

Introduction

Henrik Balslev and Ib Friis

Henrik Balslev, Department of Bioscience, Ecoinformatis and Biodiversity, Aarhus University Build 1540, Ny Munkegade 116, DK-8000 Aarhus, Denmark. E-mail: henrik.balslev@bios.au.dk

Ib Friis, Biosystematics, Natural History Museum of Denmark, Universitetsparken 15, DK-2100 Copenhagen Ø, Denmark. E-mail: ibf@snm.ku.dk

On 19th-21st May 2015 seventy four botanists from eighteen countries, including seven countries in the tropics, were gathered in Copenhagen. The occasion was a symposium entitled *Tropical Plant Collections: Legacies from the past? Essential tools for the future?* organised by and held at the premises the Royal Danish Academy of Sciences and Letters.

Already at the beginning of the symposium, we were reminded about the links between the Academy and tropical plant collections. An early member of the Academy, Christen Friis Rottböll (1727-1797), was the first to write on tropical plants in the publications of the Academy. He described three new genera of flowering plants, one named after a former president of the Academy (Fig. 1), and some additional new species collected in southern India (Rottböll 1783). The material on which this publication was founded is still in the herbarium of the Natural History Museum of Denmark. Through the following centuries, other members of the Academy contributed significantly to the botanical collections of tropical plants and to the understanding of their taxonomy, structure, and biology.

But soon the themes of the symposium turned to the realities of today. The past decade has seen dramatic changes in the conditions of and care for collections of tropical plants kept in herbaria and botanical gardens. Botanical gardens have in many places been turned into amusement parks or simply recreational parks and many herbaria have been starved economi-

cally and staff-wise and some have even been relegated to warehouses, detached from scientific activities, and sometimes under conditions where they can only be consulted with difficulty. The scientific value on which their establishment were founded seems forgotten or neglected, or the collections are seen as irrelevant in a modern society. We are concerned to watch this development and we feel that many colleagues in other countries throughout the world have the same concerns. A particularly disturbing report came from the Netherlands, one of the first and in relation to its size most important countries in the world to establish collections of tropical plants and study them (Welzen & Schollaardt 2017), but fortunately and after long struggle, the efforts seem now to lead to a sustainable solution.

The symposium brought together scientists from old institutions in the North housing significant collections of tropical plants with scientists from countries in the South, with which the northern institutions have long-standing contacts. The aim was to take a closer look at the sustainable use of classical and new collections of tropical plants and its intersection with new scientific methods and technologies which are now being used world-wide. The symposium touched on several closely related topics:

What are the conditions for continued preservation, development, and use of already existing collections of tropical plants? In this context the symposium explored economic and political problems facing

