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New record of Kallstroemia tribuloides (Mart.) Steud. (Zygophyllaceae) in Rio de Janeiro State, Brazil, after 136 years – a bioinvasion in progress?

Alex Santos, Thiago Amorim

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New record of *Kallstroemia tribuloides* (Mart.) Steud. (Zygophyllaceae) in Rio de Janeiro State, Brazil, after 136 years – a bioinvasion in progress?

Thiago de Azevedo Amorim

Universidade Federal Rural do Rio de Janeiro, BR-465, km 7, Departamento de Botânica, Instituto de Ciências Biológicas e da Saúde, 23890-000, Seropédica, Rio de Janeiro, Brasil. http://orcid.org/0000-0001-7335-6321

Alex Braz Iacone Santos

Universidade Federal Rural do Rio de Janeiro, BR-465, km 8, Colégio Técnico, 23890-000, Seropédica, Rio de Janeiro, Brasil. https://orcid.org/0000-0002-4326-8029

ABSTRACT

The occurrence of *Kallstroemia tribuloides* (Mart.) Steud. (Zygophyllaceae) in southeastern Brazil is reported after 136 years. It has been registered in recently disturbed areas of Saquarema, Rio de Janeiro, Brazil. *K. tribuloides* is recognized as a species adapted to open and sunny environments, with a preference for sandy soils, typical conditions of drylands (e.g. Caatinga Biome) and Restingas. *K. tribuloides* has attributes that may favor its distribution into the newly colonized environment and its bioinvasive potential should not be overlooked. So, further studies are strongly recommended to monitor and control the spread of *K. tribuloides* on the Brazilian southeast coast.

Key Words: alien species, distribution expansion, ecology, rediscovery.

INTRODUCTION

The Zygophyllaceae family consists of 22 genera and about 285 species, which are distributed throughout drylands of the world with a few of them extending to neighboring regions (Sheahan 2007). In Brazilian territory the family is represented by three native genera – *Bulnesia* Gay, *Gonopterodendron* (Griseb.) A.C. Godoy-Bürki and *Kallstroemia* Scop. – and four species. *Kallstroemia* is the only genus which has two species: *Kallstroemia maxima* (L.) Hook. and *Kallstroemia tribuloides* (Mart.) Steud. However, the real identification of *K. maxima* is still dubious, since the morphology of Brazilian vouchers apparently does not fit to species

description (Soares e Silva et al. 2014). Additionally, the natural occurrence of *K. maxima* is in the western region of the United States of America (Ribeiro 2023).

K. tribuloides occurs, in the following South American countries: Argentina, Bolivia and Brazil. In Brazil, the distribution of *K. tribuloides* is thought to be restricted to Caatinga Biome. The aim of this study is to report the broadening of *K. tribuloides* distribution in Brazilian territory and the possible implications of an incipient bioinvasion process since the identification of potentially invasive alien species before their spreading over the landscape has long been a major goal (Hulme 2003).

MATERIALS AND METHODS

The *K. tribuloides* specimens here reported were found after occasional identification of the first individuals, on March 06, 2023, in an urban area recently altered by civil construction works (i.e., asphalting and paving), at Boqueirão, Saquarema, Rio de Janeiro State, Brazil (-22.926911°, -42.547805°; Table I).

Table I - Sample sites of *Kallstroemia tribuloides* (Mart.) Steud. in Saquarema, RJ, Brazil.

City/State	Locality	Latitude	Longitude
Urban area			
Saquarema/Rio de Janeiro	Boqueirão	-22.929073°	-42.536613°
Saquarema/Rio de Janeiro	Boqueirão	-22.928439°	-42.535652°
Saquarema/Rio de Janeiro	Boqueirão	-22.926911°	-42.547805°
Saquarema/Rio de Janeiro	Boqueirão	-22.931944°	-42.520515°
Saquarema/Rio de Janeiro	Barra Nova	-22.927198°	-42.551917°
Saquarema/Rio de Janeiro	Boqueirão	-22.927263°	-42.542119°
Saquarema/Rio de Janeiro	Boqueirão	-22.925497°	-42.536403°
Natural area			
Saquarema/Rio de Janeiro	Boqueirão	-22.932367°	-42.537300°
Saquarema/Rio de Janeiro	Boqueirão	-22.932510°	-42.526058°

Saquarema City is situated in the central coast of Rio de Janeiro State. Local vegetation is a mosaic of a very fragmented and disturbed remnants of Atlantic Rain Forest and Sandy Coastal Vegetation (Sá & Araujo 2009) - named Restinga (Araujo 1992). The regional climate is classified as BSh, a variation of the Köppen-Geiger hot semi-arid climate, and factors such as the topography and the coastal upwelling of Cabo Frio lead to a decrease in the rainfall in

this zone (Bohrer 2009). Annual rainfall is about 800 mm (Ribeiro & Lima 2009), mainly concentrated from October to March (Alvares et al. 2013).

Samples were stored in the Herbarium RBR (Department of Botany, Federal Rural University of Rio de Janeiro) under the voucher numbers RBR58256, RBR58257 and RBR58258. We proceeded the identification using specific bibliography (Soares e Silva et al. 2014).

