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NOTA CORTA

New register of ferns in soils in contact with hot springs from an active volcano in the Ecuadorian Andes

Nuevo registro de helechos en suelos en contacto con aguas termales de un volcán activo en los andes ecuatorianos

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ABSTRACT

We registered the occurrence of three fern species (*Pityrogramma ebenea* (L.) Proctor, *Christella dentata* (Forssk.) Brownsey & Jermy. y *Blechnum occidentale* L.) in an exposed soil bank in contact with waters from hot springs from active volcanoes in Ecuadorian Andes. Our observation contributes to fill a gap of information of ferns growing in extreme environmental conditions.

Keywords: Antisana, Napo, Papallacta, Pteridophytes, Thermal waters.

RESUMEN

Registramos la ocurrencia de tres especies de helechos (*Pityrogramma ebenea* (L.) Proctor, *Christella dentata* (Forssk.) Brownsey & Jermy. y *Blechnum occidentale* L.) en un banco de suelo expuesto en contacto con aguas de fuentes termales de un volcán activo en los Andes ecuatorianos. Nuestra observación contribuye a llenar un vacío de información sobre los helechos que crecen en condiciones ambientales extremas.

Palabras clave: Aguas termales, Antisana, Napo, Papallacta, Pteridófitas.

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Thermal waters from active volcanoes can be found in the Eastern side of the Andes mountain range in Ecuador, specifically in the Papallacta Cordillera. These waters derived from the Chacana system of volcanoes (Hall *et al.* 2017), may reach temperatures of 63°C (Cumbal *et al.* 2009, Cangahuamin Rojas and Félix 2021) and spring at an altitude of ca. 3250 m a.s.l. At this elevation, ferns (pteridophytes and lycophytes) are a quite abundant group (Salazar *et al.* 2015, Riaño and Moulatlet 2022), as optimal conditions of moist and temperature led to the irradiation of especially epiphyte ferns (Barrington 1993).

On a 20 m long discharge channel of thermal waters that feed man-made thermal pools (0°21'S, and 78°8'W, 3300 m a.s.l.), we observed sporophytes and gametophytes of three fern species: *Pityrogramma ebenea* (L.) Proctor, *Christella dentata* (Forssk.) Brownsey & Jermy. and *Blechnum occidentale* L. (Fig. 1). The observation was made on the 16th of December of 2018. Water temperature on the moment of the observation was between 36°C and 38°C. All three species were growing altogether on the channel bank at about 30 cm above the water flow. The channel was shaded by mid-size tree species. The soil in the exposed bank was moist due to possible fluctuation of the water level or due to the moist condensation from the water vapor. The water level in the channel seem to vary given the marks in the bank (Fig. 1a), although at the moment of the observation the level was below the level where the species were growing. Gametophytes were found on the soil layer about 10 cm above the water flow (Fig. 1e), while sporophytes of the three species were located few centimetres above the water discharge. No fertile leaves of any of the species were found; fronds of more than 30 cm were seen in individuals of *P. ebenea* and *C. dentata*.

Pityrogramma ebenea has been reported to grow in elevations above 2000 m a.s.l before (Murillo and Murillo 1999, Arreguín–Sánchez *et al.* 2009). It is an abundant species in intervened areas characterized as a disturbance colonizer and invader (Watkins *et al.* 2007). *P. ebenea* tolerance to harsh environments may be related to its abundant waxy on the abaxial side of the leaves, which offers protection to the leaves and young shoots and to its rhizome that resist to high temperatures. For the sister species *P. calomelanos*, these adaptations have been important for the occurrence in sulphuric substrates (Spicer *et al.* 1985). The morphological and physiological features indeed permit its colonization on extreme conditions. For instance, in the Mexican central valley, *P. ebenea* is a first-stage successional colonizer. In La Selva Biological Station in Costa Rica, this species grows on roadsides exposed to high UV radiation and high temperatures (Watkins *et al.* 2007). We haven't found references for possible mechanism to explain the higher colonization success of *C. dentata* and *B. occidentale*. However, these are widespread genera in tropical Americas (Kramer *et al.* 1990, Smith 1990, Dittrich *et al.* 2015), with species that are known as colonizers of disturbed areas (Murakami *et al.* 2007, Saldaña *et al.* 2010, Jones *et al.* 2019).

Soils near thermal waters are often moist (a pre-condition for spore germination), but the temperatures can be quite variable depending on whether there is direct contact with water. In the study area, spores may germinate in temperatures lower than 30°C when the level of the thermal waters in the channel are below the species occurrence line on the soil bank. If temperatures are below ~30°C, gametophytes developed as well (Juárez-Orozco *et al.* 2013, Suo *et al.* 2015, Krieg and Chambers 2022). Later, the sporophytes, the most resistant stage in fern development, may resist to higher temperatures occasionally caused by the contact with the water level or water vapour.

Ferns tolerate diverse environmental conditions, being one of the most widespread and successful plant groups in colonizing all types of environments, except the glacial zones (Kessler 2010). Fern's success has also been associated with its sexual reproductive characteristics: fern spores are wind-dispersed and do not present evident dispersal limitation (Tuomisto *et al.* 2003). Spore germination and gametophyte production only occur if the microenvironment is appropriate (Flinn 2007, Juárez-Orozco *et al.* 2013), so ferns depend on moist conditions for the fecundation of its gametes in gametophytes. The water-dependency result in colonization limitations, as harsh environmental conditions may hamper the establishment of the gametophytes and the development of the sporophyte phase. However, ferns possess a series of adaptation that allow the occurrence on extreme environments (Hietz 2010), with some lineages perceived to have proliferated during relatively extreme environmental conditions (Vajda and Bercovici 2014) Areas of thermal waters represent a potentially harsh environment for gametophyte establishment and development. Nevertheless, ferns are reported to grow in these areas (Abuhani *et al.* 2015, Wasowicz *et al.* 2017), but such observations are largely undocumented in the scientific literature.