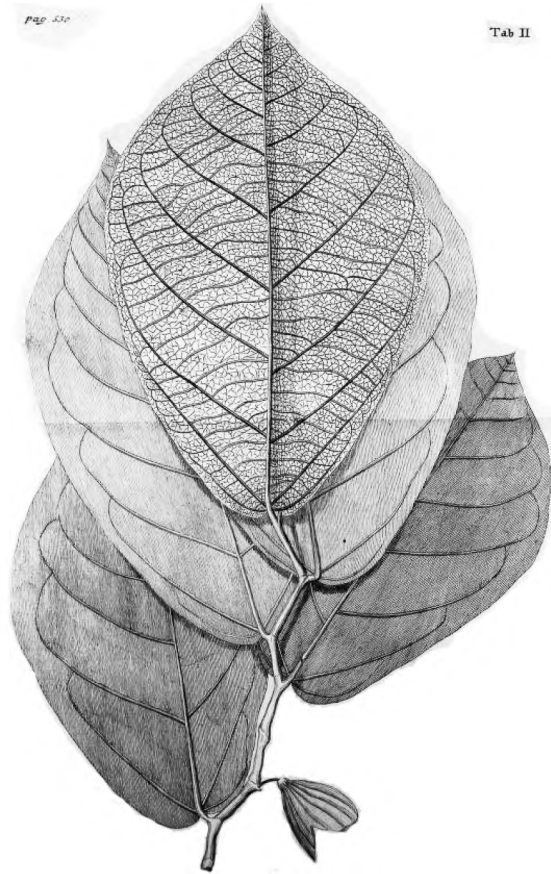


Fig. 1. The genus *Thottea* Rottb. (Aristolochiaceae) is a link between the early years of the Royal Danish Academy of Sciences and Letters and tropical plant collections. This engraving of *Thottea grandiflora* Rottb. accompanied the description of the genus published by Rottböhl (1783), based on a specimen collected in 1779 in Malacca by J.G. Koenig and still kept in the Natural History Museum of Denmark (specimen no C10012834). The genus is named after Otto Thott (1703–1785), a representative of the Danish enlightenment. He published the first academic thesis on the economy of Denmark and Norway, held numerous posts in the Danish-Norwegian government until a revolution organized by J.F. Struensee in 1770, was a highly important collector of ancient Danish manuscripts and books, and – by Royal appointment – the second president of the Royal Danish Academy of Sciences and Letters (1763–1770). When the charters of the Academy were changed in a more democratic way, Thott was re-elected president by the members in 1776, but declined serving a second term. Today, *Thottea* is known as a genus of 26 species of shrubs and climbers, widespread in the forests of tropical Asia, some with known or potential medical properties.

the collections including the questions relating to access to biodiversity and the increasing threats to biodiversity caused by population growth, industrialization and climate change.

The symposium also addressed the scientific value of the collections as archives of scientific results, *i.e.* what might be called the *scientific heritage*, encompassing collections as documentation of past and present hypothesis about the taxonomy and evolution of plant species, and simultaneously acting as potential sources of new knowledge.

Plant species new to science are surprisingly often discovered in herbaria. A recent paper in *Proceedings of the National Academy of Sciences* (Bebber *et al.* 2010) has estimated the lag between date of collection and date of acknowledging and description of new species. Remarkably, only 16% of newly discovered species are described within the first five years after they were discovered in the field, the remaining 84% after much longer time. Nearly a quarter of the new species in the study were described from herbarium specimens that were collected more than 50 years before they were described in the scientific literature.

The collections housed in herbaria and botanical gardens are very important resources for research in both classical fields such as taxonomy and phytogeography, but also to a number of emerging and new fields such as genomics, molecular systematics, biodiversity research, macro-ecology, and eco-informatics. These collections are rich resources of information and often the only ones that can provide any kind of documentation on extinct or rare species or even, as shown in examples from India, make it possible to recover species thought to be extinct (Sanjappa & Venu 2017).

Collections of tropical plants in herbaria and botanical gardens had their beginning in the collections of medicinal plants in medieval Europe. Later they became an integral part of the enlightenment and the scientific discovery of world, not least with support of the still ubiquitous naming system of Linnaeus in which all living organisms have a generic name and species epithet as in the case of our own species, *Homo sapiens*.

In the 18th and 19th century, collections of tropical plants became a tool to create a complete catalogue of all plants and an instrument supporting the western colonization of the tropics. Many large European and North American botanical gardens started building their tropical collections in the 18th century, but only few botanical gardens and associated herbaria were established in tropical regions, some exceptions being the institutions in Calcutta and Rio de Janeiro. When the European countries began to colonise the world, botanical gardens and herbaria became the colonial powers' way of assessing the natural resources in their colonies. Since the middle of the 20th century the colonies gained independence and emerged as sovereign states that needed to know their own natural resources and to protect them against exploitation and unsustainable use. So over the past 50-70 years a high number of botanical institutions and related herbaria and botanical gardens have emerged in the former colonies. This history of and transition from European and North American dominance to emerging and independent botanical research and the building of collections in herbaria and botanical gardens in the tropics was exposed and discussed thoroughly at the symposium.

The threats to the world's biodiversity through global change involving global warming and unsustainable land use changes have emerged as an issue of extreme concern - not least brought to public attention world-wide through the UN convention on biodiversity in Rio in 1992 and the subsequent conventions of parties. In the symposium a series of attempts to collaborate and close the North-South gap in Cameroon (Onana *et al.* 2017), sub-Saharan Africa (Sebebe Demissew *et al.* 2017; Nordal *et al.* 2017), India (Sanjappa & Venu 2017), Brazil (Prance 2017), Ecuador (Balslev *et al.* 2017), Thailand (Newman *et al.* 2017) and Central America (Baldini & Pignotti 2017) were demonstrated as dynamic and mutually productive.

