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New record and distribution map of *Parmotrema rubifaciens* (Parmeliaceae, Ascomycota) in the Neotropics

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Abstract: *Parmotrema rubifaciens* is recorded in this paper for the first time for Paraguay, expanding its known geographic distribution approximately 430 km southeast from its nearest locality. The species is characterized, illustrated, and compared with most related taxa. In addition, a map of its geographic distribution in the Neotropics is presented.

Key words: Paraguay, Agua Dulce, norstictic acid, dry forests, *Parmotrema cristiferum*, *P. dilatatum*, *P. gardneri*

Lichen biota of Paraguay has been poorly studied in South America. The first revision of lichens from Paraguay was undertaken in the late nineteenth century by Müller (1888), who identified 248 species of which 73 were described as new to science. Subsequently, in the early twentieth century, Malme (1897, 1924, 1925, 1926, 1927, 1928, 1929, 1934a-b-c-d, 1936, 1937) documented species of several groups of lichens increasing the knowledge available until then.

Thirty species of *Parmotrema* A. Massal. are currently known from Paraguay, a relatively low number considering it is one of the larger genera within Parmeliaceae, comprising ca. 350 species with center of distribution in the tropical regions of the world (Blanco et al. 2005; Crespo et al. 2010). Müller (1888) recorded the first 4 species of this genus of foliose lichens from Paraguay, followed by Lynge (1914), who added 4 species. Most *Parmotrema* reports were recorded between 1959 and 1976, as part of several monographic revisions made by Hale (Hale 1959, 1960, 1965, 1974b, 1976; Hale and Kurokawa 1964). Ferraro (1990) listed 15 species of *Parmotrema* among other genera of Parmeliaceae in an article about the collections of A. Schinini and E. Bordas from Paraguay. Other authors that contributed to the knowledge of this genus in Paraguay are Osorio (1970), Egan et al. (2005), and Michlig and Ferraro (2012). Below, we present a new record of *Parmotrema rubifaciens* (Hale) Hale found in Paraguay during a revision of the material from the CTES herbarium.

Studied material was collected by A. Schinini (collection number 19661; CTES) in the Agua Dulce locality, towards the northwestern region of the country, in a xerophytic forest, on *Ruprechtia* sp. (Table 1, Figures 1–5). Morphological analysis was carried out based on observations of macroscopic and microscopic characters using stereoscopic and light microscopes (Leica MZ6 and Leica CME, respectively). Pycnidia were sectioned by hand with a razor blade and then mounted in 5% KOH and 1% phloxine for examination. The identification of lichen substances was made with spot tests with 10% KOH (K), sodium hypochlorite (C), and K followed by C (KC), UV fluorescence, and thin layer chromatography (TLC) with solvent C, by comparison with authentic samples (Orange et al. 2010; White and James 1985).

Parmotrema rubifaciens was originally erected as a member of *Parmelia* Ach., subgenus *Amphigymnia* (Vain.) C. W. Dodge, section *Amphigymnia* Vain. (Hale 1965), which was later transferred to the genus *Parmotrema* by Hale (1974a). It is distinguished from other species of the genus by the combination of the following characters: eciliate lobe margins, marginal to submarginal soralia, and medullary norstictic acid (K+ yellow turning orange with rusty-red needle-like crystals visible under the microscope).

The lobes are irregularly branched, partially imbricate, plane in distal parts, turning sinuate and ascendant towards the center of the thallus, 4–10 mm wide. The upper surface is smooth to rugose towards the center, sublustrose, irregularly cracked and emaculate, with flaking cortex in some areas. The medulla is mostly white with an orange pigment in some small areas towards the lower surface, or even occasionally in soralia. The lower surface is black with a black to brown, broad and naked margin (Figure 2), with scarce, simple to sometimes irregular black rhizines, which are distributed in groups. The soralia are marginal to submarginal, linear,

