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Simultaneous relocation strategy of bromeliads as epiphytes or terricolous in the Montane Dense Ombrophilous Forest of Parque Estadual da Cantareira, São Paulo State, Brazil

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ABSTRACT – (Simultaneous relocation strategy of bromeliads as epiphytes or terricolous in the Montane Dense Ombrophilous Forest of Parque Estadual da Cantareira, São Paulo State, Brazil). Plant relocation resulting from vegetation removal is an important conservation strategy. This work aimed to investigate the simultaneous relocation of the bromeliads *Aechmea distichantha* Lem. and *Wittrockia cyathiformis* (Vell.) Leme in epiphytic and terricolous form. These bromeliads were rescued from deforested areas due to the construction of a highway. Both were fixed onto tree trunks or pitchforks or in the soil in a Montane Dense Ombrophilous Forest area of Parque da Estadual Cantareira, São Paulo State, Brazil. After one year *A. distichantha* maintained 100% survival rate, when transplanted in terricolous and 83.33 % in epiphytic form, while *W. cyathiformis* was 60% for both relocation forms. We concluded that both bromeliad species could be simultaneously relocated as epiphytes or terricolous. Direct relocation to the ground guarantees practicality, as it is difficult to find trees with forks located at small heights from the ground in which the manual fixing of the plant could be done without equipment.
Keywords: *Aechmea distichantha*, conservation of native forest, facultative habit, *Wittrockia cyathiformis,* vegetation removal

RESUMO – (Estratégia de realocação simultânea de bromélias como epífitas ou terrícolas na Floresta Ombrófila Densa Montana do Parque Estadual da Cantareira, Estado de São Paulo, Brasil). A realocação de plantas resultante da remoção da vegetação é uma importante estratégia de conservação. Este trabalho objetivou investigar a realocação simultânea das bromélias *Aechmea distichantha* Lem. e *Wittrockia cyathiformis* (Vell.) Leme na forma epífita e terrícola, resgatadas de áreas desmatadas devido à construção de uma rodovia. Ambas foram fixadas em troncos de árvores ou forquilhas ou transplantadas para o solo em uma área de Floresta Ombrófila Densa Montana do Parque Estadual da Cantareira, Estado de São Paulo, Brasil. Após um ano, *A. distichantha* manteve 100% de sobrevida, quando transplantada na forma terrícola e 83,33% na forma epífita, enquanto *W. cyathiformis* foi de 60% para ambas as formas de realocação. Concluímos que ambas as espécies de bromélias podem ser realocadas simultaneamente como epífitas ou terrícolas. A realocação direta ao solo garante praticidade, pois é difícil encontrar árvores com forquilhas localizadas a pequenas alturas do solo em que a fixação manual da planta possa ser feita sem equipamentos.
Palavras-chave: *Aechmea distichantha*, conservação da floresta nativa, hábito facultativo, supressão da vegetação, *Wittrockia cyathiformis*

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Introduction

The removal of vegetation cover for road work can result in the loss of plant biodiversity. Consequently, mitigation measures are necessary to minimize this effect (Stumpf *et al*. 2008). Among the alternatives, the relocation of plant species removed from the area destined to road works in conservation sites where the natural occurrence of these species has been detected (Araújo 2006). Primack (2008) and, more recently, Guardia *et al*. (2021) and Suzuki *et al*. (2021) have highlighted the importance of transplanting species from areas aimed for vegetation removal to other places considered suitable for their relocation, as has been recommended by Jasper *et al.* (2005) and Duarte & Gandolfi (2013), primarily in protected areas (Santos Júnior & Tamaki 2014).

Among the epiphytes, studies have reported that Bromeliaceae species are fundamental to their native ecosystem and feasible for relocation (Jasper *et al.* 2005, Duarte & Gandolfi 2013) presenting ecological importance. Some morphological characteristics of certain bromeliads, such as the overlap of leaf bases forming a cistern or phytotelmata, can serve as a shelter and storage of water and nutrients available for small animals (Benzing 2000). According to Stuntz *et al*. (2002), the evaporation of water stored in bromeliad cisterns, for example, can change the behaviour and niche distribution of the tree fauna, influencing the microclimate conditions of the canopy by enabling lower temperatures in its vicinity. Also, bromeliads offer other resources such as flowers, fruits and nectar to the natural environment (Benzing 2004, Cestari 2009).

Bromeliaceae genera have different life habits in nature, such as epiphytes, rupicolous, saxicolous, terricolous and facultatives that can live both on the ground and on trees (Fischer & Araújo 1995) and have been considered a highly important functional group of tropical forests (Barrancos *et al*. 2016). This ability to potentially adapt to different conditions is a requirement for survival after removal from the area of origin. In the relocation as epiphytes, bromeliad specimens are generally fixed onto tree pitchforks using cotton strings (Jasper *et al*. 2005). However, over time, specimens might experience inclination in relation to the trunk axis, which may cause decreased survival because it might damage the water storage in the cistern of bromeliads, which can lead to water stress, and cause the plants' fall to the soil (Freitas *et al*. 1998). Therefore, the direct relocation on the ground in the upright position could guarantee greater rosette stability, especially in large bromeliads. The stabilised rosette would also favour accumulating rainwater and nutrients between the leaves, which would be absorbed by the plant or used by the associated fauna (Benzing 2000).

