-Reyes & S. Quijas-Fonseca 10093; IBUG • Arroyo El Nogalito, 0.8 km en línea recta al SE del Ecoparque El Nogalito; 20°33’24”N, 105°14’10”W; 130 m; 20 Mar. 2022; P. Carrillo-Reyes & A.T. Núñez-Ruiz 10106; IBUG • Río Palo María; 20°33’8.76”N, 105°15’34”W; 6 m; 16 Nov. 2021; fl.; A.T. Núñez & L. Campos s.n.; IBUG.

**DISCUSSION**

*Rhipidocladum singuliflorum* is the most singular species of the genus. It is the first known to have sinflorescences bearing one terminal spikelet. All other species in the genus have at least two (and usually more than three) spikelets per sinflorescence axis. We observed some sinflorescences in *R. singuliflorum* with two spikelets, but the second spikelet appeared to arise from a gemmiparous bract at the base of the first, suggesting this species is capable of producing pseudospikelets. It is possible that the single spikelets in *R. singuliflorum* evolved through reduction of synflorescence paracles/co-synflorescences into the single spikelets observed. If true, this species may provide some insight into the evolution and origin of pseudospikelets within the bamboos. Pseudospikelets have been evolved twice in Arthrostylidiinae: in the genera *Alvimia* C.E.Calderón...
ex Soderstr. & Londoño and Elytrostachys McClure (Tyrrell et al. 2012). Elytrostachys is nested in the same clade as Arthrostylidium Rupr., Didymogonyx (L.G.Clark & Londoño) C.D.Tyrrell, L.G.Clark & Londoño and Rhipidocladum, these last three genera have spikelets. Then R. singuliflorum could be a key species to understand spikelet-pseudospikelet evolution.

*Rhipidocladum singuliflorum* is nearly indistinguishable from *R. racemiflorum* in vegetative morphology, but strikingly different in the reproductive phase. In floral morphology, *R. singuliflorum* shares the inflated lemma characteristic of *R. barbinode*, but the latter species has spicate synflorescences with two or more spikelets, spaced 5–7 mm apart (Ruiz-Sanchez et al. 2021b). It is possible that *R. singuliflorum* and *R. barbinode* could be sister species, however, a molecular phylogenetic study would be needed to test this hypothesis.

Figure 2. *Rhipidocladum singuliflorum*. A. Culm segment showing foliage leaves complement and synflorescences. B. Culm segment, showing culm leaf sheath and blade. C. Culm leaf sheath and blade abaxial view. D. Spikelet bearing 2 glumes and 5 florets. E. Glumes. F. Floret, lateral (right) and dorsal (left) views. G. Palea, frontal (right) and lateral (left) views. Drawing by Juvenal Aargón Parada based on E. Ruiz-Sanchez, A. Nuño, A. Zabalgoitia L.A. Monroy y L. Campos 722 (IBUG).
Figure 3. *Rhipidocladum singuliflorum*. A. Panoramic view of the subdeciduous tropical forest glen habitat at the Palo María river, culms showing scandent habit. B. Basal clump showing culms habit and culm leaves. C. Cross section and size cut of culm, showing hollow culm with thick wall. D. Synflorescence branches bearing one terminal spikelet. E. Close up of the spikelet showing glumes, lemma, palea and florets. F. Spikelet. Photos by Eduardo Ruiz-Sanchez (A, B, C, E) and Pablo Carrillo-Reyes (D, F).
This new species has likely been overlooked due to the long flowering cycles characteristic of many woody bamboos (Zheng et al. 2020). It is presumed that all *Rhipidocladum* species have gregarious and cyclical flowering events (Tyrrell and Clark 2013). According to our field observation, *R. singuliflorum* also exhibits a gregarious flowering pattern (Franklin 2004). In the three localities, plants were flowering simultaneously; however, we do not know if the flowering cycle length as this is the first time it has been recorded in flower. *Rhipidocladum racemiflorum* is also present in the same region and in some places, such as Rio Palo Maria and Rio El Pitillal, and it is sympatric with *R. singuliflorum* (Fig. 1B). We did not see evidence of hybridization between the two species despite having collected *R. racemiflorum* in flower at Rio Palo Maria in 2019. The individuals of *R. racemiflorum* were no longer flowering during our field investigations that uncovered *R. singuliflorum* in flower.

The Jalisciense-Tuito district together with the Jalisciense-Manantlán district are classified into the subprovince of Sierra Madre del Sur Occidental (Santiago-Alvarado et al. 2016). According to Aragón-Parada et al. (2021), this subprovince has 193 endemic vascular plants. The Sierra Madre del Sur is the richest woody bamboo floristic province in Mexico. Several other species of woody bamboos are known to inhabit the Jalisciense-Tuito district of the Sierra Madre del Sur (Santiago-Alvarado et al. 2016; Morrone et al. 2017), including: *Chusquea circinata* Soderstr. & C.E.Calderón, *Cortesia* L.G.Clarke & Ruiz-Sanchez, *Contrasiasi* Ruiz-Sanchez & L.G.Clarke, *Guadua* liebmannii E.Fourn., *Otaeas acuminata* (Munro) C.E.Calderón & Soderstr., *O. reynosoana* Ruiz-Sanchez & L.G.Clarke, and *Rhipidocladum* barbinode (Ruiz-Sanchez et al. 2020, 2021b, 2021c). Like *R. singuliflorum*, *C. contrerasii* is also endemic to this district (Ruiz-Sanchez et al. 2021c).

With the description of *R. singuliflorum*, the total number of species of *Rhipidocladum* increases to 22, with seven occurring in Mexico (Ruiz-Sanchez et al. 2021b). The number of native Mexican woody bamboo species also increases to 59, 42 (71%) of them endemic (Ruiz-Sanchez et al. 2022), and the number of woody bamboo species in the Sierra Madre del Sur province increases to 23 (Ruiz-Sanchez et al. 2020, 2021b, 2021c, 2022). The limited geographic distribution of *R. singuliflorum* and putative single population, coupled with whit its gregarious, semelparous, multyear phenology, and the potential for roadway expansion in the area, led us to assign a preliminary IUCN category of Critically Endangered to this species. Given the prospective threats, we recommend a formal assessment to be performed to establish whether any additional subpopulations can be found and to monitor trends in their size, extent and, potentially, gene flow.

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Figure 4. *Rhipidocladum singuliflorum*. A. Caryopsis dorsal view. B. Caryopsis ventral view showing indent near the hilum.
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