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Otatea ramirezii (Poaceae: Bambusoideae: Bambuseae) flower description and the importance of the Mexican national living bamboo collection

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Abstract

Botanical gardens have several aims, among which is to increase awareness of plant diversity, to study it, and to conserve it. The Francisco Javier Clavijero Botanical Garden at the Instituto de Ecología, in Xalapa, Mexico, curates the Mexican national living national bamboo collection. In 2010 a new *Otatea* species was collected, described and cultivated in the living bamboo collection. Two years after being planted, this bamboo began to flower in the summer of 2012. I decided to visit the type locality and I found the entire population flowering. Based on collected specimens, the synflorescences and spikelets of *Otatea ramirezii* are described and these structures are compared with those of the known *Otatea* species described with flowers. The living national bamboo collection of Mexico is important for the preservation of native species and, given that the flowering cycles of most bamboo species are not known, for the documentation of their life cycles.

Key words: asynchrony, botanical garden, flowering cycle, phenology, monocarpic, synflorescence

Resumen

Los jardines botánicos tienen diversos objetivos, uno de ellos es aumentar la conciencia, la investigación y la conservación de biodiversidad vegetal. El jardín botánico Francisco Javier Clavijero en el Instituto de Ecología, en Xalapa, México, resguarda la colección nacional de bambúes Mexicanos. En 2010 se colectó, describió y cultivó una especie nueva de *Otatea* en la colección nacional de bambúes. Después de dos años de crecimiento, el bambú comenzó a florecer en el verano de 2012. Decidí visitar la localidad tipo y encontré a toda la población floreciendo. Con base en los especímenes colectados, se completo la descripción de *Otatea ramirezii*, describiendo las inflorescencias y flores. Esas estructuras se compararon con la de las especies conocidas de *Otatea* descritas con flores. La colección nacional de bambúes Mexicanos es muy importante para la conservación de las especies nativas y dado que los ciclos de floración de la mayoría de las especies de bambúes no se conocen, la documentación de sus ciclos de vida es necesaria.

Introduction

In the Americas, the highest bamboo diversity and endemism is found in Brazil, the northern and central Andes, Mexico and Central America (Judziewicz et al., 1999). Prior to 2004 there were 36 native species of bamboos described in eight genera for Mexico (Judziewicz et al., 1999; Cortés Rodríguez 2000; Clark and Cortés 2004), but recent work has brought this number to 44 species (Judziewicz et al., 1999; Ruiz-Sanchez et al., 2011, 2011a; Ruiz-Sanchez 2012; Ruiz-Sanchez and Clark 2013) and three more are in the process of being described. More than the half (23) of the Mexican bamboo species are endemic and this number could increase with the description of new taxa. The Mexican bamboos grow in tropical dry and perennial forests, mixed pine-oak and pine-spruce forests, pine forests, and cloud forests from sea level to 3,000 m elevation (Cortés Rodríguez 2000; Ruiz-Sanchez *et al.*, 2011, 2011a; Ruiz-Sanchez & Clark 2013).

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The Francisco Javier Clavijero Botanical Garden at the Instituto de Ecología, A.C. (INECOL) in Xalapa, Veracruz, Mexico houses the Mexican national living bamboo collection that was created in a collaborative effort by INECOL, Bamboos of the Americas (BOTA), and the Instituto Tecnológico de Chetumal for the *ex situ* preservation of Mexican bamboo diversity, and for the purposes of research and teaching the public about Mexican bamboo species. The living Mexican bamboo collection has 31 of the 44 described species, some of which have been difficult to cultivate due their requirement for special abiotic conditions (temperature, humidity, soil type, etc.).

One of the eight genera of bamboos present in Mexico is *Otatea* (McClure & E.W. Sm) Calderón & Soderstrom (1980: 21). With eight described species (Guzmán et al. 1984; Clark and Cortés 2004; Ruiz-Sanchez et al., 2011; Ruiz-Sanchez 2012), it is the second most speciose bamboo genus in Mexico, behind *Chusquea* Kunth (1822: 151) with 18 described species (Cortés Rodríguez 2000; Ruiz-Sanchez & Clark 2013). Like most bamboos, *Otatea* is a semelparous genus with mass flowering in cycles that, according to herbarium records, occur in 8-30 year cycles (Guzmán et al., 1984; Judziewicz et al., 1999; Ruiz-Sanchez et al., 2011). Populations usually flower for two or three years consecutively and then die (Ruiz-Sanchez et al., 2011). Some species of *Otatea,* such as *O. fimbriata* Soderstrom in McVaugh (1983: 280) have synchronous flowering, while others, such as *O. acuminata* (Munro) Calderón & Soderstrom (1980: 21), *O. glauca* Clark & G. Cortés (2004: 3) and *O. ramirezii* Ruiz-Sanchez (2012: 25), flower asynchronously (Ruiz-Sanchez et al., 2011; personal observation).

