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Cover photographs. Front: *Tillandsia multicaulis*. Photograph by Marcel Lecoufle. **Back**: *Tillandsia leiboldiana* Photograph by Marcel Lecoufle.

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Towards an Understanding of Diversity Patterns and Conservation Requirements of the Bolivian Bromeliaceae

Pierre L. Ibisch[1] , Christoph Nowicki[2] & Roberto Vásquez[3]

Abstract

Are the Bolivian bromeliads candidates for 'Noah's ark'? What kind of conservation action do they require? Can answers to these questions be derived from the preliminarily known diversity patterns? In this paper we give an idea of some important issues that arise from first data base consultations. Currently, 296 species of bromeliads are known to occur in Bolivia. The Bolivian bromeliad diversity is a product of explosive speciation in some genera and of Bolivia occupying a location where many biomes meet causing high ecological and biogeographical diversity. 49% of all species are epiphytes, and 22.2% of these are endemics. Regarding terrestrial species, endemism percentage is much higher at 67.8%. The Dry inter-Andean valleys and Humid Yungas forests are almost equal in terms of total species diversity. With regard to endemism, the dry valleys are much more important. Highest species diversity is observed in the mid-elevations. Further spatial diversity and endemism patterns are shown and discussed. It is indicated that none of the Bolivian bromeliads must be regarded as either endangered or vulnerable. Highest risks exist for endemic montane rain forest species. In the Andean Yungas rain forests, which occupies less than 5% of the Bolivian territory, about 30% of the country's bromeliad species are concentrated. Fortunately, more than 35% of this area is in protected areas. Finally, recommendations for bromeliad conservation are given.

Introduction

The biodiversity of Bolivia, until quite recently, has been neglected and underestimated. Although the bromeliads in the past received more attention than other families of Bolivian plants they are still largely under explored. The recent phase of more intensive exploration and studies of diversity patterns started with Ibisch's (1996) analysis of the Bolivian epiphytes. Recent milestones were the research of Michael Kessler (Kessler in press a, b, Kessler & Krömer 2000) and the actualized checklist compiled by Krömer et al. (1999). The latter catalyzes and stimulates floristic inventory and diversity research. It also facilitated the recent CD-ROM of the Bolivian bromeliads (Ibisch & Vásquez 2000) and the study presented in this paper. Finally, we begin to understand that the bromeliad

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Figure 1: In Bolivia, *Puya* is the most endemic genus. *Puya tunariensis* is a typical example of an endemic saxicolous species resistant to land-use changes and fire that probably never will face any conservation problems.

Pierre Ibisch

Pierre Ibisch

Figure 2: *Deuterocohnia longipetala* (with *Cereus kroenleinii*, Cactaceae) at one of the northernmost sites of the genus on a tropical inselberg within Bolivian lowland rain forest. These azonal habitats have reduced conservation problems as they are not directly affected by land-use changes.

Figure 3: *Pitcairnia heydlauffii*, recently described local endemic of the Chapare rain forests, is a forest dependent species that can suffer extinction if deforestation affected its range. Currently, its habitat is covered by the Carrasco National Park.

Pierre Ibisch

Figure 4: The bromeliads of the montane Yungas rain forests will be the most endangered species if deforestation advances as in the Tablas Monte valley (Chapare, Cochabamba) which originally was covered by a very humid and species-rich forest.

Pierre Ibisch

diversity of this country should be similar to countries like Peru or Ecuador. Current rates of descriptions of new species or discoveries of new records may be higher than in other countries. Even some genera such as *Araeococcus*, *Deinacanthon* or *Greigia*, have been recorded only a few years ago.

As representatives of an institution dedicated to the conservation of biodiversity we are not exclusively thrilled by pure taxonomic and floristic facts. We try to interpret available data to obtain tools for priority setting and specific or regional conservation planning and action. Of course, we still must learn more about spatial patterns of diversity, distinctiveness, representation, endemism or potential threats for small populations of bromeliads. However, important conservation decisions must and will be made right now. In the next few years all the main areas to be protected in Bolivia will be defined and the probability and political viability of establishing new areas has already started to decrease. Another starting point of our studies was the WCMC world's plant red list (Walter & Gillett 1998) which cites many Bolivian bromeliads among the endangered or vulnerable plants of the world (e.g. 4 species of *Fosterella*, 34 species of *Puya*, 6 species of *Tillandsia*). Is it that serious? Ibisch (1998) has already expressed doubts about the subjective red list classifications and tried to propose a more objective method.

Are the Bolivian bromeliads in 'Noah's ark'? Must they be candidates for the 'ark'? What kind of conservation action do they require? Can answers to these questions be derived from the preliminarily known diversity patterns? Currently, in the framework of several interdisciplinary projects, we are trying to understand patterns of Bolivian diversity, promote knowledge of Bolivian bromeliads and other plants applying taxonomic, ecological and molecular methods. We use modern tools like Geographic Information Systems (GIS) for integrative mapping of biological data and socioeconomic variables in order to predict habitat and species conservation status. In this paper we give an idea of some important issues that have arisen from first data base consultations.

Methods

Based on the recently published checklist (Krömer *et al.* 1999) as well as on own new data on bromeliad occurrence (originally compiled for Ibisch & Vásquez 2000, now updated, using Vásquez & Ibisch 2000a and own unpublished data), especially in the different ecoregions of Bolivia and outside Bolivia (mainly based on Smith & Downs 1974, 1977, 1979 and TROPICOS database of the Missouri Botanical Garden), we can summarize some data on diversity and distribution patterns of Bolivian bromeliads. We used Microsoft Access database which permits diverse cross queries. A National Conservation Value (NCV) was calculated for all species applying the method proposed by Ibisch (1998; already used defining conservation status of Bolivian orchids, Vásquez & Ibisch 2000b, and Bolivian epiphytic cacti, Ibisch *et al.* 2000). The NCV assigns numbers to each species reflecting known species range size, abundance in Bolivia, conservation status of the habitats, specific use, and

ex-situ cultivation.

We define diversity as the number of species that coexist in a certain space. Endemism, if not differentiated, refers to the Bolivian territory. In order to quantify the degree of distinctiveness of the different dry valley areas of Bolivia we introduced a new value: the *mean distinctiveness* of a given area is the reciprocal of the sum of its Sørensen[4] values when the area inventories are compared with all others. The distinctiveness of an area which is mainly caused by the uniqueness of the composition of the biological communities is regarded to be as important as diversity or endemism when identifying areas important for conservation.

Table 1: Known and predicted taxonomic diversity and endemism of Bolivian bromeliad taxa.

Taxon	No. of recorded species	No. of predicted species	No. of currently known endemics	Endemism percentage
Tillandsia	**99**	**<120**	37	37,4%
Puya	58	<80	**48**	**82,8%**
Fosterella	24	30	17	70,8%
Pitcairnia	19	25	10	52,6%
Guzmania	17	25	2	11,8%
Racinaea	12	<20	2	16,7%
Billbergia	11	<15	5	45,5%
Deuterocohnia	11	<20	5	45,5%
Aechmea	10	<15	1	10%
Vriesea	9	10	0	0%
Dyckia	7	15	3	43,9%
Bromelia	6	<8	2	33,3%
Greigia	3	5	3	100%
Werauhia	3	<5	1	33,3%
Mezobromelia	2	2	0	0%
Ananas (without *comosus*)	1	1	0	0%
Araeococcus	1	1	0	0%
Catopsis	1	1	0	0%
Deinacanthon	1	1	0	0%
Pseudananas	1	1	0	0%

[4] $D = \frac{1}{\overline{S} \times 100}$ with D = mean distinctiveness, $\overline{S}$ = mean value of all Sørensen indexes; Sørensen index = S $\frac{2a}{(b+c)}$;

a = number of common species of area 1 and area 2, b = number of species of area 1, c = number of species of area 2.

Figure 5: In the Bolivian lowlands many bromeliads inhabit azonal sites or are species that adapt well to land-use changes. *Bromelia hieronymii* is abundant in over-grazed dry chaco forests.

Pierre Ibisch

Pierre Ibisch

Figure 6: On a national scale, *Tillandsia usneoides* is the most heavily used bromeliad. Before Christmas, in the largest cities La Paz, Cochabamba and Santa Cruz, considerable quantities are sold for ornamental purposes. However, this use probably does not threaten the populations.

Bromeliaceae total	**296**	**up to 400**	**135**	**45,6%**
Pitcairnioideae	124	<170	**83**	**66,9%**
Bromelioideae	34	<50	11	32,4%
Tillandsioideae	**143**	**<180**	41	28,7%

Results

TAXONOMIC DIVERSITY AND ENDEMISM

Now, 296 species of bromeliads are known to occur in Bolivia (Krömer *et al.* 1999: 281 spp.). In Table 1 we present the number of recorded species, subjective estimates of potential species numbers and information on endemism of all genera and subfamilies.

The genera *Tillandsia, Puya* (Figure 1) and *Fosterella* belong to the most diverse and endemic genera. The two latter ones have secondary or primary diversity centers in Bolivia. The Bolivian bromeliad diversity is the product of explosive speciation in some genera and of Bolivia being a space where many biomes meet thereby causing high ecological and biogeographical diversity. Several genera reach their southernmost edge of range in Bolivia (*Racinaea, Catopsis, Mezobromelia, Werauhia*). Others, including *Deinacanthon, Deuterocohnia*, (Figure 2) reach their northernmost or westernmost range (*Araeococcus*, *Dyckia*). More than 15% of the currently known species have been described in the 1990's (39 spp.), several more await description (own unpublished data).

