

THE TEMPERATE HOUSE RESTORATION PROJECT:
PROPAGATING IMPORTANT PLANT COLLECTIONS FOR THE
RESTORATION OF THE WORLD'S LARGEST VICTORIAN
GLASSHOUSE

Rebecca Hilgenhof¹, Scott Taylor² & Andrew Luke³

ABSTRACT

There is a long tradition at the Royal Botanic Gardens, Kew (RBG, Kew) of cultivating and displaying exotic plants from all over the globe, and the largest Victorian glasshouse, the Temperate House, traditionally showcases plants from temperate regions. The Temperate House Restoration Project was undertaken at RBG, Kew from 2012 to 2018. Over 1,000 species of plants were removed, propagated and replanted for this project, and this article describes the propagation of some of the most difficult to reproduce plant material. Four plant groups or species are presented: *Erica verticillata* P.J.Bergius, *Quercus insignis* M.Martens Galeotti, *Pinus roxburghii* Sargent and *Banksia* L. spp. This is in order to illustrate the variety of options available for propagating challenging species with attention to their ecology, biology and growing requirements. Also provided are background information, reasons why these plants are considered difficult to multiply in cultivation, how plant material was sourced and the methods employed which led to successful propagation of the material at RBG, Kew. Propagation of the plants was heavily reliant on the horticultural expertise of those involved, and this expertise ensured that most of the original plant material was rejuvenated and new collections with scientific significance were added to the restored Temperate House.

INTRODUCTION

On 5 May 2018 the Temperate House at Royal Botanic Gardens, Kew (RBG, Kew) reopened its doors to the public, and visitors have been able once again to marvel at the thousands of plants from all the main temperate regions around the world including some of the most threatened and rare species (Figs 1 & 2). Now that it has reopened it is possible for those involved to reflect on what a mammoth undertaking the project was for numerous people, including the horticulturists who look after the plants there. Most people think the project started in late 2014 when the doors shut, hoardings were

1. Rebecca Hilgenhof was formerly Tropical Nursery Supervisor at the Royal Botanic Gardens, Kew and is now studying for an MSc in Biodiversity and Taxonomy of Plants at the Royal Botanic Garden Edinburgh.

Address: 20A Inverleith Row, Edinburgh EH3 5LR, UK.

Email: r.hilgenhof@rbge.org.uk

2. Scott Taylor is Palm House Supervisor at the Royal Botanic Gardens, Kew.

Address: Palm House, Royal Botanic Gardens, Kew, Richmond, Surrey TW9 3AB, UK.

Email: s.taylor@kew.org

3. Andrew Luke is Head Gardener at Wrest Park.

Address: Wrest Park, Silsoe, Bedfordshire, MK45 4HR, UK.

Email: andrew.luke@english-heritage.org.uk



Fig. 1 The centre section of the Temperate House shortly after reopening in May 2018. Photo: R. Hilgenhof.



Fig. 2 Visitors enjoying the South African displays in the south part of the Temperate House. Photo: R. Hilgenhof.

erected and the construction phase of the project began. However, for the horticulturists involved, the project actually began in early 2012.

The first task was to assess the plant collection growing in the Temperate House at that point, a collection which has evolved since the house first opened in 1863 and formed as a result of collecting trips by some of RBG, Kew's most famous plant hunters. Over the years, many new plants were added or removed according to changes in the layout of the building, new discoveries and collecting trips. In 2012 there were approximately 1,000 species of plants growing in the building, from small herbaceous plants such as *Strobilanthes* Blume, to shrubs including *Erica* L. and large trees such as *Agathis* Salisb. and *Araucaria* Juss. Each plant was assessed according to several criteria: hardiness, provenance, scientific value, conservation rating, uses, aesthetics, age and size. Plans were put in place for the treatment of each individual specimen.

A few plants were left *in situ*. Scaffolds were built around them and wrapped in plastic to keep the dust off and provide some protection from the elements. Each 'tent' was fitted with heaters and grow lights to help the plants survive.