During fieldwork in the Querétaro state in 2010, I collected a potentially new species of *Otatea*. This specimen was described as *Otatea ramirezii* based on its vegetative morphology characters, without flowering characters because the population was sterile. Other *Otatea* species (*O. carrilloi* Ruiz-Sanchez, Sosa & Mejía-Saulés in Ruiz-Sanchez et al. (2011: 324) and *O. transvolcanica* Ruiz-Sanchez & L.G. Clark in Ruiz-Sanchez et al. (2011: 330) have also been initially described based only on vegetative morphological characters (Ruiz-Sanchez et al., 2011). The *O. ramirezii* specimen was cultivated at the Francisco Javier Clavijero Botanical Garden and deposited in the Mexican national living bamboo collection. Over the course of regular visits to the collection I saw the specimen of *O. ramirezii* flowering, and decided to visit the population in Querétaro. There, I found the entire population flowering synchronously and noted that some individuals had flowered the previous year. I collected several flowering specimens and described and illustrated the flowers of *O. ramirezii* (Fig. 1, 2) and constructed a flowering key to the species of *Otatea* with known flowers.

Key to the species of *Otatea* based on flowering characters

1. Synflorescences with 6–33 spikelets 2
1. Synflorescences with 2–7 spikelets 4
2. Synflorescences 10–15 cm long, paniculate, glume I 5–7 mm long (including the awn), glume II 7–9.5 mm long (including the awn) ..... *O. fimbriata* Soderstr.
2. Synflorescences 5–10 cm long, paniculate to racemose, glume I 2.5–8.2 mm long (including the awn), glume II 3.5–8.5 mm long (including the awn) 3
3. Lemmas 8–13 mm long (including the awn), pubescent; paleas keels pubescent; lodicules glabrous with ciliate margin ..... *O. acuminata* (Munro) C. Calderón & Soderstr.
3. Lemmas 10–14.5 mm long (including the awn), scabrous; paleas keels glabrous; lodicules pubescent ..... *O. ramirezii* Ruiz-Sanchez
4. Spikelets purple-blue; glume I 6–11 mm long (including the awn), glume II 8–12.7 mm long (including the awn); lemmas 11.5–17 mm long (including the awn)..... *O. ximenae* Ruiz-Sanchez & Clark (2011: 330)
4. Spikelets green; glume I 6.5–13 mm long (including the awn), glume II 9.5–17 mm (including the awn); lemmas 14.3–21 mm (including the awn) 5
5. Lemmas glabrous; paleas 9.7–11.7 mm long.....*O. reynosoana* Ruiz-Sanchez & Clark (2011: 328)
5. Lemmas scabrous-pubescent; paleas 14–15.4 mm long.....*O. glauca* Clark & Cortés

