

A close-up photograph of a green leaf with prominent, light-colored veins. The leaf is divided into several lobes, and the central vein is clearly visible. The background is dark, making the leaf stand out.

Aroid Species Diversity:
Are we underestimating the number of aroids?

Thomas B. Croat
P. A. Schulze Curator
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Megagenera with over 500 species

Frodin, Taxon 53:753-776
2004

Rank	Genus	Species	Family
1	Astragalus	3,270	Fabaceae / Leguminosae
2	Bulbophyllum	2,032	Orchidaceae
3	Psychotria	1,951	Rubiaceae
4	Euphorbia	1,836	Euphorbiaceae
5	Carex	1,795	Cyperaceae
6	Begonia	1,484	Begoniaceae
7	Dendrobium	1,371	Orchidaceae
8	Acacia	c. 1,353	Fabaceae / Leguminosae
9	Solanum	c. 1,250	Solanaceae
10	Senecio	c. 1,250	Asteraceae / Compositae
11	Croton	1,223	Euphorbiaceae
12	Pleurothallis	1,120+	Orchidaceae
13	Eugenia	1,113	Myrtaceae
14	Piper	1,055	Piperaceae
15	Ardisia	1,046	Primulaceae
16	Syzgium	1,041	Myrtaceae
17	Rhododendron	c. 1,000	Ericaceae
18	Miconia	1,000	Melastomataceae
19	Piperomia	1,000	Piperaceae
20	Salvia	945	Lamiaceae / Labiatae
21	Erica	860	Ericaceae
22	Impatiens	850	Balsaminaceae
23	Cyperus	839	Cyperaceae
24	Phyllanthus	833	Phyllanthaceae
25	Allium	815	Amaryllidaceae
26	Epidendrum	800	Orchidaceae
27	Vernonia	800-1,000	Asteraceae / Compositae
28	Lenanthes	c. 800	Orchidaceae
29	Anthurium	789	Araceae
30	Diospyros	767	Ebenaceae
31	Ficus	750	Moraceae
32	Indigofera	700+	Fabaceae / Leguminosae
33	Justicia	c. 700 ^{sq}	Acanthaceae
34	Silene	700	Caryophyllaceae
35	Oxalis	700	Oxalidaceae

Rank	Genus	Species	Family
36	Crotalaria	699	Fabaceae / Leguminosae
37	Centaurea	695	Asteraceae / Compositae
38	Cassia	692	Fabaceae / Leguminosae
39	Eucalyptus	681	Myrtaceae
40	Oncidium	680	Orchidaceae
41	Galium	661	Rubiaceae
42	Cousinia	655	Asteraceae / Compositae
43	Ipomoea	650	Convolvulaceae
44	Dioscorea	631	Dioscoreaceae
45	Cyrtandra	622	Gesneriaceae
46	Helichrysum	600	Asteraceae / Compositae
47	Ranunculus	600	Ranunculaceae
48	Habenaria	600	Orchidaceae
49	Schefflera	584	Araliaceae
50	Ixora	561	Rubiaceae
51	Berberis	556	Berberidaceae
52	Quercus	531	Fagaceae
53	Pandanus	c. 520	Pandanaceae
54	Panicum	500+	Poaceae / Gramineae
55	Eria	500	Orchidaceae
56	Polygala	500	Polygalaceae
57	Potentilla	500	Rosaceae



Aroids with potentially large numbers of species

- **Anthurium**- Currently 1484; Anticipated, perhaps as many as 3000 species
- **Philodendron**- 487; Surely as many as 1500 species
- **Homalomena**- Believed by Peter Boyce to contain 500 species
- **Stenospermation**- Possibly as many as 500 species. Currently have 128 species in New Lucid Key and few indetermined collections have been studied.

Reasons for Optimism that Species Diversity is much higher than anticipated.