In analyzing endemism patterns it is interesting to consider the life style. On the one hand, 49% of all species are epiphytes, and 22.2% of those are endemics. 62.5% of them have a wide range, i.e. they are found in more than one other neighboring country. On the other hand, 67.8% of all terrestrial species are endemics, while only 15% have a wide range (as defined before). The same pattern is observed even within the genus *Tillandsia*: 88.2% of all terrestrial (saxicolous) species are endemics, but only 29.4% of the epiphytes are. Even when we compare the endemism percentages of saxicolous and epiphytic gray *Tillandsia* species exclusively from dry inter-Andean valleys the difference is significant: 56.5% vs. 28.6%, respectively! Obviously, the relationship between predominant life styles and taxa has a strong influence on the statistics of the subfamilies: Pitcairnioideae show 66.9% endemism, and less than 10% of the species have a wide distribution. In Tillandsioideae it is just the opposite: 28.7% are endemics and 55% have wide ranges. The Bromelioideae, a less species-rich group, is different with having 32.4% endemism and about 55% wide ranging. The genera with the most endemic representatives are *Greigia, Puya* and *Fosterella*.

Spatial patterns of diversity and endemism

Table 2 illustrates the distribution of bromeliad diversity and endemism in the different ecoregions. The Dry inter-Andean valleys and Humid Yungas forests are almost equal in terms of species diversity. With regard to endemism the dry valleys are much more important.

Table 2: Distribution of Bolivian endemics in the different ecoregions.

Ecoregions	No. of endemic species	No. of species (total)	Endemism percentage	Especially promising areas for new discoveries (especially promising genera)	Probability of threats to bromeliad habitats caused by anthropogenic conversion
Dry inter-Andean valleys	54	99	54.5	Santa Cruz, Chuquisaca *(Puya, Tillandsia)*	Very low
Humid Yungas forests	32	**107**	29.9	Cochabamba: Northern Ayopaya, Cocapata; La Paz: Madidi; Santa Cruz: inner Amboró *(Fosterella, Guzmania, Pitcairnia, Racinaea, Tillandsia)*	High
Tucuman-Bolivian forests	17	39	43.6	Chuquisaca *(Fosterella, Pitcairnia, Puya)*	High
Ceja cloud forests	16	34	47,1	La Paz: Madidi *(Guzmania, Tillandsia)*	High
High Andean non-forest formations	11	17	**64.7**	Cochabamba southwards *(towards Tarija)* *(Puya)*	Very low
Montane Chaco forest	11	34	32.4	Chuquisaca *(Puya, Tillandsia)*	Low
Northern humid Amazon forests and Andean foothills	8	31	28,1	Cochabamba: Isiboró-Securé; La Paz: Madidi; Pando *(Fosterella, Pitcairnia)*	High
High Andean forests	7	12	58.3	-	Very low
Evergreen humid forest of the Brazil. shield and Cerrado	6	28	21.4	Santa Cruz: montane Cerrado (e.g. Serranía Sunsas); northern inselbergs *(Dyckia, Fosterella, Pitcairnia)*	Medium to very low
Dry Chiquitano forest	5	26	19.2	Inselbergs *(Dyckia, Fosterella, Pitcairnia)*	Very high
Dry Chaco forest	4	25	16	-	Low
Transitional humid Amazon forests	0	16	0	Cochabamba: Isiboró-Securé, Bosque Chimanes *(Guzmania)*	High
Humid savannas	0	5	0	-	Very low

Analyzing the endemism centers of the most species-rich genera it can be concluded that in the case of *Tillandsia* the dry valleys are of special importance (70% of all endemics; very important: Chuquisaca). Only 13.5% are found in the species-rich Yungas forests. A total of 44% of the Puya endemics are found in the dry valleys (very important are Tarija and Santa Cruz; also High Andean non-forest formations, especially in La Paz). The endemic *Fosterella* species are mainly found in humid Yungas forests (41.2%).

For the importance of the dry valleys it is interesting to differentiate the diversity patterns in the distinct valley regions (here provisionally using political department limits):

Table 3: Analysis of relative diversity, endemism importance and distinctiveness of Dry inter-Andean valleys' bromeliads.

	No. of species in *dry valleys* of department	No. of Bolivian endemics in *dry valleys* of department	No. of local endemics restricted to *dry valleys* of department	No. of species in department	No. of Bolivian endemics in the department	Mean distinctiveness value of *dry valley's* bromeliads
Chuquisaca	**54**	**21**	8	67	25	0.13
Tarija	50	16	**9**	63	20	**0.20**
Santa Cruz	41	13	5	126	49	0.14
Cochabamba	39	14	4	118	39	0.11
La Paz	36	12	4	**162**	**58**	0.17
Potosí	28	10	2	20	12	0.17

In the Chuquisaca department we find the major diversity and highest rates of endemism, followed by the southernmost departments of Bolivia and Tarija. Species numbers are comparable in Santa Cruz, Cochabamba, La Paz and Potosi. Calculating the mean distinctiveness the Tarija department is especially prominent. Cochabamba, in the center of the country, has the least unique dry valley bromeliad flora.

Table 4: Analysis of relative diversity and endemism importance of Yungas rain forests' bromeliads.

	No. of species in Yungas in department	No. of Bolivian endemics in Yungas in department	No. of local endemics restricted to Yungas of department	No. of species in department	No. of Bolivian endemics in the department
La Paz	96	27	12	162	58
Cochabamba	59	13	3	118	39
Santa Cruz	12	12	1	126	49

If we consider the humid rain forests of the Yungas (only present in La Paz, Cochabamba and Santa Cruz, see Table 4) we observe a latitudinal gradient: diversity is decreasing with increasing latitude. In the case of the dry valleys this gradient was almost inverse. The absolute area of existing habitat, the geodiversity, and the rate of geographic fragmentation are important factors. The La Paz Yungas cover a larger area than those in Cochabamba or Santa Cruz. Furthermore, the La Paz Yungas are characterized by several complex river systems which fragment humid forest habitats. However, some latitudinal tendency also should exist because many humid-forest-genera are elements of the northern Andes which reach their southern range limit in Bolivia, sometimes hardly touching its territory.

The Bolivian bromeliad diversity mainly is concentrated in the Andes. Therefore, it is worthwhile differentiating diversity patterns along the altitudinal gradient. Figure 7 shows that highest species diversity is observed in the mid-elevations (between 500 and 2,500 m). In the humid Yungas forests the maximum is located in lower altitudes (1,000-1,500 m) than in the Dry inter-Andean forests (2,000-2,500 m). Endemism percentage increases with altitude, being especially low below 500 m. All endemics of the Bolivian lowlands are found exclusively in the ecoregion of the Chiquitano Dry Forest. In the most species-rich altitudes of the Yungas the endemism percentage is lower (23-33%) than in the Dry inter-Andean forests (35-55%)

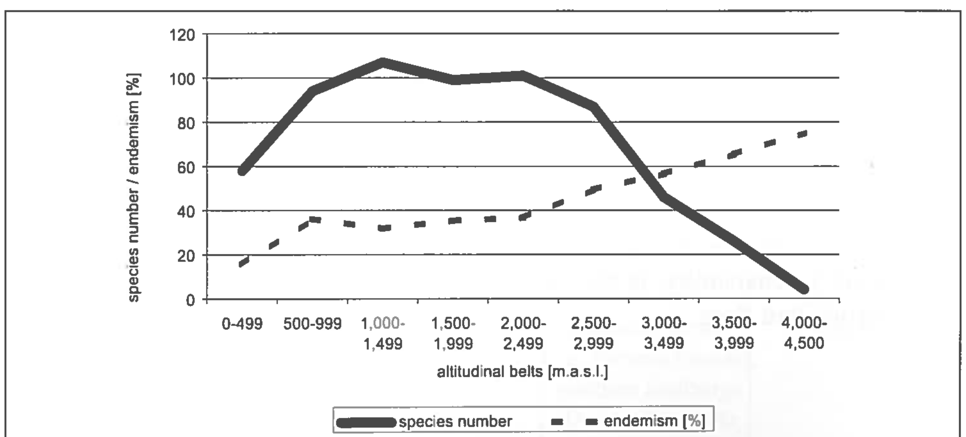

Figure 7: Altitudinal patterns of species richness and endemism of Bolivian bromeliads.

Without being able to present the complete list of the species and their National Conservation Values (NCV) we can indicate that none of them really must be regarded either as endangered or vulnerable. As the applied methods heavily reflects known range size one third of the species merits special attention for being endemic to Bolivia - however, endemic does not mean endangered (see discussion). When considering the 25 species that are characterized by the highest NCV, all are local endemics. Several of them are recently discovered and poorly known species (e.g. *Fosterella chiquitana, Tillandsia kessleri, Greigia atrocastanea, Guzmania remediosensis*). There is the hope that their ranges after some more research may be larger than they appear to be now. About 40% are terrestrial species of humid habitats, 36% are epiphytes, most of them occur in the La Paz department (44%), and almost 70% are species of the Andean Yungas or foothill rain forests.

Discussion

Diversity and endemism - taxonomic and spatial patterns

Regarding the high diversity of Bolivian bromeliads, it is an important fact that a considerable number of tropical and subtropical genera are represented in Bolivian ecosystems. Main causes are an enormous diversity on the ecoregion and ecosystem level, which is a consequence of the geographic position of Boliva in the center of South America, shaped by complex climatic transitions, and the turbulent climatic history. Kessler (in press a) points out that the highest alpha diversity is found at mid-elevations in humid areas and that northern Bolivia has higher alpha diversity than the southern part of the country. However, it is remarkable that in dry areas southern Bolivia is more species-rich than the north. That may be related to the total habitat area available. Species of arid habitats, terrestrials and epiphytes respectively, are more endemic than their equivalents in more humid areas possibly due to geographical isolation effects: smaller fragmented dry valley systems vs. larger continuous humid forest belts.