Initially, collection-based research primarily resulted in classical taxonomic monographs and revisions and to large extent practical manuals and regional and national floras, as exemplified by the long line of manuals and regional floras produced during

the colonial period of India and South Africa (Sanjappa & Venu 2017; Muasya 2017). This work, now rejuvenated to fit the needs of the present-days nations in the tropics, is still ongoing and involves many tropical countries. Unfortunately, these activities are facing unprecedented financial challenges and failing recognition in academic incentive structures in the North. At the same time botanists and institutions in the South increasingly recognize the needs to complete their national botanical inventories both for conservation purposes and to create a base-line for sustainable use of their plant resources. Botanical gardens strive to survive, while new structures, *e.g.* seed banks appear as repositories for plant genetic resources. In assessing the challenges facing research in tropical botany, the symposium particularly realised the threats confronting established institution in the North and the lacking growth of the new or more established institution in the South.

The universal spread of new types of collections, sparked by the rapid development of new methods, such as tropical seed banks, DNA- and cryopreservation of plant tissue has enabled a gamut of new techniques and methods in the study of tropical plant diversity. The symposium addressed the importance of the intersection between classical herbarium collections and botanical gardens and the development of molecular techniques such as genomics in the 21st century. Further, it argued how interaction between researchers who apply new methodologies and classical botanical research is necessary to reach broad ranging scientific syntheses and that this interaction needs to involve researchers and institution both in the North and in the South. A good example was provided by the highly biodiverse South Africa (Muasya 2017), where the development of the new techniques may be an example to other countries in the South.

As it turns out, much of the research based on highly technical methods involving molecular aspects does not make sense without reference to collections in herbaria and botanical gardens. First of all these collections provide material that is identified to the taxon it belongs to. Such materials often originate from freshly collected herbarium material from or in