The lack of trees with pitchforks at approximately 2 m high, which facilitate manual fixation without equipment, should also be considered to evaluate the relocation of epiphytic bromeliads directly on the ground, since large pitchforks are most located in the crown of large trees. If survival of epiphytic species in the soil is feasible for a prolonged period, direct relocation to the ground could guarantee greater practicality, allowing the continuity of their development by producing sprouts and inflorescences (Araújo 2006). Considering pollination, Varassin & Sazima (2000) observed the hummingbirds *Phaethornis eurynome* and *Ramphodon naevius* pollinating bromeliads in the lower strata of the forest. Then, the translocation to the ground vs. onto trees at high elevations, could not affect the pollination of the transplanted species. *Nidularium rubens*, a soil species, for example, is visited by *P. eurynome* (Machado & Semir 2006).

Many species of epiphytic bromeliads absorb nutrients not only through aerial parts but also through roots (Nievola & Mercier1996) since they show efficient growth in nurseries to be commercialised in pots with a substrate (Negrelle *et al*. 2011). Therefore, ground relocation may be a viable strategy. Some studies have shown success in relocating bromeliads in soil, on tree trunks, or in both conditions in the same community, regardless of their life strategy (Freitas *et al.* 1998, Benzing 2000, Araújo 2006). However, no studies have hitherto compared the efficiency of the simultaneous relocation of bromeliads as epiphytes on trees and as terricolous in the same crown projection area of the same tree. In this way, it would be possible to relocate a larger number of specimens on the same day, optimising the process in the field and reducing the labour and operational cost.

In Brazil, the bromeliad *Aechmea distichantha* Lem. is distributed in areas of Cerrado and Atlantic Rainforest in the States of Minas Gerais, Espírito Santo, São Paulo, Rio de Janeiro, Paraná, Santa Catarina, Rio Grande do Sul and Mato Grosso do Sul (Forzza *et al*. 2010, Faria *et al.* 2022). *Wittrockia cyathiformis* (Vell.) Leme occurs in the Atlantic Rainforest between the States of Minas Gerais and Santa Catarina, from 750 to 1,900 m of altitude (Wanderley *et.al.* 2007). Both bromeliads have a facultative habit and are pollinized by birds (Cestari 2009). *Aechmea distichantha* has been considered as a vulnerable species (Martinelli *et al*. 2008) and least concern (Faria *et al.* 2022). *W. cyathiformis* as an endemic (Martinelli *et al*. 2008, Tardivo 2022). Plants of *A. distichantha* flowers throughout the year, while the flowering period of *W. cyathiformis* is from April to June and from August to December (Wanderley *et al*. 2007). Individuals of these two species were rescued, during deforestation caused by the construction of a road project, which began in 2013 (Mário Covas Highway, São Paulo, Brazil).

This work aims to evaluate the simultaneous relocation of the bromeliads *A. distichantha* and *W. cyathiformis* rescued from the region impacted by road work construction to a nearby Montane Dense Ombrophilous Forest area, to mitigate the effect of deforestation. Those species were selected as the most abundant in the deforested area. This study can contribute to mitigate the impact caused by deforestation, allowing the conservation of native species and the maintenance of genetic diversity. It provides knowledge on the development of low-cost techniques that will speed and enhance the success rate of colonization for Bromeliaceae.

Material and methods

Study area – The plants were rescued from the area determined as Section 4, in Arujá, São Paulo State, and São Paulo, São Paulo State, where vegetation suppression work occurred due to the construction of the Rodoanel Mário Covas Trecho Norte, also reported in Guardia *et al*. (2021). The layout is depicted in Figure 1 a. The relocation site of the rescued plants was located at 4 km from the suppression area (figure 1 b) (Google Earth 2022). The selected site for relocation was in the Montane Dense Ombrophilous Forest in Parque Estadual da Cantareira (PEC), São Paulo State, Brazil. This park has 7,916.52 ha and is considered one of the largest urban forests worldwide and one of the main forest remnants in the metropolitan region of São Paulo city. In this region, there are many springs, and UNESCO considered protected area as the Central Zone of the São Paulo City Green Belt Biosphere Reserve (São Paulo 2009). Most of the forest is in the middle stage of regeneration, but there are also a few significant stretches in advanced and mature stages (São Paulo 2009). The climate is characterised as mesothermal and humid with minor rainfall deficiencies and water excess in summer (Cfb classification, Koëppen 1948, Alvares *et al*. 2013). The mean annual rainfall is 1,322 mm, with 229.8 mm in the rainiest month (January) and 31.7 mm in the least rainy (August) (São Paulo 2009). In this region relocation area of forest presented 75% shading (Minipa® digital lux meter), in Macuco Trail (23º24'29" S and 46º34'57" W). The temperature in this area ranged from 16.5 ºC (June and July) to 26 ºC (January and February), exceeding 32 ºC in the hottest months during work of relocation (figure 2). This temperature variation was similar to that detected at the period of harvesting of plants (2013-2014 from 15 ºC to 26 ºC, exceeding 32 ºC in the hottest months in according to INMET 2022). The mean annual rainfall in 2013-2014 was 1,322 mm.

Studied bromeliad – The species used were *Aechmea distichantha* Lem. (figure 3 a) and *Wittrockia cyathiformis* (Vell.) Leme (figure 3 b). From 2013-2015, specimens of both species were rescued during the removal of vegetation for constructing the northern section of the Mario Covas Highway in São Paulo, São Paulo State, Brazil. All of the bromeliads were in the adult stage.

Plant harvesting – After deforested, adult individuals (60 specimes) of both species living had lived on tree branches and soil were harvested at random by fieldworkers, taking care to cause the least possible mechanical damage in the root system. The collected plants were mixed and randomly transplanted into pots, not considering whether they had been taken from trunks or from the ground. The rescues were conducted by the research group of Instituto de Botânica of São Paulo State, Brazil. In sequence, they were cultivated in *Pinus* composted bark substrate and maintained in a nursery covered with a high-density polyethylene black shade cloth with 50% of shading for half to one year until relocation (figures 3 a-b).