Groups with more efficient reproduction mechanisms in a lesser extent tend to have restricted ranges and adaptive radiation (wide distribution of Bromelioideae with birds and mammals dispersal vs. Tillandsioideae with long distance wind dispersal) (Ibisch 1996, Kessler in press b). Following Kessler (in press b) fruit types, apart from elevation and habitat area, show the most significant relationship with range sizes of the taxa. The same author discusses the problem of different range sizes in terrestrial and epiphytic species as follows: "Ibisch et al. (1996) suggested that the tendency towards larger ranges among epiphytic bromeliads was the result of enhanced ecophysiological plasticity among epiphytes relative to finer niche-tuning among terrestrial species, facilitating separation and subsequent speciation. While these factors may certainly play a role, the results of the present study suggest that epiphytic species may simply have larger ranges because they have diaspores predisposed for long-distance dispersal." If this is true, why are terrestrial *Tillandsioideae* with the same kind of diaspores more endemic than their epiphytic sisters? Why is there such a marked difference between the endemism percentages of saxicolous and epiphytic species of gray tillandsias of the Dry inter-Andean valleys? In the Dry valleys the rock habitat is practically as continuous as the canopy habitat. The fragmentation of the Dry Valley ecoregion affects both groups. Still, there seems to be a relationship between lifestyle and endemism (Ibisch 1996, Ibisch *et al.* 1996).

Independently from this discussion it is important to recognize that, especially in the Andes, some groups with less ecophysiological plasticity and less efficient dispersal mechanisms experience a dynamic speciation responding to some geophysical factors; in some genera such as *Puya* or *Fosterella* many species should be quite young.

For conservation purposes it is important that diversity centers (especially the humid Yungas) are not necessarily identical with endemism centers (dry valleys). And both do not necessarily indicate where the most distinctive communities (southern dry valleys) are found. So, the bromeliad analysis confirms that for the identification of conservation priority areas we should consider as many variables as possible. It must be confirmed in the future to what extent the patterns of the better known bromeliads indicate patterns of other, rather unknown groups.

Conservation status

The conservation status analysis shows that most species, up to now, are not threatened. Some existing studies on conservation status (e.g. World Conservation Monitoring Center, Walter & Gillett 1998) or species extinction directly deduce threat categories from endemism, e.g. in the case of species of *Fosterella* spp. (3 endangered / 1 vulnerable), *Puya* spp. (34 / 5), *Tillandsia* spp. (6 / 3). In the case of Bromeliaceae, especially in non-forest land adapted Pitcairnioideae, this is inadmissible. Most endemic Pitcairnioideae do and will survive anthropogenic land-use changes. In the dry valleys and the Andean non-forest formations local endemics coexist with human activities at least for many centuries. The terrestrial non-saxicolous species mostly are quite fire and grazing resistant, e.g. *Puya raimondii*, a species not as endangered as supposed by many authors (Ibisch *et al.* 1999; own unpublished data). The saxicolous species are the last to suffer from anthropogenic habitat conversion (Figures 1, 2). Contrarily, many are benefited by expansion of degraded lands with poor soils and scarce vegetation (Ibisch 1998).

The only species that are potentially threatened are those occurring in the Andean Yungas rain forests (Figure 3). Here, on less than 5% of the Bolivian territory about 30% of the country's bromeliad species are concentrated. Rain forests tend to disappear in many regions (Figure 4), however in the Bolivian Yungas there is still hope: conservation efforts in this area have advanced well; more than 35% is covered by protected areas (Ibisch *et al.* in press) and an even

higher percentage is characterized by a good or very good conservation status (Araujo & Ibisch 2000). In the Bolivian lowlands (Figures 2 and 5) where most endemic species are restricted to some specific azonal sites probably none of the species will suffer from severe conservation problems.

Some endemic dry valley species, especially of the genus *Tillandsia*, could possibly be endangered by illegal harvesting for ornamental purposes. Utilizing the scarce information currently available, we suppose that for now at least, none of the Bolivian species have been endangered by trading activities (Figure 6).

Bromeliad conservation action required?

First of all we suggest that, for the moment, Bolivian bromeliad species should not appear on any red lists. Red list species are not better species and long red lists are not better red lists. Conservationists must take care to try to avoid exaggeration when warning the public about conservation problems. The conservation issue is not necessarily a high priority with the general public and people may start to say: "You warned us about extinction decades ago and now there are still so many plants and forests that possibly the situation is not as bad as you are constantly trying to tell us ..."

Currently, there is no urgent action required. Most rain forest bromeliad species must be conserved by habitat protection. We think that most of them will be fine when the existing protected areas really will be implemented. Several species of drier habitats must be protected against illegal harvesting for ornamental use. The best way to achieve this is to start propagation programs, e.g. involving tissue culture techniques as now started by our F.A.N. laboratory "germoFAN". A fundamental activity for propagation are *ex-situ* collections that make available the Bolivian bromeliad diversity to taxonomic and reproduction research. F.A.N. is establishing the largest and only scientific bromeliad collection within Bolivia. Legislation must be improved facilitating *ex-situ* plant reproduction and commercialization. Perhaps in some cases monitored wild harvesting would be possible, but currently there is no legal basis for that kind of activity.

Although they are not among the most endangered taxa, bromeliads should be explored as flagship species for conservation of Bolivian biodiversity. Many of them are beautiful and conspicuous representatives of the unique and endemic flora of Bolivia (e.g. Figure 3) and could help promote a better appreciation for the native flora. In the case of *Puya raimondii*, we have identified an opportunity for bromeliad-based nature tourism that can support the *Puya* populations and benefit local communities. When tourists come to Bolivia wanting to see puyas and other bromeliads and are willing to pay for these experiences, the local peasants will be stimulated by this added value of the native flora.

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Santa Cruz, Bolivia

Tillandsia juerg-rutschmannii: A Footnote

Virginia Guess and Robert Guess

In a recent issue of this Journal[1], we reported on our first observations of *Tillandsia juerg-rutschmannii* Rauh in Cañon del Sumidero, to date, its only known habitat. Since then, we have periodically visited the canyon in Chiapas, Mexico, in order to monitor this endemic species.

At our initial visit in 2000, we saw many plants nearing maturity, but only a few with fully developed inflorescences. One year later, in the same month as in the preceding year, several hundred flowering plants were visible along both faces of the canyon. The pink, pendulous inflorescences of *T. juerg-rutschmannii*, silhouetted against the limestone cliffs, could be seen either by standing at the rim and looking with binoculars across the gorge, or from a launch on the Rio Grijalva. They ranged from the top of the canyon to just above river level, a distance of some 800 meters. Boatmen familiar with the flora of this region remarked that this was one of the most unusual displays they had seen in many years.

Our recent sightings help to confirm that *T. juerg-rutschmannii* consistently flowers from mid-November to the end of December, and that the number of plants in flower varies dramatically from year to year. Furthermore, they verify Juerg Rutschmann's (1984) initial comment that this is a highly synchronized plant community. We guarantee that a visit to Cañon del Sumidero coinciding with the flowering of this *Tillandsia* promises an awesome prospect.

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Santa Barbara, California

[1] J. Bromeliad Soc. 50(3):99-104

Robert Guess

Figure 8. The inflorescence of *Tillandsia juerg-rutschmannii* first appears erect. Since the plants mature on steep cliffs where observations are extremely difficult, this initial phase is rarely visible in the natural habitat.

Robert Guess

Figure 9. Within a few weeks, the inflorescence of *Tillandsia juerg-rutschmannii* develops a pink blush and begins to arc downward. The pendulous inflorescence of *Tillandsia juerg-rutschmannii* attains a length of 150 centimeters or more.

Bromeliad Exploring in the Lesser Antilles

Jeffrey Kent

Our hearts were pounding, our legs were aching, and we were all wet and chilled as we approached the famous Boiling Lake in Morne Trois Pitons National Park on the island of Dominica. The sulphurous fumes became more annoying after a 3½ hour march through Desolation Valley. Our guide had been listening intently to my "bromeliad ramblings" during the journey as I attempted to explain the differences between *Glomeropitcairnia penduliflora* and *Pitcairnia angustifolia*. The former is a true giant in the Bromeliad family reaching a height in excess of 9 feet in flower. This monocarpic bromeliad produces thousands of seeds at anthesis, but no offsets for the enthusiast to separate and grow.

Dominica, a small 10 by 30-mile island located in the eastern Caribbean between Guadeloupe and Martinique is in the Lesser Antilles. The mountainous regions of Dominica receive in excess of 300 inches of annual rainfall and has more than six peaks exceeding 3,000 feet in elevation. Called the "Garden Island", Dominica possesses about 18 species of bromeliads.

Tillandsia utriculata and *T. flexuosa* occur in the dry scrub woodland commonly found on the western coast of Dominica. The two species seem to be especially common near the cities of Portsmouth and Cabrits. While dry scrub woodlands form a widespread habitat on the Island, it is home to very few bromeliad species. For those, one has to journey to the interior mountains.

These interesting mountains form an imposing central spine of the island in a north-south direction. Here, above 2,000 feet in the cloud forests, can be found *Guzmania dussii, G. megastachya,* and *G. plumieri*. The former two species may well be synonymous. Moving up into the Desolation Valley region at 2,500 feet one can find the endemic *Pitcairnia micotrinensis* growing terrestrially amongst the fumaroles. This bromeliad seems to love the acidic soils laden with sulfides and oxides of iron. *Pitcairnia angustifolia* can also be found in the montane forest, but not directly in the Desolation Valley area. Also found in this cool cloud forest environment is a dwarf yellow-bracted form of *Mezobromelia capituligera*.