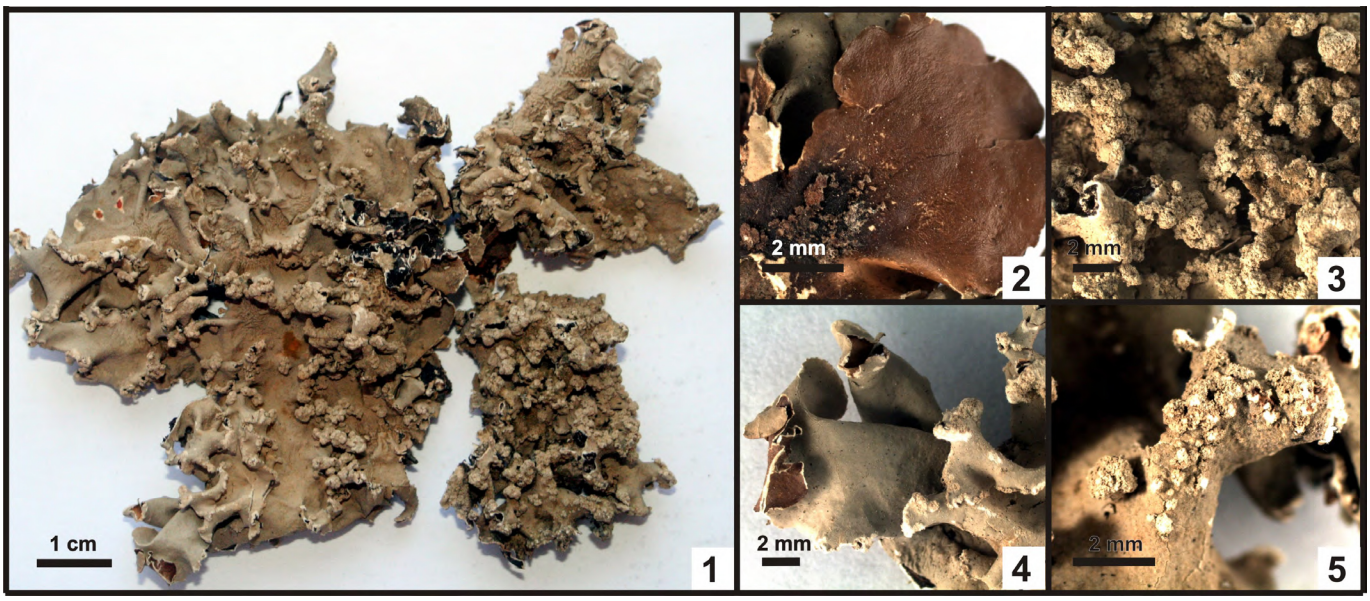
Table 1. Known records of *Parmotrema rubifaciens*. Herbaria acronyms are according to Thiers (2014).

Country	Department/ province/ state	Locality	Date	Geographic coordinates; elevation	Voucher	Reference
Bolivia	Santa Cruz department, Ibañez province	Jardín Botánico, dry forest, over bark	30 September 1997	17°43′ S, 063°03′ W; 380 m	*K. Bach 595* (B, LPB)	Kukwa et al. (2012)
Brazil	Minas Gerais state	n/d	n/d	n/d	*Burchell 1105* (K)	Hale (1965)
	São Paulo state	Mongaguá, near the water treatment station SABESP, on the way to Bichoró river, low restinga forest on river margins	15 December 2003	n/d	*M. N. Benatti and M. P. Marcelli 1654A* (SP)	Marcelli and Benatti (2010)
Colombia	Amazonas department	n/d	n/d	n/d; 240 m	*H. Sipman and J. Duivenvoorden 28174* (ARA, B)	Sipman et al. (2008)
Costa Rica	n/d	n/d	n/d	n/d	n/d	Umaña-Tenorio et al. (2002)
Guatemala	Petén department	La Libertad	n/d	n/d	*Lundell 2237* (MICH)	Hale (1965)
	Zacapa department	Gualán	3 January 1906	n/d	*Kellerman n/n* (OS, US)	Hale (1965)
Mexico	Veracruz state	24 km northwest of San Andrés Tuxtla	n/d	n/d	*Hale 19777* (US)	Hale (1965)
	Yucatán state	Tekax	n/d	n/d	*Gaumer 1210d* (F)	Hale (1965)
Nicaragua	Managua department	Vicinity of Casa Colorado, near El Crucero, summit of Sierra Managua	14–25 May 1947	n/d; 800–900m	*P. C. Standley 8409* (F, US)	Hale (1965)
Paraguay	Alto Paraguay department	Agua Dulce, in xerophytic forest, on *Ruprechtia* sp.	5 October 1979	20°14′ S, 060°07′ W; n/d	*A. Schinini 19661* (CTES)	This work
United States	Florida state	n/d	n/d	n/d	n/d	Harris (1995)

usually thick, turning lobes very sinuous towards the center of the thallus (Figures 1, 3 and 4), with farinose to granular soredia. In some areas it may also develop laminal orbicular to capitate soralia, which are solitary or confluent (Figure 5). Apothecia are absent in the studied material, and although pycnidia were observed (not reported before for the species), they were empty. This species produces cortical atranorin, and medullary norstictic (major) and connorstictic acids (trace). Although the presence of connorstictic acid was not detected in its original description (Hale 1965), it was confirmed by Marcelli and Benatti (2010). Kukwa et al. (2012) also reported lecanoric acid in Bolivian material. There is not much information available about its ecology in literature. It is probably an exclusively corticolous species, as seen in this collection and reported also by previous authors (Kukwa et al. 2012; Marcelli and Benatti 2010).