Relocation – The plants of *A. distichantha* and *W. cyathiformis* utilized for the relocation showed an average of 19.61 and 13.65 leaves, respectively, and showed a good phytosanitary condition. The relocation was carried out in November 2015, during the highest rainfall period, as recommended by Lunelli *et al*. (2015). For the relocation of bromeliads as epiphytes, plants were fixed on trees on their pitchforks or trunks regardless of the species, as also reported by Jasper *et al*. (2005). The bromeliads were relocated by properly trained fieldworkers using stairs to reach the highest pitchforks and trunks and fixed using sisal string onto trunks or pitchforks, to prevent falls, and transplanted on the ground. All bromeliads were identified with numbered plastic tags. For the terricolous relocation, the bromeliads were removed from the pots and transplanted in the same crown projection area of the tree crown where the epiphytes were fixed. Plants were placed into holes made with a hoe, duly filled with soil and compacted to make the bromeliads firm on the ground. Thus, 30 units were relocated to soil simultaneously and other 30 plants fixed onto tree trunks or pitchforks of each species, totalling 60 bromeliads of each species, being therefore 60 plants of *A. distichanth*a and 60 of *W. cyathiformis*. As shown in Figure 4, *Aechmea distichantha* plants were simultaneously relocated as terricolous (figure 4 a) or epiphytic (figures 4 b and c). *Wittrockia cyathiformis* plants were simultaneously relocated as terricolous (figure 5 a) or epiphytic (figure 5 b). The specimens were randomly distributed to simulate the fieldwork carried out by technicians of companies who relocate the rescued specimens in a simple procedure, regardless of the presence of sprouts, inflorescences and without considering the size variation between them. Then, the distribution of plants was not distinguished as to the reproductive or vegetative stages. At the end of the random relocation procedure, the distribution of *A. distichantha* was: 20% (12 plants) and 21.7% (13 plants) in the epiphytic and terrestrial forms, respectively with bromeliads in the reproductive stage. In the vegetative stage 30% (18 plants) of bromeliads were relocated as epiphytes and 28.3% (17 plants) as terrestrials. These percentages were calculated from 60 bromeliads.

Analyzed variables – The evaluated variables included the survival percentage, calculated from the number of dead plants, number of emerging sprouts and number of leaves. The dependent variables sprout and survival were evaluated during nine readings, while the leaves were evaluated during five readings from October of 2015 to November of 2016.

