



## Extension of the *Cryptanthus* range in Northeastern Brazil with new findings in the phenotypic variation including changes in the trichome's distribution, thus enhancing the understanding of the *Cryptanthus zonatus* complex (Bromeliaceae)

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### Abstract

In this paper we describe the first occurrences of the genus *Cryptanthus* in the state of Rio Grande do Norte (RN), establishing a new northern distribution limit for the genus. Additionally, we report the finding of three forms of *C. zonatus* growing in sympatry within two different localities in Rio Grande do Norte along with the phenotypic variation in this species complex including changes in trichome's distribution. *Cryptanthus zonatus* is one of the most popular bromeliads due to its banded leaves. Nevertheless, the fact that it exists in two distinct glabrous-leaved forms is not readily accepted by all the authors. Confusion could be attributed to the fact that they were described from cultivated material without any information about provenance. Based on extensive fieldwork and observations we document here that banded leaves can become glabrescent and that green and red-maroon leaves (treated as forms) may occur on the same shoot. Our finding is important for future biogeographic works when considering Bromelioideae genera distribution in Eastern Brazil center of diversification. This leads to a better understand of species delimitation within this poorly known complex and would impact conservation strategies, given that all the species related to *C. zonatus* are under threat.

**Key words:** Atlantic forest, Bromelioideae, color morphs, endemism, earth stars, *restinga*

### Introduction

Bromeliaceae is a key element in the Neotropical landscapes, however species definition in several groups may be difficult and taxa complexes are constantly being revised (e.g., Faria *et al.* 2010, Versieux 2011). The existence of distinct color phenotypes for one species in a single population (called color morphs), is documented under natural conditions for some species (e.g., Barbará *et al.* 2007). On the other hand, ornamentation due to discolourous pigmentation in leaves of a single specimen is a frequent characteristic within several genera (e.g., *Neoregelia*, *Vriesea*), and this has defined new cultivars much appreciated by horticulturists (Benzing 2000a). Leaf color varying from green to deep wine red in a single species of bromeliad is also traditionally accepted as a consequence of growing conditions, particularly sun light (Rauh 1990). Basically, (for other than yellow, green and white) this is a consequence of anthocyanin accumulation in leaves, which may be related to abiotic or biotic effects such as extensive light, UV-B radiation, nutrient deficiency, reactive oxygen molecules, water stress (osmoregulation), and herbivory (Close & Beadle 2003, Manetas 2006), which may be avoided due to aposematic coloration in red leaves (Cooney *et al.* 2012). In the genus *Alcantarea*, juvenile rosettes already show the color segregation pattern and color morphs (green and red individuals) may represent separate genetic clusters (Barbará *et al.* 2007), suggesting the necessity to keep studying these kind of plant variations in order to understand their genetic base. In the present paper we

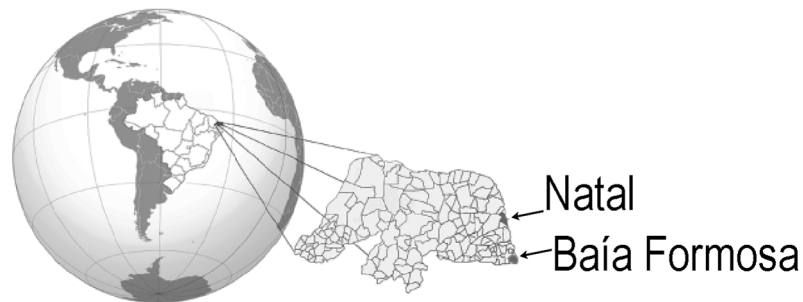
document and discuss the color morphs existent in *Cryptanthus zonatus* (Visiani 1847: 4) Beer (1856: 76). This may have confused taxonomists in the past who described distinct phenotypes as new taxa. We further present the first vouchered records of all the color morphs of *Cryptanthus zonatus* in Rio Grande do Norte state, which now is the most northern recorded distribution limit of this genus.

