Research Collections

The Role of Scottish Plants in RBGE's Living Collections for Research and Conservation

Aline Finger & Martine Borge

RBGE makes extensive use of its living collections for conservation and restoration programmes in Scotland. These collections contribute significantly to Target 8 of the Global Strategy for Plant Conservation which aims to safeguard 75 per cent of a country's threatened plants in cultivation. Of the 181 threatened Scottish plant species, RBGE has 86 per cent protected as living collections. The collections form the basis for conservation translocation and ecosystem restoration, and also provide opportunities for research, for example on the viability, ecological demands and reproductive biology of plants. Such *ex situ* non-invasive research allows conservation work on our rarest species while minimising the risk of disrupting already small and vulnerable wild populations, for instance by trampling or handling plant material.

Among RBGE's living collections are some of Scotland's rarest plants, such as *Cicerbita alpina* (alpine blue sow-thistle), Britain's rarest fern, *Woodsia ilvensis* (oblong woodsia), *Polygonatum verticillatum* (whorled Solomon's seal), *Oxytropis halleri* (purple oxytropis) and montane willows, to name just a few. Most of these species used to be more widespread but due to human-induced land use change, pollution or climate change they remain only as small and scattered populations, often unable to reproduce. Further to their scarcity many have also been left with a low genetic diversity and close relatedness within populations which can lead to a lack of successful reproduction. We are therefore using the living collection to propagate genetically mixed (cross-pollinated) plants that are more likely to create healthy populations.

RBGE's Nursery is also used for urban projects such as the Edinburgh Living Landscape project where, for example, three native butterfly food plants have been grown and established on Edinburgh rooftops to provide forage for the larvae of the northern brown argus, in the hope that it, and other native butterflies (the common blue and small copper), can spread through city greenspace.

Fig. 1 *Oxytropis halleri*. Photo: RBGE.

Zingiberaceae Research

Mark F. Newman & Axel Dalberg Poulsen

RBGE has had a research focus on the ginger family since the 1960s. Some of the oldest ginger plants in the collections were collected in Borneo at that time and numerous research projects since then have been facilitated by the living collections. The projects have in turn contributed to the growing collection from Africa and Asia. The gingers in the widest sense include two plant families: Costaceae and Zingiberaceae. At RBGE there are 930 collections in Costaceae (51) and Zingiberaceae (879), with around 380 species (including those yet to be described) distributed in five and thirty-four genera respectively. The collections are mostly planted in glasshouses heated to tropical temperatures. All species of *Roscoea* and some of *Hedychium* are cultivated outside.

The ginger family in SE Asia

The Flora of Thailand project is nearing completion, and one of the last few families to be revised is the gingers. Mark Newman of RBGE and Sunisa Sangvirotjanapat of Mahidol University, Bangkok are the joint coordinators, corresponding with authors of the 28 genera found in Thailand and editing their contributions for publication in 2022. We expect that there will be 380–400 species in the publication, though it is likely that more will be discovered as fieldwork continues.

The largest genus that Mark and Sunisa are revising is *Globba*. There are at least 100 species in this genus, about 20 of which are grown at RBGE. Most of them have been collected in Cambodia, Lao PDR, Thailand and Vietnam since 2006 and have been immensely useful to our research.

Twenty-six species have been described as new to science since 2019, several of them in cultivation in Edinburgh, such as *Globba impar* (2008.1114) from Vietnam. Other plants from Thailand and neighbouring countries have been re-identified as a result of this research. Two accessions thought to be *Globba albiflora* var. *aurea*, collected in Lao PDR (2006.0805) and Vietnam (2008.1112), are now known to be *Globba thorelii*, for example.

Globba plants are usually about 50 cm tall and grow in savanna or at forest margins, often along watercourses. Like all gingers, they are herbs which grow by rhizomes. Most species of *Globba* die back to the underground rhizome at the end of the rainy season and pop up again at the start of the next rainy season. Their flowers are extraordinarily beautiful and delicate, usually opening before dawn and falling before nightfall the same day.