Around 500 plants were lifted from the Temperate House beds following careful root pruning, which in some cases took up to a year. This lengthy process involved digging a trench at the desired distance from the plant and cutting the roots that had spread beyond the trench. This was then back-filled with fresh compost and clearly marked above ground. The trench was checked regularly for the emergence of new roots by lightly digging the fresh compost. On average it took three months for plants to grow a healthy network of fibrous roots after which the next side of the plant could be root pruned and the process repeated until the entire rootball was reduced to a manageable size with good fibrous root systems within. The lifted plants were placed in pots and transferred to the nurseries, to be grown on and replanted before the opening. However, the majority (nearly 80 per cent of the plants now growing in the Temperate House) were propagated by a number of methods including seed, air-layering, grafting and cuttings.

This undertaking came with a great number of challenges. These are discussed below using the examples of four important collections that are once again part of the display in the Temperate House. For each of these plants, background information is provided as to why these groups are important and what made it challenging to propagate. The successful methods carried out at RBG, Kew are explained.

HEEL CUTTINGS OF *ERICA VERTICILLATA* AND RELATIVES

Erica verticillata, the whorled heath or marsh heath, is one of 28 species of Cape heath cultivated at RBG, Kew. Just over half of these species were displayed in the fynbos sections within the southern parts of the Temperate House before restoration. Now, a total of 19 species have been returned to the display.

The genus *Erica* comprises 868 species (The Plant List, 2018) and its centre of diversity is in the Cape region of South Africa. Here, the approximately 690 Cape endemics make up a large portion of the unique fynbos vegetation (Manning, 2012).

One of these endemic species is *E. verticillata*. This medium-sized evergreen shrub bears short needle-like leaves and produces attractive pink, tubular flowers arranged in neat whorls, organised in distinct groupings (Schumann & Kirsten, 1992). Not only is this handsome species well known for its ornamental value, but it is also the flagship of fynbos conservation. Once relatively common in the damp sandy areas of the Cape flats, this species was driven to the brink of extinction by the second half of the 20th century due to vast loss of its habitat (Hitchcock, 2013).

Fortunately, in 1984 the species was rediscovered in Protea Park, Pretoria. Six years after this discovery, two further clones were found at the foot of Table Mountain, and almost simultaneously a plant matching the species descriptions was found among the living collections at RBG, Kew. These four clones and an additional four found in collections worldwide were introduced into a breeding programme run by the South African National Biodiversity Institute (SANBI) at Kirstenbosch, Cape Town (Hitchcock & Rebelo, 2017). Although RBG, Kew's clone, which was named *Erica verticillata* 'African Fanfare', turned out to be a sterile clone, it is still grown at RBG, Kew together with other accessions mostly originating from material donated by SANBI.

The successful propagation method carried out at RBG, Kew

In comparison to their hardy relatives, the propagation of Cape heaths in cultivation is not considered easy, yet neither is it impossible. For this project, genetically identical material was required, therefore despite seed sowing being the simplest and most guaranteed method, in this case it was not an appropriate choice. Furthermore, seedlings often take a long time to grow to a suitable size for display.

The challenge of vegetative propagation of ericas in *ex situ* collections is the availability of a sufficiently large quantity of vigorous and appropriately mature material. At RBG, Kew the best time to propagate Cape heaths is late summer, with heel cuttings giving the best rooting success. In preparation, lateral semi-ripe shoots about 5 cm in length were torn off the primary branch structure in order to retain some of the cambium from the more mature wood on the main stem. The lower half of each cutting was then gently defoliated, with the end of the heel slightly trimmed. This was then dipped into rooting hormone suitable for woody propagation material: in this case, a rooting powder containing 0.25 per cent Indole-3-butyric acid.

As important as the preparation of the cutting material is the choice of propagation compost. This was selected according to the following criteria: sterility, low in nutrient content, free-draining and, most importantly, with a low pH ranging from 4.5 to 5.5. At RBG, Kew a 50/50 mix of sustainably sourced⁴ peat and washed river sand has given very good results. Trials made using these ingredients in different ratios showed that a higher proportion of sand in the mix led to a stronger root system with fewer roots,

4. A product called 'Moorland Gold' is used at RBG, Kew. This is a by-product of the water industry in the Pennines. The water pouring off the mountainsides naturally picks up particles of peat which are then collected in filters before the water enters the reservoirs, thus the peat has not been mined and the moors have not been dug.

whereas a higher proportion of peat (more organic matter) led to an increase in root formation, but these were generally weak and prone to being torn off easily.

