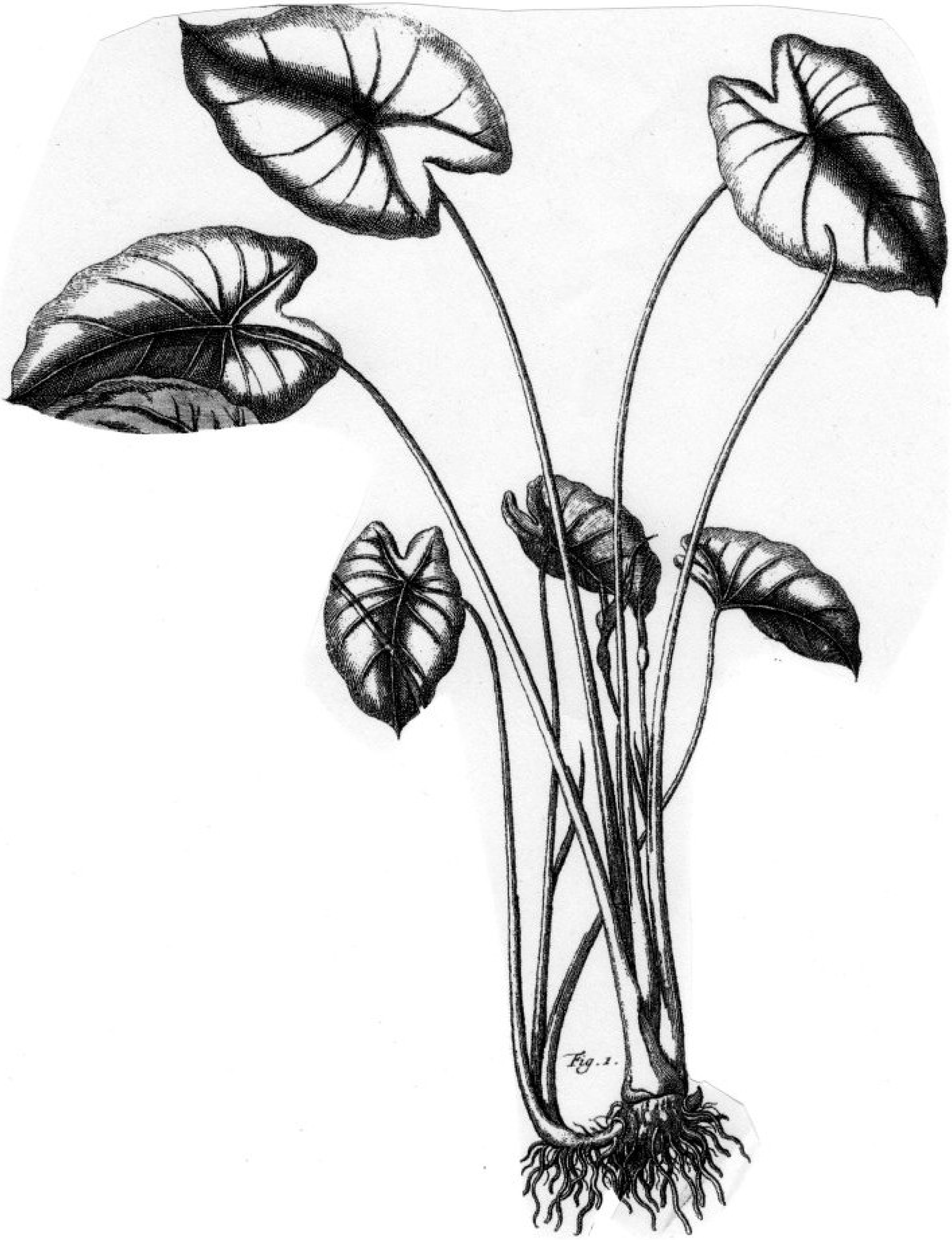
AROIDEANA

International Aroid Society, Inc.

Volume 38E
No 1
May 13,2015
ISSN 2310-0745



XIth International Aroid Conference
Hanoi, Vietnam
December 2013

I.A.S. Board of Directors

2012-2015
Marco Busse
Dylan Hannon
Lester Kallus
Andrew Schrimsher
Barry Schwartz

2013-2016
Don Bittel
Albert Huntington
Andrew Leonard
Peter Matthews
Joep Moonen

2014-2017
Alex Bello
Peter C. Boyce
Zach DuFran
Enid Offolter
Greg Ward

Honorary Directors
Dr. Sue Thompson
Dr. Thomas B. Croat

Officers
President: Enid Offolter
Vice President: Alex Bello
Treasurer: Don Bittel
Recording Secretary: Andrew Schrimsher
Corresponding Secretary: Greg Ward

Newsletter
Editor: Carla Kostelac

Aroideana
Editor: Dr. Derek Burch
Scientific Editor: Dr. Thomas B. Croat

Website
http://www..aroid.org/

Aroideana is an illustrated annual devoted to information about the family Araceae and published by the International Aroid Society, Inc. No material may be reproduced by any means without written permission from the editor. Manuscripts, corrected proofs, and all editorial correspondence should be sent to: Dr. Derek Burch. All other correspondence is to be sent to:
International Aroid Society,
P.O. Box 43-1853, So. Miami, FL 33143-1853 U.S.A.

Scientific and Nonscientific Manuscripts

All manuscripts should be submitted to the editor in electronic format (either on 3.5 inch floppy disk or as an e-mail attachment) in MS Word 7 (or later) or compatible. Only in extraordinary circumstances would hard copy be necessary or acceptable, and then only by prior agreement of the editor. Papers would then be typed on standard A4 paper, be double spaced throughout, with 2.5 cm (1") margins on all sides. Authors should follow recommendations of the Council of Biology Editors Style Manual. Measurements are to be in metric units.

Sequences of Sections

Follow this order: title, author name and address, abstract, introduction, materials and methods, results, discussion, acknowledgments, and literature cited. Captions must accompany all tables and figures. Abstracts should summarize the character and scope of the paper in 250 words or less, followed by no more than eight key words. Literature cited must be referenced in the text and listed alphabetically by author.

Illustrations

Line drawings and tables must be in black, high resolution ink, clearly labeled, and consecutively numbered. Photos must be completely labeled and show desired cropping if any. Figures will be published either one column (six cm) or two columns (12.6 cm) wide. Full page illustrations will be no more than 12.6 cm x 20 cm. Original art will be returned to the author. Figures will be published in black and white unless special arrangements have been made with the editor for reproduction in color.

> IMPORTANT NOTE:
> When submitting material to IAS publications, please realize that the resolution of the photos embedded in Word documents is often not suitable for publishing as individual figures. Though they may look okay in the document, the individual elements can be just thumbnail size or adhered together into a small number of plates. In the past, these articles have been dealt with despite their complexity.
> As of now, we can only accept separate high resolution photos in addition to the Word document, in JPEG or TIFF format. Made-up plates in PDF format with high resolution images embedded are acceptable for Aroideana only. Other articles with embedded photos will be returned to the authors. Many thanks for your help in this matter and thank you for supporting Aroideana.

Processing Manuscripts

Upon receipt, manuscripts are acknowledged and sent for critical review. Accepted manuscripts are sent to authors for revision in consideration of reviewers' comments and returned to the editor for typesetting. Page proofs are sent to the author for proofreading, with any changes other than typographical errors being charged to the author at cost at the editor's discretion. Authors with research support will be billed for page charges at the rate of $30.00 per printed page at the editor's discretion.

Voucher Materials

Descriptions of new species require deposit of type materials in a recognized herbarium.

Aroideana ISSN: 0197-4033 (Print) 2310-0745 (Online)
©2013 International Aroid Society, Inc.

AROIDEANA
International Aroid Society, Inc.

CONTENTS (XIth International Aroid Conference Issue)

Front Cover: The "Water Kelady" (*Caladium aquatile*) illustrated by Rumphius. Scan P. Matthews.
Back Cover: A cultivated form of *Colocasia gigantea*. Photo P. Matthews

XIth International Aroid Conference

Hanoi, 11th -13th December 2013

Programme, abstracts, and list of presenters

Sponsors

- International Aroid Society (IAS)
- Institute of Ecology and Biological Resources (IEBR), Vietnam
- National Foundation for Science and Technology Development (NAFOSTED), Vietnam
- Singapore Gardening Society
- Vietnam Academy of Science and Technology (VAST)

Organisers

Dr Nguyen Van Du, Institute for Ecology and Biological Resources, Hanoi , Vietnam
Tel. (m) 090 4140936
Email: vandu178@gmail.com

Dr Peter J. Matthews, National Museum of Ethnology, Osaka, Japan
Tel. +81 6–6878–8344
Email: pjm@idc.minpaku.ac.p

Venue and contact

Army Hotel, 33A Pham Ngu Lao Street, Hoan Kiem District, Hanoi City
Tel. +84 4 3825–2896 or +84 4 3826–5541, email: armyhotel@fpt.vn
Compiled 9th Dec. 2013, Hanoi

PROGRAMME

WEDNESDAY, Dec. 11, 2013

Reception & Registration 7:30 am - 9:00 am, at Army Hotel.

Welcome comments 9:00–9:25 am

- Ninh Khae Bau, Assoc. Prof., Head, Department of International Cooperation, **VAST**, Vietnam.

- Le Xuan Canh, Assoc. Prof., Director, **IEBR**, Vietnam.

- Do Tien Dung, Dr., Director of Executive Board, **NAFOSTED,** Vietnam

- Tom Croat, Prof., **International Aroid Society**

Opening Lecture 9.30–10:00 am

S1. Thomas Croat (Missouri Botanical Garden, USA) "Neotropical Araceae"

10:00–10:15 Coffee break

Session I: Discovery and Conservation

Session chair: Chunlin Long (Minzu University of China, & Kunming Institute of Botany)

10:20–12:00 am, 4 presentations (each 20–25 mins)

- **S2.** 10:20–10:45 Greg Ruckert (Australia): "IAS and the conservation of aroids"

- **S3.** 10:45–11:10 Truyen D. Minh & MASHOR Manshor (Universiti Sains Malaysia) "The distribution of Araceae along the lower section of Perak River, Malaysia"

- **S4.** 11:15–11:40 Zulhazman Hamzah et al. (Universiti Malaysia Kelantan) Notes on Araceae in Hill Dipterocarp Forest of Mt Chamah, Kelantan, Peninsular Malaysia.

- **S5.** 11:40–12:00 Peter C. Boyce (Malaysia) "Is the 'Flora Malesiana' Araceae a practicable undertaking?"

Lunch 12:00 (provided)

Session II: Systematics and Taxonomy

Session chair: Wong Sin Yeng (University Malaysia Sarawak)

1:30–5:00 pm - 6 presentations (each 25 mins)

- **S6**. 1:30–1:55 Anna Haigh (Royal Botanic Gardens, Kew, London) "Araceae and emonocot: An online resource for monocot plants"

- **S7.** 2:00–2:25 Yujing Liu et al. (Minzu University of China) "*Pinellia hunanensis* (Araceae), a new species supported by morphometric analysis and DNA barcoding"

- **S8.** 2:30–2:55 Genevieve Ferry & Thomas Croat (Nancy Botanical Garden, France, & Missouri Botanical Garden, USA) "*Anthurium* in western Carchi Province, Ecuador"

  3.00–3.20 pm Coffee break

- **S9.** 3:20–3:45 Lars Nauheimer (Germany) "Araceae in time and space - Fossils help to understand historic dispersal routes"

- **S10.** 3:50–4:15 Claudia L. Henriquez et al. (Washington University in St. Louis) "The Good, the Bad and the Ugly: Plastid and mito phylogenomics of Araceae"

- **S11.** 4:20–4:45 Ibrar Ahmed et al. (Massey University, NZ): "Mutational dynamics of aroid chloroplast genomes, and the phylogenetic analysis of closely-related species".

Evening: OPEN

THURSDAY, Dec. 12, 2013

Session III: Ecology and Reproduction

Session chair: Peter Matthews, Japan.

9:00–12:00 am, 5 presentations (each 25 mins)

- **S12.** 9:00–9:25 Marion Chartier et al. (Austria and France) "The evolution of pollinator/plant interaction types in the Araceae"

- **S13.** 9:30–9:45 Amots Dafni (Haifa University, Israel) "The contribution of Jacob Koach to studies on the pollination of Arum, Biarum, Arisarum and Eminium"

- **S14.** 9:50–10:15 Kohei TAKANO et al. (Tohoku University, Japan) "Pollination mutualisms between *Colocasiomyia* flies (Diptera: Drosophilidae) and aroids: Chemical analyses of exudates, as a floral reward, from staminodes of *Alocasia odora* (Araceae) in Okinawa, Japan"

  10:15–10:30 am Coffee break

- **S15.** 10:35–11:00 Masako Yafuso et al. (Okinawa, Japan) "Pollination mutualism between flower-breeding flies of the genus Colocasiomyia (Diptera, Drosophilidae) and expansion of their aroid host plant species in Southeast Asia"

- **S16.** 11:05–11:30 Desika Moodley et al. (University of KwaZulu-Natal, South Africa) "A global assessment of invasiveness in Araceae: is there a general suite of invasive traits?"

- **General discussion (Sessions I-III):** 11:30–12:00

Lunch 12:00 (provided)

Session IV: Posters

1.00–2.00 pm Presenters may introduce their posters. *Coffee provided*

- **P1.** Li Rong and Li Heng (Kunming Institute of Botany, China) "Is *Remusatia* (Araceae) monophyletic? Evidence from three plastid regions"

- **P2.** Takashi Masuno et al. (National Museum of Ethnology, Osaka) "Use of aroids as fodder plants in a Yao community, northern Vietnam"

- **P3.** Nguyen Van Kien & Vu Linh Chi (Plant Resources Center, Vietnam) "The Vietnam national collection of edible aroids".

- **P4.** Niels Jacobsen et al. (University of Copenhagen, Denmark) "The use of AFLP markers to elucidate the relationships within the genus *Cryptocoryne* (Araceae)".

- **P5.** Dr Kartini Saibeh (Universiti Malaysia Sabah) "The variation in leaf anatomy of *Scindapsus* Schott of Malaysia"

- **P6.** Ms Thilahgavani Nagappan et al. (Universiti Malaysia Sabah) "Chemical profiling and bioactive potentials of *Alocasia princeps*"

- **P7.** Tiwtawat Napiroon & Duangchai Sookchaloe (Kasetsart University, Thailand) "Biological activities of lipophilic extract from *Lasia spinosa* (L.) Thwaites (Araceae) effect on seed germination and seedling growth of invasive plant in Thailand."

- **P8.** Sutida Maneeanakekul &Duangchai Sookchaloem (Kasetsart University, Thailand) "Distribution and ecology of Araceae on limestone mountains, Lop Buri and SaraburiProvinces, Thailand"

- **P9.** Andrea Kee et al. (Gardens of the Bay, Singapore) "Observations on the unfurling of the inflorescence of *Amorphophallus* 'John Tan" at Gardens by the Bay"

- **P10.** Shuang Zhang et al. (Minzu University of China) **"Ethnobotany of *Acorus calamus* in China"**

- **P11.** Y.C . Hoe et al. (Universiti Malayasia Sarawak) "Pollination investigations in *Schismatoglottis calyptrata* (Roxb.) Zoll. & Moritzi Complex"

Session V: Further Systematics and Taxonomy

Session chair: Jin Murata, Koishikawa Botanical Gardens, University of Tokyo

2.00–6.00 pm, 7 presentations (each 25 mins)

- **S17.** 2:00–2:25 Josef Bogner (Botanischer Garten München-Nymphenburg, Germany) "Remarkable traits of the African genus *Stylochaeton*"

- **S18.** 2:30–2:55 Nils Köster &Nadja Korotkova(Botanic Garden and Botanical Museum Berlin-Dahlem, Germany) "Phylogeny of the genus *Philodendron* - first results from an analysis using chloroplast markers"

- **S19.** 3:00–3:25 Wong Sin Yeng (Universiti Malaysia Sarawak) "*Homalomena* on Borneo: How many new species?"

  Coffee break 3:30–3:45 pm

- **S20.** 3:50–4:15 Low Shook Ling (Universiti Malaysia Sarawak) "*Schottarum* (Schismatoglottideae): An example of a cryptic taxon in *Schismatoglottis* exposed by combined morphological and molecular analyses"

- **S21.** 4:20–4:45 Alejandro Zuluaga et al. (University of Wisconsin-Madison) "Advances in the systematics of *Monstera* and its relationships within Monsteroideae"

- **S22.** 4:50–5:15 Kumar S. Patil (Smt. K. W. College, India) RAPD analysis of genetic diversity in genus *Arisaema* (Araceae) of the western ghats of Maharashtra (India)

- **S23.** 5:20–5:45 Melanie Medecilo (De La Salle University, Dasmarinas, Philippines) "Taxonomic review of Philippine *Alocasia* (Araceae)"

Evening: Open

FRIDAY, Dec. 13, 2013

Session VI: IAS activities

9:30–10:00 am

Session chair: Peter Matthews.

- Conference publishing plans (Nguyen Van Du)

- Awards (T. Croat)

- IAS directions (*Aroideana*, Shows, Membership, etc.)

- Discussion (Q & A)

10:00–10:20 am Coffee break

Session VII Ethnobotany and Economic Botany

Session chair: Niels Jacobsen

10:25 am - 4:00 pm, with lunch break; 8 presentations (each 25 mins)

- **S24.** 10:25–10:50 Chunlin LONG et al. (Minzu University of China) "Aroid crops in China"
- **S25.** 10:55–11:20 Nguyen Van Du, et al. (Institute for Ecology and Biological Resources, Hanoi): "Useful aroids and their prospects in Vietnam"
- **S26.** 11:25–11:50 Nguyen Van Kien et al. (Plant Resources Center, Hanoi) "Ethnobotany of taro stolon use in northern Vietnam"

  Lunch 12:00–1:00 (Provided)

- **S27.** 1:05–1:30 Peter Matthews (National Museum of Ethnology, Osaka): "Ethnobotany and natural history of two species of wild taro: *Colocasia esculenta* and *C. formosana*"
- **S28.** 1:35–2:00 Nguyen, Viet X. et al.(Hanoi National University of Education) Genetic relationships among different species of taro in Vietnam, as revealed by SSR loci
- **S29.** 2:05–2:30 Jennifer Castillo et al. (De La Salle University, Dasmarinas): "Ethnobotany of *Alocasia macrorrhizos* in the Philippines"
- **S30.** 2:35–3:00 Tran Thi Y Nhi et al. (Institute of Chemistry, Vietnam) "Analysis of glucomanan in flour prepared from wild *Amorphophallus* spp. in Vietnam"
- **S31.** 3:05–3:30 Orachorn Mekkerdchoo et al. (University of NSW, Australia) "Taxonomy and economic potential of *Amorphophallus* species in Thailand"

General discussion (Sessions IV-VII) 3.30–4:00 **With coffee.**

Banquet at 7:00 pm(provided - please add your name to list at registration desk if you wish to join).Awards will be announced.

SATURDAY, Dec. 14, 2013

Conference excursions

1. Kenh Ga - Hoa Lu 1 Day Tour: $50 USD

2. Halong Bay 1 Day Tour: $40 USD

Abstracts

Note: Abstracts throughout have been edited for brevity for the purposes of this programme, and do not represent the final work of the authors concerned. This programme should not be cited as a formal publication.

Opening lecture

S1. Studies of Neotropical Araceae

Thomas B. Croat, Missouri Botanical Garden, USA.

The last decade has seen many changes in research with Neotropical Araceae. The largest genus, *Anthurium,* remains still poorly known overall with only three sections, namely *Pachyneurium*, *Polyphyllium*, and *Semaeophyllium* that have all been revised. *Philodendron* is more fully known with subgenus *Meconstigma*, many members of subgenus *Pteromischum* and the Central American subgenus *Philodendron* which have all been fully revised. The genera *Dracontium* and *Chlorospatha* have now been revised. Revisionary work is being carried out on *Monstera*, *Spathiphyllum* and *Stenospermation* but the latter is still very poorly known. *Dieffenbachia* and *Xanthosoma* remain poorly known. Most of the smaller genera are by now relatively well known, especially the recently revised *Spathicarpeae* inhabiting eastern South America and the western Andes. Genera which have been at least partially revised include *Adelonema (*formerly *Homalomena sect. Curmeria)* and *Rhodospatha*.

Floristic studies are more all-encompassing with published or in-press floristic studies have been carried out in Paraguay and checklist treatments of Ecuador, Peru and Bolivia have been completed in the past 10 years. Floristic accounts of Venezuela have been completed and a checklist for the Flora of Colombia and for Brazil is nearing completion. The Araceae for the Flora of Mesamerica and for the Guianas is expected to be completed in the next five years.

Molecular studies of Neotropical Araceae, especially *Spathicarpeae*, *Monstera* and *Anthurium* at the sectional level are either completed or on going. Molecular studies are also being carried out on *Philodendron* and *Monstera*.

Studies of pollination are still in their infancy in the neotropics with only a few total species having been studied for their pollinators but several important studies are ongoing.

Perhaps one of the most important things to note with Neotropical Araceae is the extent to which new species are being discovered. This is true throughout the range of the family but especially in the Andes of western South America where species diversity and endemism is highest. This discovery process is expected to continue for many years at the current rate of discovery.

Session I: Discovery and Conservation

S2. IAS and the conservation of aroids

Greg Ruckert, Nairne, South Australia

The International Aroid Society (IAS) is the pre-eminent organisation for people interested in aroids. Its membership comprises professionals with a focus on the study of aroids as well as amateurs who are passionate about them. This presentation sets out why the IAS is so important and suggests possible ways it might take a stronger role in the conservation of Aroids.

S3. The distribution of Araceae along the lower section of Perak River, Malaysia

Duong Minh Truyen[1] and Mashhor Mansor[2]

School of Biological Sciences, Universiti Sains Malaysia, Malaysia, 11800 Penang, Malaysia.

[1]Email: dmtruyen88@gmail.com

[2]Email: mashhor@usm.my

Araceae is one of the biggest families of monocotyledonous plants and is regarded as essentially a mesophytic family. The family is especially diverse in the Old World and New

World tropics and many species are also found in the northern temperate regions. Within Asia, the diversity of aroid species is relatively rich and widely distributed in tropical South East Asia. In this region, basic research on the Araceae is especially important for conservation purposes. Our survey of Araceae along the lower section of Perak River, Malaysia,was conducted from April to May, 2013 and four survey stations were selected, namely Kuala Kangsa, Parit, Teluk Itan and Bagan Datuk. These locations were selected based on previous reviews of the main (vegetation) groups of the Perak River landscape. We detected many aroid genera in this region, including *Colocasia, Alocasia, Philodendron, Caladium,*and *Lasia*. The genera *Colocasia* and *Alocasia* were dominant in the areas surveyed and *Colocasia* was most common. At Teluk Itan, *Colocasia esculenta* is the most common species, growing in the lowlands, and extending from sea level. *Colocasia gigantea* was also recorded but was not abundant. Other species were found occasionally in rice fields and canals in the region surveyed. Most aroid species obtain nutrients from ground near the river. A survey of the social values of Araceae in life was also conducted to supplement the botanical survey of Araceae along the lower Perak River.

S4. Notes on Araceae in Hill Dipterocarp Forest of Mt Chamah, Kelantan, Peninsular Malaysia

Zulhazman, H[1]., Norzielawati, S[1]., Nik Yuszrin, Y[1]., Mashhor, M[2] .and P.C. Boyce[2]

[1]Faculty of Earth Science Department,-Universiti Malaysia Kelantan, Locked Bag 100, 17600 Jeli, Kelantan, Malaysia. Email: zulhazman@umk.edu.my (corresponding author).

[2]School of Biological Sciences, Universiti Sains Malaysia,11800 USM, Pulau Pinang, Malaysia.

A total of 31 species from 14 genera of aroids were recorded from Mt Chamah and surrounding areas in the district of Gua Musang, Kelantan, Peninsular Malaysia. This represents about 22% out of an estimated 140 species and 50% of the 28 genera of aroids reported for Peninsular Malaysia. These include the rare species; *Arisaema anomalum* Hemsl.and *Alocasia puber* (Hassk.) Schott. There are eight new species records for Kelantan, which include a remarkable novel species *Homalomena* Crytocladon Supergroup (sp.1).

S5. Is the 'Flora Malesiana' Araceae a practicable undertaking?

Peter C. Boyce, School of Biological Sciences, Universiti Sains Malaysia,11800 USM, Pulau Pinang, Malaysia. Email: phymatarum@gmail.com

The Araceae, one of the larger families still remaining to be worked up for *Flora Malesiana* (FM), looked until a few years ago likely to be one of the few large families for which a *comprehensive* FM account *was* practicable. At that time (ca year 2000) the total of aroid genera for Malesia stood at 37, with a species total estimated at ca 350. Precursory accounts had been published for all except two of the bisexual-flowered genera (*Anadendrum* and *Scindapsus*), and for all but three of the unisexual flowered genera (*Cryptocoryne*, *Furtadoa*, and *Homalomena*), although *Cryptocoryne* effectively covered by various separate papers.

Overall, the distinct impression was that, apart from some taxonomic tidying, most of the work was completed. It is therefore ironic that as work started on *Homalomena* the percentage of undescribed taxa rose such it was soon apparent that while the number of genera remaining to be dealt with were few, the species numbers remaining to be worked-up were significant.

At about the same time a world-wide expansion in aroid research revealed further problems, not least in generic circumscriptions, while extensive fieldwork in West Malesia began to uncover an almost staggering number of distinct new species. The situation is that it is now clear that for most Malesian genera only a fraction of the species have been formally described.

Session II: Systematics and Taxonomy

S6. Araceae and emonocot: An online resource for monocot plants

Anna Haigh, Royal Botanic Gardens Kew, London. Email:a.haigh@kew.org

eMonocot (http://e-monocot.org) is an online resource for monocot plants created by the eMonocot project, a consortium of the Royal Botanic Gardens, Kew, Oxford University and the Natural History Museum, London, as well as contributions from monocot taxonomists and communities worldwide. When complete it will enable identification of Monocot Plants, promote understanding of their biodiversity and evolutionary relationships, and allow the user to explore a wealth of information. The data previously collected as part of the CATE Araceae project (2005–2009), is now included in eMonocot.

The content underpinning the project is being compiled by monocot plant systematists from many institutions worldwide. Data are being contributed through the online taxonomic information resources, for most groups, including Araceae, this is a scratchpad (http://araceae.e-monocot.org/). Scratchpads are providing support and tools to enable taxonomists and their communities to manage and present their taxonomic data online and in doing so contribute to eMonocot.

The emonocot portal is aimed primarily at biodiversity scientists but open to all. The portal provides a powerful and intuitive way to access the aggregated information across all monocot taxonomic groups. The fully attributable content includes interactive multi-access identification keys, images, distribution maps, references, descriptions and geographical, ecological and conservation data. Registered users are able to download search results and provide feedback on the content which is then fed back to the original data provider. We encourage you to join the Araceae scratchpad and contribute data to enrich the site and in so doing make it more valuable for all.

S7. *Pinellia hunanensis* (Araceae), a new species supported by morphometric analysis and DNA barcoding

Yujing Liu[1], Steven Newmaster[2], Xianjin Wu[3], Yue Liu[1], Subramanyam Ragupathy[2], Timothy Motley[1,4] and Chunlin Long[*1,3,5]

[1]College of Life and Environmental Sciences, Minzu University of China. 27 Zhang-guan-cun South Ave, Beijing 100081, China, * Tel/fax: +86–10–68930381; Email: long@mail.kib.ac.cn

[2]Centre for Biodiversity Genomics and Biodiversity Institute of Ontario Herbarium, University of Guelph, Guelph, Ontario, Canada,

[3]Key Laboratory of Hunan Province for Study and Utilization of Ethnic Medicinal Plant Resources, Huaihua University, Hunan 418000, China,

[4]Department of Biological Sciences, Old Dominion University, Norfolk, Virginia 23529–0266, USA,

[5] Kunming Institute of Botany, Chinese Academy of Sciences. 132 Lanhei Road, Kunming 650201, China

Pinellia hunanensis C. L. Long & X. J. Wu, a new species from China, is described and illustrated. A key for the identification of all *Pinellia* species in China, Korea and Japan is included. A detrended correspondence analysis identified 6 groups of taxa including the sp. novum from the 20 samples, analyzing 38 morphological characters. A discriminant function

analysis was used to rigorously test the classification of specimens provided in the cluster analysis. DNA Barcoding provided phylogenetic support using NJ and Bayesian methods to distinguish all six taxa including the putative sp. novum. This study provides preliminary evidence of morphometric variation within and among species of *Pinellia*, which allows further development of hypothesis concerning species boundaries. Discussions concerning medicinal product substitution within the genus *Pinellia* are presented in the context of conservation initiatives of species in China.

S8. The genus *Anthurium* in Northern Carchi Province in Ecuador.

Geneviève Ferry[1] and Thomas B. Croat[2]

[1]Nancy Botanical Garden, France.

[2]Missouri Botanical Garden, USA.

The Araceae is the most poorly known plant family in the Neotropics and is still in need of much taxonomic work in Ecuador. One of the richest areas in the world for Araceae, Ecuador especially the far northwestern corner of the country which abuts Colombia is still unknown. Carchi Province is situated in the NW part of Ecuador and is the richest part of the country with the highest rainfall and with a broad range of elevations and up to four distinct life zones in the Holdridge life zone system.

The area is replete with undescribed species of Araceae. *Anthurium* is the largest genus in the flora with approximately 203 species (including 206 taxa). The region is particularly rich in section *Calomystrium* with 38 species and section *Cardiolonchium* (both with 37 species and 38 taxa), especially at lower elevations and for *Belolonchium* (32 species), especially in the higher elevations. Equally large but found at middle to low elevations is section *Polyneurium* (32 species), followed by section *Xialophyllium* and section *Porphyrochitonium* (both with 21 species), section *Tetraspermium* (7 species totaling 9 taxa); section *Digitinervium* (with 7 species), section *Multinervium* (with 6 species) and section *Decurrentia* (with 2 taxa). More than 60% of all species are deemed to be new to science.

S9. Araceae in time and space - Fossils help to understand historic dispersal routes

Lars Nauheimer[1] and Susanne Renner[2]

[1]Systematic Botany and Geography of Plants, Freie Universität Berlin, Altensteinstraße 6, 14195 Berlin, Germany.

[2]Department of Biology, University of Munich, 80638 Munich, Germany

The Araceae family (>3300 species, 118 genera) is one of the oldest monocot lineages and has an exceptional fossil record that includes Cretaceous flowers, fruits, pollen, and leaves as well as numerous fossils from later periods. The family is world-wide distributed, but the vast majority of species occurs in the humid tropics. Six of the eight subfamilies and 16 genera occur disjunctly on two or more continents, separated by large ocean expanses. Fossil evidence shows that many groups once lived in regions they no longer occupy, indicating extinction.

We constructed an almost complete genus-level phylogeny based on plastid DNA (> 4300 basepairs) and performed divergence dating with different fossil constraints, clock models, uniformly and log-normally distributed fossil constraints, and complex or simple substitution models. A novelty is that my ancestral area reconstruction not only takes into account past connectivity between landmasses, but also includes formerly occupied ranges of certain groups (deduced from the fossil occurrence). Effects of this fossil inclusion in the models were assessed by comparing runs with and without fossil occurrences as well as comparing different ways of the inclusion.

The results show that the Araceae clade diverged from the remaining Alismatales in the Early Cretaceous, during the final stages of the breakup of Pangea. Subfamilies began to diversify before the K/T boundary, and early lineages have persisted in Laurasia. Several lineages reached Africa in the Late Cretaceous and South America in the Paleocene and Eocene, while most transitions to Africa, South America, Southeast Asia, and Australia happened in the Neogene (often following trans-oceanic dispersal). Extinctions in the temperate region probably were caused by the climate cooling in the Oligocene. Past distributions inferred when models included fossil (no longer occupied) ranges differed in nontrivial ways from those without fossil ranges and improved the reconstruction.

S10. The good, the bad and the ugly: plastid and mito phylogenomics of Araceae

Claudia L. Henriquez[2], Tatiana Arias[3], J. Chris Pires[3], Thomas B. Croat[2] and Barbara A. Schaal[1]

[1]Evolution, Ecology & Population Biology, Division of Biology, Washington University in St. Louis, One Brookings Drive, St. Louis, Missouri, 63130, U.S.A.

[2]Missouri Botanical Garden, 4344 Shaw Blvd., St. Louis, Missouri, 63110, U.S.A.

[3]Department of Biological Sciences, Univeristy of Missouri, Columbia, Missouri 65211, U.S.A. Author for correspondence: Claudia L. Henriquez, chenriquez@wustl.edu

The biogeography, chromosome number evolution, and evolutionary history of the plant family Araceae have become much clearer in recent years. The still poorly resolved backbone of the family phylogeny, however, precludes answering questions about the early evolution of the family. With the advent of next generation sequencing, phylogenetic analyses can now be based on thousands of informative nucleotides, which greatly enhance our confidence in the resulting phylogeny.

We used reference-based assemblies of Illumina data for 37 genera from across the backbone of the family to resolve the remaining questions in the deep phylogeny of Araceae. Reference-based assemblies were performed using the chloroplast and mitochondrial genomes of two species of Araceae from Genbank. Sequences from the chloroplast genome produced strongly supported phylogenies, using both coding sequences alone and the entire genome. In contrast, the mitochondrial genome proved to be much more problematic in terms of assembly and the resulting alignment had negligible phylogenetic signal. Better-supported clades in the new study are:

1. Tribe Spathiphylleae, as sister to the rest of Monsteroideae;
2. The Unisexual Flowers clade, with the bisexually-flowered genus *Calla* included, and recovered with strong support;
3. *Anubias* and *Montrichardia*, forming a clade sister to the *Zantedeschia* clade; and
4. *Zantedeschia* as sister to the Old World *Anchomanes* clade.

However, despite the strong statistical support for almost all nodes in the chloroplast phylogenies, the placement of the bisexually-flowered genus *Calla*, and the rheophytic genus *Schismatoglottis* within the Unisexual Flowers clade remains unclear.

S11. Mutational dynamics of aroid chloroplast genomes, and the phylogenetic analysis of closely-related species

Ibrar Ahmed, Institute of Molecular Biosciences (IMBS), Massey University, Palmerston North, New Zealand.

Chloroplast genomes contain vast amounts of evolutionary information which has been used in macro- as well as micro-evolutionary studies. Different parts of the genomes are under differential selection, which results in elevated rates of evolution in certain parts compared to the other parts. We have demonstrated that the two types of mutations, substitutions and indels, are correlated with each other as well as with the distribution of oligonucleotide repeat sequences in the aroid chloroplast genomes. This information is useful in selecting appropriate loci for the kind and level of phylogenetic study being planned. In this talk I will highlight initial evidence for hybridisation between *Colocasia* species in northern Vietnam, based on a combination of chloroplast and nuclear DNA analyses.

Session III: Ecology and Reproduction

S12. The evolution of pollinator/plant interaction types in the Araceae

Marion Chartier[1], Marc Gibernau[2], and Susanne S. Renner[3]

[1] Department of Structural and Functional Botany,University of Vienna, 1030 Vienna, Austria. E-mail: chartier.marion@gmail.com

[2]Centre National de Recherche Scientifique, Ecologie des Forêts de Guyane, 97379 Kourou, France

[3]Department of Biology, University of Munich, 80638 Munich, Germany.

Most plant/pollinator interactions are mutualistic, involving rewards provided by flowers or inflorescences to pollinators. Antagonistic plant/pollinator interactions, in which flowers offer no rewards, are rare and concentrated in a few families including Araceae. In the latter, they involve trapping of pollinators, which are released loaded with pollen but unrewarded. To understand the evolution of such systems, we compiled data on the pollinators and types of interactions, and coded 21 characters, including interaction type, pollinator order, and 19 floral traits.

A new phylogenetic framework has been derived from a matrix of plastid and new nuclear DNA sequences for 135 species from 119 genera (5342 nucleotides). The ancestral pollination interaction in Araceae was reconstructed as probably rewarding, albeit with low confidence since information is available for only 56 of the 120–130 genera. Bayesian stochastic trait mapping showed that spadix zonation, presence of an appendix, and flower sexuality were correlated with pollination interaction type.

In the Araceae, having unisexual flowers appears to have provided the morphological precondition for the evolution of traps. Compared with the frequency of shifts between deceptive and rewarding pollination systems in orchids, our results indicate less lability in the Araceae, probably because of morphologically and sexually more specialized inflorescences.

S13. The contribution of Jacob Koach to studies on the pollination of *Arum*, *Biarum*, *Arisarum* and *Eminium*

Amots Dafni (Haifa University, Israel)

Institute of Evolution and the Department of Evolutionary Biology

Haifa University, Haifa, Israel. Email: adafni@research.haifa.ac.il

Jacob Koach (1944–2007) submitted his (mostly unpublished) Ph. D: "Bio-ecological studies of flowering and pollination in Israeli Araceae" in 1985 at Tel Aviv University. His study dealt with the flowering phenology, thermogenesis, pollination and breeding systems of *Arum palaestinum* Boiss., *A. dioscoridis* Sm., *A. elongatum* Steven., *A. hygropylum* Boiss. , *Biarum pyrami* (Schott) Engler, *B. bovei* Decaisne, *B. olivieri* Blume and *Arisarum vulgare* Targ.-Tozz.

For most of these species he was the first to: test experimentally the thermogenesis schedule in relation to environmental variables, describe the breeding system and the pollination process, and to identify the pollinators. Some of these taxa were never studied before Koach or later.

The presentation will discuss the main achievements of Koach's thesis with special regard to modern studies in species related to those he studied, and studies of floral scent and pollinator behavior.

S14. Pollination mutualisms between *Colocasiomyia* flies (Diptera: Drosophilidae) and aroids: Chemical analyses of exudates, as a floral reward, from staminodes of *Alocasia odora* (Roxb.) K. Koch (Araceae) in Okinawa, Japan

Takano Takenaka Kohei[1], Katagiri Chihiro[2,3], Katayama Noboru[4,5], Yafuso Masako[6], Li Nan-nan[7,8], Gao Jian-jun[8], Katoh Toru[4], Inari Naoki[4], Kobayashi Norio[9], Yoneya Kinuyo[5], Miyake Takashi[10] and Toda Masanori J.[4]

[1]Tohoku University, [2]Mathematical Assist Design Laboratory, [3] Tokyo Denki University, [4]Hokkaido University, [5]Kyoto University, [6]Naha, Okinawa, [7]Southwest Forestry University, [8]Yunnan University, [9]Saitama Prefectural University and [10]Gifu University

The flies of the genus *Colocasiomyia* (including 25 described and 65 undescribed species; M. J. Toda, unpublished data) visit flowers of several families of 'basal' angiosperms (Magnoliaceae, Araceae and Arecaceae). Many have evolved pollination mutualisms with some host plants of Araceae. Some are obligatory as seen in the fig-fig wasp and yucca-yucca moth systems: the flies depend on specific host plants throughout almost their entire lifecycles from egg to adult, and in turn serve as specific, indispensable pollinators for their host plants. Furthermore, in contrast to the fig-fig wasp and yucca-yucca moth systems, in which the host plants sacrifice some ovules or developing seeds as rewards to the pollinators, *Colocasiomyia* flies do not damage the reproductive organs of their host plants: larvae consume decayed tissues and/or exudates of host plants.

Through field observation and experiments in the present study, we confirmed that adult flies of *Colocasiomyia alocasiae* and *Co. xenalocasiae* feed on exudates from staminodes in the lower part of the sterile inflorescence of *Alocasia odora* in Okinawa, Japan. The exudates were collected in the field and analysed using two-dimensional thin-layer chromatography (TLC) and high performance liquid chromatography (HPLC). In TLC, any lipid was not detected whereas spots corresponding to sugars and amino acids were determined. In HPLC, retention times of several peaks observed in chromatographs of the exudates coincided with those of standard sugar solutions such as glucose, sucrose and fructose.

These results imply that the exudate is typical floral nectar and that the staminodes in the lower part of the sterile inflorescence of *A. odora* especially serve as an organ that provides a reward for its pollinators. The staminodes in the lower part of the sterile inflorescence locate next to the female inflorescence. *Colocasiomyia* flies were observed to be attracted to the staminodes in the early phase of the flowering (i.e., female stage). Such location and timing of nectar presentation seem to guide flies to efficiently pollinate the host plant. We also introduce a tentative phylogenetic hypothesis about the genus *Colocasiomyia*, which is necessary to understand the evolution of this very efficient mutualism between *Colocasiomyia* flies and relatively ancient angiosperm plants.

S15. Pollination mutualism between flower-breeding flies of the genus Colocasiomyia (Diptera, Drosophilidae) and expansion of their aroid host plant species in Southeast Asia

Masako Yafuso[1], Bui Tuan Viet[2] and Shinichi Adaniya[3]

[1] 1–2-21, Uema Naha, Okinawa, 902–0073 Japan. E-mail: yafusom@juno.ocn.ne.jp

[2] Vietnam National Museum of Nature, 18 Hoang Quoc Viet, Cau Giay, Hanoi

[3] Faculty of Agriculture, University of the Ryukyus, Nishihara, Okinawa, 903–0213 Japan

Mutalistic co-evolution between species-specific pollinator flies of the genus C*olocasiomyia* (Drosophilidae) and their host plant species was observed in wet tropical to subtropical Southeast Asia. Complicated host plant routes suggest the adaptive radiations in both *Colocasiomyia* species and Araceae species. Pollen germination rates attaching on the pollinator flies were about 70%. This suggests that the *Colocasiomyia* flies contribute to the male reproductive success of their host plants.

S16. A global assessment of invasiveness in Araceae: is there a general suite of invasive traits?

D. Moodley[1,2,3], Ş. Procheş[1] and J.R. Wilson[2,3]

[1] School of Environmental Sciences, University of KwaZulu-Natal, Westville Campus, Private Bag X54001, Durban 4000, South Africa

[2]Invasive Species Programme, South African National Biodiversity Institute, Kirstenbosch National Botanical Gardens, Claremont, South Africa

[3] Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa

Corresponding author: Desika Moodley (desikamoodley29@gmail.com)

Significant progress has been made in understanding biological invasions recently, but one of the key findings is that the determinants of naturalization and invasion success vary from group to group. Here we explore these issues for Araceae. We determine which species have been introduced outside their native ranges, the pathways of introduction, and which traits separate those species that have been introduced from those that are known to be invasive. To do this we first developed a database of species that have been introduced worldwide using online databases (e.g. Global Invasive Species Database and the Global Biodiversity Information Facility) and literature sources (e.g. New Zealand naturalised vascular plant checklist and Aroideana).

We analysed various explanatory variables (e.g. traits associated with morphology, reproduction and distribution) using regression techniques, then used morphological traits to build a phylogenetic tree showing clades defined by characters identified as key for invasiveness. The tree can be used to predict potentially invasive species. Results are discussed in terms of traits that confer invasiveness on a global scale, which are potentially useful for screening taxa. Araceae provides an excellent study group for identifying determinants of invasiveness in herbaceous plants, since this is one of the largest plant families in the world, and among the most popular with horticulturists, with species occupying various habitats.

One of the aims of our study is to develop general advice for managing invasions, so we would greatly appreciate insights and experiences of cases where Araceae has (and has not) naturalized and spread.

Session IV: Posters

P1. Is *Remusatia* (Araceae) Monophyletic? Evidence from Three Plastid Regions

Rong Li and Heng Li, Key Laboratory of Biodiversity and Biogeography, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming 650201, China

The genus *Remusatia*(Araceae) includes four species distributed in the tropical and subtropical Old World. The phylogeny of *Remusatia* was constructed using parsimony and Bayesian analyses of sequence data from three plastid regions (the *rbcL*gene, the*trnL-trnF*intergenic spacer, and the *rps16* intron). Phylogenetic analyses of the concatenated plastid data suggested that the monophyly of *Remusatia* was not supported because *R.*

hookeriana did not form a clade with the other three species *R. vivipara*, *R. yunnanensis*,and *R. pumila*. Nevertheless, the topology of the analysis constraining *Remusatia* to monophyly was congruent with the topology of the unconstrained analysis.

The results confirmed the inclusion of the previously separate genus *Gonatanthus* within *Remusatia* and disagreed with the current classification of the genus.

P2. Use of aroids as fodder plants in a Yao community, northern Vietnam

Masuno T.[1], N. A. Luu Dam[2], V. D. Nguyen[2] and P. J. Matthews[1]

[1]National Museum of Ethnology, Osaka,Japan,E-mail:masuno_takashi@goo.jp

[2]Institute of Ecology and Biological Resources, Hanoi, Vietnam.

A range of wild and cultivated aroids are present in Ba Vi National Park and its vicinity, about 70 km west of Hanoi city. We investigated pig fodder usage in several households in one village at the foot Ba Vi mountain, using interviews and direct observation. The research was conducted in August and December 2012 (mid-wet to early-dry season). Many households grow paddy rice for home consumption and maize in hillside areas for pig feed. Collecting bamboo shoots and medical plants also seems to be an important source of cash income. Most villagers keep about 1–3 sows and piglets in a pig house in their backyard. Pigs are usually fed three times per day (morning, mid-day, and evening). They mix locally-grown rice bran, maize flour, and vegetables such as sweetpotato leaves and stems (*Ipomoea batatas*), banana stems (*Musa acuminata*), and the leaves of aroids to feed their pigs. These leafy fodder plants are mostly obtained from the home garden of each household.

The villagers mainly use three species of aroid leaf: Taro leaf (*Colocasia esculenta*), yautia leaf (*Xanthosoma sagittifolium*) and elephant ear leaf (*Alocasia odora*). In wet season of August, taro and yautia were the main fodder plants. In dry season of December, *Alocasia* leaf was the main fodder. The methods used to prepare taro and *Alocasia* leaves differ in detail, but always include chopping and boiling of the whole leaf (blade and petiole). This treatment reduces the acridity of the leaves. The villagers regard sweetpotato greens as the best fodder for pigs, but not enough are available for daily use. The leaves of aroids are used daily, and to understand backyard pig keeping better, attention needs to be given to the diversity and seasonality of aroids as fodder plants. Aroids are widely used as pig fodder in Vietnam, and methods for their production and use, in different seasons, and in combination with other fodder materials, are of historical and practical interest.

P3. The Vietnam National Collection of Edible Aroids

Vu Linh Chi and Nguyen Van Kien, Plant Resources Center, Ankhanh, Hoaiduc, Hanoi, Vietnam. Tel. 84.4.33845802. Fax. 84.4.33650625. Website: http://www.pgrvietnam.org.vn

The National Collection of Edible Aroids has been maintained for many years at the Center, which is located on the outskirts of Hanoi City. All the main economic genera of Araceae are represented. The collection has been used in local and international studies of the diversity, production, and uses of aroids in Vietnam. The Collection is also used for the development and distribution of promising cultivars.

P4. The use of AFLP markers to elucidate the relationships within the genus *Cryptocoryne* (Araceae)

Niels Jacobsen[1], Jan Bastmeijer[2], Claus Christesen[3], Takashige Idei[4], Jihad Orabi[1], Duangchai Sookchaloem[5], Fiorello Toneato[1]and Marian Oergaard[1].

[1] Department of Plant- and Environmental Sciences, University of Copenhagen, Rolighedsvej 21, DK 1958, Frederiksberg C, Denmark

[2] Oude Roswinkelerweg 72, NL 7872 AG Emmen, The Netherlands

[3] 23–14, 1 Chome Amanogahara, Katano City, Osaka 576–0034, Japan

[4] AquaDiscover, Solbaerhaven 118, DK-8520 Lystrup, Denmark

[5] Department of Forest Biology, Faculty of Forestry, Kasetsart University, 50 Pahonyothin Rd., Ladyoa, Chatuchak, Bangkok 10900, Thailand

In the ongoing molecular studies of the Aroid genus *Cryptocoryne* it was decided to study four species-complexes in more detail: The *C. beckettii* complex (Sri Lanka), the *C. crispatula* complex (Mainland Asia), and selected accessions from the di- and polyploid cordate leaved species from Malesia (*C. cordata* etc.), altogether comprising 400+ accessions.

The Amplified Fragment Length Polymorphism (AFLP) study proved capable of not only being able to discriminate within the species complexes, but it was also able to cope with all 400+ accessions in one run, discriminating the *C. beckettii* group, the *C. crispatula* group, and,

within the cordate-leaved Malesian species, it was able to discriminate between diploids, tetraploids and hexaploids forming very robust relationship groupings.

The AFLP study also showed that geographical proximity revealed closer genetical relationship contrasting morphologically similar accessions geographically further apart.

Naturally- and artificially-produced interspecific hybrids included in the investigation corroborated the genetical and morphological interpretations.

P5. The variation in leaf anatomy of *Scindapsus* Schott of Malaysia

Kartini Saibeh, Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Jalan UMS, 88450 Kota Kinabalu, Sabah, Malaysia. Email: k_saibeh@ums.edu.my

Leaf anatomy of 16 species of the genus *Scindapsus* was studied to evaluate the diagnostic potential for taxonomic purposes. All the species studied had bifacial laminae. The epidermal cell size varies within the same specimen. The presence of an adaxial hypodermis was observed in most species studied. Druses and raphides are represented mainly by irregular shaped prisms of varying sizes found in the mesophyll. The druses were absent in the mesophyll of *S. lucens*. The raphides were absent in the mesophyll of *S. borneensis* and *S. rupestris*.

This study show that some species have some leaf traits in common, and some are confined to only one or a group of species and should assist in taxonomic classification and identification.

P6. Chemical Profiling and Bioactive Potentials of *Alocasia princeps* W. Bull

Kartini Saibeh[1], Salani Selveno[1], Thilahgavani Nagappan[1,*] and Charles S.Vairappan[1]

[1]Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah,

UMS Road, 88400 Kota Kinabalu, Sabah. * Email: thila_vani@yahoo.com

Alocasia princeps W. Bull, or the "Purple Cloak" is a widely-spread aroid species in Borneo,typically found growing in rain forest on well-drained slopes and ridge tops. This species can be identified morphologically by its distinctive V-shaped, dark green upper-leaf

and deep purple-red under-leaf. Although *A. princeps* is known as an ornamental plant, we began investigating its bioactive potentials by exploring its chemical properties, as some *Alocasia* species are edible.

A specimen of *A. princeps* from Gaya Island, Sabah, was cleaned, chopped into sections, soaked for a week in 70% ethanol.

The solvent was then double filtered and concentrated *in vacuo* to obtain total crude extract. Crude extract of tuber, petiole and leaves was subjected to preliminary chemical profiling using Thin Layer Chromatography (TLC) and High Performance Liquid Chromatography (HPLC). Lipid and FAME content was quantified to identify possible presence of chemotaxonomical markers. In addition, antibacterial assay was carried out against human pathogenic microbes to exhibit potential as antimicrobial agent.

P7. Biological activities of lipophilic extract from *Lasia spinosa* (L.) Thwaites (Araceae): effect on seed germination and seedling growth of invasive plant (*Mimosa diplotricha* C. Wright ex Sauvalle) in Thailand.

Tiwtawat Napiroon[1], Srunya Vajrodaya[2] and Duangchai Sookchaloem[1]*

[1]Department of Forest biology, Faculty of Forestry, Kasetsart University, Bangkok 10900 Thailand. * E-mail: ffordcs@ku.ac.th

[2] Department of Botany, Faculty of Sciences, Kasetsart University, Bangkok 10900 Thailand

The study of lipophilic extract from *Lasia spinosa* (L.) Thwaites rhizome effect on seed germination and seedling growth of invasive plant, *Mimosa diplotricha* C. Wright ex Sauvalle was done in September - November 2012. Five different concentrations (0, 10, 20, 30 and 40 mg/ml) were used.

The results of lipophilic extract from *L. spinosa* rhizome showed inhibition of seed germination, seedling growth and characteristics (after transplanting 1 week). When concentrations increased, the shoot and root length decreased significantly ($P< 0.05$). Thin Layer Chromatography (TLC) screening, preliminary test and detection using different specific reagents showed terpenoids, phenolic compounds, courmarin, alkaloids and *C*-glycoside.