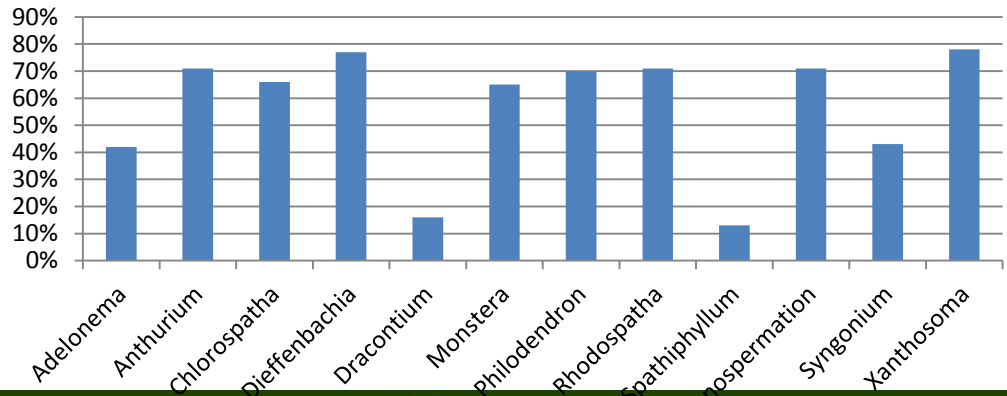
- 1. **Large growth** in numbers of species of Araceae
- 2. **Comparative Studies** of Central America vs. South America
- 3. Use of **Lucid Keys** for any genus

1. Large growth in numbers of species of Araceae

Most growth in the size of Araceae has occurred in the past 40 years

- *Adelonema* (42%)
- *Anthurium* (71%)
- *Chlorospatha* (66%)
- *Dieffenbachia* (77%)
- *Dracontium* (16%)
- *Monstera* (65%)
- *Philodendron* (70%)
- *Rhodospatha* (71%)
- *Spathiphyllum* (13%)
- *Stenospermatum* (71%)
- *Syngonium* (43%)
- *Xanthosoma* (78%)

