THE UNVERSITY OF OXFORD BOTANIC GARDEN

Sharing the scientific wonder and importance of plants with the world

C J Thorogood[1]

[1]University of Oxford Botanic Garden, Rose Lane, Oxford, OX1 4AZ

Summary. The University of Oxford Botanic Garden is the UK's oldest botanic garden, established as a physic garden in 1621 in which medicinal plants were grown for teaching purposes. Today, the garden holds a collection of over 5,000 taxa, some of which have international conservation importance. The collections of Oxford Botanic Garden are discussed with a focus on their historic, conservation and research value, and their potential for engaging people with the importance of plants at a time when it has never been more urgent in the face of global challenges.

Introduction

The first botanic garden was founded in Padua, Italy, in 1545. Today, four and a half centuries later, there exist over 2,500 botanic gardens worldwide (Golding et al., 2010). Together they hold millions of living and dried plant specimens. The University of Oxford Botanic Garden is the oldest botanic garden in the UK, founded in 1621. Like Padua Botanic Garden which preceded it, it has been a centre of botanical research where people have marvelled at the scientific wonder of plants for centuries. It was first established as a physicke garden for the cultivation of medicinal plants used for teaching the University of Oxford's medical students, and maintains its historic cruciform configuration. Shaped over the course of 400 years, the garden occupies a unique place in history as the birthplace of botanical science in the UK (Thorogood & Hiscock, 2019).

Today Oxford Botanic Garden and its sister site Harcourt Arboretum, as a department (OBGA), hold a collection of about 5,000 taxa, both temperate and tropical. Some are exceptionally rare and endangered in the wild. Like most botanic gardens, it contains species from around the world and from across plant families and phylogenetic divisions. Worldwide, botanic gardens' collections are known to vary with geography, population size, and country Gross Domestic Product (GDP) (Golding et al., 2010). Recent analysis by Botanic Gardens Conservation International indicates that 107,340 accepted species grow in botanic garden collections, representing 31% of vascular plant species. However, 93% of these species are housed in temperate regions. The foci of OBGA's collections, specifically, relate to the garden's history, as well as its conservation work and research, each of which are discussed briefly here.

Historical collections

Oxford Botanic Garden's collections have evolved over the course of four centuries and there are still echoes of the work started by the seventeenth century keepers of the garden in today's activities (Harris, 2017). In 1621, Henry Danvers (1573-1644) gave the University of £250 to buy the lease of five acres (c. 2 hectares) of pasture land by the River Cherwell. At two o'clock on Sunday 25th July 1621, a stone was laid in the leased plot and the Garden was officially founded (Harris, 2017; Thorogood & Hiscock, 2019). Then in the 1630s the Danby Gate, designed by Nicholas Stone, was constructed. This remains the garden's most prominent architectural feature today, and frames an iconic view of Oxford.

In the 1640s, the garden was planted by its first superintendent, Jacob Bobart the Elder (c. 1599-1680), who kept meticulous records of the species that were cultivated. In 1648 he published a list of the c.1,400 plant taxa that grew in the garden, entitled 'Catologus plantarum Horti medici

Oxoniensis' (catalogue of the plants in the Oxford medicinal garden). Many of the temperate species featured in the list are still grown today in a dedicated collection in the south-west corner of the Walled Garden. Then, as now, visitors to the garden could also encounter tender exotics and botanical novelties grown in conservatories and stove houses (Harris, 2017). Charles Daubeny (1795-1867) took over as Sherardian Professor in 1834 and commissioned the construction of a new glasshouse containing a great tank heated by hot water flowing through pipes, for the cultivation of the giant Amazonian waterlily (*Victoria amazonica*). The plant flowered in 1853 and it, along with its relatives such as the hybrid *Nymphaea* x *daubenyana* that was raised in Oxford, have been grown at the garden in the same tank ever since, inspiring visitors to this day.

John Sibthorp (1758-1796) was the Sherardian Professor of Botany whose exploration of the Levant led to the publication of the Flora Graeca (1806-1840), described as 'Oxford's finest botanical treasure' and one of the finest floras ever produced (Harris, 2007). Sibthorp was inspired by the Ancient Greek philosophers including Aristotle (384–322 BC) and Theophrastus (c. 371–287 BC) - the founding fathers of Zoology and Botany respectively, and the co-founders of Biology (Thanos, 1994), and by Dioscorides (c. 40–90 AD), a military doctor for Emperor Nero who, based on his botanical expeditions, wrote a pharmacopeia describing over 600 plants, their habitats, methods of preparation, and medicinal uses (Haas, 1996). Sibthorp compared the plant specimens he encountered with the early scientists' original descriptions, and was intrigued by how people used the plants in the Levant. From March 1786 to December Sibthorp collected and described plants whilst his accompanying illustrator Ferdinand Bauer prepared dried specimens and colour-coded pencil sketches. Bauer's watercolours were prepared in Oxford from these annotated sketches and many of them depicted species new to science. A legacy of 2,462 pressed specimens from the Flora Graeca are housed in the Sibthorpian Herbarium at the University of Oxford. Today Oxford Botanic Garden's Rock Garden, situated in the Lower Garden, contains a collection of Mediterranean plants that are a living celebration of the Flora Graeca. Here visitors can enjoy the full sensory experience of walking through an aromatic Mediterranean landscape whilst learning about the work of Sibthorp and Bauer, and its important botanical and horticultural legacy.