P8. Distribution and ecology of Araceae on limestone mountains of Lop Buri and Saraburi provinces, Thailand

Sutida Maneeanakekul and Duangchai Sookchaloem, Department of Forest Biology, Faculty of Forestry, Kasetsart University, Chatuchak, Bangkok 10900.

Araceae is a monocotyledonous family, having numerous potential useful plants, such as: edible plants, medicinal plants, and ornamental plants. Twenty-nine genera and 130 species of Araceae were reported in Thailand, of which 39 species were reported as endemic species and 18 rare species. About 50 % of endemic species and rare species were found in limestone areas.

Recently, these areas have been seriously threatened by land-use changes for economic development. Many species of Araceae are classified as rare and under risk of extinction (threatened plants); they should be a priority for conservation. Our study of the distribution and ecology of Araceae plants was carried out in Lop Buri and Saraburi limestone mountains, with the following purposes:

1) to study species diversity and distribution of Araceae plants in limestone mountains,

2) to clarify relationships of species richness and abundance with environmental gradients, and

3) to provide suggestions about conservation and management of threatened plants.

The research was conducted from November, 2010 until present. All data on Araceaereported in Thailand were collected from literature reviews. Herbarium specimens in the Forest Herbarium (BKF), National Park Wildlife and Plants Conservation Department, and Bangkok Herbarium (BK), Department of Agriculture were studied. Preliminary field surveys and selection of representative study areas were carried out. Collection of specimens took place between December, 2011 March, 2012 and October, 2012.

A total of 37specimens were collected, including 34 specimens in Saraburi province (6 from Pra-Phut- Tabat mountain, Pra-Phut-Tabat district, 3 from Khao Wong mountain, Pra-Phut-Tabat district, 9 from Khao Pra-Phut- Tabat -Noi mountain, Kaeng Koi district, 8 from Pra-Po -Thi -Sat mountain, Kaeng Koi district, 5 from Khao- Pha- Lad mountain, Muk Lek district, and 6 from Khao-Wong-Pra-Chan mounatain, Muk Lek district). Three specimens were collected from Khao-Sap-Kaeng-Kai mountain, Lumsomboon district, Lop Buri province.

Among the collected specimens, 9 genera were found: *Aglaonema*, *Alocasia, Amorphophallus, Amydrium, Hapaline, Pseudodracontium, Pycnospatha*, *Scindapsus,* and *Typhonium.*

P9. Observations on the unfurling of the inflorescence of *Amorphophallus* 'John Tan" at Gardens by the Bay

Andrea Kee, Chua Siok Sin and Lim Mei Leng, Gardens by the Bay, Singapore

Amorphophallus 'John Tan' is a cross between the seed parent plant of *A. variabilis* and the pollen parent plant of *A. titanum*. It was carried out by Ralph Mangelsdorff in Frankfurt Palmengarten (Germany) in May 2002.

Both parents of *Amorphophallus* 'John Tan' are native to Indonesia. *A. titanum* occurs only in Sumatra while *A. variabilis* is found wild in several islands in Indonesia such as Java, Madura and Kangean Islands (Jansen et al. 1996).

Amorphophallus 'John Tan' was placed in a controlled environment in Gardens by the Bay. Studies were carried out on temperature, light and humidity during the period of the unfurling of the inflorescence. Observation of growth data was collected on hourly basis for a 12-hour interval. Information leading to the opening of the inflorescence can then be shared amongst other aroid growers or enthusiasts.

P10. Ethnobotany of *Acorus calamus* L. in China

Shuang Zhang[1], Feifei Li[1]& Chunlin Long[1,2]*

[1] College of Life and Environmental Sciences, Minzu University of China. 27 Zhong-guan-cun South Ave, Beijing 100081, China.

[2] Kunming Institute of Botany, Chinese Academy of Sciences. 132 Lanhei Road, Kunming 650201, China.

* Corresponding author. Tel/fax: +86–10–68930381; Email: long@mail.kib.ac.cn

Acorus calamus (Acoraceae), usually called *Chang-pu* or *Shui Chang-pu* in Chinese, was traditionally placed in the family Araceae. Its traditional botanical knowledge especially the cultural and ethnomedicinal values had been presented in this paper based on our recent literature studies and ethnobotanical investigations in different provinces of China.

Acorus calamus has become a symbolic cultural plant in China for many centuries. It has been used as an important festival item in the whole country. The ethnic people and Han Chinese have used the leaves of *A. calamus* for more than 2000 years, for packing *Zong-zi* (a special food with cultural significance made from sticky rice and other foodstuff), and hung its leaves on the door as powerful weapons to drive evil spirits out of houses and to keep healthy environment during the Dragon Boat Festival (May 5th of the lunar calendar). On April 14 of the lunar calendar, it was the birthday of *A. calamus*. It is the only plant which acquires this honor. *Chang-pu* was also regarded as one of the "Four Beauties in Flowers and Herbs" in traditional Chinese literature.

A. calamus has been used as a traditional Chinese medicine (TCM) and ethnomedicine by many ethnic groups. It was firstly mentioned in 200BC-200AD and used for treating deaf ears, blind eyes, cramps and digestive disorders. The Miao people used the rhizomes to treat dysentery, flatulence and anti-epileptic. The dead bodies should be washed with hot water in which *A. calamus* or peach leaves should be added to prevent spreading germs. The Buyi people used *A. calamus* for curing appendicitis. The Uygur people used its leaves for making milk tea as supplementary to treat headache, stomachache and digestive disorders.

P11. Pollination investigations in *Schismatoglottis calyptrata* (Roxb.) Zoll. & Moritzi Complex

Hoe Y.C.,[1] Ooi I.H.,[1] Wong S. Y.[1]* and Boyce P.C.[2]

[1]Department of Plant Science and Environmental Ecology, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Samarahan, Sarawak, Malaysia. * Email: sywong@frst.unimas.my

[2]School of Biological Sciences, Universiti Sains Malaysia, 11800 USM, Pulau Pinang, Malaysia

The pollination of four species of *Schismatoglottis calyptrata* complex was investigated: 1) type, *Schismatoglottis calyptrata* (Roxb.) Zoll. & Moritzi on Ambon Island, Indonesia; 2) *Schismatoglottis baangongensis* sp. nov., West Sarawak, Malaysia; 3) *Schismatoglottis giamensis* sp.

nov., West Sarawak, Malaysia and 4) *Schismatoglottis muluensis* M. Hotta, North Sarawak, Malaysia. Each of these four investigated *Calyptrata* species is highly endemic, and their flowering mechanisms and pollinators are still unknown. Beetles (Nitidulidae, Staphylinidae, *Chaleonus* sp) visited all investigated *Calyptrata* except *S. calyptrata.*

Schismatoglottis calyptrata was pollinated by *Colocasiomyia* sp., but *S. muluensis, S. baangongensis* and *S. giamensis* were pollinated by both *Colocasiomyia* sp. and Nitidulidae. The arrival of the *Colocasiomyia* and Nitidulidae were correlated with the spathe opening and intensified odour emission during onset of female anthesis. At the end of the male anthesis, they left with adhered pollen. The visitation number of the *Colocasiomyia* and Nitidulidae were the highest, and were significant different (Kruskal-wallis) as compare with other visiting insects. Staphylinidae sp1 was the opportunistic pollinator (*S. muluensis* and *S. giamensis*). Unidentified fly, unidentified midge, *Chaleonus* sp1–3, Staphylinidae sp2, *Trigona sp* and *Parastasia nigripennis* were the visitors. Our investigations show that *Calyptrata* species growing at different localities were visited by different insects.

Session V: Further Systematics and Taxonomy

S17.The Genus *Stylochaeton* (Araceae)

Josef Bogner, Botanischer Garten München-Nymphenburg, Germany

Stylochaeton Lepr. (Araceae) is an African genus of about 20 species, distributed from the south of the Sahel zone (Senegal, Mali, Burkina Faso, Chad, South Sudan and Ethiopia) to southern Africa (RSA [Transvaal, Natal], Zambia and Angola). The species are found at altitudes from sea level to 1600 m. and most occur in areas with wet and dry seasons (savannas or deciduous forests) - the plants survive the dry season as dormant underground rhizomes which have fleshy roots to keep them alive. These species flower before the beginning of the first rains, when the leaves appear. Only a few species are found in the rain forest region of Africa (Cameroon, Gabon, Zaire [Congo]) and these are evergreen and flower with the leaves (e.g. *Stylochaeton zenkeri*). Other species grow in evergreen forests (e.g. Usambara mountains) but there undergo a dormant period. The systematic position of *Stylochaeton* lies between the genera with bisexual and unisexual flowers (see molecular tree) and it is one of only three genera with both unisexual flowers and a perigone (the other two are the African genera *Gonatopus* and *Zamioculcas* of subfamily Zamioculcadoideae). All genera of subfamily Aroideae have unisexual flowers without a perigone (and inaperturate pollen grains), while the genera of the other subfamilies have bisexual flowers with or without a perigone (and aperturate pollen grains).

The leaf blades of *Stylochaeton* are entire (hastate, sagittate, cordate, ovate, lanceolate, linear or rounded) and the venation is reticulate. The spathe margins are connate in the lower part and free in the upper part, opening to a greater or lesser extent according to species. The spadix is fertile to the apex; the female flowers are situated at the base in a whorl or in spiral rows. Each female flower is surrounded by a more or less urceolate perigone with connate tepals, the ovary is 1- to 4-locular and the ovules anatropous. The male flowers have a rather shallow connate perigone and three to six (2–7) stamens with free, filiform filaments (rarely they are thickened apically, e.g. *Stylochaeton kornasii*); the pollen grains are inaperturate and the exine is more or less reticulate. The infructescence is subterranean in many species; the fruit is a berry with one or two seeds with endosperm, an elongate embryo and a costate testa. Known chromosome numbers are 2n=28 or 56 (n=14).

Little is known on pollination, although beetles were once reported from a Tanzanian species. *Stylochaeton* is rarely cultivated and several species remain incompletely known. The fleshy roots of species in drier regions are eaten by the Naked Mole Rat (*Heterocephalus glaber*) from East Africa. No economic uses have been reported.

S18.Phylogeny of the genus *Philodendron* - first results from an analysis using chloroplast markers

Nils Köster[1] and Nadja Korotkova

[1]Botanic Garden and Botanical Museum Berlin-Dahlem, Freie Universität Berlin

Königin-Luise-Straße 6–8, D-14195 Berlin, Germany. E-mail: n.koester@bgbm.org; phone: +4930–838–50121; fax: +4930–838–50186.

With nearly 480 published taxa and an estimated total of 700 species, *Philodendron* is the family's second largest genus after *Anthurium* and one of the most diverse genera in the New World tropics. It occurs from northern Mexico to southern Uruguay, and it is especially diverse in tropical humid forests. Due to its impressive morphological diversity regarding leaf shape, size, and coloration, many *Philodendron* species are important ornamental plants.

Traditionally, three subgenera have been recognized in the genus: subgenus *Pteromischum* with about 80 species, subgenus *Meconostigma* with about 20 species, and the type subgenus *Philodendron* with probably more than 600 species. Previous studies gave evidence for the monophyly of the three subgenera, but suggested the paraphyly of the closely related, predominantly Asian genus *Homalomena* - with the few Neotropical *Homalomena* species being the sister group to *Philodendron* or even nested within *Philodendron*. Thus, the relationships among the three subgenera and Neotropical *Homalomena* are still ambiguous, and affinities within the largest subgenus *Philodendron* remain largely unexplained.

In order to initiate a larger project on the phylogeny of *Philodendron*, we sampled the living collection housed at Berlin Botanic Garden and sequenced the chloroplast region trnK/matK for 52 *Philodendron* and 6 outgroup accessions, covering 50 *Philodendron* and 6 outgroup taxa.

Our results show a basal polytomy of four well-supported clades representing the subgenera *Pteromischum* and *Meconostigma*, a clade combining the South American sections *Baursia* and *Philopsammos* of subgenus *Philodendron*, as well as a clade comprising all remaining species of that subgenus. Within the latter clade, a group of species from the Amazon and the Guianas with mainly three-lobed or deeply incised-lobate leaf blades is highly supported, including the sections *Polytomium* and *Schizophyllum*. Another clade of species from the Andes of northwest South America, although not attributable to any traditional infrageneric taxon, represents mostly those species with conspicuously velvety or at least completely matt adaxial leaf surfaces.

S19. *Homalomena* on Borneo: How many new species?

Wong Sin Yeng

Department of Plant Science & Environmental Ecology, Faculty of Resource Science & Technology

Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia. Email: sywong@frst.unimas.my

Homalomena Schott comprises 75 described species with ca 500 novel species yet to be formally described. Most species are Malesian with a few species in continental tropical Asia and the neotropics. Asian *Homalomena*, however, forms a separate clade from the Neotropical *Homalomena*. Four sections are recognized within the Asian *Homalomena*: *Homalomena* Engl. & K.Krause, *Cyrtocladon* (Griff.) Furtado, *Chamaecladon* (Miq.) Engl. & K.Krause, and *Punctulata* Engl.

Section *Cyrtocladon* comprises at least 300 novel species with many species are restricted to Borneo. All species so far studied undergo a complex series of seemingly coordinated spathe and spadix movements during anthesis.

Section *Cyrtocladon* currently consists of four complexes: Borneensis, Giamensis, Hanneae and Rostrata and by far, is the most speciose section in the genus in Indomalaya. Frequently, several species from either sections or complexes occur sympatrically, often flowering synchronously with no hybrids being observed in the wild. Therefore, for this study, we chose several species from three complexes in section *Cyrtocladon*, Hanneae complex, Giamensis complex, and Borneensis complex for investigation on its flowering mechanisms, pollination strategies and floral odour compounds.

The results provided suggestions for the rich level of diversity in *Homalomena* on Borneo.

S20.*Schottarum* (Schismatoglottideae): An example of a cryptic taxon in *Schismatoglottis* exposed by combined morphological and molecular analyses

Low Shook Ling

Department of Plant Science & Environmental Ecology, Faculty of Resource Science & Technology,

Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia. Email: shookling5052@hotmail.com

Generic boundaries among parts of Schismatoglottideae remain unclear for several reasons:

(1) large numbers of taxa are being revealed through our on-going fieldwork, now expanded to previously unsampled localities on Borneo; (2) established occurrence of a high level of homoplasies among the morphological characteristics hitherto used to delimitate genera; and (3) gene regions used in previous studies contradicted some of current taxonomic placements.

Among the unsolved groups from previous studies a clade of *Schismatoglottis* species from above the Lupar Divide of west Sarawak, comprising *Schismatoglottis sarikeensis* and *S. josefii*, was investigated to resolve the position of these two species, using combined plastid regions: *trn*L intron and *trn*L-F intergenic spacer, coding *mat*K+partial 3' *trn*K, intergenic spacer *trn*H-*psb*A, and nuclear region, ITS. Analyses of the combined datasets with parsimony, maximum likelihood, and Bayesian methods revealed that *S. sarikeensis* and *S. josefii* do not belong to *Schismatoglottis*, and that furthermore have several morphological characteristics that are homoplasious with their analogues in *Schismatoglottis*. These species are to be transferred to *Schottarum* (≡*Hottarum sarikeense* ≡*Schismatoglottis sarikeense*). Molecular support and notes on morphological structure, flowering mechanism, pollination strategy, and fruitset (of *S. sarikeense*) are also presented.

S21.Systematics and evolution of Monsteroideae, with a focus on the Neotropical genus *Monstera*

Alejandro Zuluaga[1], Ken Cameron[1]and Tom Croat[2]

[1] Department of Botany, The University of Wisconsin-Madison. Email: zuluagatroch@wisc.edu

[2] Missouri Botanical Garden

Monsteroideae is the third richest subfamily with some 500 species (many still undescribed) of mostly hemiepiphytic and epiphytic climbers, and it is restricted to tropical America and Asia, except for one or two species, which are native to tropical Africa. As part of one of the earliest diverging lineages in the family, Monsteroideae may help to provide a clearer picture of the evolution within this ecologically important family. The generic composition of Monsteroideae has been largely stable, but considerable debate has persisted around the relationships and circumscription of the genera, especially *Amydrium, Epipremnum*, *Monstera*, *Rhaphidophora* and *Scindapsus*. The current classification recognizes twelve genera grouped into three clades: the tribes Heteropsideae, Monstereae, and Spathiphylleae. We test the current classification using molecular data from five plastid (*matK, rbcL, trnL-F, trnC* and *ycf1*), and two nuclear (*PhyC* and *Chalcone Synthase*) regions. Major clades within Monsteroideae are recovered in analyses with plastid and nuclear markers.

Our results support Spathiphylleae as sister to rest of Monsteroideae, and most of the genera appeared monophyletic except *Amydrium*, *Epipremnum* and *Rhaphidophora*. On the other hand, the genus *Monstera,* with about 50 species, is part of the Monstereae and sister to a clade compound of *Amydrium* and *Epipremnum pinnatum*. Sectional classification of *Monstera* is not completely supported. *Monstera deliciosa* (section Tornelia), or a clade comprising *M. deliciosa*, *M. tuberculata* (section Echinospadix) and most of the species from section Marcgraviopsis, appear as sister to rest of the genus. Molecular dating analyses and the lack of variation in the DNA sequences support a very recent diversification in the core on

Monstera. All these results support a paleotropical origin for *Monstera* with a subsequent invasion to South America. Finally, we explored the taxonomic and phylogenetic utility of morpho-anatomical characters of flowers and fruits of *Monstera*.

S22. RAPD analysis of genetic diversity in genus *Arisaema*(Araceae) of the Western Ghats of Maharashtra (India)

K. S. Patil, Department of Botany, Smt. K. W. College, Sangli 416416, India.

Molecular studies of genus *Arisaema* (Araceae) are unknown in the study region. The present study was carried out to optimize DNA isolation and PCR conditions for RAPD analysis of three species of genus *Arisaema* (Araceae) found in the Western Ghats of Maharashtra. Modified Doyle and Doyle DNA extraction method employing 0.4 M NaCl in 4% polyethylene glycol (PEG) increased the DNA yield. The optimized conditions for DNA isolation and RAPD- PCR obtained were used to study the genetic diversity and evolution in genus *Arisaema*. In RAPD studies, OPA 01 primer produced a total of 16 reproducible PCR bands that were used to calculate genetic distance coefficients among the species. Genetic distances ranged from 0.18 to 0.30 leads to genetic variation in *Arisaema species*.

A dendrogram was produced using unweighted pair group method using arithmetic averages (UPGMA) using Gel documentation unit and software (Cell Biosciences, AlphalmagerHP, EP and EC). *A. tortuosum* and *A. murrayi* together formed a cluster whereas *A. neglectum* shows separate entity. 70 %, 75 % and 82 % genetic similarity was observed between *A. neglectum* and *A. tortuosum, A. neglectum* and *A. murrayi*, *A. tortuosum*and *A. murrayi* respectively.Clusters did not relate to morphological characters. Nevertheless, RAPD markers fingerprinting allowed a rapid assessment of the level of genetic variation that would otherwise be difficult to evaluate using the limited number of morphological markers present among these closely related *Arisaema* species.

S23. Taxonomic review of Philippine *Alocasia* (Araceae)

Melanie P. Medecilo, Biological Sciences Department, De La Salle University - Dasmariñas, City of Dasmariñas, Cavite, Philippines. Email: lanie_medecilo@yahoo.com

This study was conducted to clarify the taxonomy of Philippine *Alocasia* by investigating the morphology, anatomy and pollen characters of the component species. Results showed that morphological characters can be used to a certain extent in delimiting taxa while leaf anatomical characters showed continuous variation between species and are of little value for taxonomic recognition when used alone. The combined morphology, anatomy and pollen characters showed a clear distinction on the heterophylla, longiloba, macrorrhizos,odora, princeps' and scabriuscula groups, which agrees with the classification of *Alocasia* proposed by Hay (1991, 1998, 1999).

The distribution, ecology and conservation status of the species were also studied. The center of diversity of *Alocasia* in the Philippine archipelago is in Luzon and Visayan Regions. All of the species except *A. macrorrhizos* are endemic to the country. This study shows that the Philippines now ranks second, next to Borneo, in terms of the species diversity of *Alocasia*.

Session VII Ethnobotany and Economic Botany

S24. Aroid Crops in China

Yujing Liu[1], Bo Liu[1] and Chunlin Long*[1,2]

[1] College of Life and Environmental Sciences, Minzu University of China. 27 Zhong-guan-cun South Ave, Beijing 100081, China.

[2] Kunming Institute of Botany, Chinese Academy of Sciences. 132 Lanhei Road, Kunming 650201, China.* Tel/fax: +86–10–68930381; Email: long@mail.kib.ac.cn

The history of aroid cultivation in China is briefly introduced. Based on literature study and field investigation, 16 species in the family Araceae are recognized as crops cultivated in the country. Among them, three species have very high values both in Chinese history and today. They are taro (*Colocasia esculenta*, a common food crop), konjac (*Amorphophallus konjac*, a medicinal and industrial crop), and *Ban Xia* (*Pinellia ternata*, an important herbal medicinal crop). The taxonomic issues at species and cultivar levels are argued and discussed. Suggestions for future studies are proposed for aroid crop development.

S25. Useful aroids and their prospects in Vietnam

Nguyen Van Du, Tran Y Nhi, Nguyen Thi Van Anh and Bui Van Huong

Institute of Ecology and Biological Resources,Vietnam Academy of Science and Technology, 18, Hoang Quoc Viet Road, Cau Giay District, Hanoi, Vietnam

In Vietnam, the family Araceae is represented by around 135 species belonging to 24 genera. Among them, 28 species in 15 genera are used for medicine, 19 species in 9 genera have ornamental value, and 9 species in 4 genera are eaten. Taro (*Colocasia esculenta* L.) is commonly cultivated as a leaf vegetable and source of starchy corms. Recently we discovered four species of *Amorphophallus* that contain glucomannan. The flour of *A. konjac* is very commonly used in China and Japan as a food providing dietary fibre. The results of our chemical analysis show that the glucomannan of *A. krausei*, *A. konjac* and *A. corrugatus* are similar. Further study on propagation, cultivation and glucomannan content of these four species in Vietnam is in progress, in order to develop new sources for glucomannan products.

S26. Taro stolons in Northern Vietnam: a common but little-studied vegetable food

Nguyen Van Kien[1] and Vu Linh Chi [2]

[1] Division of Genebank Management, Plant Resources Center, Ankhanh, Hoaiduc, Hanoi, Vietnam. Tel: 84.4.33656602. Fax: 84.4.33650625. Email: kiennguyenvan8@hotmail.com

[2] Head of Seed Multiplication and Germplasm Evaluation, Plant Resources Center

Ankhanh, Hoaiduc, Hanoi, Vietnam. Email: vlinhchi@yahoo.com

Taro (*Colocasia esculenta*) is considered as an indigenous cultivated plant in Vietnam and other Southeast Asian countries. Previous isoenzyme analyses (TANSAO project) showed that the diversity of Vietnamese cultivars is very high. While most cultivars are used to obtain starchy corms, some are used primarily to obtain leaves or stolons (i.e. as vegetables). Here we introduce how taro varieties with edible stolons are identified, harvested, stored, and prepared for eating among different ethnic groups in northern Vietnam.

We hope that our report will raise awareness of this common but little-studied food among farmers, consumers, plant breeders, and other taro researchers, in Vietnam and other countries.

S27. Ethnobotany and natural history of two species of wild taro: *Colocasia esculenta* and *C. formosana*

Peter J. Matthews, National Museum of Ethnology, Osaka, Japan. Email: pjm@idc.minpaku.ac.jp

A critical problem for the taxonomy of *C. esculenta*, and for understanding the evolution and domestication of this species, is that there is no way to recognise, by simple visual inspection, a wild population of taro as part of a natural distribution. This is because people throughout Southeast Asia have long used wild taro as a vegetable for human and animal consumption (as food and fodder). The example of *C. formosana* Hayata is introduced here because our observations so far indicate that this is a naturally-distributed wild species throughout its known range, despite its close phenotypic similarity to *C. esculenta*. For understanding the evolution and domestication of *C. esculenta*, there may be much to learn from closer study of *C. formosana*.

S28. Genetic relationships among different species of taro in Vietnam, as revealed by SSR loci

Viet Xuan Nguyen[1], Dang Thi Thanh Mai[2] and Nguyen The Anh[3]

[1] Hanoi National University of Education (HNUE), Vietnam.

[2]Bacninh teacher training College, Bacninh, Vietnam.

[3] Lang Son Province Department of Education and Training. Vietnam.

Thirty-three accessions of taro (*Colocasia esculenta* and *C. gigantea*) from six locations in northern Vietnam, together with accessions of two wild species of *Colocasia* and two accessions of *Alocasia odora*, were analysed by using primer pairs for fourteen Simple Sequence Repeat (SSR) loci.

Ten (71%) of the loci were polymorphic. Seven polymorphic loci were used for a phylogenetic analysis of *Colocasia* species, using *Alocasia* as an outgroup. A total of 87 polymorphic alleles were detected in this analysis, and the number of alleles per locus ranged from 6 to18, with an average of 12 alleles per locus. The highest Polymorphic Information Content (PIC) value for SSR loci was 0.84 (locus Xu73) and the lowest was 0.48 (locus HK31), with a mean value of 0.71. In the dendrogram created using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA), *C. gigantea* clustered in the main group together with all accessions of *C. esculenta*, while the two wild diploid species, *C. lihengeae* and *C. menglaensis*, clustered together and closer to the two *Alocasia* accessions than to *C. esculenta* and *C. gigantea*.

These SSR loci may be useful for germplasm management, evolutionary studies, and marker assisted selection (MAS) for introgression of agriculturally important traits into taro cultivars.

S29. Ethnobotany of *Alocasia macrorrhizos* in the Philippines

Jennifer Castillo[1], Peter J. Matthews[2], and Melanie Medecilo[1 *]

[1] Biological Sciences Department, De La Salle University - Dasmariñas, City of Dasmariñas, Cavite, Philippines. *Email: lanie_medecilo@yahoo.com

[2] National Museum of Ethnology, Osaka, Japan.

Alocasia macrorrhizos (L.) Don is a widely distributed stem crop in Southeast Asia and the Pacific. Cultivars and wild forms of this species are common in the Philippines, and appear of particular historical and economic significance in the central Philippines. Historically, the starchy above-ground stems of this plant were known as a source of dried starch that could be stored for use by sailors. At present, the largest area of cultivation appears to be in the area of Calbiga in Samar Island. This area has supplied a modern cottage food industry for the production of *binagol*, a special sweet dish that is popular as a food for special occasions, and also as a souvenir food for export to other regions of the Philippines and abroad. This industry is based in the city of Tacloban, northern Leyte Island, which was devastated by Typhoon Yolanda (also called Haiyan) in November 2013. *Alocasia macrorrhizos* is known to be tolerant of strong wind conditions that are damaging for other crops, and has apparently survived the most recent typhoon.

S30. Analysis of glucomanan in flour prepared from wild *Amorphophallus* spp. in Vietnam"

Tran Thi Y Nhi[1*], Do Truong Thien[1], Lai Thi Thuy[1], Nguyen Quoc Ba[1], Pham Thi Bich Hanh[1], Nguyen Kim Thanh[1] and Nguyen Van Du[2]

[1]Institute of Chemistry, Vietnam Academy of Science and Technology.

[2]Institute of Ecology and Biological Resources, 18, Hoang Quoc Viet Road, Cau Giay District, Hanoi, Vietnam.

* Author for correspondence: Email: ynhivh@gmail.com

The content of glucomannan is a key indicator for evaluating the quality of konjac flour.This study focused on preparation and quantitative analysis of glucomannan content in *Amorphophallus corrugatus* flour by 3,5-Dinitrosalicy (DNS) colorimetric assay. The results showed that glucomannan content in the dried sample was 40±5%.

By applying a two-stage extraction method, the glucomannan content of the flour reached 78±5%. Applying this method, the content of other *Amorphophallus* species (e.g. *A. krausei*) was determined. We have also characterized the glucomannan of *A. corrugatus,* using IR and NMR.

S31. Taxonomy and economic potential of *Amorphophallus* species in Thailand

Orachorn Mekkerdchoo[1*] and George Srzednicki[2]

[1]Program in Biotechnology, Chulalongkorn University, Bangkok, 10330 Thailand.E-mail: orachorn_m@hotmail.com

[2]Food Science and Technology, School of Chemical Engineering, University of New South Wales, Sydney, NSW 2052, Australia.

Amorphophallus spp. are known under the common name of konjac or elephant foot yam. Some of the species have potential to become highly profitable crops for South East Asia as raw material for various industries. However, considerable variation in morphological features of many species of *Amorphophallus* makes it is difficult to identify them in the vegetative form. DNA Sequencing and Randomly Amplified Polymorphic DNA (RAPD) are often used to determine the genetic identity of plants. This research is aimed at studying the genetic relationship of various accessions of *Amorphophallus* spp. collected in Thailand. Combined data of nucleotide sequences of three different genes namely the chloroplast gene trnL-trnF spacer, the internal transcribed spacers (ITS) and the second intron of FLORICAULA/LEAFY (FLint2) were used as a tool for molecular phylogeny reconstruction using Bayesian analysis. In addition, RAPD method with thirteen primers was applied for the phylogenic analysis. Those were used to calculate genetic distances which were then visualised using multidimensional scaling and cladogram. Results from phylogenetic analysis of both methods are mostly congruent in producing a clade of *A. bulbifer*, *A. xie* and *A. muelleri* that are the economically important species due to their ability to form glucomannan. Moreover, AB-10 primer from RAPD analysis had ability to produce

unique band for economical species (high and medium glucomannan levels). As a result, these markers could be used as selection tools for economical species aiming at improving the industrial production of konjac glucomannan in Thailand.

List of Presenters

Note: See spoken (S) and poster (P) presentations in the programme and abstracts above

Ahmed, Ibrar	**S11**
Bogner , Josef	**S17**
Boyce, Peter C.	**P11,S4,S5**
Castillo, Jennifer	**S29**
Chartier, Marion	**S12**
Croat, Thomas	**S1, S8, S10, S21**
Dafni, Amots	**S13**
Duangchai Sookchaloem	**P8, P7**
Duong Minh Truyen	**S3**
Ferry, Genevieve	**S8**
Haigh, Anna	**S6**
Henriquez, Claudia L.	**S10**
Hoe Y. C.	**P11**
Jacobsen, Niels	**P4**
Kee, Andrea	**P9**
Köster, Nils	**S18**
Leng, Lim Mei	**P9**
Li , Feifei	**P10**
Li Heng	**P1**
Li Rong	**P1**
Liu, Bo	**S24**
Liu Yujing	**S7, S24**
Long, Chunlin	**P10,S7,S24**
Low Shook Ling	**S20**
Mashor, Manshor	**S3, S4**
Masuno, Takashi	**P2**
Matthews, Peter J.	**P2,S27, S29**
Medecilo, Melanie	**S23, S29**
Mekkerdchoo, Orachorn	**S31**
Moodley, Desika	**S16**
Nagappan, Thilahgavani	**P6**

A Review of Studies of Neotropical Araceae

Thomas B. Croat
P.A. Schulze Curator of Botany
Missouri Botanical Garden
P.O. Box 299, St. Louis, MO 63166
Thomas.croat@mobot.org

ABSTRACT

The last decade has seen many changes in research with neotropical Araceae. There have been a lot of revisionary efforts especially with smaller genera but relatively few changes in the largest and most complex genera. Several key floristic studies have been completed and several more are underway. Increasingly phylogenetic studies are being carried out among genera of all sizes. This review will provide a history of past monographic and floristic efforts and will summarize by suggesting the areas most in need of further work.

REVISIONARY STUDIES

The largest genus, *Anthurium,* remains still poorly known overall with only three sections, namely *Pachyneurium* (Croat, 1991), *Polyphyllium* (Croat, 1978) and *Semaeophyllium* (Croat & Carlsen, 2004) that have been revised. With the discovery of many new species, especially in the Andes of Western South America, the number of named and described (albeit not yet published) species exceeds 1690 and the upper limit will certainly exceed 2000 when more sections, especially section *Porphyrochitonium*, are studied. A Lucid multichotomous key for *Anthurium* was created by staff at Kew Gardens and has been used to key out potential new species. The diagnosis of the putative species can then be written to show differences from species already published. It has been continuously upgraded during the last five years by adding new species and by making modifications in the key to make it more useful. The Lucid *Anthurium* key now contains about twice as many species as were present when initially made available.

A recent paper by Croat & Carlsen (2013) realigns the palmately lobed *Anthurium* species, merging Schott's section *Schizoplacium* to section *Dactylophyllium* and excluding three Mexican species and a single Colombian species.

Marcus Nadruz Coelho published a revision of *Anthurium* section *Urospadix* subsection *Flavescentiaviridia* (Coelho et al., 2009) and Livia Temponi (Temponi, 2006) did a molecular analysis on section *Urospadix* resulting in considerable realignment of the section and the sinking of section *Chamaerepium*, a previously endemic section to Brazil.

Philodendron is perhaps more fully known, with subgenus *Meconostigma* (Mayo, 1991; Gonçalves & Salviani, 2002), the subgenus *Pteromischum* from Central America, West Indies and Pacific Tropical South America and Central America having been fully revised (Grayum, 1992; 1996). Some published work also has occurred in the Guianas (Croat & Grayum, 1994). In addition *Philodendron* subgenus *Philodendron* section *Macrobelium* of Brazil has been revised (Sakuragui, 1998; Sakuragui & D. C. Zappi, 2005). A Lucid multichotomous key for *Philodendron* prepared by Marcela Mora contains most of the species with the exception of some new species from Brazil. The inital key with 465 species resides on the CATE website and Thomas Croat and his staff of volunteers are continuing to populate it with new species. It now contains 529 species for an increase of 12% during the past 6 years.

The genus *Dracontium* with 23 species has been revised (Zhu & Croat, 2004) and a Lucid key for *Dracontium* is being prepared by Croat. The *Chlorospatha* with 68 species (Croat & L. P. Hannon, 2015; in press) have now been revised and a Lucid key is contemplated as well.

Adelonema with 16 species has recently been revised (Croat et al., in prep) and is expected to be submitted for publication sometime in 2015.

Revisionary work is being carried out on *Monstera* for the Flora of Mesoamerica (Croat, in prep.) and Alejandro Zuluaga, now a Ph.D. student at the University of Wisconsin, Madison, is concentrating on a molecular phylogeny of the genus. The very useful revision by Madison (Madison, 1977) is now somewhat out of date, especially with many new species in Central America (Grayum, 1997).

The genus *Spathiphyllum* with an estimated 63 species was last revised by Bunting (Bunting, 1960) where 36 species were covered. *Spathiphyllum* is now being studied by Felipe Cardona at the Universidad de Antioquia (Cardona, 2000; 2001; 2004). In Central America there are about 25 species of *Spathiphyllum*.

Stenospermation, with an estimated 250 mostly undescribed species is one of the most poorly know of all aroid genera. No complete revision has been made since that of Engler in Das Pflanzenreich (Engler, 1908) which covered only 20 species. A revision of *Stenospermation* for Central America (A. P. Gómez, 1983) comprised only 9 species but since that time many species have been found, especially in Panama and Costa Rica with as many as 30 species now reported (Croat, in prep.). Numbers of new species are even larger in South America. A recent survey of *Stenospermation* in Carchi Province in

Ecuador yielded 26 new species. Natalia Castaño Rubiano from Colombia is working on a revision of Colombian species of *Stenospermation* (Castaño Rubiano, 2013) and is also working on the creation of a Lucid key for the genus.

Dieffenbachia with an estimated 140 species has been revised for Central America (Croat, 2004) with 26 species represented but most of the species in South America are still poorly known. An unpublished key to South America with 104 species has been prepared (Croat, in prep.) and a Lucid key to *Dieffenbachia* is being planned.

Xanthosoma with an estimated 90 species remains poorly known, certainly one of the most poorly known genera in the neotropics. Central America has about 13 species but there are many new species in the western Andes (Croat et al., in prep.) and even in the Guianas (Croat et al., in press). Eduardo Gonçalves is working on *Xanthosoma* and has described 10 new species (Gonçalves, 1999; 2000; 2011).

Most of the smaller neotropical genera are by now relatively well known, especially the recently revised *Spathicarpeae* inhabiting eastern South America and the western Andes (Gonçalves, 2002a). That revision covered initially 8 genera in subtribe Spathicarpeae, namely *Incarum*, *Asterostigma*, *Spathicarpa*, *Synandrospadix*, *Mangonia Gorgonidium*, *Spathantheum* and *Gearum*. Later the new genera *Croatiella* (Gonçalves, 2005) and *Lorenzia* (Gonçalves, 2012). were added. The study compared subtribe *Spathicarpeae* with the related subtribe *Bognerineae* and subtribe *Dieffenbachineae*.

Rhodospatha with about 79 species has been at least partially revised and a Lucid key to the genus is anticipated.

FLORISTIC STUDIES

Much of the neotropics is undergoing a floristic review of the Araceae. In Central America completed floristic studies have been made for Costa Rica (Grayum, 1982; Grayum et al. 1983; 2003, 2003a), Guatemala (Croat & Vannini, in prep.) and Nicaragua (Croat & Stiebel, 2001), Veracruz (Croat & Acebey, 2015). The Flora of Mesoamerica treatment of the Araceae is expected to be completed by 2016. Although the largest genera *Anthurium* (Croat, 1983; 1986) and *Philodendron* (Croat, 1997) and well as several smaller genera, *Chlorospatha* (Croat & L. P. Hannon; in press), *Dieffenbachia* (Croat, 2004), *Dracontium* (Zhu & Croat, 2004) have been completed for Central America this Flora of Mesoamerica treatment will result in the first revision of most of the smaller genera. Floristic studies in South America are a more daunting task owing to its much greater complexity. The Andean countries have been partly reviewed with modern Araceae Checklists having been created for Peru (Croat, 1993), Ecuador (Croat, 1999) and Bolivia (Kessler & Croat, 1999; Croat & Acebey, 2015). Colombia, clearly the largest floristic region in all of South America does not have a published flora but an effort is underway by a group of Colombian aroiders to produce such a checklist. Venezuela is reasonably well known floristically owing to work by Bunting (1979) as well as a later study by Croat & Lambert (1986). The Guianas are now reasonably well known floristically after a National Geographic Sponsored expedition of four months made to the region. The flora of the Guianas comprises about 160 species and treatment is expected to be completed in four years. Brazilian aroiders are also generating a Checklist of the Araceae and the current total is 477 species; Argentina has only17 species (Crisci, 1971). Paraguay, the only other country with a significant aroid flora has a completed flora with 9 genera and 16 species of Araceae (Croat & Mount, 1988).

Floristic studies are more all encompassing with published or in press floristic studies having been carried out in Paraguay and checklist treatments of Ecuador, Peru and Bolivia have been completed in the past ten years. Floristic accounts of Venezuela have been completed and a checklist for the Flora of Colombia and for is nearing completion. The Araceae for the Flora of Mesoamerica and for the Guianas is expected to be completed in the next five years.

MOLECULAR STUDIES

Molecular studies of neotropical Araceae are still in their infancy but significant studies have been made on Tribe *Spathicarpeae* by E. G. Gonçalves (Gonçalves, 2002b). His studies showed a close relationship between the *Spathicarpeae* to both *Bognera* and *Dieffenbachia*..

Alejandro Zuluaga is carrying out molecular studies with *Monstera* and these studies will be published as a part of his Ph.D. thesis. Molecular studies carried out by Peter Boyce and Sin Yeng Wong principally on Old World *Homalomena* have shown the American element, namely *Homalomena* section *Curmeria* Linden & André to be distinct from Asian species so that group will adopt the generic name, *Adelonema* (Wong & Croat, in press). *Adelonema* has 12 species and ranges from Costa Rica to most of northern South America as well as the Amazon basin. As yet unpublished molecular studies with 8 species by Merrow & Croat showed *Adelonema* to cluster in three well-supported clades. Two molecular studies (Gauthier et al., 2008; Tam et al., 2004) found *Adelonema* to fall within *Philodendron* but this conflicts with studies by Wong & Croat (in press) that show it to be distinct from *Philodendron*, though most closely related to *Philodendron* subgenus *Pteromischum* and completely distinct from the Asian *Homalomena*.

Currently two separate molecular studies are being carried out on *Philodendron*, one by Nils Köster and Dubán Canal working at the Berlin Botanical Garden and one by Santelmo Vasconcellosas from Brazil. Both involve collaboration with Croat.

Molecular studies of *Anthurium* (Carlsen, pers. com.) have successfully separated 18 clades and have major advances in our understanding of the sectional classification of *Anthurium*. Among the findings are a validation of a West Indian clade corresponding to Engler's section *Episeiostenium*, the isolation of two new distinct Mexican clades, one of which corresponds to Schott's section *Andiphlium* and one which represents species with cordate-sagittate blades with dark glandular punctations on the lower blade surfaces. *Anthurium* section *Pachyneurium* series *Multinervium* is recognized at the sectional level as section *Multinervium* Croat and *Anthurium* at the sectional level are either completed or ongoing.

Molecular studies are also being carried out on *Philodendron* and *Monstera*.

POLLINATION STUDIES

Pollination biology of Araceae is still much understudied and most serious studies of pollination are still in their infancy in the neotropics with only a few total species having been studied for their pollinators but several important studies are ongoing.

Nevertheless we have strong intitiatives, especially through the efforts of Marc Gibernau working in French Guiana and sometimes working with Denis Barabé at the Montreal Botanical Garden, Quebec, Canada, Gerhard Gottsberger working in Brazil and Heiko Hentrich from Germany, working in Mexico with Pedro Diaz.

Danny Beath, employing techniques learned in Central West Africa made significant observations on pollination of *Anthurium* and *Dieffenbachia* while working in Costa Rica (Beath, 1999). Julio Sierra-Giraldo has made observations on pollinators in the Andes of western South America in Risaralda Department and reported what appears to be a likely pollination system involving frogs pollinating Araceae (Sierra-Giraldo, 2014).

Considering the vast array of syndromes and the incredible richness of the Neotropical aroid flora pollination, the biology of Araceae is likely to be a very lucrative field of study for many years to come.

DISCOVERY OF NEW SPECIES

Perhaps the most significant effect of research with Araceae in recent years is the realization that more than any other tropical plant family so far studied the Araceae represents a group that is proving to be exceedingly rich in species. Most genera have grown in size (numbers of species) but percentage-wise the growth has been greatest in the two largest genera of Araceae, namely *Anthurium* and *Philodendron*. *Anthurium* has grown from about 600 species to 1392 species in less than 5 years with most of the growth in species coming from Panama, Colombia, Ecuador and Peru. *Philodendron*, though not heavily studied is also growing dramatically from 469 species to 529 species at present. Moreover it looks like this rate of increase will not soon diminish with the addition of hundreds of new collections from areas not previously explored. This single attribute of Araceae, namely the ability to produce many new species, makes it seemingly unique though I do not know what is happening to other families. Single site visits often yield an array of unknown species, most of which are apparently new and the same thing could be found true in clearly related sites. Despite repeated visits to the El Queremal-Anchicaya region on the western slopes of the Andes between Cali and Buenaventura, each visit presents a surely unique set of discoveries of new species for each stop.

Interestingly, though perhaps less dramatic, the situation in Asia also shows that many new species still exist there. Since 1980 *Amorphophallus* has grown by about 90 species and now totals 210 species. About 80% of this growth is due to the efforts of Wilbert Hetterschied. Both *Homalomena* and *Schismatoglottis* have grown dramatically owing to the efforts of Hay & Yuzammi (2000) and Bogner & Hay (2000) but especially by Peter Boyce and Sin Yeng Wong in Sarawak. In the tribe *Schismatoglottideae* the genus *Apobalis* was resurrected; *Aridarum* has increased from 9 to 24 species; *Bakoa* was described as a new genus with 4 new species; *Bucephalandra* increased from 2 to 28 species; *Hestia* was described as a new genus; *Hottarum* with 2 species was resurrected from *Piptospatha*; *Ooia* was described as a new genus with 3 species; *Pichinia* is described as a new monotypic genus; *Piptospatha* with 15 species increased by 9 species; *Schismatoglottis* with 110 species has increased by 35 species; *Schottariella* a new monotypic genus is described and *Schottarum* with 2 species is described. In *Homalomena* with 93 species about 40 species have been described by Boyce and or Sin Yeng alone.

At least in the neotropics and Asia where vast expanses of forest in poorly explored areas still exist and especially in light of the high rate of narrow endemism in the family, this process of discovery of new species is likely to continue for a long time.

USE OF LUCID MULTICHOTOMOUS KEY

What have made determinations of new species possible are the Lucid keys which have been developed for both *Anthurium* and *Philodendron*. The Lucid database stores all of the important qualitative and quantitative information on all published species for all species in a specific genus. The key enables one to select a series of conservative features which in turn causes the key to reject any species not possessing that feature. After passing through a series of characters the remnant list of species is then compared with the plant being determined to see if there is a match.

Lucid keys are powerful tools when fully developed and they should be developed for other genera. Mention has already been made about the development of Lucid keys for *Monstera* and *Stenopermation* which have already been developed but others will be developed for *Aglaonema*, *Chlorospatha*, *Dieffenbachia*, *Dracontium* and *Rhodospatha*.

CONCLUSIONS

The results of our collective investigations with Neotropical Araceae have been fruitful in recent years with significant monographic, floristic and molecular studies produced especially in smaller taxonomic groups. Floristic, studies though by now widespread, are needed for more areas and they must be continuously reviewed with the ability to make updates as new species or new country or regional record are added since they otherwise quickly become outdated. Larger groups, especially *Anthurium* and *Philodendron* have proven to be so species-rich that any end product remains somewhat elusive though attempts are under way to at least describe species and add them to Lucid keys. Molecular studies are beginning to produce reliable end products that were previously dubious. Nevertheless broader and more species-rich surveys are required to better understand the sectional classification of the larger genera. Studies of pollination must be encouraged at all levels since we have scarcely begun this study and the results are so promising at both the biological and taxonomic level.

LITERATURE CITED

Bogner, J. & A. Hay. 2000. *Schismatoglottideae* (Araceae) in Malesia II – *Aridarum*, *Bucephalandra*, *Phymatarum* and *Piptospatha*. *Telopea* 9(1): 179 –222.

Cardona, F. 2000. Patrones de distribución de epífitas vasculares en robledales. Revista de la Facultad Nacional de Agronomía. Medellín, Vol. 53, pp. 969–983.

Cardona, F. 2001. Diversidad y composición de epífitas vasculares en robledales de Antioquia (Colombia). *Actualidades Biológicas*. Universidad de Antioquia, Medellín, Vol. 23 No. 74: 25–31.

Cardona, F.. 2004. Synopsis of the Genus *Spathiphyllum* (Araceae) in Colombia. *Ann. Missouri Bot. Gard.* 91(3): 448–456.

Carlsen, M. 2013. A molecular phylogeny of the species-rich Neotropical genus *Anthurium* (Araceae) based on combined chloroplast and nuclear DNA. *Syst. Bot.* 36(3): 576–588.

Castaño Rubiano, N. 2013. "Revisión Taxonómica de *Stenospermation* para Colombia", Master's Thesis, Universidad Nacional de Colombia, Bogota.

Coelho, M. A. N., J. L. Waechter & S. J. Mayo. 2009. Revisão Taxonômica das Espécies de *Anthurium* (Araceae) seção *Urospadix* Subseção

Flavescentiviridia. *Rodriguésia* 60(4): 799–864.

Crisci, J. V. 1971. Flora Argentina: Araceae. *Revista Mus. La Plata, Secc. Bot*. 11: 193–284.

Croat, T. B. 1991. A revision of *Anthurium* section *Pachyneurium* (Araceae) *Ann. Missouri Bot. Gard*. 78: 539–855.

Croat, T. B. 1993. Araceae. Pp. 71–82. In: L. Brako & J. L. Zarucchi, Catalogue of the flowering plants and gymnosperms of Peru. *Monogr. Syst. Bot. Missouri Bot. Gard*. 45.

Croat, T. B. 1997. A revision of *Philodendron* subgenus *Philodendron* (Araceae) and Central America. *Ann. Missouri Bot. Gard*. 84: 311–704.

Croat, T. B. & A. Acebey. 2015. [in press]. Araceae, *In*: A. Gomez-Pampa et al., Flora de Veracruz, Xalapa, Mexico.

Croat, T. B. & R. Baker. 1978. Studies in Araceae II, *Anthurium* Section *Polyphyllium*. *Selbyana* 2: 230–238.

Croat, T. B. & M. Carlsen. 2004. New species of *Anthurium* sect. *Semaeophyllium*. *Novon* 14: 401–414.

Croat, T. B. & M. Carlsen 2013. A reassessment of *Anthurium* species with palmately divided leaves, and a reinterpretation of *Anthurium* *Dactylophyllium* (Araceae). *PhytoKeys* 23: 41–54.

Croat, T. B. & D. Mount. 1988. Araceae. Pp. 1–46. In: R. Spichiger & J. M. Mascherpa (eds.), Flora del Paraguay. Conservatoire et Jardin Botanique, Geneva & Missouri Bot. Gard.

Croat, T. B. & M. H. Grayum. 1994. *Philodendron* subgenus *Pteromischum* (Araceae) from Saül, French Guiana. *Novon* 4: 211–219.

Croat, T. B. & L. P. Hannon. 2015. [in press]. A Revision of *Chlorospatha* (Araceae). *Ann. Missouri Bot. Gard*. 20xx.

Croat, T. B., V. Pelletier, L. Salmon & J. Weigel. 2014. A new species of *Xanthosoma* from western French Guiana. *Aroideana*, in press.

Croat, T. B. & T. Stiebel. 2001. Araceae. *In*: W.D. Stevens, C. Ulloa Ulloa, A. Pool & O. M. Montiel (eds.), Flora de Nicaragua. *Monogr. Syst. Bot. Missouri Bot. Gard*. 85: 136–188.

Croat, T. B. & G. Zhu. 2004. A revision of *Dracontium* (Araceae). *Ann. Missouri Bot. Gard*. 91(4): 593–667.

Engler, A. & K. Krause. 1908. Araceae-Monsteroideae. Pp. 4–138. In: A. Engler (ed.), Das Pflanzenreich IV. 23B(Heft 37). W. Engelmann, Berlin.

Gauthier, M.-P. L., D. Barabé, and A. Bruneau. 2008. Molecular phylogeny of the genus *Philodendron* (Araceae): delimitation and infrageneric classification. *Bot. J. Linn. Soc.*156: 13–27.

Gonçalves, E. G. 1999. A New Pedate-leaved Species of *Xanthosoma* Schott (Araceae: Tribe *Caladieae*) with Linear Leaflets, from the Brazilian Pantanal. *Aroideana* 22: 3–6

Gonçalves, E. G. 2000. *Xanthosoma riparium* (Araceae), a New Species from Goiás, Brazil. *Novon* 10(1): 26–28.

Gonçalves, E. G. 2002a. New Aroid Taxa from Brazil. *Aroideana* 25: 16–35.

Gonçalves, E. G. 2002b. Sistemática e evolução da tribo *Spathicarpeae* (Araceae). Ph.D. thesis, Universidade de São Paulo, São Paulo, Brazil

Gonçalves, E. G. 2005. Two new Andean genera for the tribe Spathicarpeae (Araceae). *Willdenowia* 35(2): 319–326.

Gonçalves, E. G. 2011. The Commonly Cultivated Species of *Xanthosoma* Schott (Araceae), including Four New Species. *Aroideana* 34: 3–23.

Gonçalves, E. G. 2012. *Lorenzia* (Araceae — Spathicarpeae): A New Genus from Northern Brazil Supported by *matK* Sequence Data Systematic Botany 37(1):48–52. 2012 doi: http://dx.doi.org/10.1600/036364412X616620

Gonçalves, E. G. & E. R. Salviani. 2002 New species and changing concepts of *Philodendron* subgenus *Meconostigma* (Araceae). *Aroideana* 25: 2–15.

Grayum, M. H. 1997. Nomenclatural and taxonomic notes on Costa Rican Araceae. *Phytologia* 82(1): 30–57.

Grayum, M. H. 1982. The aroid flora of Finca La Selva, Costa Rica: A lowland wet forest locality. *Aroideana* 5(2): 47–62.