Evidence of great increases in the number of species in these genera



Best examples of growth are in Anthurium



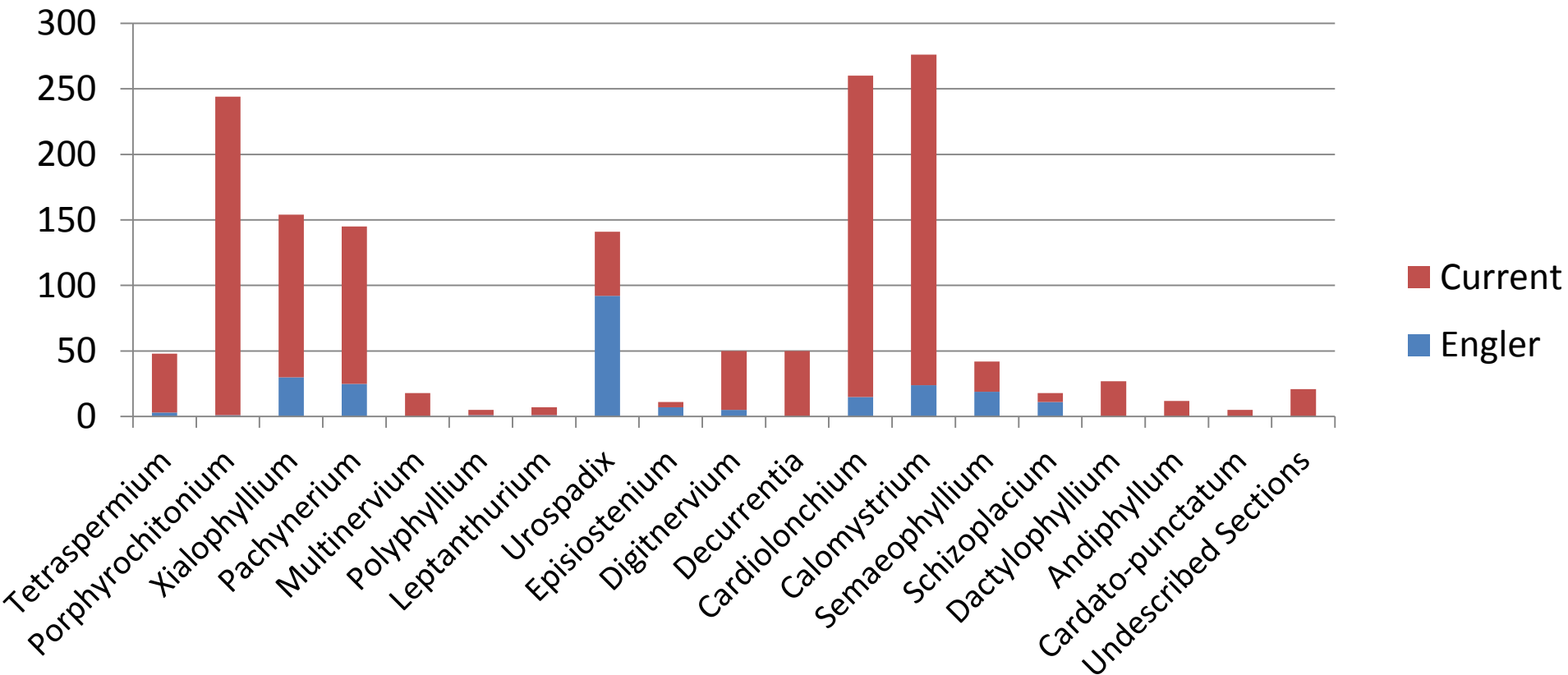
Engler's sections of Anthurium

	Engler	Current
Tetraspermium	4	3
Gymnopodium	1	1
Porphyrochitonium	1	1
Pachyneurium	54	25
Polyphyllium	1	1
Xialophyllum	43	30
Polyneurium	47	23
Urospadix	92	49
Episiostenium	7	4
Digitinervium	16	5
Cardiolonchium	30	15
Chamaerepium	2	1
Calomystrium	27	24
Belolonchium	90	54
Semaeophyllum	24	19
Schizoplacium	15	11

Most of Engler's sections were reduced owing to synonymy



Growth in Size of Sections



Growth in Size of Sections

	Engler	Current
• Tetraspermium	3	45
• Porphyrochitonium	1	243
• Xialophyllum	30	124
• Pachyneurium	25	120
• Multinervium	0	18
• Polyphyllum	1	4
• Leptanthurium	1	6
• Urospadix	92	49
• Episiostenium	7	4
• Digitinervium	5	45

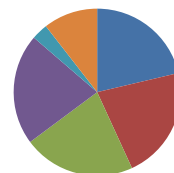
Growth in Size of Sections, cont.

	Engler	Current
• Decurrentia	0	50
• Cardiolonchium	15	254
• Calomystrium	24	252
• Semaephyllium	19	23
• Schizoplacium	11	7
• Dactylophyllium	0	27
• Andiphyllum	0	18
• Cordato-punctatum	0	5
• Undescribed Sections		21

Areas of Greatest Growth

- Anthurium sect. **Polyneurium** from Lita-San Lorenzo Region, 2018; - Revision by Jordan Teisher; Carchi Prov. Revision by X. Delannay & REU Student Rob Wood & (2015)
- Anthurium sect. **Belolonchium**
 - Revision by Croat Jim Grib; REU Students Hartley & Hughes (2016) & Jim Grib
- Anthurium sect. **Cardiolonchium**
 - Revision by Croat & Bob Hormell; REU Student Clarice Guan (2016)
- Anthurium sect. **Tetraspermium**
 - Revision by Croat & Anbreen Bashir
- Anthurium sect. **Calomystrium**
 - Revision by Jere Deal & David Belt
- Anthurium sect. **Xialophyllum**
 - Revision by Croat & Jonathan Watt
- Anthurium sect. **Porphyrochitonium**, King of Species Growth