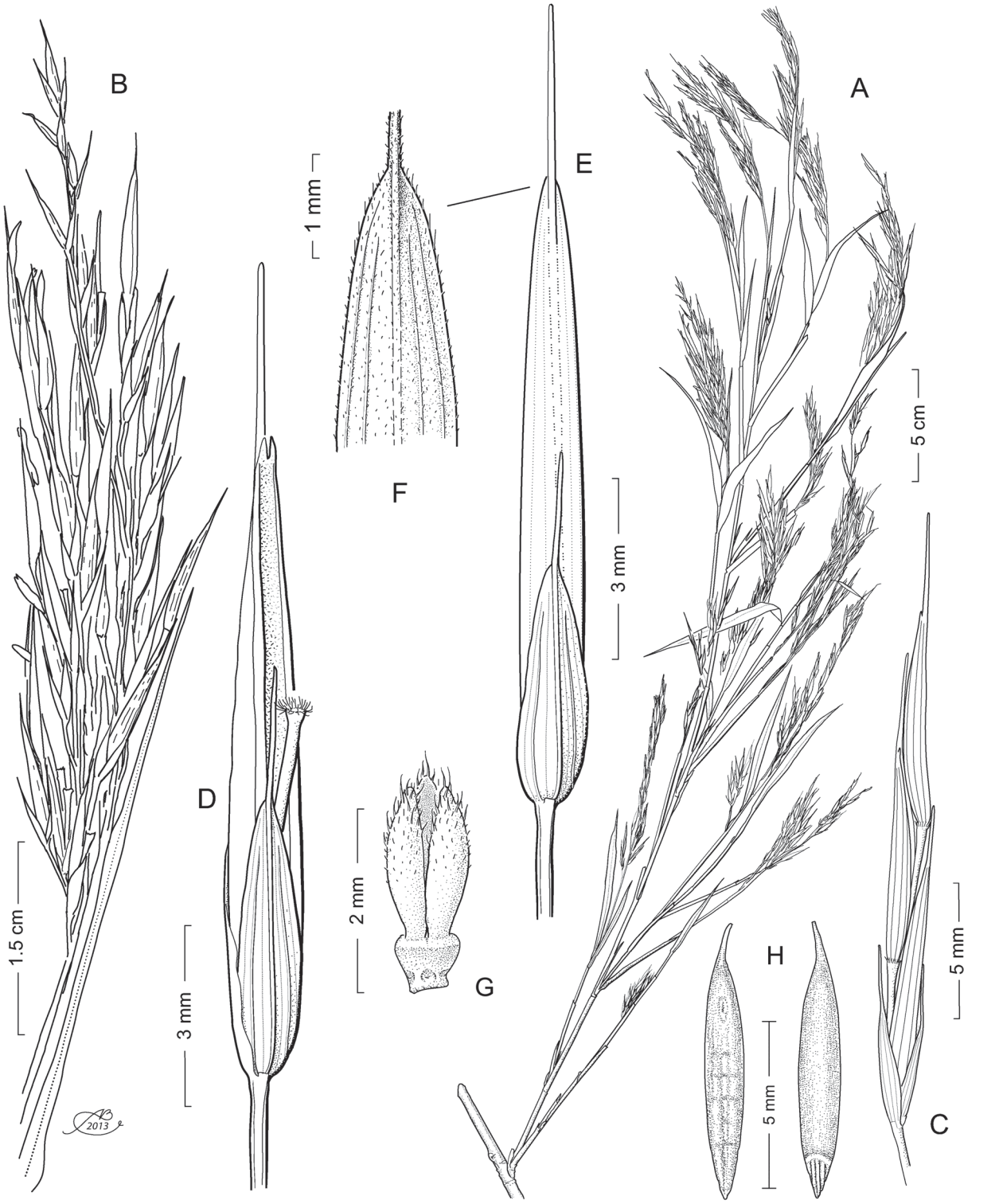

FIGURE 1. *Otatea ramirezii*. A. Flowering branch, with synflorescences. B. Synflorescence. C. Spikelet, showing florets and rachilla joints. D. Spikelet ventral lemma view, showing glabrous awned glume I, rachilla joint with pubescent apex, palea with glabrous keels, pubescent sulcus and bifid apex and lateral view of awned lemma. E. Spikelet dorsal lemma view showing glabrous awned glume II, and awned lemma. F. Detail of the scabrous lemma. G. Anterior pubescent lodicules pair, abaxial view and adaxial apex of the posterior one. H. Caryopsis hilum (left), embryo (embryo). Based on *E. Ruiz-Sanchez, L. Pérez & A. Núñez* 410. Drawn by Alfonso Barbosa.