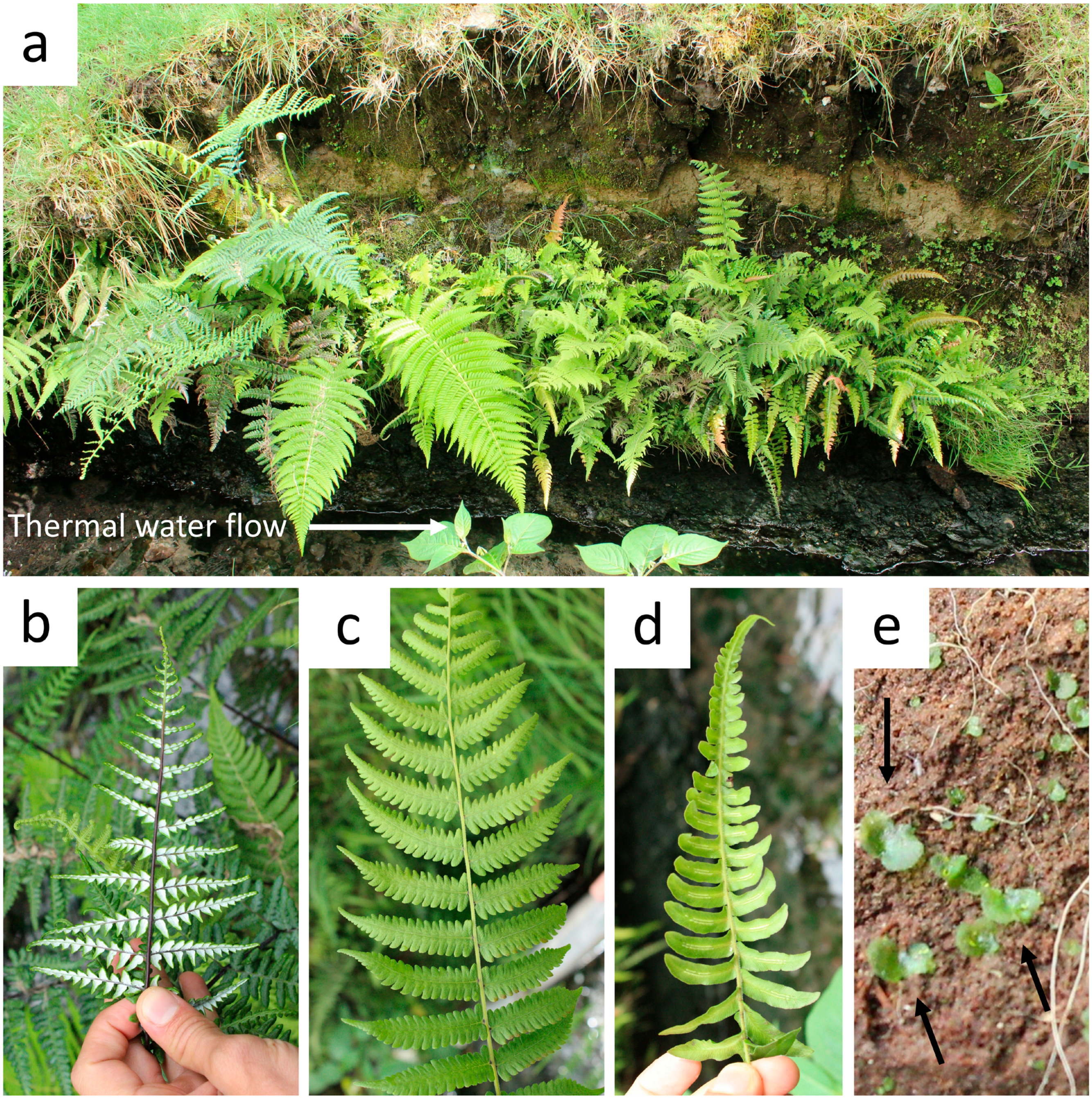

Figure 1. a) Fern colonization in the bank of a human-made channel where thermal waters flow (as indicated by the white arrow). b) Abaxial surface of *Pityrogramma ebenea*, c) Adaxial surface of *Christella dentata*., d) Abaxial surface of *Blechnum occidentale*, e) Dark arrows indicate gametophytes found in the site.

Morphological, anatomical, and physiological adaptations could explain the thermal tolerance of these species. Tropical plant communities presumably live close to their climatic optimum (at temperatures below ~27.5°C, with maximum around 31° to 34°C, (Jaramillo *et al.* 2010), so environments with temperatures above than that may allow the establishment of few species that tolerate such conditions and are good dispersers. Elevated air temperatures influence the photosynthetic rate of C3 plants, which stop fixing carbon and start a process known as photorespiration, where they consume O_2 and release CO_2, so in humid environments and with air temperatures above 30°C, C4 species are more commonly found (Ehleringer and Monson 1993). Most ferns present C3 metabolism, with some exceptions from xeric environments that are CAM. Whether the metabolism type facilitates for the occurrence near to thermal waters still remain to be investigated. In any case, our observations show that fern species can germinate and persist therein, but further investigations should be done to understand the mechanisms of tolerance of fern germination and establishment under extreme environmental conditions, on the edge of their thermal limits.

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