Grayum, M. H. 1986. New taxa of *Caladium*, *Chlorospatha*, and *Xanthosoma* (Araceae: Colocasioideae) from southern Central America and northwestern Colombia. *Ann. Missouri Bot. Gard.* 73: 462–474.

Grayum, M. H. 1987. New taxa of *Caladium* and *Chlorospatha* (Araceae–Colocasioideae) from Panama and NW Colombia. *Ann. Missouri Bot. Gard.* 74: 659–660.

Grayum, M. H. 1992. New species of *Philodendron* subgenus *Pteromischum* (Araceae) from Mesoamerica and

Pacific South America. *Phytologia* 73: 30–39.

Grayum, M. H. 1993[1992] A remarkable new *Anthurium* from Costa Rica. *Aroideana* 15: 40–43.

Grayum, M. H. 1996. Revision of *Philodendron* subgenus *Pteromischum* (Araceae) for Pacific and Caribbean Tropical America. *Monogr. Syst. Bot. Missouri Bot. Gard.* 47: 1–233.

Grayum, M. H. 1997. Nomenclatural and taxonomic notes on Costa Rican Araceae. *Phytologia* 82: 30–57.

Grayum, M. H. 1999. Araceae. In: P. Jørgensen & S. Leon, Catalogue of the vascular plants of Ecuador. *Monogr. Syst. Bot. Missouri Bot. Gard.* 75: 109–952.

Grayum, M. H. 2003. Araceae. Pp. 59–200 *in*, B. E. Hammel, M. H. Grayum, C. Herrera & N. Zamora (eds.), Manual de plantas de Costa Rica. Vol. II. Gimnospermas y monocotiledóneas (Agavaceae–Musaceae). *Monogr. Syst. Bot. Missouri Bot. Gard.* 92: 1–694.

Grayum, M. H. 2003a. Lemnaceae. Pp. 618–622 *in*, B. E. Hammel, M. H. Grayum, C. Herrera & N. Zamora (eds.), Manual de plantas de Costa Rica. Vol. II. Gimnospermas y monocotiledóneas (Agavaceae–Musaceae). *Monogr. Syst. Bot. Missouri Bot. Gard.* 92: 1–694.

Hay, A. & Yuzammi. 2000. Schismatoglottideae in Malaysia I - *Schismatoglottis* *Telopea* 9(1): 1–177.

Kessler, M. & T. Croat. 1999. State of knowledge of Bolivian Araceae. *Selbyana* 20(2): 224–234.

Mayo, S. J. 1991. A revision of *Philodendron* subgenus *Meconostigma* (Araceae). *Kew Bull.* 46: 601–681.

Sakuragui, C. M. 1998. Filogenia e Taxonomia de *Philodendron* seção *Calostigma* no Brasil. Unpublished Ph.D. Thesis. University of São Paulo, Brazil. 238 p.

Sakuragui, C. M. & D. C. Zappi. 2005. Taxonomic revision of Brazilian species of *Philodendron* section *Macrobelium*. *Kew Bull.* 60: 465–513.

Sierra-Giraldo, J. A. 2014. First record of Anura (*Dendropsophus columbianus* -Anura: Hylidae-) as floral visitors of Araceae (*Zantedeschia aethiopica* (L.) Spreng). *Aroideana* 37E, No. 1: 4–10.

Tam, S., P. C. Boyce, T. M. Upson, D. Barabé, A. Bruneau, F. Forest & J. S. Parker. 2004. Intergeneric and infrafamilial phylogeny of subfamily Monsteroideae (Araceae) revealed by chloroplast *trn L–F* intergenic spacer. *Amer. J. Bot.* 91(3): 490–498.

Temponi, L. 2006. Systematics of *Anthurium* sect. *Urospadix* (Araceae) [online]. São Paulo: Instituto de Biociências, University of São Paulo, 2006. Doctoral Thesis in Botânica.

IN PREPARATION

Croat, T. B. A key to South American species of *Dieffenbachia* (Araceae).

Croat, T. B. A revision of *Rhodospatha* (Araceae).

Croat, T. B. A revision of *Stenospermation* (Araceae) for Central America.

Croat, T. B., L. P. Hannon & X. Delannay. New species of *Xanthosoma* from western Andes of South America.

Croat, T. B., M. Moffler & R. Wunderlin. A Revision of *Adelonema* (Araceae).

Croat, T. B. & J. Vaninni. New species of Araceae from Guatemala.

IAS and the Conservation of Aroids

Greg Ruckert
PO Box 421
Mt Barker, South Australia 5251
Australia

ABSTRACT

The International Aroid Society (IAS) is the pre-eminent organisation for people interested in aroids. Its membership comprises professionals with a focus on the study of aroids as well as amateurs who are passionate about them. This presentation sets out why the IAS is so important and suggests possible ways it might take a stronger role in the conservation of Aroids.

PRESENTATION

Good Morning. My name is Greg Ruckert and I am here because I am passionate about aroids. My wife calls me obsessive. I live near Adelaide, the capital of South Australia.

While my presentation is about the future conservation of aroids and the role of the International Aroid Society (IAS) therein, I stress that I am only an ordinary member of the society and these are my personal views. I also point out that my observations are based on Australian experiences and certainly may not be extended to the way things are done in other countries.

Many of the problems that I will outline are not restricted to aroids but apply to most plant genera. The main problem that we have is the human population which currently sits at about seven billion. According to the United Nations, Department of Economic and Social Affairs, Population Division document entitled WORLD POPULATION TO 2300, this number will grow to almost nine billion in 2050, just thirty-seven years away. That is an increase of nearly thirty percent.

What does this mean. If we look at man's use of our planet the amount of space currently used for livestock and cropping is equivalent to South America and Africa. (**Figure 1)**

If all the cities in the world were put together they would occupy the whole of Australia.(**Figure 2)**

The area of the world regarded as desert is equivalent to Asia. (**Figure 3)**

There are other regions such as mountains and tundras that offer little for plants, food production or the support of the human

Figure 1

Figure 2

Figure 1. The amount of space currently used for livestock and cropping is equivalent to South America and Africa.

Figure 2. If all the cities in the world were put together they would occupy the whole of Australia.

population. Now, what happens when we allow for increased human requirements of thirty percent? Very little space will be left for plant and animal diversity.

So what are the conservation problems facing aroids? The first issue is the conversion of the natural environment to support humanity. Aside from *Colocasia esculenta* very few species are considered useful for food. A few species are used as decorative or garden plants and some are used to produce cut flowers but that is a very small percentage of the species that exist. Hence aroids are of limited interest to the average person.

The main conservation education available to the general population is via television documentaries, however plants receive a very low profile. Programmes on animals tend to focus on them eating each other or their danger to man. Even programmes such as Bill Bailey's effort to lift the profile of Darwin's co-author Wallace, show Bailey trampling through the wilds, ignoring the plants, to look at animals. Sir David Attenborough is one of the few to look at the role of plants but again they occupy a small fraction of the work he has produced. The general population are not aware of, nor particularly interested in protecting, the diversity of aroids or for that matter most other plant species.

Some would suggest that conservation should be the role of government and their agencies. Sadly, my experience has been that they are neither interested nor capable.

Figure 3

Figure 4

Figure 3. The area of the world regarded as desert is equivalent to Asia.

Figure 4. The majestic Bicentennial Conservatory, set in the Botanic Gardens in Adelaide, is one of South Australia's major tourism draw cards.

Governments have an economic focus rather than an environmental one.

The majestic Bicentennial Conservatory, set in the Botanic Gardens in Adelaide, is one of South Australia's major tourism draw cards (**Figure 4)**. Opened in 1989 to celebrate Australia's Bicentenary, this spectacular edifice was designed by local architect Guy Maron and has received many awards.

At 100 metres long it was the largest single span conservatory in the southern hemisphere, and was built to exhibit a tropical rainforest in Australia.

In 2012 the power was turned off as a cost saving measure. The saving is $50,000 per year. (**Figure 5)**. Staffing at the botanic gardens has also been dramatically reduced, while the government spends half a billion dollars to upgrade one existing sporting facility.

I have even heard stories of herbarium specimens being thrown out because institutions are running out of space.

Knowledge is crucial to conservation and one would expect that the organisations that retain the knowledge would be happy to see it generally available. My wife collects members of the genus Oxalis. Via the internet I found that the Adelaide Botanic Gardens had a copy of one of the few monographs on the genus, from the 1940s. When I enquired about accessing the copy I was told that I would have to apply for special permission just to look at the book.

Switch-off kills plants

KATRINA STOKES

A DECISION to turn off the heating in the Botanic Garden's Bicentennial Conservatory has caused the death of 15 per cent of its plant collection.

Staff approved the move - in conjunction with other stakeholders including the building's architect Guy Maron - to switch off the heating in March. They believed the decision would lead to the loss of 30 per cent of tropical plants, but only 15 per cent - about 60 plants - have since died.

Garden director Stephen Forbes said he "firmly believed" they made the right environmental decision. The conservatory previously created 50 per cent of the garden's greenhouse gas emissions.

FRIDAY DECEMBER 6 2013 ADVERTISER.COM.AU

Figure 5

Figure 6

Figure 5. Power turned off at the Bicentennial Conservatory.

Figure 6. *Amorphophallus titanum* in bloom (Photo Credit; Peter Dippl)

There was no guarantee that I would be given permission. One can only wonder what damage I might have inflicted on such a book or, indeed, if anyone else had ever looked inside its cover. Fortunately I found a second Australian copy of the book held by the University of Adelaide which my daughter was able to borrow for me.

Correct communication with the public is another crucial component in conservation. In December, 2012, the Melbourne Botanic Gardens flowered *Amorphophallus titanum* for the first time (**Figure 6**). This brought widespread press but I was very disappointed that the information given by the staff contained wrong information and a lack of knowledge as to what was happening, even with that species, in Australia. I have tried to contact the Melbourne Botanic Gardens on other matters but do not even get a response. Sadly, the attitude of these gardens is akin to the way Zoos were managed a century ago.

Figure 7

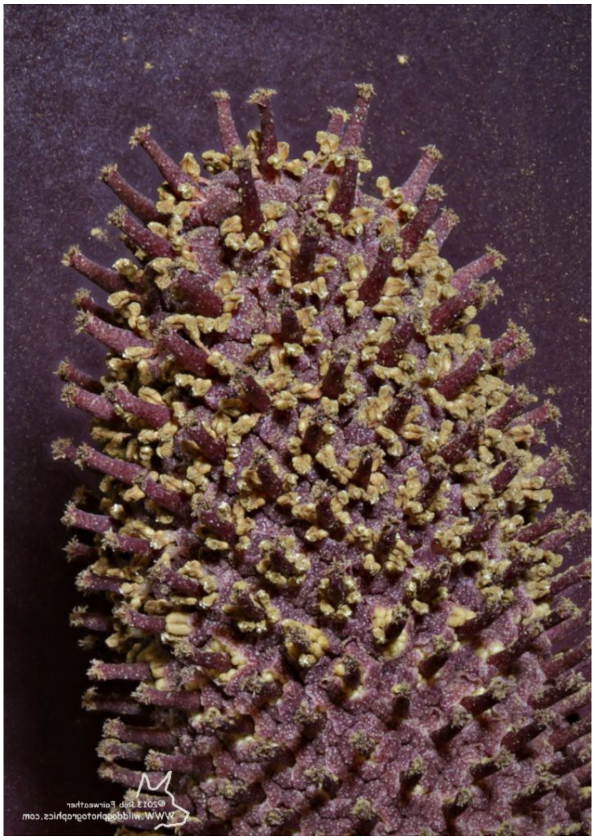


Figure 8

Figure 7. Oxalis pes-caprae Bermuda buttercup

Figure 8. *Dracontium polyphyllum* (Photo Credit; Rob Fairweather)

At a national level, our new Australian government is to apply to have a large section of land currently on the world heritage list de-listed so that it can be logged to make wood pulp! Our change of elected government is setting many environmental strategies aside for short term economic reasons. Our government also displays a very curious attitude to the conservation of rare plants. Because our country is an island we have very strict laws in regard to what can be imported. For me to import an aroid tuber into Australia it would have to be examined, treated under pressure with Methyl bromide for two hours and then actively grown in a Government run quarantine station for three months. I would expect the cost to be around $US1,000, even if it didn't survive. This means that our only option is the importation of seed. The authorities have a list of seeds permitted for import and, while it is possible to have new species added to the list, the process can be more than the average enthusiast can handle.

The list includes noxious weeds such as Oxalis pes-caprae (**Figure 7)** which can be legally imported to Australia. Sadly, when seed of critically endangered plants is detected by our customs service they are confiscated and destroyed rather than being sent somewhere to be grown or returned to the sender. This is a conservation policy that is beyond belief.

At an even higher level I despair at the issues, that I regard as defects, caused by the Convention on Biological Diversity. To me, as an amateur in the plant field, my understanding of the convention is that botanists collecting genetic material in the field are not allowed to distribute that material, outside the country of origin, unless a fee has been determined and paid to the country of origin. I do not believe that most countries have the interest or the formula for calculating such fees. How would they put a value on a new species of *Typhonium* or *Aridarum*? This is at the same time as so much pristine country is being destroyed and converted to agricultural production or mining with the consequent extinction of many species.

Most of the aroid species are unlikely to become popular like tulips. Certainly I can not see them creating an "Aroid Madness" like the "Tulip Madness" of 1637. The ultimate aroid, *Amorphophallus titanum* can be bought in the United States as a flowering size tuber for little more than one week's salary. It is worth noting here that I am talking about plants that are highly unlikely to have large commercial value and generally require expertise to grow. I could only imagine the outcry if someone took one of a lovely new species of *Amorphophallus*, produced a million of them by tissue culture and distributed them through the nursery industry as an indoor plant. Then they start flowering! As much as they might be beautiful, the smell of rotting flesh is not an attraction to most people.

In Australia (and possibly much of the developed world) we have seen a major change in the way people live. Houses are getting larger while the blocks of land they are built on are getting smaller. There is less opportunity for people to have space to pursue their botanical passion. Supporting those who do pursue this type of interest is critical to the future conservation of aroids.

This brings me to the International Aroid Society, its worldwide membership and its possible role in conservation. The Society's main claims to fame are its professional annual publication, *Aroideana*, its quarterly newsletter, its email discussion group and its website. Here I am ignoring the annual show and sale as it is a local event. *Aroideana*, a peer-reviewed journal, edited by Derek Burch, brings together professional botanists, institutions, horticulturists, obsessives and anyone with an interest in Aroids. The Society website provides the best source on the internet for information about Aroids and their pictures. There is also the internet communication facility known as Aroid-l that allows botanists and amateurs to communicate freely. Current membership of the Society is 385 including 41 institutions. It began in 1977 and by 1984 there were 150 members in Australia. Today there are only 34 in Australia. The Society brings together the world's leading aroid botanists and amateur enthusiasts and enables them to engage with each other.

So why do I believe that the International Aroid Society is critical to the future conservation of aroids? I have indicated why I believe that governments and individual institutions should not be generally relied upon as part of the big picture. It is the combination of the professional botanist who can provide the scientific knowledge and the enthusiastic amateur who has the enthusiasm and resources to continue to keep species alive by being cultivated.

There are two areas where I feel that the IAS can be a spearhead for the conservation of aroids.

The first is knowledge and its dispersal.

While I acknowledge the fabulous resource being built on the internet known as CATE Araceae (I have no intention of stealing Anna Haigh's thunder) the IAS website is becoming a definitive knowledge base. I have what I regard as an extensive aroid library but it is expensive and difficult to try to keep it up to date. Through the IAS website members can access the historical aroid works of Engler and Schott. More recently Peter Boyce and Wong Sin Yeng have made their prodigious writings available to the members. On behalf of the members I thank them for this. It is very difficult for anyone outside the academic community to access reference material particularly when published in the more obscure publications. I encourage anyone publishing work on aroids, if not in Aroideana, to make their documents available to the IAS so that members can access them. The IAS must also be complimented, following the sudden death of its secretary, Steve Lucas, taking over the ongoing hosting of his wonderful website and keeping its knowledge available to the public. It is a prime example of what can be achieved by enthusiastic amateurs.

The second issue is engagement.

When I started writing this presentation I was thinking in terms of the need for communication but that is generally a one way process. Engagement is much more a two way process. It takes an organisation to engage with not only its membership but the general community to grow something different, successfully.

Like people, however, we must be aware that societies need to change with time. The International Bulb Society held a very similar position to the International Aroid Society. It was formed in 1933 and published two internationally recognized journals, *Herbertia* and *Bulbs*. Sadly it didn't continue to engage with its membership and has now been replaced by an internet based group known as the Pacific Bulb Society (PBS).

The PBS is largely internet focused and has an active communication network, similar to Aroid-l, but much more active. It engages with its members on a daily basis, and its members respond. What it also has is a very active seed and bulb exchange where members donate plant material, much of it rare, for distribution to other financial members. It creates a reason for the members to pay and be involved.

There is a network of *Arisaema* growers who have a yearly exchange of seed which is sent around the world. While not in any way a part of the IAS, this internet-based group called Arisaema-l, comprises some members and non-members of the IAS. Though an informal group of people, drawn together by a common interest, it has been operating successfully for decades.

I have seen occasions where Tom Croat has put a call out to members of the IAS for genetic material to assist students with their aroid research. It would be a wonderful aid to aroid conservation for the IAS to establish a similar distribution methodology to the PBS and Arisaema-l, especially if institutions could be encouraged to supply excess seed. From the IAS perspective, part of this process could also be identifying the aroid growers around the world who specialise in particular genera. Some countries have rare collection holders and these could form a model to be followed by the IAS. It would be a great aid to conservation to be able to get genetic material to these growers who would then be able to propagate the plants and distribute them to other growers on their continent. The wider the spread of enthusiasts propagating plants, the more likely they will be saved for future generations.

Part of what I have talked about so far has included facilitation. Bringing people together, helping the spread of knowledge and plant material all contributes to conservation. It is important that the IAS knows who and what its members are. By that I don't just mean knowing what they grow. In an age where so many people are protective of their privacy enthusiasts tend to be generous offering their capabilities to a good cause. In South Australia one of our Universities has embarked on annual research projects using what they call “community science”.

Each year they have selected a native animal (this has included the Australian Magpie (*Cracticus tibicen*) and the Koala (*Phascolarctos cinereus*) with data collected from hundreds of members of the community. At the end of each project a book has been produced recording new insights into behaviour and distribution.

There have been times when institutions have made similar use of enthusiasts, without qualifications, to assist in their fieldwork. I had the privilege of joining two botanical expeditions to Gaoligong Shan in the late 1990s with Kunming Institute of Botany. My participation was facilitated by the late Zhu Guanghua to whom I am indebted. The problem for botanists is that they don't know who might be available to assist them or what the individuals' capabilities might be. One example of skills available includes photographic capabilities.

Ultra-detailed macro photography is now being extended to three-dimensional modelling such as this example of a flowering *Daubenya*. It is possible for this type of work to be performed in the field, allowing the professional to spend time doing examinations and further study back in appropriate facilities.

With modern technology, photographs such as this detailed shot of *Dracontium polyphyllum* (**Figure 8)** are now achievable in the field and this is the type of assistance that can be provided to the trip leaders. Most enthusiasts would be happy to play any role requested. This would be a great resource for botanists.

The benefits for the institution are that the individual brings knowledge, financial support and extra hands so that more can be achieved. I know that the term Ecotourism should be applied here and there are many examples in the Australian scientific community where paying volunteers are contributing significantly to research outcomes by having a working holiday alongside and assisting professional scientists. I certainly am not one whose idea of a good holiday is shopping or sitting on a beach!

It would be a simple matter for the IAS to keep a list of members prepared to join field trips and the capabilities they bring. The internet has given the society the opportunity to engage with a massive new group of enthusiasts. The Society's Facebook page now has over 1050 subscribers and, while they won't all want to be paying members of the society, they have taken the first step to gaining information and plants. There are other groups including one for *Amorphophallus* with over 400 members. Engaging with these people to a greater extent is a way to grow the society membership and its resources.

Engagement is a double edged sword. I recall one botanist at this conference who made his presence known on Facebook only to be overwhelmed by the amount of engagement that the enthusiasts wanted. They were hungry for information. That is part of the challenge. The same botanist also raised this issue on Facebook, "the problem is that the horticulturists so seldom read the science. Alistair Hay's excellent series of regional monographs set out a really rather reliable taxonomy that is being mostly ignored - for example, I still see *Alocasia melo* being sold as *A. rugosa* (a none-existent name), and all sorts of names being applied wrongly. And that is for the DISTINCT species!”

I see the problem being that most horticulturists don't have easy access to the information they need and want. This is a problem that only the IAS can help and I commend the Society for supporting projects such as CATE Araceae (now part of the larger e-Monocot project.

There was a time when we could rely on specialty nurseries for rare plants however most of these have now gone out of business, pushed to the financial wall by the large cut price garden centres which all offer the same plants. It is now up to the networks provided by the Society to get these rare plants in cultivation and keep them thriving. This quote from our Australian Broadcasting Commission's television programme Gardening Australia encompasses my thoughts. After a session on a newly established domestic garden the host said “What better **way** to protect endangered species than for them to be grown by the home gardener. With aroids the word “gardener” should be replaced with “enthusiast”.

In our economy, the annual price of membership of the IAS is the same as buying six good cups of coffee. This is a small price to pay to assist the conservation of aroids for future generations, especially as it includes the subscription to *Aroideana*.

Already we see some old herbarium specimens as the only record of species. The unacceptable outcome of no leadership in conservation would be, in one hundred years time, for the only botanists studying aroids to be Paleobotanists!

POSTSCRIPT

Peter Boyce, aside from continuing to make his publications freely available on the IAS website now plays an active role on the Society Facebook page and has actively contributed to that site, drawing in many other people interested in the plants that he is studying.

The IAS Facebook page now has in excess of 1800 members.

The Australian Government's move to delist a section of World Heritage listed land has failed.

The distribution of Araceae along the lower section of Perak River, Malaysia

Duong Minh Truyen & Mashhor Mansor
School of Biological Sciences,
Universiti Sains Malaysia,
Malaysia, 11800 Penang, Malaysia

ABSTRACT

Araceae is one of the biggest families of monocotyledonous plants, and is diverse in both Old World and New World tropics and some are found in north temperate regions. The diversity of their species composition in the tropical Asian region is relatively rich and widely distributed in countries of South East Asia. In researching Araceae, the investigation and conservation of species are addressed accordingly.

The survey of the distribution of Araceae along the lower section of Perak River, Malaysia was conducted from April to May, 2013 on several sites in each of four areas, namely **Kuala Kangsar, Parit, Teluk Itan and Bagan Datuk** which were selected based on the reviews about the main groups of Perak River's landscape. During the field assessments, 17 aroid species in 13 genera were detected in this region. From the data collected, *Colocasia* and *Alocasia* are most frequent in areas surveyed and *Colocasia* is the most common genus. From Teluk Itan, *Colocasia esculenta* is the most common species because it grows in lowlands, extending from sea level. *Colocasia gigantea* is also recorded but not abundant. Besides the dominant species found, other species are occasionally found in rice fields and canals in the region surveyed. Most of Araceae species obtain nutrient substances from the area close to the river. Other surveys about the social values of Araceae usages are also conducted to supplement this work about Araceae in the Perak River.

INTRODUCTION

Perak River is located in the Northeast of Malaysia with 400km length, several towns are observed on both sides of the river. It is the second longest river in Peninsular Malaysia. The State of Perak has a rich and valuable collection of species in many regional sites. This provides information not only for ecologists but also environmental planners and nature reserve designers. With plant species, the Perak River ecosystem gives a plant map for the biogeography to provide value for the conservation. Perak River also has been a range of biodiversity system with unique species in both flora and fauna data (**Figure 1)**.

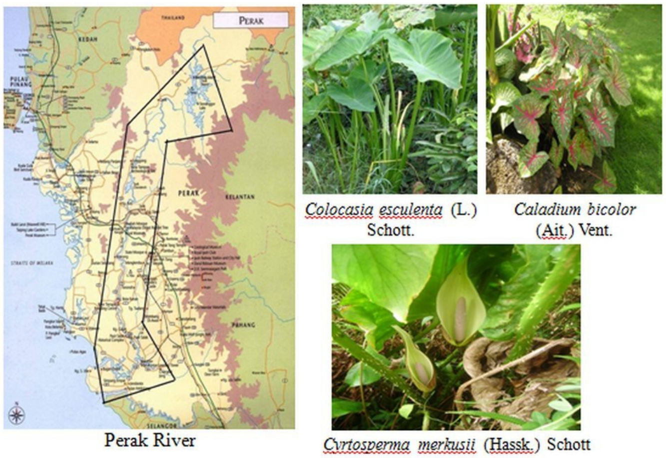


Figure 1. Perak River and the flora.

The Araceae, the monocotyledonous flowering plants in which flowers are collected on a fleshy spadix is commonly found in Perak. The family, with 107 genera and over 3700 species recognised so far, is the most noticably diverse family in the tropics. Besides the medicinal or food value, a large number of species of Araceae are used as ornamental plants because of its adaptation to lower light conditions.. Many of the species have a narrow distribution and with the number of individuals very small. Therefore, the investigation and conservation of species need to be studied in great details.

In addition, the diversity of aroid species composition in Indochina is very rich. Probably, many species are new to science and done more intensivelyfurther additions to the Araceae flora of this region will be detected if surveying is conducted continuously. Therefore, researching about Araceae is necessary, which also includes the ecological distribution of Araceae family in different habitats along the Perak River side, and estimates of the dominant and rare species.

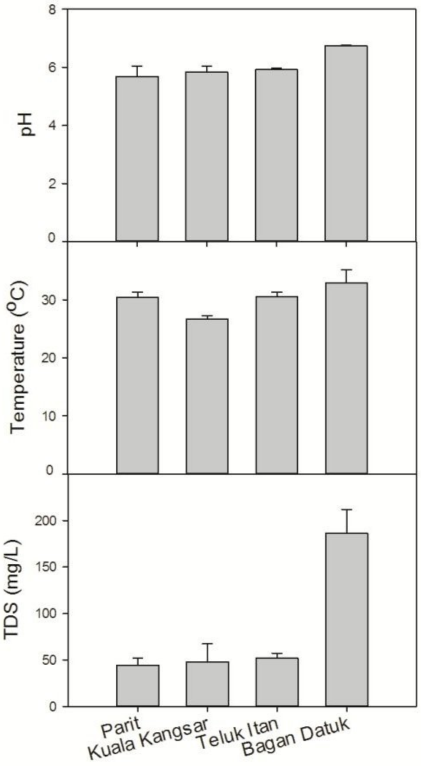


Figure 2. Hydrology values.

METHODS

Materials

The following categories were used in this survey:

The Malaysia Road map and Highway Guide of Malaysia (1 : 916 560)

Alocasia longiloba Miq. *Alocasia macrorrhiza* (L.) G. Don *Amorphophallus prainii* Hook.

Caladium bicolor (Ait.) Vent. *Colocasia esculenta* (L.) Schott. *Colocasia gigantea* Hook.

Figure 3

Cyrtosperma merkusii (Hassk.) Schott *Dieffenbachia maculata* (Lodd.) G. Don *Epipremnum aureum* (Linden & André) G.S.Bunting

Epipremnum giganteum (Roxb.) Schott *Epipremnum pinnatum* Schott *Lasia spinosa* (L.) Thwaites

Figure 4

Figures 3-5. 17 aroid species found in lower section of Perak River.

Philodendron bipinnatifidum Schott *Syngonium podophyllum* Schott *Typhonium trilobatum* (L.) Schott

Xanthosoma sagittifolium (L.) Schott *Zamioculcas zamiifolia* (Lodd.) Engel.

Figure 5

The documents of classification and ecological description of Araceae and environmental factor of plants.

The materials to field survey : maps, measuring tap, notebook and camera.

Plants

To compare the Araceae communities of the lower Perak River, the species of different plants a number of sites in four areas along the river were collected. Each survey was conducted to compare occurrence of species between each habitat of the sites.

Water quality

All of our sites were broadly humid ecosystems, so that we measured the evironmental factors to determine if the different habitats affected the species found. We used water quality measurements of pH, temperature and TDS as well as analysis of soil cores to determine the variability along the lower Perak River. Appropriate measuring equipment was used at each site: Kuala Kangsar, Parit, Teluk Itan and Bagan Datuk .

Soil

We collected soil cores at the four sites for comparison, using an Eijkelkamp piston sampler. We used a Munsell Color Book to identify the color and made note of the texture, moisture, biological activity, land use, elevation, depth and any other distinguishing features. We did not test for the presence of pyrite using H_2O_2, but we did take note of Jarosite present, which is also an indicator of pyrite. We were only able to take a soil core to 20 cm. We cut a portion of the outside of the core away to view the core in section where less mixing in the profile may have occurred as a result of the coring process.

RESULTS

Soil

Araceae plants prefer the humus ecosystem . Additionally, at four surveyed locations, we observed the surface soils. Soil cores were not collected, but a 20 cm deep layer of dark, organic matter, submerged by water was observed. This soil exhibited an odor, that could be identified as H_2S, from the highly reduced conditions.

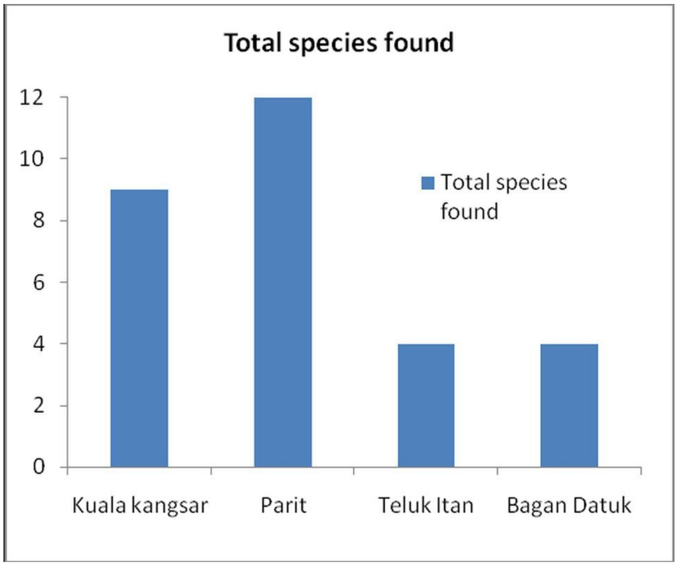


Figure 6. Total number of species found in sites surveyed.

From the results, we can see that textures along this section of the Perak River are mostly sand. Some soil profiles found near the river are wet while other found in palm field or in mountain are dry.

Hydrology

The bar graphs illustrate the hydrology values of four places surveyed in the lower section of Perak River. The first chart compares the pH values between locations. In Parit, the pH value recorded was lower (at pH 5.7), than in Kuala Kangsar and Teluk Itan, which were similar, with figures range around 6.0. Bagan Datuk had the highest pH of nearly 7.0.

Temperatures reported were high in all places, fluctuating between 25^0 and 32^0C.

There are dramatical differences between TDS of locations surveyed. Bagan Datuk was well over 150 mg/l, much higher than the other three places.

Plants

With the exceptions noted, the four locations were similar in their overall characteristics, favoring a limited group of aroids, and lacked the edaphic and topographic conditions that give much greater aroid variety in areas higher up the river system and further from the actual river itself.

With 13 species, the ecosystem in Parit was observed as the most suitable for species of Araceae. Temperatures are warm, fluctuating between 28.3^0C and 32.4^0C. Some aroid species are most suited by tropical regions where it is warm and humid such as *Colocasia esculenta* , and in Parit, *Colocasia esculenta* is one of the most common plants found with a large natural population. Some ornamental species like *Caladium bicolor* and *Philodendron bipinnatifidum* are cultivated but in only small numbers. Species observed in Parit are ornamentals of genera like *Zamioculcas, Dieffenbachia, Epipremnum, Syngonium, Caladium*, together with three naturally occurring species, namely *Colocasia esculenta, Lasia spinosa* and *Typhonium trilobatum.*

In Kuala Kangsar, the soil and water are also favorable for a number of species. Temperatures are warm, the highest is 29.4^0C and pH is not too low, ranging between 4.97 and 6.68. Nine species were found here. Most of species are natural, such as *Alocasia macrorrhizos* (in other places, *Alocasia macrorrhizos* is an ethnobotanically essential plant, and a tropical indoor plant cultivated for its tubers and leaves, used as animal fodder), *Amorphophallus prainii* and *Colocasia esculenta. Colocasia gigantea* were found, but the frequent plant encountered was *Amorphophallus prainii.* Worthy of note is that *Xanthosoma sagittifolium* was only found in Kuala Kangsar.

Bagan Datuk is located near the river mouth where reaches the sea. The pH values were higher than that of recorded in other places, as was the TDS (212 and 160 mg/l). Bagan Datuk has not many Araceae species, but all are naturally occurring, namely *Alocasia longiloba, Alocasia macrorrhizos and Colocasia esculenta,* except that one *Caladium bicolor* was found. Four species were found in Teluk Itan (*Colocasia esculenta, Colocasia gigantea, Lasia spinosa, Dieffenbachia maculata*), all probably of natural occurrence. *Lasia spinosa* was the rare species there with only very small populations found. The soils in these two places are not much different, being clay and sand. Water quality is similar with figures of pH in Bagan Datuk, being higher slightly. TDS in Bagan Datuk follow the trend with 212 mg/l and 160 mg/l. It can be seen that the closer the locations are to the sea, the higher the TDS values are.

Of the 17 species found (**Figures 3-5)**, there were native and endemic species, ornamental species, common species and weedy species.

- Native species: *Alocasia longiloba*, *Amorphophallus prainii*, *Cyrtosperma merkusii, Lasia spinosa*, *Typhonium trilobatum*.

- Introduced, ornamental plants: *Alocasia macrorrhizos, Dieffenbachia maculata*, *Epipremnum aureum, Epipremnum giganteum*, *Epipremnum pinnatum*, *Philodendron bipinnatifidum*, *Syngonium podophyllum*, *Zamioculcas zamiifolia.*

- Introduced carbohydrate crop: *Colocasia esculenta, Xanthosoma sagittifolium*.

The bar chart shows the significantly different number of Araceae species found in the places surveyed. The plant specimens collected from the lower section of Perak can be identified to 17 species. With 12 species of the 17 found, Parit takes the first place considered as the most diverse location. Kuala Kangsar follows closely by with 9 species recorded, The diversity in Teluk tan is low as same as in Bagan Datuk, with figures having only 4 species recorded.

The percentage of species occurrence varies considerably. *Colocasia esculenta* was found 100% from Kuala Kangsar to Bagan Datuk. This species has the largest distribution in the lower section of the Perak River. *Alocasia macrorrhizos, Colocasia gigantea* and *Dieffenbachia maculata* occurred in three areas, *Syngonium podophyllum* and *Lasia spinosa* were found in two locations. Most species were found in only one area surveyed,

Notes on each genus:

Alocasia: The most frequent species is *Alocasia macrorrhizos,* which was found along the mountain slopes or near the drain, while *Alocasia longiloba* was found commonly in the river habitat of Bagan Datuk, but in small populations.

Amorphophallus: We discovered a large population in the mountain and some places around the mountain slope, *Amorphophallus prainii* grew in humid environment and shade.

Caladium: *Caladium bicolor*, usually having pink spots in the leaf was found around housing sites.

Colocasia: The most frequently found species is *Colocasia esculenta* living in the stable aqua-system, mostly be found near the drains or dump ground. Because the tuber of this species can be used as provision, it also is found in the housing sites.

Cyrtosperma: *Cyrtosperma merkusii* was recorded in the palm plantations, where it was abundant in large sizes in the fields.

Dieffenbachia: Only *Dieffenbachia maculata* was found in the areas surveyed, but with a large population.

Epipremnum: *Epipremnum pinnatum* was surveyed in the palm field with a big size, growing in shade and dry conditions. The other species were less common.

Lasia: *Lasia spinosa* was found near the sewers or stagnant ponds. Some populations live in the basalt soil and have bigger size than the others

Philodendron: The most frequent species of the genus is *Philodendron bipinnatifidum*. This genus is considered to be climbers, so that the species were found in the palm field or the mountain; sometimes be found in the housing areas but near the ancient trees.

Syngonium: *Syngonium podophyllum* was found near the river, bridges or the canals but next to the ancient trees.

Typhonium: The *Typhonium* community needs humid condition and occurs next to river or channel

Xanthosoma: only *Xanthosoma sagittifolium* was found and be found in drier locations near the streets or housing places.

Zamioculcas: *Zamioculcas zamiifolia* occurred around houses. Usually just several individuals found.

In this study, 17 species of plant were collected from Kuala Kangsar, Parit, Teluk Intan and Bagan Datuk along the Perak River. Based on 125 genera and about 3750 species including the Lemnaceae, some of specimen from this study is recorded for the distribution along four places surveyed, including climbing species *Philodendron* sp. and the mountainous species *Amorphophallus prainii* were collected from Kula Kangsar. Moist, ever wet or per humid lowland to hill dipterocarp forest is the suitable habitats for Araceae species with the most diversity and abundance species occurring in forest on steep slopes above streams and close to small rivers . Some genera occur in the lower slope zone or some be found at the valley bottom with cooler, wetter or consistently humid niches such as *Homalonema* and *Schismatoglottis* while the other like *Alocasia* and *Amorphophallus* prefer the lighter and warmer conditions with atmospheric humidity and drainage . Most species found in the lower section of Perak River survive with the warm temperature from 24.3^{0}C up to 33.9^{0}C and usually close to the small rivers with humid condition.

Perak River habitat comprises several kinds of landforms, such as, meandering river scar, hill, mountain, etc. Therefore, Kuala Kangsar and Parit are more mountainous and far from the river mouth than the others. The species found in Parit reach the peak with 12/17 species. Kuala Kangsar is followed closely with 9/17 species. Because of the thick river – network with many canals and branches help to manage the water level, Araceae species can be found easily near the canals or branches such as *Colocasia esculenta*. The condition from the topography, soil, and water control the vegetation on each area. From the result of this study, it might be concluded that high habitat diversity cause high diversity of Araceae species. Approximately 100% *Colocasia esculenta* was occurred and 75% *Colocasia gigantea* found. Therefore, *Colocasia* community is singled out to be the dominant submerge species in the lower section of Perak. They were found in almost humid habitats ranging from rivers, canals, small ponds to sewers. Evidently, the number of *Colocasia* was found embedded in the organic soil. Some populations grow faster when their roots is embedded in the silt soil. It can also survive in the polluted water, not highly polluted. For example, in the Kuala Kangsar 6 (pH 4.97), *Colocasia esculenta* was occurred, but the leaf was small and deformed. Generally, only *Colocasia esculenta* was found in the low pH while other communities were found in higher pH and fresh habitats. They can be grown in habitats with pH ranging from 4.97 to 7.04 and TDS values ranging between 13.05 mg/l and 212 mg/l. It can be postulated that this species could survive in acidic. They were also dominant in the canals along the Perak River, even near the river mouth where the TDS value was so high. The high reading may be due to the effect of the seawater, especially during the high tide. We can see that *Colocasia esculenta* has the largest distribution from Kuala Kangsar to the end of Perak River. It is widely diverse expended most humid tropical and subtropical areas . Being known as an edible root, having 70 – 80% moisture, 27% dietary fiber, starch, protein, some vitamins such as vitamin C, E and B6, sugar. . . . *Colocasia esculenta* was found very common in Perak naturally. It is considerable abundance species in the lowlands, extending from sea level to lower and also to mid-zones . From the results, *Colocasia esculenta* can survive in acidic water and fresh water (from 4.92 to 6.76); in some places, be found in polluted water. *Colocasia esculenta* L. was recorded as a removal arsenic plant with the largest and fastest arsenic removal rate (68 mg As/m^2/day in compare with *Canna glauca* L. (61 mg As/m^2/day), *Cyperus papyrus* L. (56 mg As/m^2/day) and *Typha angustifolia* L. (61 mg As/m^2/day). Its arsenic removal rate was recognized in submerged soil polluted research by arsenic . *Colocasia gigantea* was recorded with the distribution from Kuala Kangsar to Teluk Itan, occurring in seasonally dry forest , withstanding pH from 4.97 to 6.13 and warm temperature. *Colocasia esculenta* and also *Alocasia macrorrhizos* usually maintain naturalized, adventives and large populations seasonally. The former has considered as a carbohydrate crop and minor vegetable and be cultivated more popular since antiquity while the latter was recorded in the history as a medicinal plant . *Alocasia* genus was the second community found. Mostly, *Alocasia odora* was discovered in the housing place while *Alocasia macrorrhizos* was found in wild from mountain slope to hills. They can survive in the aluminum soil based on the soil profile which contained jarosite in 20 cm depth. In *Alocasia* group, *Alocasia longiloba* was seldom found near the canals, they grow in the mountainous places. *Caladium* community found in Kuala Kangsar, Parit, and Bagan Datuk has different colors and spots on the leaf's surface. *Caladium* seldom produces flower and seeds while flower are found in *Alocasia* commonly. Besides, there were several communities of Araceae, which were found during the survey. *Amorphophallus prainii* occurred in Kuala Kangsar and sometimes with large populations. Some were found in the palm field, namely *Dieffenbachia maculata*, *Epipremnum pinnatum*, *Zamioculcas zamiifolia*. Among the climbing group *Philodendron*, *Philodendron bipinnatifidum* was considered the most common species found.

In 4 places recorded, Araceae species are found; including ornamental species, natural species or weedy species in different land uses between mountain, river band and housing or palm fields from the middle of Perak River to the river mouth, extending to the sea and reaches the brackish water.

CONCLUSION

It can be noted that out of the 17 surveyed species, two species are from the genus *Colocasia*, two are from *Alocasia* and three are from *Epipremnum*. The rest were from nine other genera (*Amorphophallus*, *Caladium*, *Dieffenbachia*, *Lasia*, *Philodendron*, *Syngonium*, *Typhonium*, *Xanthosoma*, and *Zamioculcas*).

Colocasia and *Alocasia* are dominants in areas surveyed and *Colocasia* is the commonest found with large populations. It has the strongest survival and can survive in acidic and polluted habitats. Besides the dominant species, other species are occasionally found in rice fields and canals, and palm fields in the region surveyed, or in association with present or former dwellings.

ACKNOWLEDGEMENTS

First, we would like to express our deep appreciation to Universiti Sains Malaysia for their generous support and for their sponsorship and for funding the publication fee under the Individual Research Grant (1001/PBiologi/816217). Second, we would like to thank all friends for their invaluable assistance.

REFERENCES

Jomjun, N., T.Siripen, S.Maliwan, N. Jintapat, T.Prasak, C.Somporn & P.Petch 2011. Phytoremediation of arsenic in submerged soil by wetland plants. [Research Support, Non-U.S. Gov't]. *Int J Phytoremediation, 13*(1): 35–46.

Kreike, C. M., H. J.Van Eck & V. Lebot. 2004. Genetic diversity of taro, Colocasia esculenta (L.) Schott, in Southeast Asia and the Pacific. [Comparative Study Research Support, Non-U.S. Gov't]. *Theor Appl Genet, 109*(4): 761–768. doi: 10.1007/s00122–004–1691-z

Kuruvilla, K. M., & A. Singh. 1981. Karyotypic and Electrophoretic Studies on Taro and Its Origin. *Euphytica, 30*(2), 405–413. doi: Doi 10.1007/Bf00034004

Mansor, Mashhor, P. C. Boyce, Ahmad Sofiman Othman & Baharuddin Sulaiman. Penerbit Universiti Sains Malaysia. 2012. *The Araceae of Peninsular Malaysia*. Glugor , Pulau Pinang: Penerbit Universiti Sains Malaysia

Nauheimer, L., P. C.Boyce & S. S.Renner. 2012. Giant taro and its relatives: a phylogeny of the large genus Alocasia (Araceae) sheds light on Miocene floristic exchange in the Malesian region. [Research Support, Non-U.S. Gov't]. *Mol Phylogenet Evol, 63*(1): 43–51. doi: 10.1016/j.ympev.2011.12.011

Reddy, M., R.Moodley, A. Kindness & S. B.Jonnalagadda. 2011. Impact of soil quality on elemental uptake by, and distribution in Colocasia esculenta (Amadumbe), an edible root. *J Environ Sci Health B, 46*(3): 247–256. doi: 10.1080/03601234.2011.540533

Why is 'Flora Malesiana' Araceae not currently a practicable undertaking - *Fenestratarum* as an example

Peter C. Boyce
Honorary Research Fellow
Institute Of Biodiversity and Environmental Conservation (IBEC)
Universiti Malaysia Sarawak
94300 Kota Samarahan
Sarawak, Malaysia
phymatarum@gmail.com

ABSTRACT

Flora Malesiana is a systematic account of the flora of Malesia, the plant-geographical unit spanning seven countries in Southeast Asia: Indonesia, Malaysia, Singapore, Brunei Darussalam, the Philippines, Timor Leste, and Papua New Guinea. The Araceae is one of the larger plant families of Malesia, currently comprising 42 described genera and, conservatively, about 1200 species. A substantial proportion of Malesian aroid species are either only recently named, or have yet to be formally described. Despite encouraging progress with regional monographic accounts in the1990s and early 2000s, notably for *Alocasia*, *Schismatoglottis*, *Pothos*, *Epipremnum*, and *Rhaphidophora*, the intervening years, marked by a significant increase in field-based research, have revealed an extraordinary wealth of novel diversity such that none of the terrestrial and rheophytic genera can be currently be considered adequately known. Highlighting increases in described species in the past 15 years, and drawing on the example of the recently described genus *Fenestratarum*, reasons why *Flora Malesiana* Araceae is not currently practicable are enumerated, and practicable alternatives proffered.

KEY WORDS

Borneo, Indonesia,

INTRODUCTION

Flora Malesiana (FM) is a systematic account of the flora of Malesia, the plant-geographical unit spanning seven countries in Southeast Asia: Indonesia, Malaysia, Singapore, Brunei Darussalam, the Philippines, Timor Leste, and Papua New Guinea (http://floramalesiana.org/). The Araceae is one of the larger plant families of Malesia, currently comprising 42 described genera (excluding three genera of former Lemnaceae) and an estimated 1200 species (excluding nine species of former Lemnaceae) with a substantial percentage of species either only recently named, or yet to be formally described (**Table 1**; Boyce & Croat 2011).

Table 1. Changes in species numbers of Araceae of *Flora Malesiana* region over the last 15 years

Taxon	2001	2015	% increase	2001 + known novelties	% increase since 2001
Aglaodorum Schott	1	1	0	1	0
Aglaonema Schott	17	17	0	17	0
Alocasia (Schott) G.Don	59	63	7	87	48
Amorphophallus Blume ex Decne.	57	63	11	78	37
Amydrium Schott	3	3	0	0	0
Anadendrum Schott	10	12	20	47	370
Apoballis Schott [≡ *Schismatoglottis* Rupestris Group in Hay & Yuzammi 2000].	[12]	12	0	20	67
Aridarum Ridl.	8	24	200	26	225
Arisaema Mart.	14	14	0	15	7
Bakoa P.C.Boyce & S.Y.Wong [≡ *Piptospatha* pr. pte in Bogner & Hay 2000].	[2]	4	100	4	100
Bucephalandra Schott	2	29	1350	50	2400
Colocasia Schott	3	3	0	3	0
Cryptocoryne Fisch. ex Wydler	37	41	11	44	19
Cyrtosperma Griff.	12	12	0	12	0
Epipremnum Schott	13	13	0	13	0
Fenestratarum P.C.Boyce & S.Y.Wong	0	1	0	2	100
Furtadoa M.Hotta	2	2	0	2	0
***Gen. nov.* 1**	0	0	0	1	100
***Gen. nov.* 2**	0	0	0	1	100
***Gen. nov.* 3**	0	0	0	1	100
Hapaline Schott	3	3	0	3	0
Hestia S.Y.Wong & P.C.Boyce [≡ *Schismatoglottis longifolia*, Hay & Yuzammi 2000].	[1]	1	0	5	400
Holochlamys Engl.	1	1	0	1	1
Homalomena Schott	88	131	49	350 *[1]	297
Hottarum Bogner & Nicolson [≡ *Piptospatha* pr. pte, Bogner & Hay 2000].	[1]	1	0	2	100
Lasia Lour., Fl. Cochinch.: 81 (1790).	2	2	0	2	0
Nephthytis Schott	1	1	0	1	0
Ooia S.Y.Wong & P.C.Boyce [≡ *Piptospatha* Grabowskii Group pr. pte, Bogner & Hay 2000].	[2]	3	50	10	400
Pedicellarum M.Hotta	1	1	1	1	0
Phymatarum M.Hotta	1	1	1	1	0
Pichinia S.Y.Wong & P.C.Boyce	0	1	100	1	0
Pistia L.	1	1	0	1	0
Piptospatha N.E.Br.	11	12	9 *[2]	15	36
Podolasia N.E.Br.	1	1	1	1	0
Pothoidium Schott	1	1	1	1	0
Pothos L.	41	41	0	43	5
Remusatia vivipara (Roxb.) Schott	1	1	0	1	0
Rhaphidophora Hassk.	81	83	2.5	88	9
Sauromatum Schott	2	2	0	2	0
Schismatoglottis Zoll. & Moritzi	89	118	33 *[3]	180 *[4]	102
Schottariella P.C.Boyce & S.Y.Wong	0	1	100	1	0
Schottarum P.C.Boyce & S.Y.Wong [≡ *Schismatoglottis* pr. pte, Hay & Yuzammi 2000].	[1]	2	100	3	200
Scindapsus Schott	32	32	0	33	3
Spathiphyllum Schott	3	3	0	3	0
Typhonium Schott	7	7	0	7	0
Totals	**634**	**765**	**21%**	**1180**	**86%**

*[1] this total is undoubtedly conservative, based as it is only on undescribed species that are well-resolved; the genuine total could easily be half as much again, i.e., ca 500 species.
*[2] taking into account species removed from *Piptospatha* sensu Hay & Bogner the % increase is 100%
*[3] taking into account species removed from *Schismatoglottis* sensu Hay & Bogner the % increase is 59.6%
*[4] this total is conservative, based as with *Homalomena* on undescribed species that are well-resolved; the total will likely stabilize around 300 species.

During the IV International Aroid Conference (Moscow, 24–30 August 1992) a group of then-active tropical Asian aroid researchers gathered to agree on the best approach to tackling the Araceae for *Flora Malesiana*. The outcome was a division of labour under the general editorship of Alistair Hay, with genera allotted according to individual expertise and interests (Hay 1994). The general agreement as a starting point was the compilation and publication of a checklist and bibliography for the Araceae for Malesia. This was published in 1995 (Hay et al., 1995). Thereafter the years leading up to 2001 saw the publication of monographic and regional accounts for *Alocasia* (Hay, 1998; 1999b), *Colocasia* (Hay, 1996b), *Epipremnum* (Boyce, 1998), *Hapaline* (Boyce, 1996), *Homalomena* (Hay, 1999a), the Potheae (Boyce & Hay, 2001), *Rhaphidophora* (Boyce, 1999; 2000a,b; 2001a,b; Boyce & Bognerm 2000), *Schismatoglottis* (Hay, 1996a), and the Schismatoglottideae (Bogner & Hay, 2000), together with the description of a new and remarkable Bornean species of *Nephthytis*, a genus until then known only from tropical West Africa (Hay et al., 1994). In combination with reliable earlier accounts for *Aglaonema* (Nicolson, 1969), *Alocasia* (Hay & Wise, 1991), *Cryptocoryne* (Jacobsen, 1985; Jacobsen & Bogner, 1986, 1987), the Lasioideae (Hay, 1988), and *Pothos* (Hay, 1995) this body of work looked to provide a very significant contribution towards completion of the Araceae for *Flora Malesiana* within 10 years, as originally envisaged at the Moscow gathering.

However, after 2001 owing to employment changes three of the “Moscow Team” ceased full-time research on the Araceae of Malesia, although the situation improved somewhat late in 2002 when the author relocated to Sarawak and was again able to begin work on aroids, at least for Borneo. Paradoxically it was the opportunity to be based long-term in the wet tropics that brought into sharp focus that despite the numerous publications to date much remained to be done, even for taxa such as the Schismatoglottideae which had received significant attention from established specialists. Two factors, establishment of a substantial living collection and the concomitant removal of dependency on herbarium collections – the problems associated with dependency on herbarium material for studying aroids has been previously discussed (Boyce & Wong, 2012; Wong & Boyce, 2014) – and access to a molecular lab., impacted substantially on what thought we knew to the point that it became clear that we remain a long way from being in a position to work up a complete account for the aroids of Malesia.