Conservation collections

OBGA carries out conservation work both locally, in Oxfordshire, and internationally in botanically rich regions around the world, such as Ethiopia, the Mediterranean Basin and the Canary Islands, and particularly Japan - a biodiversity hotspot. Globally, thirty-six areas qualify as biodiversity hotspots. These are typically defined as areas with the highest species richness that are undergoing an exceptional loss of habitat (Myers et al., 2000). Survey work and seed collecting alongside partners across Japan, such as the University of Tokyo and Botanical Gardens of Toyama, have culminated in an *ex situ* collection of 400 temperate and subtropical species in Oxford, including rare endemics such as the Chichibu birch (*Betula chichibuensis*) which is assessed by the IUCN Red List as Critically Endangered. Subtropical species in the collection under glass from Japan include basal angiosperms such as *Aristolochia liukiuensis* and *A. zollingeriana* which hold important teaching and research value. Together, the species wild-collected from Japan comprise an important conservation collection, and play a role in informing people about biodiversity hotspots and the world's flora.

Research collections

OBGA holds a legacy of plant collections linked to former research at the University. Some have intrinsic conservation value. For example a species of ant plant (*Anthorrhiza echinella*) collected for research purposes that was collected in the Morobe Province of Papua New Guinea in the 1970s, is now known with certainty only to exist in cultivation at Oxford. The single specimen has informed

research activities and now features in the latest phylogeny of the genus. The species features in this issue of Curtis's Botanical Magazine.

A more recent collections-focus at OBGA is on plants that have been largely negelected by botanic gardens due to their percieved intractability to cultivation (Thorogood & Rumsey, 2021). Parasitic plants are poorly represented in botanic gardens internatioally; in fact many of the vascular plant families entirely absent from cultivation are parasitic (Mounce, Smith and Brockington, 2017). Parasitic plants feature prominently in this issue of Curtis's Botanical Magazine, highlighting the need for greater conservation efforts and propagation attention. OBGA is currently cultivating parasitic plants from five of the 12 families, with variable success, generally favouring the use of host plants collected from the same population as the parasite. In 2020, the first flowering stems of *Orobanche coerulescens* appeared on *Artemisia japonica*, both propagated from seeds collected in Honshu, Japan in 2018; this is the first record of cultivation of this species in the UK. Several British native species of *Orobanche* have also prospered on pot-grown and 'plunge-planted' host plants. However cultivation trials for the sister genus *Cistanche* using seed collected from the Middle East and China, have to date proved unsuccessful, despite using the correct host species. This suggests that a combination of factors (possibly edaphic and temperature-related) determine the success of parasitic plant cultivation. *Cistanche* has global potential as a desert crop, a topic which is explored further in this issue. *Cistanche* are parasitic on the roots saxaul and tamarisk which are being planted widely to form stabilising shelter forests to halt desertification. Farmers have started to grow desert hyacinths alongside these shelter forests as an ancillary crop in in China, where the plants are prized for food and herbal medicine. This suggests that *Cistanche* farming could meet requirements for food and medicine, whilst reducing the need to harvest rare wild species under threat more widely (Thorogood et al., 2021). Many of the parasitic plants are cultivated at Oxford Botanic Garden for research purposes are now on public display with accompanying interpretation panels to explain their biology.

Plant collections can also inspire design solutions to technological problems. For example the wettable peristomes (the slippery rims) of carnivorous pitcher plants (*Nepenthes*) have inspired new types of lubricant-infused, slippery surfaces (Wong et al., 2011; Smith et al., 2013). In an interdispliinary project based on Oxford Botanic Garden's *Nepenthes* collection, scientists recently showed how the peristome facilitates the trapping and directed transport of droplets to inform our understanding of the prey capture mechanism (Box, Thorogod & Guan., 2019). Based on observations of ants, *Drosophila* flies, and droplets sliding on the slippery peristome, artificial surfaces were created, inspired by the plant, capable of trapping, retaining and directing the travel of liquid droplets. The work revealed a potential mechanism for developing systems in which the transport of droplets can be guided by curved 'energy railings'. These would provide a biomimetic means of transporting and sorting droplets that is straightforward to implement in droplet-based fluidic devices and could enable the efficient mass transport of liquids along pre-determined pathways.