Two color forms of the spectacular *Aechmea smithiorum* occur in the lower montane rainforest. We saw the more common lavender form growing high in *Ficus* trees throughout the island while we only saw the rare white form in collections on the island. Also of note is the green-bracted *Guzmania lingulata*. *Werauhia ringens* and *W. gladioliflora* were ubiquitous here. This forest occurs between 800 and 2,000 feet and is found beneath the mountain peaks throughout the island.

The most notable thing about the flora of Dominica is the characteristic of the bromeliads to be self-pollinating. This characteristic was also notable on the islands of Trinidad and Tobago. The copious production of seed without pollinators ensures that very uniform progeny, ideally suited to the existing habitat, are always produced. When a cataclysmic event occurs, such as a Hurricane David, that destroys extensive habitat on the island, bromeliads can more easily recolonize the regions where they originally occurred. Stable environments are more apt to produce great species diversity, encouraged by external cross-pollination. Only one bromeliad, *Guzmania dussii* (figure10), possessed a long yellow flower tube suitable for pollination by hummingbirds. Of the four species of hummingbirds seen on the island: the Antillean Crested (*Orthorhyncus cristatus*), and the Blue-Headed (*Cyanophaia bicolor*), are most often observed, usually while pollinating the non-native ginger's and heliconias!

Tobago

My collecting permit secured, I contacted Mr. William Trim of the Forestry Department on the island of Tobago. Our destination was the Main Forest Reserve to do an extensive study of the local bromeliads. This would later be compared to those I would collect on Trinidad.

Tobago formed the first Forest Reserve (not a national park) in 1765 to protect the island's watershed beneath the steep hillsides in order to grow sugar cane successfully. The main ridge on the northern section of the island reaches 2,200 feet and within this region flourishes a lowland tropical forest. In 1963, Hurricane Floyd ravaged 95% of the forest canopy on the windward side of the island. Rainfall here averages nearly 100 inches annually which allows certain bromeliad species to flourish. The rarest species include the mesic *Guzmania lingulata* and *Vriesea splendens* var. *formosa*. Found in only a few riparian drainages, these two delicate epiphytes hover on the brink of extinction. Compared to neighboring Trinidad, few young seedlings could be seen and then only in the most protected areas of the island. *Aechmea dichlamydea* var. *dichlamydea* (figure 12) was undoubtedly the most common decorative species in flower during my trip here in January, 2001. The huge 1 meter (5 ft) spikes of lavender and red formed brilliant lanterns to guide my way through the forest. At slightly lower elevations, *Aechmea aquilega* and *Aechmea nudicaulis* were commonly seen in flower in the larger trees.

Normally a hike along the "knife edge" of the ridge yields new and different species, but here in Tobago, 28 years after Hurricane Floyd, only a species of *Werauhia* could be located. Only 5% of the original forest remains and these trees mostly lacked epiphytes other than *Ae. dichlamydea* var. *dichlamydea*.

Outside of the main forest reserve up to 7 bromeliad species (*Aechmea nudicaulis, Ae. aquilega, Tillandsia bulbosa, T. fasciculata, T. utriculata, Catopsis floribunda,* and *Guzmania monostachia*) can be found growing on large mango trees at 1,500 feet elevation. These ubiquitous, self-seeding, bromeliad

Figure 10. *Guzmania dusii*

Jeffrey Kent

Figure 11. *Guzmania plumieri*

Jeffrey Kent

Figure 12. *Aechmea dichlamydea* var. *dichlamydea*

Jeffrey Kent

Figure 13. *Vriesea splendens* var. *formosa*

Jeffrey Kent

"weeds" occupied every available niche. This area was cleared for agriculture 25 years ago and the species make-up is typical for this elevation in this part of the Caribbean.

Trinidad

Trinidad is a large island located Southwest of Tobago. An extension of the Andean mountain chain continues eastward from Venezuela and continues through Trinidad to Tobago before its terminus on the continental plate. Here on Trinidad, this mountainous extension reaches to elevations over 3,000 feet and has produced a highly diverse population of bromeliads on the island. Many more species occur on Trinidad than Tobago. Future studies may yield more information about endemism and bromeliad biodiversity between these islands and mainland bromeliad populations.

We made a brief, one-day trip above the city of Loango, hiking about 3 miles into the mountains and reaching about 3,000 feet in elevation west of the forest reserve of El Cutuche. The lowland tropical rainforest was mostly intact above 500 meters since they have not encountered any hurricanes in recent times. The rainfall in this region is nearly 150 inches annually resulting in an evergreen forest at elevations above 1,500 feet. Below is a partially cut tropical deciduous forest containing large *Ceiba pentandra* trees sometimes taller than 150 feet.

The tropical deciduous forest contained only epiphytic bromeliads including: *Vriesea bituminosa, Tillandsia gardneri, Guzmania lingulata, Catopsis floribunda* and many other species unidentifiable in the high canopy.

The evergreen forest was resplendent with terrestrial V. *splendens* var. *formosa* (figure 13), found everywhere at the ridgetop of the mountain. Also found here were *V. glutinosa, V. didistichioides, Guzmania lingulata, G. sanguinea, Aechmea fendleri, Tillandsia fendleri,* and some other yet-to-be identified species.

While this wasn't an exhaustive collecting trip, many friends and contacts were made, including a few unwelcome ones such as the chiggers we discovered the next day. I hope to return this June to better identify other species on this island.

Vista, California

Singapore revisited

Derek Butcher

In April this year I received a phone call from my mate at the Adelaide Botanic Gardens asking whether I would like to take a trip to the Singapore Botanic Gardens - all expenses paid - to help them identify their bromeliad collection. This was an offer too good to be missed, but I just had to take my able assistant, who also happened to have been my wife for the past 43 years, along with me. Margaret knows just as much about bromeliad names as I do but is a lot less noisy about it! If you want to find out how the plants got to Singapore you are referred to "Bromeliads in the Singapore Gardens" by Len Colgan in J. Bromeliad Soc. Volume 49 (1999): pp165-7.

Just before the plane landed at Changi Airport we were treated to a propaganda video of what to expect in Singapore. It was very informative and we got excited when the wrought-iron gates of the botanic garden appeared. We then learned that orchestral concerts were held here! No orchids were visible so what hope was there for bromeliads! On the ride to our hotel the Assistant Director of the Singapore Botanic Gardens was duly advised about this omission!

Singapore is an island virtually on the equator with an elevation of about 50 to 100 meters, but is so close to Malaysia on one side and Indonesia on the other that you could not say it enjoys a typical island climate! We went in what is loosely termed the "dry' season where it only seemed to rain for 3 hours each day! 30 degrees centigrade and above was the norm so every Singaporean had an umbrella which alternately provided shade from the sun and protection from the rain.

And so to work - well, THEY called it work - we thought it play, even though it caused perspiration! It is still called the "National Orchid Garden" and still occupies some 3 hectares with the northern 1/8th of it devoted to Bromeliaceae. Unlike the time that Len Colgan visited in1999, this time all the workers were aware of the existence of bromeliads even though orchid workers outnumbered bromeliad workers 20 to 1. Oft was the time when some cheerful soul would say "Hi Uncle Derek!" When you realize that Singaporeans come in all shapes, sizes, colors and creeds, I realized that my immediate family must have been as fecund and promiscuous as neoregelias! So if you ever visit the National Orchid Garden everyone will now be able to tell you where the bromeliads are.

The main problem facing the bromeliad grower in Singapore is the lack of temperature change, not only between night and day, but between seasons as well. The changes in these two areas are often what triggers flowering. Plants not in flower mean difficulty in establishing identification. The plants were, in many cases, large enough to flower so they may need chemical inducement. Many bromeliads only color up at flowering and there was a worry by the locals that the plants were too dull. But as Mr Lee - yet another Orchid Man - stated, the pastel shadings in orchids are just as important as the more strident colors. Plants here will never reach the vibrant colors you see in Florida nurseries full of neoregelias just before sale, or in catalogues.

Perhaps the biggest change in appearance has been in the gray leafed types of the genus *Tillandsia* over the last 6 years or so. This is to be expected. Even plants attached to the smallest piece of wood would die from excess water and it was surprising how so many had survived purely from the intuition of the gardener in having tillandsias dancing on vertical stainless steel wires (nylon disintegrates!). Plans are at hand to have a cool house where moisture and temperature can be controlled. Time will tell if this experiment will work. In any event, while we all try to grow plants in the same environment it may be better for the Singaporeans not to spend too much time on the dry loving species.

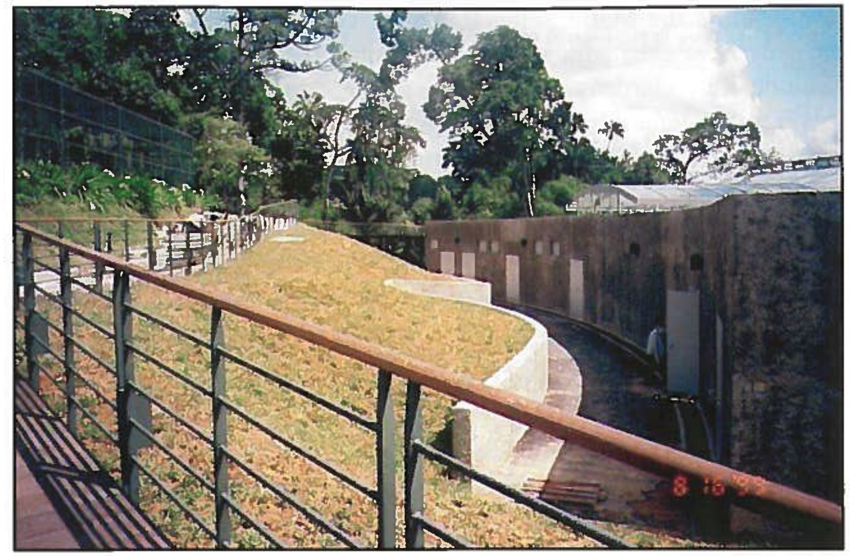
Still, there were just as many success stories using the advantages of the climate. One is based on the variation you can get in the outside edges of bromeliad leaves - this is called the abaxial by Harry Luther! In Adelaide I had thrown out my *Aechmea* 'J. C. Superstar' purely because the inflorescence did not live up to its superstar name. Here it was planted high enough for you to see the delightful pink shades of its leaves.