Sections



■ Belolonchium

■ Calomystrium

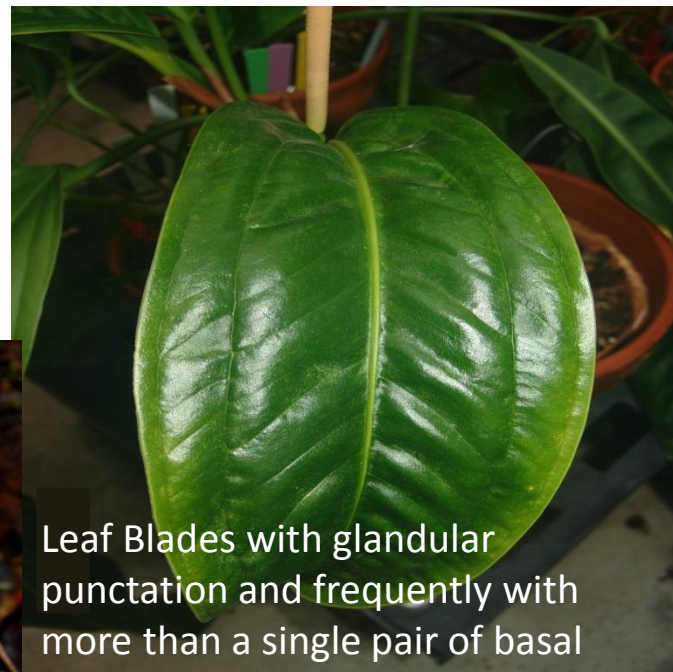
■ Cardiolonchium

Section Tetraspermium



Characterized by:

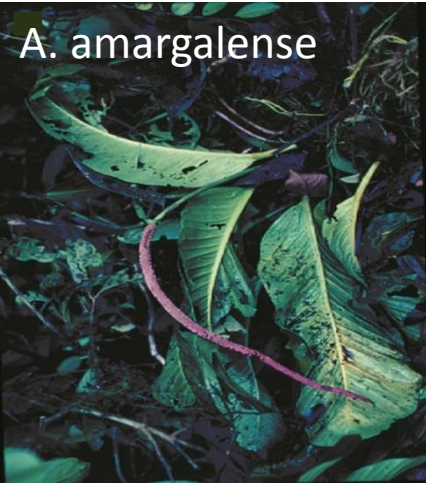
- elongated internodes
- glandular punctations
- berries with 2-4 seeds per locule
- chromosome base # 10



Leaf Blades with glandular punctation and frequently with more than a single pair of basal

Increase from 3 to 45 species
Being revised by Dr. Anbreen Bashir

Section Porphyrochitonium



Constituting the largest increase among the larger sections increasing from 28 to 243 species.



Characterized by:

- elongated glandular-
- punctate leaf blades
- short internodes
- persistent catapyll fibers
- berries 2 or more per locule
- chromosomes $2n = 29-31$