Parmotrema rubifaciens is the only sorediate species of the genus with norstictic acid known so far from Paraguay. *Parmotrema perforatum* (Jacq.) A. Massal. has medullary norstictic acid, but lacks vegetative propagules (Hale 1965; Müller 1888). The species resembles *Parmotrema cristiferum* (Taylor) Hale, a cosmopolitan species widely distributed in tropical and subtropical regions, cited also from Paraguay (Ferraro 1990), which shows a similar configuration of soralia but differs in its medullary chemistry by producing salazinic acid (K+ yellow turning red, without rusty-red needle-like crystals visible under the microscope). Some authors also mentioned the presence of scarce cilia in a few specimens of *P. cristiferum*, structures not observed in the studied material (Elix 1994; Marcelli and Benatti 2010). Other morphologically related species are *Parmotrema dilatatum* (Vain.) Hale and *Parmotrema gardneri* (C.W. Dodge) Sérus. recorded also from Paraguay (Ferraro 1990; Michlig and Ferraro 2012). In both species, the soralia are narrower and clearly differ from *P. rubifaciens* in their medullary chemistry, as they produce protocetraric acid, associated also with echinocarpic acid in *P. dilatatum*.

Parmotrema rubifaciens is an exclusively American species known only from scattered records in the Neotropical region (Figure 6). It was initially described from Nicaragua by Hale (1965), who also studied additional material from Guatemala, Mexico, and Brazil. Since then, there have been neither new records nor new information available of this species for over three decades, when it was recorded by Harris (1995) from United States. More recently, the species was recorded from Costa Rica (Umaña Tenorio et al. 2002), southern Colombia (Sipman et al. 2008), southeastern Brazil (Marcelli and Benatti 2010), and Bolivia (Kukwa et al. 2012). Its geographic distribution is here expanded to northwestern Paraguay.



Figures 1–5. *Parmotrema rubifaciens* (Hale) Hale. **1:** Complete thallus. **2:** Erhizinate margin in the lower surface. **3:** Soralia at the center of the thallus. **4:** Marginal soralia toward the periphery of the thallus. **5:** Laminal soralia.