Gingers of New Guinea

New Guinea has the world's richest island flora (Cámara-Leret *et al.*, 2020) and several families are in need of revision, including Zingiberaceae and Costaceae. There are 18 species of Costaceae known in New Guinea, all but one belonging to the genus *Tapeinochilos*. Axel is collaborating with Prof. Osia Gideon, at the University of Technology, Lae in Papua New Guinea, on a revision of the genus including describing new species. One of these (accession 2013.1999) flowered at RBGE for several months in the spring of 2019. Seed has been collected for many of these species and five are cultivated at RBGE, one of which,

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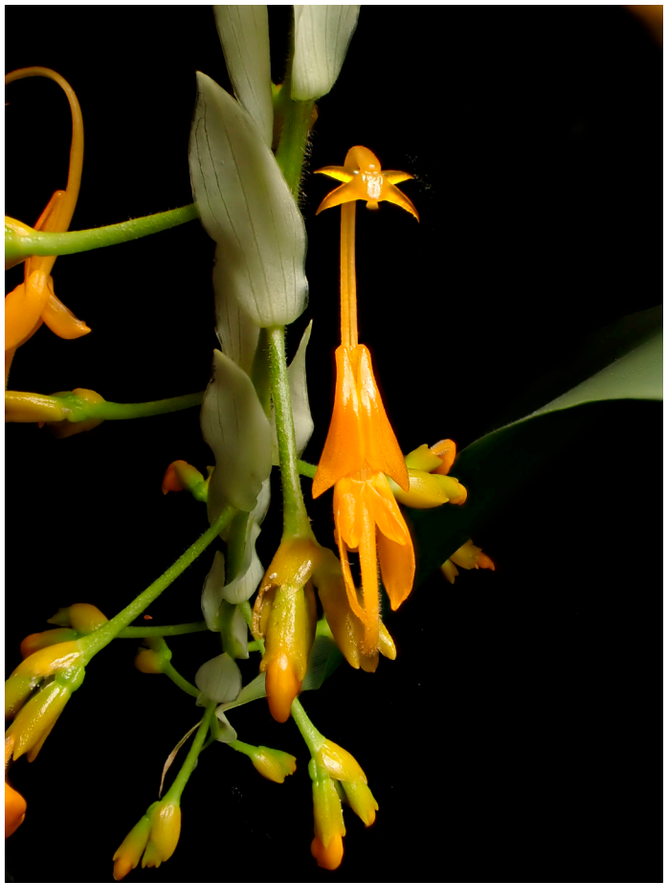

Fig. 2 *Globba grandis* 2014.0050. Photo: Axel Dalberg Poulsen.

Fig. 3 *Tapeinochilos hollrungii* is a difficult ginger to collect and impressive to display in a public glasshouse or tropical garden. The inflorescence is 45 cm long by 18 cm wide. Seed was collected from this plant and is growing at RBGE with accession number 2016.0403. Photo: Axel Dalberg Poulsen.

Fig. 4 A hitherto unidentified species of *Etlingera* collected in Papua New Guinea as seeds and flowering at RBGE in 2019. This is accession 2013.1994. Photo: Axel Dalberg Poulsen.

T. hollrungii, is expected to grow to more than 6 m tall and have a huge flower spike. When it flowers, this peculiar ginger will provide a great opportunity to engage visitors with the flora of Papua New Guinea and the importance of biodiversity research.

There are 204 species of *Etlingera* in Zingiberaceae, 17 of which are native to New Guinea. Axel has revised the genus in Borneo (Poulsen, 2006) and Sulawesi (Poulsen, 2012) and with his extensive experience in the field predicts that the number of species could double once the revision is complete. The living collections at RBGE include five *Etlingera* collections from New Guinea. Thorough studies are made possible when these flower in cultivation, including photography of morphological details. Such detailed study is often difficult to do during fieldwork due to time restrictions, weather conditions and physical exhaustion. The combination of researcher experience, field studies and cultivation is essential to add to knowledge of these large families occurring in habitats about which there is still much to understand.

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The *Begonia* Living Collection

Mark Hughes & Catherine Kidner

The *Begonia* living collection is used for classical taxonomy, developmental biology and genomic studies. Many new species have been described from plants in the living collection, having been brought back from the tropics as seeds or non-flowering cuttings, and later flowering in the glasshouse. The collection reflects the diversity of the genus, and is particularly strong in species from Peru and SE Asia. Recent additions are rarities from Borneo and Papua New Guinea collected on collaborative expeditions with Herbarium Bogoriense and Lae Botanic Garden respectively.