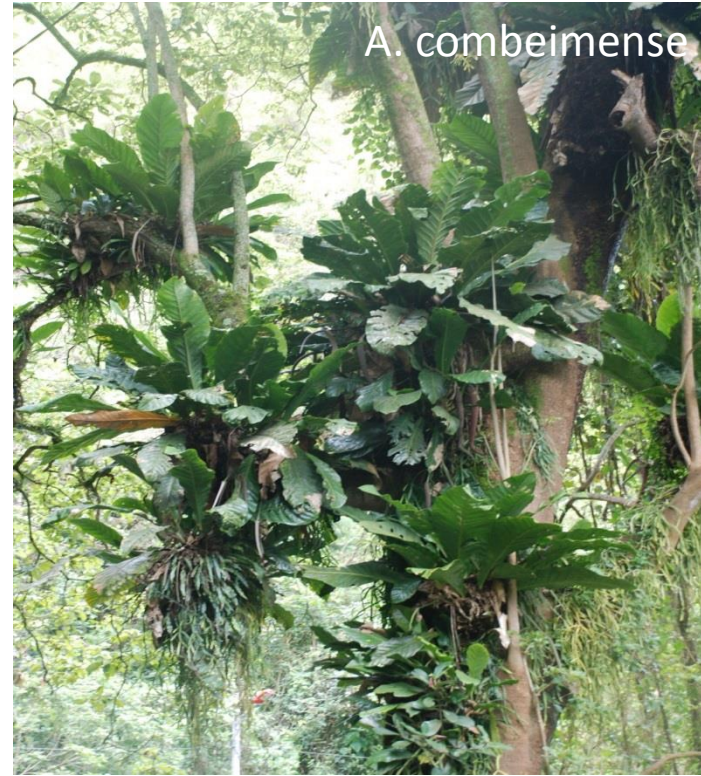


Section Pachyneurium

A. nervatum



A. combeimense



Characterized by:

- mostly bird's nest habit
- involute vernation
- short internodes
- dense roots

Engler revised with 25 sp.
(1905).

Revised by Croat with
114 spp (1991).

Today there are 120 spp.
From 25 to 120, a 380%
increase.

A. wagnerianum



Sect. *Multinervia*

Section novo, 16 species of which were included with sect. *Pachyneurium* (Croat, 1991).

Molecular studies show it to be distinct at sectional level.



A. holmnielsenii



Characterized by:

- involute vernation
- usually bird's nest habit
- inconspicuous primary lateral veins
- usually orange berries



Sect. Polyphyllium

Probable novel
pollination syndrome

Characterized by

- elongate internodes
- roots along internodes
- fruits with black shiny seeds

1 species included
by Engler;
currently 4 species

A. flexile



A. clidemioides



Characterized by

- epiphytes with short internodes
- roots with velamen
- heavily sheathed petioles
- chromosome base number 10

Sect. *Lepanthurium*

1 species treated by Schott & Engler, now 6 to 10



Sect. Decurrentia

Characterized by

- short internodes
- elongated epunctate blades

New section by Croat (2005) initially with 6 species. Now with 50 species in the section.

A. caullorhizum



A. chucantiense



A. anchicayense

Sect. *Xialophyllum*

Characterized by

- elongated internodes
- leaves elongated

Probably two natural groups

1. glossy & drying brown, fruits red to purplish
2. matte and drying matte, berries green to yellow

30 species included by Engler, now 124 species, a 313% increase.

A. *microspadix*



A. *carnosum*



A. *mindense*



Characterized by

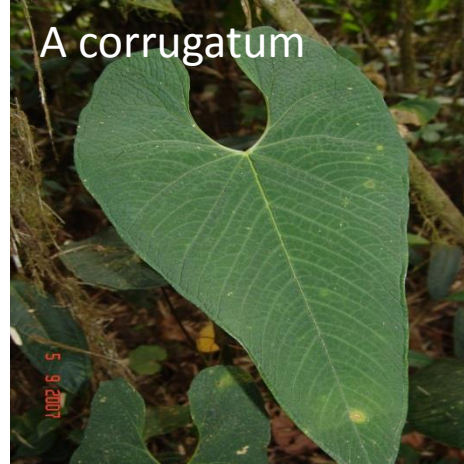
- short internodes
- fibrous cataphyll fibers

Possibly two sections

1. blades semiglossy, moderately few veins.
2. blades matte, primary lateral veins many

Engler treated 23 species; currently there are 188 species, an increase of 164%.

Sect. *Polyneurium*



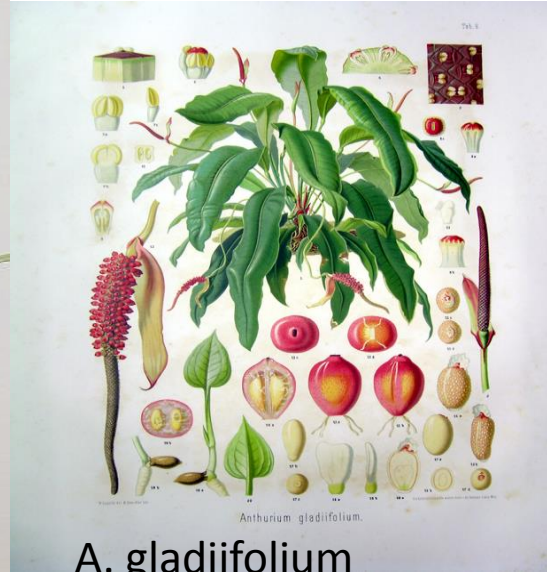
Characterized by:

- mostly eastern Brazil
- mostly elongated blades
- sometimes punctate but not glandular-punctate.