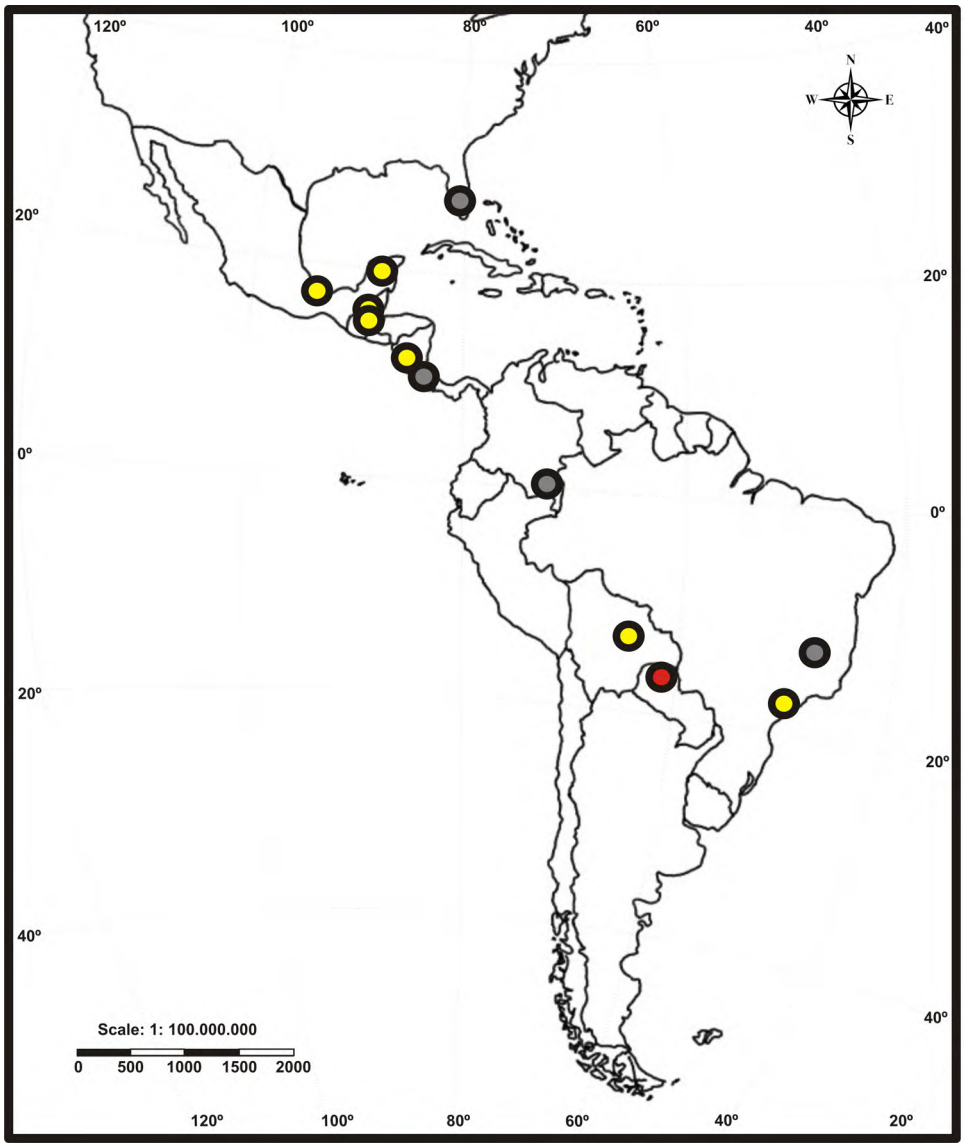


Figure 6. Geographical distribution of *Parmotrema rubifaciens* in the Neotropics based on revised material and literature (Table 1). The red dot corresponds to the new record and gray dots indicate collections with uncertain localities.

The geographic distribution of *P. rubifaciens* is shown in Figure 6, based on studied material and records available in the literature (Table 1). According to this information, its distribution pattern seems to be approximately coincident with tropical and subtropical dry forests (TDFs hereafter) in America (Miles et al. 2006; Portillo-Quintero and Sánchez-Azofeifa 2010). In South America, where TDFs are particularly well represented (Miles et al. 2006), its distribution is mostly overlapped with the Pleistocenic Arc of the Tropical Seasonal Forests Region, which was defined by the distribution of many woody species of deciduous and semideciduous forests (Prado 2000; Oakley and Prado 2011).

Although the exact sites where some of these collections were found are unknown (Hale 1965; Harris 1995; Umaña et al. 2002; Sipman et al. 2008), considering the distribution of TDFs in America it is probable that most of them have been collected in environments with those ecological conditions. The material reported by Hale (1965) from Brazil was found in Minas Gerais state, which has extensive areas covered by TDFs, that mostly belong to the Cerrado biome (Oliveira-Filho and Ratter 2002), and the much drier Caatinga, which is restricted to the northern region of the state (Queiroz 2009). The collection cited by Harris (1995) from Florida in United Sates could have been collected towards the southernmost region of the state, where TDFs are confined (Gillespie et al. 2006; Pennington et al. 2006), while the record from Costa Rica might have been found towards the northwestern region of the country, where TDFs are located (Gillespie et al. 2000). Nevertheless, the collection reported by Sipman et al. (2008) from southern Colombia appears to be excluded from TDFs' range extension, since this type of vegetation is situated between the interandean valleys of Magdalena and Cauca rivers and in Caribbean plain regions, towards the northwestern region of the country (Ruiz Linares and Fandiño Orozco 2009).

The distribution of TDFs in South America was recently considered as a possible explanation for the geographic patterns of other fungal species, which were also scarcely collected (Romero et al. 2012; Robledo et al. 2014). Even though the distribution of epiphytic lichens is not always correlated with that of the plants (Will-Wolf et al. 2004), it would be interesting to analyze other distribution patterns to establish which species might have similar ecological preferences, and to detect possible endemisms. This might constitute an important contribution, as these forests are currently considered one of the ecorregions prioritized for conservation (Olson and Dinerstein 2002), since they harbor a high biodiversity, including an appreciable level of genera and species endemism (Prado 2000; Portillo-Quintero and Sánchez-Azofeifa 2010).

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