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Short communication

Tank bromeliads capture Saharan dust in El Yunque National Forest, Puerto Rico

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ABSTRACT

Dust from Saharan Africa commonly blows across the Atlantic Ocean and into the Caribbean. Most methods for measuring this dust either are expensive if collected directly from the atmosphere, or depend on very small concentrations that may be chemically altered if collected from soil. Tank bromeliads in the dwarf forest of El Yunque National Forest, Puerto Rico, have a structure of overlapping leaves used to capture rainwater and other atmospheric inputs. Therefore, it is likely that these bromeliads are collecting in their tanks Saharan dust along with local inputs. Here we analyze the elemental chemistry, including rare earth elements (REEs), of tank contents in order to match their chemical fingerprint to a provenance of the Earth's crust. We find that the tank contents differ from the local soils and bedrock and are more similar to published values of Saharan dust. Our study confirms the feasibility of using bromeliad tanks to trace Saharan dust in the Caribbean.

1. Introduction

Approximately 800 billion kilograms of dust each year is created in the Sahara and Sahel deserts of northwest Africa; a significant proportion of this dust is wind-transported across the Atlantic Ocean and into the Caribbean (Prospero et al., 1970; Huneeus et al., 2011; Prospero and Mayol-Bracero, 2013). Traces of this dust have been identified throughout the Caribbean region, including Puerto Rico (e.g., Reid et al., 2003; McClintock et al., 2015). This allochthonous input is likely critical for Caribbean ecosystems, especially with regards to limiting nutrients like phosphorus (Pett-Ridge, 2009), and has the potential to carry viable fungi and bacteria (Prospero et al., 2005).

The dwarf rainforest of the Luquillo Mountains in Puerto Rico's El Yunque National Forest (Fig. 1) is characterized by almost constant cloud cover and an average of 95–100% relative humidity throughout the year, which provides an abundance of cloudwater in addition to 30–60 cm per month of rainfall (Brown et al., 1983; Weaver, 1995; Daly et al., 2003; Murphy et al., 2017). The high humidity creates an environment that is excessively saturated, and soils are usually anoxic or suboxic (Weaver, 1995; Mount and Lynn, 2004).

Owing to the rain and cloudwater, the dwarf forest contains many epiphytes—plants that grow on other plants without bearing their roots in soil. The average epiphyte load on trees here is 555 g/m^2 (Weaver, 1972), with even higher loads on windward slopes (> 700 g/m^2; Brown et al., 1983). Tank bromeliads are epiphytes in the family Bromeliaceae that are characterized by a system of tightly overlapping leaves that forms a small "tank" in the middle of the plant's body; the most common tank bromeliad in the dwarf forest is *Vriesea sintensisii* (Baker) L.B. Sm. & Pittendr. (Fig. 2; Howard, 1968; Brown et al., 1983). The tank is used to capture rainwater, leaf litter, and other small particles or even organisms. This constitutes the plant's main source of nutrients (Nadkarni and Primack, 1989; Benzing, 2000). This hints at a possible dust contribution to epiphyte nutrition that could help these plants succeed in their harsh environment.

Two common ways to collect dust are by sampling the air directly with high-volume filtering systems mounted on towers (Prospero and Lamb, 2003; Kumar et al., 2014; Pourmand et al., 2014) or by analyzing the small traces deposited in soils (Muhs et al., 1990, 2007; Muhs and Budahn, 2009; McClintock et al., 2015). Sampling dust from the air directly can be cost prohibitive, requires time to set up equipment and wait for sufficient exposure, and doesn't fully capture the fraction deposited locally because some of the suspended dust may land elsewhere; identifying dust from soil can be difficult owing to its dilute (often < 1%; McClintock et al., 2015) and sometimes pedogenically altered nature.