Sect. *Urospadix*

Engler treated 92 species; now 89 owing to many which were not really sect. *Urospadix*.

A. gladiifolium



A. gladiifolium

Sect. Episeiostenium



Characterized by:

- **endemic to West Indies**
- typically cordate blades but without good characters

4 species recognized by Engler, currently 8 species.
Confirmed by molecular studies by Carlsen.



Characterized by:

- usually having ovate-cordate blades with 2 or more basal veins that reach apex
- **glandular-punctate surfaces**
- ovules 2 or more locular
- berries usually square when young.

Engler treated 5 species, currently there are 45 species.

Sect. *Digittinervium*



Sect. *Cardiolonchium*

Characterized by:

- typically velvety blades which dry greenish
 - often ribbed petioles
 - chromosomes $2n=32$ with B chromosome
- From Engler's 15 species, the count is now 245, an increase of

A. angamarcanum



A. queremalense



A. carlablackiae

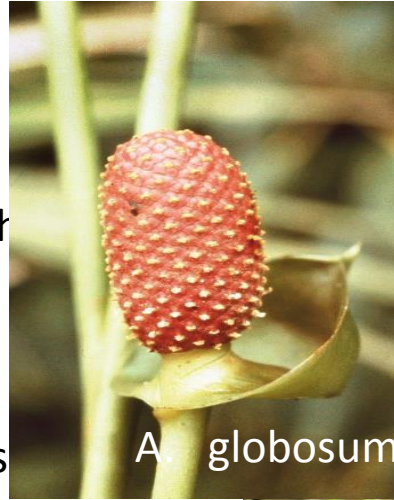


Sect. Calomystrium

Characterized by:

- persistent **intact cataphylls**
- typically terete petioles
- usually cordate blade
- frequently with short pale lineations and with dark punctations
- typically thick and glossy flowers

Engler included only **15** species; current count is **252** a 950% increase.



A. globosum



A. oyulelae



A. angustisinus



A. corrientense



A. roseonavicularum

Section Belolonchium

Characterized by:

- typically from high elevation
- **cataphylls** persisting as **dense fibers**
- no punctations
- spathe hooding
- frequently pendent spadix

Engler treated **54** species;
current count is **276**,
an increase of 410%



A. albessei

A. herthae



A. cupulispatum



A. antonioanum

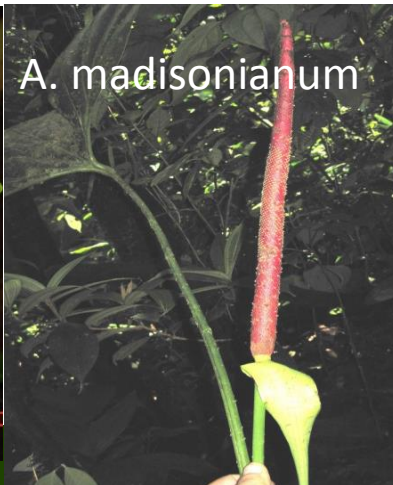


Sect. *Semaeophyllum*

Characterized by **three lobed blades**

Likely a polyphyletic group

19 species were treated by Engler; section was revised by Carlsen & Croat (2007) with a total of 23 species.



Sect. *Dactylophyllum*

Characterized by leaf blades 3 or more lobed with lobes free to the base.

Treated as sect. *Schizoplacium* by Engler with 11 species.

Presently there are 28 species.