Begonia is one of the world's largest plant genera, and is divided into 70 sections. We recently published a new classification for all c. 2,000 species, the first classification to use DNA evidence, much of which came from the living collection (Moonlight *et al.*, 2018). The same DNA data have been used to reconstruct the geographic evolution of the genus (Thomas *et al.*, 2012; Moonlight *et al.*, 2015; Wilson, 2021).

In addition to describing species diversity the living collection is used to look at the genetics of species differences, with the genome structure being compared to that of the sister genus, *Hillebrandia*. Research carried out at RBGE has shown that *Begonia* has a remarkably dynamic genome, with highly variable genome size and chromosome number across the genus. Many species have large amounts of repetitive DNA which may be one factor driving the evolution of genetic novelty (Campos-Dominguez, 2020). We have a draft genome of *Begonia*, and have used this to design DNA baits which we can use to 'fish' in the DNA of hundreds of different species. This work gives more insights into the genetic changes underlying the evolution of species diversity in this huge genus.

Fig. 5 *Begonia samhaensis*, endemic to the peak of Samha Island (Yemen) in the Indian Ocean. It is listed as Endangered by the IUCN. Photo: Lynsey Wilson.

As well as supporting several strands of scientific inquiry, the collection has a strong conservation aspect as many of the species at RBGE are threatened in the wild, and some of these are not in cultivation anywhere else.

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Streptocarpus in the Living Collection

Michael Möller, Kanae Nishii, Sadie Barber & Nathan Kelso

There are currently 336 accessions of 67 species of *Streptocarpus* in Gesneriaceae cultivated at RBGE. Together with accessions in the seedbank, this is probably the largest collection in the world and includes most floral types found in the genus (Möller *et al.*, 2019). The living collection is essential for the description of new species and genera and for anatomical, genetic and developmental studies.

Recent PhD and MSc projects on *Streptocarpus* have focused on generating genomic resources (Chen, 2018), unravelling the morphological development of different growth forms (Sells, 2018), and characterising flower development and evolution (Luna Castro, 2016; Upton, 2014; Payne, 2013; Chen *et al.*, 2020).

For cytological studies the living collection is irreplaceable. It provides materials for chromosome counts and studies on the interrelations of genome size, chromosome numbers and pollen sizes (Möller, 2018).

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Fig. 6 *Streptocarpus stomandrus* (left) and *S. thysanotus* (right). Photos: Michael Möller.

The morphology of *Streptocarpus* is extensively studied, and plants collected from Tanzania in 2013 have enabled a great step forward in the infrageneric classification of the genus that now includes all eight Malagasy and African genera of subtribe Didymocarpinae, including the iconic *Saintpaulia* (Nishii *et al.*, 2015).

The plant material now in cultivation is critical for developmental studies to unravel the steps in the evolutionary transition from caulescent to unifoliates (cf. Nishii *et al.*, 2017). We are currently working on large-scale genetic studies in order to isolate key genes (Chen, 2018).

The collection also plays a role in conservation. Several species are threatened in the wild. *Streptocarpus bullatus*, *S. stomandrus* and *S. thysanotus* are all from Tanzania and IUCN categorised as Endangered (the first two) and Critically Endangered (the last).

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Research on the Genus *Cyrtandra*

Hannah Atkins

Cultivated at RBGE are 1,012 accessions of 300 species in 68 genera of Gesneriaceae from 36 countries. Together with the seedbank accessions, this is probably the largest collection of Asian and African Gesneriaceae anywhere in the world. *Aeschynanthus* and *Streptocarpus* are particularly well represented, the former being a National Collection.

Ongoing research on the largest genus in the family, *Cyrtandra*, has made extensive use of the collections for taxonomic and biogeographic studies and been the focus of four recent field trips to Indonesia (Sumatra, Sulawesi, Papua and Kalimantan) to bring back new living material and to study the plants in the wild.

Fig. 7 *Cyrtandra vittata* Bramley & H.J.Atkins. Photo: Lynsey Wilson.

In the last few years, seven species have been described using material in the living collection. This includes the striking *Cyrtandra vittata* and *C. bungahijau* from New Guinea (Atkins *et al.*, 2019), *C. boliohutensis* and *C. rantemarioensis* from Sulawesi (Kartonegoro *et al.*, 2018) and *C. argentii* (Olivar *et al.*, 2020) from the Philippines.

A number of samples were also included in a biogeographic study of the genus in SE Asia which showed that the genus most probably originated on the island of Borneo about 13 million years ago and dispersed across the region from west to east before eventually crossing the Pacific to Hawaii (Atkins *et al.*, 2020).