Using 2001 as being the last year in which any *comprehensive* regional monograph was published, the taxonomic changes to the aroids of Malesia are shown **Table 1**. Column '2015' is the total described, accepted species per genus at the beginning of 2015 as compared with the same total shown in column '2001' – for the family this is an increase of 21% in 15 years. Column '2001+ known novelties' is the total *known* species (described and undescribed) for each genus, a family-wide increase of 86% for the period 2001–2015. As indicated in the footnotes, these are conservative figures.

It might seem from the above that great strides have been made in the past 15 years such that now it is the time to 'stop' and work up the aroids for FM – however, the novelties that Table 1 highlights are overwhelmingly (>90%) described from Borneo – very substantial tracts of the Flora Malesiana region, notably Sumatera and Sulawesi, as well as a significant part of Borneo, are still virtually unknown.

Borneo continues to produce extraordinary novelties, exemplified by a new genus *Fenestratarum*, the existence of which was unimagined, described at the very end of 2014 (Boyce & Wong, 2014). As surprising as the appearance *Fenestratarum* was, a greater surprise was in store when, literally as the proofs the ms were being checked a second species of *Fenestratarum*, likewise unforeseen, came to light over 600 km further east than the Type locality of the first. This second species is currently in press (Boyce & Wong, in press). Aside from providing a pleasurable frisson of excitement the discovery of *Fenestratarum* has usefully 'solved' a support problem at the base of an otherwise "good" clade, enabling taxonomic resolutions to be made about several problematic species currently assigned to inappropriate genera, and resolving the placement of yet another novelty as a new genus.

ARACEAE FOR *FLORA MALESIANA* – WHAT ARE THE OPTIONS?

The speed and especially the magnitude of taxonomic change occurring within the Araceae of the *Flora Malesiana* region effectively prohibits the prospect of producing a printed *Flora Malesiana* account for the aroids in the next decade, or longer. But it is enormously important that what is published is made freely available via an archived and readily up-dateable portal. To this end with the assistance of Albert Huntington we have been archiving all our publications on the International Aroid Society's website:

http://www.aroid.org/gallery/boyce/

http://www.aroid.org/gallery/wong/

We strongly urge all researchers to do likewise.

In addition, over the past few years we have established a significant image resource of living plants and Type specimens, together with scans of original descriptions (protologues) on our Flickr site:

https://www.flickr.com/photos/araceae_of_sunda/collections/

We encourage those with images to make them available through this or a similar reliable free-to-use public portal.

Currently there are several web-based resources for the aroids in genera. One of the best is:

Emonocot:
http://emonocot.org/taxon/urn:kew.org:wcs:family:3

Much of the early literature for Araceae in general and South East Asian in particular is not easy to access in libraries, although in recent years the situation has become easier with several web-based resources, in particular:

The Biodiversity Heritage Library:
http://www.biodiversitylibrary.org/

Botanicus Digital Library:
http://www.botanicus.org/

In addition to these institutionally-based resources we have compiled a free to download resource of all the critical early literature for Araceae in DropBox – please contact the author – phymatarum@gmail.com – for access permission.

CONCLUSIONS

Compiling the Araceae for *Flora Malesiana* is a noble enterprise but one with a considerable burden imposed by the combination of reduction in full-time researchers, increasing rate of habitat disturbance, ironically a marked increase in the discovery of taxonomic novelties, and a shifting understanding of higher taxa delimitation into which the units we call species are grouped and catalogued. Production of a 'traditional' printed account is neither practicable in terms of time available to the current researchers nor indeed desirable given the very fluid nature of the subject, notably the taxonomy. Provision of well-advertized on-line access to published accounts and reliably identified images is of paramount importance to keep everyone abreast of the research that is occurring until such time that a full account is deemed appropriate.

REFERENCES

Bogner J. & A. Hay. 2000. *Schismatoglottideae* in Malesia II – *Aridarum*, *Bucephalandra*, *Phymatarum* and *Piptospatha*. *Telopea* 9: 183–194.

Boyce, P. C. 1996. *Hapaline* (Araceae: Aroideae: Caladieae). *Kew Bull.* 51(1): 63–82.

Boyce, P. C. 1998. The genus *Epipremnum* Schott. (Araceae–Monsteroideae–Monstereae) in west and central Malesia. *Blumea* 43: 183–218.

Boyce, P. C. 1999. The genus *Rhaphidophora* Hassk. (Araceae–Monsteroideae–Monstereae) in Peninsular Malaysia, and Singapore. *Gard. Bull. Singapore* 51: 183–256..

Boyce, P. C. 2000a. The genus *Rhaphidophora* Hassk. (Araceae–Monsteroideae–Monstereae) in the southern and western Indonesian archipelago. *Gard. Bull.Singapore* 52: 101–183.

Boyce, P. C. 2000b. The genus *Rhaphidophora* Hassk. (Araceae–Monsteroideae–Monstereae) in the Philippines. *Gard. Bull. Singapore* 52: 213–256.

Boyce, P. C. 2001a. The genus *Rhaphidophora* Hassk. (Araceae–Monsteroideae–Monstereae) in Borneo. *Gard. Bull. Singapore* 53: 19–74.

Boyce, P. C. 2001b. The genus *Rhaphidophora* Hassk. (Araceae–Monsteroideae–Monstereae) in New Guinea, Australia and the tropical western Pacific. *Gard. Bull. Singapore* 53: 75–183.

Boyce, P. C. & J. Bogner. 2000. An account of neotenic species of Rhaphidophora Hassk. (Araceae–Monsteroideae–Monstereae) in Australia and New Guinea. *Gard. Bull. Singapore* 52: 89–100.

Boyce, P. C. & T. B. Croat. (2011 onwards).The Überlist of Araceae, Totals for Published and Estimated Number of Species in Aroid Genera. http://www.aroid.org/genera/140601uberlist.pdf

Boyce, P. C. & A. Hay. 2001. A taxonomic revision of Araceae tribe Potheae (*Pothos*, *Pothoidium* and *Pedicellarum*) for Malesia, Australia and the tropical Western Pacific. *Telopea* 9(3): 449–571.

Boyce P. C. & S. Y. Wong. 2012. Studies on *Schismatoglottideae* (Araceae) of Borneo XX: Beccari's «La Piu piccola delle Aracee» (*Microcasia pygmaea*) recollected and transferred to *Bucephalandra* Schott. *Webbia* 67: 139–146.

Boyce P. C. & S. Y. Wong. 2014. Studies on Schismatoglottideae (Araceae) of Borneo XXXXIII: *Fenestratarum culum* - A new genus and species from Kalimantan Barat, Indonesian Borneo. *Aroideana* 37E(2): 4–10.

Boyce, P. C. & S. Y. Wong. in press. Studies on Schismatoglottideae (Araceae) of Borneo XXXXVI: *Fenestratarum mulyadii* – A second species of a recently described genus. *Aroideana.*

Hay, A. 1988. *Cyrtosperma* (*Araceae*) and its Old World allies. *Blumea* 33: 427–469.

Hay, A. 1994. Araceae – an internationally coordinated major family for the accelerated Flora Malesiana project. *Fl. Males. Bull.* 11: 5–8.

Hay, A. 1995. The genus *Pothos* L. (Araceae–Pothoeae) in New Guinea, Solomon Islands and Australia. *Blumea* 40: 397–419.

Hay A. 1996a. The genus Schismatoglottis Zoll. & Moritzi (Araceae: Schismatoglottideae) in Peninsular Malaysia and Singapore. *Sandakania* 7: 1– 30.

Hay, A. 1996b. A new Bornean species of Colocasia Schott (Araceae: Colocasieae), with a synopsis of the genus in Malesia and Australia. *Sandakania* 7: 31–48.

Hay, A. 1998. The genus Alocasia (Araceae–Colocasieae) in West Malesia and Sulawesi. *Gard. Bull. Singapore* 50: 221–334.

Hay, A. 1999a. A revision of *Homalomena* Schott (Araceae–Homalomeneae) in New Guinea,the Bismarck Archipelago and Solomon Islands. *Blumea* 44: 41– 71.

Hay, A. 1999b. The genus Alocasia (Araceae–Colocasieae) in the Philippines. *Gard. Bull. Singapore* 51: 1–41.

Hay, A., J. Bogner & P. C. Boyce. 1994 *Nephthytis* Schott (Araceae) in Borneo: A new species and new generic record for Malesia. *Novon* 4(4): 365–368.

Hay, A. & R. Wise. 1991. The genus *Alocasia* (Araceae) in Australasia. *Blumea* 35: 499–545.

Hay, A. & Yuzammi. 2000: *Schismatoglottideae* in Malesia I – *Schismatoglottis. Telopea* 9(1): 1–177.

Hay, A. [et al. 1995], J. Bogner, P. C. Boyce, W. L. A. Hetterscheid, N. Jacobsen & J. Murata. 1995. Checklist & Botanical Bibliography of the Aroids of Malesia, Australia, and the tropical western Pacific. *Blumea, Suppl.* 8: 1–210.

Jacobsen, N. 1985. The *Cryptocoryne* (Araceae) species of Borneo. *Nordic J. Bot.* 5 (1): 31–50.

Jacobsen, N. & J. Bogner. 1986. Die Cryptocorynen der Malaiischen Halbinsel (1. Teil). *Aqua-Planta* 11: 135–139.

Jacobsen, N. & J. Bogner. 1987. Die Cryptocorynen der Malaiischen Halbinsel: (2. – 4. Teil). *Aqua-Planta* 12: 13–20, 56–60, 96–103.

Nicolson, D. H. 1969. A revision of the genus *Aglaonema* (Araceae). Smithsonian Institution Press, pp. 63.

Wong S. Y. & P. C. Boyce. 2014. Studies on *Schismatoglottideae* (Araceae) of BorneoXXX – New species and combinations for *Bucephalandra*. Willdenowia 44: 149–199.

Araceae and eMonocot: An online resource for monocot plants of the world

Anna Haigh
Royal Botanic Gardens, Kew
Richmond, Surrey UK TW9 3AB

ABSTRACT

eMonocot (http://e-monocot.org) is an online resource for monocot plants created by the eMonocot project, a consortium of the Royal Botanic Gardens, Kew, Oxford University and the Natural History Museum, London, as well as contributions from monocot taxonomists and communities worldwide. Method and progress are described, including the addition and gathering of information on Araceae.

KEY WORDS

Araceae, eMonocot, eTaxonomy, collaboration

INTRODUCTION

In an era when plant classification is being driven forward by increasing volumes of molecular data, the species-level taxonomy of taxa such as Araceae remains as important as ever. Increasingly taxonomists are seeking to collaborate with colleagues around the world including volunteer biologists, horticulturists, and the general public in order to share information and resources such as checklists, original publications, herbarium records and specimens, bibliographic references, illustrations, photograph libraries, datasets and distribution maps. Historically such resources have been held by institutions. Access for both specialist taxonomists and the general public normally requires special permission.

THE DISTRIBUTED RESOURCES, ONLINE RESOURCES, AND ACCESS FOR ALL

There is a great deal of information on species, but much of it is distributed across many journals, books and websites. Much of this is only available in specialist libraries to which many don’t have access. In recent years several initiatives have gone some way to making this information accessible, such as the Biodiversity Heritage Library (http://www.biodiversitylibrary.org/), where digital copies of many texts are available online. The Global Plants Initiative (via http:/Iplants.jstor.org) has been digitising Herbarium specimens around the world and making these accessible. These resources are transforming the way taxonomy is done today. However for many users of information on plants, these resources are still hard and time consuming to interpret if they simply want to know the identification or current information on a given plant.

THE EMONOCOT PROJECT

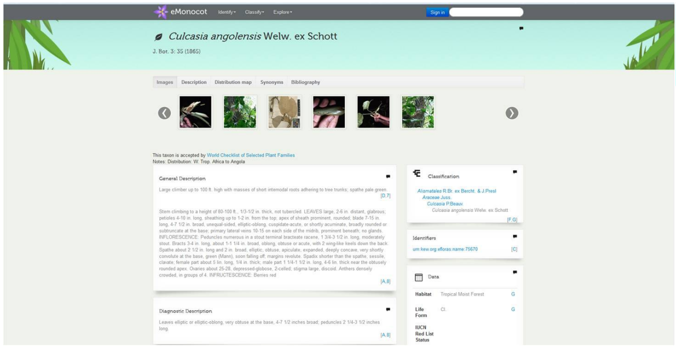
The eMonocot project brings information about all monocot species together in one place. From having static species descriptions and dispersed datasets, we can have a comprehensive website that is updated, by the community around the world. It is a consortium project led by the Royal Botanic Gardens, Kew in collaboration with Oxford University and the Natural History Museum, and funded by the Uks Natural Environment Research Council (NERC). Monocots were chosen for this ground-breaking project for several reasons. They are a large group, with over 70, 000 species making up 20% of the flowering plants, with high economic importance. Also, several resources were already available to feed data into the system. These include the World Checklist of Selected Plant families (http://apps.kew.org/wcsp/home.do), Palmweb (http://palmweb.org/) and CATE Araceae.

The primary output of eMonocot is the eMonocot portal (www.e-monocot.org), a website that is rapidly becoming a media-rich, interactive tool of discovery and education. This is targeted at all users from biodiversity scientists to the interested public, and everybody in between. All the data is available free of charge, to anyone who can access the internet. There is referenced information on each species, genus and family of Monocots, with images, distribution, nomenclatural information, synonymy, conservation status and more. Other tools include identification keys, faceted searching, map searches and more. All this is brought together by a community of amateurs and professionals from reliable scientific resources.

How eMonocot works

eMonocot works as a distributed information system or a “hub and spoke” model. The eMonocot Portal is at the centre of this, and it harvests data from a variety of resources which are being continuously updated. The World Checklist of Selected Plant Families provides the “backbone” classification, with accepted names and synonyms of all monocots, including their Authors, place and date of publication. This checklist also provides geographical, habitat and lifeform data.

Most descriptive data and images feed into the portal from a variety of Scratchpads (www.scratchpads.eu). These are interactive e-taxonomy community research tools, which enable researchers to manage, share and publish taxonomic data online. Scratchpads allow researchers to work collaboratively on the the groups of organisms they study and disseminate their research outputs to a large audience via the



Culcasia angolensis Welw. ex Schott

J. Bot. 3: 35 (1865)

This taxon is accepted by World Checklist of Selected Plant Families
Notes: Distribution: W. Trop. Africa to Angola

General Description

Large climber up to 100 ft. high with masses of short internodal roots adhering to tree trunks; spathe pale green. [D.7]

Stem climbing to a height of 80-100 ft., 1/3-1/2 in. thick, not tubercled. LEAVES large, 2-6 in. distant, glabrous; petioles 4-10 in. long, sheathing up to 1-2 in. from the top; apex of sheath prominent, rounded; blade 7-15 in. long, 4-7 1/2 in. broad, unequal-sided, elliptic-oblong, cuspidate-acute, or shortly acuminate, broadly rounded or subtruncate at the base; primary lateral veins 10-15 on each side of the midrib, prominent beneath; no glands. INFLORESCENCE: Peduncles numerous in a stout terminal bracteate racene, 1 3/4-3 1/2 in. long, moderately stout. Bracts 3-4 in. long, about 1-1 1/4 in. broad, oblong, obtuse or acute, with 2 wing-like keels down the back. Spathe about 2 1/2 in. long and 2 in. broad, elliptic, obtuse, apiculate, expanded, deeply concave, very shortly convolute at the base, green (Mann), soon falling off; margins revolute. Spadix shorter than the spathe, sessile, clavate; female part about 5 lin. long, 1/4 in. thick; male part 1 1/4-1 1/2 in. long, 4-6 lin. thick near the obtusely rounded apex. Ovaries about 25-28, depressed-globose, 2-celled; stigma large, discoid. Anthers densely crowded, in groups of 4. INFRUCTESCENCE: Berries red [A.8]

Diagnostic Description

Leaves elliptic or elliptic-oblong, very obtuse at the base, 4-7 1/2 inches broad; peduncles 2 1/4-3 1/2 inches long. [A.8]

Classification

Alismatales R.Br. ex Bercht. & J.Presl
Araceae Juss.
Culcasia P.Beauv.
Culcasia angolensis Welw. ex Schott
[F.G]

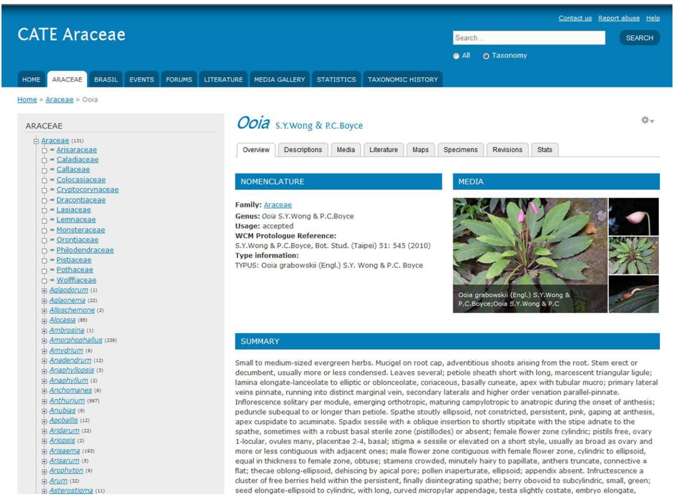
Identifiers

urn:kew.org:efloras:name:75670 [C]

Data

Habitat	Tropical Moist Forest	G
Life Form	Cl.	G
IUCN Red List Status		

Figure 1



Home » Araceae » Ooia

ARACEAE

- Araceae (131)
  - = Arisaraceae
  - = Caladiaceae
  - = Callaceae
  - = Colocasiaceae
  - = Cryptocorynaceae
  - = Dracontiaceae
  - = Lasiaceae
  - = Lemnaceae
  - = Monsteraceae
  - = Orontiaceae
  - = Philodendraceae
  - = Pistiaceae
  - = Pothaceae
  - = Wolffiaceae
  - *Aglaodorum* (1)
  - *Aglaonema* (22)
  - *Alloschemone* (2)
  - *Alocasia* (85)
  - *Ambrosina* (1)
  - *Amorphophallus* (239)
  - *Amydrium* (6)
  - *Anadendrum* (12)
  - *Anaphyllopsis* (3)
  - *Anaphyllum* (2)
  - *Anchomanes* (6)
  - *Anthurium* (997)
  - *Anubias* (9)
  - *Apoballis* (12)
  - *Aridarum* (22)
  - *Ariopsis* (2)
  - *Arisaema* (193)
  - *Arisarum* (5)
  - *Arophyton* (9)
  - *Arum* (32)
  - *Asterostigma* (11)

Ooia S.Y.Wong & P.C.Boyce

Family: Araceae
Genus: *Ooia* S.Y.Wong & P.C.Boyce
Usage: accepted
WCM Protologue Reference:
S.Y.Wong & P.C.Boyce, Bot. Stud. (Taipei) 51: 545 (2010)
Type information:
TYPUS: Ooia grabowskii (Engl.) S.Y. Wong & P.C. Boyce

Ooia grabowskii (Engl.) S.Y.Wong & P.C.Boyce;Ooia S.Y.Wong & P.C

Small to medium-sized evergreen herbs. Mucigel on root cap, adventitious shoots arising from the root. Stem erect or decumbent, usually more or less condensed. Leaves several; petiole sheath short with long, marcescent triangular ligule; lamina elongate-lanceolate to elliptic or oblonceolate, coriaceous, basally cuneate, apex with tubular mucro; primary lateral veins pinnate, running into distinct marginal vein, secondary laterals and higher order venation parallel-pinnate. Inflorescence solitary per module, emerging orthotropic, maturing campylotropic to anatropic during the onset of anthesis; peduncle subequal to or longer than petiole. Spathe stoutly ellipsoid, not constricted, persistent, pink, gaping at anthesis, apex cuspidate to acuminate. Spadix sessile with ± oblique insertion to shortly stipitate with the stipe adnate to the spathe, sometimes with a robust basal sterile zone (pistillodes) or absent; female flower zone cylindric; pistils free, ovary 1-locular, ovules many, placentae 2-4, basal; stigma ± sessile or elevated on a short style, usually as broad as ovary and more or less contiguous with adjacent ones; male flower zone contiguous with female flower zone, cylindric to ellipsoid, equal in thickness to female zone, obtuse; stamens crowded, minutely hairy to papillate, anthers truncate, connective ± flat; thecae oblong-ellipsoid, dehiscing by apical pore; pollen inaperturate, ellipsoid; appendix absent. Infructescence a cluster of free berries held within the persistent, finally disintegrating spathe; berry obovoid to subcylindric, small, green; seed elongate-ellipsoid to cylindric, with long, curved micropylar appendage, testa slightly costate, embryo elongate,

Figure 2

Figure 1. Example of a taxon page from the eMonocot portal.

Figure 2. Example of a taxon page from the CATE Araceae Scratchpad. A classification tree allows the user to explore and navigate to a particular taxon. A series of tabs on each taxon page allows the user to explore the different data pertaining to that taxon.

web. They can handle a variety of file types and data including bibliographic records, DNA datasets, morphological character matrices, media files and text pages. They are free to set up and have proved very popular with a wide variety of individuals and groups. Specifically eMonocot-themed Scratchpads have been created so that individuals and groups of individuals interested in contributing to eMonocot can create taxon-focused websites. There are 28 scratchpads that currently feed into eMonocot. One of these covers the Araceae family (http://araceae.e-monocot.org).

Data from these sites, and other taxon specific sites as well as other resources such as Global Biodiversity Information Facility (GBIF) and IUCN redlist, are harvested by the portal regularly, and are presented on a web page for each taxon (**Figure 1.**). This model of working could eventually be used to cover information on all groups of plants from all over the world in one site.

Araceae and eMonocot

The Araceae scratchpad contains data that used to be in www.cate-araceae.org. This data was gathered as part of a previous project called creating a taxonomic eScience, also funded by NERC that ran from 2005–2008 (Haigh et al., 2008). After a period of time the software behind this site became outdated and the data has now been imported into http://araceae.emonocot.org/ which is now also available through www.emonocot.org. The Araceae site is being worked on intensively and we now have species descriptions for over 65% of accepted taxa (**Figure 2)**. New species are added, and are available on the Scratchpad before they are imported into the Portal. So for up-to-date species information, this is the place to go.

There are identification keys to the Araceae family, as well as some groups including *Anthurium*, African species, and *Arum*. You will find you can use the portal to ask questions such as: How many species of Araceae are there? How many genera? What are the epiphytes in the drylands of South America? There are diffent ways of searching for data including map searches, and results can be downloaded and presented graphically.

How you can become more involved

We are always looking to improve the site and welcome any input. Permission to use data is gratefully received, as is the contribution of time to add data. Of particular interest are high quality, accurately identified images of live plants, notes on uses and cultivation methods. To become more involved in the Araceae site, please register on http://araceae.e-monocot.org, or email me. If you would like to get involved with or find out more more about the project, please contact enquiries@e-monocot.org.

ACKNOWLEDGEMENTS

Thanks to all those who have contributed to this project, whether that be as an author of information, or giving time to add data to the site. Particular thanks to Tom Croat, Peter Boyce, Wong Sin Yeng, Greg Ruckert, Mark Naylor, Laura Reynolds, Marcela Mora, Lucinda Lay, Odile Weber, Joseph Bogner and Simon Mayo.

REFERENCES

A. Haigh, J. Bogner, P.C. Boyce, M.H. Grayum, C. Kostelac, Thomas B. Croat, A. Hay, W. Hetterscheid, R. Keating, L. Lay, S. J. Mayo, M. Mora, L. Reynolds, M. Sellaro, Wong Sin Yeng. (2008). A new website for Araceae taxonomy on www.cate-araceae.org. *Aroideana* 31: 148--154.

A Preliminary Analysis of *Anthurium* (Araceae) from Carchi Province, Ecuador

Thomas B. Croat
P.A. Schulze Curator of Botany
Missouri Botanical Garden
P.O. Box 299, St. Louis, MO 63166
Thomas.croat@mobot.org

Geneviève Ferry
Conservatoire et Jardins
Botaniques de Nancy
France

ABSTRACT

A preliminary survey of *Anthurium* (Araceae) Carchi Province, Ecuador is provided with a total of 146 named species, including seven taxa and 72 as yet unnamed species. More than 60% of all species are deemed to be new to science. The region is particularly rich in section *Cardiolonchium* (with 34 species and 2 taxa) and section *Calomystrium* with 29 species. Both are most abundant at middle to lower elevations. Section *Belolonchium* with 26 species is especially abundant at higher elevations. Even larger and found at middle to lower elevations is section *Polyneurium* (38 species), followed by section *Porphyrochitonium* (20 species) and section *Xialophyllium* (17 species), section *Tetraspermium* (6 species totaling 8 taxa); section *Digitinervium* (with 7 species), section *Multinervium* (with 12 species) and section *Decurrentia* (8 species).

KEY WORDS

Anthurium, sectional distribution, Araceae, Carchi, Ecuador.

INTRODUCTION

The Araceae is one of the larger families of flowering plants in the neotropics but remains the most poorly known taxonomically. Ecuador is one of the richest areas in the world for Araceae and the far northeastern corner of the country which abuts Colombia is replete with undescribed species. The region has been the subject of recent studies and this paper is the first report on the findings.

A total of four expeditions were made to the Department of Carchi, two of them funded by the National Geographic Society. The region has proven to be an area of high endemism. The far western areas of Ecuador are now much more well-known owing to these National Geographic sponsored studies in Carchi Province but some of the more remote areas are still poorly known. Many of the collections included in this report clearly appear to be new to science but are either sterile or incomplete and eventually must be recollected to be described.

The flora of Ecuador is one of the richest in the Neotropics. The Flora of Ecuador checklist (Croat, 1999) reported 404 published species of Araceae (many of which are still poorly known) but it is estimated that the total aroid flora contains about 1500 species and many areas contain a high percentage of endemic species with 60% or more of the species considered to be undescribed.

The Araceae is the most poorly known plant family in the Neotropics and is reknown for high species diversity and a large percentage of endemic species (Croat, 1971, 1991, 1992a, 1992b, 1994, 1997, 1998). Ecuador, which lies in the heart of the tropics on both sides of the equator is among the richest areas on earth for the study of Araceae (Croat, 1995). This study of the Araceae in Carchi Province will not only contribute to our understanding of the biogeography of Ecuador but will be a direct benefit to the completion of the Araceae treatment for the Flora of Ecuador.

History of Studies of Araceae in Carchi Province

The earliest collections from the region were made on an expedition by Dr. Michael Madison, Libby Besse and Tim Plowman, operating out of Selby Gardens in Sarasota, Florida. At that time a road went from Tulcán on the Colombian border through the Paramo del Angel to the village of Maldonado. Madison and his group walked on to the village of El Chical, located at 1200 m then on down in the lowlands, passing through Piedras Blancas, then San Marcos. Another expedition was carried out by Scott Hoover who also collected in the region, especially at Cerro Golandrias. By the time of Hoover's expedition the road had been completed to El Chical.

The senior author did not visit the area until 2004 when, after spending many years of working extensively in the Lita-San Lorenzo region, he made a trip with Geneviève Ferry to El Chical to compare the flora of that area with that of Lita-San Lorenzo. We expected to find few species in this region that were different from those found in the Lita-San Lorenzo area. It was surprising to found that we did not recognize many species in the region. Many of the species that were seen in the area have proven to be new. It was on this trip that we met Elisa Levy, a young local woman who had a great interest in plants. Elisa helped us collect plants and helped press plants. She went on to pursue a biology degree from the Universidad Catolica and has served as our Ecuadorian collaborator on the National Geographic Expeditions to the region.

A return trip to El Chical in February 2005 was made with Geneviève Ferry and Chris Davidson. On these first two trips the main road from Tulcán extended past El Chichal to Peñas Blancas which consisted of a single farm house but one that served as a stop-off point on the trek to the lower elevations and the many indigenous communities such as San Marco. It was the original home of Elisa Levy's mother who incidentally met and later married Peace Corps Volunteer, James Levy who was working with the indigenous communities of the Awa and frequently overnighted at the house while making many treks back and forth to Maldonado.

In those days another road led from near the Río El Chical where it departed the main El Chical to Peñas Blancas Road heading south in the direction of Gualchan. Road construction had begun but was abandoned owing to many landslides but it gave us access to wonderful forests.

In 2012 the National Geographic Society provided support for an extensive trip to the region and we again used El Chical as a base of operations, staying at the home of Elisa Levy's family. On this trip the crew included in addition to Tom Croat & Geneviève Ferry, David Scherberich from the Lyon Botanical Garden in Lyon, France, Claudia Henríquez from Washington University in St. Louis, Missouri and Elisa Levy. The region had recently been augmented by an additional road that extends from El Chical to La Virginia (El Limonal). This area had just been open to exploration and has proven to have many new species. As is true of all newly opened roads there is usually limited time to explore the region to collect the new species before the forest is decimated and turned into agricultural units. Already much of the area has been converted into pasture.

A final trip was made to the region in August 2013, this time with the support of two Colombian graduate students, Alejandro Zuluaga from the University of Wisconsin in Madison, Wisconsin and Natalia Castaño, from the Universidad Nacional in Bogotá, both specialists on Araceae.

Using El Chical as our base of operations allowed easy access to all parts of the region. El Chical is centrally located and provides a good drive to most localities approachable by road. This project has sampled Araceae in all accessible areas. While there are few roads in the western Carchi region, it benefits by being an area relatively narrow with a long road running throughout much of the region. The area between El Chical and Gualchan proved particularly rich in undescribed species. Collections were transported to Quito and dried at the Herbario Nacional in Quito (QCNE). Collections were field pressed and preserved in alcohol since drying facilities in the area do not exist. Herbarium collections, including duplicates of all numbers and all unicate collections were deposited at the National Herbarium of Ecuador (QCNE).

The number of species that have proven to be new in this very wet region is extremely high. For example the Lita-San Lorenzo region with over 250 species of Araceae has proven to have nearly one half of its species being new to science and the situation in the northern perimeter in the valley of the Río San Juan has proven to be equally species-rich. New access by road is also now available in the Río Baboso area near Lita which lies near the boundaries of both Imbabura and Esmeraldas Provinces.

Recent Field work in Carchi Province

The Maldonado-El Chical-Peñas Blancas region and the El Chical to La Virginia were extensively surveyed and the portions of southern Carchi Province near Lita were also studied owing to new access over the Río Mira near Lita. Collections were also made along a trail along the Río San Pedro south of El Chical and on the slopes of Cerro Obscuro. The region between Peñas Blancas and San Marcos on the south side of the Río San Juan has been much degraded but still has remnants of disturbed virgin forest. A provisional road now extends for a considerable distance into the lowlands but is frequently closed to vehicular traffic by landslides. Nevertheless our expedition was able to get down to as low as 600 m and find several very interesting areas of forest.

Results

A review of the collections of the Carchi Province has shown the region to be exceedingly rich for Araceae with a total of 395 species, 247 of which are now named. The remainder all appear to be distinct species but the collections are not yet determined. Some are sterile or are inadequate to serve as type specimens even though they mostly appear to be undescribed species. Seventy-four of the named species represent species which are new to science and most of the other collections without names probably will prove to be undescribed species. If this proves to be the case the total number of new species would be 146 species which would represent 44 percent of the total flora.

Anthurium, the subject of this present paper, is the largest genus in the flora with approximately 146 named species (including 7 taxa) and 72 unnamed species. The region is particularly rich in section *Cardiolonchium* (with 34 species and 2 taxa) and section *Calomystrium* with 29 species. Both are most abundant at middle to lower elevations. Section *Belolonchium* with 26 species is especially abundant at higher elevations. Even larger and found at middle to lower elevations is section *Polyneurium* (38 species), followed by section *Porphyrochitonium* (20 species) and section *Xialophyllium* (17 species), section *Tetraspermium* (6 species totaling 8 taxa); section *Digitinervium* (with 7 species), section *Multinervium* (with 12 species) and section *Decurrentia* (8 species).

More than 60% of all species are deemed to be new to science.

The Araceae of Carchi Province has proven to be exceedingly rich and in portions of the region, especially at elevations between Tobar Donoso near the border of Esmeraldas and the village of Maldonado but even at elevations up to more than 2500 meters, many new species have been discovered. It is clear that major investigations are required in adjacent areas of Nariño Department in Colombia where even fewer studies have been made.

ACKNOWLEDGMENTS

All of the expeditions to the Carchi region were funded by the National Geographic Society (NGS 9110–12) and the authors gratefully acknowledge this essential support. We also acknowledge the support of Dr. Christopher Davidson who paid for most of the expenses of the expedition to the region to Carchi in 2005.

REFERENCES

Croat, T. B. 1971. Summit Garden, Panama Canal Zone: its role in botanical research. *Taxon* 20: 769–772.

Croat, T. B. 1991. A revision of *Anthurium* section *Pachyneurium* (Araceae). *Ann. Missouri Bot. Gard.* 78: 539–855.

Croat, T. B. 1992a. Species diversity of Araceae in Colombia: a preliminary survey. *Ann. Missouri Bot. Gard.* 79: 17–28.

Croat, T. B. 1992b. (1994) Taxonomic status of neotropical Araceae. *Aroideana* 17: 33–60.

Croat, T. B. 1994(1995). Taxonomic status of neotropical Araceae. *Aroideana* 17: 33–60.

Croat, T. B. 1995. Floristic comparisons of six Ecuadorian florulas. Pp. 489–499. In: S. P. Churchill, H. Balslev, E. Forero, & J. Luteyn (eds.*), Biodiversity and Conservation of Neotropical Montane Forests.* New York Botanical Garden.

Croat, T. B. 1997. Revision for *Philodendron* of Mexico and Central America. *Ann. Bot. Missouri Bot. Gard.* 84(3): 311–704.

Croat, T. B. 1998. Tropical Aroids: Taxonomy, Diversity and Ecology, pp. 235–286. In: P. Mathew & M. Sivadasan, Eds. *Diversity and Taxonomy of Flowering Plants*. Mentor Books, Calicut.

Croat, T. B. 1999. Araceae. In: P. Jørgensen & S. Leon (Eds.), Catalogue of the vascular plants of Ecuador. *Monogr. Syst. Bot. Missouri Bot. Gard.* 75: 227–246.

Pollination mutualism between flower-breeding flies of the genus *Colocasiomyia* (Diptera, Drosophilidae) and their host plant routes of Araceae in Vietnam.

Masako Yafuso
1–2-21, Uema, Naha,
Okinawa 902–0073, Japan.
yafusom@juno.ocn.ne.jp

Bui Tuan Viet
Vietnam National Museum of Nature
18 Hoang Quoc Viet, Cau Giay, Hanoi.
btviet@iebr.vast.ac.vn

Shinichi Adaniya
Faculty of Agriculture, University of the Ryukyus, Nishihara,
Okinawa, 903–0213. Japan.
b986089@agr.u-ryukyu.ac.jp

ABSTRACT

Mutualistic co-evolution between host plant species of the family Araceae and species-specific pollinator flies of the genus *Colocasiomyia* (Diptera, Drosophilidae) was observed in wet, tropical to subtropical Southeast Asia. Complicated host-plant routes suggest the adaptive radiations in both *Colocasiomyia* species and Araceae species. Germination rates of pollen attaching to the pollinator flies were about 70%, while germination rate of collected pollen was often lower, which suggests that the *Colocasiomyia* flies contribute to the male reproductive success of their host plants.

KEY WORDS

Araceae, pollinator drosophilids, mutualistic co-evolution, host plant route, pollination germination

INTRODUCTION

The genus *Colocasiomyia* de Meijere, 1914 is a flower-breeding genus (Diptera, Drosophilidae), including 25 known and 65

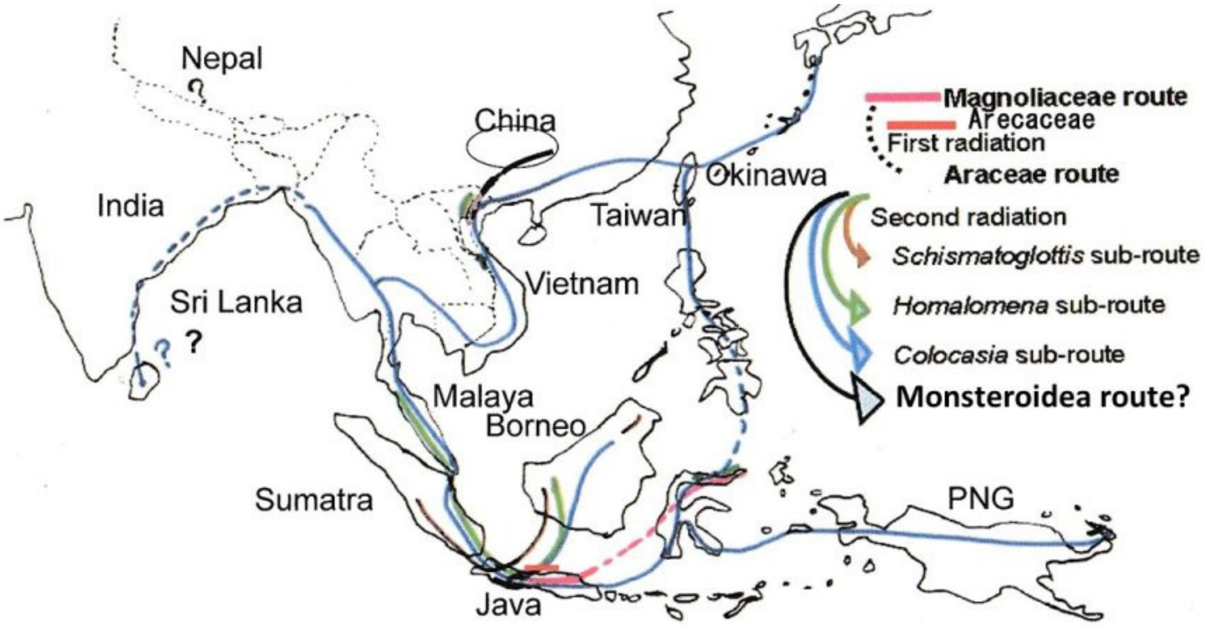


Fig. 1. Presumed process of radiation and complicated host plant-insect sub-routes of the genus *Colocasiomyia* on Araceae.

undescribed species (Fartyal et al., 2013), being distributed in the tropical to subtropical wet regions of Southeast Asia (e.g., Carson & Okada, 1980, Okada, 1975, Yafuso & Okada, 1990, Grimaldi, 2001, Fartyal et al., 2013). These species were divided into 6 phylogenetic species-groups using 70 morphological characters (Fartyal et al., 2013): *baechlii* species-group including 2 known and 28 unknown species; *cristata* species-group including 11 known and 21 unknown species; *toshiokai* species-group including 5 known and 4 unknown species; *gigantea* species-group (newly established with 2 new species by Fartyal et al., 2013); *crassipes* species-group including 2 known species; *zeylanica* species-group including 2 known and 5 unknown species.

Each species-group breeds exclusively on the species specific host inflorescences of Araceae (e. g., Carson & Okada, 1980; Okada, 1975; Yafuso & Okada, 1990; Mori & Okada, 2001; Sultana et al., 2002; Takenaka, et al., 2006; Fartyal et al., 2013). The distribution of *Colocasiomyia* in relation to their host plant species was named “host plant route” by Okada, 1986.

The *baechlii* species-group depends on *Schismatoglottis* sub-route of Araceae route; *cristata* species-group on *Colocasia* sub-route of Araceae; *toshiokai* species-group on *Homalomena* sub-route of Araceae; newly established *gigantea* species-group utilizes the host plant species of the subfamily Monsteroidea, Araceae, in very peculiar way (Fartyal et al., 2013). Then, we call the route as “Monsteroid route” for convenience in this paper; *crassipes* species-group from Magnoliaceae route; *zeylanica* species-group from Arecaceae route. The relationships

Schismatoglottis sp.

Fig. 2. *Schismatoglottis* and *Colocasia* sub-routes in Pu Mat. Photo by M. Yafuso. Feb. 2010.

between *Colocasiomyia* flies and their host plant species suggest the symbiotic, mutualistic co-evolution (Futuyma, 1986; Jermy, 1984). *Colocasiomyia* species contribute to female (seed set rate) reproductive success of their host plants as species-specific pollinators (Yafuso, 1993), without any damages to the host inflorescence. In turn, host plant species offer all of the necessary resources for pollinator flies such as breeding site and larval niche, in addition to the infallible clue of floral scent (Miyake & Yafuso, 2003, 2005) emanated from host inflorescences to attract *Colocasiomyia* flies to the female Stage II) or male phase (Stage III) of flowers. The mutualistic relationships between *Colocasiomyia* species and their host plant species are considered to be Type B or Type C of Jermy, 1984.

Hitherto, Magnoliaceae route, Arecaceae route and Araceae route, being made up of 4 sub-routes, were recorded in tropical and subtropical Southeast Asia. A new species-group, the *gigantea* species-group consisted of *gigantea* (Okada, 1987) and 2 new species described by Fartyal et al. 2013 under the name of *C. rhaphidophorae* Gao & Toda, 2013 and *C. scindapsae* Fartyal & Toda, 2013, was established based on the host plant data from Malaysia (Sabah) and China (Yunnan) (Fartyal, et al, 2013). Araceae route expanded all over Southeast Asia extending to the Ryukyu Archipelago (**Figure 1)**. Field survey in subtropical area, however, has been inadequately done.

In this paper, we (1) report the distribution of this genus in Vietnam with the records of their host plant routes, and (2) examine the pollen longevity and germination rate of

Fig. 3. *Colocsia* and *Homalomena* sub-routes in Cat Tien. A-C: *Colocasia gigantea*: A, plant; B, inflorescences in Stage III, IV; C, puparia and one adult fly just emerging. D: *Homalomena* sp. No fly emerged from inflorescence. E-F: *Alocasia* sp. Photo by Yafuso. December, 2004.

pollen attaching on the pollinator flies breeding in the inflorescences of *Alocasia odora* C. Koch to clarify the role of *Colocasiomyia* flies on the male reproductive success of androgynous aroid species.

MATERIALS AND METHODS

- The distribution data in Vietnam were obtained by the field survey from 1998 to 2011. Cat Tien: 27.XII.2004–4.I.2005; Da Lat: 5–6.I.2005; Tay Ninh; 30–31.III.2000; Ba Na; 18–29.VII.2005; Pu Mat: 29.IX-6.X.2007, 21–28.II.2010; Cuc Phuong; 7–10.XI.1998, 2–5.IV, 18–29.VI.2000; 7–10.VI.2002; 10–12.IX.2003; 24–25.VI.2005; 21–26.III, 18–24.VI.2006; Hoa Binh: 10–11.XI.1998; 4–6.VI.2000; Ba Vi: 6–7.IV.2000, 19–28.III.2005, 14–23.II.2009, 2–7.III.2011; Tam Dao: 12–13.XI.1998, 30.XII.2006–1.I.2007, 8–10.III.2011; Ba Be: 24–29.XII.2006; Sa Pa: 10–11.XI.1998, 31.V-3.VI.2000.

- Experiments were carried out under the laboratory conditions (25.8±0.2 ℃) in the University of the Ryukyus. RHs were measured by Thermo Recorder (T&R Co., Japan). To examine the RH in inflorescence, inflorescence of *Alocasia odora* in the developing stage II (Yafuso, 1983, Takenaka et al., 2005) was used. Medium constitution for pollen development was as follows: sucrose 50g/L, boric acid 50mg/L, agar 10g/L. All collections of inflorescences and pollinator flies were made on the campus of the

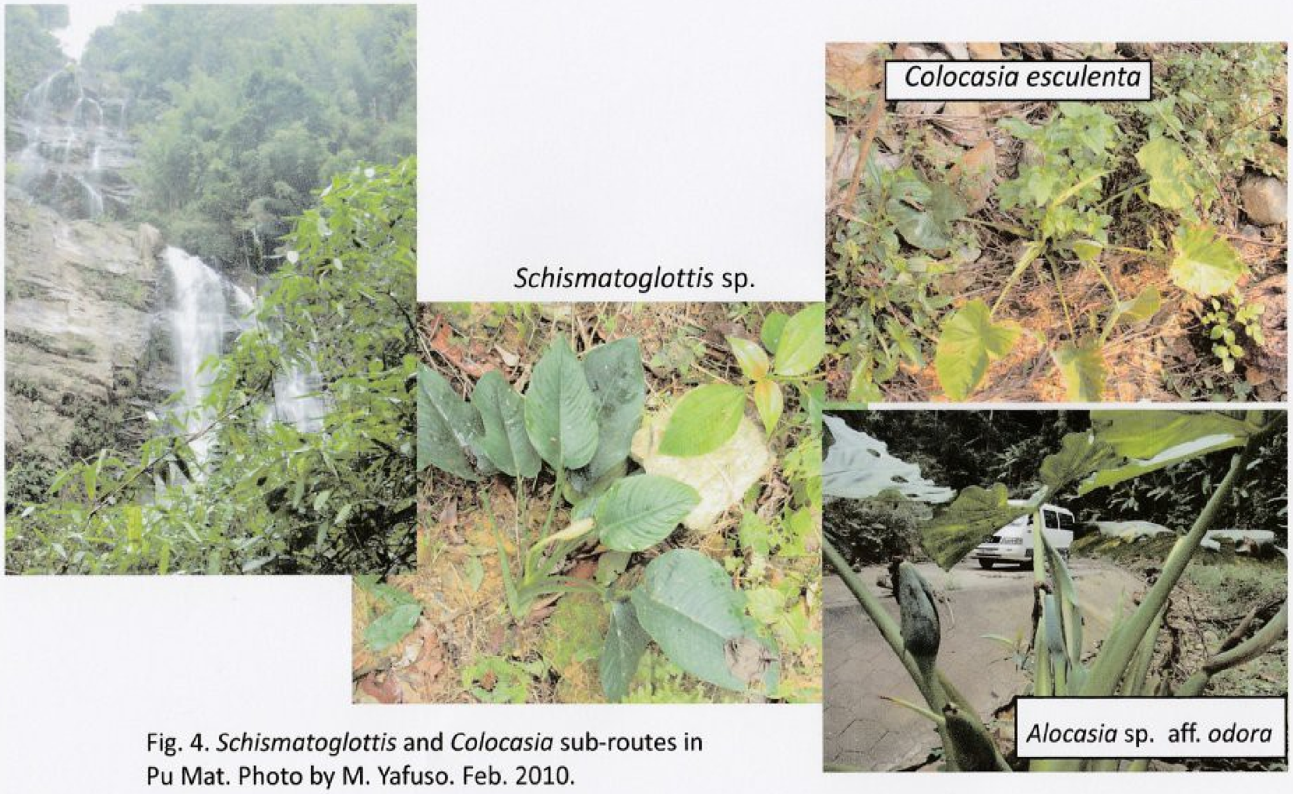


Fig. 4. *Schismatoglottis* and *Colocasia* sub-routes in Pu Mat. Photo by M. Yafuso. Feb. 2010.

Alocasia atropurpurea. Stage III. April, 2000. Identified by Dr. M. Hotta.

Colocasia indica? July, 2006.

Homalomena sp. July, 2006.

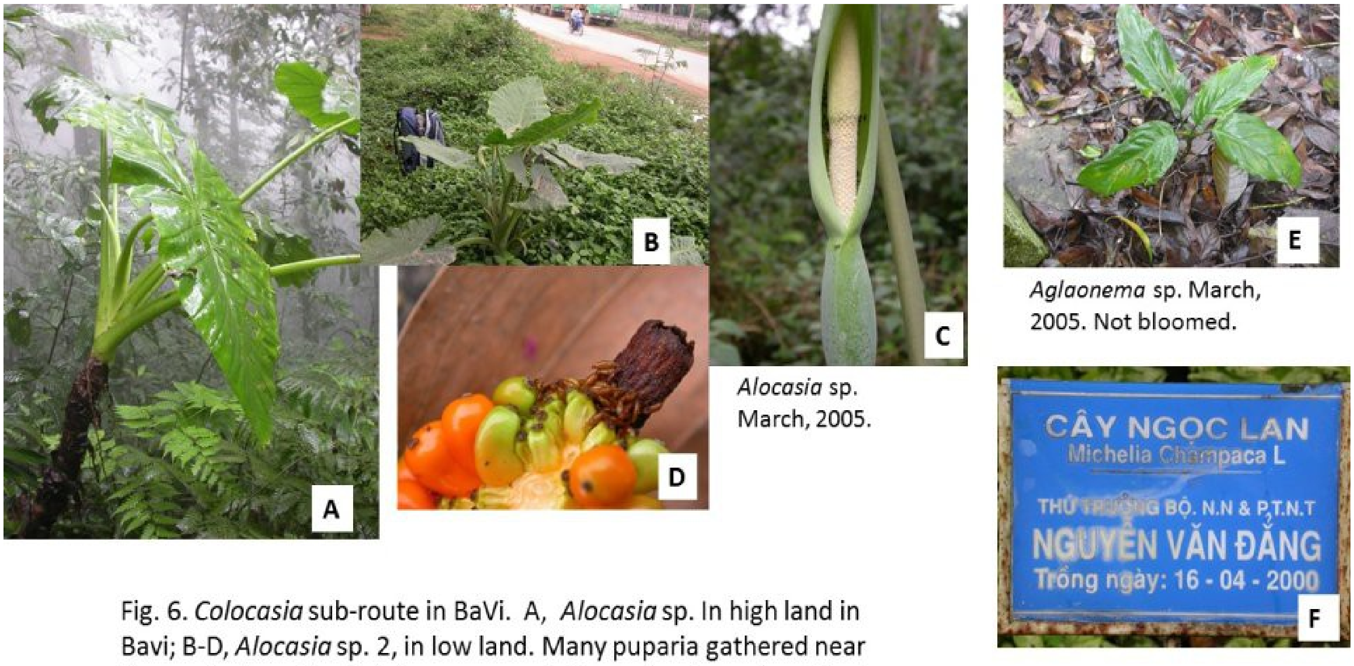
Steudnera cf. *discolor* April, 2000. Id. by Dr. M. Hotta.

Fig. 5. *Colocasia and Homalomena* sub-routes in Cuc Phuong. Steudnera cf. *discolor* bloomed. But no *Colocasiomyia* fly was collected. Photo by M. Yafuso.

Table 1. *Colocasiomyia* species collected in the host inflorescences in Vietnam (1998–2011).

Locality	Host plant species	*Colocasiomyia* species
Tay Ninh	*Colocasia esculenta*	*diconina* *
Cat Tien	*Alocasia* sp.	3 spp.
	Alocasia sp. (near *odora*?)	1 sp.
	Colocasia gigantea	3 spp.
DaLat	*Alocasia* sp. (near *odora*?)	1 sp.
Ba Na	*Alocasia* spp.	4 spp.
	Colocasia sp.	1 sp. (*steudnera*? *)
Pu Mat	*Alocasia* sp. (near *odora*?)	*alocasiae**
		*xenalocasiae**
		1 sp.
	Colocasia esculenta	*alocasiae**
		*xenalocasiae**
		*steudnera**
		2 spp.
	Schismatoglottis sp.	1 sp.
Hoa Binh	*Colocasia gigantea*	*alocasiae* *
		*xenalocasiae**
		*steudnera**
		1 sp.?
Cuc Phuong	*Alocasia atropurpurea*	*alocasiae*
		xenalocasiae
		sp. 1 aff. *iskandari**
		sp. 2 aff. *diconica* *
	Alocasia odora?	*alocasiae**
		*xenalocasiae**
	Colocasia indica?	*alocasiae**
		*xenalocasiae**
	Homalomena sp.	*erythrocephala*
Ba Bi	*Alocasia odora*?	*alocasiae**
		xenalocasiae?*
Ba Be	*Alocasia* spp.	*alocasiae**
		*xenalocasiae**

(*: identified by M. J. Toda, Hokkaido University).



Aglaonema sp. March, 2005. Not bloomed.

Alocasia sp. March, 2005.