What drier place in a wet climate could there be than a vertical wall? In the development of the cool house there was an inevitable wall and bromeliads have been used to soften its appearance. Here again abaxials have come to the fore and the clinging roots of the bromeliad show their adaptability (figures 14 and 15).

A group of *Ananas* in fruit were a great talking point, especially with the Europeans who really wondered if *Ananas bracteatus* was edible. They looked askance at the pale Aussie under a coolie hat who told them that all bromeliad fruit is edible. It just depends how hungry you are or whether you liked your fruit crunchy. They smiled, so they must have understood Aussie English.

Many really red *Neoregelia* 'Fireball' were on logs or tree stumps and one slightly larger 'Fireball' type had us stumped. It looked much like the *Neoregelia* 'Fosters Little Gem' we grow in Australia but then we wondered if it could be Hummel's 'Rio Red'. The manifest from 1994 showed we had *Neoregelia* 'Hummel's Red', Hummel's Red Hybrid, and 'Red Rio' which we could only assume was 'Rio Red'! At the end of the article mentioned in the first paragraph the Journal Editor, Chet Blackburn showed how varied in origin the Shelldance collection was. It is easy to see how we have this problem of many names, probably for the same plant! No wonder a predominantly orchid botanical garden staff would have been confused!

The only botanical garden I have been where many of the tombstone labels have not moved away from the correct plant, or the plant has not moved away



Derek Butcher

Figure 14. The wall before bromeliad planting

Derek Butcher

Figure 15. Bromeliads planted on the wall not only provide a more colorful wall but good growing conditions for the bromeliads as well.

from the label, is the Marie Selby Botanical Garden in Sarasota, Florida. Even so, here they have cheated a bit by having only the BRAG plants on display! I even include Kew Gardens in this observation. Maintaining correct naming of plants where the general public is allowed to roam at will is a problem. The Singapore gardens have an increased problem in that it has many orchid experts but few people knowledgeable about bromeliads. We are working towards having a photo index of all living bromeliads linked to correct names on a computer file. We are also working on initiatives to reduce the number of tombstone labels on view because most visitors are interested in the beauty of a plant, not its name.

So if you do happen to visit Singapore, look for a bit of excitement at the Botanic Gardens - and you will not be disappointed. But please take an umbrella!

Fulham, South Australia

Changes in Dues and Postage

In January, the U.S. Postal Service dramatically increased the cost of mail delivery outside of the U.S., but particularly the surface delivery rate. It now costs almost four times as much to ship the JOURNAL by surface mail than it did last year. It actually became less expensive to ship all JOURNALS outside of the U.S. by airmail rather than by surface delivery.

At the same time, it was noted that the cost of membership processing and producing the JOURNAL was not being recovered by our present dues structure. After much discussion, the board decided that a portion of the income from the world conference should be used to hold membership dues down, so no increase in dues was proposed this year. The postage increases were so dramatic, however, that something had to be done to recover more of the cost of shipping JOURNALS outside of the U.S. Instead of charging postage, a new dues structure was proposed. The new rates will take effect on July 1, 2001.

Dues within the U.S.	$30.00 single, $35.00 dual (no change)
Dues outside the U.S.	$40.00 single, $45.00 dual

The dues rate of $40.00 and $45.00 outside the U.S. **will include** the cost of air mail delivery. This is a great bargain for members outside of the U.S. It costs $3.20 per issue to mail to Germany, for example, $3.05 to Brazil and $3.50 to Australia. That means the BSI is absorbing almost half of the actual cost of overseas delivery.

Guzmania loraxiana, a New Species from Panama

Jason R. Grant[1]

[**Ed. Note:** *This article originally appeared in the March-April 2001 issue, Volume 51(2):86-89. However, through no fault of the author's, an intermediate version of the article had been sent to the printers by mistake, not the final version. The version that appeared in print in the March-April 2001 issue both lacked the Latin description required and omitted a paragraph relating to the eponymy of the species. The article is therefore being reprinted here in its correct form.*]

Abstract. A new species related to *Guzmania filiorum* L.B. Sm., G. *patula* Mez & Wercklé, G. *subcorymbosa* L.B. Sm., and G. *virescens* (Hook.f.) Mez var. *laxior* L.B. Sm., is described from Panama as *Guzmania loraxiana* J.R. Grant, sp. nov.

***Guzmania loraxiana* J.R. Grant, sp. nov**. (Figures 16-17)

A *Guzmania patula* Mez & Wercklé cui affinis, sed spicis 1-6, floribus erectis arcte compactis, et capsulis brevioribus differt.

Type. Panama: CHIRIQUI: Reserva Forestal Fortuna, roadside forest 66 km north of Chiriqui, 8° 46' 333" N, 82° 11' 016" W, 28 December 1997, *Grant 97-02660 & Rundell* (holotype US).

Plant short caulescent to acaulescent, found terrestrial, but also likely epiphytic, flowering to 70 cm tall. **Leaves** 30-45 cm long; sheaths elliptic, 7-9 cm long ˘ 3-4 cm wide, elliptical, bright green streaked with prominent reddish-maroon vertical striations on both the upper and lower surfaces, especially on the lowermost leaves of the rosette; blades linear-long, attenuate, 21-38 cm long x 1.0-(1.3-2.3)-3.5 cm wide, bright green. **Scape** erect, to 50 cm long. **Scape bracts** acuminate to linear-long, 3.0-22 cm long, the lower ones foliose, green with vertical maroon-red striations. **Inflorescence** to 10 cm long, bipinnate compound with 2-(3-6) spikes (rarely simple); spikes fasciculate, 6-15 flowered. **Primary bract** (the single bract that subtends the inflorescence), green to yellowish-tan yet tinged with vertical maroon-red striations (like the scape bracts), triangular, apiculate, 19-24 mm long, 14 mm wide (when pressed to one dimension), usually slightly exceeding the length of the floral bract of the first flower of the inflorescence, (but not longer that the sepal of that flower). **Flowers** diurnal, non-fragrant, sessile. **Floral bract** green to yellowish-tan, triangular, obtuse to acute, margin reddish, nerves dotted reddish, 7 mm long ˘ 6 mm wide (when pressed to one dimension), shorter than the calyx. **Sepals** green to yellowish-tan, narrowly-triangular in outline, acuminate, firm, pungent, glabrous, free, thickly-carinate, 15-17 mm long, navicular, 3 mm wide (yet 5 mm

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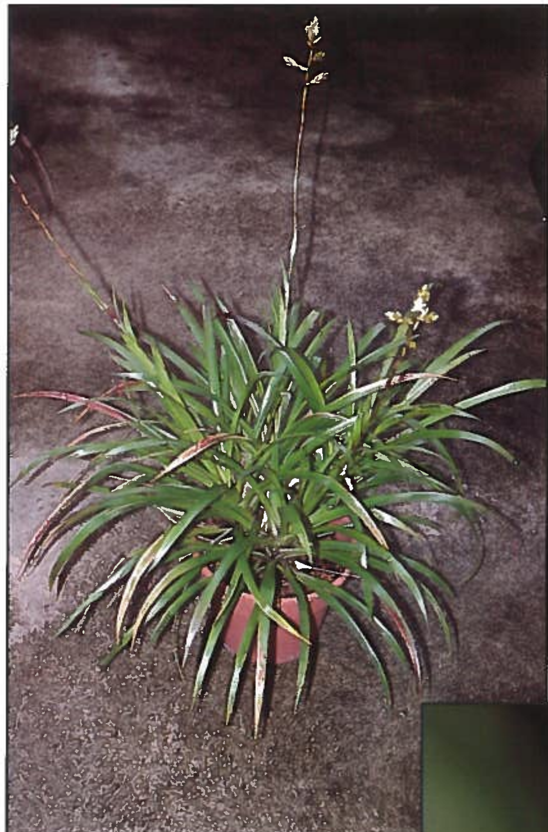

Figure 16. *Guzmania loraxiana* habit.

Jason Grant

Figure 17. *Guzmania loraxiana.* Closeup of inflorescence.

Jason Grant

wide when pressed to one dimension). **Corolla** actinomorphic at anthesis, becoming zygomorphic while fading where the exserted portion one petal remains erect, while other two reflex downward. Petals white-hyaline, ovate, apically acute to retuse, glabrous, unappendaged, 24-25 mm long, 2/3 connate, the portion included within the calyx 2-3 mm wide; the exserted petal lobes 8-9 mm long, 5-6 mm wide at broadest, involute, reflexed at anthesis. **Stamens** white-hyaline, exserted, spreading laterally in a star-like fashion, 24-25 mm long, the exserted portion 6-7.5 mm long, six in number with two series of three stamens, the outer series opposite the stamens, the inner opposite the petals, and twice as many as the petals; filaments 22.0-22.5 mm long, 0.25 mm wide, the exserted portion 4-5 mm long; anthers linear, 2.0-2.5 mm long, 1 mm wide, basifixed. **Pollen** white. **Pistil** 23-24 mm long, exserted to 7 mm; ovary green, ovate, superior, 3-4 mm long, 2 mm wide at anthesis; style white-hyaline, 21 mm long, 0.5 mm wide; stigma 0.5 mm long, 1.0-1.5 mm wide.