Here we seek to test if we can detect Saharan dust within the tanks

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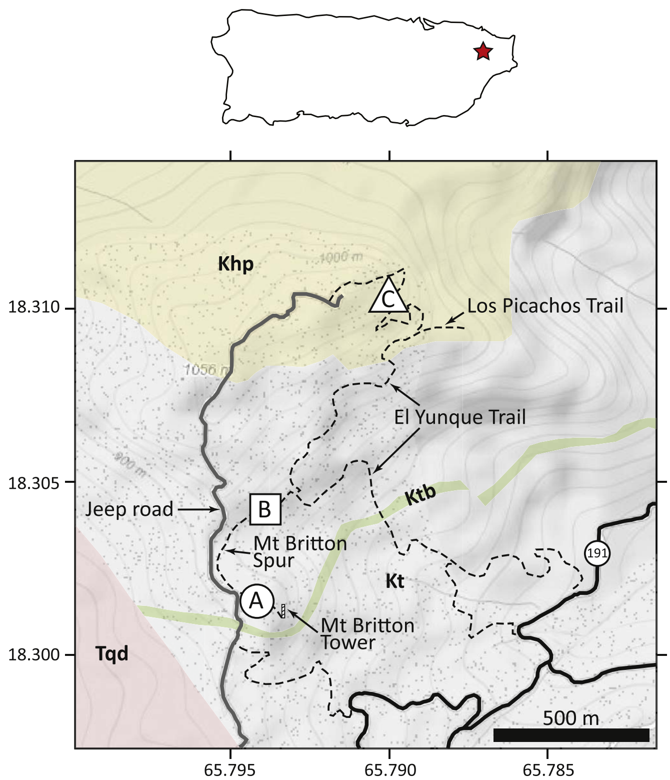

Fig. 1. Map of Puerto Rico with general field area marked with red star (top) and detailed map of field area (bottom). Field sites are marked "A", "B", and "C". Khp = Hato Puerco Formation; Kt = Tabonuco Formation (Ktb = breccia-conglomerate member); Tqd = Río Blanco stock. Geology comes from Seiders (1971); topographic base map comes from Esri's world topographic map. Tick marks show latitude (°N) and longitude (°W). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 2. Field photo showing the technique of sampling a tank of the bromeliad *Vriesea sintensisii*.

of bromeliads growing in the El Yunque dwarf forest. We use standard chemical fingerprinting techniques for detecting provenance, including the relative ratios of trace metals (e.g., Sc, Th) and rare earth elements (REEs; e.g., Eu, La, Sm, Yb) (e.g., Muhs et al., 2007). Our more general goal is to test how well tank bromeliads serve as a natural vessel for distinguishing the regional sources of atmospheric deposition. If successful, the approach could be a simpler and lower-cost alternative to existing approaches.

2. Material and methods

We sampled bromeliad tanks of *Vriesea sintensisii*, soil, and bedrock at three sites in the El Yunque dwarf forest over the course of three field campaigns (January 2009, 2015, and 2017; different tanks were sampled each year). Site A is along the trail between the junction of the Mt. Britton Spur and paved jeep road (18.302°N, 65.795°W; 900 m a.s.l.) and the Mt. Britton tower; site B is along the Mt. Britton Spur between its junction with the El Yunque Trail (18.305°N, 65.793°W; 875 m a.s.l.) and jeep road; and site C is alongside the El Yunque trail, several hundred meters north of its junction with the Los Picachos Trail (18.311°N, 65.790°W; 1000 m a.s.l.) (Fig. 1). At each site, we sampled the upper 15 cm of six soils with a plastic trowel. Soils were put in sealed plastic bags, then later dried at 50 °C and passed through a 75 µm sieve, removing most sand-sized (and coarser) particles; nearly all African dust in the Caribbean basin is finer than 75 µm (Prospero and Mayol-Bracero, 2013).

At sites B and C, we sampled rock in the form of loose rock (intact bedrock is rare in this deeply weathered landscape). The ridgelines are within a few hundred meters at both sites, and these upper hillslopes are underlain by the same bedrock as at our sites (Fig. 1); we therefore consider the sampled rock representative of the parent material for our soils. We used a rock hammer to trim weathered regions; the remaining rock was then homogenized in a shatterbox.

The bromeliad tanks usually contain a mixture of water, organic matter, and small inorganic particles. We extracted these contents with a 60 ml plastic syringe attached to ~20 cm of Tygon tubing (Fig. 2). For some tanks, we used a plastic spoon or deionized water to loosen the particles adhered to walls. All tank contents were then transferred to plastic centrifuge tubes. We combined the contents of ten tanks per tube in 2009, and five tanks per tube in 2015 and 2017. All plastic equipment was cleaned with dilute trace-metal grade HNO_3, rinsed in doubly-deionized water, and dried. Clean syringes, tubing, and spoons were used for each set of five tanks (or ten for the 2009 sampling). We sampled 35 tanks at site A and 60 tanks each at sites B and C, resulting