Trays of cuttings were placed onto a heated bench with a soil temperature of 19°C, whilst air temperature was kept around 16°C. Trays have the advantage over pots in that larger quantities of cuttings can be placed relatively close to one another (2.5 cm apart), creating a microclimatic condition that the material seemed to favour. The medium was kept damp throughout. To minimise further moisture loss, the humidity was increased by covering the trays loosely with propagator lids. A small gap between the seed trays and lids ensures good air movement that is preferred by the *Erica* cuttings and minimises moisture loss. Good ventilation is important as the material is prone to fungal disease, which could easily lead to rotting off. The marsh heath is found naturally in moist areas and it appeared to cope better with wetter conditions in comparison to other Cape heath species. For this reason, it is advisable to keep other Cape heaths on the drier side.

In *Erica* spp. rooting can take place from six weeks on the heated bench but in many cases will take up to three months. Throughout this time the cuttings were checked frequently and picked over to remove dead and diseased material. In addition, regular treatment of fungal pesticide was applied to prevent any spread of disease.

In general, heaths dislike root disturbance, therefore care was taken once the cuttings were ready to be potted on. Initially a potting compost made up of a combination of named mixes was used as the first potting-on compost. This was 50 per cent 'general *Erica* potting compost' and 50 per cent '*Erica* propagation compost'. This decision was made so as to avoid stressing the plants by forcing them too quickly into soil conditions with such different porosity and moisture retention. Once they had grown on the plants were potted into the 'general *Erica* potting compost' containing equal parts of sand, grit, sustainably sourced peat and RBG, Kew's standard mix, 'Kew Potting'. This is a multi-purpose mix containing coir, composted bark, sterilised soil, grit, sand and wood fibre. Air-pots® were used for the growing-on containers. These pots encourage a healthy root system and are easy to handle when planting out, avoiding excessive root disturbance (Single & Single, 2010). Throughout this period the plants were regularly pruned to produce a compact and multi-branched form (Figs 3, 4, 5 & 6).

QUERCUS INSIGNIS FROM SEMI-MATURE CUTTINGS

The genus *Quercus* has 450–500 species of mainly medium to large trees. *Q. insignis* has the largest and most impressive fruits (acorns) of all the oaks, often reaching 10–12 cm across (Heathcoat Amory, 2009). The species also has a wide distribution (Le Hardy de Beaulieu & Lamant, 2010). In Central America it is found in Guatemala, Nicaragua, Costa Rica, Belize, Honduras and Panama. It is also known to occur further north in Mexico. It is endangered in Mexico and Panama, partially due to deforestation making way for coffee plantations (Oldfield & Eastwood, 2007). Allen Coombes introduced the species into cultivation in Europe in 1995 with seed collected on a field trip to Mexico.

RBG, Kew has a large collection of *Quercus*, found mainly in the Arboretum, with



Fig. 3 *Erica verticillata* planted out near the water feature of the South African section after the restoration. Photo: R. Hilgenhof.



Fig. 4 Rooted *Erica verticillata* cuttings potted on five months after they were taken. Photo: R. Hilgenhof.



Fig. 5 *Erica verticillata* six months after potting on for the first time. Photo: R. Hilgenhof.



Fig. 6 *Erica verticillata* grown from heel cuttings, now 18 months old, being potted on into a 3-litre Air-pot®. Photo: R. Hilgenhof.

a few tender species cultivated in the Temperate House. The individual of *Q. insignis* growing in the Temperate House prior to its recent restoration was a seed raised plant, collected by Allen Coombes (COBA 221) in Mexico at 1,155 m altitude. It grew fast and within seven years of planting it was touching the roof.

This plant was valuable to the collection and too large to be removed and replanted once restoration was complete, therefore it was essential to propagate it. As far as is known, all the *Quercus insignis* in cultivation are seed raised plants, so it was a fresh challenge to reproduce this plant vegetatively.