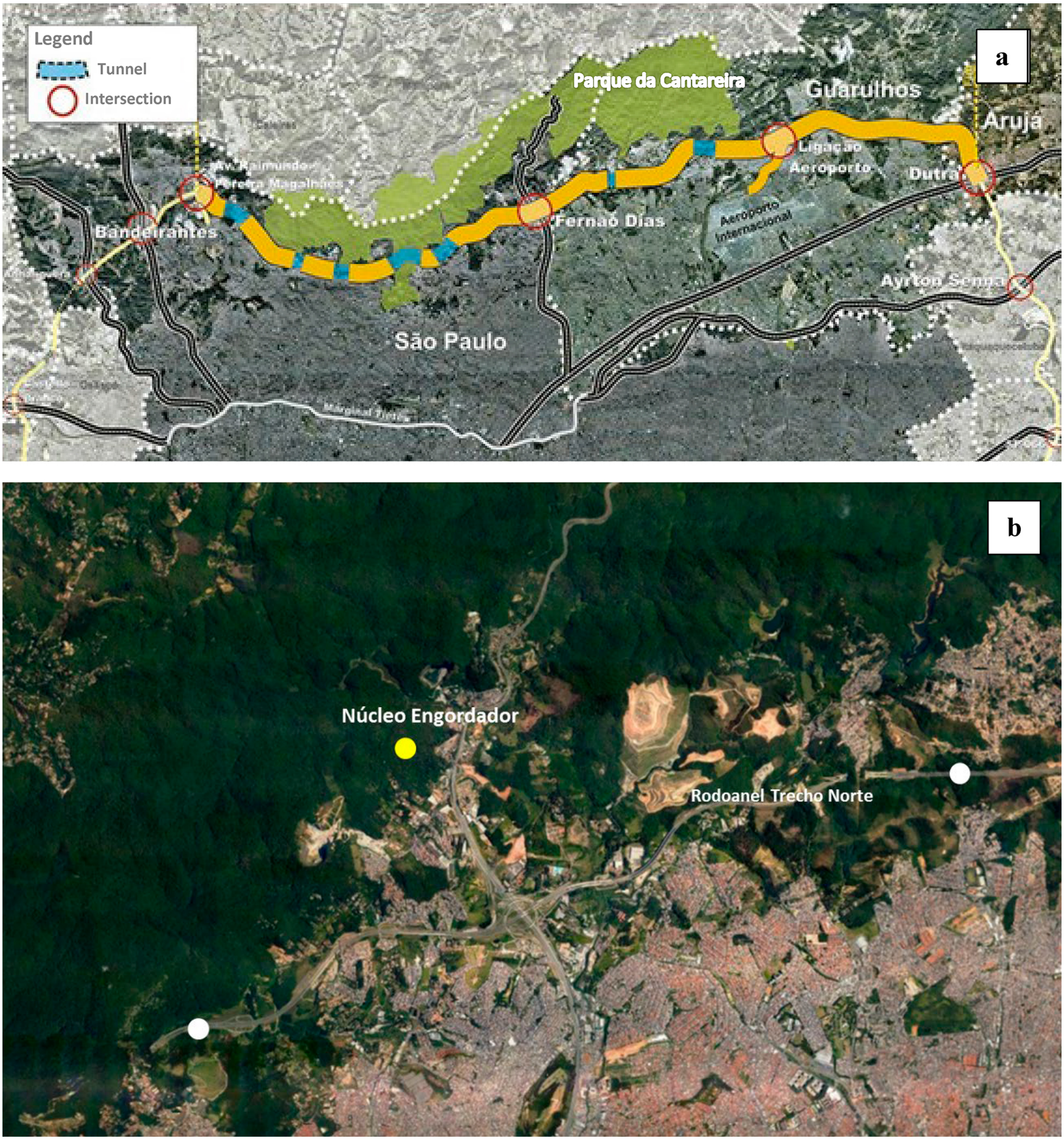

Figure 1. a. Map of the Mário Covas Rodoanel – North Section (Adapted from Azambuja Neto *et al.* 2016). b. Satellite image (Google Earth, 2022) showing the Rodoanel Mário Covas-Norte highway (section 4), São Paulo, São Paulo State, Brazil. The white dots refer to the approximate extreme limits of the vegetation suppression area. The yellow dot shows the location of the Núcleo Engordador – Parque Estadual da Cantareira (23°24’31”S-46°35’14”W) where the bromeliads *Aechmea distichantha* Lem. and *Wittrockia cyathiformis* (Vell.) Rudder were relocated.

Experimental design – Two independent experiments were carried out, using the bromeliads *Aechmea distichantha* and *Wittrockia cyathiformis*. The experimental design adopted was with the treatments arranged in split plot in time, distributed in three blocks, with the main treatment being the relocation form (epiphytic or terricolous). Additionally, the independent variables of the *Aechmea distichantha* were also evaluated, considering the phenological stage (vegetative or reproductive).

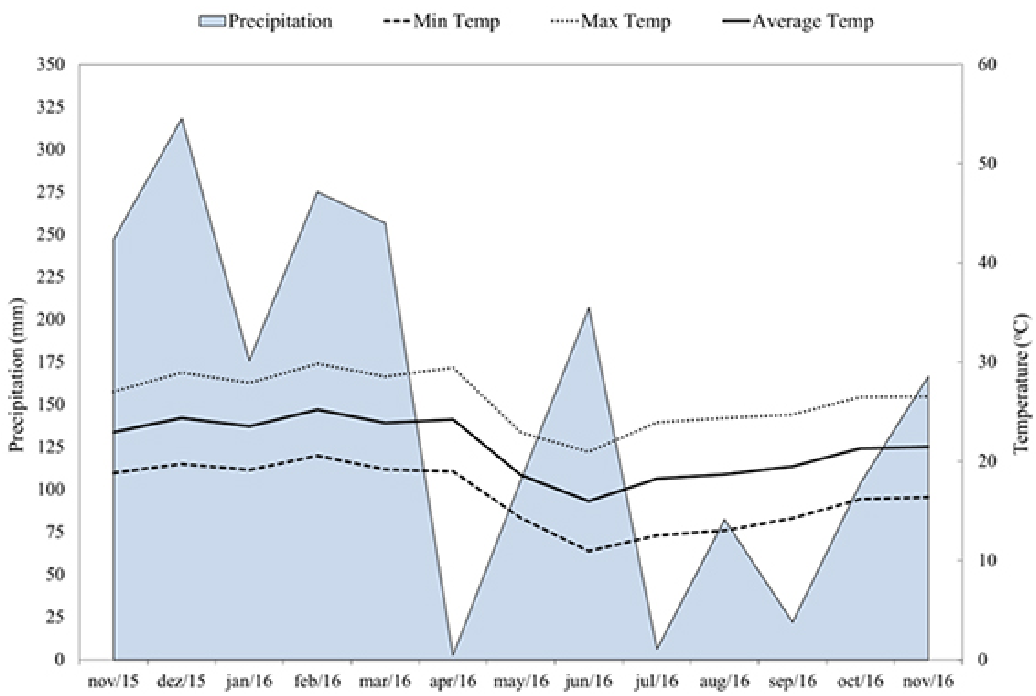

Figure 2. Monthly precipitation (mm) and minimum, average, and maximum temperatures (ºC) in northern São Paulo, São Paulo State, Brazil, from October 2015 to November 2016, during experiment. Data was provided by National Meteorological Institute (INMET), using the Meteorological Database for Teaching and Research (BDMEP) (Guardia *et al.* 2021).

Figure 3. Plants of *Aechmea distichantha* Lem. (a) and *Wittrockia cyathiformis* (Vell.) Rudder (b) maintained in a waiting nursery built with 50% shade screen cover until relocation to a selected area of Dense Montane Ombrophilous Forest in Parque Estadual da Cantareira, São Paulo, São Paulo State, Brazil.

Experimental setup in the field – The individuals were marked from 1 to 60 with white plastic tags attached to the youngest among the adult leaves and the most physiologically active. Tags were attached through a punched hole in the leaf with a plastic string. Thus identified, they were brought to the site of the installation of the experiments in the forest, when the plants were randomly selected by drawing, through previously numbered pieces of paper. In these ways, the bromeliads that were placed on the pitchfork and trunk or on the ground were randomly chosen.

The specimens of *W. cyathiformis*, which also consisted of 60 plants, were all relocated with 100% of them in the vegetative stage, with no plants with evidence of floral scape.