Fig. 6. *Colocasia* sub-route in BaVi. A, *Alocasia* sp. In high land in Bavi; B-D, *Alocasia* sp. 2, in low land. Many puparia gathered near the neck of spadix. E, *Aglaonema* sp. Is the understory, clonal herb in the forest. F, *Michelia champaca*. Tall tree. No bloomed. Photo by M. Yafuso.

University of the Ryukyus, Nishihara, Okinawa I., Japan.

Ex. I. Pollen longevity. Fresh pollen of *Alocasia odora* were collected from 3 inflorescences in the male stage (Stage III, Takenaka et al., 2005) and mixed in a petri dish and stored for 5 days in room conditions tightly closed in a plastic bag. Pollen was scattered on the medium day by day for following 5 days. After one day incubation, the number of pollen producing the pollen tube was counted under the binocular microscope.

Ex. II. Germination rate. Adult flies of *Colocasiomyia alocasiae* (Okada, 1975) and *C. xenalocasiae* (Okada, 1980) were collected from inflorescences in Stage III (male phase) of *A. odora*. After being anesthetized with a mosquito coil, 15–20 flies were put on a slide glass covered with agar medium. Pollen attaching on fly bodies was scattered on the medium by drawing slowly the bodies one by one with forceps under the binocular microscope. After one day incubation, the number of pollen producing the pollen tube was counted.

RESULTS AND DISCUSSION

- Distribution of the genus *Colocasiomyia* and their host plant routes in Vietnam.

Collecting data is shown in Table 1. In Tay Nihn, *C. diconica* (Toda & Okada, 1983) which belongs to the *cristata* species-group of *Colocasiomyia* obtained from inflorescence of *Colocasia esculenta* L. In Cat Tien

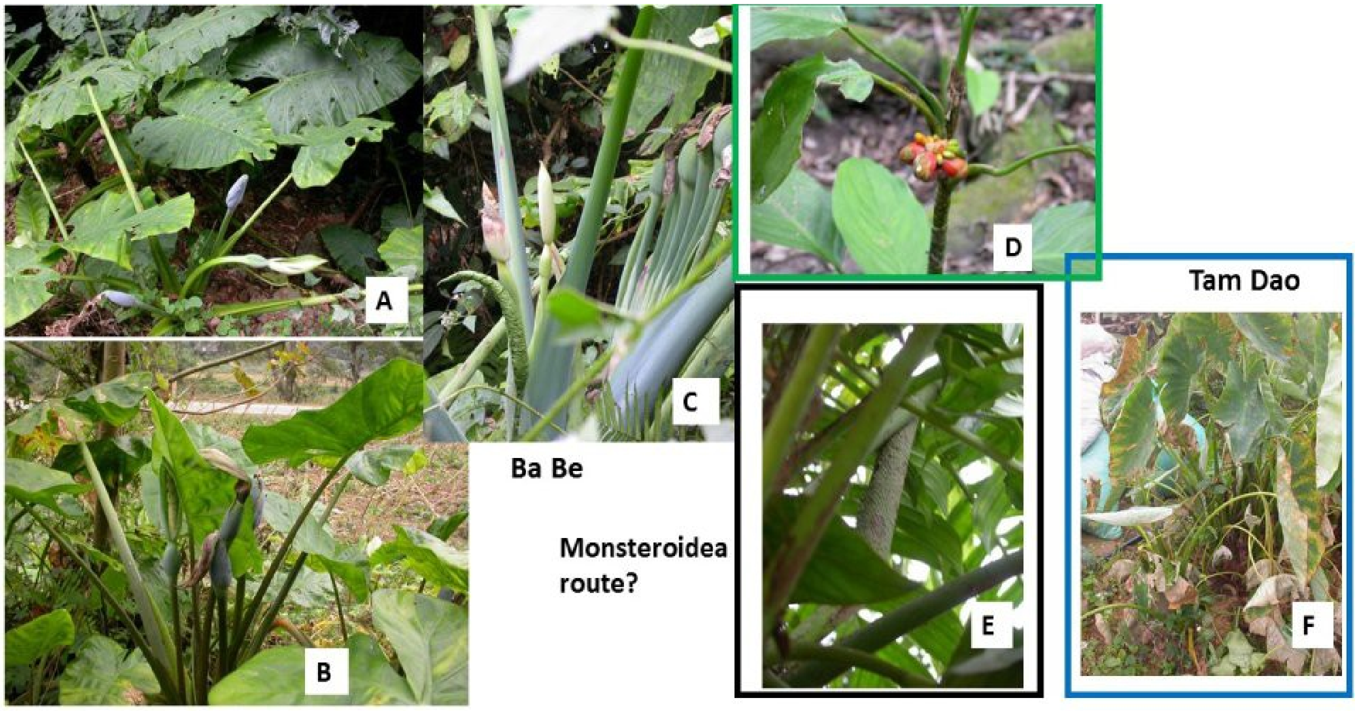
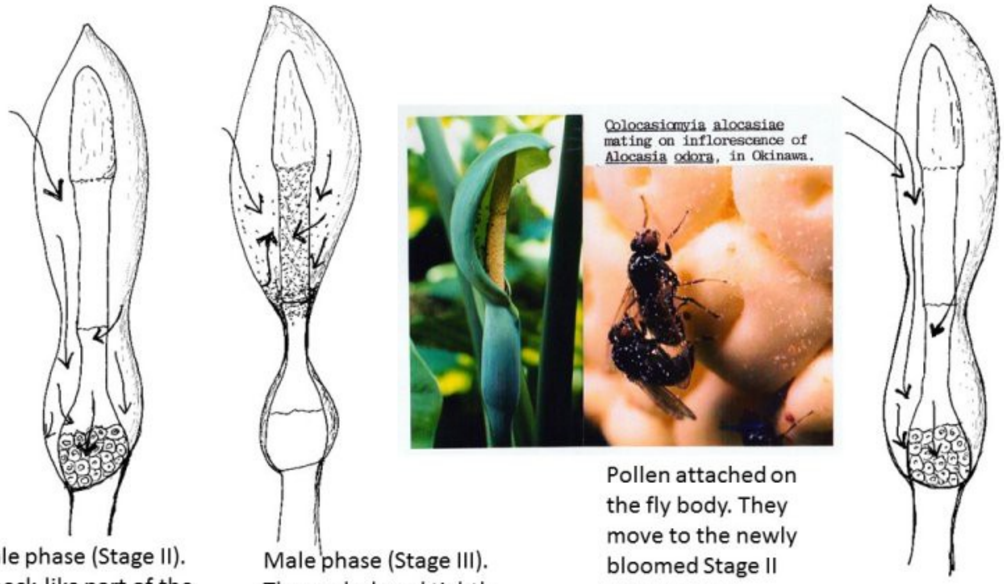


Fig. 7. *Colocasia* sub-route in Ba Be: A, *Alocasia* sp.; B, *Alocasia* sp. 2; C: *Gigantea indica*?; D, *Agraonema* sp.; E, Monstroidea route?. F, *Colocasia esculenta* in Tam Dao. Photo by M. Yafuso.

(**Figure 2)**, 3 species from *Alocasia* sp. and also 3 species from *Colocasia gigantea* (Blume) Hook, of which one species was common with the species obtained from *Alocasia* sp. Although *Homalonema* sp. had old inflorescences of Stage IV, no flies emerged. In Da Lat, one species of *cristata* species-group was collected from *Alocasia* sp. In Ba Na (**Figure 3)**, one species of *cristata* species-group harbored in the inflorescences of *Colocasia* sp. (cultivar?). Another four species of *cristata* species-group were collected from *Alocasia* sp. There was a big tree of *Michelia faveolata* (Magnoliaceae) on the top of the mountain, no flower was seen. Pu Mat was a mountainous area with big water falls and rivers (**Figure 4)**. Along the river, there were *Schismatoglottis* plants with some inflorescences in Stage IV. One species belonging to the *baechlii* species-group was obtained. The two known species, *alocasiae* (Okada, 1975) and *xenalocasiae* (Okada, 1980), and one unknown species belonging to the *cristata* species-group were collected from *Alocasia* sp. Three known species, *alocasiae, xenalocasiae* and *steudnerae* Takenaka & Toda, 2006, were collected from *Colocasia esculenta* together with other two unknown species of the *cristata* species-group.

In Hoa Binh, *Colocasia gigantea* was popular in the area occupied by human beings. Three known species, *alocasiae, xenalocasiae* and *steudnerae*, were also collected from *Colocasia gigantea*. Cuc Phuong Nation, Park is one of the famous biodiversity hotspots in the country (see, "Seed plants of Cuc Phuong National Park, Vietnam", Soejarto et al., 2004). Cuc Phuong (**Figure 5)** had a



Female phase (Stage II). The neck-like part of the spathe is open and flies easily come in the lower female part.

Male phase (Stage III). The neck closed tightly. Flies gather in the shadow part altogether.

Pollen attached on the fly body. They move to the newly bloomed Stage II inflorescence.

Fig. 8. Pollen flow from male phase (Stage III) inflorescence to female phase (Stage II) inflorescence.

number of *Alocasia* plants along the forest path. The synhospitalic (Eichler, 1966; Okada, 1980) pair of *alocasiae* and *xenalocasiae* were found in the host inflorescences of *Alocasia atropurpurea* Engler (identified by Dr. M. Hotta) and two unknown species were collected. All of them belong to *cristata* species-group. From *A. odora*-like plant species growing in the human being area, the same species-pair of *alocasiae* and *xenalocasiae* were collected together. *Colocasia indica* planted in the National Park Garden produced the pair of *alocasiae* and *xenalocasiae*. *Homalomena* sp. grows along the road in the National Park, from which *C. erythrocephala* Sultana & Yafuso was collected (Sultana et al., 2002). This was the first record of the *toshiokai* species-group from Vietnam. In other word, *Homalomena* sub-route of the host plant species of *Colocasiomyia* was recognized in Cuc Phuong. *Steudnera colocasiifolia* C. Koch (identified by Dr. M. Hotta) in the National Park Garden bloomed, but *C. steudnerae* Takenaka & Toda, 2006 was absent. In BaVi (Fug. 6), where the colonial summer resort of France was, *Alocasia odora*-like species grow up from low land to higher, cool area. The pair of *alocasiae* and xenalocasiae? was collected. *Aglaonema* sp. was also found in the forest, but not blooming. *Michelia champaca* might have been planted from somewhere, from which no flower was found. In Tam Dao (**Figure 7)**, some *Colocasia esculenta* were seen along the road without inflorescences when we visited. Plants of *Alocasia* sp. were few in the high land. Only one inflorescence in Stage II was found, but no fly was there. In Ba Be (**Figure 7)**, there were many *Alocasia* sp. plants in low land. The known species-pair of a*locasiae* and *xenalocasiae* were collected

Cross-pollination (open)

Fig. 9 . Female RS of *Alocasia odora* in Okinawa.

Self-pollination (bagged)

from *Alocasia* species. *Colocasia indica* was also found in human occupied area, but *Colocasiomyia* flies were not collected.

As a result, three complicated sub-routes of Araceae route were confirmed in Vietnam (**Figure 1**): *Schismatoglottis* sub-route and *Colocasia* sub-route in Pu Mat; *Colocasia* sub-route in almost all localities examined here except Sa Pa and Tam Dao where the plants of host species were distributed but not blooming; *Homalomena* route in Cuc Phuong. Hitherto, the *gigantea* species-group (Fartyal et al., 2013) has not been collected in Vietnam, in spite of *Colocasia gigantea* blooming in Cat Tien, Cuc Phuong and Hoa Binh.

The *crassipes* species-group associated with inflorescences of Magnoliaceae was not obtained, although *Michelia champaca* was distributed in Cuc Phuong and *M. faveorata* in Ba Vi and another flowering species of Magnoliaceae was found in Pu Mat.

The *zeylanica* species-group breeding in inflorescences of Arecaceae were not collected. One of authors had a chance to examine inflorescences of coconut palm, Arecaceae in Tay Ninh in South Vietnam, no fly was there.

- Pollen longevity of *Alocasia odora*.

Adult flies of *C. alocasiae* and *C. xenalocasiae* visit on the female phase inflorescences of their host plant of *Alocasia odora,* attracted by the peculiar odor emanated from the host inflorescence (Miyake & Yafuso, 2003, 2005), and stay there for the following 2–4 days until male phase starts and scatters the

Table 2. Pollen longevity of *Alocasia odora* in room conditions. May 25–30, 2013. Okinawa I., Japan.

RH in plastic bug (%)	n	Duration of pollen storage (day)				
		1d	2d	3g	4d	5d
85–86	8	57.9a	45.8ab	26.4abc	22.1b	4.8c
89–98	8	44.6a'	16.0a'b'	10.3a'b'	7.4b'c'	3.9c'

(Scheffe's test at the level of 99%)

Table 3. Germination rate of pollen of *Alocasia odora* attaching on pollinator flies of *Colocasiomyia alocasiae* and *C. xenalocasiae*. May 28–29, 2013.

RH in plastic bug (%)	n	
85–86	8	71.4a
89–98	8	39.0b
89–98	8	41.1b

(Scheffe's test at the level of 99%)

pollen from male part of the flower (**Figure 8,** left). Flies with pollen on the body (**Figure 8,** middle) move to the other newly opened female phase flowers (**Figure 8,** right). Pollination is performed between different inflorescences. The seed set rate between cross-pollination was 71.6±19.0%, while self-pollination produced significantly lower seed rate of 12.4±13.4% (Mann-Whitney U test, $p<0.01$) (Yafuso, 1993). The *Colocasiomyia* flies contribute to the female reproductive success of their host plant species (**Figure 9)**.

Then, how do they contribute to the male reproductive success of their host inflorescences as pollen carriers?

Pollen longevity in a petri dish was shown in Table 2. One day after releasing, the germination rate was about 50% or so, then decreased rapidly to almost 3–4% after 5 days. In contrast, germination rate of pollen attaching on the pollinator flies was 71.3±9.15% (n=8) under about 85%RH in the room (Table 3). It indicates that the pollinator flies bring the live pollen to the different female phase inflorescences, in spite of staying for 2–4 days in a male phase flower. Because male flowers release fresh pollen day by day after the start of the male phase, flies can bring enough fresh pollen on their bodies when they leave the inflorescence to move to the following young inflorescence in Stage II.

CONCLUSION

- Three complicated sub-routes of Araceae were confirmed in Vietnam. Monsteroid route of the family Araceae, Magnoliaceae route and Arecaceae route still need to be investigated.

- *Colocasiomyia* flies contribute not only female reproductive success but also to the male reproductive success of host flowers. The unique morphology of the spathe of Araceae may be effective in keeping high humidity in the inflorescences for pollen germination.

ACKNOWLEDGEMENTS

We thank Dr. Masanori J. Toda, emeritus Professor of Hokkaido University for his great help in identification of specimens. this work was funded by a Grant-in-Aid from the Ministry of Education, Science, Sports and Culture, Japan (No. 15255006 and No. 19405013).

REFERENCES

Carson, H.L. & T. Okada. 1980. Drosophilidae associated with flowers in Papua New Guinea. I. *Colocasia esculenta*. *Kontyu* 48: 15–29.

Eichler, W. 1966. Two new evolutionary terms for speciation in parasitic animals. *System. Zool.* 15: 216–218.

Fartyal, R.S., J.-J. Gao, M.J. Toda, Y.-G. Hu, T.K. Takano, A. Suwito, T. Katoh,

T.Takigahira & J.-T. Yin. 2013. *Colocasiomyia* (Diptera: Drosophilidae) revised phylogenetically, with a new species-group having peculiar lifecycles on Monsteroid (Araceae) host plants. *System. Entomol.* 28: 763–782.

Grimaldi, D.A. 1991. Systematics of the genus *Colocasiomyia* de Meijere (Diptera: Drosophilidae): cladistics, a new generic synonym, new record, and a new species from Nepal. *Entom. Scand.* 22: 417–426.

Jermy, T. 1984. Evolution of insect/host plant relationships. *Amer. Nat.* 124: 609–631.

Miyake, T. & M. Yafuso 2003. Floral scent affects reproductive success in fly-pollinated *Alocasia odora* (Araceae). *Am. J. Bot.* 90(3): 370–376.

Miyake, T & M, Yafuso. 2005. Pollination of *Alocasia* c*ucullata* (Araceae) by two *Colocasiomyia* flies known to be specific pollinators for A*locasia odora*. *Pl. Species Biol.* 20: 201–208.

Mori, Y. & H. Okada. 2001. Reproductive biology and pollen flow of a rheophytic aroid, *Furtadoa sumatrensis* (Araceae) in the Malesian wet tropics. *Pl. System. Evol,,* 227: 37–47.

Okada, T. 1975. The oriental drosophilids breeding in flowers. *Kontyu.* 43: 356–363.

Okada, T. 1980. Systematic evolution of the genus *Drosophilella* Duda (Diptera, Drosophilidae), with description of a new species from Okinawa and Taiwan. *Kontyu* 48: 218–225.

Okada, T. 1986. Estimation of the routes of synhospitalic distribution of the genus Drosophilella (Diptera, drosophilidae). *Proc. Japanese Soc. System. Zool.* 33: 32–39

Soejarto, D.D., N.T. Hiep, P.K. Loc, N.M. Cuong, L.K. Bien, T.D. Dai, J. Regalado, M.R. Kadushin, N.T.T. Huong & T.Q. Bich. 2004. *Seed Plants of cuc Phuong National Park, Vietnam. A documented checklist.* Agriculture Publishing House, Ha Noi, Vietnam. pp. 54–63.

Sultana, F., Y.-G. Hu, M.J. Toda, K. Takenaka & M. Yafuso. 2006. Phylogeny and classification of *Colocasiomyia* (Diptera, Drosophilidae), and its evolution of pollination mutualism with aroid plants. *Syst. Entomol.* 31: 684–702.

Takenaka, K., J.T. Yin, S.Y. Wen & M.J. Toda. 2006. Pollination mutualism between a new species-group of the genus *Colocasiomyia* de Meijere (Diptera, Drosophilidae) and *Steudnera colocasifolia* (Araceae) in Yunnan, China. *Entomol. Science* 9: 79–91.

Yafuso, M. 1993. Thermogenesis of *Alocasia* o*dora* (Araceae) and the role of *Colocasiomyia* flies (Diptera, Drosophilidae) as cross-pollinators. *Environ. Entom.* 22: 601–606.

Yafuso, M. & T. Okada. 1990. Complicated routes of the synhospitalic pairs of the genus C*olocasiomyia* in Java, with descriptions of two new species (Diptera, Drosophilidae). *Esakia*, Special Issue. 1: 137–150.

Testing the monophyly of *Spathiphyllum*, and the relationship between Asian and tropical American species.

Alejandro Zuluaga and Kenneth Cameron
Department of Botany
University of Wisconsin-Madison,
Madison, WI 53706

Thomas Croat
P. A. Schulze Curator of Botany
Missouri Botanical Garden
P.O. Box 299, St. Louis, MO 63166

Melanie Medecilo
Biological Sciences Department,
De La Salle University-Dasmarinas
Cavite, Phillipines

ABSTRACT

As part of a broader phylogenetic study of the subfamily Monsteroideae we used three plastid and one nuclear markers to test the monophyly of the genus *Spathiphyllum*. Our results support the tribe Spathiphylleae as sister of the remaining Monsteroideae, and the monophyly of *Spathiphyllum*. The monotypic genus *Holochlamys* appears nested within *Spathiphyllum* in a clade with the Asian species and *S. cannifolium*. However, support for this clade is low. The section *Spathiphyllum* shows a high support and is sister to the remaining species in the genus. As a consequence *Spathiphyllum* remains as the only disjunct aroid genus between the Old and New World Tropics.

INTRODUCTION

With the increased application of molecular data for phylogenetic analysis, the understanding of relationships within Araceae has been improved considerably (Cabrera, 2008, Cusimano, 2011, Henríquez, 2014). Additionally, new fossils and biogeographical studies have helped to elucidate the historical and current geographic distribution patterns in the family (Nauheimer, 2012a). As a result, aroid classification has changed dramatically; several genera have been resurrected; and new genera have been created (Cabrera, 2008, Cusimano, 2011). Nevertheless, many critical issues are still in need of more data.

Before this molecular era there were thought to be three geographically disjunct genera between the old world and new world tropics. Species in the genera *Homalomena*, *Schismatoglottis* and *Spathiphyllum* were found in both tropical America and tropical Asia, particularly within the Malay Archipelago and Melanesia (van Steenis, 1962, Grayum, 1990, Mayo et al., 1997). However, recent studies (Barabé, 2002, Gauthier, 2008, Wong et al., 2013) have shown evidence challenging the monophyly of disjunct *Schismatoglottis* and *Homalomena* (they are no longer disjunct in their revised circumscriptions), leaving *Spathiphyllum* as the only remaining aroid genus with a tropical disjunction.

The genus *Schismatoglottis*, with only three species in South America, and about 150 in tropical Asia, belongs to the tribe Schismatoglottidae that in its current circumscription comprises 11 genera. Several of these genera are small groups recognized thanks to molecular data (Wong et al., 2010a, 2010b, Low, 2014). The three Neotropical species previously recognized in *Schismattoglotis* are now in the resurrected genus *Philonotion* (Wong, 2010c) that belong to its own tribe Philonotieae. Equally, the genus *Homalomena* is considerable more diverse in Tropical Asia with about 500 species, versus only 10 species in Tropical America (Boyce & Croat, 2013). Unlike *Schismatoglottis*, molecular evidence for the separation of Neotropical *Homalomena* is not conclusive (Barabé, 2002, Gauthier, 2008, Wong et al., 2013). The most plausible options for the assignment of the Neotropical *Homalomena* would be the resurrection of the genus *Adelomena,* or the combination of these species of *Homalomena* with *Philodendron* subgenus *Pterosmischum* in the genus *Elopium* (Wong et al., 2013). Thus, more extensive sampling and more molecular data are necessary to fully understand the relationships among *Homalomena*, and the subgenera of *Philodendron*.

Finally, we have the genus *Spathiphyllum,* which has a different distribution pattern. The genus is more diverse in Tropical America with about 50 species (Cardona, 2004), and only three species in Southeast Asia. *Spathiphyllum commutatum* Schott is widespread in Malesia and reaches Micronesia; *S. solomonense* Nicolson is restricted to the Solomon Islands; and *S. schlechteri* (Engl. & K.Krause) Nicolson is restricted to New Guinea. Neotropical species are concentrated in the northern Andes, with only a few species reaching Central America and Mexico (Cardona, 2004), and one species, *S. leave* reaches Cocos Island in the Pacific Ocean west of Costa Rica. No comprehensive phylogenetic studies, until now, have included more than three *Spathiphyllum* from Tropical America, or any of the Asian species.

Spathiphyllum together with *Holochlamys becarii* form the tribe Spathiphylleae in the subfamily Monsteroideae (Cabrera, 2008, Cusimano, 2011). The relationships of the tribe Spathiphylleae within Monsteroideae have been controversial, but recent studies strongly support Spathiphylleae as sister to the remaining Monsteroideae (Chartier, 2014, Henriquez, 2014). These two genera are very similar morphologically and ecologically, differing mainly in a few characteristics of the flowers. Whereas *Spathiphyllum* species have two to three locules and ovules with axillar placentation, *Holochamys* has one locule and ovules with basal placentation (Bunting, 1960, Mayoet al.,1997). Nevertheless, anatomical studies suggest that the *Holochlamys* ovary could actually have two locules, and the placentation may not be basal (Eyde, 1967, Carvell,1989).

Currently, *Spathiphyllum* is divided into four sections based the fusion of the perianth segments, the form and length of the pistils relative to the perianth, and the attachment the spathe to the peduncle (Bunting, 1960). Asian species together with *S. cannifolium* and *S. leave* form the section *Massowia,* which is recognized by having the perianth segments completely connate forming a cup around the pistil. This trait led Bunting (1960) to propose the monophyly of this group. However, Williams & Dressler (1967) and Grayum (1984, 1990) suggested this could be an artificial group with *Holochlamys* nested within it. Sections *Amomophyllum, Dysspathiphyllum*, *and Spathiphyllum* have free perianth segments.

As part of a broader systematic study of the subfamily Monsteroideae (Zuluaga, unpublished data) we tested the monophyly of *Spathiphyllum* and *Holochlamys,* and investigated the relationships of the Asian and American species of *Spathiphyllum*.

METHODS

Taxon Sampling and DNA sequencing. During the sampling for the study of systematics of the subfamily Monsteroideae we sequenced a total of seven accessions of the genus *Spathiphyllum* from Tropical America, *S. commutatum* and *S. solomonense* from Tropical Asia, and one accession of *Holochlamys becarii*. Additional sequences for *S. phryniifolium* were obtained from GENBANK. For this study we used representatives from all ten additional Monsteroideae genera, plus six other aroids as outgroups.

DNA was extracted from silica-dried plant material using the DNeasy Plant Mini Kit (Qiagen, Valencia, CA, USA) according to the manufacturer's specifications. Some samples were extracted using a CTAB method adapted from Doyle & Doyle (1987). We sequenced four plastid markers, *matK*, *rbcL*, *trnC-petN* spacer, and partial *ycf1*. PCR products were purified using ExoSap-It (Cleveland, OH). Sequencing reactions used the BigDye Terminator Cycle Sequencing Kit, and cleaned using Agencourt CleanSeq (Beverly, MA) magnetic beads. BigDye Terminator Cycle Sequencing Ready Reaction Kit (Applied Biosystems, Foster City, CA, USA). Samples were sequenced using PE-Biosystems version3.7 of Sequencing Analysis at the University Wisconsin–Madison Biotechnology Center.

Molecular analysis. All sequences were manually edited in Geneious6.0 (Biomatters, http://www.geneious.com). Sequences were aligned in Geneious6.0 using a combination of Muscle (Edgar 2004) and MAFFT (Katoh 2002). Finally, all alignments were checked manually. We performed individual and combined phylogenetic analyses. Analyses for each marker/dataset were performed under Maximum Likelihood using RaxML 7.0 (Statamakis, 2006), and MrBayes 3.1.2 on XSEDE, as implemented in the CIPRES portal. For RaxML, we used the GTRGAMMA model in all cases. For Bayesian analysis models were calculated using Jmodeltest2 (Darriba, 2012).

RESULTS.

So far at least one of the four molecular markers has been successfully sequenced for *S. cannifolium* (two accessions), *S cochlearispathum*, *S. commutatum*, *S. floribundum*, *S. minor*, *S. patulinervum, S. solomonense, S. wallisii*, and *Holochlamys becarii*. Only the *trnC-petN* spacer was sequenced for the Asian *Spathiphyllum*. The combined alignment length is 4970 bp with 36% missing data. Despite using four molecular markers the identical sites between pairs of species within *Spathiphyllum* is more than 97%. This low variation is common within the genera of the subfamily Monsteroideae (Unpublished data).

Trees derived from individual gene analyses are congruent, however the resolution is low except for a clade comprising the species of the section *Spathiphyllum*. Thus, a combined gene analysis is presented (**Figure 1)**. All individual and combined analyses show the tribe Spathiphylleae as monophyletic and sister to the remaining Monsteroideae, thus supporting the topology presented by Chartier (2014) and Henríquez (2014). Section *Spathiphyllum* represented by *S. cochlearispathum*, *S. phryniifolium*, and *S. wallisii* shows strong support, and is sister to the remaining Spathiphylleae. The genus *Holochlamys* appears nested within *Spathiphyllum* in a clade with the Asian species and one accession of *S. cannifolium* (section *Massowia*). Section *Amomophyllum* (*S. minor*, *S. floribundum*, *S. patulinervum*) and one accession of *S. cannifolium* are sister to the clade containing *Holochlamys*. However support for the last two clades is low (Figure1).

DISCUSSION.

A monophyletic tribe Spathiphylleae has been supported since the first molecular studies in Araceae, based on only a few genes, were published (Tam, 2004, Cabrera, 2008). However, the position of Spathiphyllleae as sister to rest of Monsteroideae is only recovered in the most recent studies with more data included

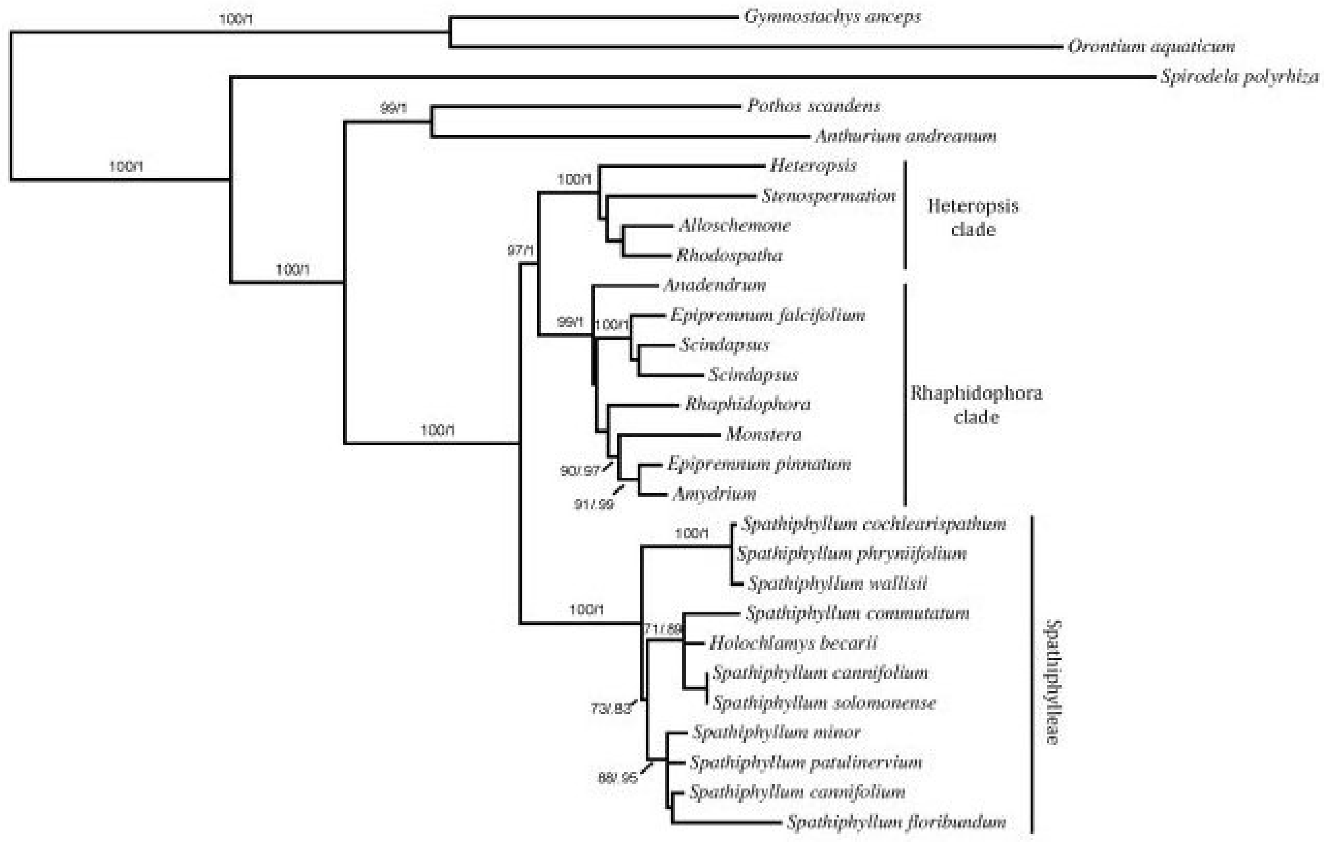


Figure 1. Maximum likelihood tree from RaxML using four plastid markers (*matK*, *rbcL,* *trnC-petN*spacer, and partial *ycf1*). Bootstrap supports >75 and Bayesian posterior probabilities >0.85 are shown on the branches.

(Chartier, 2014, Henriquez, 2014). Our results strongly support this topology (**Figure 1)**. Most of the synapomorphies defining Monsteroideae as presented in Cusimano (2011) seem to be more appropriate to be assigned to the clade containing all Monsteroideae but Spathiphylleae. These synapomorphies and the alternative characters in Spathiphylleae are: pollen zonate (ring-like) (vs. pollen multiaperturate with exine surface striate/polyplicate); spathe soon deciduous with a distinct basal abscission (vs. Spathe marcescent), large trichosclereids not in bundles (vs. smaller trichosclereids in bundles). The only synapomorphy remaining for Monsteroideae is the presence of trichosclereids.

Within the tribe Spathiphylleae, the support for the position of *H. becarii* is not conclusive, but some markers suggest this species may belong to the genus *Spathiphyllum*. *Holochlamys* appears consistently embedded in a clade with section *Massowia*. These two genera are very similar in habit and morphology (Bunting,1960), stem vasculature (French & Tomlison, 1981), palynological features (Grayum,1992), and floral anatomy (Carvell, 1989). Moreover, *Holochlamys* shares with section *Massowia* the presence of fused perianth parts forming a cup around the pistil (Bunting, 1960, Carvell, 1989). The proposed differences between these two genera - a unilocular ovary, and ovules with basal placentation - have been challenged by more detailed anatomical studies (Eyde, 1967). Carvell (1989) undertook a very detailed anatomical study of Monsteroideae and Pothoideae, and reported unilocular ovaries, and basal ovules for *H. becarii*. However, he also reported the presence of an incomplete septum in several flowers, and the attachment of some the ovules to that septum. Additionally, Carvell (1989) found considerable intra- and interspecific variation in locule, ovules, tepals, and stamen numbers in *Spathiphyllum*. Despite the fact that we consider there to be no strong morphological evidence to separate *Holochlamys* from *Spathiphyllum* (especially from the section *Massowia*), our analysis currently lacks adequate resolution within this clade, and so we prefer to be cautious at this point in time, necessarily gathering more data before proposing any taxonomic changes for these species.

Our sampling did not allow a complete assessment of the sectional classification in *Spathiphyllum* as proposed by Bunting (1960). The only section with strong support through all our analysis is the section *Spathiphyllum*, which is also supported by the morphology of their flowers with a long and conical pistil exceeding the perianth (Bunting, 1960). Williams and Dressler (1967), and Grayum (1984, 1990), discussed hypotheses for the origin and biogeography of *Spathiphyllum* and *Holochlamys*. We are undertaking additional molecular and biogeographical analyses of the subfamily Monsteroideae, and more detailed discussion on this topic will be presented in subsequent papers.

REFERENCES

Barabé, D., A.Bruneau, F. F.orest & C.Lacroix, 2002. The correlation between development of atypical bisexual flowers and phylogeny in the Aroideae (Araceae). *Plant. Syst. Evol.* 232: 1–19.

Boyce, P.C. & T.B.Croat. 2013. The Überlist of Araceae, totals for published and estimated number of species in aroid genera. Available at http://www.aroid.org/genera/130307uberlist.pdf (accessed November 2014).

Bunting, G. S. 1960. A revision of the genus *Spathiphyllum* (Araceae). *Mem. New York Bot. Gard.* 10: 1–54.

Cabrera, L. I., G. A. Salazar, M. W. Chase, S. J. Mayo, J. Bogner, & P. Davila. 2008. Phylogenetic relationships of aroids and duckweeds (Araceae) inferred from coding and noncoding plastid DNA. *Am. J. Botany* 95(9): 1153–1165.

Cardona F. 2004 Synopsis of the genus *Spathiphyllum (Araceae)* in Colombia. *Ann. Missouri Bot. Gard.* 91(3): 448–456

Carvell, W.N. 1989. *Floral anatomy of the Pothoideae and Monsteroideae (Araceae).* PhD Dissertation. Miami University. Miami, FL, USA.

Chartier, M., M.Gibernau & S.*S*.Renner. 2013. The evolution of pollinator-plant Interaction types in the Araceae. *Evolution* 68(5): 1533–1543

Cusimano, N., J. Bogner, S.J. Mayo, P.C. Boyce, S.Y. Wong, M. Hesse, W.L.A. Hetterscheid, R. C. Keating, & J. C. French. 2011. Relationships within the Araceae: Comparison of morphological patterns with molecular phylogenies. *Am. J. Botany* 98(4): 1–15.

Eyde, R.H., D.H. Nicolson, & P. Sherwin. 1967. A survey of floral anatomy in Araceae. *Amer. J. Bot. 54*: 478–497.

French, J.C. & P.B. Tomlinson. 1981. Vascular patterns in stems of Araceae: subfamily Pothoideae. *Amer. J. Bot.* 68(5): 713–729.

Gauthier, M. P.L., D.Barabe & A. Bruneau. 2008. Molecular phylogeny of the genus Philodendron (Araceae): delimitation and infrageneric classification. *Bot. J. Linn. Soc.* 156(1): 13–27.

Grayum, M.H. 1990. Evolution and phylogeny of the Araceae. *Ann. Missouri Bot. Gard.* 77: 628–697.

Grayum, M.H. 1992. Comparative external pollen ultrastructure of the Araceae and putatively related taxa. *Monogr. Syst. Bot. Mo. Bot. Gard.* 43: 1–167.

Gonçalves, E.G. 2012. *Lorenzia* (Araceae-Spathicarpeae): a new genus from northern Brazil supported by *matK* sequence data. *Syst. Bot.* 37(1): 48–52.

Low, S.L., S.Y. Wong & P.C. Boyce. 2014. *Schottarum* (Schismatoglottideae: Araceae) substantiated based on combined nuclear and plastid DNA sequences. *Plant. Syst. Evol.* 300(4): 607–617.

Mayo, S.J., J. Bogner & P.C. Boyce. 1997. The Genera of Araceae. Royal Botanic Gardens, Kew, UK.

Nauheimer, L., D. Metzler & S.S. Renner. 2012a. Global history of the ancient monocot family Araceae inferred with models accounting for past continental positions and previous ranges based on fossils. *New Phytologist* 195: 938–950.

Nauheimer, L., P.C. Boyce & S.S. Renner. 2012b. Giant taro and its relatives: A phylogeny of the large genus *Alocasia* (Araceae) sheds light on Miocene floristic exchange in the Malesian region. *Mol. Phylogenet. Evol.* 63(1): 43-51.

Nauheimer, L., & P.C. Boyce 2014. *Englerarum* (Araceae, Aroideae): a new genus supported by plastid and nuclear phylogenies. *Plant. Syst. Evol.* 300(4): 709–715.

Stamatakis, A., 2006a. RAxML-VI-HPC: maximum likelihood-based phylogenetic analyses with thousands of taxa and mixed models. *Bioinformatics*, 22(21): 2688–2690.

Stamatakis, A., 2006b. Phylogenetic models of rate heterogeneity: a high performance computing perspective. In: Proceedings of the 20th IEEE/ACM International Parallel and Distributed Processing Symposium (IPDPS2006), Rhodos, Greece.

Stamatakis, A., P. Hoover & J. Rougemont. 2008. A rapid bootstrap algorithm for the RAxML Web servers. *Syst. Biol.* 57(5): 758–71.

Swofford, D.L., 1991. PAUP: Phylogenetic Analysis Using Parsimony, Version 3.1 Computer program distributed by the Illinois Natural History Survey, Champaign, Illinois.

Steenis, C.G.G.J. van. 1962. The land-bridge theory in botany with particular reference to tropical plants. *Blumea* 11: 235–372

Tam, S., P.C. Boyce, T. Upson, D. Barabé, A. Bruneau, F. Forest & J.S. Parker. 2004. Intergeneric and Infrafamilial Phylogeny of Subfamily Monsteroideae (Araceae) Revealed by Chloroplast trnL-F Sequences. *Am. J. Botany* 91(3): 490–498.

Wong, S.Y. & P.C. Boyce. 2010a. Studies on Schismatoglottideae (Araceae) of Borneo IX: A new genus, Hestia, and resurrection of *Apoballis*. *Bot. Stud. (Taipei)*, 51: 249–255

Wong, S. Y. P.C. & Boyce, P. C. 2010b. Studies on Schismatoglottideae (Araceae) of Borneo XI: *Ooia*, a new genus, and a new generic delimitation for *Piptospatha*. *Bot. Stud. (Taipei)* 51: 543–552.

Wong, S.Y., P.C. Boyce, A.S.B. Othman & L.C. Pin. 2010c. Molecular phylogeny of tribe Schismatoglottideae (Araceae) based on two plastid markers and recognition of a new tribe, Philonotieae, from the Neotropics. *Taxon* 59(1): 117–124.

Wong, S.Y. T.P. Jean, N.K. Kiaw, A.S.B. Othman, L.H. Boon, F.B. Ahmad & P.C. Boyce. 2013. Phylogeny of Asian *Homalomena* (Araceae) based on the ITS Region Combined with Morphological and Chemical Data. *Syst. Bot.* 38(3): 589–599.

Aroid crops in China

Yujing Liu, Heng Li, Devra Jarvis, Chunlin Long*

Yujing Liu
Jiangsu University
No.301 Xuefu Road, Zhenjiang, Jiangsu 212013, China
jing_yuzhouniao@126.com
Minzu University of China
27 Zhong-guan-cun South Ave, Haidian District, Beijing 100081, China

Heng Li
Kunming Institute of Botany, Chinese Academy of Sciences
132 Lanhei Road, Kunming 650201, China
Email: liheng@mail.kib.ac.cn

Devra Jarvis
Bioversity International
Via dei Tre Denari 472/a, 00057 Maccarese, Rome, Italy
d.jarvis@cgiar.org

Chunlin Long*
Author for correspondings.
Minzu University of China
27 Zhong-guan-cun South Ave, Haidian District, Beijing 100081, China
Kunming Institute of Botany, Chinese Academy of Sciences
132 Lanhei Road, Kunming 650201, China
Email: long@mail.kib.ac.cn, Tel/fax: +86–10–68930381

ABSTRACT

The history of aroid cultivation in China was briefly introduced in the present paper. Based on the approaches of literature study and field investigation, 16 species in the family Araceae were recognized as crops cultivated in the country. Among them, three species are with very high values both in Chinese history and nowadays. They are taro (*Colocasia esculenta*, a common food crop), konjac (*Amorphophallus konjac*, a medicinal and industrial crop), and *Ban Xia* (*Pinellia ternata*, an important herbal medicinal crop). The taxonomic issues at species and cultivar levels were argued and discussed. Suggestions for future studies were proposed for aroid crop development.

KEY WORDS

Araceae, Aroid, *Colocasia esculenta*, *Amorphophallus konjac*, *Pinellia ternata*, Classification, Cultivation

INTRODUCTION

Aroid is not a common name which everybody knows. It refers to the members in the family Araceae, a group of monocots. A few aroid members, however, are very famous for their values or unusual morphology. People know taro (*Colocasia esculenta*) for its big leaves and starchy tubers, which feed about 400 million people in the world (Bown, 2000). Other aroids are also cultivated for food, such as members in *Xanthosoma* and *Amorphophallus*. The value of aroids is not limited to the edible. The flamingo flower (*Anthurium andraeanum*) has become a symbol of many exotic locations, even in the north temperate areas. Aroids are now entering homes, hotels, restaurants, conference halls and other indoors very often. The calla lily (*Zantedeschia aethiopia*), giant taro (*Alocasia odora* and *A. macrorrhizos*), red-leaf philodendron (*Philodendron erubescens*) and elephant's ear (*P. domesticum*), Swiss cheese plant (*Monstera deliciosa*), *Dieffenbachia*, *Aglaonema*, and many others are fashionable decorative plants. Aroid members are also known as the Arum family, which consists of 111 genera and over 3500 species occurring in the New World tropics, Old World tropics and north temperate regions (Li *et al.*, 2010).

In China, there are 26 genera and 181 species of aroids, in which 72 species are endemic to the country. Cultivation of aroids in China is a common phenomenon in the southern regions. The ornamental aroids, for example, have been grown in gardens, residential areas, and even in the northern indoors. Some aroids have been cultivated as crops for more than 2000 years.

Unfortunately, nobody can tell how many aroid crops have been cultivated in China. The history, evaluation, classification and nomenclature of cultivated aroids in China are still in question marks. This paper will try to answer these questions, focusing on the aroid crops.

MATERIALS AND METHODS

Literatures had been collected and studied, including the ancient Chinese books which recorded aroids. Over 30 volumes of ancient books have been checked. Recent publications were also studied in terms of the taxonomy, cultivation, agronomy and horticulture of Chinese aroids.

The cultivated aroids were investigated in the past twenty years, including those growing in farming fields, outdoors, indoors and pots. The wild types of these cultivated aroids have been surveyed. Voucher specimens and living plants of unconfirmed taxa were collected and conserved in Kunming Botanical Garden.

The taxonomical methods had been applied to identify the specimens and living collections. Other specimens deposited in Kunming (KUN) and Beijing (PE) had been examined in the last three years.

RESULTS AND DISCUSSIONS

A brief history of aroid cultivation in China

To understand the history of aroid cultivation in China, we investigated the ancient Chinese literatures. Three members of aroids, taro (*Colocasia esculenta*), konjac (*Amorphophallus konjac*) and Ban Xia (*Pinellia ternata*) are the most frequent species to be recorded in old literatures. For example, the names for taro changed from one dynasty to another (Table 1).

Dynasty	**Author**	**Book title**	**The name for Taro in different book**
Warring States	Qu Yuan	*Songs of Chu*	Yu he(芋荷);
Han Dynasty	Ban Gu	*Qian Han Shu*	Qun chi(踆鸱);
Western Han Dynasty	Si Maqian	*Shih Chih*	Cun chi(蹲鸱);
Eastern Han Dynasty	Xu Shen	*Shuo Wen*	Yu(芋,芌);
Han-Jin Dynasty	Tao Hongjing	*Supplementary Records of Famous Physicians*	Yu(芋), Tu zhi (土芝), Cun chi(蹲鸱);
Liang Dynasty	Tao Hongjing	*Annotation of Materia Medica*	Yu(芋), lü yu(梠芋);
Three Kingdom Period, Wei Dynasty	Zhang Yi	*Guang ya*	Yu(芋), Wu yu(乌芋);

Northern Wei Dynasty	Jia Sixie	*Arts for the People*	Yu(芋), Niao yu(鳥芋), Gu shui yu(姑水芋), Che gu yu(车毂芋), Man yu(蔓芋), Jiu Mian yu (九面芋), Jun zi yu(君子芋), Bai guo yu(百果芋), Su yu(素芋), Bai zi yu(百子芋), Da yu(大芋), Bo shi yu(博士芋), Jun zi yu(锯子芋), Pang ju yu(旁巨芋), Qing bian yu(青边芋), Tan shan yu(谈善芋), Chang wei yu(长味芋), Ji zi yu(鸡子芋), Han yu(旱芋), Jiu mian yu(九面芋), Xiang kong yu(象空芋) , Qing yu(青芋), Su yu(素芋);
Tang Dynasty	Su Gong	*Xin Xiu Ben Cao, Tang Materia Medica*	Qing yu(青芋), Zi yu(紫芋), Zhen yu(真芋), Bai yu(白芋), Lian chan yu(连禅芋);
Song Dynasty	Luo Yuan	*Er Ya Yi*	Yu kui(芋魁), Yu qu(芋渠), Bai guoyu(白果芋), Bai ziyu(百子芋), Qing yu(青芋), Zi yu(紫芋), Bai yu(白芋), Ye yu(野芋), Che gu yu(车毂芋), Ju yu(君芋), Yu zi(芋子);
Song Dynasty	Wang Zhi	*Shao Tao Lu*	Shui Yu tou(水芋头);
Song Dynasty	Song Qi	*Yi Bu Fang Bu Lue Ji*	Zhan yu(鸇芋), man yu(蠻芋), fu yu(槫芋), Qing yu(青芋), Zi yu(紫芋), Lian chan yu(连禅芋), Lian chan yu(连禅芋), Bai yu(白芋);
Song Dynasty	Xie Weixin	*Gu Jin He Bi Shi Lei Bei Yao*	Jun zi yu(君子芋), Qing bian yu(青边芋), Dan shan yu(淡善芋), Geng yu(羹芋), Dou yu(豆芋), Cun chi(蹲鸱), Yu(芋), Tu zhi(土芝);
Song Dynasty	Dai Tong	*Liu Shu Gu*	Yu(芋, 芌);
Song Dynasty	Li Fang	*Tai Ping Yu Lan*	Bei yu(卑芋);
Song Dynasty	Luo Yuan	*Er Ya Yi*	Yu(芋, 芌);
Song Dynasty	Tang Shenwei	*Zheng Lei Ben Cao*	Yu(芋), Tu zhi(土芝);
Ming Dynasty	Yang Shen	*Gu Yin Pian Zi*	Cun chi(蹲鸱), Qun chi(踆鸱);
Ming Dynasty	Chen Yumo	*Pian Zhi*	Yu(芋), Jun zi yu(君子芋), Bai guo yu(百果芋), Bo shi yu(博士芋);

Ming Dynasty	Cao Xuequan	*Shu Zhong Guang Ji*	Yu(芋), Cun chi(蹲鸱), Man yu(蔓芋), Jun zi yu(锯子芋), Qing yu(青芋), Zi yu(紫芋), Bai yu(白芋), Zhen yu(真芋), Lian chan yu(连禅芋),
Ming Dynasty	Li Shizhen	*Compendium of Materia Medica*	Yu(芋), Tu zhi(土芝), Yu tou(芋头), Cun chi(蹲鸱), Jun zi yu(君子芋), Lian chan yu(连禅芋), Bai guo yu(百果芋), Qing bian yu(青边芋), Pang ju yu(旁巨芋), Che gu yu(车毂芋), Chang wei yu(长味芋) , Ji zi yu(鸡子芋), Jiu mian yu(九面芋), Qing yu(青芋), Cao yu(曹芋), Xiang yu(象芋) , Shui yu(水芋), Han yu(旱芋), Man yu(蔓芋);
Ming Dynasty	Peng Sunyi	*Ming Zhai Ji*	Yu he(芋荷);
Ming Dynasty	Chen Yuanlong	*Ge Zhi Jing Yuan*	Cun chi(蹲鸱), Tu zhi(土芝), Qing dao yu(青岛芋), Qing yu(青芋), Zi yu(紫芋), Bai yu(白芋), Yu tou(芋头), Tian he sheng(天河生);
Qing Dynasty	Gui An, Wu Jingxu	*Li Dai Shi Hua*	Ju yu(莒芋);
Qing Dynasty	Wu Qijun	*Zhi Wu Ming Shi Tu Kao*	Da yu(大芋), mian yu(麫芋) , Gou zhua yu(狗爪芋), Shui yu(水芋), Pu yu(璞芋), Shao yu(韶芋), Zong yu(棕芋), Bai yu(白芋), Ma yu(麻芋), Dong yu(冬芋), Shui li hong(水黎红), Da tou feng yu(大头风芋), Ji mu yu(鸡母芋), Dong yu(东芋), Qing zhu yu(青竹芋), Huang yu(黄芋), Fan yu(番芋), Er yu(儿芋), Dian yu(滇芋);

Table **1**. Collected old names for taro (*Colocasia esculenta*)

The earliest record of aroid in China was *Chu Ci*, a book written by Qu Yuan, the most famous poet in Warring States Period (BC 475–221), in which he recorded the first Chinese name for taro (*Colocasia esculenta* Schott). In *Supplementary Records of Famous Physicians,* a medicinal book issued in Han-Jin Period (220–450), taro was recorded as an herbal medicine for the first time. The earliest cultivation record was discovered in a book of Liang Dynasty (501–521). A monograph on taro called *Yu Jing* (Book of Taro) was issued in Ming Dynasty (16th century, 1368–1644) by Huang Sheng Zheng. In Huang's monograph, he provided information of classification (types of taro), cultivation methods, and the value of taro to preventing famine in his time.

Ban Xia (or *Fa Ban Xia*, *Pinellia ternata* Ten. ex Breitenb.) firstly appeared in *Huang*

Di Nei Jing, an ancient medicinal book issued after Zhan-guo Period (BC 475–221). It was regarded as a medicinal plant, collected from the wild. Ban Xia was artificially cultivated as a crop after 1970s.

The earliest record of konjac (*Amorphophallus konjac* K. Koch) was Xi Han Dynasty (BC 202-AD 9) in *Er Ya*, a famous book in ancient China. As a medicinal plant, konjac was recorded in *Ming Yi Bie Lu*, an ancient medical book issued in BC 50. In Jin Dynasty (AD 250–260), it was firstly described in *Shu Du Fu* (a book written by Zuo Si) that konjac was cultivated in vegetable gardens as a food crop. Therefore, the cultivation of konjac in China happened at least 1700 years ago (Li & Long, 1989).