After identification we carried out a survey at online Herbaria databases: Virtual Herbarium of Plants and Fungi (*species*Link network 2023) and Rio de Janeiro Botanical Garden Virtual Herbarium (Jabot RB 2023). They are the most comprehensive virtual database of herbaria specimens in Brazil and have continuously been updated. In both databases we adopted a broad search using initially the family name (Zygophyllaceae).

Subsequently, we proceeded with some steps to provide a data cleaning. First, the spreadsheets downloaded from the websites were merged. We preserved the fields related to Herbarium which provided the data, taxonomic information, sampling location, geographic coordinates, collectors, and collection date. The second step was to filter the spreadsheet by country, keeping only the Brazilian records. After that, we checked and standardized all the scientific names. The Flora e Funga do Brasil website (Flora e Funga do Brasil 2023) and the World Flora Online website (WFO 2023) were used to compare scientific names. The next step was to filter the dataset according to the species name: "*Kallstroemia tribuloides*". Then we examined whether a given voucher had the geographic coordinates. We inferred the geographic coordinates based on the localities names when this information was not originally provided.

We made a distribution map of the species based on our field collections and information from the virtual herbaria to represent the current distribution of *K. tribuloides* in the Brazilian territory. Data preparation were carried out in R programming language (R Core Team 2022) using the following packages for each step: data cleaning – tidyverse (Wickham et al. 2019); inferring geographic coordinates from localities – tmaptools (Tennekes 2021); map making – geobr (Pereira & Gonçalves 2023), ggspatial (Dunnington 2022) and tmaptools (Tennekes 2021).

RESULTS

Kallstroemia tribuloides description

Prostrate herb with radial growth (Figure 1a). Branches with a dichotomous pattern of branching and a slight dilatation at the nodes. Leaves compound and opposite, paripinnate normally with 3 to 6 pairs of elliptical to lanceolate leaflets. Isolated, pedunculated, yellowish to orange flowers with five free sepals and five free petals (Figure 1b). Androecium with ten free stamens. Gynoecium with superior ovary with 10 locules. Tuberculated schizocarp fruit (Soares e Silva et al. 2014). Diaspore dispersal is probably epizoochoric. Flower anthesis is diurnal.

Figure 1 - Individuals of *Kallstroemia tribuloides* (Mart.) Steud. found in Saquarema City, Rio de Janeiro State. A: a view of the plant in an urban environment. B: a close-up view of the opened flower. C: a view of the plant in the restinga vegetation. D: a close-up view of the plant in restinga vegetation.

Kallstroemia tribuloides distribution

We found 239 records of *K. tribuloides* based on our virtual herbaria survey. From 239 records, 204 originally had the geographic coordinates. The 35 remaining records were based on inferred coordinates obtained from the localities names. The records were mainly located in Caatinga Biome, Northeast Brazil. We found one record of the species in Espírito Santo State, Southeast Brazil. Besides our personal report, surprisingly we found a very old record of *K. tribuloides* in Rio de Janeiro, made in the XIX century (1877). Furthermore, we found two records in Fernando de Noronha Archipelago, located on the Northeastern Brazilian Coast (Figure 2). Besides the specimens sampled and stored at Herbarium RBR, we also detected individuals of *K. tribuloides* growing on the native vegetation (Restinga) nearby the beach (Figure 1c-d).

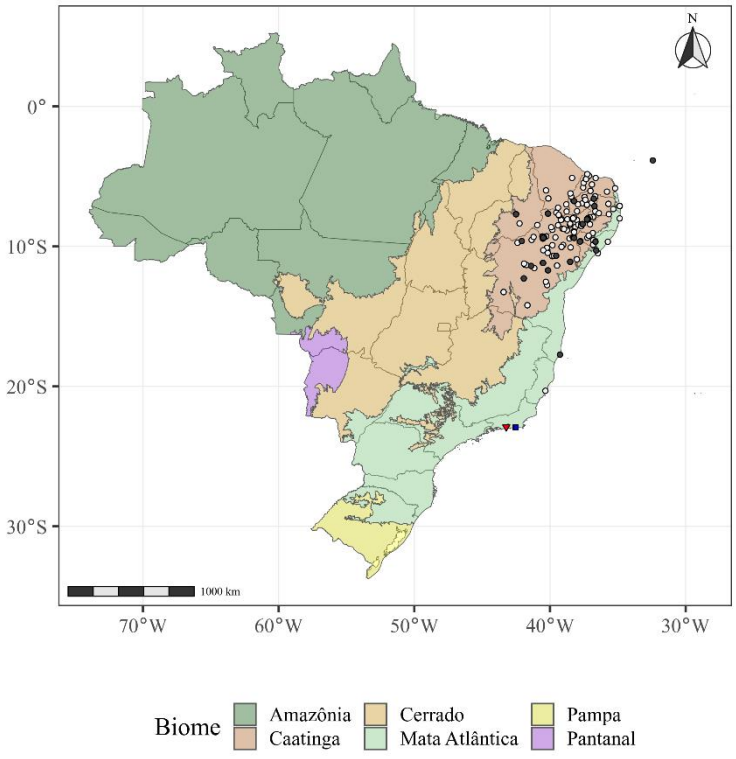

Figure 2 - Distribution map of *Kallstroemia tribuloides* (Mart.) Steud. across the Brazilian territory. Brazilian Biomes are highlighted. Gray circles are records with original information of geographic coordinates in the vouchers. Black circles are records in which the geographic coordinates were inferred using localities' names. Blue squares are the field collections made by the authors. Red triangle is the first report of this species in Rio de Janeiro State in the XIX century (1877). The black circle located “in the ocean” is the report of the species in Fernando de Noronha Archipelago.