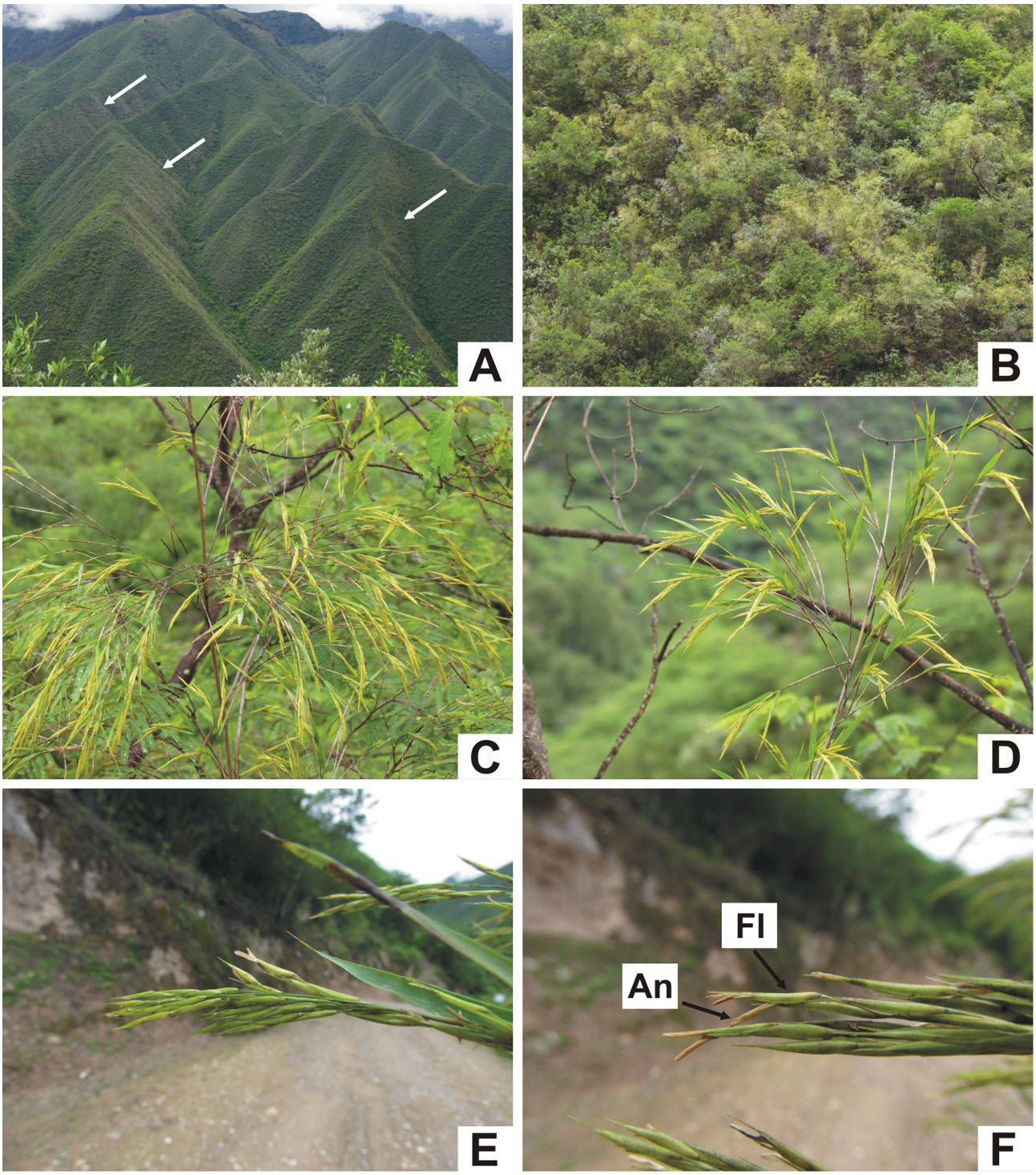

FIGURE 2. A. White arrows indicate mass flowering populations in the hills of the Sierra Gorda in the state of Querétaro, Mexico. B. Close-up of the mass flowering population. C. Individual flowering, showing the plant with terminal synflorescences. D. Close-up of the branches showing terminal synflorescences. E. Synflorescence showing several spikelets. F. Close-up of the synflorescence, An = anthers, Fl = single floret. Photos by E. Ruiz-Sanchez.

Otatea ramirezii Ruiz-Sanchez amended description

Type:—MÉXICO. Querétaro: 500 m antes de llegar a San Juan Tetla desde El Apartadero, municipio de San Joaquín, bosque tropical caducifolio, suelos calizos, 20°58'40.8" N, 99°29'47" W, 1223 m, 10 July 2010, *E. Ruiz-Sanchez* & *A. de Nova* 304 (holotype: IBUG!; isotypes: IEB!, MEXU!, XAL!).