Species of aroid crops in China

As crops to be cultivated in farming systems, there are only 16 species in China. They are listed in Table 2. We did not include *Acorus calamus* L. in the list, although it was a member of Araceae but has been moved to another family, Acoraceae, which is far from Araceae based on molecular phylogenic evidence (Nauheimer *et al*., 2012).

Table 2. List of Aroid Crops in China

Scientific Name	**Chinese Name**	**Use & Parts Used**	**Area of Origin**	**Cultivation places**	**Reference**
Alocasia cucullata D. Don	Laohuyu, Damayu, Dafuzi, Zhubugong, Jianweiyu, Jiahaiyu, Jianweicao	Whole plant for green fencing and gardening. Stems for medicine	South China, Myanmar, NE Indian to Sri Lanka	Yunnan, Hainan, Guangxi	Bown, 2000; Li, 1996, Li et al., 2011
Alocasia macrorrhizos D. Don	Haiyu	Whole plant as horticultural and medicinal purposes	Tropical Asia	Tropical region	Bown 2000; Li et al., 2011
Alocasia odora K. Koch	Haiyu, Dishuiguanyin	Whole plant for horticultural purpose	Tropical Asia	Most areas in China	Bown 2000; Li et al., 2011
Amorphophallus albus P. Y. Liu et J. F. Chen	Baimoyu	Tuber for making refined powder as industrial materials, or directly as vegetable	Valleys between Yunnan and Sichuan	Southern China	Long, 1998; Dong & Liu, 2008; Li et al., 2011
Amorphophallus bulbifer Blume	Zhuyamoyu, Hongmoyu	Tuber as vegetable	South Asia, Myanmar, SW Yunnan	Southern Yunnan	Long, 1998; Dong & Liu, 2008; Li et al., 2011

Scientific Name	**Chinese Name**	**Use & Parts Used**	**Area of Origin**	**Cultivation places**	**Reference**
Amorphophallus dunnii Tutcher	Nanshebang	Tuber as vegetable	Tropical Asia	Southern Yunnan and Guangxi	Long, 1998; Dong & Liu, 2008; Li et al., 2011
Amorphophallus kachinensis Engler & Gehrmann	Menghaimoyu	Tuber as vegetable	Tropical Asia	Southern Yunnan	Long, 1998; Dong & Liu, 2008; Li et al., 2011
Amorphophallus konjac K. Koch	Moyu, Huagannanxing, Huamashe, Huamoyu, Maoyu, Juruo	Tuber for making refine powder as industrial materials, or directly as vegetable. Tuber and inflorescence as medicine	Southern China	Most areas in China	Long, 1998; Dong & Liu, 2008; Li et al., 2011
Colocasia esculenta Schott	Yu, Yutou, Maoyutou, Yunai, Zhiwuyu	Tuber as food and medicine. Leaves as food, medicine and forage. Whole plant as Horticultural purpose. Stolon as food	Tropical Asia	Most areas in China	Dong & Liu, 2008; Li et al., 2011
Colocasia fallax Schott	Jiayu, Wangen	Stolon as food. Leaves as forage	SE Asia	Southern Yunnan	Dong & Liu, 2008; Li et al., 2011

Scientific Name	**Chinese Name**	**Use & Parts Used**	**Area of Origin**	**Cultivation places**	**Reference**
Colocasia gigantea J. D. Hooker	Dayeyu, Dishuiyu, Yucai, Guangyu, Guangcai	Whole plant as horticultural purpose. Petiole as vegetable	SE Asia	Yunnan, Guangxi, Guizhou, Hunan, Hainan	Li et al., 2011
Pinnellia ternata Tenore ex Breitenbach	Banxia	Tuber as medicine	Eastern Asia	Most areas in China	Li et al., 2011
Pinnellia pedatisecta Schott	Huzhang	Tuber as medicine	China, Japan	Southern China	Li et al., 2011
Pistia stratiotes L.	Dapiao, Shuibaicai, Shuifulian	Whole plant as aquatic ornamental purpose and as forage	Pantropical	Southern areas in China	Li et al., 2011
Xanthosoma sagittifolia Schott	Jianyelanyu	Whole plant for horticultural purpose. Tuber as food	Tropical America	Southern China	Li et al., 2011
Xanthosoma violaceum Schott	Lanyu	Whole plant for horticultural purpose. Tuber as food	Tropical America	Southern China	Li et al., 2011
Zantedeschia aethiopica Spreng	Matilian, Shuiyu, Ciguhua, Guanyinlian	Inflorescence as cutting flower	Eastern and southern Africa	Southern China	Li et al., 2011

Among these aroid crops, 13 species are native to China. The ancient Chinese people acclimatized most of these plants and passed the cultivation knowledge to next generations. One native species, *Alocasia odora* did not become a crop until last two decades. It has, however, been very commonly used as an indoor ornamental plant in the whole country.

Only three aroid crop species, calla lily (*Zantedeschia aethiopica*), tannia (*Xanthosoma sagittifolia*) and violet tinnia (*X. violaceum*), are recently introduced into China. The calla lily was introduced as an ornamental crop in 1950s. It has become a common cutting flower in China since 1980s. Two *Xanthosoma* species were introduced from China's tropical neighbors (Laos, Myanmar and Vietnam) and cultivated as fodder plants. Their cultivation area is now spreading in the warm and remote villages in southern China.

Some species of aroids are cultivated for aesthetic purposes occasionally or in a small scale. In particular, they are used as pot flowers or for gardening in a few areas. They do not become a crop. These aroid plants include those from different genera: *Aglaonema*, *Alocasia*, *Anthurium*, *Caladium*, *Dieffenbachia*, *Monstera*, *Philodendron*, *Spathiphyllum* and *Syngonium*. There are a lot of cultivars introduced from tropical countries. Three genera, *Anthurium*, *Dieffenbachia* and *Philodendron*, possess the most horticultural cultivars in China.

Significance of aroid crops in China

Some aroid species are very important crops in China. They are food crops, herbal medicines, or ornamental plants. Two species are very significant cash crops in southern China. They are taro (*Colocasia esculenta*) and konjac (*Amorphophallus konjac*). In addition, *Ban Xia* (*Pinellia ternata*) is widely cultivated as a medicinal plant in China.

Recent researches revealed that wet cultivation of taro is among the most productive traditional agricultural techniques in the world, revealed only by the homologous systems based on rice (*Oryza sativa*) (Matthews & Spriggs, 2012). In Asian and Pacific regions, over 40 millions of people take taro as their staple food. This crop is related to not only food security and agricultural production, but also social and political systems including wars and human population.

Taro is also the most important aroid crop in China. The cultivation area in China reached 85,210 hm^2 and the yield was 14,580,000t in 2010. The selling price of fresh tuber is 1–1.6 RMB/kg (http://www.shucai123.com/yutou/). Thus, the total value could be 18,954,000,000 RMB per year.

Konjac takes the second position in terms of its economic values. The cultivation area in China reached about 40,000 hm^2 and the yield was 200,000t in 2010. The enterprises produced 10000t of refined powder each year. The selling price of refined konjac powder was 80–120 RMB/kg. The total value could be 1,000,000,000 RMB per year (Dong & Liu, 2008). Most importantly, the konjac powder has become an industrial material, and has been used widely in food industry, pharmaceutical industry, petroleum industry, textile industry, and environmental protection enterprises based on its miracle features of glucomannan containing in konjac tubers.

Ban Xia (*Pinnellia ternata*) is a common crop used as herbal medicine in traditional Chinese medicine (TCM) or ethnomedicine in China. The dry tuber is an important ingredient in TCM combination products. *Pinellia* has to be processed prior to use, to remove toxic elements through the traditional method of cooking it with ginger, vinegar and/or alum. Many of these products are used for preventing vomiting, influenza (flu), swine flu, nausea, morning sickness, cough, birth control, pain and swelling (inflammation).

Taxonomic issues at species level

The taxonomy of aroid crops occurring in China is not clear yet. There are nomenclatural and classification arguments at species level.

The wild types of taro (*Colocasia esculenta*) were taxonomically treated as another species (e.g. *C. antiquorum* Schott, *C. tonoimo* Nakai) or sub-level taxa of *Colocasia esculenta* (e.g. var. *aquatilis*, var. *antiquorum*) (Li et *al*., 2010). They are also regarded as wild populations or genetic resources of cultivated taro (*Colocasia esculenta*). The reality is that there are morphological variations among different specimens. Sometimes the differences are very distinguished. Whether do they represent one species or not? Molecular approaches including DNA barcoding and molecular markers should be used to solve the taxonomical issues.

The nomenclature of *Colocasia gigantea* should be reconsidered. Molecular evidences showed its phylogenic relationship with *Alocasia* (Nauheimer *et al*., 2012). We prefer to resurrect *Colocasia gigantea* back to *Leucocasia gigantea* (Blume) Schott.

The cultivated species number of *Amorphophallus*, for example, is not clear. Probably the cultivated *A. xiei* H. Li & Z. L. Dao is not be a good species although it has been accepted in the *Flora of China* (Li & Dao, 2006; Li & Hetterscheid, 2010). It may be a cultivar of *A. bulbifer* (Long & Yang, 2004).

Taxonomic issues at variety/cultivar level

There are many cultivars and landraces among cultivated taro (*Colocasia esculenta*). In China more than 300 accessions of taro have been collected. They are classified into 3 types and 11 sub-types (Dong & Liu, 2008). However, there is no record about the cultivar numbers or names. It was generally said the major cultivars reached more than 60 in China. This number is far from the reality. For example, in Fujian Province, only 33 cultivars of cultivated taro have been recorded and documented. Over 10 provinces in China cultivate taro on a large scale and they have rich taro germplasm resources. It is still a big job to investigate and document the whole country's cultivars and landraces of cultivated taro.

The elephant yam (*Amorphophallus paeoniifolius* Nicolson) has been regarded as a tuber crop and serving as an important food for humans and as animal feed (Li *et al.*, 2010). Especially in India, it is widely cultivated as a food crop. In China, however, this species has never been cultivated, neither used for food because it is poisonous. Taxonomically, the genetic resources are from the same species, i.e. *Amorphophallus paeoniifolius*. Whether are they different varieties or cultivars or landraces? Further explorations should be conducted, including its taxonomy, phytochemistry, agronomy and others.

Prospective studies on aroid crops in China

Many biological and biochemical mysteries are kept in the aroid crops. For instance, inflorescence odor and pollination biology of konjac, synthesis and gene regulation of calcium oxalate (or other compounds) in aroids, biological characteristics and bioactivities/pharmacology of glucomanan or other chemical components, prolonging photosynthesis of *Ban Xia*, and many others are important scientific issues.

There are a lot of landraces and other genetic resources of aroid crops in China. The wild relatives are distributed in remote areas but threatened or ignored. The investigation, collection, preservation (*in situ* and *ex situ*), evaluation, innovation and application of these germplasm resources become urgent, because of the fast loss of these resources.

New varieties breeding, especially molecular breeding and improvement will be the major development orientation in aroid production in China. Pathological studies will focus on the root rots of konjac and taro.

The origins of aroid crops are interesting topics. Taro, for example, keeps many secrets in its origin, development, evolution and traditional uses. Anthropological, ethnobotanical, taxonomic, molecular biological, genomic, and many other approaches should be applied to study this magic aroid crop.

The ornamental aroids will be developed in the near future to be huge products for gardening, cutting flowers and pot-flowers in the tropics and temperate as well. Horticultural, aesthetic and architectural studies will be helpful for the commercial development of aroid industry.

ACKNOWLEDGEMENTS

This work was supported by the National Natural Science of China (31161140345), the Ministry of Education of China (B08044, YLDX01013), the Ministry of Science and Technology of China (2012FY110300), and EU Seventh Framework Programme (PIRSES-GA-2009–269204).

REFERENCES

Bown, D. (2000). *Aroids: Plants of the Arum Family (2nd Ed)*. Timber Press, Portland.

Dong, Y.C. & X. Liu. 2008. *Crops and Their Wild Relatives in China: Vegetable Crops*. China Agriculture Press, Beijing.

Huang, S.Z. 2012. *Yu Jing. Senri Ethnological Studies* 78: 45–51.

Li, C.Y., G.Y. Zhang, K. Hammer, C.Y. Yang & C.L. Long 2011. A checklist of the cultivated plants of Yunnan (PR China). *Genetic Resources and Crop Evolution* 58: 153–164. doi: 10.1007/s10722–010–9638–5.

Li, H. & C.L. Long. 1989. Verification of konjac, a medicinal plant. *Natural Product Research and Development* 1: 87–91.

Li, H. & Z.L. Dao. 2006. A new species of *Amorphophallus* (Araceae) from Yunnan, China. *Novon*16: 240–243. doi: 10.3417/1055–3177.

Li, H., G.H. Zhu, P.C. Boyce, J. Murata, W.L.A. Hetterscheid, J. Bogner, & N. Jacobsen. 2010. *Araceae*. p. 1–80. In: Z. Y. Wu, P. H. Raven and D. Y. Hong (eds.), *Flora of China*. 23, Science Press, Beijing, and Missouri Botanical Garden Press, St. Louis. http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=10056

Li, Y.H. (1996). *List of Plants in Xishuangbanna*. Yunnan Nationality Press, Kunming.

Long, C.L. (1998). Ethnobotany of *Amorphophallus* of China. *Acta Botanica Yunnanica* 20: 89–92. http://journal.kib.ac.cn/CN/volumn/volumn_1203.shtml#

Long, C.L. & S.H. Yang. 2004. A new disease-resistant variety of konjac: Yunnan Red Konjac. *Journal of Changjiang Vegetables* 10: 10–11.

Metthrews, P.J. & M. Spriggs. 2012. Irrigated taro (*Colocasia esculenta*) in the Indo-Pacific: Biological, social and historical perspectives. *Senri Ethnological Studies* 78: 1–5.

Mayo, S.J., J. Bogner & P.C. Boyce 1997. *The Genera of Araceae*. Royal Botanical Gardens, Kew, London, UK.

Nauheimer, L., D. Metzler & S.S. Renner. 2012. Global history of the ancient monocot family Araceae inferred with models accounting for past continental positions and previous ranges based on fossils. *New Phytologist* 195: 938–950. doi: 10.1111/j.1469–8137.2012.04220.x.

Useful aroids and their prospects in Vietnam

Nguyen Van Du, Bui Hong Quang,
Nguyen Thi Van Anh
Institute of Ecology and Biological Resources,
Vietnam Academy of Science and Technology,
Hanoi, Vietnam.

Tran Van Tien
National Academy of Public Administration,
Hanoi, Vietnam.

Masuno T.
Graduate University for Advanced Studies,
Hayama, Japan.

Peter J. Matthews
National Museum of Ethnology,
Osaka, Japan.

ABSTRACT

Although aroids are best known as food plants, a large majority of the wild and cultivated species in Vietnam have medicinal uses. Detailed studies of optimal growth conditions and effectiveness for medicinal use are needed for all of these plants. Ethnobotanical and practical studies also needed for sustainable management of wild aroid populations. This paper highlights the general scarcity of information on medically useful aroids.

KEY WORDS

Vietnam, Araceae, ethnobotany, medicine, food, fodder, ornamental

INTRODUCTION

In Vietnam, the family Araceae comprises 135 species belonging to 24 genera that are distributed throughout the country. Many are used for medicinal, food, fodder, and ornamental purposes. Some also have significance in superstition. The uses vary between areas and tribes and many uses represent local customs that may have great antiquity. Here the plants are categorized into four main usage groups: medicinal, food, fodder, and ornamental. Some taxa have multiple uses, and some, despite being found in Vietnam only recently, have great potential for industrial development.

While discussing each usage group, we comment on the conservation status and prospects for particular species. Special emphasis is given to the potential of *Amorphophallus konjac* as a crop for the food industry in Vietnam.

COMPILATION OF DATA

Relatively little has been published on the uses of aroids in Vietnam, and the available reports are very brief. Most reports concern medicinal uses. The present compilation (Table 1) is derived from sources cited in the reference list, and from authors' observations. Information is lacking for several genera. Exotic aroid taxa that have been introduced to Vietnam very recently, as ornamental plants, but are not included here (see discussion).

Table 1. Uses of aroid species in Vietnam, with particular reference to the plant parts used. Abbreviations: Medicinal (M), food (Fd), fodder (Fr), ornamental (O), indigenous (I), exotic (E), natural (wild) source (Nat), cultivated (Cult), abundant (Ab) limited abundance (L). Vernacular names are given for each genus, followed by details for species. Information sources are indicated.

Scientific name	**Vietnamese name**	**Uses**	**Parts used**	**Origin & abundance**
Aglaonema Schott	*Van nien thanh*			
A. costatum N. Br.	*Van nien thanh song, Van nien dom*	• M: respiratory diseases (Vo, 2003)	stem	I, Nat, Ab
A. modestum Schott ex Engl.	*Van nien thanh sang*	M: throat inflammation, diphtheria, intestine and snakebite (Vo, 1997; 2003)	stem	I, Nat, L

Scientific name	Vietnamese name	Uses	Parts used	Origin & abundance
A. tenuipes Engl.	*Van nien thanh manh.*	M: snakebite, venom extraction (Vo, 1997; 2003) laxative, poultice for carbuncles (Nguyen 1993)	stem	I, Nat, Ab
Alocasia (Schott) G. Don.	*Chi ray*			
A. cucullata (Lour.) G. Don	*Ray duoi nhon, Ray tui*	M: colds, windpipe inflammation, pulmonary tuberculosis, snakebite (Vo, 1997; 2003)	rhizome	I, Cult, Ab
A. longiloba Miq.	*Ray tai la dai,*	M: sore-eye with pus in cattle; rhizome heated in bathwater to treat hives, itches, pimples (Vo, 1997; 2003)	rhizome	I, Nat, L
A. macrorrhizos (L.) G. Don	*Ray rung*	M: uses similar to *A. odora*, next. Also Fd, O (Nguyen, 2000)	stem	E, Cult, L
A. odora C. Koch	*Ray dai, Da vu, Ray bac ha.*	M: gout, stomach ache or pain, cholera, broken bone, snakebite, scorpion bite, boiled-water burn, bleeding, liver detoxification (Vo, 1997; 2003; 2004). poultice for furuncles (Nguyen, 1993). Also O	stem	I, Nat, Ab
Amorphophallus Blume ex Decne	*Chi nua*			
A. paeoniifolius (Dennst.) Nicolson	*Nua chuong, Khoai na, Khoai nua, To ngu (bung ran)*	M: dysentery, encourage formation and ejection of sputum (Vo, 1997; 2003; 2004). Also Fd	corm (M), corm & petiole (Fd)	I, Nat, Cult, Ab

Scientific name	**Vietnamese name**	**Uses**	**Parts used**	**Origin & abundance**
A. konjac K. Koch	*Khoai nua, Khoai ngai, Nua konjac*	M: cancer, lung sputum, apoplexy (unconsciousness), aphonia, tightened chest, indigestion, malaria, etc. (Vo, 1997; 2003); reducing blood sugar level; poultice for furuncles (Nguyen, 1993). Also Fd	corm	I, Cult, L
Anadendrum Schott	*Thang moc*			
A. montanum (Blume) Schott	*Ray thuong thu nui, Thang moc nui*	M: snakebite, malaria, etc. (Vo, 1997; 2003)	stem & leaves	I, Nat
Arisaema Mart.	*Nam tinh*			
A. consanguineum Schott	*Nam tinh khong long, Thien Nam tinh*	M: toxicosis blood, children's convulsion, indigestion, snakebite, skin disease (Vo, 1997; 2003)	corm	I, Nat, L
A. decipiens Schott	*Nam tinh ky di*	M: detoxification (Nguyen, 1993).	corm	I, Nat, L
Colocasia Schott	*Khoai nuoc, Khoai mon*			
C. esculenta (L.) Schott	*Khoai nuoc, Mon nuoc, Khoai so, Khoai mon*	M: snakebite, pimples, etc. (Vo, 1997; 2003); Fd (Nguyen, 2000, Vo, 1997; 2004), Fr (Masuno et al., 2012)	corm, leaf, stolon	Nat, Cult
C. gigantea (Bl. Ex Hassk.) Hook. f.	*Mon To, Doc Mung*	M: heated in bathwater to treat hives, leprosy (Vo, 1997; 2003). Fd: peeled petiole	whole plant, leaf	Nat, Cult
Epipremnum	*Ray leo*			

Scientific name	Vietnamese name	Uses	Parts used	Origin & abundance
E. pinnatum (L.) Engl.	*Ray ngot*	M: Treating sore-eye, rheumatism bone pain, itches, poultice for furuncles (Vo. 2003). Also O	stem & leaves	Nat, Cult
Homalomena Schott	*Chi thien nien kien*			
H. gigantea Engl. & K. Krause	*Thien nien kien la lon*	M: rheumatism (Nguyen. 1993), tendon aches and curled paralysis (Vo, 1997; 2003); stimulating digestion under the style of decoction or alcohol soaked; coughing up blood, tuberculosis, flu, rheumatism bone pain, pimples, swollen foot (Nguyen, 2007); reducing heat, fever, pain; strengthening tendon.	rhizome	I, Nat, L
H. occulta (Lour.) Engl.	*Vat veo, Hia hau ton (Dao), Thien nien kien, Son thuc*		rhizome	I, Nat, L
H. tonkinensis Engl.	*Thien nien kien bac bo.*		rhizome	I, Nat, L
H. vietnamensis Bogner & V.D. Nguyen	*Thien nien kien pi-e*		rhizome	I, Nat, L
Lasia Lour.	*Chi choc gai*			

Figure 3. *Doc mung*, a popular soup made with peeled and sliced sections from the petiole of *Colocasia gigantea* (thin pieces in center of the dish, showing aerenchyma). There is little or no acridity, and minimal cooking is required. Red River valley, northern Vietnam, 2011. (Image Matthews.)

Figure 4. *Amorphophallus paeoniifolius* in cultivation. Ba Be, northern Vietnam, 2010. (Image Nguyen.)

Scientific name	Vietnamese name	Uses	Parts used	Origin & abundance
L. spinosa (L.) Thw.	*Ray gai, Mop gai, K'lang don (K'ho)*	M: sputum, phlegm, asthma, kidney diseases, edema, osteoarthritis pain, cough, inflammation of throat rheumatism (Nguyen, 1993), light hepatitis and skin healing. Fd also.	whole plant (M); petiole (Fd)	I, Nat, L
Pistia L.	*Chi beo cai*			
P. stratiotes L.	*Beo cai*	M: skin disease (pimples, rashes) cough, asthma, menstrual cramps, diuretic (Nguyen, 1993, Vo, 1997; 2003; 2004) emmenagogue antiasthmatic	-	I, Nat, Ab
Pothos L.	*Chi ray leo*			
P. repens (Lour.) Druce	*Ray leo*	M: hemorrhage, restless pregnancy, brain membranes pain, post-injury spasm, wrong joints; stem extract for joint pain	whole plant	I, Nat, Ab
P. scandens L.	*Ray leo la hep, Day than lan, Trau ba rung*	M: snakebite, smallpox, asthma; post-natal recovery	stem & leaves	I, Nat, Ab
Remusatia Schott	*Ray mon*			
R. vivipara (Lodd) Schott	*Ray nham, Ray mon*	M: pimples, scabies (Vo, 1997; 2003; 2004)	stem	Nat
Rhaphidophora Hassk.	*Duoi phuong*			

Scientific name	Vietnamese name	Uses	Parts used	Origin & abundance
Rh. decursiva (Roxb.) Schott	*Ray leo la rach, Cay duoi phuong, Lan to uyn, Day song ran.*	• M: muscle pain; strong antibiotic (substitute for penicillin or sulfonamide to treat wound) (Nguyen, 1993; Vo, 1997; 2003; 2004),	stem & leaves	I, Nat, Ab
Rh. hongkongensis Schott	*Duoi phuong hong kong*	M: whip wounds, broken bone, rheumatism, respiratory impairment, whooping-cough (Vo, 1997; 2003; 2004)	stem & leaves	I, Nat, Ab
Rh. hookeri Schott	*Ray leo la lon, Tram dai*	M: soak in alcohol for aphrodisiacal drink*;* whip wound, broken bone, rheumatic, respiratory impairment, whooping-cough (Vo, 1997; 2003; 2004)	stem	I, Nat, Ab
Scindapsus Schott	*Dau ba*			
S. officinalis (Roxb.) Schott	*Day ba, Ray day la lon*	M: snakebite (Do, 1995; Vo, 1997; 2003; 2004)	stem & leaf	I, Nat, L
Steudnera K.Koch	*Khoai thom*			
S. henryana Engl.	-	M: rheumatism bone pain; snakebite (Vo, 2004)	stem & corm	Nat, Cult
Typhonium Schott	*Ban ha*			
T. blumei Nicolson & Sivadasan	*Ban ha, Choc ri*	M: internal wound (small dose) (Do, 1995; Vo, 1997; 2004); phlegm, lung disease (Do, 1995; Vo, 1997; 2004)	corm	I, Nat, Cult, Ab
T. trilobatum Schoott	*Cu choc, Ban ha ba thuy, Ban ha nam*		corm	I, Nat, Cult, Ab
T. flagelliforme (Lodd.) Blume	*Ban ha roi, Choc roi, Rau choc.*	M: sputum, respiratory disease, pimples, insect bite (Do, 1995; Vo, 1997; 2004)	corm	I, Nat, Ab

Scientific name	Vietnamese name	Uses	Parts used	Origin & abundance
Xanthosoma	-			
X. sagittifolium (L.) Schott	*Mon*	Fd, Fr (Masuno et al., 2012)	corm, leaf	E, Cult

DISCUSSION

Medicinal uses

So far 32 aroid species belonging to 16 genera have been recorded as medicinal plants (Table 1). They are used to treat both internal and external conditions, and are often taken unsustainably from natural (wild) sources. Only five of the medicinal aroids are also reported as food plants. Detailed studies of optimal growth conditions and effectiveness for medicinal use are needed for all of these plants. Ethnobotanical and practical studies are also needed to record current practices, and future requirements for sustainable management of wild aroid populations, which grow under diverse social and environmental conditions.

Food uses

Mon group. Two species from two different genera are classed together as *Mon*: *Colocasia esculenta* (L.) Schott (taro) and *Xanthosoma sagittifolium* (L.) Schott.

Taro (*C. esculenta*) is grown widely and is a common food. It also is called *Khoai so*, and many different cultivar names exist (Nguyen 2000, Trinh et al., 2004). Taro provides considerable income for people in some provinces, and has helped to alleviate poverty. Taro yields in Ninh Binh, for example, are 10–11 ton/hectare, earn nearly 100 million VND/hectare. In that province, more than 200 hectares are used for taro cultivation, mostly in the districts of Nho Quan, Yen Mo, Tam Diep. Annually, these districts produce more than 2000 tons.

Among the aroids of Vietnam, *C. esculenta* and *C. gigantea* are most widely used as vegetables. In many areas, the young leaves and stolons of colocasia (wild or cultivated) are cooked for various dishes. The cooking procedures, despite being simple, still require a certain amount of care because the acridity of the plants used varies. Some people believe that avoiding use of chopsticks while cooking will prevent the food becoming itchy.

Wild *C. gigantea* is abundant in Vietnam, especially in kaarst (limestone) regions (**Figure 1)**. The petiole of cultivated *C. gigantea* (**Figure 2)** is a widely popular vegetable eaten by most Vietnamese. The plant is commonly known as *Bac ha* in southern Vietnam and as *Doc mung* in northern Vietnam. The leaf stem is peeled, chopped, salted and boiled carefully with pork ribs or bones along with seasonings such as turmeric, chilli, and onion. *Doc mung* soup (**Figure 3)** is one of Vietnam's distinctive dishes (Nguyen, 2005).

Xanthosoma sagittifolium originated in South America and was introduced to Vietnam at an unknown date. Possibly the earliest botanical record of in Vietnam is in the *Flora Cochinchinensis* of Loureiro (1789), who described it as a minor cultigen, under the name *Arum sagittifolium*. The corms and leaves can be used in the same way as the corms and leaves of taro. *Xanthosoma sagittifolium* is easy to grow, can be grown in a wide range of environments, and can give higher yields than *C. esculenta*. The yield of *Xanthosoma* has been reported to be as much as 20 tons/ha in Vietnam, with a value equivalent to 1,500 USD. However, the cultivation area of this crop in Vietnam is not known.

Amorphophallus group: Recently five species of *Amorphophallus* (*A. konjac, A. krausei, A. corrugatus, A. yuloensis,* and *A. yunnanensi*) have been newly discovered in Vietnam. The corms of these species are only used as food among the Mong and Nung minorities in some high mountain areas. In Japan, Korea and China the corms of edible *Amorphophallus* species are commonly known as konjac, are used in the food industry, and are highly regarded as a source of dietary fiber, or medicinal food. For mountain farmers in Vietnam, konjac corms could become a good income source. Every year, Vietnam has been importing thousands of tonnes of konjac flour from China. The discovery of diverse, edible *Amorphophallus* species in Northern Vietnam suggests that konjac can be developed as a commercial crop in Vietnam. Research on methods of cultivation, breeding and evaluation of glucomannan content are now being conducted. It is hoped that Vietnam can produce konjac flour on a larger scale in the near future.

From tropical and subtropical Asia to Madagascar and the Pacific Islands, *Amorphophallus paeoniifolius* (syn. *A. campanulatus* Bl. ex Decne.) is best known as a source of carbohydrate produced by large underground corms (Burkill, 1966; Whistler, 2009). In Vietnam the petiole of this plant (**Figure 4)** is also a traditional vegetable. In Quang Tho (Quang Dien district of Hue city) this vegetable has been eaten for many generations. After being peeled and cut, the petiole is cooked for many different food dishes, including salad, fish soup, and braised fish.

Other taxa used as food. *Alocasia macrorrhizos* is a widespread introduced plant in Vietnam, in the vicinity of human settlement, but is not well known as a food source at present. In some areas in Vietnam, the young leaf of *Lasia spinosa* is also eaten as vegetable. This usage is not widely known due to limited distribution of the plant. It is likely that other wild aroid taxa are also used as food sources.

Figure 1. *Colocasia gigantea* growing wild; these have a milky sap (latex) and are very acrid. Sapa District, northern Vietnam, 2012. (Image Matthews.)

Figure 2. A cultivated form of *Colocasia gigantea*, with larger number of veins in the blade than the wild form in **Figure 1.** Morphological diversity in wild and cultivated forms of this species has not been studied. Near Ba Vi, Hanoi district. (Image Matthews.)

Fodder uses

Aroids are also important fodder plants in Vietnam, especially for pigs. The taxa used include *Alocasia odora*, *A. macrorrhizos*, *Colocasia esculenta*, *C. gigantea*, and *Amorphophallus paeoniifolius*. Most commonly used is C. *esculenta*, which contributes significantly to small-scale pig raising and household income (Masuno et al., 2012). Other species (*Alocasia odora* and *A. macrorrhizos*) are also fed to pigs but only during dry seasons. Additionally, *A. odora* is fed to pigs that are only raised to serve the demand of local people. Pigs that feed on *A. odora* plants produce pork with distinct taste and other qualities, when compared to factory-reared pigs fed on industrial mash and grains. In Hue, central Vietnam, the corm of *Amorphophallus paeoniifolius* is no longer made into a special cake for human consumption due to a complicated and time-consuming procedure. The plant is now solely used to feed pigs in the place of other fodder plants.

Ornamental uses

Historically, only a few species have been used as ornamental plants in Vietnam, most notably: *Alocasia odora, A. macrorrhizos,* and *Epipremnum pinnatum*. These are used for garden, perimeter and interior decoration.

Figure 3

Figure 4

Today, many aroid species and hybrid species from Southern America, are imported into Vietnam in large numbers, usually through a third country. Many of these have leaf and inflorescence with attractive color and shape. Moreover, many of them can survive in relatively dark conditions, making them appropriate for indoor decoration. The majority of these new ornamental introductions belong to *Aglaonema*, *Alocasia*, *Anthurium*, *Caladium*, *Homalomena*, and *Zantedeschia*.

CONCLUSIONS

Many aroid are widely used in the daily life of Vietnamese people. *Amorphophallus* and *Colocasia* species are commercially and economically valuable, and are cultivated on a large scale inside or outside Vietnam. Most of the taxa used for medicinal purposes come from natural or wild environments and are likely to become more scarce with the continued destruction of forest habitats. Some may respond positively to limited disturbance of natural habitats.

The preservation of these plants will depend closely on the preservation and management of the forests and the environment in general. Close attention also needs to be given to the value of these plants for local communities and for trade, and the potential for commercial production under cultivation as an alternative to gathering from the wild.

ACKNOWLEDGMENTS

This work was partly supported by a cooperative project of the Institute of Ecology and Biological Resources, Vietnam, and the National Museum of Ethnology, Osaka. The first author would like to thank Mr John Tan Hoe, Gardening Society of Singapore, for his generous support during the study of Araceae in Vietnam. The last two authors were supported by JSPS KAKENHI Grant No. 23405004, Japan.

REFERENCES

Burkill, I. H. 1966. *A Dictionary of the Economic Products of the Malay Peninsula*, Ministry of Agriculture and Co-operatives, Kuala Lumpur.

Do T. L. 1995. *Medicinal Plants and Remedies in Vietnam*. NXB Khoa học Kỹ thuật, Hà Nội.

Loreiro, J. D. 1789. *Flora Cochinchinensis, Vol. 1*. Ulyssipone: Typis, et expensis academicis.

Masuno, T., L. D. Nguyen, V. D. Nguyen & P. J. Matthews 2012. Fodder sources and backyard pig husbandry in BaVi, Hanoi province, northern Vietnam. *Proc. of the 1st International Conference on Animal Nutrition and Environment*. Khon Kaen University Press, Khon Kaen, pp. 657– 660.

Nguyen, M. L. T. 2005. Vietnamese soup recipe: *Colocasia gigantea*, *Eryngium foetidum*, and *Limnophila chinensis* subsp. *aromatica* in a cultural food context. *Society for Economic Botany Newsletter* 19: 14–15.

Nguyen T. 2007. *Handbook of Protected Medicinal Plants in Vietnam.*Non Timber Forest Production Oganization, Hanoi.

Nguyen, T. N. H. 2000. Taro diversity and use in Vietnam. In D. Zhu, P. B. Eyzaguirre, M. Zhou, L. Sears and G. Liu (eds) *Ethnobotany and genetic diversity of Asian taro: focus on China*. IPGRI Office for East Asia, Beijing, pp. 12–17.

Nguyen T. P., Nguyen T.P., Tran. D.T., and T.B. Nguyen. 2009. Research on the selection of cocoyam varieties (*Xanthosoma sagittifolium* Schott) with high quality and yield and disease-free, in Van Hoa highland, Son Hoa district, Phu Yen province (Internet: http://www.socialforestry.org.vn).

Nguyen V. D. (Duong) 1993. *Medicinal Plants of Vietnam, Cambodia and Laos*. Mekong Printing, pp. 63–70.

Nguyen V. D.(Dzu) 2005. Araceae Juss. - Ho Ray. In Nguyen T. B. (ed.), *Checklist of Plant Species of Vietnam 3*:. Agr. Publ. Ha Noi, pp. 871–898.

Trinh, L. N., D. H. Chien & N. P. Ha 1994. Exploration for collecting taro genetic resources in Vietnam. *Annual Report on Exploration and Introduction of Plant Genetic Resources* 10: 117–132.

Vo V. C. 1997. Dictionary of Medicinal Plants in Vietnam. Medicinal Publ., Hanoi.

Vo V. C. 2003. *Dictionary of Common Useful Plants*. Vol. 1. Science and Technological Publ., Hanoi.

Vo V. C. 2004. *Dictionary of Common Useful Plants*. Vol. 2. Science and Technological Publ., Hanoi.

Whistler, W. A. 2009. *Plants of the Canoe People: An Ethnobotanical Voyage through Polynesia*. National Tropical Botanical Garden, Lawai.

Aroids germplasm conserved at Plant Resources Center: Past-Present and Future

Nguyen Van Kien*[1], Duong Thi Hanh
Plant Resources Center
An Khanh
Hoia Duc
Ha Noi, Vietnam

Peter Matthews
National Museum of Ethnology,
Osaka, Japan

Nguyen Van Du
Institute for Ecology and Biological Resources,
Hanoi, Vietnam

*** Corresponding Author: kiennguyenvan8@hotmail.com**

ABSTRACT

Economic aroids are likely to have an increasingly important role in food security and agro-biodiversity. Vietnam is located within the Southeast Asian region that appears to be a cradle of origin for aroid crop species. Aroids have had long cultural and economic history among the diverse ethnic communities within Vietnam. There is not only a wealth of biological diversity among the economic aroids of Vietnam, but also a wealth of local knowledge concerning the planting, care, harvest, storage and use of aroids. The Plant Resources Center (former Plant Genetic Resources Center) is a focal point of the National Plant Genetic Resources conservation network in Vietnam and has conducted field surveys, collecting missions, and conservation efforts for economic aroids and related knowledge in Vietnam. We will introduce the previous history, study, and utilisation of aroid collections at the Plant Resources Center. The Center currently maintains 600 accession of *Colocasia*, 100 accessions of *Xanthosoma*, 16 accessions of *Amorphophallus*, 12 accessions of *Alocasia* and more than 32 unidentified

accessions. We will also discuss aroid conservation strategies for Vietnam in the future.

INTRODUCTION

Vietnam is a tropical climate country, located in southeast extremity of the Indochinese Peninsular, where a number Aroids species on the world have probably originated. Diversity of topography and climate features as well as culture and social conditions of 54 ethnic groups have created aroids species diversity and knowledge of them. According to famous botanist Pham Hoang Ho, there are 108 aroids species in Vietnam and Indochina. Many amongst them could be used for different purposes such as vegetable, ornamental, medicine, decorating and fodders. Today, scientific and technological development is promoting new values and knowledge on aroid use, typical processing industry, functional food such as Konjac from *Amorphophallus* species and *Colocasia esculenta* among others,. However, erosion and loss of aroids species diversity and knowledge of them have become greater issues than before ever because of human kind impacts such as deforestation, transferring agricultural land into industrial land and developing facilities. Moreover, the promoting of new crop varieties has also lead to area reduction of indigenous/traditional crop varieties, including aroid species.

Plant Resources Center is an organization mandated for plant genetic resources conservation and their use for food and agriculture in Vietnam. The Center implemented surveying, inventory, collecting and ex-situ/in-situ conservation, and traditional knowledge of aroid species in Vietnam. Although aroids species diversity conservation and use has achieved preliminary successes, constraints and challenges of aroid species sustainable conservation and use still remains. Therefore, we would like to present the state of aroid germplasm conservation and use in Vietnam to oversea colleagues better understanding of our natural resources conservation and use.

MATERIAL AND METHODS

Materials:

- Published books, papers on family *Araceae* of Vietnam.
- Previous preliminary survey and collecting information/data on family *Araceae* in Plant Resources Center
- Data of Aroids species conservation and use in Plant Resources Center

Methods:

- Collecting information/data from official sources
- Using statistics methods for analyzing/ processing information/data.

- Using Diva Gis, Excel software.

RESULTS AND DISCUSSION

From an illustrated flora of Vietnam by Pham Hoang Ho, a general map on aroid species location in Vietnam was developed and regularly updated to build the ground on research, inventory, conservation and use works on aroids crops in Vietnam.

On the map it may be seen that aroid species are distributed over Vietnam from swamp, mountain, plains and islands areas in both of North and South regions. Moreover, according to recently statistics, there are 38 new aroids species discovered in Indochina during 1995–2009, of which there are 28 species discovered in Vietnam, 8 species discovered in Lao and 2 species discovered in Cambodia. Moreover, there are now records of 29 species distribution in Indochina, including 15 originated species in China, 10 originated species in Thailand, 2 originated species in Myanmar and 1 originated species in Indonesia, respectively. Three of the most scientifically-studied 24 genera are *Typhonium*, *Amorphophallus* and *Arisaema,* with 12 species, 10 species and 4 species, respectively. Some of aroids genera are new their distribution in Indochina, the widest distribution is the genus *Arisaema* including 11 species and one from the genus *Amydrium* added into their distribution in Vietnam and Indochina. All of them were updated into the map, yellow cross points.

Family *Araceace* is a familiar crop family in Vietnam. Typically, in remote and marginal areas with multi-used purposes from food, fodders, vegetable to ornamental and decorating. Amongst them taro is second ranked to rice in use by ethnic minorities of Vietnam for a longtime. Furthermore, there are some species as *Colocasia esculenta*, X*anthosoma*, *Amorphophallus* sp. and *Alocasia* sp. which are the staple food sources of the ethnic minorities.

From 1991 to date, there were 3 milestones in activities of aroid species conservation and use in PRC as follow:

- During 1991–1995: National Root Crops Program sponsored by CIP, IDRC, CIAT, IPGRI
- During 2000–2003: TANSAO project sponsored by EU
- During 2007–2013: National crop germplasm collecting program surrounding Son La hydraulic power plant works sponsored by MOST and national breeding project by MARD.

Table 1: Edible aroid species component and quantity collected in 3 important periods

No	**Time**	**Number of collected accessions**	**Number of species**	**Distribution areas**
1	1991–1995	402	39	Northeast, Northwest, Red river Delta, Central North, Central South, highland, Mekong river delta, Southeast.
2	2000–2003	399	10	Northeast, Northwest, Red river delta,
3	2007–2013	450	12	Northeast, Northwest,

However during three of these periods, the number of collected accessions and collected species were also gradually decreased. The reason for this could be explained that inventory/collecting ranges was made more and more narrow from whole country, to North Vietnam, and finally Northeast/Northwest. Moreover, species collection is focused on edible and major aroids species such as *Colocasia esculenta, Xanthosoma, Amorphophallus, Alocasia.* Currently, Plant Resource Center conserved edible and majority aroid crop such as *Colocasia* sp*, Xanthosoma* sp*, Amorphophallus* sp*, Alocasia* sp and data is presented in table 2

Table 2: State of edible aroid species conservation and use at Plant Resources Center

No	Name Collections	Accessions number	Documentation/data	Maintained type
1	*Colocasia esculenta*	650	650	Field, near in-situ and in-vitro
2	Xanthosoma	100	100	Field
3	Amorphophallus sp	16	20	Field
4	Alocasia sp	12	24	Field
5	Other	31	32	Field

On table 2, edible and major aroid crops were concentrated on collecting, maintaining on the field as well as describing, evaluating and documenting. In addition to researches on in-situ conservation and in-vitro is also carried out in taro varieties that are difficult to maintaining on the field. The distribution of the aroids germplasm is also mapped out and presented on map 2.

On the map, conserved edible aroid crops at PRC are distributed alternately with various root and tuber crops. Almost of them were collected in North region with diversity of edible aroid species but in South region there are some collected *Xanthosoma* and *Amorphophallus* species maintained until today. This could be explained that ecological difference is impacted strongly to results of conserving on the field and there is some high adapted species like *Xanthosoma*, *Amorphophallus*. Major aroid species (*Colocasia esculenta*, *Xanthosoma*, *Amorphophallus* sp. *and Alocasia*) were distributed in all agro-ecological regions of Vietnam. Before this our researches/reports were analyzed for diversity indicators in population, species levels by morphology and molecular data..On the other hand, used purposes of aroid species is an issue of great interest. Therefore, for exploitation and use in the future, values of traditional use are recorded and presented in table 3.

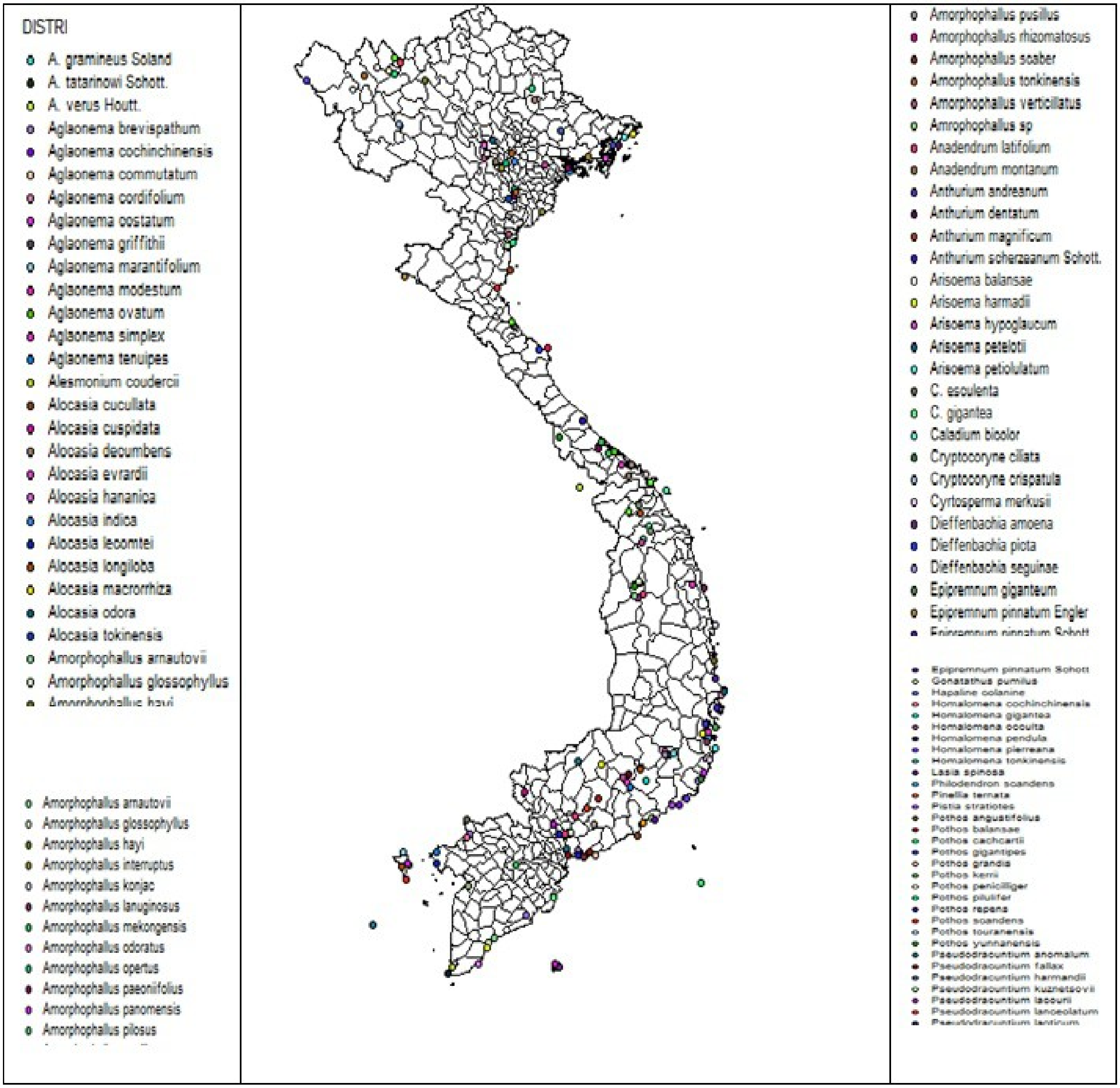


Figure 1. Map of aroid species appeared sites in Vietnam

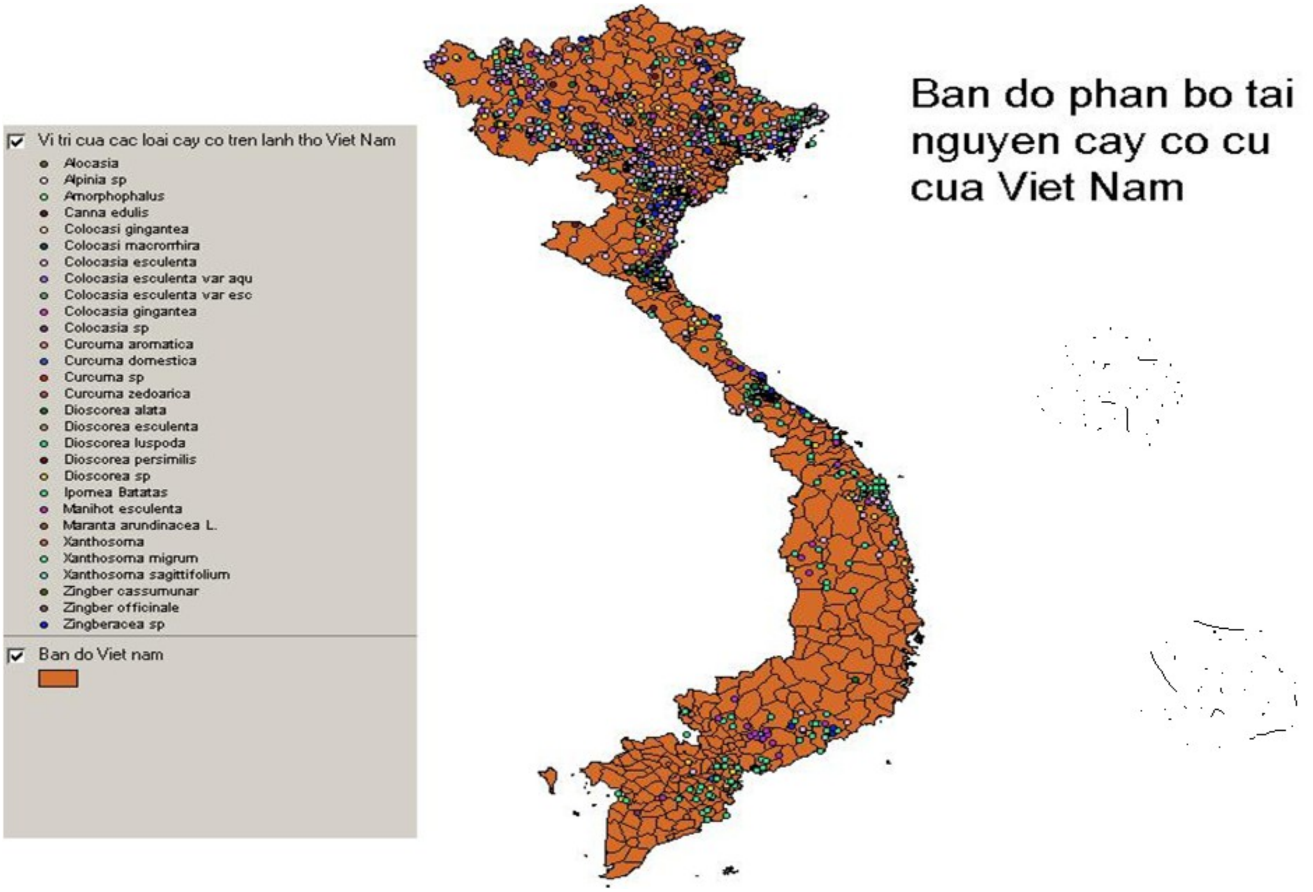


Figure 2. Map of distribution of Aroid species conserved at Plant Resources Center

Table 3: Ethnobotany on Aroid species use in Vietnam

No	Used purposes	Used parts	Significantly species
1	Food	Tubers	*Colocasia esculenta, Xanthosoma,*
2	Feed	Tubers, leaves, petioles.	*Colocasia esculenta,*
3	Vegetables	Petioles, stolon	*Alocasia, Colocasia esculenta*
4	Medicine	Tuber, leaves, petioles	*Alocasia*
5	Ornamental, decorating	Whole plants	*Caladium bicolor,*

From recorded information and data during inventory, collecting activities, indigenous knowledge and ethnobotany system were collected, combined and composed for conservation and use on aroid germplasm in plant resources center and Vietnam. However, indigenous knowledge and ethnobotany system are only experienced as scattered items. They are dispersed and without adequate scientific base and in natural conditions so that it is not persuasive and convincing. Thus indigenous knowledge and ethnobotany systems need more research on a scientific basis and with applied values.

The initial results of aroid germplasm exploitation and utilization by Plant Resources Center are presented in table 4.