Figure 4. *Aechmea distichantha* Lem. specimens simultaneously relocated as terricolous (a) or epiphytic (b). Detail of epiphytic specimens of *Aechmea distichantha* (Vell.) Rudder with inflorescence (c), São Paulo, São Paulo State, Brazil.

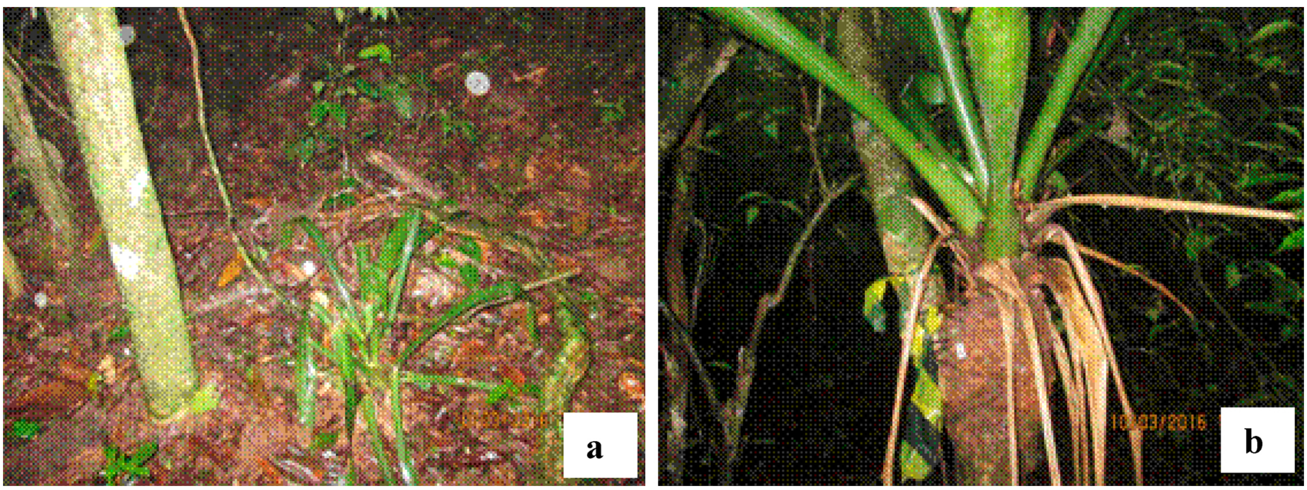

Figure 5. *Wittrockia cyathiformis* (Vell.) Rudder specimens simultaneously relocated as terricolous (a) or epiphytic (b), São Paulo, São Paulo State, Brazil.

Statistical analyses – A generalized mixed linear modeling (GLMM) approach was used to analyze the leaves and sprouts of *Aechmea distichantha* and the means were compared by the Bonferroni test. Also, the data of the variables number of leaves and sprouts of the specie *Wittrockia cyathiformis* were analysed by the Shapiro-Wilk test to verify the assumptions of normality. Thus, the data were submitted to the Friedman test, whose medians were compared using the Parwise Comparisons test (Durbin-Conover). Data were analyzed using JAMOVI software (The Jamovi Project 2022). The survival of the two species of bromeliads was analyzed using the SISVAR program (Ferreira 2011), whose experimental design was split-plot in time, distributed in three blocks, with the main treatment being the relocation form.

Results and discussion

Survival of relocated specimens at each observation, and over time – Relocation has been considered a method for plant conservation in cases of forest removal for road works (Jasper *et al.* 2005) and Barrancos *et al*. (2016) showed that transplanting bromeliads can be a simple and non-destructive approach to overcome the limitations of epiphyte dispersal and accelerate the recovery of biodiversity. As shown in Table 1, specimens of *A. distichantha* transplanted in the terricolous form did not present statistically significant difference ($p > 0.05$) in the survival rate between vegetative or reproductive stages of the entire observation period. When the plants were relocated as terricolous or epiphytic in the vegetative stage, presented 100% survival (table 1). Only when the plants were relocated as epiphytes in the reproductive stage did survival statistically decrease (83.33%) after 287 days from the beginning of the experiment (100%) (table 1). Even so, the survival rate could be considered high. The high percentage values are probably since both bromeliads under nursery conditions in pots where the plants are better nourished and with good phytosanitary conditions. The survival percentages observed herein for *A. distichantha* were higher than those in similar studies of relocated *Aechmea* species with 62,5% (Araújo 2006). In this work, this procedure was similar to the usually performed in rescue procedures by companies' workers, in which *A. distichantha* plants are found in the natural environment of the forest were randomly collected, and regardless of whether they were epiphytic or terricolous.

The results also show that *W. cyathiformis* plants (table 2) relocated as terricolous or epiphytic did not show significant differences in survival rates. Therefore, the form of relocation did not influence survival during the experiment for this species. Nevertheless, the survival rate was significantly reduced over time in both relocation forms, being constant from 252 days until the end of the experiment at 60% (table 2). This behaviour indicates that *W. cyathiformis* is under stress after 196 days of transplanting, until the definitive establishment. Jasper *et al*. (2005) relocated 14 bromeliad species rescued from the clearing of a forest area aimed at hydro-energetic use. These authors verified a 67% mean survival after relocation, varying from 79% to 50% according to the species, in a period of 10 months after transplantation. Barrancos *et al*. (2016) showed that the survival rate of tank bromeliad *Werauhia gladioliflora* (H. Wendl.) J. R. Grant fixed onto trunks and branches after nine months varied among sites between 65 and 95%, although the period of evaluation was shorter than in the present study (12.4 months). Duarte & Gandolfi (2013) observed similar survival rates (75.9%) for *Aechmea bromeliifolia* (Rudge) Baker one year after relocation as an epiphyte. The vulnerability of epiphytes after relocation can be explained by the fact that they do not receive irrigation and depend on rainfall events for water uptake (Benzing 2000). Consequently, epiphytes are constantly and naturally exposed to drought. For instance, Carvalho *et al.* (2017) showed a significant decrease by 37% of relative water content (RWC) in plants of *Guzmania monostachia* (L.) Rusby ex Mez exposed to eight days without water irrigation, as similar to the relocation effects observed herein.