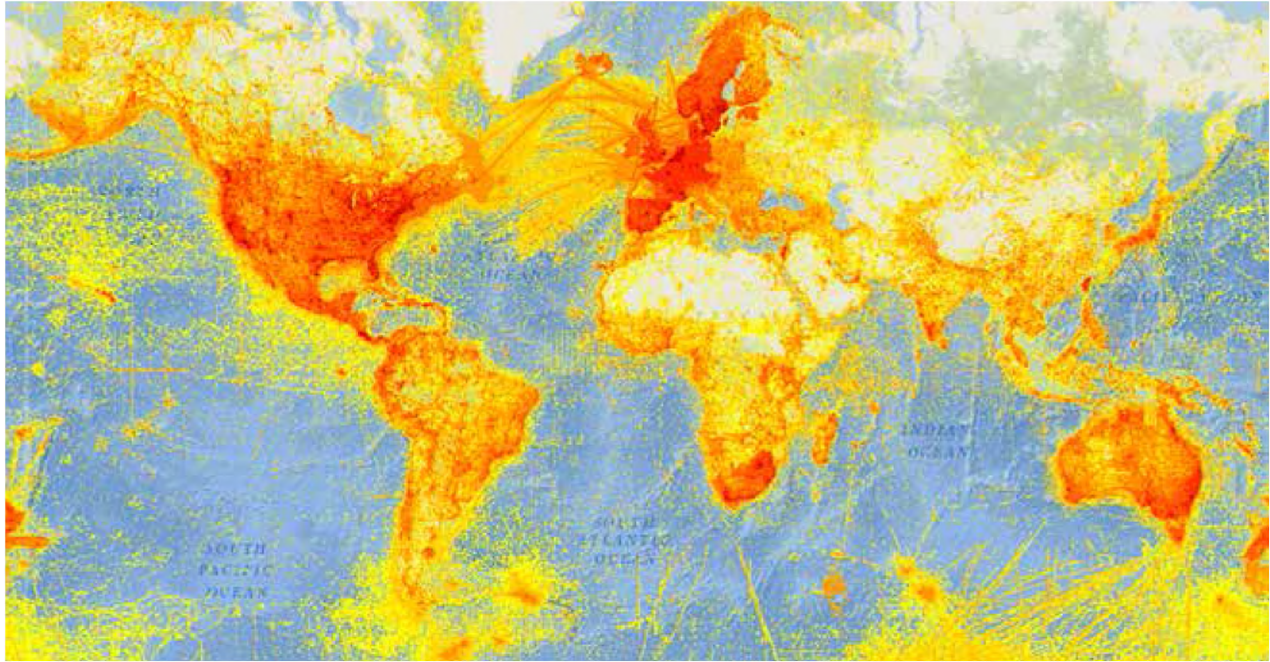


Fig. 2. Density and locations of 655,159,045 occurrence data with geo-referenced localities available in the Global Biodiversity Information Facility network (GBIF; <http://www.gbif.org/occurrence>). The data presented here include both occurrences based on specimens and observations without vouchers in collections (a significant majority of the records represents specimen data). The data set includes both records of animals (ca. 2/3) and plants (ca. 1/3) and organisms in both terrestrial and marine environments. This huge availability of primary biodiversity data is in sharp contrast to the few specimens of each species available and considered necessary at the time of discovery of *Thottea* (Fig. 1), but the contrast between the amount of data available from the less biodiversity-rich temperate regions and the biodiversity-rich tropics is also notable.

the South or from the living collections in botanical gardens. The efforts and costs to obtain representative samples is greatly reduced by sampling already existing collections when compared to the efforts needed to collect samples from natural populations (Bakker *et al.* 2017; Queenborough 2017). Over the past decades molecular researchers have developed methods that use herbarium specimens to extract the DNA needed for phylogenetic and other research. Considering the enormous coverage of herbarium collections from all over the world this opens up for a treasure trove of information which has been exploited in many recent studies.

Digitization of botanical data in databases such as the Global Biodiversity Information Facility (GBIF) and high resolution images of herbarium specimens

held at the Global Plants Initiative (GPI), Global Plants on JSTOR, has drastically globalized plant diversity research (Fig. 2). GBIF now gives access to over 700 mio records of primary biodiversity data, many of which are from herbaria, and close to 27 billion records are downloaded from the facility every month (www.gbif.org). GBIF is a truly North-South collaboration in which the richer and industrialized countries in North America, Europe and Asia share information from their herbaria and other collections with developing countries in the South. This is often the former colonial powers in the North that make information about specimens in their collections available to the new nations in the South, and as such GBIF functions in the process of repatriation, but it is increasingly beginning to work in other directions as

South-North or South-South sharing of information (Sebsebe Demissew *et al.* 2017). At the same time data about soils, climate and other factors affecting the conditions for the occurrence of plants and shaping the patterns of diversity are becoming available in digitized and easily downloadable formats.

Combining plant data with digital data on many ecological features has made it possible to develop new ecoinformatic methodologies that help answering questions that could not even be asked before at geographic scales from very local to the Global ones. Because herbarium and botanical garden collections include the names of plants in combination with information about the locality where they were collected the combination of data from many herbaria can provide very accurate information about the distribution of species. If this information is combined with information about the ecological conditions (climate, soil, *etc.*) at the same localities, the data can be used to model the potential distribution of species using so-called Species Distribution Modelling. Such models – when combined with predictions for the expected changes in climatic conditions – can be used to model the future distribution of species. Herbarium collections also make it possible to study functional traits of a broad range of species over a diversity of habitats and ecosystems, for example leaf area and specific leaf area which are important for understanding fundamental characteristics of ecosystems (Quenborough 2017). Because herbarium records all have dates of collection the information can also be used to detect actual changes in distribution over time as demonstrated in a study of how climate change affects the position of various forest types along elevational gradients (Feeley 2017). Voucher specimens in herbaria can also be used to construct molecular phylogenies which, when combined with fossil evidence, can enhance our understanding of the biogeography and history of evolutionary lineages and how they have interacted with biotic and abiotic events in the past (Antonelli 2017). Although these herbarium and botanical datasets are far from the size of datasets derived from commercial activities and banking operations, they still qualify as ‘big data’ and can only be

handled with previously unavailable algorithms and analytical methods, but also cause new complications unless followed up by new testable theories (Soberón 2017). These and other themes were explored in the symposium with emphasis on how primary data from herbaria and botanical gardens enhances new globalized digital plant research, truly ‘big data’ – as well as its practical uses for biodiversity.