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Rhododendrons at RBGE

Alan Elliott

RBGE's role in the Global Conservation Consortium for Rhododendron since 2018 has given a new conservation focus to our world-leading collection, and across the four Gardens we continue to find new uses for the living *Rhododendron* species.

Each of the threatened *Rhododendron* species in the four Gardens has been given a red label detailing its conservation status. This work has been made possible thanks to generous support from the Friends of RBGE. The label, as a simple piece of interpretation, illustrates with a repeating visual 'red flag' just how threatened members of the genus are.

The skill and knowledge of the horticulturists who maintain the unique Vireya collection have been used to build capacity remotely with partners in Malaysia. They are working to conserve threatened high-altitude species on Mount Kinabalu and Bukit Monkobo. Through sharing horticultural knowledge and skills RBGE will continue to support the conservation efforts of Sabah Forestry and Kinabalu Park to develop their *ex situ* collections and secure threatened *Rhododendron* diversity there.

The living collection continues to be used to support collaborative international research. Leaf samples have been sent to colleagues in China and New Zealand who are using them as a resource to help resolve taxonomic questions and gain a better understanding of how the genus evolved. Two new *Rhododendron* taxa from Vietnam have been described by researchers at RBGE and the Institute of Ecology and Biological Resources – Vietnam Academy of Science and Technology (Baines *et al.*, 2021). As part of the process, cultivated material was used to supplement field collections made during international fieldwork with in-country partners.

A novel use of the collection has involved an MSc student using the living collection to help train artificial intelligence in the Pl@ntNet identification app (www.plantnet.org) to differentiate *Rhododendron* species. This project has required her to take photos on a phone of wild-collected accessions as well as using the store of digital images. This has improved Pl@ntnet's ability to correctly identify rhododendron at the genus, subgenus, section, subsection and species ranks and demonstrates the value that living collections have in 2021 that could not have been predicted when some of these specimens were collected over a century ago.

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Fig. 8 Thought to be extinct in the wild, *Rhododendron adenosum*, with a red conservation label, is a priority accession for tissue culture. Photo: David Knott.

Conifer Research Collection

Philip Thomas

Over the last 50 years conifer researchers at RBGE have built up one of the world's most comprehensive living collections of conifers. The collection extends over the four Gardens and the network of safe sites that forms the backbone of the International Conifer Conservation Programme. It contains representatives of all the families, more than 90 per cent of the genera and about 60 per cent of the known conifer species.

The original impetus for the diversity of the collections was taxonomic, with an emphasis on relationships between families and genera. Many of the earlier collections were made by Dr C.N. Page in the 1970s and 1980s in support of his work on conifers for vol. 1 of *The Families and Genera of Vascular Plants* (Page, 1990). In the following decades, under the leadership of Martin Gardner, the programme embraced conservation of threatened conifers and associated species through *ex situ* and *in situ* work in collaboration with researchers worldwide.

Research includes evolutionary genetics of New Caledonian *Araucaria* and conservation genetics of commercially important genera such as *Taxus* in China and the Himalayas. Field surveys have been carried out in poorly known areas such as the Solomon Islands and the mountains of Lao PDR and Vietnam, and these have led to the discovery of new taxa and populations. Global conservation assessments through the

Fig. 9 *Amentotaxus argotaenia* fruits. Photo: Martin Gardner.

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IUCN's Conifer Specialist Group and Red List Authority are coordinated by RBGE.

Horticultural research in the living collection has included developing germination protocols for recalcitrant species in the families Podocarpaceae and Taxaceae, hybridisation experiments for genera such as *Amentotaxus*, innovative growing techniques using Air-Pots® and the use of hedges for maintaining large numbers of genotypes within small areas (Gardner *et al.*, 2019).

One of the rationales for maintaining conifer collections is to support threatened species or to allow for their future restoration either to their native habitats or to other suitable areas. Unfortunately, this type of work is likely to be needed more frequently, particularly as the impacts of climate change amplify the effects of habitat destruction and overexploitation. RBGE's long-term commitment to this type of work is exemplified by the recent reintroduction of plants of *Amentotaxus argotaenia* to Hong Kong where the original population had been almost completely lost. These plants were originally collected in 1976 and held within the living collection for more than 40 years before the opportunity arose to realise their potential (Gardner, 2021).

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