Among the factors related to the mortality of the epiphyte specimens, Jasper *et al*. (2005) cited the importance of the efficient fixation to the host with materials that resist for at least 10 months. With this in mind, the authors used biodegradable string, while sisal was used in this work. Due to this requirement, the direct relocation to soil can be an interesting alternative to avoid the loss of the rescued specimens (Jasper *et al*. 2005) in relation to facultative species. Therefore, specimens with facultative habits, such as *Aechmea calyculata* (E. Morren) Baker transplanted to the soil, showed 79.6% survival. Freitas *et al*. (1998) performed transplant experiments to assess the epiphytic growth of terricolous ramets of *Nidularium procerum* Lindman and *Nidularium innocentii* Lemaire, two tank bromeliads considered facultative epiphytes, and found that all ramets survived after two years.

Leaf number of relocated specimens at each observation, and over time period – The results showed that leaf number of *A. distichantha* bromeliads in the vegetative and reproductive (table 3) stages transplanted as terricolous or epiphytic forms did not differ significantly from each other ($p > 0.05$) during the experiment at each period of observations. Thus, the relocation form and phenological stage do not affect leaf emission. Also, the results show that in both phenological stages and relocation form, the number of leaves significantly decreased ($p > 0.05$) from 252 days and remained constant until the end of the experiment. The reduction in leaves in *A. distichantha* e *W. cyathiformis* observed in this work might be considered an adaptive response to abiotic stress, which results in leaf senescence (Leopold 1975) during the establishment of bromeliads in a new environment (Freitas *et al*. 1998), although sprouting is part of life cycle of bromeliads, which may have been accelerated by environmental stress. Additionally, most bromeliads, as *Vriesea neoglutinosa* Mez stops producing leaves and start producing new sprouts when they reach its maturity (Sampaio *et al.* 2002). One of the abiotic stresses that might have occurred during the experiment in all relocation form and affected leaf emission is water deficit (drought months), observed in July 2016 and September 2016 (figure 2). Despite the loss of leaves, the percentage of survival was high. It should be considered that bromeliads also absorb water retained in the soil, through the root system, in addition to the tanks formed by the imbrications of leaves (Nievola & Mercier1996). Although this kind of transplanting to the soil and canopy does not allow the accurate measurement of the emission of new roots, it is possible to assume that these can contribute to the absorption of mineral nutrients, which would lead to adequate mineral nutrition for growth and development.

Furthermore, it is noted that in *W. cyathiformis* (table 4), the number of leaves of bromeliads transplanted as terricolous or epiphytic did not differ significantly ($p > 0.05$) in different observed periods. This shows that the number of leaves does not depend on the form of relocation, as also noted for *A. distichantha*. However, the number of leaves of *W. cyathiformis* decreased significantly ($p > 0.05$) from 252 days onwards and remained constant until the end of the experiment. This behavior probably shows those bromeliads could have an abiotic water and nutritional stress when relocated.

During the initial stage of establishment in the new environment, i.e., between bromeliad removal and relocation, a nutritional deficiency could also occur due to the limited nutrient availability, contributing to apical bud inactivation and leading to the stimulation of the axillary sprout production. According to Freitas *et al.* (1998), the leaf loss that occurs during their establishment in the new environment might be related to natural senescence or an adaptative response.

Table 1. Observed means of the percentage (%) of survival in each observation period and over time as a function of the phenological stage (vegetative and reproductive) inside the relocation form (terricolous and epiphyte) of the bromeliad *Aechmea distichantha* Lem. in an area of Montane Dense Ombrophilous Forest in Parque Estadual da Cantareira, São Paulo, São Paulo State, Brazil. The same bold lowercase letters in a column indicate non-significant differences between the survival as a function of phenology within the terricolous relocation form, and the same italic lowercase letters in column indicate non-significant values between the survival as a function of phenology within the epiphyte relocation form, and the same capital letters in line indicate non-significant values between percentage of survival over time.

Phenology	Relocation form	Time (days)																	
		0		84		112		133		196		252		287		350		371	
Vegetative	Terricolous	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**
	Epiphytic	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**	100.0	A**a**
Reproductive	Terricolous	100.0	A*a*	100.0	A*a*	100.0	A*a*	100.0	A*a*	100.0	A*a*	100.0	A*a*	100.0	A*a*	100.0	A*a*	100.0	A*a*
	Epiphytic	100.0	A*a*	100.0	A*a*	100.0	A*a*	100.0	A*a*	100.0	A*a*	91.67	B*b*	83.33	B*b*	83.33	B*b*	83.33	B*b*

Table 2. Observed means of the percentage (%) of survival in each observation period and over time as a function of the relocation form (terricolous and epiphyte) of the bromeliad *Witrochia cyathiformis* (Vell.) Rudder in an area of Montane Dense Ombrophilous Forest in Parque Estadual da Cantareira, São Paulo, São Paulo, Brazil. The same lowercase letters in a column indicate non-significant differences between the survival as a function of relocation form, and the same capital letters in line indicate non-significant values between the survivals over time.