Description:—Rhizomes with necks 5–15 cm long. Culms 2–5 m tall, 0.8–2.5 cm in diameter at base, erect; internodes 12–16 cm long, terete, glabrous, green-glaucous and pruinose when young, brownish-yellow when old, hollow, the walls 3–5 mm thick, the lacuna occupying < 50% of the total diameter. Culm leaves 12–17 cm long, non-overlapping, deciduous; sheaths 10–12 cm long, 3.5–5 cm wide at the base, the blades 1.8–4.5 cm long, triangular, erect, abaxially and adaxially glabrous, the margins ciliate when young, glabrous when old; inner ligule a coriaceous rim 0.5–1 mm long, irregular, ciliate; oral setae absent; fimbriae at the apex of the sheath on both sides of the blade, 1–3 mm long, ca. 0.05 mm wide, terete, free, curly; blades 1.8–4.5 cm long, triangular, erect, persistent, shorter than the sheaths, glabrous on both sides, the margin glabrous, the apex attenuate-subulate. Branching intravaginal; one main branch per node, if two then the central branch 3–4 times wider than the lateral branch, sometimes both branches subequal and these diverging from each other and rebranching, 33–48 cm long, diverging from the main culm at 45–60°, with only one branch per node in the second and third orders of branching; supranodal ridge pronounced; nodal line horizontal. Foliage leaves 3–5(–7) per complement; sheaths glabrous, rounded on the back; oral setae absent; fimbriate at shoulderlike sheath summit, the fimbriae 1–2 mm long, ca. 0.05 mm in diameter, terete, free, curly; outer ligule an irregular glabrous rim up to 0.1 mm long; inner ligule 0.3–0.5 mm long, truncate, ciliate; pseudopetioles ca. 1 mm long, brownish, pulvinate at the base; blades (6.5–)8–11(–12.5) cm long, 0.4–0.8(–1.2) cm wide, linear to linear-lanceolate, green adaxially and glabrous abaxially, with a patch of white cilia at the base extending along one side of the midrib for 2–3 mm, the base attenuate, the apex attenuate-subulate, the margins weakly serrulate. Synflorescences 5–9.5 cm long, paniculate, of 6–25 spikelets, the rachis rounded, glabrous; pedicels 2–25 mm long, angular, scabrous. Spikelets 2.5–3 cm long, green, with 3–4 florets, sometimes the upper floret sterile, the basal floret persistent and the two or three florets deciduous; rachilla joints 5–7.5 mm long, pubescent, densely pubescent at the apex of each joint; glumes narrowly triangular and navicular, abaxially slightly scabrous; glume I 4–8.2 mm long including the awn, 3–5-nerved, the awn 1–3 mm long; glume II 5.5–8.5 mm long including the awn, 4–7-nerved, the awn 1–3 mm long; lemmas 10–14.5 mm long including the awn, narrowly triangular and navicular, abaxially scabrous, 7–9-nerved, the awn 1–4 mm long, antrorsely scabrous; paleas 8–11 mm long, the keels glabrous, the sulcus pubescent, the wing glabrous, the apex bifid with antrorsely scabrous teeth. Lodicules 3, abaxially pubescent, brownish to the base with the anterior pair 1–1.3 mm long, the posterior one 1–1.2 mm long; anthers 5–6 mm long; ovary 1.2–1.8 mm long, green, glabrous. Caryopsis 7.8–8.2 mm long, sublinear, tapering to a narrow beak, brown to amber.

Specimens Examined:—MEXICO. Querétaro: on the El Apartadero road to San Juan Tetla, 6 Km from El Apartadero to San Juan Tetla and approx. 500 m before arriving at San Juan Tetla, San Joaquín Municipality ,tropical deciduous forest, calcareous soils, 20°58'40.8" N, 99°29'47" W, 1250 m, 18 August 2012, *E. Ruiz-Sanchez, L. Pérez & A. Núñez* 407a, 407b, 407c, 408, 409, 410, 411, 412 (IEB!).