Paratypes. Panama: CHIRIQUI: Reserva Forestal Fortuna, 58-64 km north of Chiriqui, primary forest surrounding Lago Fortuna, 18 March 1996, *Grant 96-02423 & Rundell* (US); Reserva Forestal Fortuna, roadside forest 59 km north of Chiriqui, 8° 45' 803" N, 82° 12' 757" W, 13 August 1997, *Grant 97-02836 & Rundell* (US). COLÓN: Near Peluca, km 25.6 from Transisthmian Highway on the road to Nombre de Dios, upstream on tributary to Río Boqueron, 25 February 1973, *Kennedy 2664* (US). PANAMÁ: Gatun Station, S. Hayes 340 (NY); 6 miles above Goofy Lake on road to Cerro Jefe, 3 July 1971, *Croat 15202* (US). VERAGUAS: Valley of Rio Dos Bocas on road between Alto Piedra (above Santa Fé) and Calovebora, primary forest along road, 350-400 m, 29 August 1974, *Croat 27393* (US).

This cryptic species has affinities to *Guzmania filiorum* L.B. Sm., G. *patula* Mez & Wercklé, G. *subcorymbosa* L.B. Sm., and G. *virescens* (Hook.f.) Mez var. laxior L.B. Sm., with which several herbarium collections have been confused, and to which the latter may be contaxonomic. The type of G. *virescens* var. *laxior*, formerly at the U.S. Army Summit Herbarium Canal Zone, has since been transferred to STRI in Panama City, Panama. From its photo at US, it appears to be similar to *G. loraxiana*, yet there are significant differences in the lengths of the floral bracts and sepals. Should the two be recognized as the same entity in the future, the name *Guzmania loraxiana* has priority at the species rank.

Other bromeliads collected at or within 15 km of the holotype include the following 34 species: *Catopsis nutans* (Swartz) Grisebach (96-02644), *Guzmania angustifolia* (Baker) Wittm. (96-02436), *G. calamifolia* André ex Mez (97-02820), *G. circinnalis* Rauh (96-02665, 00-3682), G. *donnell-smithii* Mez ex Donnell Smith (96-02647, 96-02659, 00-3697), *G. plicatifolia* L.B. Sm. (96-02416, 00-3681), *G. rosea* L.B. Sm. (96-02417, 00-3695), *G. spectabilis* (Mez & Wercklé) Utley (96-02646, 96-02661), *Pitcairnia arcuata* (André) André (00-3696), P. geotropa J.R. Grant (96-02645, 97-02816, 00-3684), *P. lyman-smithiana*

Luther (97-02819), *P. nigra* (Carrière) André, *P. rundelliana* J.R. Grant (96-02643, 96-02648, 97-02821, 97-02822), *P. valerioi* Standley (96-02408, 00-3685, 00-3703), *P. wendlandii* Baker (96-02666, 97-02837), Tillandsia insignis (Mez) L.B. Smith & Pittendrigh (96-02407, 96-02418, 96-02656, 00-3680), *T. singularis* Mez & Wercklé (96-02418, 96-02657), Werauhia attenuata (L.B. Sm. & Pittendrigh) J.R. Grant (00-3694), *W. comata* (Mez & Wercklé) J.R. Grant (00-3693), *W. gladioliflora* (Wendland) J.R. Grant (96-02662, 96-02667, 00-3690), *W. greenbergii* (Utley) J.R. Grant (96-02654, 97-02814), *W. hygrometrica* (André) J.R. Grant (96-02411, 96-02445, 96-02655, 00-3692), *W. kupperiana* (Suessenguth) J.R. Grant (96-02422, 96-02663), *W. latissima* (Mez & Wercklé) J.R. Grant (96-02446, 97-02817, 00-3689), *W. notata* (L.B. Sm. & Pittendrigh) J.R. Grant (96-02410, 97-02815, 97-02835, 00-3683), *W. sanguinolenta* (Linden ex Cogniaux & Marchal) J.R. Grant (96-02664), *W. cf. singuliflora* (Mez & Wercklé) J.R. Grant (00-3702), *W. cf. viridiflora* (Regel) J.R. Grant (96-02658, 00-3699), *W. vittata* (Mez & Wercklé) J.R. Grant (00-3700), *W. umbrosa* (Utley) J.R. Grant (00-3701), *W.* sp. A (3686), *W.* sp. B (3687), *W.* sp. C (3691), and *W.* sp. D (3698).

Key *Guzmania loraxiana* and related species in Panama based on herbarium specimens:

A Inflorescence simple, sepals connate; leaves 25 cm long x 2.5-3.0 cm wide; sepals 14-16 mm long; floral bracts 15-30 mm long; capsules 40-45 mm long.. ***G. filiorum***

A typically compound, rarely simple, sepals free............**B**

B Spikes in a dense congested cluster at the apex of the spike, always overlapping another, if all perhaps appearing to originate at the same place in a "sub-umbel"; sepals 9-15 mm long, floral bract 5-12 mm long, capsules 15-25 mm....***G. subcorymbosa***

B Spikes remote with long internodes, rarely ever overlapping another, never appearing as a "sub-umbel"..........................**C**

C Spikes 1-3, flowers loosely positioned in the spike, each typically spreading to horizontal or slightly erect; sepals 9-16 mm long, floral bracts 9-15 mm long, capsules 25-32 mm long...***G. patula***

C Spikes 1-6, flowers tightly compacted, always erect, never horizontal; sepals 12-15 mm long (15-17 mm fresh), floral bracts 9-12 mm long, capsules 21-25 mm long ....***G. loraxiana***

Eponymy: This species is named for the character 'the Lorax' of the same title by Dr. Seuss (Theodor Seuss Geisel). The Lorax (first published in 1971) a classic children's book, is renowned for its lesson of deforestation, habitat preservation and biodiversity. The Lorax represents a moral voice for the forest, whose notable line is: "I am the Lorax. I speak for the trees. I speak for the trees, for the trees have no tongues."

Deforestation is a serious threat to the survival of such rare and delicate species, many still unknown to science. If the forests disappear, who knows what fascinating organisms may be lost forever?

ACKNOWLEDGMENTS

I thank the staffs of NY and US for their hospitality during visits to examine herbarium specimens, and the greenhouse staff at the 'Jardin Botanique de l'Université et de la Ville de Neuchâtel, Switzerland' for their excellent care of my living bromeliad collection.

Neuchâtel, Switzerland

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Bromelain: Part I -History, Biology, and Uses

Samuel P. Fletcher[1] and Gregory K. Brown[2]

In recent years there has been a surging interest in herbal medicinal products in the United States. For example, advertisements for products containing *Ginkgo, Allium,* or *Echinacea* are commonplace, and most pharmacies now devote shelf space to the common herbal dietary supplements. Pharmacies with a broader offering of herbal products, retail catalogs specializing in medicinals, and specialized health food or nutritional stores and web sites market less frequently seen herbal medicinals such as bromelain tablets, capsules, or powder.

Bromelain refers to a group of enzymes obtained from *Ananas comosus,* the pineapple (Omar *et al.*,1978). These enzymes have documented proteolytic activity, that is, they have the ability to breakdown, or digest, proteins. Perhaps you have witnessed the protein digesting attribute of bromelain? If not, try preparing a gelatin-based recipe (e.g., Jello™) with fresh pineapple fruit and/or juice. You will discover that the gelatin does not congeal, remaining a runny-liquid. This is a demonstration of the proteolytic activity of bromelain, which has degraded the gelatin proteins needed to form the gel. Canned pineapple fruit or juice may be used to prepare gelatin because the high temperatures used during the canning process denature, or destroy, the bromelain enzymes.

Bromelain was first described from pineapple juice in 1894 (Chittenden, 1894). In addition to the pineapple (*Ananas comosus*), proteases are reported for two species of *Bromelia; B. pinguin L.* (Asenjo *et al.*, 1942); and *B. hieronymi* Mez (Natalucci *et al.*, 1985). The Pineapple Research Institute of Hawaii, reported that stems, leaves, and fruits of all pineapple varieties contain bromelain and suggested that all species of Bromeliaceae probably contained similar proteases (Collins, 1960). In pineapple, the concentration of bromelain is reported to increase as the plant matures (Heinicke and Gortner, 1957).

Chemical History

As indicated earlier, bromelain does not refer to a single enzyme. As research has progressed towards a better characterization of the proteolytic components found in bromelain it is clear that the protein digesting factors are complex. So complex, that a full characterization has not yet been accomplished. It is well documented, however, that bromelain from fruits and bromelain from stems, the latter being the commercial source (Suh *et al.*, 1992), have different characteristics (Heinicke and Gortner, 1957).

Significant efforts have gone into the characterization of stem and fruit bromelains, however, progress has been slowed by conflicting results. For example, two active components were identified from crude stem bromelain by both Scocca and Lee (1969), and Arroyo-Reyna and Hernandes-Arana (1995). In contrast, Ota *et al.*, (1985) isolated six proteolytic active compounds from stem bromelain, and two from fruit bromelain. Rowan *et al.*, (1990) concluded that three, and perhaps four, distinct proteases were present in stem extracts, and that fruits contain two. Recently Harrach *et al.*, (1995) report detection of at least nine proteolytic components from pineapple stems. It is not clear whether this variation reflects the different testing methods, or natural variation in the pineapple plants examined, or both.