Relocation form	Time (days)																	
	0		84		112		133		196		252		287		350		371	
Terricolous	100.00	Aa	100.00	Aa	100.00	Aa	93.33	Aa	80.00	ABCa	73.33	BCa	66.67	Ca	63.33	Ca	60.00	Ca
Epiphytic	100.00	Aa	100.00	Aa	100.00	Aa	100.00	Aa	96.67	Aa	83.33	ABa	80.00	ABa	66.67	Ba	60.00	Ba

Table 3. Observed means of the leaf number in each observation period and over time as a function of the relocation form (terricolous and epiphyte) inside the phenological stage (vegetative and reproductive) of the bromeliad *Aechmea distichantha* Lem. in an area of Montane Dense Ombrophilous Forest in Parque Estadual da Cantareira, São Paulo, São Paulo State, Brazil. The same bold lowercase letters in a column indicate non-significant differences between the leaf number as a function of relocation form within the vegetative phenology, and the same italic lowercase letters in column indicate non-significant values between the leaf number as a function of relocation form within the reproductive phenology, and the same capital letters in line indicate non-significant values between leaf number over time.

Phenology	Relocation form	Time (days)									
		0		252		287		350		371	
Vegetative	Terricolous	20.29	A**a**	13.24	B**a**	12.90	B**a**	11.35	B**a**	10.31	B**a**
	Epiphytic	20.89	A**a**	12.78	B**a**	14.22	B**a**	12.44	B**a**	12.44	B**a**
Reproductive	Terricolous	19.00	A*a*	12.08	B*a*	11.31	B*a*	10.31	B*a*	11.35	B*a*
	Epiphytic	18.25	A*a*	10.50	B*a*	11.00	B*a*	10.25	B*a*	10.25	B*a*

Sprout number of relocated specimens at each observation, and over time period- The results of relocation for *A. distichantha* (table 5) showed that the specimens transplanted as terricolous did not show statistically significant differences ($p > 0.05$) of sprouts between the phenological stages in each period observed. Also, the data did not show statistically significant differences ($p > 0.05$) when they were transplanted on the soil, independently of the phenological stages, over time. This result shows that soil transplanting is independent of the different phenological stages of *A. disthichanta*. However, bromeliad of *A. disthichanta* (table 5) showed statistically significant differences over time ($p \leq 0.05$) when transplanted as epiphytic form in the vegetative stage with an increase in the number of sprouts at 252 days (c.a. 10%), remaining constant at 1.06 and 1.12 sprouts, while those transplanted during the reproductive stage did not show statistically different differences ($p > 0.05$) over time (table 5). The production of new organs like sprouts can be related to leaf senescence, which can be understood as a recycling process that contributes to better nutrient management, leading to an efficient resource economy (Guiboileau *et al*. 2010). This increase in sprouts might be due to abiotic stress, which induced the emission of axillary sprout, while bromeliads in the reproductive stage allocated as epiphytic form did not show a significant increase ($p > 0.05$) in sprout number, since they had been induced to produce these during the emission of the floral scape.

Regarding *W. cyathiformis* (table 6), when relocated as terricolous or epiphytic, they did not show significant differences between the numbers of sprouts during each observation ($p > 0.05$). This indicates that the form of relocation, terricolous or epiphytic, did not influence the emission of sprouts during the experiment. Also, it was observed that sprout production remained constant ($p > 0.05$) over time, either in the form of terricolous or epiphytic. This behavior denotes that the emission of sprouts is constant over time, regardless of the form of relocation. Probably, the emission of new sprouts was due to the abiotic stress caused by the new environment of fixation in the phorophytes and transplantation in the forest ground. According to Jasper *et al*. (2005) the new roots originated from the shoots might contribute to its fixation to the phorophyte. These authors related that the new root development is slow and occurred in a mean of six to 12 months after transplanting. In this work, it was decided not to evaluate the development of the root system in order not to cause physical damage to the young roots due to the removal of the specimens from the relocation site, such as from the soil. The importance of the root system for epiphyte attachment was commented by Jasper *et al*. (2005) who found high mortality rate in *Vriesea friburgensis* Mez due to insufficient attachment to the phorophyte. Likewise, Barrancos (2016) showed that presence of new roots gripping the trunk contribute to survival of relocated specimen.

Duarte & Gandolfi (2013) observed that the size of the bromeliad specimen to be relocated could influence survival. These authors found that the largest individuals of *Aechmea bromeliifolia* (Rudge) Baker could better resist the stress of transplantation and guarantee their permanence in the environment. Although the size of bromeliads was not considered in this study, only adult bromeliads were allocated, not using small plants. For this purpose, the number of leaves with 19.61 and 13.65 in average, respectively for *A. distichantha* and *W. cyathiformis*, was considered to indicate the growth phase. Considering that the emergence of sprout occurs when the largest plants reach the adult stage, these results indicate that the selection of specimens of *A. distichantha* and *W. cyathiformis* with sprout could improve relocation since they would have reached a compatible development to withstand the relocation stress.

The results indicated that *A. distichantha* might have greater adaptability after relocation than *W. cyathiformis*. However, as mentioned earlier, survival rates of both species were similar to those previously published for other relocated bromeliads. It is worth adding that the relocation form adopted for these species (i.e., epiphytic or terricolous) could contribute to attracting pollinators, seed production, and the establishment of new populations since *W. cyathiformis* is one facultative bromeliad visited by birds (Cestari 2009), pollinated by hummingbirds (Kaehler *et al*. 2005). The facultative *A. distichantha* (Mania 2010) can be pollinated either by bees or hummingbirds (Scrok & Varassin 2011). Considering pollination, Varassin and Sazima (2000) observed the hummingbirds *Phaethornis eurynome* and *Ramphodon naevius* pollinating bromeliads in the lower strata of the forest.