*Cryptanthus* (Otto & Dietrich 1836) comprises around 70 species and is a genus endemic to Brazil (Smith & Downs 1979, Luther 2010, Versieux *et al.* 2010, Gouda *et al.* 2012). According to the recently published Brazilian list of plants, *Cryptanthus* can be found in the Northeastern region of this country, along the states of Paraíba, Pernambuco, Bahia, Alagoas, and Sergipe and in the Southeastern region, where most species occur, along Minas Gerais, Espírito Santo, and Rio de Janeiro states (Forzza *et al.* 2013). *Cryptanthus* species are worldwide cultivated, popularly known as “earth stars” and congregate collectors into specialist horticultural societies, such as the *Cryptanthus* Society (Steens 2007). Species of *Cryptanthus* are reported as being pollinated mainly by insects, particularly Euglossinae bees (Benzing 2000a, Siqueira-Filho & Leme 2006). Besides the sexual reproduction, asexual or vegetative reproduction occurs by axillary stolons (Benzing 2000a). *Cryptanthus* differ from most bromeliads due to the production of usually white and inodorous flowers and is among the few Bromeliaceae genera possessing dioecy. *Cryptanthus* can grow under the canopies of evergreen forest, tolerating low light and growing within the leaf-litter substrate (Benzing 2000b). Discontinuous trichome cover can produce striking displays as horizontal banded leaves as may be seen in *Cryptanthus zonatus*.

Less than the 20000 specimens of vascular plants representing the Flora of Rio Grande do Norte state are held within its two major herbaria collections, namely MOSS and UFRN (Thiers, [continuously updated]). Within this state, the historical lack of investment in extensive and intensive research programs focused on biodiversity inventories and limitation in the number of graduate programs devoted to form locally trained botanists are two of the main causes of this scenario. As a consequence, Rio Grande do Norte is listed as one of the poorest Brazilian states in terms of species numbers, harboring 1259 species. This is clearly interpreted as a consequence of poor botanical sampling and lack of investigations rather than actual species poverty (Forzza *et al.* 2010). Besides the *caatinga* (the dry woodland from northeastern Brazil) that covers most of Rio Grande do Norte area, this state is also a landmark as the northern limit of the coastal Atlantic forest, which is considered to be a hotspot full of endemic bromeliads and the center of diversification of *Cryptanthus* (Martinelli *et al.* 2008). In this paper we describe the first occurrence of *Cryptanthus* in Rio Grande do Norte state, a finding that we consider important in evaluating the biogeography of the genus, the connectivity of the coastal Atlantic forest, as well as to add material to our scientific collections allowing more understanding of this genus given the paucity of specimens in herbaria (cf. Martinelli *et al.* 2008). Additionally, we indicate the *Cryptanthus zonatus* complex needing to be further revised. We expect that this data will allow the establishment of a better conservation status for the taxon and will further characterize species of the herbaceous stratum found amongst the vegetation of sand dunes in Rio Grande do Norte. These plants have received insufficient attention in previous floristic works (Queiroz & Loiola 2010).

## Material and methods

Since the year 2010 collections have been made along the Parque Estadual das Dunas de Natal (PEDD), a reserve of 1172 hectares located inside the city of Natal, capital of the state covered by Atlantic Forest and the coastal sand dunes shrubby vegetation (Fig. 1). Each population of *Cryptanthus zonatus* was georeferenced using a GPS and photographs were taken in the field to document phenotypic variability. Individuals have been collected and dried specimens were deposited in the herbarium UFRN (UFRN 14066, 14169, 14840, 14841). Additionally, field expeditions to the Private Reserve Mata Estrela (PRME), located at Baía Formosa, close to the border of Rio Grande do Norte and Paraíba states (Fig. 1) were carried out and specimens collected there (*Magalhães 18, 20* UFRN) are now cultivated in the garden of the Department of Botany, Ecology and Zoology of the Federal University of Rio Grande do Norte. The herbaria RB and UFRN were also inventoried for *Cryptanthus*. Floral analysis, particularly the measuring of bracts and sepals was made in individuals collected and fixed in ethanol 70% (N = 5). Notes on the phenology were taken during field work.



**FIGURE 1.** Map of Rio Grande do Norte state indicating the two new occurrences of *Cryptanthus zonatus*.

## Results

So far seven populations of *C. zonatus* have been located within the PEDD, where at least three different color morphs can be seen in sympatry (Fig. 2 B–F). Plants may present the adaxial surface of the leaves totally green (forma *viridis*) to dark wine-red almost maroon (forma *fuscus*) or, typically, it can show white bands of trichomes, explaining the *zonatus* epithet (i.e., divided into zones). We documented variability in blade width, particularly for the green color morph, with plants having linear or almost obovate blades. The same was observed for the adaxial indumentum, which may fall with the aging of the leaf that becomes nearly glabrous (Fig. 2 B–C). In PEDD, plants were found growing on sandy soil, at 50–80 m elev., usually along shaded areas. In PRME in the southern limit of Rio Grande do Norte (RN) (70 km south from Natal) we found larger populations than those in PDD (Fig. 2 A). At this place one specimen was collected (*Martinelli 15081*, RB herbarium) a few years ago but remained undetermined. There we also found the three distinct color morphs (Fig. 2). The measuring of bracts and sepals carried out for the flowers available here (N = 5) resulted in the bracts mean length = 1.87 cm, and sepals mean length = 2.8 cm. These results obtained indicate that our specimens would fit within the concept of *C. zonatus*.