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Bromelain is classified as a member of the cysteine category of proteases (Harrach *et al.*, 1995; Lee *et al.*, 1997). Other enzymes also in this category include papain from papaya (*Carica papaya*) and actinidin from kiwi fruit (*Actinidia chinensis*). Bromelain is remarkably heat stable, retaining proteolytic activity at temperatures (40-60°C; 104-140°F) where most enzymes are destroyed, or denatured (Balls *et al.*, 1941; Natalucci *et al.*, 1985). The optimal temperature for the proteolytic activity of stem-bromelain is reported to range from 35 to 50°C (95 - 122°F) in one study (Greenberg 1955), and 60°C (140°F) in later studies (Natalucci et al., 1985; Suh *et al.*, 1992). These are temperatures well beyond what is normal, or even likely, for live plant tissues. Suh *et al.* (1992) reported fruit bromelain to be fully active at 70°C (158°F), with complete denaturation (i.e., inactivation) of both stem and fruit bromelains at 80°C (176°F). Like temperature, pH, or the relative measure of acidity (pH = O to 6.99) or alkalinity (pH = 7.1 to 14) of a solution, will greatly influence the activity of most enzymes. Early reports indicated that the optimal pH for bromelain proteolytic activity was close to 7, or neutral (Rowan *et al.*, 1990). However, discovery and study of the individual bromelain components found that the pH optima for these varied. For example, Harrach *et al.*, (1995) found one set of bromelain components to have an optimal pH of 4.0 to 4.5, while another component had an optimal pH of 6.5 to 7.0.

Ananain, and comosain are two names that have been used for specific components of pineapple bromelain (Rowan *et al.*, 1990; Lee *et al.*, 1997). Asenjo & Fernandes (1942) suggested the name pinguinain for the protease isolated from *Bromelia pinquin* fruits. Other authors (e.g., Warrach *et al.*, 1995) have devised codes (F1, F2, F3,... etc.) to refer to the different proteolytic factors isolated from bromelain.

Biology

The biological function, or functions, of bromelain are unknown. Collins (1960) suggested that they probably do not act as proteolytic enzymes within the intact, healthy plant, but if they do, then the mechanism preventing self-digestion of other proteins is not known. An attractive hypothesis for the function of bromelain involves anti-herbivore and/or antimicrobial activity. In this hypothesis the pre-attack, undisturbed plant would, as suggested by Collins (1960), have bromelain rendered inactive or sequestered within cellular organelles (e.g., vacuole). Damage to plant tissues by herbivore or pathogen attack would result in the activation or release of bromelains and subject the herbivore (*e.g.* egg, larval or adult) or pathogen proteins to enzymatic degradation.

In other plants, cysteine-category proteases have been linked to natural senescence processes in leaf and other tissues (Buchanan *et al.*, 2000), and perhaps, bromelain has a similar metabolic function. However, as with many interesting and useful plant compounds, biologists have no documentation of natural function, with regard to the plant.

Human Uses

Documented human use of bromelain falls into two general categories, industrial and pharmacological (Table 1). The known industrial applications are relatively few and straight forward, and are not discussed further. Bennett (2000) summarizes ethnobotanical uses of bromeliads, and the medicinal uses of *Ananas* are attributed to bromelain. Overall, the medical/pharmacological uses and respective physiological reactions that bromelain illicits are numerous, complex, and poorly understood (Table 1). For example, there is persuasive evidence that after oral administration (Kolac *et al.*, 1996), bromelain is detected in blood serum, with intact enzymatic activity (Castell *et al.*, 1997). How non-degraded, biologically active bromelain enters the blood, not to mention how it interacts with serum components, is a mystery. Another example of the complex, poorly understood medical/pharmacological actions include reported hypersensitivity reactions. Topical exposure to high doses of bromelain may cause separation of the superficial layers of the skin and may increase skin and capillary permeability (Lewis and Lewis, 1977). Other reported allergic reactions include nausea, vomiting, and diarrhea (Soltice.com, 2000; M.F. Bromelain Pages, 2000; MotherNature.com, 2000).

Currently, the United States Food and Drug Administration (FDA) has not sanctioned bromelain for any dietary or medicinal uses. Furthermore, FDA regulations prohibit labeling on herbal supplements that make efficacy claims without the required studies to document such claims (FDA, 1999). Thus when a consumer examines the package label on an herbal supplement (*e.g.*, bromelain), there are no statements concerning health or nutritive benefits that the product will provide.

In contrast, mail order catalogs, Web sites, and other herbal supplement literature are not prohibited from making direct reference to putative herbal and/or nutritive benefits associated with a particular product. Consequently, some rather curious claims are made that have no apparent justification or biological basis. Let us consider three examples, with author-inserted bracketed items for clarity.

1) "...it [bromelain] recognizes the beneficial proteins which make up normal cells and refrains from attacking them," (The Vitamin Shoppe, 2000). According to this claim, bromelain has the ability to selectively identify and degrade abnormal, presumably non-beneficial proteins, leaving the normal proteins alone!

Table 1. Examples of reported industrial uses, and pharmacological effects of, and uses for Bromelain,

I.INDUSTRIAL USES	
Meat tenderizer	(Subramanian *et al.*, 1977)
Chill proof beer	(Subramanian *et al.*, 1977)|
Improve stability of protein emulsifiers in latex paints	(Subramanian *et al.*, 1977)
Treat leather	(Subramanian *et al.*, 1977)
II. PHARMACOLOGICAL USES AND/OR PHYSIOLOGICAL RESPONSES	
Anti-inflammatory action	(Taussig and Batkin, 1988)
Skin debridement properties	(Taussig and Batkin, 1988)
Interfere with growth of malignant cells	(Taussig and Batkin, 1988)
Topical treatment for wounds, inflammations and edemas	(Alban *et al.*, 1997)
Adjuvant tumor therapy	(Alban *et al.*, 1997)
Therapy for rheumatic & autoimmune disease	(Alban *et al.*, 1997)
Dissolve mucus prior to X-rays of uterus	(Subramanian *et al.*, 1977)
Alleviation of menstrual pain	(Subramanian *et al.*, 1977)
Inhibit blood platelet aggregation	(Taussig and Batkin, 1988)
Modulate immune response in bacterial and viral infection (including AIDS)	(Alban *et al.*, 1997)
Alternate or supplement to cortisone and immunostimulatory agents	(Kolac *et al.*, 1996)
Increase permeability of the mucosal epithelium	(Kolac *et al.*, 1996)
Block extracellular signal transduction	(Mynott *et al.*, 1999)

2) "Bromelain is an anti-inflammatory agent and since baldness is also mediated by inflammation, then use [oral intake] of bromelain may inhibit the process," (Nature Health Consultants, 2000). This claim is typical of many in that the stated effect (inhibition of baldness) is qualified, in this example by "may". This claim also deserves skepticism on other grounds, most notably the implied direct link between inflammation and baldness. If true, baldness should be easily cured with powerful anti-inflammatory compounds like aspirin.

3) Bromelain is commonly touted as an "aid-to-digestion" (Nutritional Warehouse 1999; The Vitamin Shoppe, 2000), a seemingly legitimate, yet undocumented statement. Nonetheless related claims can get quite detailed, for example: "Bromelain is a digestive enzyme that works at any pH, anywhere in the GI[gastrointestinal] tract, and it also assists in the absorption and assimilation of nutrients from foods," (Nature Health Consultants, 2000). At the very least this claim is misleading in that bromelain will only digest proteins, and has no impact on carbohydrates or fats. Furthermore, we find no data or study to support the "any pH" and "absorption and assimilation" claims. The "any pH" claim is interesting because stem bromelain will remain proteolytic within a wide pH range (4.0-7.0), presumably due to the different pH-optima for the different components. However, the typical human stomach with pH of 2 to 3 may be too acidic for bromelain proteolytic activity.

It is interesting that Web sites not selling bromelain (e.g. Mother Nature.com) provide more believable and referenced claims for use and efficacy. In our view, consumers need to be skeptical of many of the health and dietary benefits attributed to bromelain, especially those found in catalogs or Web sites selling bromelain supplements. *Ananas comosus* is a beautiful and valuable species, made even more interesting by its ability to produce bromelain. However, if bromelain truly has all of the suggested medicinal attributes that are claimed, we suspect that pineapples would be grown mostly for the pharmaceutical by-products!

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Nominations wanted for Wally Berg Award of Excellence

Tom Wolfe

Nominations for the second Wally Berg Award of Excellence to be presented at the World Bromeliad Conference in St. Petersburg, Florida in 2002 are now being solicited. The award is a horticultural award established in 1999 to honor the contributions made by the late Wally Berg. Individuals noted for exceptional skills in the area of bromeliad horticulture, and who are members of the BSI, are eligible for nomination.

Any BSI member in good standing may submit a nomination. Nominations should be submitted to the person named below by November 1, 2001. Voting by the BSI Board of Directors will take place by February 1, 2002 and the award presented to the chosen recipient at the 2002 World Bromeliad Conference in St. Petersburg, Florida. Send the nominations to:

A. Keith Smith
1330 Millertown Rd.
Auburn, CA 95603
U.S.A.

Nominations may also be submitted by e-mail to vickychir@aol.com

New Beginnings Within the BSI

Hattie Lou Smith

The World Bromeliad Conference 2000, the Golden Anniversary of BSI, was the beginning of many new programs of the BSI, both ongoing and as part of the World Bromeliad Conferences. This was the first WBC where the Bromeliad Society International assumed responsibility for the financial risk and the burden of conference coordination. It was realized that although a host society from the city of the conference was necessary, much of the work of a WBC could be conducted by committee and board members of BSI, if assisted by members and friends of the BSI. This proved to be difficult because of the impossibility of regular meetings of the Committees and slow because of communications problems and distance. We were cheered to realize that though difficult and slow, the job was one that could still be done with the help of dependable local members. The second BSI sponsored WBC will be held in St. Petersburg, Florida in May 2002. Lessons learned should make for better and better Conferences, that will be even more fun, more informative and more international in scope.