The successful propagation method carried out at RBG, Kew

Material taken from the top of the tree was sent to the Arboretum Nursery. Here it was cut up into a selection of softwood and hardwood cuttings, and placed in a range of conditions in order to maximise the chances of rooting.

The propagation environment was key to the success of this challenge. A fog tent set



Fig. 7 *Quercus insignis* cutting. Photo: A. Luke.

at 98 per cent humidity with basal heat set at 20°C was used. The droplet size of the fog produced is very fine, so that the fog lingers and does not cause damaging water droplets to form on the leaves, even at this high humidity. The fog tent has a small number of holes cut out of it near the top, which enables the movement of hot air out of the tent. There is also a small fan at one end of the tent which circulates the air and provides even humidity. The dense fog assists in keeping the leaves cool as well as hydrated.

A heated mat set at 20°C provides a warm rooting zone, which helps to speed up the rooting process because it increases cell division which contributes to formation of roots. These conditions create a good rooting environment for many species, ensuring stable conditions in which to keep the rooting zone within the containers warm and the foliage cool. Nodal, semi-ripe cuttings of *Quercus insignis* were taken in July–August and prepared to 25 cm, with the base cut just below a node. The lower leaves were cut off leaving four to six leaves per cutting. The bottom 4 cm was wounded vertically on two sides and the base of the cutting (5 mm wide) was then dipped in 2 per cent strength liquid of Indole-3-butyric acid just before being struck into the substrate.

The growing media used to root these cuttings consisted of 30 per cent sustainably sourced peat, 30 per cent propagation bark, 10 per cent coarse sand, 5 per cent sterile loam and 25 per cent perlite. This mix successfully holds moisture yet is sufficiently free draining and therefore difficult to overwater. The cuttings were rooted directly into 3-litre Air-pots® with a single cutting placed in each pot. At this relatively large size of container for a single cutting the water levels of the growing medium are far more stable and remove the need to pot on the cuttings once rooted, helping to avoid unnecessary root damage.

To avoid the substrate sinking within the pots, the growing medium was firmed in before and after the cutting was placed with its bottom 6–8 cm into the substrate, preventing movement of the plant material at any time. The pots were then watered in and placed in the centre of the fog tent. The pots were checked at least three times per week and watered, and damaged leaves removed to prevent disease.

It was approximately six months before the first roots were showing through the base of the Air-pots®, and by this time the cuttings had doubled in size. After a further two weeks, the material was weaned. The pots were transferred into a separate fog tent with humidity set at approximately 80 per cent. They remained in these conditions for another month before being moved onto a bench inside the same glasshouse. A young plant of *Quercus insignis* has recently been planted in the central section of the Temperate House.

GRAFTING *PINUS ROXBURGHII*

Pinus roxburghii Sargent, the Chir pine, has the shortest needle retention time in the genus. Needles are usually retained for a year. Charles Sprague Sargent named this species in honour of William Roxburgh (1751–1815), a Scottish surgeon and botanist who was famed for working extensively in India (American Conifer Society, 2017). *P.*

roxburghii is widespread in the north-east oriented outer valleys of the Himalaya and in its foothills, occurring in Bhutan, China, India, Nepal and Pakistan at altitudes of 400–2,500 m. This species is economically important for resin production across the Himalayan region, especially in NW India. Fewer trees are now dying prematurely as improved and more sustainable methods of resin tapping are now being carried out in those areas (Farjon, 2013).

The genus *Pinus* has the largest number of species within the gymnosperms; between 110 and 116 species are currently accepted (Grimshaw & Bayton, 2009). RBG, Kew has a large collection of *Pinus* most of which are fully hardy in the UK and are growing in the Pinetum. The few tender species can be found growing in the Temperate House, including *P. roxburghii* collected by M. Campbell (Camm) in Nuwakot, Nepal in 1978.

Prior to the recent restoration, the tree that was growing at the north end of the Temperate House was relatively old and therefore quite tall. It was impossible to dig out and replant the specimen due to its large size, therefore grafting of the plant was required in order to secure it for the collection. Grafting was chosen as a propagation method over cuttings, as *Pinus* spp. grown from cuttings rarely have the vigour required to grow into large specimens.