In recent time the relationship between North and South with respect to maintaining tropical plant collections has changed. Initially institutions from the North were dominating, but influence from the South has been continuously increasing – changing roles fostered by mutual interests, collaboration and new friendships between researchers in North and South, realisation of complementary possibilities with regard to access to scientific material, technology and resources. Although digitization, the building of herbarium- and botanical gardens collections in the South, and international North-South collaboration helps building our understanding of the biodiversity in the tropical parts of the world, much remains to be done (Sebsebe Demissew *et al.* 2017; Muasya 2017; Onana *et al.* 2017). Because of history, it has been amply demonstrated that the collections held in the North are indispensable for the understanding of biodiversity and the related resources and ecosystem services in the South (Baas 2017; Baldini & Pignotti 2017; Cribb 2017; Friis 2017). The countries in the North therefore must continue to engage in the exploration and documentation of plants and their importance to the new nations in the South. In a historical perspective, the symposium saw this as obvious obligations derived from the former exploitation of the South. Countries in the North cannot live up to these obligations if they continue the trend to relegate their own herbaria to inaccessible warehouses where the collection can only be consulted with difficulties. The same goes for the trend to change botanical gardens with important historical plant collections into amusement parks or recreational zones. Local politicians and administrators should not only look at short term benefits and impact as measured with new bibliometric methods. The impact of being serious about the obli-

gation to those countries and areas where the collections came from should be given the serious credit it deserves and should supplement some of the new narrow ways of seeing impact in modern society and universities.

Possible solutions to the challenges raised in the previous sessions surely require enthusiasm, innovative thinking, futuristic views, and new ways of collaboration between North and South. The symposium discussed possible ways forward. One way, on which much hope has been founded since the signing of the Convention on Biological Diversity (CBD), may be to focus on the utility of tropical plants, as the focus was in the colonial period, but now with international agreements on fair benefit sharing. The importance of collections for the development of modern drugs is an example of this utility aspect which should be possible to explain to politicians and the general public (Rønsted *et al.* 2017). That said, there was an overwhelming agreement about the fact, that regardless of political, economic, and other impediments, tropical plant collections in herbaria and botanical gardens must continue to support a wide range of societal needs in research, conservation and sustainable management of natural resources. That can only happen through the continued strengthening of already existing North-South collaborations and also through establishing new ones in the many countries with emerging capacities for research.

Acknowledgements

We are deeply grateful for the interest, understanding and financial support we have received from the Royal Danish Academy of Sciences and Letters in connection with this symposium. When the editors of these proceedings first presented our ideas about a symposium on tropical plant collections to the Academy our plans were encouraged and sustained by the then President Kirsten Hastrup and the presidium. At the symposium this was demonstrated by the warm welcome by Mogens Høgh Jensen, then General Secretary of the Academy and now its new President, who

also gave a first presentation about the traditions of the Academy. We are no less indebted to the donors of the financial support which we have received from other sides: the Aksel Tovborg Jensen Endowment, the Carlsberg Foundation, and from our institutions in Denmark, the Natural History Museum of Denmark and the Faculty of Science and Technology, Aarhus University. We are grateful to the authors of the texts in this volume and for the help we have had from approximately 20 reviewers, helping us to evaluate and improve the manuscripts. Last, but not least, we wish to thank the Editor-in-Chief of the publications of the Royal Danish Academy of Sciences and Letters, Marita Akhøj Nielsen, for her sympathy and help with the work of bringing these proceedings out as part of the long sequence of scholarly publications, which the Academy has produced since 1745.