A. cutacuense



A. arisaemoides



A. clavigerum



Sect. *Andiphyllum*

Treated principally as sect. *Belolonchium* by Engler but now a distinct endemic section in Mexico and Guatemala. 12 species



Characterized by:

- Mexican and Guatemalan endemic
- Usually D-shaped petioles
- Mostly ovate-cordate blades
- Epunctate
- Berries orange
- Mesocarp pasty
- Seeds large and pale



Sect. Cordato-punctatum

Characterized by:

- Unique to Mexico & Guatemala
 - Cordate blades with glandular punctations.
- Only a single species was recognized by Engler who placed it in sect. Belolonchium. The remainder were described later.

Currently there are only 6 species in the section.



2. Comparative Studies of Central America vs. South America



South America is 2.6 times larger than South America



South America: Species of Araceae by Country

South America has 44 genera and 1433 published species



Araceae Checklist for Central America shows stark contrasts with South America

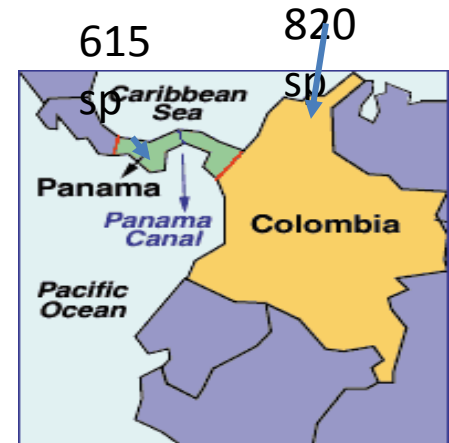
CHECKLIST OF ARACEAE OF CENTRAL AMERICA				Mexico	Guat.	Bel.	El Salv.	Hond.	Nic.	CR	Pan	Middle Am	Mexico	Guat.	Belize	El Sal.	Hond.	Nic	CR	Pan	
ADELONEMA	Species c	Var. & Ssp																			
<i>A. allenii</i> (Croat) S. Y. Wong & Croat	1									1	1	1									
<i>A. hammelii</i> (Grayum & Croat) S. Y. Wong & Croat	1									1	1	1								1	
<i>A. panamense</i> Croat & R. Mansell	1										1	1								1	
<i>A. peltata</i> (Masters) S.Y. Wong & Croat	1										1	1									
<i>A. picturata</i> (Linden & André) S. Y. Wong & Croat	1									1	1	1									
<i>X. mafaffa</i> Schott	1									1	1	1									
<i>X. mexicanum</i> liebmann	1		1	1	1	1			1	1	1	1									
<i>X. ortizii</i> Croat	1										1	1								1	
<i>X. petaquillense</i> Croat, Delannay & Ligan	1										1	1								1	
<i>X. pringlei</i> Croat	1		1								1	1		1							
<i>X. robustum</i> Schott	1		1	1	1	1	1	1	1	1	1	1									
<i>X. sagittifolium</i> (L) Schott Introduced	1		1	1	1	1	1	1	1	1	1	1									
<i>X. cerrosapense</i> Croat & O. Ortiz	1										1	1								1	
<i>X. undipes</i> C. Koch	1									1	1	1									
<i>X. violaceum</i> Schott	1		1								1	1									
<i>X. wendlandii</i> (Schott) Schott	1		1	1		1	1	1	1	1	1	1									
<i>X. yucatanense</i> Engler	1		1								1	1		1							
Total Xanthosoma	18	0	7	4	3	4	3	4	4	8	13	8	2	0	0	0	0	0	0	1	6
ZANTEDESHIA																					
<i>Z. aethiopica</i> (L.) Spreng.	1		1							1	1	1									
Total Zantedeschia	1	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
Grand Total Species	781.5	44.5	139.5	91	54	32	71	108	327.5	615	321	91	16	2	0	4	2	152	551		
		826	18%	12%	7%	4%	9%	14%	42%	79%		65%	18%	4%	0%	6%	2%	46%	90%		
Total Genera	25																				

Comparison of Araceae of Central America with Araceae of Colombia

- 781 species in Central America
- 820 species in Colombia
- Panama has 0.95 % as many species as Colombia but is much larger in size.