The successful propagation method carried out at RBG, Kew

Due to the vigorous growth of *Pinus radiata* D. Don, and its similarity to *P. roxburghii*, also a three-needled pine, it was chosen as a potentially compatible rootstock and was expected to form a successful graft union. The most healthy and vigorous material was collected from the top of the tree in the Temperate House. Lateral branches were avoided so that the scion material selected would have a strong apical dominance once grafted and would produce vigorous straight, upright plants.

For rootstocks the thickest *Pinus radiata* from two- to three-year-old Air-pot[®] grown (3-litre) plants were selected. The thickness of the scion material available was matched to the rootstock plants available. The grafting took place in early February using the side veneer method and a clean, sharp grafting knife. The rootstocks were prepared by first removing 10 cm of needles from the main stem. Then a small cut was made at an angle of 45° towards the base of the stem approximately 1 cm above soil level. A second cut was made 3–4 cm above the first cut, creating a straight downward cut angled slightly into the rootstock, meeting the bottom of the first incision, in effect taking out a slice of bark, exposing a veneer and leaving a notch for the scion to rest in.

The scions were prepared by trimming the material to a length of 15–20 cm, with the bottom end cut at a 45° angle. A second cut 3–4 cm long was then made running towards the base. Care was taken to not go too deep and to create a flat cut. The cuts were placed against each other, with the bottom of the scion sitting in the notch on the rootstock, to assess how well they would line up. There should be no air gaps or exposed inner wood when the two are placed against each other for a good grafting union. See Toogood

(1999) for descriptions and diagrams of grafting methods. Both parts were then bonded firmly together by wrapping grafting tape along the entire length of the graft, making sure that all the cuts were covered. The completed grafts were then placed in a fog tent set at 98 per cent humidity and with an air temperature of 12–15° C. The grafts were kept moist and checked for callus formation, which could be seen through the clear tape. Once the scion started to put on new growth, the rootstock was headed back (pruned) by 50 per cent, and after a further two months the rootstock top was cut off just above the graft. At this stage the scion had now put on vegetative growth and had started to show apical dominance. After two weeks the grafts were taken out of the fog tent and placed on a bench in the same glasshouse under shading. The grafts were then potted up from a 3-litre to a 12-litre Air-pot®. One of these plants can now be seen growing in the north end of the Temperate House (Figs 8 & 9).

RAISING *BANKSIA* L.F. SPECIES FROM SEED

Another important group of plants that has been successfully propagated and planted in the newly restored Temperate House are members of the genus *Banksia*, commonly



Fig. 8 *Pinus roxburghii* growing in the Temperate House. Photo: A. Luke.



Fig. 9 *Pinus roxburghii*. The graft union is just visible in the new and thriving plant. Photo: A. Luke.

known as Australian honeysuckle. Banksias are woody evergreen plants ranging from small, multi-branched, prostrate shrubs to single-trunked, erect trees that can reach a height of up to 30 m (McLean, 1991–1993). Their flower heads are composed of hundreds, sometimes thousands, of tiny, yellow-to-red coloured individual flowers arranged in pairs. Their infructescences are equally unique and although they are often referred to as ‘cones’ they actually consist of single woody follicles that are merged together on a single column. These often extremely tough fruits protect the seeds and will not usually open up until exposed to high temperatures caused by, for example, fire.

Species within this genus have a long tradition as part of the display in RBG, Kew’s largest Victorian display house. Sir Joseph Banks is an important historical figure and was the first European to collect material of this group of plants, for which reason Linnaeus named the genus in his honour. Even today, banksias are of great importance in the Australian displays of the Temperate House, making up a large portion of the SE Australian section in the centre block as well as the redesigned Davies Exploration House, which displays Western Australian species.

Nearly all *Banksia* species are endemic to the Australian continent, with one exception, *B. dentata* L.f., which extends as far north as Papua New Guinea, Irian

Jaya and the Aru Islands. Of these, 80 per cent occur exclusively in Western Australia (McLean, 1991–1993). Many species occupy distinct habitats, making some of them narrow endemics and therefore very vulnerable to any disturbance of their natural environment. An example of this is the endangered *B. brownii* Baxter ex R.Br., which is restricted to only two small populations in Western Australia (Harvey, 1995).