Comparison:—On the basis of vegetative morphology *Otatea ramirezii* is similar to *O. acuminata*, *O. carrilloi* and *O. glauca*, but based on flowering characters *O. ramirezii* is more similar to *O. acuminata* and *O. fimbriata*. Synflorescence size in *O. fimbriata* is 10–15 cm long with 30–33 spikelets, whereas in *O. acuminata* the synflorescence size ranges between 6.5–10 cm long with 6–15 spikelets, while the synflorescence length in *O. ramirezii* is 5–9.5 cm with 6–25 spikelets. The average lengths of glumes, lemmas and paleas are very similar in *O. acuminata* and *O. ramirezii*; the differences are the following: *O. acuminata* has the lemma and palea keels pubescent and the lodicules glabrous with ciliate margins, whereas *O. ramirezii* has the lemma keels scabrous, the palea keels glabrous and pubescent lodicules.

Discussion

The purposes of botanical gardens include increasing public awareness and promoting research and the conservation of plant diversity (Wyse Jackson 1999; Pautasso and Parmentier 2007). Today there are more than 3,000 botanical gardens in 156 countries, with over 6 million accessions of living plants, and

approximately 80,000 taxa in cultivation (Pautasso and Parmentier 2007; Dosmann and Groover 2012). One such garden is the Francisco Javier Clavijero Botanical Garden at the INECOL in Xalapa, Veracruz, Mexico, which is home to two living national collections: the national cycad collection and the Mexican national living bamboo collection. Living collections are curated for various purposes including scientific education and research (Dosmann and Groover 2012). Living collections include germplasm repositories that preserve plant genetic resources for research and conservation. There are also experimental research plots, seed banks, conservatories, and germplasm repositories for research carried out by universities and research institutions (Dosmann and Groover 2012).

Living collections are important for understanding how plants respond to global climate change because they are particularly valuable sources of long-term data (Primack and Miller-Rushing 2009). Researchers at botanical gardens can address the question of how long-lived individual plants respond to climate change and other environmental stimuli over their lifetimes in terms of physiology, growth, anatomy and phenology (Primack and Miller-Rushing 2009).

It is challenging to study phenology in woody bamboos because their flowering cycles last between 3 and 120 years (Janzen 1976). Several hypotheses have been invoked to explain this: the predator satiation hypothesis (Janzen 1976); the resource allocation hypothesis (Gadgil and Bossert 1970; Schaffer 1974); the habitat modification hypothesis (Stearns 1980); and the bamboo fire cycle (Keeley and Bond 1999). Franklin (2004) described four spatio-temporal patterns of flowering, in addition to gregarious monocarpy, that have been detected among semelparous bamboos:

1. A small percentage of clumps flower the year (or two) before and after the main flowering event, and this is called "flowering distribution" by Janzen (1976);
2. Gregarious flowering occurs in patches in successive years, referred to as a "flowering wave" by Troup (1921);
3. Variation in periodicity between populations leads to diffuse temporality within a species;
4. "Sporadic flowering" may imply random or other non-gregarious patterns of flowering (Franklin 2004).

In *Otatea acuminata* the first and third patterns have been observed (Ruiz-Sanchez et al. 2011). For *O. fimbriata* the second pattern has been observed in Chiapas (personal observation), and a specimen collected there in 2005 was planted in the living national bamboo collection. In 2008 the cultivated plant flowered and flowering was verified the same year in the field. For *O. ramirezii,* I observed a few clumps in the living collection that had flowered in 2011, because we saw dead or dying clumps and a few new seedlings in the soil, directly beneath the potential mother. Then, in the summer of 2012, I saw the entire wild population flowering gregariously. These field observations agree with the pattern of Janzen's (1976) "flowering distribution". For *O. glauca* we observed the fourth pattern of "sporadic flowering". We collected only a single plant with flowers in 2005 in Chiapas and the rest of the clumps were sterile. On subsequent visits to the population we did not observe any other clump flowering.

Without the living national bamboo collection, it would have been difficult to observe the flowering of *Otatea ramirezii*; the flowering of *O. ramirezii* in the living collection allowed us to confirm flowering in the wild population. To date, there are still two *Otatea* species for which the flowers have not been described: *O. carrilloi* and *O. transvolcanica*. The latter is under cultivation in the collection and hopefully will be observed flowering in the years to come. We will then have the opportunity to confirm its flowering in the field. Another advantage of having the living national bamboo collection is that over time, we can determine the flowering cycles of *O. ramirezii* and other species living in the collection for which flowering cycle records are not currently available.

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