Our preliminary results on the phenology and flower biology of *C. zonatus* complex in PDD indicate that the red color morph blooms in March, April and October, and that anthesis occurs between 5:30–6:00 a.m. The green color morph was collected with fruits in August. The *zonatus* form individuals so far observed were blooming in March.

## Discussion

*Cryptanthus zonatus* was described from plants collected in the state of Pernambuco, where the species appears to be locally rare and is considered important as an ornamental (Mendes *et al.* 2010, Siqueira-Filho & Machado 2001, Sousa & Wanderley 2000). After locating blooming individuals in Rio Grande do Norte we considered it important to further investigate this first occurrence, given the lack of knowledge relating to populations of this taxon regardless of its ornamental / conservational importance.

The new occurrence is reported here for an urban reserve, PEDD, as well as for the PRME assuring that populations are protected. Previous floristic work indicates that at least 350 plant species occur within the PEDD (Freire 1990), however no reference has been made to *Cryptanthus*. This could be a consequence of low sampling, since populations are fragmented and sometimes shoots are difficult to be seen among the leaf-litter (Fig. 2). Our preliminary phenological observations also indicate that few individuals bloom at a time and flowers are short-lived. As documented for other southern areas (e.g., Pernambuco and Alagoas states, Siqueira-Filho & Leme 2006) we found three color morphs growing in sympatry or very close to each other: silver banded maroon leaves, green leaves, and glabrous red/maroon leaves, intermediary forms are also seen between these three patterns. We also observed that older leaves of the banded form may become glabrous.



**FIGURE 2.** A. Two color morphs (maroon and green – indicated by the arrow) growing intermingled in the understory of Mata Estrela. B. Maroon color morph plant growing next to a banded individual that present a basal glabrous leaf (arrow) at Parque das Dunas. C. Signs of trichome loss on the older leaves (arrow), by a maroon banded individual from Parque das Dunas. D. Green individual showing dark red/maroon marks on the base of the leaves, Parque das Dunas. E. Two rosettes showing similar pigmentation (green along the center and dark red/maroon at the margins) but contrasting in the banded-lepidote versus glabrous adaxial surface. F. Individual displaying the colors green and wine-red spots (scale = 14 cm). G. Blooming individual of the banded form presenting a staminate flower. H. Bisexual flower of the maroon morph. I. Basal stolon (arrow), in the maroon morph. J. Basal stolon (arrow), in the banded morph.

This occurrence highlights the lost connectivity of the coastal forest of northeastern Brazil, which are nowadays completely fragmented and also stresses the need for PEDD and PRME to protect patches of the Atlantic rainforest, since this biome is a hotspot and has been progressively reduced and is now severely fragmented (Ribeiro *et al.* 2009). New species, and even a recently described new genus (Cabral *et al.* 2012) of other biological groups have been reported for PEDD indicating the necessity for more research within this reserve.

Due to difficulties with identification and to assure the plants from RN were, in fact, *C. zonatus* and not another species we analyzed the descriptions from Smith (1952) and Smith & Downs (1979), Ramírez-Morillo (1996), Siqueira-Filho & Leme (2006) and the results are the following: Smith & Downs (1979) in their identification key highlighted the differences between *C. zonatus* vs. *C. fosterianus* (Smith 1952: 63) by the size of the sepals (19 mm vs 8 mm respectively), the free sepal lobes shapes and margins (acuminate, auriculate, entire vs. acute and apiculate, broadest at base, serrulate) and by the leaf texture (relatively thin and flexible vs. thick, fleshy and rigid). These authors also recognize three forms, namely *C. zonatus* f. *zonatus*, *C. zonatus* f. *viridis* (Mez 1934: 19), and *C. zonatus* f. *fuscus* (Visiani 1847: 4) Mez (1896: 58), the two later were described from cultivated material with unknown distribution in Brazil and were recently synonymized under *C. zonatus* by Siqueira-Filho & Leme (2006).