Table 4: Results of exploitation and utilization on conserved Aroid species at PRC

No	**Name of germplasm (Scientific name)**	**Accession number**	**Main agro-biological traits**
1	KS4- *Colocasia esculenta* var *antiquum*	T 3382	Plant is low and strong, 40–60 cm height. Thick leaves, light purple petiole in base. Corm and cormel are same size. Flesh color: white Growth duration: 100–120 days; yield: 15–20 tons/ha
2	KMN1- *Colocasia esculenta* var *esculenta*	11409	Plant is high and strong, 60–120 cm height. Thick leaves, whole purple petiole. Flesh color: yellow Growth duration: 210–240 days; yield: 25–30 tons/ha, max: 60–70 tons/ha.

In the work of conserving edible aroids collections on the field, Plant Resources Center discovered, exploited and extended the cultivation areas of the taro varieties named KS4, KMN1 for improving livelihood and productivity of horticulture households. The two taro were approved by MARD for widening cultivation areas in North Vietnam. Besides, Plant Rresources Center annually distributed 50–100 accessions of aroids crops and relevant information to end-users. The utilization and exploitation of conserved edible aroids crops at Plant Resources Center will be strengthened and improved specifically and concretely if there are more interests and investments from managers and policy-makers. For examples, these are *Amorphophallus* sp, vegetable use stolon-bearing taro and *Xanthosoma*.

CONCLUSION

Edible aroids germplasm and wild species relatives are abundant and rich in term of living materials and knowledge of them. There are more new aroids species recently discovered in Vietnam and added list of aroid species on the world.

Diversity of aroid species in Vietnam is being threatened by human activities such as deforestation, transferring agricultural land in to other purposes, priority policies on industrial and staple food crops development, or indigenous knowledge erosion/loss.

Effort and initiated achievement of PRC for edible aroids species conservation and use are not enough for rich and various aroid species of Vietnam.

Under strictly and alternatively natural and socio-economic conditions, new approaches on Aroid germplasm conservation and use in Vietnam need further study and application.

RECOMMENDATION AND IMPLICATION ON POLICY

Aroid germplasm conservation and use in Vietnam is urgently and essential for maintaining agro-biodiversity and improving sustainable livelihood and productivity of stakeholders.

- *National strategy on sustainable conservation and use of Aroids germplasm*

- Reciprocal strategy on ex-situ conservation and in-situ conservation of Aroids germplasm;

- Complimentary methods on safety duplication needed on ex-situ conservation such as in-vitro or cryopreservation;

- Promoting sustainable exploitation and use of Aroids germplasm;

- A synchronous policies system on awareness arising, extension missions, benefit sharing;

- Training/education on capacity building and rising infra-structures

- *Call for international/regional/bilateral collaborations on available areas*

- Inventory, collecting of Aroids germplasm;

- Conservation and diversity evaluation;

- Exploitation and use of Aroid germplasm;

- Study of Indigenous knowledge and ethnobotany on aroid crops;

- Testing of tolerance and resistance of Aroid germplasm.

ACKNOWLEDGEMENTS

We would like to thank sincerely and deeply to International Aroid Society and PRC for publishing the paper as well as their efforts on root crops conservation and use in particular and agricultural and rural development sector in general

REFERENCES

Edible aroid conservation strategies. Proceeding of Global Crop Diversity Trust. Rome, Italy (Draft)

Nguyen Van Du & Vu Tien Chinh. The new discovery of Araceae in Vietnam during last 15 years. *Proceeding of ecological and biological resources conferences.*

Pham Hoang Ho. *An illustrated flora of Vietnam.* Youth publishing house. 1999

Pham Thi Sen & Luu Ngoc Trinh. Vietnam; second country report on the state of the nation's plant genetic resources for food and agriculture.

Plant Resources Center. National strategy on developing science and technology of sustainable plant genetic resources conservation and use for food and agriculture by the year 2015, with a vision to the year 2020 (in draft)

Truong Van Ho et al. *Root crops germplasm research in Vietnam.* The international Potato Center (CIP) Box 933, Manila, Philippines, March 1995.

Taxonomy and ethnobotany of *Colocasia esculenta* and *C. formosana* (Araceae): implications for the evolution, natural range, and domestication of taro

Peter J. Matthews
National Museum of Ethnology
Osaka, Japan

Nguyen, Van Dzu,
Institute for Ecology and Biological Resources
Hanoi, Vietnam

Daniel Tandang,
National Museum of the Philippines,
Manila, Philippines

E. Maribel Agoo,
De La Salle University,
Taft, Manila, Philippines

Domingo A. Madulid,
De La Salle University,
Taft, Manila, Philippines

ABSTRACT

A critical problem for the taxonomy of taro (*C. esculenta*), and for understanding the evolution and domestication of this species, is that there is no way to recognise, by simple visual inspection, a wild population of taro as part of a natural distribution. This is because people throughout Southeast Asia have long used wild taro as a vegetable for human and animal consumption (as food and fodder). The example of *C. formosana* Hayata is introduced here because our observations so far indicate that this is a naturally-distributed wild species throughout its known range, despite its close phenotypic similarity to *C. esculenta*. To learn about the evolution, natural range, and domestication

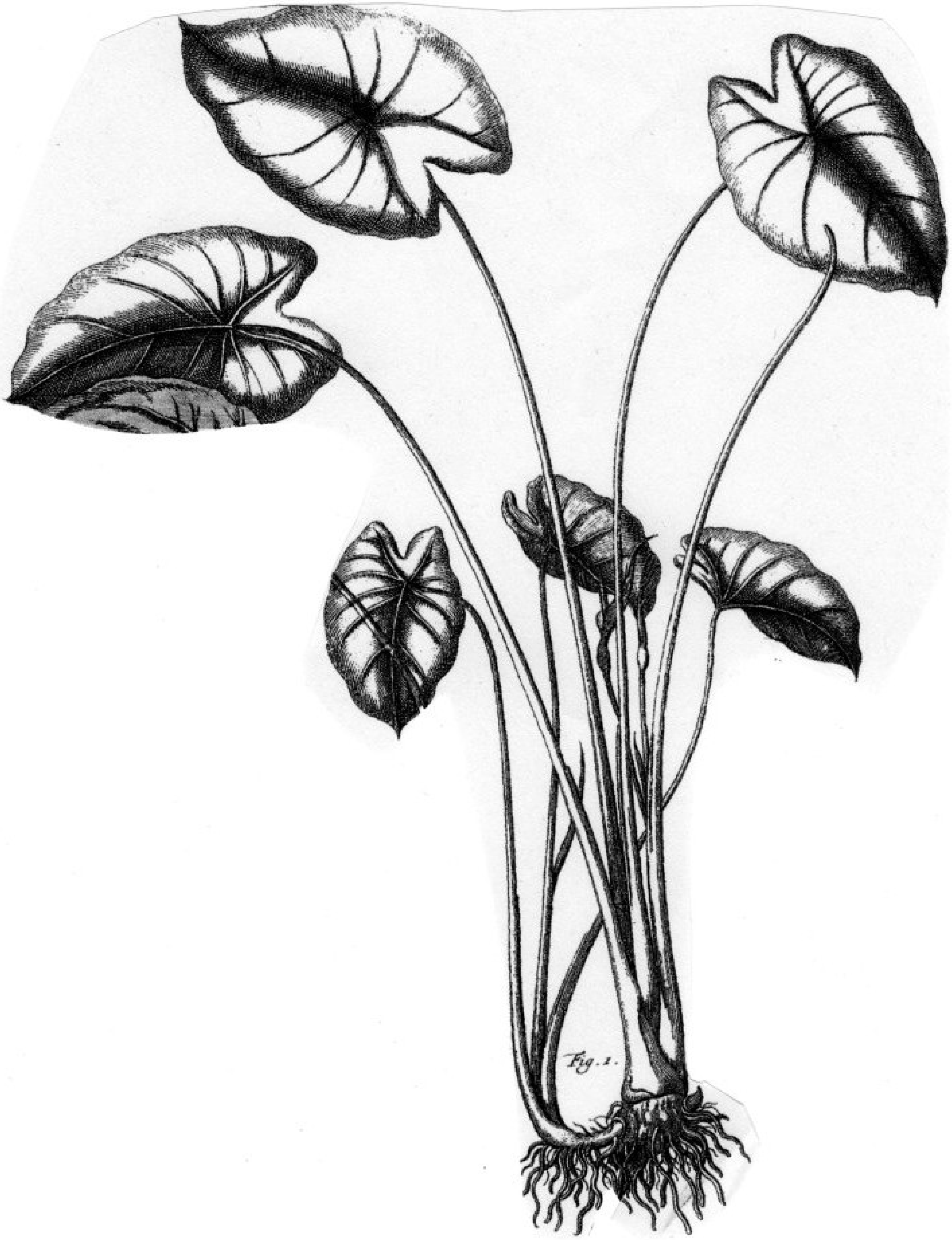


Figure 1 The "Water Kelady" (*Caladium aquatile*) illustrated by Rumphius 1741–50 (2011) in *The Ambonese Herbal.* Hasskarl (1848) referred to this work to establish the name *C. esculenta* Schott var. *aquatilis* (Rumph). The parent plant is flowering, and a new shoot has sprouted from the stolon at left.

of taro, closer study of *C. formosana* is recommended.

INTRODUCTION

The distribution, use, ecology, and genetics of wild forms of taro, *Colocasia esculenta* (L.) Schott, have been explored over many years in an attempt to discover the genetic and geographical origins of cultivated taro, a starchy root crop that is found in tropical to temperate regions of the world (Matthews, 2014). The current species name, *C. esculenta* (L.) Schott, is generally understood to refer to a single highly-polymorphic species, with several varieties, but historically there has been great uncertainty about definition of the varieties and their taxonomic status as botanical varieties or distinct species (Plucknett, 1983; Orchard 2006). The original descriptions for the species, and for two commonly recognised varieties, var. *esculenta* and var. *antiquorum* Hubbard & Rehder (1932) are all based on cultivated plants, while a third variety, var. *aquatilis* Hasskarl (1848) is based on an illustration and written description by Rumphius 1741–50 (2011) of an Indonesian wildtype or possibly naturalised (feral) wild taro (Hay, 1998). As a result, the polymorphism apparent in previous taxonomic descriptions reflects variation produced by human selection during domestication, as well as variation produced during natural evolution of the species. Rumphius gave two alternative Latin names for the same plant, based on where it could be seen growing: *Caladium vicorum* ('taro of the villages'), and *Caladium aquatile* ('aquatic taro'; also called 'water kelady' by Rumphius) (**Figure 1)**. The ambiguity of its status as a wild plant seen growing in and around villages, and along rivers, is already apparent in the naming and description provided by Rumphius.

Formal descriptions of natural botanical varieties or sub-species should, in principle, be based on wildtypes present in naturally-distributed wild populations. According to the international codes of nomenclature for wild and cultivated plants (Spencer et al., 2007), a natural sub-species is 'generally understood as having defining characteristics that are usually geographically separated, although they may occupy different ecological niches', while a 'variety' is 'often understood as having characters that differ in a minor way' in plants that 'do not have a clearly defined geographical or ecological distribution'. A critical problem for the taxonomy of *C. esculenta*, and for understanding the evolution and domestication of this species, is that there is no way to recognise, by simple visual inspection, a wild population of taro as part of a natural distribution. We can assume neither that a particular patch of wild taro represents a natural variety or sub-species, nor that it is derived from cultivated plants. This is because people throughout Southeast Asia have long used wild taro as a vegetable for human and animal consumption (as food and fodder). The example of *C. formosana* Hayata 1919 is introduced here because our observations so far indicate that this is a naturally-distributed wild species throughout its known range, despite its close phenotypic similarity to *C. esculenta*. For understanding the evolution and domestication of *C. esculenta*, there may be much to learn from closer study of *C. formosana*.

Previous theories of natural range and the origins of cultivated taro

Wild breeding populations of taro are distributed in tropical and subtropical regions from South Asia to East Asia, and through Southeast Asia to northern Australia and Papua New Guinea. In all these regions, there are many local uses for wild taro, which has served as a food source (corms, stolons, leaves, inflorescences, and - though rarely reported - fruit), medicinal plant, and as a fodder for domestic pig (Matthews et al., 2012; Masuno et al., 2012). Since wild forms of taro are useful plants, and are known from field interviews to be transplanted, it is not easy to distinguish naturally-distributed wild taro populations from populations that may arise directly or indirectly through human activities.

Following a survey of records of taro in botanical literature and European herbarium collections, and a survey of wild and apparently breeding populations of taro in northern Australia and Papua New Guinea (Matthews, 1987; 1990), maps were published showing the global distribution of taro in cultivation, the likely natural range of wild taro, and the distribution of two better-known wild species (*C. affinis, C. fallax*) (Matthews, 1991; 2006). Previously, taro was most commonly known as a vegetatively propagated crop, and even today, it is still a surprise for many people to learn that wild breeding populations exist in many countries. In Queensland, Australia, inflorescences and fruit with seeds were seen in a large wild taro patch, in a region where taro is rarely cultivated. Many leaf samples were collected in transects through the patch, the leaves were frozen in liquid nitrogen, carried to a laboratory for DNA was extraction, and the extracts were preserved in freezers from 1987 to the present day. Now it is known that taro DNA can be more easily sampled by simply drying the leaves in bags with silica gel. The 1987 samples were recently sent to the McDonald Institute for Archaeological Research in the United Kingdom for microsatellite DNA analysis, and our results provided the first genetic evidence of breeding in a wild taro population, while also indicating the predominance of one genetic clone in the taro patch studied (Hunt et al., 2013).

In Japan, and other regions of Northeast Asia, taro is cultivated at high latitudes that experience cold winters with snow. Under such conditions, farmers must give special care to ensure the survival of living plants from autumn until the next spring, despite the fact that the plants appear adapted to the cool and seasonal environment. The northern cultivars typically produce many side-corms that can be easily stored during winter, using storage methods that vary according to latitude and altitude (Matthews, 2002). The parent corms and child side-

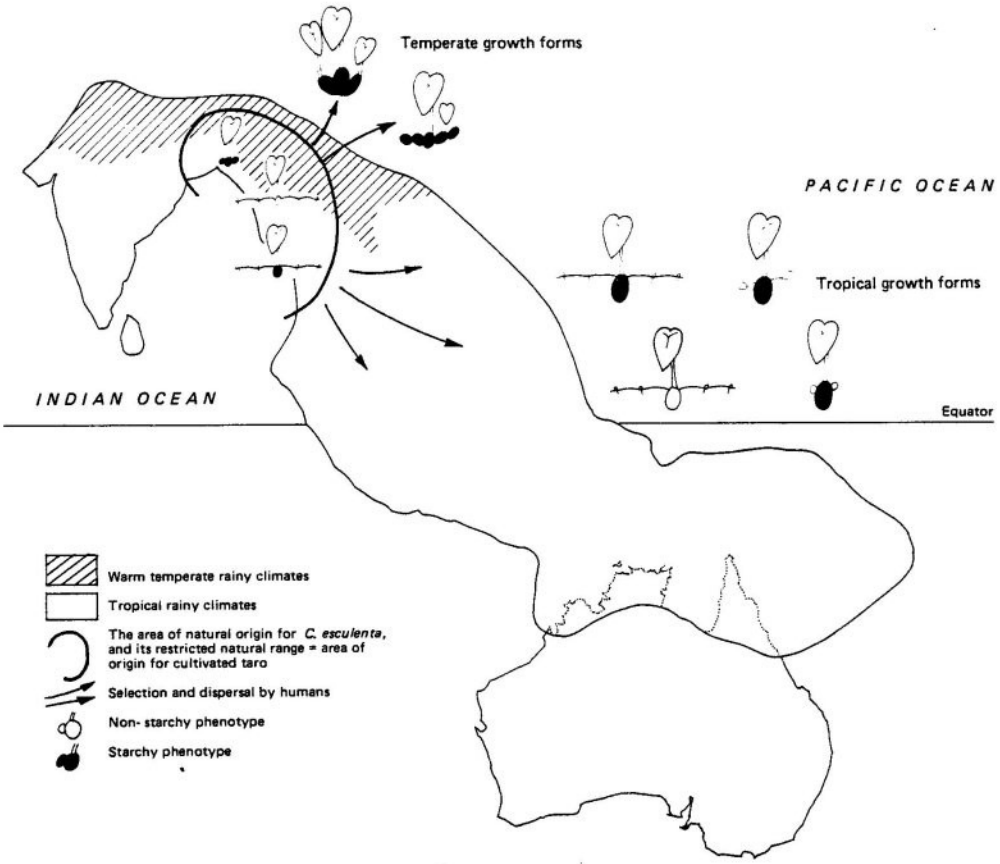


Figure 2. The possible *restricted natural range* of taro (*C. esculenta*), representing a single area of origin for cultivated taro in Southeast Asia. Diversity in the morphology of temperate and tropical cultivars is indicated outside the map boundary. In this scheme, wild populations in northern Australia and Papua New Guinea may have been derived from wild or cultivated forms introduced by people. The large area outlined, encompassing the region from India to northern Australia, is the maximum likely natural range (see **F3)** (from Matthews, 1990; 2014).

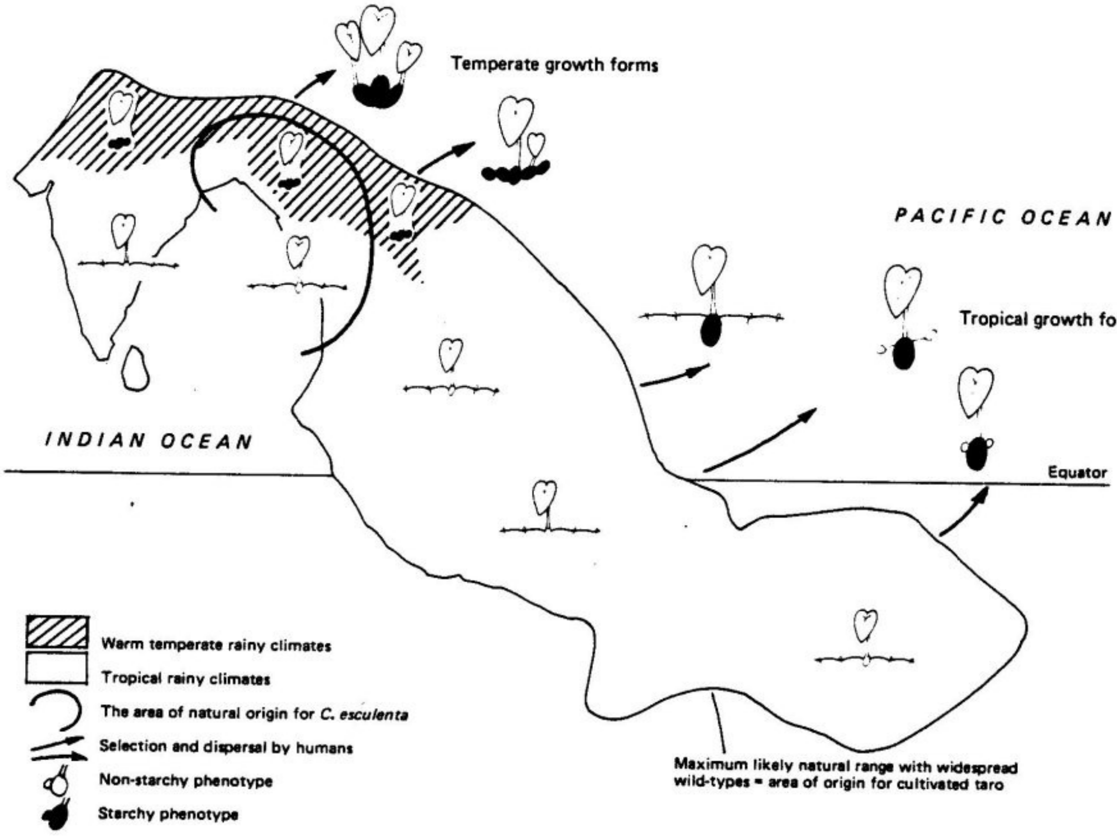


Figure 3. The *maximum likely natural range* for taro (*C. esculenta*), in Asia and the Pacific, and the possible multiple origins of cultivated forms throughout this range. In this scheme, wild taro in northern Australia and Papua New Guinea arrived first through natural dispersal. Diversity in the morphology of cultivated taro is indicated outside the map boundary. The possible area of natural origin for the species is unchanged from **F2** (from Matthews, 1990; 2014).

corms become dormant during winter, and carry many buds for regrowth in spring. Even with cold damage, and the death of some buds or shoots, the northern cultivars will sprout again in spring, and are easy to maintain.

The observations in tropical Australia and Papua New Guinea, and in temperate Japan, led to suggestion that there had been two main sources and directions for the domestication of taro (Matthews, 1990; 2014): (i) cool-adapted wild forms of taro the Himalayan mountains (somewhere in the region from northeast India to China) leading to the temperate adapted cultivars of taro (mainly triploids), and (ii) warm-adapted forms of taro in a tropical lowlands area (somewhere in the region from India to northern Australia and Papua New Guinea) leading to tropical cultivars.

Since little was known about the uses and dispersal of wild forms of taro, it was considered possible that the natural range of taro: (i) is restricted to a region of mainland Southeast Asia where mountain and lowland environments are present, within the vicinity of other wild *Colocasia* species known at that time (**Figure 2)**, or (ii) extends throughout the region from India to Southeast Asia, northern Australia and Papua New Guinea (**Figure 3)**.

In these figures, the maximum likely natural range of taro was identified according to the observations in northern Australia and Papua New Guinea, and scattered records of wild taro in botanical literature and herbarium collections, for these and other regions (Matthews, 1991).

In the first scheme (**Figure 2)**, the selection and dispersal of taro by humans began with starchy wildtypes that evolved and dispersed naturally within a range restricted to mainland Southeast Asia. This scheme followed the suggestion by Hotta (1983) (see also Hutterer, 1983), that root crops developed where species hibernated naturally in response to either seasonal dry periods or seasonal cold periods. It was thus assumed that starch was a target for the initial selection, use, dispersal, and cultivation of wild forms. In the second scheme (**Figure 3)**, selection and dispersal of taro by humans began with non-starchy wildtypes of wide natural occurrence, in tropical and warm temperate zones, respectively. In this case, it was suggested that starchiness increased in multiple areas of domestication, after breeding and selection in early farming systems, and specifically in early swidden systems or nursery plantings (Matthews, 1995). Such systems and plantings provide obvious opportunities for breeding among cultivar assemblages. Fallow gardens within the swidden cycle often include remnant plants that can be later reincorporated into active gardens, and during the fallow period, taro may breed, out of sight of the farmer.

In the many years since these two contrasting theories were proposed, new evidence has emerged concerning the economic uses of wild taro, the diversity and distribution of wild species of *Colocasia*, the ecological requirements for wild breeding populations of taro, and genetic relationships among *Colocasia* species.

Below, we highlight some of the recent evidence, leaving genetic data aside, and recommend a focus on commensal wild populations and naturalisation in order to define natural range limits, and learn about the evolution and domestication of *C. esculenta*.

The uses of wild taro (*C. esculenta)*

Among cultivated taros, two main morphotypes are recognised: var. *esculenta*, with a large edible main corm and few cormels, and var. *antiquorum*, with a small or medium-sized main corm and a large number of small cormels (Plucknett, 1983). A wide range of intermediate forms is also known, as well as forms in which stolons appear to have become shortened and enlarged. In contrast to the great diversity of cultivated forms, the vegetative morphology of wild taros in warm regions of Southeast Asia to Australia and Papua New Guinea is relatively uniform (Ivancic & Lebot, 2000; Matthews, 1991;1997; Matthews & Naing, 2005; Matthews et al., 2012). Most wild taros do not display swelling of the corm relative to the leaf-base diameter at the corm apex (thus leading to elongate shapes in larger plants), and the corms are often fibrous and watery (less-starchy). However, such differences in corm dimensions and starchiness have not been studied in detail under controlled conditions.

Although the corms of wild taros are generally considered by local people to be more acrid than those of cultivars, differences in acridity have also not been studied systematically. Acridity and starch production in wild taros are likely to vary according to both genotype and environmental conditions. Such variation may also be reflected in the different local uses of wild taros. Wild taro corms have been recorded historically as a useful but minor food, or as a famine food, in northern Australia (Scarlett, 1985; Matthews, 2014), Myanmar (Matthews & Naing, 2005), and southern Japan (Matthews et al., 1992), but not yet in Papua New Guinea (Matthews, 2014). In Australia and Papua New Guinea, the leaves and stolons of wild taro have not been reported as edible, but these parts are commonly eaten in China (Yang & Xu, 2000), Myanmar (Matthews & Naing, 2005), Philippines (Matthews et al., 2012), and Vietnam. Although the use of taro stolons is widespread, little has been reported regarding their variation, production, selection, utilisation, and nutritional value as vegetables.

In southern Japan (Matthews et al., 1992), Myanmar (Matthews & Naing, 2005), the Philippines (Matthews et al., 2012), and northern Vietnam (Matsuda & Nawata, 2002, Masuno et al., 2012), wild taro leaves are commonly cooked with other ingredients as a fodder for pigs. Use of wild taro (**Figure 1)** as 'a plain potherb for slaves and common people', and as pig fodder, was reported in eastern Indonesia in the 18th century (Rumphius, 2011). Since pig husbandry is ancient in Southeast Asia, it is likely that the use of wild taro as a fodder for pigs is an ancient and widespread practice.

In the Philippines, wild taro was previously reported as absent or derived from cultivated populations. Wild taro today is common in warmer and wetter regions of the archipelago, and is used extensively and intensively as leaf vegetable for human consumption (Matthews et al., 2012). This may largely explain the general absence of flowering during our surveys, since cutting the plant tops prevents inflorescences from developing. A wild breeding population has been found in only one area, in northwestern Luzon, where wild plants are mainly used as a source of edible stolons. These can be harvested without obviously interfering with the flowering cycle (there may be non-obvious physiological consequences).

In Australia and Papua New Guinea, the use of wild taro leaves as a vegetable for human consumption has not been reported. This may explain why flowering, fruiting and seed production can be easily observed in wild taro patches (Matthews, 1990; 1995; Price et al., 2008; Hunt et al., 2013).

For human consumption especially, the risk of encountering strong acridity may be the main factor that determines whether or not wild taros in a particular location or region are used and transplanted. Informants very often express concern about acridity when using wild taro corms, leaves, or stolons, and give various reasons for the occasional experience of acridity even after wild taro parts have been cooked (e.g., Matthews et al., 2012). Other less obvious anti-nutritional factors may also have contributed to whether or not wild taro plants were used in the past, and eventually domesticated (Matthews, 2010).

The widespread use of wild taro as a vegetable for human consumption, and as a fodder for pigs, was not known when the two models of domestication (above) were first proposed. The main difference between the two models is whether or not wild taros were widespread in Southeast Asia and the western Pacific before domestication, regardless of the manner of dispersal (natural, human transfer, or both). It is now clear that people can and do transplant both wild and domesticated taro into wild or disturbed habitats, for economic purposes, with or without interest in the use of corms for starch. At the same time, it is also clear that wild taros in tropical Asia and the Pacific can easily spread by natural means, through the production of sweet fruit that are attractive to birds and other animals.

Figure 4. *Colocasia formosana* Hayata from roadside at edge of forest, Mt Polis, Ifugao, Philippines, in 2011. The leaves display typical rounded shape with a relatively shallow sinus. Note fruiting heads at left, and young stolon emerging at right. The overall green colour and indeterminate stolon growth of *C. formosana* are also common in wild populations of *C. esculenta* (L.) Schott.

Figure 5. Fruit of wild *Colocasia formosana* Hayata, in Taiwan, 2008. The fruit of this species can be used as a bait to catch birds in simple spring-noose snares (Yuasa, 2000).

Hutterer (1983) and Matthews (1996) emphasized that the common distinction between 'wild' and 'cultivated' is not the same as the distinction between a wildtype (natural genotype) and domesticate (genetically modified through human selection). Cultivars can be wildtypes, and domesticates can enter wild habitats and become naturalised. Pollen and seed may disperse more-or-less freely between the different habitats. Wildtype plants can also be introduced to geographical areas outside their natural range, and then become naturalised. Nevertheless, in regions where wild breeding populations are present, an individual plant found in a wild breeding population can be regarded as a possible wildtype, and the likelihood of this being true increases when local people regard the plant as wild, or naturally-occurring, or as inedible, and if they give the wild plant a different name from the cultivated forms they are familiar with.

In our fieldwork in Southeast Asia and the Pacific, we have focused on collecting possible wildtype taros, and recording information on their uses, in order to:

(i) Compare genetic variation in different wild taro populations,

(ii) Compare genetic variation in wild and cultivated taros,

(iii) Look for correlations between usage and genotype among wild taros.

Wild populations that are not used, or are little-used, and that are genetically distinct from cultivated taros, are more likely to be naturally-occurring wild populations. Combining ethnobotanical and genetic data to characterise different wild taro populations, may eventually make it possible to distinguish naturally-distributed populations and those derived from cultivars through introduction and naturalisation.

Wild (non-cultivated) species of *Colocasia* are more diverse and widespread than previously thought

The genus *Colocasia* Schott is now believed to contain at least twelve and perhaps many more distinct species, all of which are found in humid to semi-aquatic habitats in Southeast Asia to southern China. The closely related genera *Ariopsis*, *Steudnera* and *Remusatia* include mainly shade-loving species (in the understorey of tropical forests), and are native to the Himalayan region, though their distributions may range further (Bown, 2000). The following list of wild *Colocasia* species (not complete) is illustrative for the present discussion. More than half the known species of *Colocasia* have been described within the last 20 years.

1. *C. affinis* Schott 1859, wild in Southeast Asia (including Northeast India), lower altitudes.

2. *C. boyceana* Gogoi and Borah 2013, wild in Arunachal Pradesh, Northeast India, at altitudes of 1200–1600 m.

3. *C. debangensis* Gogoi and Borah 2013, wild in Arunachal Pradesh, Northeast India, at altitudes of 1800–2200 m.

4. *C. fallax*, Schott 1859, wild in Northeast India.

5. *C. formosana* Hayata 1919, abundant and widespread in Taiwan, where it forms a morphologically homogeneous wild population and is not known as a domesticate; it is morphologically distinct, but minimally so, from wild *C. esculenta*.

6. *C. gaoligongensis* H. Li & C.-L. Long 1999, wild in high mountains, Yunnan, at 3,700 m asl.

7. *C. lihengiae* Long & Liu 2001 wild in mountains, northern Vietnam to Yunnan, China. The known range of this species was

recently extended to Arunachal Pradesh in Northeast India (Gogoi & Borah, 2013).

8. *C. menglaensis* Yin, Li & Xu 2004, wild in mountains, northern Vietnam to Yunnan, China.

9. *C. oresbia* Hay 1996, wild on Mt Kinabalu, Borneo, Malaysia (also in Bangladesh, according to Ara & Hassan, 2005).

10. *C. yunnanensis* Long & Cai 2006, wild in mountains, Yunnan, China.

The evolutionary origin of *C. esculenta* was previously considered to be somewhere in the vicinity of Northeast India, because that is where the greatest diversity of other wild *Colocasia* species was known (**Figures 2** and 3). Now we can see that wild *Colocasia* species are spread over a huge region, from India to southern China and Malaysia. Within the expanded region of known diversity in *Colocasia* species, further unknown species are likely to be located in steep and inaccessible mountain valleys at altitudes between 400 and 4,000 metres.

The diversification of *Colocasia* species in Himalaya may reflect gradual uplift of the mountain ranges, and repeated cycles of warmer and cooler climate, over many millions of years. As mountain populations became increasingly isolated, they may have given rise to new species. Somewhere in this mountain zone of speciation, *C. esculenta* may have evolved as a low-elevation plant adapted to warm, sunny, and constantly wet environments, in contrast to the cooler, shadier, drier, and more elevated environments occupied by most of its wild relatives. Although the full diversity of species in *Colocasia* is not yet known, recent fieldwork and genetic analyses (Ahmed, 2013; Ahmed et al,. 2013) suggests that three wild species may be of special significance for the evolution and domestication of *C. esculenta*, namely: *C. lihengiae* and *C. yunnanensis* (both sister species?) and *C. formosana* (a recently evolved species derived from taro?). In this paper, we give particular attention to *C. formosana*.

Wild breeding populations require warm and wet conditions, and insect pollinators

In experimental living taro collections that are not subject to harvesting, flowering is common. In temperate regions such as central Japan and northern New Zealand, floral development is quickly terminated by the arrival of cold winter conditions (Matthews, 1985; 1995; 2014), and require glasshouse heating and hand pollination for breeding experiments in central Japan (cf. Yoshino, 2002). The present authors have observed wild breeding populations, with fruit and seed production, in Papua New Guinea, northern Australia, Myanmar, northern Vietnam, northern Philippines, and northern India. In Papua New Guinea, seedlings are common on wet ground around the fruiting parent plants. When collected from ripe fruit, and planted immediately, taro seeds germinate after about two weeks at room temperature, when sown on wet soil in a covered container.

It is likely that the most sensitive stage in the life cycle is when young seedlings are first establishing roots, as the seedlings quickly die or become stunted if they experience drought under laboratory conditions. In tropical to subtropical regions, warm temperatures and continuously damp or wet ground conditions appear to be ideal for wild breeding populations. Young plants may grow slowly in shaded micro-environments near the parent plants, or wherever deposited by animal agents, but once established, it is likely that they can quickly take advantage of any available sunlight (for example, when a canopy gap exists or is created by vegetation disturbance). In laboratory experiments with taro seeds and seedlings, the rate of growth and size of taro seedlings can easily be controlled by restricting or increasing available nutrients and light (unpublished notes, Field Sciences Laboratory, National Museum of Ethnology). The young seedlings require only water and little light, but are very tolerant of low or high nutrient conditions, and low or high light conditions. When placed in fertile soil, in larger pots, with more light, the plants quickly increase in size. In wild taro patches, the flowering individuals are usually larger plants growing in sunny positions with deep soil.

Another important requirement for successful breeding by taro is the presence of more-or-less specialised insect pollinators. When *Colocasiomyia* spp. (Drosophilidae) were first observed on taro in Papua New Guinea and Southeast Asia, it was believed that they were very host-specific (Carson & Okada, 1980; Matthews, 2014). This may be true where wild plant populations and the insects have co-existed in a stable environment for long periods. However, when the host plants are moved into new environments by transplantation, or when the host plants naturally disperse and mix with other aroid taxa in disturbed habitats, ecological relationships between host plants and insect pollinators may change rapidly. It is now known that *Colocasiomyia* spp. are able to move between *Alocasia* spp. as host plants (Miyake & Yafuso, 2005), and here (Table 1) we report the presence on *Colocasia* spp. of *Colocasiomyia steudnerae*, which was first observed on *Steudnera* (Takenaka et al., 2006). When pollen are moved between different genera, sterile hybrid offspring may be produced like those described by Yoshino (2002). When pollen is carried between previously-isolated but closely-related species in the same genus, hybridisation might occur easily. If hybrid individuals become isolated from their parent species, and form a new breeding population, then a new species of hybrid origin may emerge. The causes and consequences of hybridisation are thus closely linked to pollen flow, plant dispersal, and any changes in environment that affect the relative fitness of parent and hybrid populations.

In northern Vietnam, while travelling by road from the lowlands to the mountain area of Sapa, and in the hills around Sapa, we collected *Colocasiomyia* samples at various altitudes from the inflorescences of *C. esculenta*, *C. lihengiae*, *C. menglaensis*, and *C. yunnanensis*. The associations found (Table 1) suggest that the diversity of pollinators is higher in the mountain zone where multiple wild species of *Colocasia* are present. However, the collecting region is a region where there has been both ancient and modern intrusion of farmers and settlements into the mountains, creating new opportunities for the expansion of existing wild *Colocasia* species, and also introducing *C. esculenta* as a cultigen into close proximity with those species. The full range of possible genetic interactions between the different host taxa, and between the different pollinator taxa, is unknown. With the insect pollinators present and able to follow the floral scents of different host plants, there may be a double-synergy of diversification in host plant populations and diversification in the pollinators. This is a clearly a region where much can be learned about the ecology and genetic potentials of wild and cultivated *Colocasia* species.

Table 1. Multiple species of *Colocasiomyia* (Drosophilidae) associated with *Colocasia* species in northern Vietnam. Samples collected by Matthews and Nguyen Van Dzu in 2012. Summary data based on initial identifications provided by M. J. Toda, Hokkaido University Museum.

Host *Colocasia* species	*Colocasiomyia* species identified			
	xenalocasieae	*alocasiae*	*steudnerae*	other spp.
C. esculenta	+	+	+	+
C. yunnanensis	+	-	+	+
C. lihengieae	+	-	+	+
C. sp. Mau Son	-	-	-	sp. 2 aff. *iskandari*
C. gigantea	+	+	-	+

Is *Colocasia formosana* Hayata a distinct species?

Japanese botanists who observed, collected, and first described *Colocasia formosana* Hayata (1919) in Taiwan in the early 20th century came from a country with no wild breeding population of taro, and a cultivar assemblage dominated by cool-adapted, triploid forms of *C. esculenta*. Most cultivars known to them in central or northern Japan would have displayed leaves with a dark-green upper surface and pale lower surface, together with starchy mother corms and many side-corms (i.e., the morphotype of *C. esculenta* var. *antiquorum*). From the cultivar assemblages of southern Japan and Taiwan, they may also have been familiar with plants producing large starchy corms and few side-corms (i.e. the morphotype of *C. esculenta* var. *esculenta*) (Plucknett, 1983). For them, wild *C. formosana* must have appeared very different from all the known cultivated forms of taro.

In recent years, the diversity of Japanese taro cultivars has been quite thoroughly described in morphological and genetic terms (Hirai et al., 1989; Matsuda 2002), and a wild form of taro, *C. esculenta* var. *aquatilis*, has been reported in Okinawa, southern Japan, where it is not known to breed (Hotta, 1970; Matthews et al., 1992). This plant is likely to have been introduced as an edible wild vegetable or as a fodder plant from Southeast Asia. Phenotypically similar wild taros are common throughout Southeast Asia, New Guinea, and across northern Australia, but are not uniform in their chloroplast DNA sequences (Ahmed, 2013). These wild taros often form breeding populations in wet open habitats, and are most abundant in the vicinity of human settlements. In terms of overall plant colour (green), and vegetative morphology (relatively small corms and long stolons), they are generally more similar to *C. formosana* in appearance than tropical and temperate cultivars, but their acridity and morphology do vary, across Asia and the Pacific, and remain to be compared systematically. In morphological terms, *C. formosana* is not clearly distinct from *C. esculenta*. In our experience, all traits described in the original species description (Hayata, 1919) lie within the range of variation of *C. esculenta*.

Recently, we have discovered a small number of apparently isolated populations of *C. formosana* in wet mountainous regions of Luzon, in the northern and central Philippines (**Figure 4)**. In both Taiwan and the Philippines, *C. formosana* is known to be very acrid, and is generally not regarded as an edible wild vegetable, though methods for preparing the plant to make it edible are known. Detailed studies of the ethnobotany of this species are needed, but already it appears to be a much less useful plant than wild *C. esculenta*, which is so widely used as a vegetable and fodder plant in Southeast Asia (see above).

The populations of *C. formosana* found until now, in Taiwan and the Philippines, appear homogeneous in colour and general morphology, and are readily recognised in the field because of a very rounded leaf blade with shallow sinus. All inflorescences seen on plants in the Philippines and Taiwan have a long sterile appendage, like that found on the original type specimen from northern Taiwan, and the proportions of different parts of the spadix are quite uniform. Fruit colour in wild *C. esculenta* varies from bright orange/red in Myanmar (Matthews & Naing, 2005) to a yellowish-brown colour in Papua New Guinea (Price et al., 2008). Fruit colour in *C. esculenta* generally (including wild and cultivated forms) ranges from green to orange and purple (Ivancic & Lebot, 2000). Thus, the bright orange/red fruit colour of *C. formosana* (**Figure 5)** is not a distinguishing trait, though it is consistent within the species.

The northern distribution of *C. formosana* in island Southeast Asia hints at a natural presence of the species in southern China, and dispersal eastwards from there, following or before a split from *C. esculenta*, or within *C. esculenta*. The northern distribution also lends support to the model of wide natural range (for *C. esculenta*) as suggested in **Figure 3,** assuming that *C. formosana* is derived from *C. esculenta*. A genetic bottleneck, in *C. esculenta* or *C. formosana,* could have arisen during long distance dispersal from a mainland source region, and/or increasing isolation in Taiwan as a result of rising sea level and changing climate (during the late Pleistocene, for example). Genetic comparisons of the known populations in Taiwan and the Philippines might provide evidence for movement of *C. formosana* from west to east, from Taiwan to the Philippines.

Naturalisation and crop domestication

It is difficult to investigate the natural history, domestication, and dispersal of taro, when so many uncertainties remain in the basic description of closely-related species and their distributions. Where did *C. esculenta* originate as a natural biological species, and how many species are really encompassed by the current taxonomic concept of *C. esculenta*? Most wild species of *Colocasia*, and especially those that have been described only recently, are known from relatively few locations. Future exploration to map these species in wet monsoonal regions of Asia might also reveal further new species of *Colocasia*, and these might include new candidates for involvement in the domestication of taro. The optimal search space for *Colocasia* as a genus is gaining definition, and predictive mapping methods can be developed and used for the genus as a whole, and for particular known species.

On morphological grounds it is difficult to support *C. formosana* as a species separate from *C. esculenta*, but since *C. esculenta* is itself poorly circumscribed, we cannot reject *C. formosana* without further study. In the future, when wild populations of *C. esculenta* are better known, it may be necessary and possible to split *C. esculenta* into multiple species, or subspecies, based on wildtypes of defined natural range rather than basing the taxonomy on a mix of wild and cultivated forms with poorly known distributions. This brings us back to the problem of how to recognise wildtypes in a species, or species-complex, when the plants can easily naturalise and perhaps hybridise. A broad answer to this conundrum is that we must integrate ethnobotanical, ecological, and genetic approaches to the study of the genus and its species.

In particular, our priorities should be: (i) Systematic comparison of different wild populations of taro (*C. esculenta*), within the full range of wild species of *Colocasia*. Of special interest are the genetic relationships between wild and cultivated taro in lowland to mountain habitats in Asia and the western Pacific. (ii) Genetic testing for introgression and hybridisation among wild *Colocasia* species, including *C. esculenta*, during the evolution and domestication of taro. (iii) Ecological study of seed production, dispersal and germination, and also the distribution, host range, habitat requirements, and diversity of insect pollinators, in order to understand how seed dispersal and pollination may limit or promote hybridisation and speciation in the genus *Colocasia*. (iv) Ethnobotanical study of the uses and management of wild taro (*C. esculenta*) and other wild *Colocasia* species that may have been involved in the evolution and domestication of taro. This, along with the ecological approaches, will help us to understand the role of commensal and naturalised populations in the historical development and domestication of the crop.

It may be no exaggeration to say that for 99% of living crop species, there has been little or no consideration of how human activities might have extended the geographical range of wild populations, or of naturalisation as a long-term historical process. Ignoring the problem of how to recognise natural range is convenient for biological studies, because it simplifies the interpretation of genetic variation in wild populations, and comparison between wild forms and cultivars. For understanding crop history, however, this problem must be faced directly. Plant taxonomists have nevertheless helped circumscribe the problem through their studies on aroid taxonomy and the genus *Colocasia* in particular. Knowing more about the wild species of *Colocasia* makes it easier to recognise the outer limits of diversity within *C. esculenta*, which in turn makes it possible to define geographical limits for the species as a whole.

To recognise and locate the genetic and geographical origins of cultivated taro, we must continue looking for ways to recognise and map natural wild populations in this species. This work is difficult because it requires the combined efforts of many researchers, in collaboration with diverse local communities, using diverse local languages. The work is also difficult because natural wild populations can also have economic significance, which makes it impossible to exclude the possibility of a human role in their biological history.

In Southeast Asia, the uses of wild taro as food and fodder are significant contemporary economic activities. They are likely to have started long before domestication of the crop. They also link the history of taro to the history and domestication of pig, itself an important component of economic history in Southeast Asia. Range extension to new habitats and new regions, and naturalisation in new habitats (e.g. ruderal habitats in cleared land) and new regions (outside the true natural range), could be central to domestication in taro, in terms of the process, without necessarily being central in terms of the geography.

Naturalisation is a process that can create new breeding populations that are to some degree isolated from natural wild populations with undesirable traits. In crosses between selected (favoured) cultivars and wild taros in any given area, the offspring are likely to be poor and not favoured, unless people are in the habit of using the particular wild parent plants involved, or existing cultivars are not much different from the wild plants (as might be the case during an early period of domestication), or the wild plants belong to a population derived from cultivated forms, through naturalisation.

In the last case, the naturalised population might consist of a mixture of clones derived from cultivation, and their sexual offspring, thus retaining the favoured traits of parent cultivars, or producing new combinations that are potentially superior to those of the parents. In modern breeding trials in Papua New Guinea, using wild taro as a source of disease resistance was very difficult because the genetic basis of resistance was not easily separated from undesirable qualities introduced from wild parents that may have been natural wildtypes. Even with deliberate backcrossing, assessment, and selection, it was difficult to produce acceptable new cultivars using unscreened wild parent plants (Ivancic & Lebot, 2000).

Naturalisation as a central focus for research

In many areas of Southeast Asia, including the Philippines and Vietnam, naturalised populations derived from cultivated taro are likely to be the main sources of wild taro as a food and fodder plant. Since ancient times, such populations might have been important for the generation of new cultivars, including cultivars resistant to pests and diseases. Commensal wild populations present in and around human settlements may or may not be naturalised, or deliberately spread. This uncertainty is not a reason to ignore them as 'invasive weeds', or too difficult to study, or of secondary historical importance. Over thousands of years, naturalised populations may have had central and continuing roles in the primary and secondary domestication of taro. Defining the natural range of taro (**Figures 2 and 3**) is a necessary challenge for evolutionary study of the species, and has helped bring the process of naturalisation into focus. To develop more realistic models for the evolution and domestication of taro, and many crops, it may help to make naturalisation a central focus of research. Further taxonomic and ethnobotanical studies will also help in the development of models that embrace commensal wild populations and naturalisation. The phenomenon of natural wild populations becoming 'denaturalised' or commensalized, as they spread by natural dispersal into human environments, is also of interest. This can be seen in Taiwan, where *C. formosana* has been found (in just one location, to date) in an agricultural lowland near forested mountains.

ACKNOWLEDGMENTS

Special thanks to M. J. Toda, Hokkaido University Museum, Japan, for insect identifications, I. Ahmed, for research discussions, W. Wilfredo, Department of Botany, National Museum, for field support in the Philippines, T. Masuno, Graduate University of Advanced Studies, Japan, for field support in Vietnam, and E. Tabuchi, National Museum of Ethnology, for technical assistance. Recent fieldwork in Taiwan was assisted by K. C. Tsai. This paper was prepared under academic agreements between the National Museum of Ethnology, Japan, and the National Museum, Philippines (2012–2017), and the Institute for Ecology and Biological Resources, Vietnam (2012–2017). The research was supported in part by JSPS KAKENHI Grant No. 23405004, Japan.

REFERENCES

Ahmed, I. 2013. *Evolutionary Dynamics in Taro (*Colocasia esculenta *L.). Ph.D. thesis*, Massey University, Palmerston North.

Ahmed, I., P. J. Matthews, P. J. Biggs, M. Naeem, P. A. McLenachan, P. J. Lockhart. 2013. Identification of chloroplast genome loci suitable for high-resolution phylogeographic studies of *Colocasia esculenta* (L.) Schott (Araceae) and closely related taxa. *Mol. Ecol. Resour.* 13: 929– 937.

Bown, D. 2000. *Aroids: Plants of the Arum Family*. Timber Press: Portland.

Carson, H. L. & T. Okada. 1980. Drosophilidae associated with flowers in Papua New Guinea: I. *Colocasia esculenta*. *Kontyu, Tokyo* 48: 15–29.

Hasskarl, J. K. 1848. *Plantae javanicae rariores, adjectis nonnullis exoticis, in Javae hortis cultis descriptae,* Berolini: Sumptibus A. Foerstner.

Hay, A. 1998. *Botanical varieties in taro,* Colocasia esculenta*: leaving old baggage behind.* Commissioned report. C02C/98/038. Sydney.

Hayata, B. 1919. Colocasia formosana *Icones plantarum formosanarum nec non et contributiones ad floram formosanam* 8: 133–134, f. 60.

Hirai, M., T. Sato & K. Takayanagi. 1989. Classification of Japanese cultivars of taro (*Colocasia esculenta* (L.) Schott based on electrophoretic pattern of tuber proteins and morphological characters. *Jap. J. Breed.* 39: 307–317.

Hotta, M. 1970. A system of the Family Araceae in Japan and adjacent areas, Part I. *Memoirs of the Faculty of Science, Kyoto University Series of Biology 4*(1): 72–96.

Hotta, M. 1983. Taxonomy and origin of root crops in East Asia. *The Search for Japanese Culture: the Origins of Japanese Agriculture.* K. Sasaki. NHK Publication Association, Tokyo: pp. 18–42 (in Japanese).

Hubbard, F. T. & A. Rehder. 1932. Nomenclatorial notes on plants growing in the botanical garden of the Atkins Institution of the Arnold Arboretum at Soledad, Cienfuegos, Cuba. *Botanical Museum Leaflets* 1: 1–11.

Hunt, H. V., H. M. Moots, & P. J. Matthews. 2013. Genetic data confirms field evidence for natural breeding in a wild taro population (*Colocasia esculenta*) in northern Queensland, Australia. *Gen. Resour. Crop Evo.* 60: 1695–1707.

Hutterer, K. L. 1983. The Natural and Cultural History of Southeast Asian Agriculture. *Anthropos* 78: 169–212.

Ivancic, A. & V. Lebot. 2000. *The genetics and breeding of taro.* CIRAD, Monpellier.

Masuno, T., D. N. A. Luu, V. D. Nguyen, & P. J. Matthews. 2012. Fodder sources and backyard pig husbandry in BaVi, Hanoi province, northern Vietnam. In A.-N. 2012 (Ed.), *Proc. of the 1st International Conference on Animal Nutrition and Environment,* Khon Kaen University Press, Khon Kaen, pp. 657– 660.

Matsuda, M. 2002. Taro in Japan, and its Dispersal in East and Southeast Asia. In S. Yoshida & P. J. Matthews (eds) *Vegeculture in Eastern Asia and Oceania,* Japan Center for Area Studies, Osaka, pp. 117–134.

Matsuda, M. & E. Nawata. 2002. Taro in northern Vietnam: its uses, cultivation, and genetic variation. *Japanese Journal of Tropical Agriculture* 46: 247–258.

Matthews, P. J. 1985. Nga taro o Aotearoa. *Journal of the Polynesian Society* 94: 253–272.

Matthews, P. J. 1987. Wild taro and the context of cultivation. *Aroideana* 10: 9– 13.

Matthews, P. J. 1990. *The Origins, Dispersal and Domestication of Taro*. Unpublished PhD thesis, The Australian National University, Canberra.

Matthews, P. J. 1991. A possible tropical wildtype taro: *Colocasia esculenta* var. *aquatilis*. *Bulletin of the Indo-Pacific Prehistory Association* 11: 69–81.

Matthews, P. J., E. Takei, & T. Kawahara. 1992. *Colocasia esculenta* var. *aquatilis* on Okinawa Island, southern Japan: the distribution and possible origins of a wild diploid taro. *Man and Culture in Oceania* 8: 19–34.

Matthews, P. J. 1995. Aroids and the Austronesians. *Tropics* 4: 105–126.

Matthews, P. J. 1996. Ethnobotany, and the origins of *Broussonetia papyrifera* in Polynesia (an essay on tapa prehistory). In: J. M. Davidson, G. Irwin, B. F. Leach, A. Pawley, D. Brown (eds) *Oceanic Culture History: Essays in Honour of Roger Green*. New Zealand Journal of Archaeology Special Publication, Wellington, pp. 117–132.

Matthews, P. J. 1997. Field guide for wild-type taro, *Colocasia esculenta* (L.) Schott. *Plant Genetic Resources Newsletter* No. 110: 41–48.

Matthews, P. J. 2002. Taro storage systems. In S. Yoshida & P. J. Matthews (eds.) *Vegeculture in Eastern Asia and Oceania* JCAS Symposium Series 16. Japan Center for Area Studies, Osaka, pp. 135–163.