One of several innovations for WBC 2000 was the introduction of a program of scientific seminars. These more technical seminars were in addition to the regular seminars that have long been a conference feature. Although geared toward the scientific community, any registered BSI member may attend the scientific seminars. Many feel that the BSI has a duty to support, in a tangible way, the research, preservation and categorizing of bromeliads. Thus, under Harry Luther's guidance, the scientific seminars were born and will continue to mature. The scientific seminars at the upcoming WBC 2002 will feature Renate Ehlers from Germany, Walter Till from Austria, Elton Leme from Brazil, and John Utley, David Benzing and Sue Sills from the U.S.

Another highly successful program has been the on-line BSI store. The BSI Web site (BSI.org) was set up by Dan Kinnard of California, several years ago. With his innovations, it grew to be an important informational tool. In 2000, Ken Marks of Florida, assumed the job of Webmaster and has further defined the Web site. Working with George Allaria, the BSI Sales [Publication] Committee Chair, Ken has set up a store of growing inventory and endless possibilities. Bromeliad lovers from all over the world can purchase, by credit card, the publications and items promoting bromeliads.

The usefulness of the BSI Web site for distributing BSI and affiliate news and information cannot be overstated. Cooperation and links with other Web sites insure the spread of a broad spectrum of information. A special cooperation and thanks is given to FCBS Web site and its Webmaster, Mike Andreas

New programs of the BSI that serve local affiliates are always being tried. At a time when many plant societies are disbanding for lack of interest, it is important to be part of a society that can change and grow to fill the needs of the plants and friends who are important in our lives.

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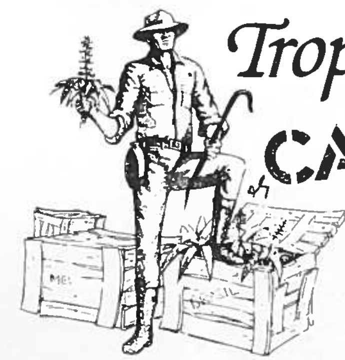

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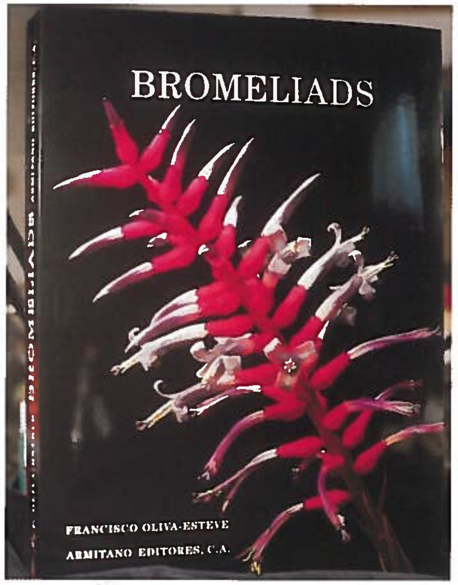

The English version of this beautiful book has now been released. The Spanish version continues to be available. The book is 460 pages in length, hardbound with a color dust jacket, and includes 980 high quality color photographs. Its dimensions are 13½ inches by 10 inches (35 cm x 25 cm), it is printed on sturdy, high quaility paper and weighs 7½ pounds.

In addition to photos and text covering descriptions of 59 aechmeas, 55 guzmanias, 25 navias, 34 pitcairnias, 11 puyas and 124 tillandsias, it also contains informative articles by some of the most respected names in the bromeliad world. Among the articles are: **Navia: an Ancient and Extraordinary Bromeliad Genus** by Richard Evans Schultes; **Some Interesting Bromeliads: from the Auyan-tepui, Venezuela** by Joseph Bogner; **Brocchinia: Genus of the Guayana Highlands** by Julian A. Steyermark; **The Prodigious World of Bromeliads** by Bruno Manara; **Cerro de La Neblina, Amazonas: A Newly Discovered Sandstone Mountain,** by Bassett Maguire and **Bromeliads of the Lost World** by Ruth and Lyman B. Smith.

The price is $149.50 plus shipping/handling and applicable sales taxes.
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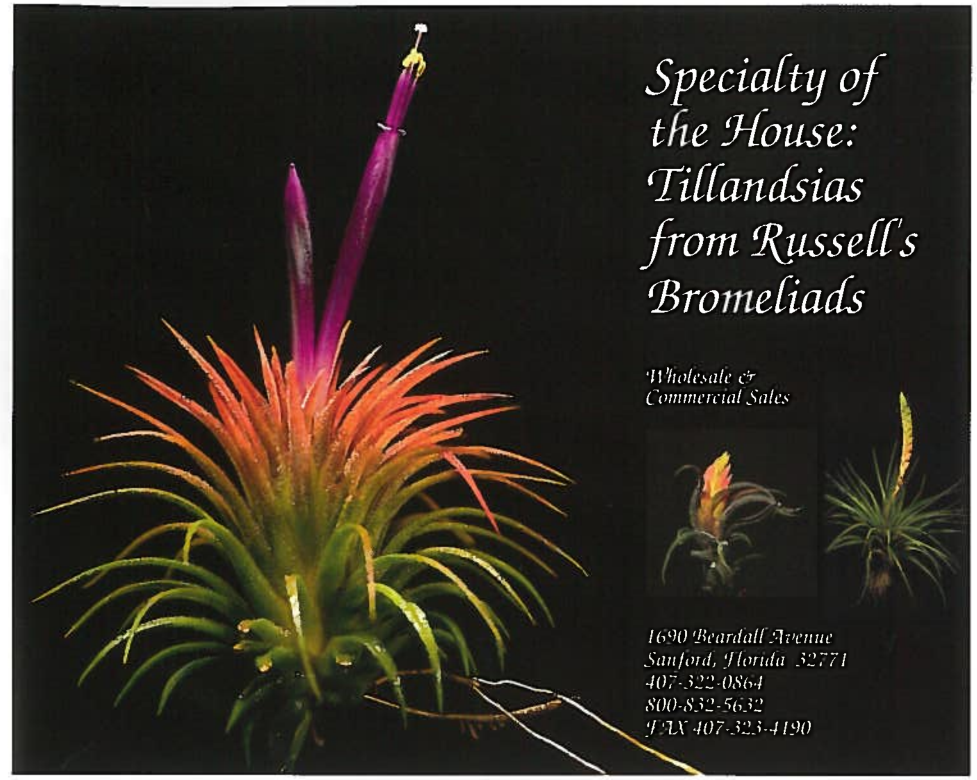

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The Bromeliad Society International

The purpose of this nonprofit corporation is to promote and maintain public and scientific interest in the research, development, preservation, and distribution of bromeliads, both natural and hybrid, throughout the world. You are invited to join.

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Photograph by Marcel Lecoufle

Tillandsia leiboldiana, the real one. Dan Arcos recognized that the plant on the cover of the January-February 2001 issue of the JOURNAL, Volume 50(1):1, labeled as *Tillandsia leiboldiana* was most likely *Tillandsia foliosa* and not *T. leiboldiana*. A closer look and subsequent conversation with Harry Luther confirmed that the plant on the cover was not *T. leiboldiana*. *Tillandsia leiboldiana*, pictured above, ranges throughout much of Central America. *Tillandsia foliosa* is found in southern Mexico.

Calendar

4-5 Aug — The South Bay Bromeliad Associates will hold their annual show and sale at Rainforest Flora's new nursery location at 19121 Hawthorne Blvd., Torrance, CA 90503. Show hours are noon to 4:30 p.m. on Saturday and 10 a.m. to 4:30 p.m. on Sunday. Plant sales are from 10 a.m. to 4 p.m. on both days. Contact: Bryan Chan, 818-366-1858 or by e-mail at bcbrome@aol.com

11-12 Aug — The North County and Saddleback Valley Bromeliad Societies will hold a combined standard show and sale at the Bird Rock Tropicals Nursery, 6587 Black Rail Road, Carlsbad, CA 92009. Contact: Dan Kinnard 760-414-9636 or Pam Koide 760-483-9393.

24-26 Aug — The Bromeliad Society of Greater Chicago will hold its 16th annual standard bromeliad show at the Chicago Botanical Garden, Glencoe, IL. Contact: Ardie or Jack Reilly at 217-486-5874 or by e-mail at jar56@one-eleven.net

24-26 Aug — The Greater Dallas-Fort Worth Bromeliad Society will host the 28th annual Southwest Bromeliad Guild and 7th annual International Cryptanthus Show at the Fort Worth Botanic Garden Center in Fort Worth , Texas. Contact: Flo Adams (817) 467-7500.

12-15 Oct — 11th Australian Bromeliad Conference 'Brom-A-Warra' at Wollongong, New South Wales, Australia. Contact: Graham Bevan, 25 Tallwong Cres., Dapto 2530 or e-mail Eileen Killingley at john.killingley@det.csiro.au

27 Oct — The Bromeliad Society of Central Florida will host the 2001 Extravaganza of the Florida Council of Bromeliad Societies at the Maitland Civic Center, 641 S. Maitland Ave., Maitland, FL (just north of Orlando). Activities include a large sale, interesting speakers, rare plant auction and banquet. Admission and parking are free, but there is a charge for the banquet. Hours are 9 a.m. to 5 p.m. Contact: Eloise Beach, 407-886-8892, e-mail floridapro@aol.com. NOTE: THIS IS A CHANGE IN BOTH DATE AND LOCATION FROM PREVIOUS LISTINGS!