The results of this work corroborated that these facultative epiphytic bromeliads can be simultaneously relocated to soil and tree trunks. However, the survival of the species to relocation varied, showing a different capacity to adapt to the physical and physiological condition imposed by the removal from their natural environment. These differences are probably due to the existence of various genetic predispositions related to the mechanisms of tolerance to relocation. The factors associated with the individual morphological characteristics, which have probably determined the survival percentages, should also be considered since both species were in good phytosanitary conditions during their maintenance in the nursery. Lunelli *et al*. (2015) observed that epiphytes have diverse responses when transplanted and recommend studying the species' biology to monitoring relocation.

We conclude that the simultaneous relocation of *A. distichantha* and *W. cyathiformis* as epiphytes and terricolous is feasible. However, relocation to soil can lower implantation costs during the rescue by significantly reducing the labour involved in relocating the bromeliads.

Table 4. Observed means and medians of leaf number in each observation period and over time as a function of the relocation form (terricolous and epiphytic) of the bromeliad *Witrochia cyathiformis* (Vell.) Rudder in an area of Montane Dense Ombrophilous Forest in Parque Estadual da Cantareira, São Paulo, São Paulo State, Brazil. The same lowercase letters in a column indicate non-significant differences between the leaf number as a function of relocation form (terricolous and epiphytic), and the different capital letters in line indicate significant values between the leaf numbers over time.

Relocation form	Time (days)														
	0			252			287			350			371		
	Mean	**Median**		**Mean**	**Median**		**Mean**	**Median**		**Mean**	**Median**		**Mean**	**Median**	
Terricolous	13.93	6.00	Aa	5.70	6.00	Aa	5.43	6.00	Aa	5.23	6.00	Aa	5.23	6.00	Aa
Epiphytic	13.37	13.00	Aa	7.13	8.00	Ba	6.93	6.50	Ba	5.83	5.50	Ba	5.83	5.50	Ba

Table 5. Observed means of the sprout number in each observation period and over time as a function of the phenological stage (vegetative and reproductive) inside the relocation form (terricolous and epiphyte) of the bromeliad *Aechmea distichantha* Lem. in an area of Montane Dense Ombrophilous Forest in Parque Estadual da Cantareira, São Paulo, São Paulo State, Brazil. The same bold lowercase letters in a column indicate non-significant differences between the sprout number as a function of phenology within the terricolous relocation form, and the same italic lowercase letters in column indicate non-significant values between the sprout number as a function of phenology within the epiphyte relocation form, and the same capital letters in line indicate non-significant values between sprout number over time.

Phenology	Relocation form	Time (days)																	
		0		84		112		133		196		252		287		350		371	
Vegetative	Terricolous	0.06	A**a**	0.06	A**a**	0.06	A**a**	0.29	A**a**	0.41	A**a**	0.65	A**a**	0.65	A**a**	0.71	A**a**	0.71	A**a**
	Epiphytic	0.12	**Ba**	0.18	**Ba**	0.18	**Ba**	0.24	**Ba**	0.24	**Ba**	1.06	A**a**	1.06	A**a**	1.12	A**a**	1.12	A**a**
Reproductive	Terricolous	0.46	A*a*	0.46	A*a*	0.54	A*a*	0.77	A*a*	0.85	A*a*	1.00	A*a*	1.08	A*a*	1.08	A*a*	1.08	A*a*
	Epiphytic	0.25	A*a*	0.25	A*a*	0.25	A*a*	0.50	A*a*	0.58	A*a*	0.92	A*a*	1.08	A*a*	1.08	A*a*	1.08	A*a*

Table 6. Observed means and medians of the sprout number in each observation period and over time as a function of the relocation form (terricolous and epiphytic) of the bromeliad *Witrochia cyathiformis* (Vell.) Rudder in an area of Montane Dense Ombrophilous Forest in Parque Estadual da Cantareira, São Paulo, São Paulo State, Brazil. The same lowercase letters in a column indicate non-significant differences ($p > 0.05$) between the sprout number as a function of relocation form (terricolous and epiphytic) and the same capital letters in line indicate non-significant values between the sprout numbers over time.

Relocation form	Time (days)															
	0		84		133		196		252		287		350		371	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Terricolous	0.43	0.0 Aa	0.43	0.0 Aa	0.33	0.0 Aa	0.40	0.0 Aa	0.37	0.0 Aa	0.40	0.0 Aa	0.0 Aa	0.0	0.37	0.0 Aa
Epiphytic	0.48	0.0 Aa	0.52	0.0 Aa	0.30	0.0 Aa	0.27	0.0 Aa	0.43	0.0 Aa	0.33	0.0 Aa	0.0 Aa	0.0	0.33	0.0 Aa

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Shoey Kanashiro: Substantial contribution in data collection, analysis, interpretation, and manuscript preparation. Contribution in data analysis, interpretation, and manuscript preparation; Formal analysis; Contribution to critical revision, adding intellectual content; field experiment setup substantial contribution in data collection.

Vivian Tamaki: Substantial contribution in data collection, field experiment setup.

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Nelson Augusto dos Santos Junior: Substantial contribution in data collection, field experiment setup, contribution to critical revision, acquisition of the financial support for the project leading to this publication and project administration.

Conflicts of interest

There is no conflict of interest.

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