The c. 400 000 vascular plants that exist on our planet represent a living library for scientists to explore. Sharing scientific wonder of plants with innovators, technologists and the general public has never been simpler than it is today, with new means of communication online (Thorogood, 2020). Botanic gardens, collectively cultivating the world's flor, are well-placed to achieve this.

Public engagement with plants

Plants are a blind spot in the human psyche that need bringing into focus. Unlike animals, plants go unnoticed by many, a phenomenon described metaphorically as 'plant blindness' (Wandersee &

Schussler, 1999; Sanders, 2019). At a time when two in five of the world's plant species are threatened by extinction (Antonelli et al., 2020), there is an urgent need to foster a greater care and awareness of the importance of plants (Thorogood, 2020). Botanic gardens' collections are visited by 300 million people per year (Williams et al., 2015) so the opportunities for engaging people with the importance of plants and plant conservation are significant. One approach is to astonish people with plants, changing their perceptions that plants are inanimate or insignificant compared with animals (Thorogood, 2020). For example carnivorous plants, those that attract and trap animal prey to obtain nutrients – have inspired generations of scientists since Charles Darwin. They turn the tables on animals and challenge conventional concepts of plant behaviour.

Another approach is to deploy new online media for communication. Such means of communication can be used to share elusive plants that cannot be seen in cultivation and are rarely encountered by people. Parasitic plants (such as those described above) lacking chlorophyll, leaves, and roots, can challenge people's perception of what comprises a plant existentially. Articles on such plants, for example *Hydnora* (Thorogood, 2018), *Oxygyne* (Thorogood, 2019), *Rhizanthella* (Thorogood et al., 2019) and *Langsdorffia* (Thorogood & Carlos Santos, 2019) published in the journal Plants People Planet, have been accompanied by visually engaging digital media, and achieved significant online activity and engagement with audiences worldwide. Some of these species happen to be of extreme conservation concern. Promoting awareness of them and the need for their conservation, beyond a conventional academic readership, may be a catalyst for the lobbying of local conservation action (Thorogood, 2020). At the very least, it should foster a greater care and attention for the bewildering plant diversity that exists on our planet.

Botanic gardens today

Biodiversity is being lost locally, regionally and globally at an alarming rate. New species are still being scientifically named and described each year, but, at the same time, others are moving towards extinction, losing the battle against the threats they face (Antonelli et al., 2020). So there is a growing urgency for botanic gardens to inform and inspire people with the scientific wonder of plants at a time of a worrying engagement ebb. The plants featured in this issue of Curtis's Botanical Magazine have been selected primarily to highlight their rarity; their power to engage and astonish people; and in some cases, their untapped potential to help combat global challenges. Some are in cultivation; others have evaded botanic gardens' collections and warrant further attention.

Finally, besides their importance in conservation, research and engagement, botanic gardens, which are often situated in cities, are green oases which are beneficial to people's mental health and wellbeing. Residential greenness has been shown to reduce the public health burden of mental disorders (Sarkar et al., 2018). First conceived as gardens of medicine centuries ago, today botanic gardens are not only sanctuaries for plants; they are places of human healing.

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Figure legends

1. Aerial view of the historic Walled Garden of Oxford Botanic Garden depicting the cruciform configuration typical of early botanic gardens.

2. The *Catologus plantarum Horti medici Oxoniensis* (catalogue of the plants in the Oxford medicinal garden) published in 1648, listing the 1,400 taxa grown at Oxford Botanic Garden at that time.

3. (Above) aerial view of the Lower Garden of Oxford Botanic Garden depicting the Rock Garden encompassing the central water lily pool; (below) The Historic Danby Arch.

4. *Aristolochia rotunda* illustrated from a specimen growing in the Sibthorp-inspired Mediterranean Rock Garden at Oxford Botanic Garden. Illustration by Rosemary Wise.

5. The original water lily tank commissioned by Charles Daubeny, containing the giant Amazonian waterlily (*Victoria amazonica*) (background) and hybrid *Nymphaea* x *daubenyana* (bottom left).

6. Plants grown in the collections at Oxford Botanic Garden that hold important conservation, research and public engagement value include: (A) *Aristolochia zollingeriana* growing in the Rainforest House, propagated from seed collected in subtropical Japan; and temperate parasitic plants including (B) *Orobanche minor* var. *pseudoamethystea* collected from its Locus Classicus in Sandwich Bay, Kent and (C) *O. coerulescens* collected in Honshu, Japan. None of these taxa have been grown in botanic garden collections in the UK previously.