Ramírez-Morillo (1996) who firstly recognized this species complex, indicated that a section should be created to place species having a unique pattern of transversal bands of trichomes on the blades. This section/complex would group, besides *C. zonatus* and *C. fosterianus*, *C. burle-marxii* Leme (1990: 12). Ramírez-Morillo further highlights that some characters previously used, such as the production of stolons is not useful to segregate taxa. Here we also observed that the same color morph may produce stolons or not. On the other hand, she considered the leaf texture, color of the blades, and the relative lengths of the sepals/floral bracts as taxonomically important. Ramírez-Morillo also stresses that further field work would be extremely valuable in order to understand if there are three different taxa or a single very variable one. In her identification key, taxa were separated by blade width, serration of the floral bracts, sepal length, floral bract/sepal length ratio (bracts about equaling the sepals or half as long as the sepals).

According to Siqueira-Filho & Leme (2006), the differences between *C. zonatus* and *C. fosterianus* are the size of floral bracts, that are longer in *C. zonatus*, the margins of the sepals that are serrate in *C. fosterianus* and minutely denticulate or smooth in *C. zonatus*, and texture of the leaves, that are more leathery and fleshy in *C. fosterianus* than in *C. zonatus*.

Although the size of sepals analyzed, is a little bit longer than given in the descriptions and the floral bract appears to be minutely serrulate at the apex, the ratio of sepal/bracts length and the sepal apex, that are the characters highlighted by Smith & Downs (1979) and Siqueira-Filho & Leme (2006), fit specimens from RN within the *C. zonatus* concept. Using the identification key provided by Cândido (1995) who also mentioned that the genus would occur in RN, we could not key out to *C. zonatus*, since this author stress that *C. zonatus* does not have stolons. The segregation of *C. burle-marxii* from *C. zonatus* also has been based upon the presence of long and slender stolons versus short axillary shoots (Siqueira-Filho & Leme 2006). In the field we observed that this is a variable character, of low utility to separate specimens even in the same population (Fig. 2 I–J), which may or may not produce such stem in the same habitat.

*Cryptanthus zonatus* was recorded in Pernambuco state also in different habitats, these being *caatinga* where the designated neotype collection came from (Ramírez-Morillo 1996) as well as from patches of Atlantic forest isolated on the top of mountain ranges known as *brejos* (Siqueira-Filho & Leme 2006). In these fragments of Atlantic forest, the species grows in clay soil, which is different to RN populations that grow in litter-rich sandy soil. Currently, *C. zonatus*, *C. fosterianus*, and *C. burle-marxii* are in the the list of Endangered Species of the Brazilian flora. *Cryptanthus fosterianus* is listed as Critically Endangered, while *C. burle-marxii* and *C. zonatus* are listed as Vulnerable (CNCFlora, 2013).

## Conclusion

Rio Grande do Norte state has a new occurrence for *C. zonatus* extending the range of this genus toward north. Here we added more data on the discussion about this poorly known species, particularly photos from populations in the field presenting different pigmentation or indumentum. Our work documented that this taxon is polymorphic and that in RN its populations are protected within two reserves with large populations. Single individual may have green or maroon leaves, and the typical banded form may lose trichomes with aging. Such phenotypic variability should be considered in order to avoid taxonomic confusion. However, field studies are still necessary to document the reproductive strategies of the species and the morphological characterization of the leaves is necessary for all the taxa involved in the *C. zonatus* complex, since leaf texture has been considered an important diagnostic feature in different identification keys. It is important to continue studying these plants, now using deeper revisionary and population genetics approaches, as a more detailed taxonomical understanding of this group will be critical to be able to decide what to conserve.

## Acknowledgments

This work was financed by CAPES (M. Sc. fellowship for the second author) and by a CNPq grant (PROTAX). We are very grateful to editor Dr. Eric Gouda for his valuable comments on the manuscript and constructive reviews and to R. Smythe for careful proofreading and comments. We also thank Parque Estadual das Dunas de Natal and RPPN Mata Estrela for the authorization to collect plant material, as well as our lab interns and ecology/biology students Adriene Samara and Eduardo Calisto for fieldwork assistance and curators from UFRN and RB herbaria for their support during our work. R. T. Queiroz allowed the use of the map.

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