DISCUSSION

Nearly all *K. tribuloides* specimens found in Brazil are distributed in Caatinga Biome. There are only two records outside the Northeast region: one in Espírito Santo State (collected in 1972) and another in Rio de Janeiro State (collected in 1877). This finding has some interesting historical issues. The record was made in the São Cristóvão neighborhood, which was home to the Brazilian Royal Family, the "São Cristóvão" Palace (Ferreira & Martins 2000). Hence, this location was a site of intense commuting of people from many places of Brazilian territory (Ferreira & Martins 2000, Mafertan 2016). However, to our knowledge we do not know if the species was brought intentionally. Notwithstanding, the record was made by an import botanist, Auguste François Marie Glaziou. Glaziou was in charge of the landscaping renovations around the Palace during the 1860s and 1870s (Mafertan 2016). The exsiccata is stored in Paris National History Museum Herbarium under the voucher number P03192077 (Vascular Plants (P) 2023). As our find is a century-old rediscovery, the species' arrival in Rio de Janeiro was probably not a unique event in Rio de Janeiro State, given this 136 years gap of report might not keep diaspores viables.

K. tribuloides is recognized as a weedy plant of Brazilian semiarid regions, occurring in annual and perennial crops, gardens, roadsides, and vacant lots (Lorenzi 2008). It is a species adapted to open and sunny environments, with a preference for sandy soils, typical conditions of drylands – in Brazil, drylands are mainly represented by Caatinga Biome (Pinheiro & Nair 2018). Drylands cover nearly 41% of Earth's land surface and face a high risk of degradation worldwide (Cherlet et al. 2018). These environments are characterized by a scarcity of water, which affects both natural and managed ecosystems, and acts as a filter for species composition. In this context, Zygophyllaceae plants have some adaptations to colonize drylands environments: morphological and anatomical traits indicate that this family can use water efficiently (Yang & Furukawa 2006, Lauterbach et al. 2016); and it is one of 19 angiosperm families that use the C_4 photosynthetic pathway (Sage 2016). This set of traits

confer advantage under the threat of extreme conditions (e.g. drought, sun, and high temperature) (Christin et al. 2011).

The coastal region of Saquarema has some environmental attributes similar to drylands, such as sandy and poor soil, low rainfall, high insolation, and water shortages, mainly in Restinga areas (Bohrer 2009, Ribeiro & Lima 2009). In nearby cities (Iguaba Grande to Cabo Frio and Búzios to Arraial do Cabo), the occurrence of a drier climate creates a peculiar environment where there is a trend of salinization and presence of xeric vegetation, also called Caatinga (Ab'Saber 1977). This "Caatinga enclave" is similar to northeastern Caatinga – that formerly had continuous distribution and is now isolated – and maintained due to regional morphoclimatic singularities (Ibraimo et al. 2004).

K. tribuloides has traits that may favor its distribution into the newly colonized environment and its bioinvasive potential should not be overlooked, particularly in Restinga areas. According to Richardson et al. (2000), non-native species are considered invasive when they sustain self-replacing and growing populations over several life cycles, reach large population densities, and widely spread far from their site of introduction. Bioinvasion frequently exert substantial impacts on native communities and ecosystem functioning (Crystal-Ornelas & Lockwood 2020, Pyšek et al. 2020). Therefore, it seems crucial and urgent to conduct further studies to monitor and control the spread of *K. tribuloides* on the Brazilian southeast coast. It is important to highlight that we have already found some individuals of *K. tribuloides* on the native restinga vegetation. It might indicate that the bioinvasion process can already be running.

Rio de Janeiro City and surrounding regions are predicted to suffer dramatic modifications on climate for the next decades, tending to harsher conditions such as temperature enhancing, decreasing of total rainfall, decreasing of rainfall distribution, and reduction of air humidity (Barata et al. 2020). Our species rediscovery after 136 years can be a sign of how these changes are already playing community and ecosystem changes, favoring species such as *K. tribuloides*, which evolved on xeric environments.

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AUTHOR CONTRIBUTIONS

Alex B. I. Santos – Study design and field data collection; Thiago A. Amorim – Study design, virtual data collection, data mining and cleaning and preparing of distribution map. Both authors contributed equally to manuscript writing.

Declaration of conflicting interests

We have no conflicts of interest to disclose.

Data availability statements

All the data set supporting the results of this study was published in the paper itself.

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