References

- Antonelli, A. (2017). Comparative biogeography, big data and common myths. *Scientia Danica, B (Biologica)* 6: 237–247.
- Baas, P. (2017). The Golden Age of Dutch colonial botany and its impact on garden and herbarium collections. *Scientia Danica, B (Biologica)* 6: 53–61.
- Bakker, F.T., Lei, D. & Holmer, R. (2017). Herbarium genomics, skimming and plastome sequencing. *Scientia Danica, B (Biologica)* 6: 271–283.
- Baldini, R.M. & Pignotti, L. (2017). Early Italian botanists in the tropics and the fate of classical collections. *Scientia Danica, B (Biologica)* 6: 41–52.
- Balslev, H., Valencia, R. & Øllgaard, B. (2017). Danish-Ecuadorian collaboration in botany as an example of North-South mutualism. *Scientia Danica, B (Biologica)* 6: 199–206.
- Bebber, D.P., Carine, M.A., Wood, J.R.I., Wortley, A.H., Harris, D.J., Prance, G.T., Davidse, G., Paige, J., Pennington, T.D., Robson, N.K.B. & Scotland, R.W. (2010). Herbaria are a major frontier for species discovery. *Proceedings of the National Academy of Sciences USA* 107: 22169–22171.
- Blackmore, S. (2017). The future role of botanical gardens. *Scientia Danica, B (Biologica)* 6: 287–299.
- Cribb, P. (2017). The botany of the British Empire. *Scientia Danica, B (Biologica)* 6: 63–72.

- Feeley, K.J. (2017). Using herbarium collections and plot data to track the effects of climate change on tropical forests. *Scientia Danica, B (Biologica)* 6: 213–222.
- Friis, I. (2017). Temperate and tropical plant collections: The changing species concept and other ideas behind their development. *Scientia Danica, B (Biologica)* 6: 15–38.
- Funk, V.A. (2017). North American herbaria and their tropical plant collections: What exists, what is available, and what the future may bring. *Scientia Danica, B (Biologica)* 6: 73–96.
- Muasya, A.M. (2017). From alpha taxonomy to genomics in South Africa: One of the hottest biodiversity hotspots. *Scientia Danica, B (Biologica)* 6: 141–148.
- Newman, M., Kongkanda Chayamarit & Balslev, H. (2017). North-South collaboration in writing tropical floras: The Flora of Thailand at a crossroads. *Scientia Danica, B (Biologica)* 6: 177–186.
- Nordal, I., Bjørå, C.S. & Stedje, B. (2017). Training in the North of researchers from the South: Experiences from Nordic-African collaboration. *Scientia Danica, B (Biologica)* 6: 187–197.
- Onana, J.-L., Mafanny, J.M. & Mekembom, Y.N. (2017). The North-South synergy: The National Herbarium and Limbe Botanic Garden experience. *Scientia Danica, B (Biologica)* 6: 117–139.
- Prance, G.T. (2017). Some Experiences of North-South synergy from the New World tropics. *Scientia Danica, B (Biologica)* 6: 207–210.
- Queenborough, S. (2017). Collections-based studies of plant functional traits. *Scientia Danica, B (Biologica)* 6: 223–236.
- Rottböll, C.F. (1783). Beskrivelse over nogle planter fra de Malebariske Kyster. [Description of some plants from the coasts of Malabar]. *Nye Samling af det Kongelige Danske Videnskabers Selskabs Skrifter* 2: 525–546, 593–594, with 6 plates.
- Rønsted, N., Iwanycki, N.E., Maldonado, C., Hassemer, G., Martinez, K., Saslis-Lagoudakis, C.H., Jäger, A.K. & Soelberg, J. (2017). The future of drug discovery – are collections needed? *Scientia Danica, B (Biologica)* 6: 255–268.
- Sanjappa, M. & Venu, P. (2017). Indian herbaria: Legacy, floristic documentation and issues of maintenance. *Scientia Danica, B (Biologica)* 6: 149–162.
- Sebsebe Demissew, Beentje, H., Check, M. & Friis, I. (2017). Sub-Saharan botanical collections: Taxonomic research and impediments. *Scientia Danica, B (Biologica)* 6: 97–115.
- Soberón, J. (2017). Challenges for biodiversity science in the era of big data. *Scientia Danica, B (Biologica)* 6: 249–252.
- Welzen, P.C. van & Schollaardt, C. (2017). How to survive as a taxonomic institute: The amalgamation of the large Dutch herbaria and their collections. *Scientia Danica, B (Biologica)* 6: 163–174.