Floristic Comparisons of Central and South America

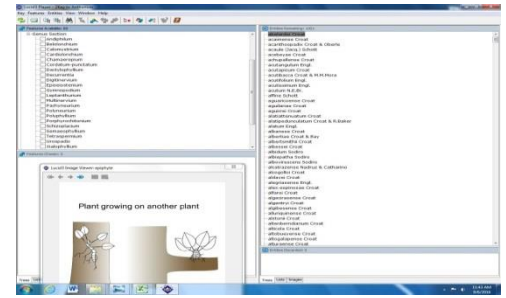
- A complete list of aroid species exists for Central America (781 species).
- Most explored parts of Central America are reasonably well-known [Probably 10% of the flora is still not yet collected].
- Endemism and Species Diversity increases dramatically as one approaches South America.
- Panama (with 79% of all the species in Central America) has 615 species, 90% of them presently believed to be endemic.
- Colombia, **15 times larger** in area and many times more diverse, has only 820 named species (Panama currently has 4/5 as many as Colombia).



Conservative extrapolation assures great increases

- Colombia alone must have between 8,000 and 12,000 undiscovered species.
- Collecting has essentially stopped or is progressing too slowly to prevent mass extinction before these species are collected, studied and described.
- Experts must be encouraged to collect for greatest efficiency.
 - Jatun Sacha Biological Station: great increases with less than 6 hours of collecting

3. Lucid Technology Has Eased the Discovery of New Species



- Lucid Technology developed in Australia; Lucid key developed at Kew
- Anthurium key- Authored by Anna Haigh, Laura Reynolds & Tom Croat
- The initial 600 species entered in Lucid at Kew
- Since ca. 2012 Lucid is being developed by MO
- Current number of species in Lucid Key **1575**

- While Engler's 1905 Revision dealt with 454 names of Anthurium, many are now considered synonyms. Thus his total number of names was only 266 species.
- This contrasts with the present total of 1834 names present in the current Anthurium spreadsheet (unpublished), an increase in 580 % from the time of Engler. Most of the species have been described in recent years and 1688 of the total are authored by Croat (92 % of the current total).

Philodendron Lucid Key

- Philodendron key- Authored by Marcela Mora, Tom Croat, Simon Mayo, Anna Haigh
- The initial 400 species entered in Lucid at Kew
- Since ca. 2012 Lucid is being developed by MO
- Current number of species in Lucid Key 621
- Growth potential, percentage-wise is much greater for Philodendron than for Anthurium

Determination Tool and added Asset to Luid

- Archive with both photographs of dried and live plants
- Descriptions (detailed with different versions)

Other Developments Which Have Led to Species Discovery

- Access to Loans from Colombia and Ecuador
- OPUS trip to Herbaria with Neotropical Collections;
- South America 25 Herbaria visited
 - 8,000 images of undeterminable specimens
 - Specimen data is being entered into Tropicos
 - Images are being labeled and added to Tropicos
- OPUS trip to 13 European Herbaria
 - 1000 images+, many of types
- OPUS trip to 16 Central American Herbaria
 - 1000 images taken.

Conclusions and Predictions

- Since this provides evidence that there are **many new species** it is critical that **more field studies** must be undertaken. Current **regulations** that inhibit or prevent collecting must be **re-evaluated**. **Experts** in specific areas should be **encouraged** to spend more **time in the field** and more time **training younger botanists**, especially those in Latin America. **Failure to take action** will certainly result in **extinction** of species before they are ever known to science.

Conclusiones y predicciones

- Dado que esto proporciona evidencia de que hay muchas especies nuevas, es fundamental que se realicen más estudios de campo. Las regulaciones actuales que inhiben o impiden la recolección deben ser reevaluadas. Se debe alentar a los expertos en áreas específicas a pasar más tiempo en el campo y más tiempo capacitando a botánicos más jóvenes, especialmente a los de América Latina. Si no se toman medidas, la extinción de las especies se producirá antes de que la ciencia las conozca.