Matthews, P. J. 2003. Taro planthoppers (*Tarophagus* spp.) in Australia and the origins of taro (*Colocasia esculenta*) in Oceania. *Archaeology in Oceania* 38: 192–202.

Matthews, P. J. 2006. Written records of Taro in the Eastern Mediterranean. In: Z. F. Ertug (ed) *Proceedings of the Fourth International Congress of Ethnobotany (ICEB 2005)*, Yayinlari, Istanbul, pp. 419–426.

Matthews, P. J. 2010. An introduction to the history of taro as a food. In V. R. Rao, P. J. Matthews, P. B. Eyzaguirre and D. Hunter (eds) *The Global Diversity of Taro: Ethnobotany and Conservation.* Bioversity International, Rome, pp. 6–30.

Matthews, P. J. 2014. *On the Trail of Taro: An Exploration of Natural and Cultural History.* National Museum of Ethnology, Osaka.

Matthews, P. J., E. Takei and T. Kawahara 1992. *Colocasia esculenta* var. *aquatilis* on Okinawa Island, southern Japan: the distribution and possible origins of a wild diploid taro. *Man and Culture in Oceania* 8: 19– 34.

Matthews, P. J. & K. W. Naing. 2005. Notes on the provenance and providence of wildtype taros (*Colocasia esculenta*) in Myanmar. *Bulletin of the National Museum of Ethnology* 29: 587–615.

Matthews, P. J., E. M. G. Agoo, D. N. Tandang & D. A. Madulid. 2012. Ethnobotany and Ecology of Wild Taro (*Colocasia esculenta*) in the Philippines: Implications for Domestication and Dispersal. In M. Spriggs, D. Addison, & P. J. Matthews (eds) *Irrigated Taro (Colocasia esculenta) in t he Indo-Pacific.* Senri Ethnological Studies 78. National Museum of Ethnology, Osaka, pp. 307–340.

Miyake, T. & M. Yafuso. 2005. Pollination of *Alocasia cucullata* (Araceae) by two *Colocasiomyia* flies known to be specific pollinators for *Alocasia odora. Plant Species Biology* 20: 201–208.

Orchard A. E. 2006. Infra-specific variation in *Colocasia esculenta* (L.) Schott (Araceae). *Australian Systematic Botany Society Newsletter* 129: 2-5.

Plucknett, D. L. 1983. Taxonomy of the Genus *Colocasia*. In J.-K. Wang (ed) *Taro: A Review of* Colocasia esculenta *and its Potentials.* University of Hawaii Press, Honolulu, pp. 14–33.

Price, T. V., K. Poka & G. Bogarei.(2008. Observations on the liberation, dispersal and germination of taro seed (*Colocasia esculenta*) under natural conditions in Papua New Guinea. *Aroideana* 31: 134–143.

Rumphius, G. E. (1741–50) [2011] *The Ambonese Herbal.* Translated, annotated and introduced by E. M. Beekman. Yale University Press: New Haven, CT [originally published in Amsterdam by Apud Fransicum Changuion, Joannem Catuffe, Hermannum Uytwerf].

Scarlett, N. H. 1985. *A preliminary account of the ethnobotany of the Kija people of Bungle Bungle outcamp.* East Kimberley Working Paper No. 6. Botany Department, La Trobe University, Bundoora.

Spencer, R., R. Cross & P. Lumley. 2007. *Plant names: A guide to botanical nomenclature.* CSIRO Publishing, Collingwood.

Takenaka, K., J.-T. Yin, S.-Y. Wen & M. J. Toda. 2006. Pollination mutualism between a new species of the genus *Colocasiomyia* de Meijere (Diptera: Drosophilidae) and *Steudnera colocasiifolia* (Araceae) in Yunnan, China. *Entomological Science* 9: 79–91.

Yang Y. and J. Xu, 2000. Ethnobotanical studies of taro, *Colocasia esculenta* (L.) Schott, in Yunnan, China. In: D. Zhu, P. B. Eyzaguirre, M. Zhou, L. Sears, G. Liu (eds) *Ethnobotany and genetic diversity of Asian taro: focus on China.* IPGRI Office for East Asia, Beijing, pp. 6–11.

Yoshino, H. 2002. Morphological and Genetic Variation in Cultivated and Wild taro. In S. Yoshida and P. J. Matthews (eds) *Vegeculture in Eastern Asia and Oceania*. Japan Center for Area Studies, Osaka, pp. 95–116.

Yuasa, H. 2000. *Segawa's Illustrated Ethnography of Indigenous Formosan People: The Tsou.* Moritani and Co., Tokyo.

Genetic diversity and phylogenetic relationships among *Colocasia* species (Araceae) in Vietnam using SSR markers

Viet Xuan Nguyen
Hanoi National University of Education (HNUE), Vietnam

Dang Thi Thanh Mai
Bacninh teacher training College, Bacninh, Vietnam

Ngo The Anh
Lang Son Province Department of Education and Training

ABSTRACT

This study addresses the phylogenetic relationship between *Colocasia* species by microsatellite markers (SSRs). The plant materials of this study consisted of a total of 36 accessions belonging to ***C. esculenta, C. gigantea, C. lihengiae, C. menglaensis*** **and two accessions of** ***Alocasia odora*** **(Roxb.) C. Koch.** Seven SSR primer combinations produced a total of 97 alleles. The number of alleles per marker ranged from 6 to 18 alleles, with an average of 10.57 alleles per marker. The highest value of PIC found for SSRs was 0.93 and the lowest was 0.64, with a mean value of 0.77. A total of 68 polymorphic alleles with an average of 9.7 alleles per marker, and the highest value of PIC range from 0.8 to 0.6, with a mean value of 0.70 observed in the accessions of *C. esculenta*. Unweighted pair group method based on arithmetic average (UPGMA) analysis was performed on jaccard's similarity coefficient matrix. According to the results, two main clusters were developed and ***C. esculenta,*** **and** ***C. gigantea*** located in the first main cluster (A). **Three wild taro species** localized in second main cluster (B). According to this study, the closest species to ***C. esculenta*** was *C. gigantea*. UPGMA analysis separated ***C. lihengiae*** and ***C. menglaensis*** from ***C. esculenta***. This study revealed that ***C. lihengiae*** is similar to ***C. menglaensis,*** distinct from ***C. gigantea***; and showed a closer genetic similarity to ***Alocasia odora*** than the *C. esculenta*.

KEY WORDS

SSRs, Genetic diversity, Phylogeney, *Colocasia*, *Alocasia, Vietnam*

1. Introduction

The genus *Colocasia* of the family Araceae in Vietnam includes four species. Two species, *C. esculenta* (L.) Schott and *C. gigantea* (Blume) Hook. F., are cultivated (Pham Hoang Ho, 1993) and two wild species are *Colocasia lihengiae* C.L.Long & K.M.Liu and *Colocasia menglaensis* J.T. Yin, H. Li & Z.F. Xu (Nguyen et al., 2003).

Taro *Colocasia esculenta* (L.) Schott ("Khoai Mon" or "Khoai So" or "Mon Nuoc") is a native crop and was planted early, around 10.000 to 15.000 years ago. It is the most widely cultivated all over Vietnam. More than 450 taro accessions were maintained as a national taro collection at the Plant genetic resources (PRC), Vietnam Academy of Agricultural Sciences (VAAS). The genetic diversity of this taro germplasm was evaluated using the morphological characters (Nguyen et al., 2010), karyotype and isozyme variation (Tahara et al., 1999; Nguyen et al., 2003) and RADP markers (Dang et al., 2012). The study on genetic relationships, however, among species in the genus *Colocasia* and related taxa is not still being carried out.

Two wild species, *Colocasia lihengiae* and *Colocasia menglaensis,* are similar in morphological characters, and it was even difficult to determine whether they belonged to *Colocasia* or *Alocasia* (Long at al., 2001; Nguyen V. D. & Nguyen X. V., 2003). Molecular approaches may reveal phylogenetic relationships among *Colocasia* species and with other close taxa.

Microsatellites, or simple sequence repeats (SSRs), which combine co-dominance, high polymorphism and good genome coverage, have proven to be particularly useful for the analysis of genetic diversity and phylogenies. They have also been capable of discriminating closely related individuals (Hu Kan et al., 2009). Reports confirm the successful use and application of SSRs in taros (Mace et al., 2002; Singh et al., 2008; Hu Kan et al., 2009). The present paper reports the genetic diversity and relationships among *Colocasia* species in Vietnam based on the SSR markers, the effectiveness of SSR markers in determining the *Colocasia* species and for the molecular taro germplasm characterization.

2. Materials and methods

2.1. Plant material and molecular markers

Seven microsatellite primer pairs were used for molecular characterization of accessions (Table 1).

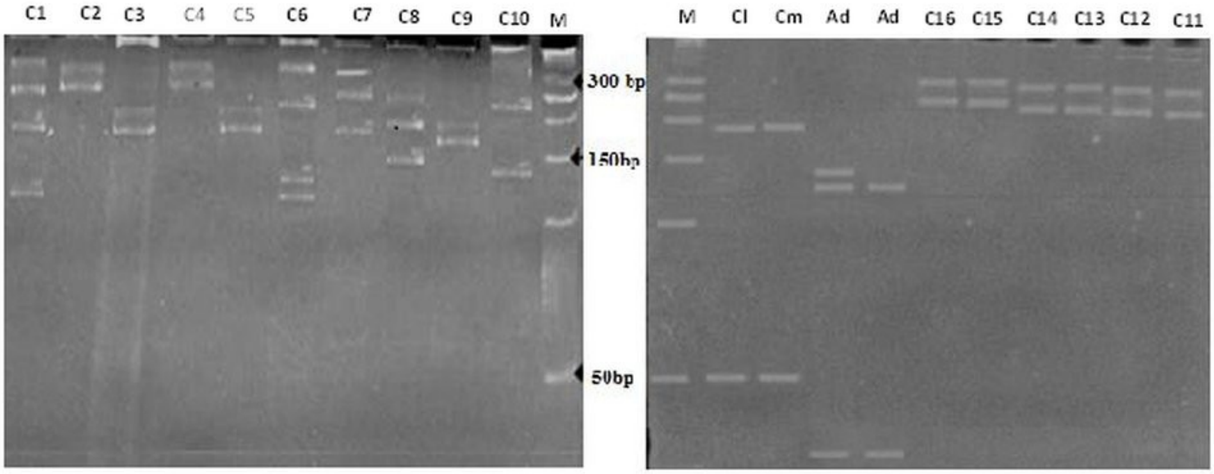


Figure 1. The markers generated by the seven primer pairs used were polymorphic and allowed the identification of total number of 97 alleles

Table 1. Seven SSR primers used along with the type of tandem and their temperature melting value

SSR ID	Repeat motif	Primer sequence (5'-3')	Annealing temp.
Xuqtem73	(CT)15	Fwd:ATGCCAATGGAGGATGGCAG Rvs:CGTCTAGCTTAGGACAACATGC	55
Xuqtem55	(CAC)5	Fwd: CTTTTGTGACATTTGTGGAGC Rvs: CAATAATGGTGGTGGAAGTGG	57
AC3	(GT)8(AG)9	Fwd: AGTGGCATAATGGAGGA Rvs: CACTAACGACGACCCAC	57
HK22	(AG)18	Fwd: CATAAACCTCTGGTGGGC Rvs: AGCAATCCTAGCCGAGGTG	57
HK31	(GT)6(GA)11	Fwd: TACCGCCGAGTGCTTATC Rvs: TACGGCTGGAATCAAAGC	55
HK34	(AG)29	Fwd:TACTCCAAACGAGGCAAAC Rvs: CTTAAGATGTTACCAAATGC	59
HK38	(AG)12	Fwd: AAACGCGGCCAGAAGATC Rvs:GAATAGCGGAACAAGGTAGA	62

A total of 36 accessions of *Colocasia* and *Alocasia* were used to investigate the level of polymorphism by the microsatellites. The thirty-two accessions of *C. esculenta* used are from the taro germplasm collections maintained at the Plant Resources Centre of Vietnam, and were selected based on the RADP patterns (Dang and Nguyen, 2012). The other accessions were collected from mountain provinces of Northern Vietnam. Five microsatellite primer pairs (AC3, KH22, HK31, HK34 and HK38) developed by Kan Hu et al. (2009) and the other two primer pairs (Xuqtem 73 and Xuqtem55) developed by Singh et al. (2007) were constructed for amplification of satellite genomic regions.

2.2. DNA extraction and PCR analysis

Total DNA was extracted from 100 mg of young leaves using the CTAB buffer according to Doyle and Doyle (1990) with some modification.

2.3. Polymerase chain reaction

DNA amplifications were carried out in 15 μL reaction mixtures containing 50 ng/μL template DNA, 15mM of each forward and reverse primer, 0.1 mM of each dNTP, 2.5 mM $MgCl_2$, 0.5 U T*aq*-DNA polymerase using the following PCR profile in a Eppendorff Mastercycler personal machine: initial denaturation at 94°C for 5 min, followed by 35 cycles of 94°C for 45s, optimal annealing temperature (ranging from 55 to 62°C) for 1 min, elongation 72°C for 2 min, and a single extension at 72°C for 10 min.

The amplification products were separated in a 6% denaturing polyacrylamide gel. The gels were stained in 0.5% ethidium bromide then exposed on UV-LM20. Molecular size of the DNA fragments was estimated by comparison with the standard 50 bp DNA ladder (Fermentas).

2.4. Data analysis

The number of alleles per locus and their frequency were estimated. The polymorphic information content (PIC) values were calculated (Lynch & Walsh, 1008).

For genetic diversity and phylogenetic relationship determination, all gels were scored in a binary format where the presence of a band was 1 and the absence was 0. Similarity matrices (SM) were calculated from these data based on Jaccards coefficient (Jaccard, 1908). The percentage of polymorphism obtained with each primer was calculated from this matrix. Cluster analyses were performed using the unweighted pair-group method with arithmetic averages (UPGMA) and Neighbor joining procedures. The previously mentioned data analyses were done using NT-SYSpc, version 2.11x.

3. Results and discussion

The markers generated by the seven primer pairs used were polymorphic and allowed the identification of total number of 97 alleles (Table 2, **Figure 1)** in the accessions analyzed. The number of alleles per marker ranged from 6 to 18 alleles, with an average of 10.57 alleles per marker. The highest value of PIC found for SSRs was 0.93 (HK22) and the lowest was 0.64 (HK31), with a mean value of 0.77.

Table 2. The primers used in this study along with the number of alleles, polymorphic information content (PIC) and allele size ranges

SSR primer	Alleles	PIC	Allele size range (bp)
AC3	7	0.75	50 – 280
HK31	8	0.64	50 – 260
Xu73	14	0.81	50 – 240
HK38	8	0.74	60 – 200
HK22	18	0.93	30 – 400
HK34	13	0.83	100 – 500
Xu55	6	0.71	30 – 180
Average	74	0.77	

In the taro cultivated accessions (*C. esculenta*), there is a total of 68 polymorphic alleles were detected from seven SSR markers with an average of 9.7 alleles per marker. The number of alleles per marker ranged from 6 to 14. The highest number of alleles was observed for the microsatellites HK34 and the lowest was Xu55. The highest value of PIC found for SSRs was 0.802 (HK34) and the lowest was 0.603 (HK31), with a mean value of 0.70.

The high percentage of polymorphic SSRs markers and the allele average (9.7/per marker) detected in this study was consistent with previous studies (Sardos et al, 2012) which reported 89 alleles amplified from 9 SSR primer pairs, and the number of polymorphic alleles range from 6 to 17 with an average of 9.89 in 344 taro accessions of Vanuatu. Our results is higher than that reported by Mace and Godwin (2009) in taro from Southeast Asia and Oceania (3.2 alleles/marker), or 4.3 alleles per marker detected by Singh et al. (2008).

The dendrogram created using the SM coefficient and UPGMA clustering showed that the accessions of the five species were clustered in two main groups (**Figure 2)**.

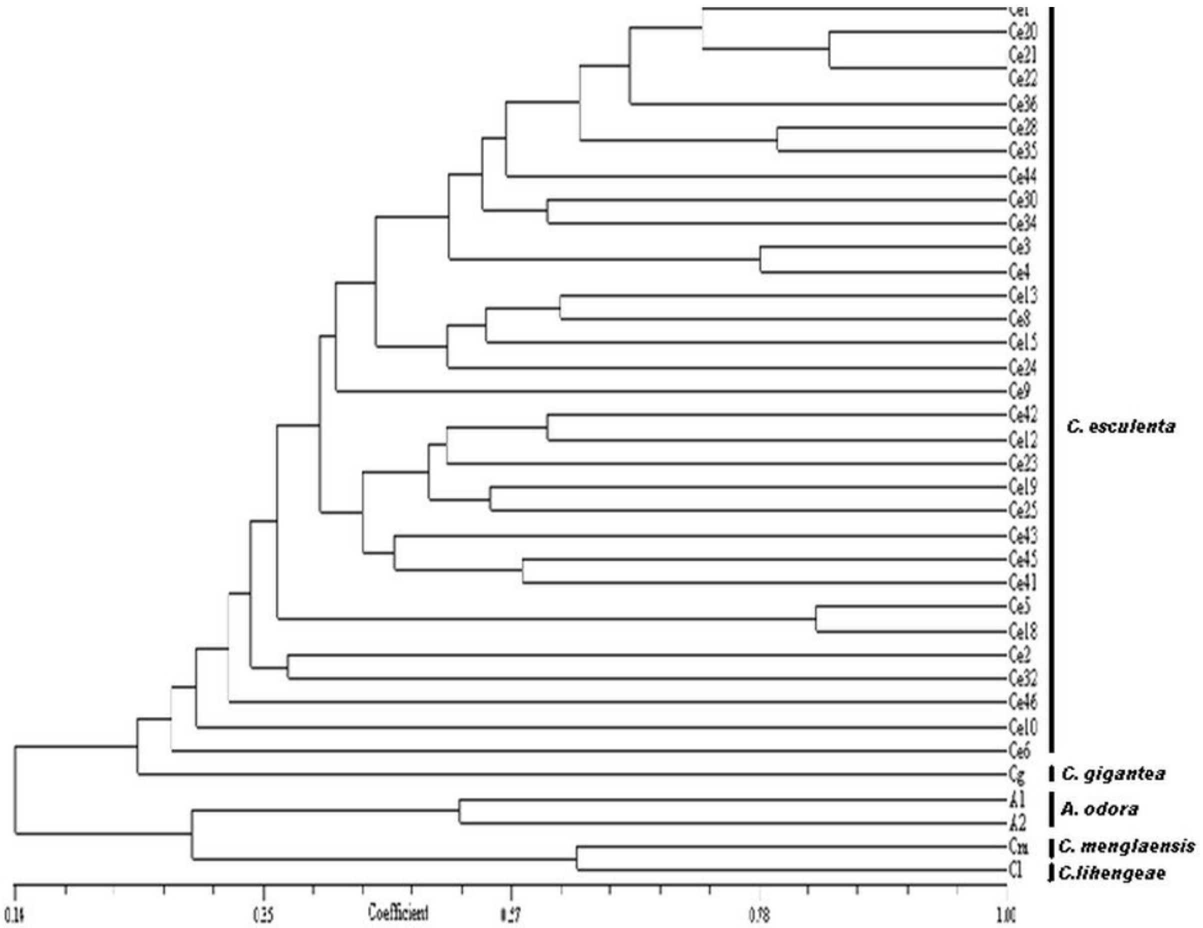


Figure 2. Dendrogram illustrating genetic similarity among 32 *Colocasia esculenta*, 1 *C. gigantea*, 1 *Colocasia lihengiae*, 1 *Colocasia menglaensis* and 2 *Alocasia odora* accessions generated by UPGMA cluster calculated from 7 SSR markers.

Group A included accessions of cultivated taro belong to species *Colocasia esculenta* and *C. gigantea*, whereas group B included the remaining accessions comprising wild taro species, *C. menglaensis* and *C. lihengiae,* and *Alocasia odora*. Furthermore, each group was subdivided in two subgroups: subgroup A1 included accessions of *C. esculenta* while *C. gigantea fell* into subgroup A2. Group B was divided into subgroup B1 including two accessions of the species *A. odora,* and subgroup B2 including the wild taro species (*C. lihengiae* and *C. menglanensis*).

The dendrogram obtained from the UPGMA analysis based on the SSRs data from seven primer pairs showed that the two taro wild diploid species, *Colocasia* *lihengiae* and *C. menglaensis*, clustered in the B group together with the species of *Alocasia*, seems to be genetically distant from the cultivated species *C. esculenta*.

Our finding from SSRs markers in this study confirmed the close relationship between *C. lihengiae* and *C. menglaensis*. These two species are reported as new species from China and Vietnam (Long and Liu, 2001; Yin et al., 2004; Nguyen, 2003; 2005), and the *C. menglaensis* is fairly similar to *C. lihengiae* (Yin et al., 2004)]. *Colocasia lihengiae* and *C. menglaensis* were clustered together in chloroplast DNA analysis, and *C. lihengiae* is very close to *C. esculenta* (Ahmed et al., 2013). Our results, however, showed that these two species seemed closely related to *Alocasia sp.* rather than to the *C. esculenta*. On the dendrogram, they along with subgroup of *A. odora* clustered in the same group B, and this observation is in agreement with results presented on the close relationship between *C. lihengiea* and *C. menglaensis* species using RADP analysis (Dang et al., 2012).

C. lihengiae with long stolons and large leaf blades, and with inflorescences lacking an appendix, was difficult to determine as belonging to *Colocasia* or *Alocasia* (Yin et al., 2004). The level of similarity based on the SSR analysis was considered a better indicator of genetic similarity than the morphological characterization. And it may reveal phylogenetic relationships between *Colocasia species* and others of *Alocasia*.

According to the number of alleles and polymorphic information contents the genetic polymorphism and grouping for the taro accessions with seven SSR markers (Dang & Nguyen, 2014), indicated that these markers were capable of generating sufficient information to ensure their use to establish genetic relationships among closely related materials.

Summarizing our findings, based on the SSR primer pairs used, the following are evident: The seven SSR markers seemed to be efficient to evaluate genetic diversity among taro accessions. These SSRs can be used to translate the genetic differences and to resolve the difficulties of determining closely related *Colocasia* species. *Colocasia lihengiae* and *C. menglaensis* share a close genetic similarity and seemed very closely related to *Alocasia odora*.

REFERENCES

Ahmed, I., P. J. Matthews, P. J. Biggs, M. Naeem, P. A. McLenachan, P. J. Lockhart 2013. Identification of chloroplast genome loci suitable for high-resolution phylogenetic studies of *Colocasia esculenta* (L.) Schott and closely related taxa. *Mol. Ecol. Resourc.* 13: 929–937.

Dang T.T.M & V.X Nguyen. 2012. Analysis of genetic diversity in taro, *Colocasia esculenta* (L.) Schott, and related species using RADP markers. *Proc. 1st national scientific conference on biological research and teaching in Vietnam*. Agriculture publishing house: 611–619.

Dang T.T.M & V.X. Nguyen . 2014. Assessment of genetic diversity of taro (*Colocasia esculenta* (L.) Schott using SSR markers. *Vietnam J. Agricult. & Rural Developm.* 16: 10–16.

Hu Kan, Xing Fang Huang, Wei Dong & Yi Ding. 2009, Characterization of 11 microsatellite loci in taro (*Colocasia esculenta*), *Mol. Ecol. Resour.* 9: 582–584.

Long C. L. & K. M. Liu 2001. *Colocasia lihengiae*, a new species from China. *Bot. Bull. Acad. Sin.* 42: 313–317.

Mace E.S. & I.D. Godwin 2002. Development and characterization of polymorphic microsatellite markers in taro (*Colocasia esculenta*). *Genome* 45(5):823–832.

Nguyen V.D. & V.X. Nguyen. 2003. A new record of *Colocasia* discovered in Vietnam. *Proc. 2nd national conference in life sciences.* Science and technics publishing house: 66–68 (in Vietnamese).

Nguyen Thi Ngoc Hue, Nguyen Van Viet, Vu Linh Chi & M.S Prana. 2010. Taro germplasm collection in Vietnam. In *The Global diversity of taro: Ethnobot. Conserv.*: 60–68.

Nguyen V.X. 2003. Karyotype analyses on diploid, triploid and tetraploid of *Alocasia odora* (Roxb.) C. Koch in Vietnam. *Proceedings of the 2nd national conference in life sciences.* Science and technics publishing house: 1069–1072.

Pham Hoang Ho 1993. *VegetationVietnam – An illustrated flora of Vietnam, 2nd ed.* Young Publishing House.

Sardos Julie, J.L, Noyer, R. Malapa, S. Bouchet & V. Lebot. 2012. "Genetic diversity of taro (*Colocasia esculenta* (L.) Schott) in Vanuatu (Oceania): an appraisal of the distribution of allelic diversity (DAD) with SSR makers", *Genet. Resour. Crop Evol,* 59: 805– 820.

Singh. D. et al. (2007), "Assessment and rationalization of genetic diversity of Papua New Guinea taro (*Colocasia esculenta*) using SSR DNA fingerprinting", *Genet. Resour. Crop Evol*, 55: 811–822.

Tahara M., Viet Xuan Nguyen, and Hiromich Yoshino 1999. Isozyme analyses of Asian diploid and triploid taro, Colocasia esculenta (L.) Schott. *Aroideana*, 21: 71–78.

Yin, J.T., H. Li & Z.F.Xu. 2004. *Colocasia menglaensis* (Araceae), a new species from southern Yunnan, China. *Ann. Bot. Fennici* 41: 223–226.

The use of AFLP markers to elucidate relationships within *Cryptocoryne* (Araceae)

Niels Jacobsen[1], Jan Bastmeijer[2], Claus Christensen[3], Takashige Idei[4], Conny Asmussen Lange[1], Jihad Orabi[1], Duangchai Sookchaloem[5], Fiorello Toneato[1] & Marian Oergaard[1].

1) Dept. of Plant- and Environmental Sciences, Univ. of Copenhagen,
Rolighedsvej 21, DK 1958, Frederiksberg C, Denmark.
2) The Netherlands.
3) AquaDiscover, Denmark.
4) Japan.
5) Department of Forest Biology, Faculty of Forestry, Kasetsart University,
50 Pahonyothin Rd., Ladyoa, Chatuchak, Bangkok 10900, Thailand

ABSTRACT

Four species complexes in *Cryptocoryne* were included in a study of genetic diversity: The *C. beckettii* complex (Sri Lanka), the *C. crispatula* complex (Mainland Asia), and selected accessions from the di- and polyploid cordate leaved species from Malesia, altogether comprising 400+ accessions. The Amplified Fragment Length Polymorphism (AFLP) method was discriminative not only within but also between species complexes. Within the cordate leaved Malesian species, it was also possible to discriminate between diploids, tetraploids and hexaploids forming very robust relationship groupings. The AFLP study also revealed that, geographical proximity exposed closer genetical relationship than morphologically similar accessions geographically apart.

INTRODUCTION

The about 55 species of *Cryptocoryne* are aquatic to amphibious herbs with far creeping and proliferously dividing subterranean rhizomes, thereby enabling them to form large stands in streams and rivers. The shape of the leaves and the shape and colours of the limb of the spathe are important diagnostic taxonomic characters (Bastmeijer, 2015).

Cryptocoryne that live in larger river systems are exposed to innumerable habitats/niches (see e.g. **Figure 2)** and these are principally connected with each other.

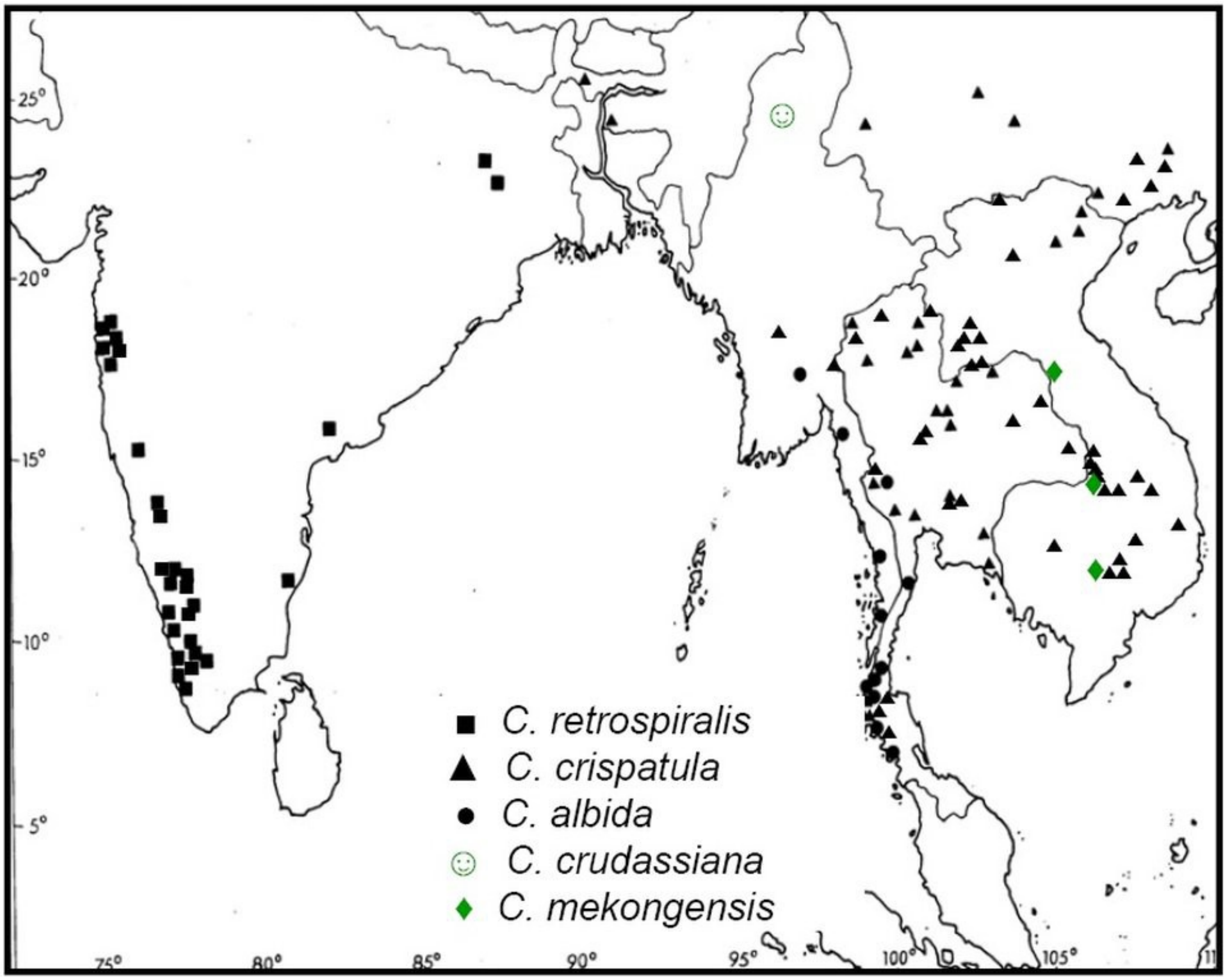


Figure 1. Distribution of the *Cryptocoryne crispatula* complex in south-east Asia.

Seeds and rhizome fragments may be transported freely within river systems, and where species are mixed in populations they may hybridize and exchange genes stochastically within operation distance of the pollinating flies.

Cryptocoryne genotypes can theoretically "exist for ever" by means of vegetative reproduction; over time viable hybrids will therefore accumulate.

More than 25% of the about 91 named and unnamed *Cryptocoryne* have proven to be of hybrid origin (54 species, an additional 12 varieties and 25 natural hybrids).

MATERIALS AND METHODS

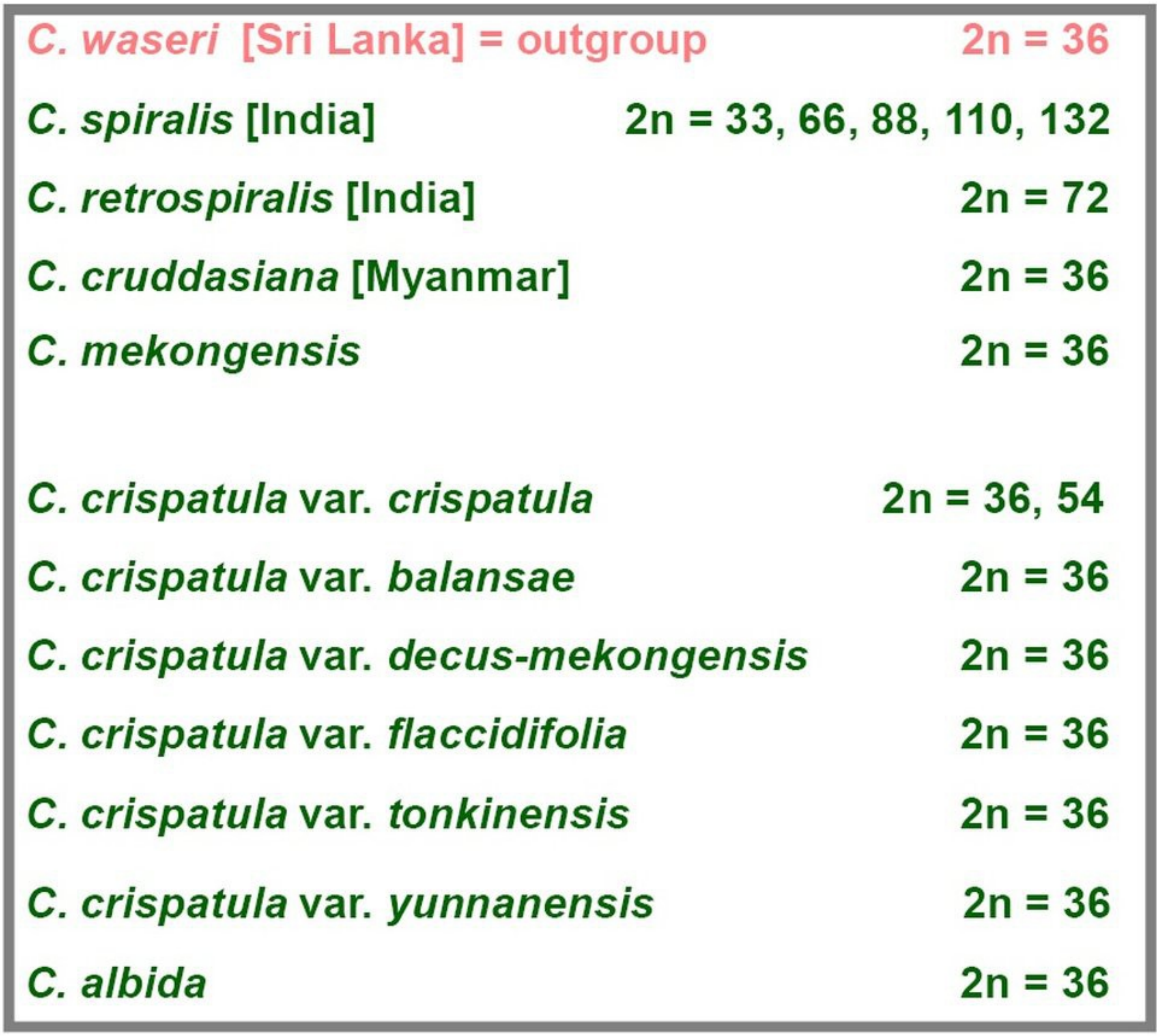
Population structure (**Figure 5)** was analyzed with a Bayesian based clustering approach using 'STRUCTURE' v.2.3 software (Pritchard et al., 2009). In order to find the best group (K) number, the number of groups (K) was tested from K=2 to

Figure 2. *Cryptocoryne* habitat in southern Thailand showing a stand of *C. albida* Parker on top of the sandbank and *C. crispatula* Engler *var. flaccidifolia* N. Jacobsen in the water around the sandbank. Khao Sok N.P.

K=12 with 20 replicates of each run and a 'burn-in' period of 10,000 iterations and 10,000 Markov chain Monte Carlo (MCMC) iterations. The optimal number of groups was determined according to Evanno et al. (2005). Finally, ten replicates with the optimal number of groups were run at a 'burn-in' period and MCMC iterations of 100,000. Based on Jaccard's genetic distance, principal component analysis (PCO) was used to visualize the genetic distance between the four groups inferred by the STRUCTURE analysis. For this purpose, the R language and environment software (v.2.11.1; R Development Core Team, 2011) including the 'Modern Applied Statistics with S-plus' package was employed (Venables and Ripley, 2002).

RESULTS

In the ongoing molecular studies of variation and evolution of the genus *Cryptocoryne,* it was decided to study four species complexes in more detail: The *C. beckettii* Trim. complex (Sri Lanka), the *C.*



C. waseri [Sri Lanka] = outgroup	2n = 36
C. spiralis [India]	2n = 33, 66, 88, 110, 132
C. retrospiralis [India]	2n = 72
C. cruddasiana [Myanmar]	2n = 36
C. mekongensis	2n = 36
C. crispatula var. *crispatula*	2n = 36, 54
C. crispatula var. *balansae*	2n = 36
C. crispatula var. *decus-mekongensis*	2n = 36
C. crispatula var. *flaccidifolia*	2n = 36
C. crispatula var. *tonkinensis*	2n = 36
C. crispatula var. *yunnanensis*	2n = 36
C. albida	2n = 36

Figure 3. *Cryptocoryne* taxa of the *C. crispatula* complex included in the Fig. 6 AFLP investigation.

crispatula Engl. complex (Mainland Asia; **Figure 1;** Jacobsen & al., 2012), and selected accessions from the di- and polyploid cordate leaved species from Malesia (*C. cordata* Griff. etc.), altogether comprising 400+ accessions.

The Amplified Fragment Length Polymorphism (AFLP) study proved capable of not only being able to discriminate within the species complexes, but it was also able to cope with all 400+ accessions in one run, discriminating the *C. beckettii* group, the *C. crispatula* group, and, within the cordate leaved Malesian species, it was able to discriminate between diploids, tetraploids and hexaploids forming very robust relationship groupings.

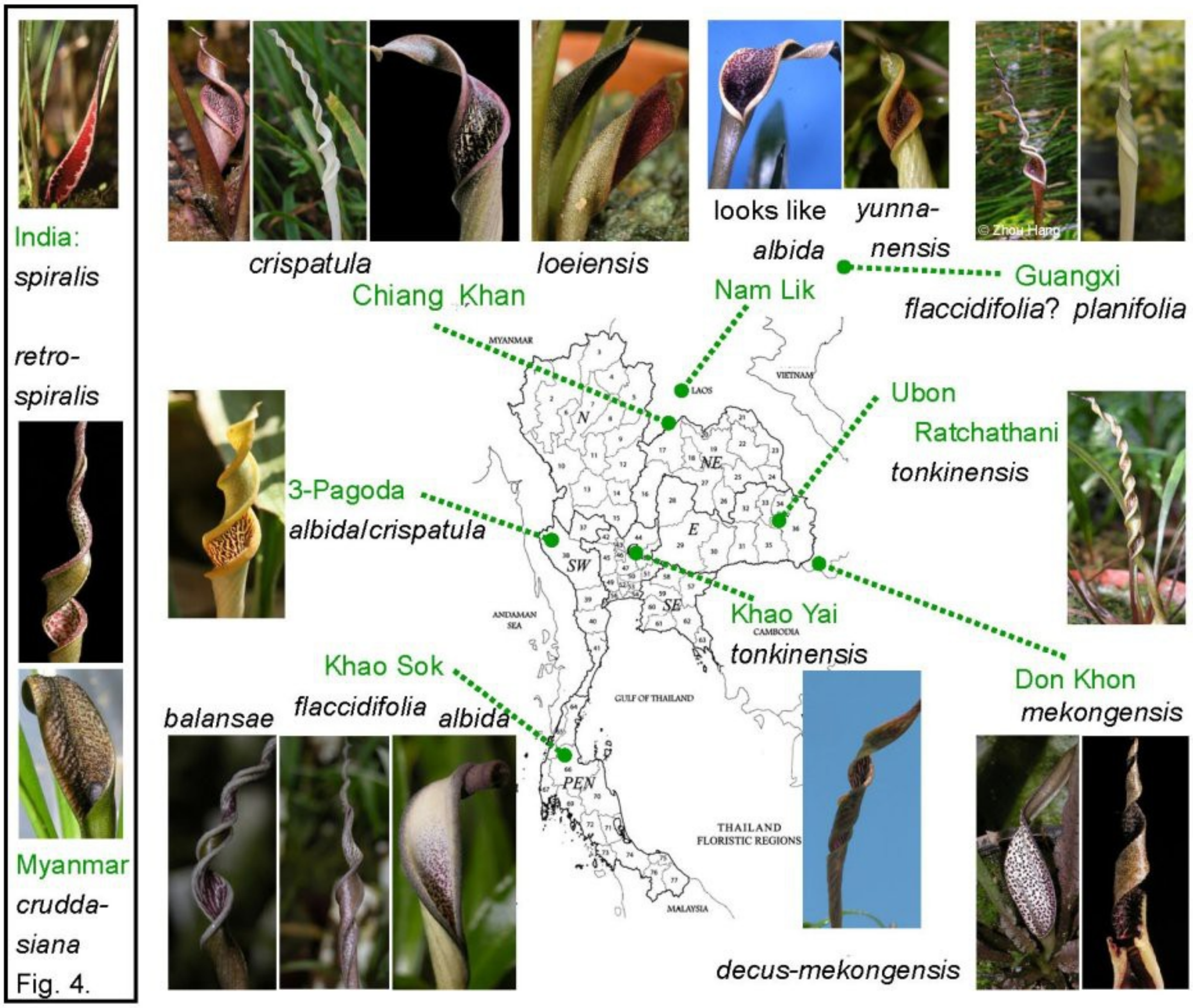


Figure 4. Examples of the species in the *Cryptocoryne crispatula* group centered around Thailand.

The AFLP study also showed that, geographical proximity revealed closer genetical relationship contrasting morphologically similar accessions geographically further apart.

The PCO analysis separated the collection into four major complexes: 1) Sri Lanka, 2) Malesia (diploids), 3) Malesia (tetra- and hexaploids) and 4) Mainland Asia (**Figure 5**).

The graph in **Figure 6** depicts the genetic distances between the accessions of group 4, the *C. crispatula* complex (**Figure 3**), as shown in **Figure 4**. The names are based on the morphology of the leaves and the limb of the spathe. The diagram shows that there are shorter genetic distances within geographical regions than there are ”within” names, i.e. *flaccidifolia* and *balansae* from from Khao Sok are closer to each other than e.g.

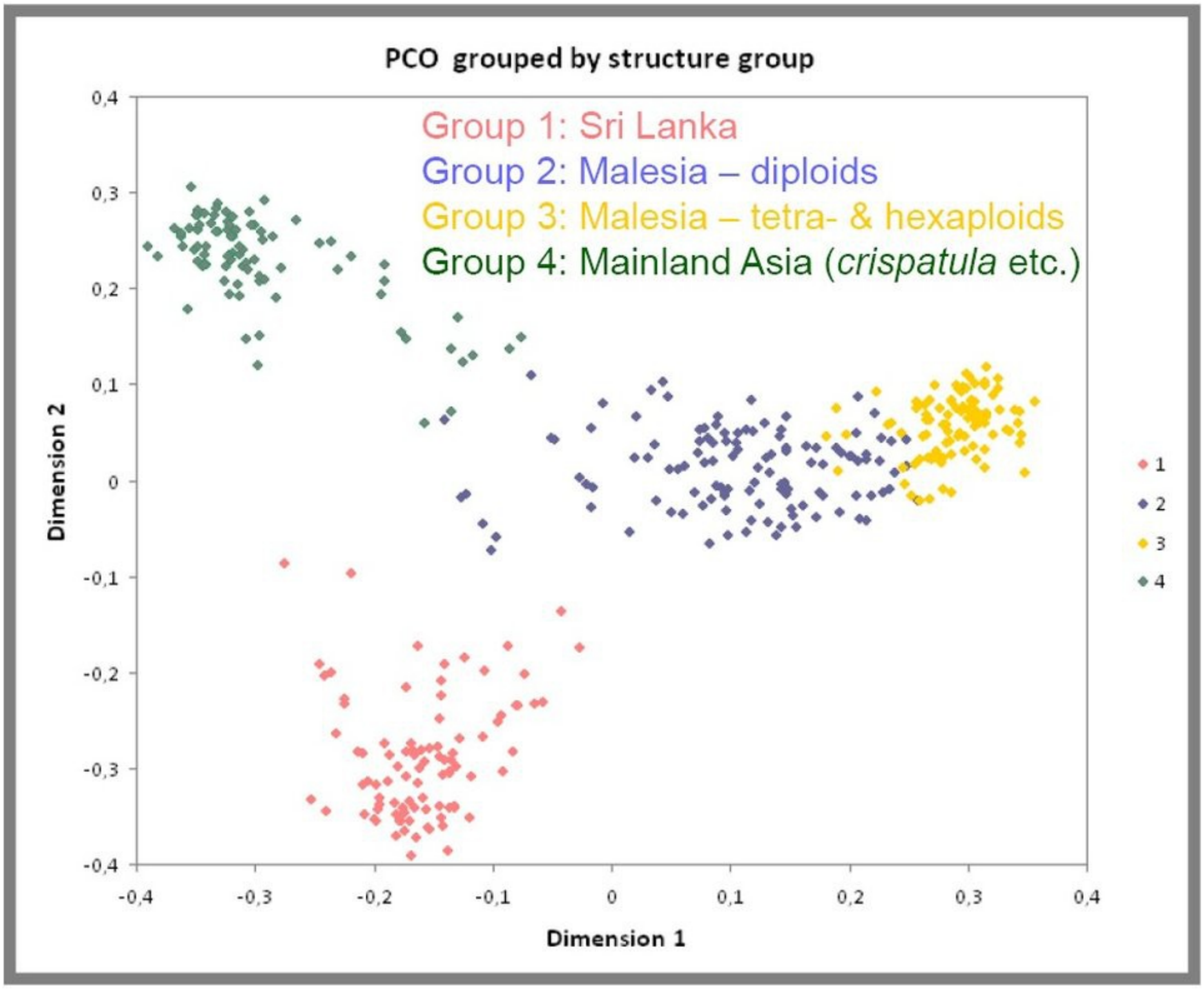


Figure 5. Population structure was analyzed using 'STRUCTURE' v.2.3 software resulting in four groups. Principal component analysis (PCO) was used to visualize Jaccard's genetic distance between the four groups. The PCO analysis separated the collection into four major complexes: 1) Sri Lanka, 2) Malesia (diploids), 3) Malesia (tetra- and hexaploids) and 4) Mainland Asia.

the *balansae* from Khao Sok and Khao Yai are.

DISCUSSION

We often think and talk about "species" as if they exist as natural evolutionary units. The word "species" means "an outward appearance" – a "look" – a kind.

And as "kinds" they exist and the populations of different kinds – whatever kind they may be – genotypes – will sexually reproduce – and when the different kinds look different – we say that they hybridize.

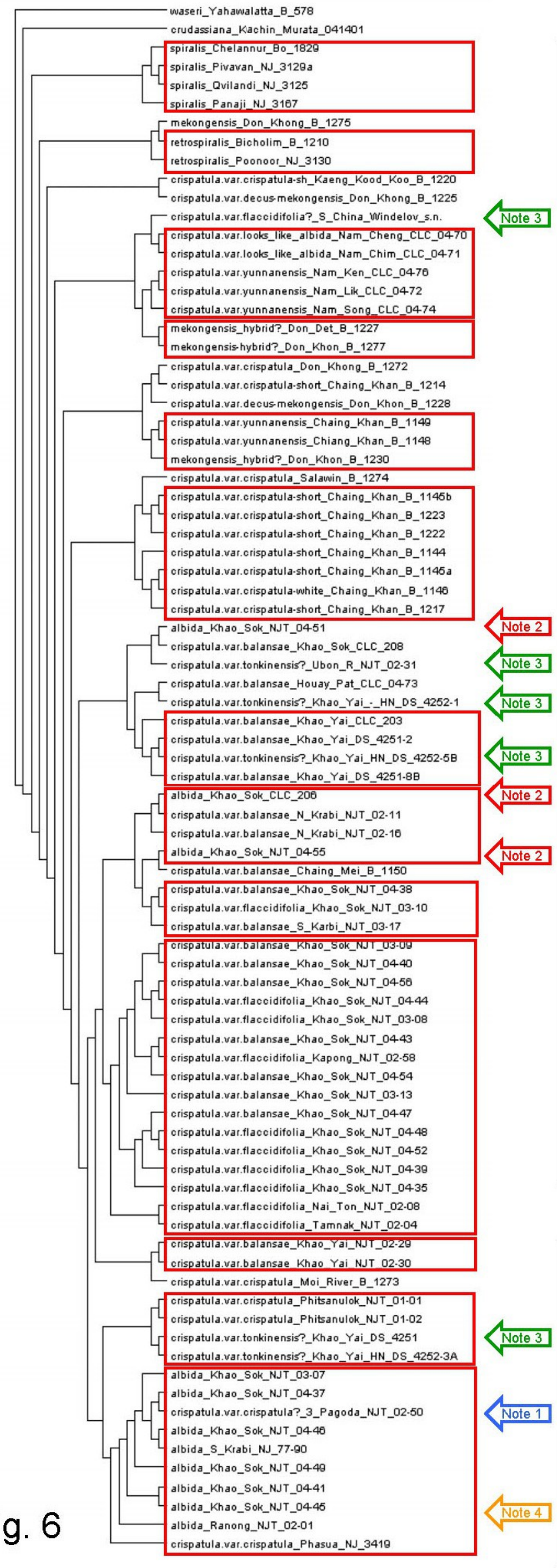


Fig. 6

Figure 6. Genetic distances between accessions of group 4, the *C. Crispatula* complex, as shown in **Figure 5.** Interestingly there are shorter genetic distances between taxa sharing habitats, i.e. *flaccidifolia* and *balansae* from Khao Sok than there are ”within taxa”, e.g. The *balansae* accessions from Khao Sok and Khao Yai.

Note 1. The *crispatula* in the *albida* grouping most likely represents an *albida* with *crispatula* like traits (i.e. spathe limb form).

Note 2. The three *albida* found away from the other *albida* accessions in association with *balansae* (Khao Sok, N Krabi & Chiang Mai) may represent plants of hybrid origin (not recognized on the basis of their morphology).

Note 3. The geographically different accessions named *tonkinensis* seem to be “unrelated”, and the very narrow leaved “*flaccidifolia*” from China could perhaps just as well have been named *tonkinensis* (based on the 2–3 mm wide leaves).

Note 4. The diagram also clearly shows that what has been called *C. albida* clearly falls within *C. crispatula* in a broad sense.

Species are traditionally considered as the natural evolutionary units. However, this study strongly supports the view that it is in the populations evolution takes place and that they should be regarded as the naturally evolutionary centres.

Cryptocoryne can be considered as numerous genetically different populations living in different river systems. Hybridization is a driving evolutionary force which continuously produce new genotypes which subsequently are dispersed randomly in the river systems.

“Species” as such cannot be considered as the natural evolutionary unit, but what we see are populations that are the results of random/stochastic events brought about by the “historical” events etc. etc. - - “Species” are the “leftovers”.

ACKNOWLEDGEMENTS

Vinnie Deichmann has skilfully performed the technical laboratory work.

REFERENCES

Bastmeijer, J. D. (2015). http://crypts.home.xs4all.nl/Cryptocoryne/index.html [accessed 8 May 2015].

Evanno, G., Regnaut, S. & Goudet, J. 2005. Detecting the number of clusters of individuals using the software STRUCTURE: a simulation study. Molecular Ecology 14: 2611–2620.

Jacobsen, N., Idei, T. & Sookchaloem, D. 2012, ‘11. *Cryptocoryne*’, in: Boyce, P, & al., 2012. ‘Flora of Thailand, Acoraceae & Araceae’, Vol. 11, 2, p. 218 – 232 & Plates XLV-LVIII.

Pritchard, J., Wen, X. & Falush, D. 2009. Documentation for STRUCTURE software: Version 2.3. Chicago, IL: University of Chicago Press.

Venables, W. N. & Ripley, B. D. 2002. Modern Applied Statistics with S. 4th edn. New York: Springer-Verlag