Banksia spp. tend to occupy habitats that are subject to fires. This has a great impact on how species survive and spread naturally, and equally it determines the breeding success when grown *ex situ*. Like many other members of the family Protea, specimens, particularly when mature, dislike root disturbance. As a result most of the plant material originally grown in the Temperate House was lost and new material was required. Seventeen species were reintroduced to the Temperate House. Ten of these are of Western Australian origin and were planted into the Davies Exploration House, including *B. petiolaris* F.Muell., *B. coccinea* R.Br. and *B. brownii* (Figs 10–12).

The successful propagation method carried out at RBG, Kew

Propagating *Banksia* spp. can be challenging and seed is usually the most successful method. Nearly all of the seed material processed was sourced from the Millennium Seed Bank (MSB). Thanks to the seed-collecting efforts of MSB Australian partners there is a variety of natural source seed material available which is complete with comprehensive, detailed collection data.



Fig. 10 View of the new Western Australian planting in the Davies Exploration House. Photo: R. Hilgenhof.



Fig. 11 *Banksia ornata* grown from seed, now planted and establishing in the Western Australian section. Photo: R. Hilgenhof.



Fig. 12 *Banksia brownii*, an endangered species from Western Australia putting on new growth in the Davies Exploration House. Photo: R. Hilgenhof.

The first of these seeds was sown in autumn 2015 in order to allow enough time for plants to grow to the desired size before the end of the project. Most of the seed material was pre-cleaned and only in the case of *Banksia serrata* L.f. did seeds have to be extracted from the follicles first. In this case, the infructescence was placed into an oven at 200°C for ten minutes, at which point the follicles started to open. Seeds were sown fresh to achieve the best germination rates. Unlike their South African relatives, Australian proteas do not require any special treatment prior to sowing, as most species are not affected by chemical or physical dormancy. Only species found in sub-alpine habitats may require cold stratification to trigger sprouting (McLean, 1991–1993).

The seed material obtained from cold storage in MSB was rehydrated by soaking in warm water for a couple of hours. During this period viable seeds swelled up significantly. In common with all species in Proteaceae, banksias do not respond well to root disturbance, and for that reason seeds were sown directly into 1-litre Air-pots®. Air-pots® were often chosen in the propagation stages of the material for the Temperate House because they not only encourage a well-branched fibrous root system but are also easy to open up, requiring minimum root disturbance when planting. The sowing mix used for this group was Kew's multi-purpose compost 'Kew Potting', with equal parts of sustainably sourced peat, grit and washed river sand. This is a low pH (4.5–5.5) medium that provides good aeration while ensuring adequate moisture retention. The medium was filled firmly almost to the very top of the pots, leaving enough room for an extra finely sieved layer of mix containing 50/50 coir and washed river sand. This acts as seedbed, including the top dressing, whilst still allowing the usual gap for watering. The fine, even layer of compost into which the seeds were embedded ensured full coverage of the seed with the moist medium, enabling adequate water uptake needed to coax the embryo to germinate and consequently emerge through the then softened testa. A final layer of 5 mm horticultural grit was applied as a top dressing. This prevents algae and moss from establishing, and also contributes to a top weight that prevents seeds as large as these from lifting out of the medium (Figs 13 & 14).

The pots were placed in Kew's purpose-built propagation house at a minimum temperature of 12°C during the winter, with a preferred maximum of 16°C during the summer and a venting temperature of 22°C. To ensure a rapid germination the pots were placed onto a heated bench at a constant 19°C. The seeds were quick to germinate, taking about two weeks from sowing to the first visible shoot. Once the seedling produced a couple of true leaves they were lifted off the heated bench. Proteaceous plants generally dislike warm soil temperatures and could respond with severe dieback if left on the heat.

Depending on the species, seedlings stayed in the pots for up to a year, or even two, in order to make sure the root systems were well established before potting on. Greatest care was taken with potting on to minimise root disturbance. The medium of the young plants was kept constantly moist for the first two years. Protecting the seeds from complete dryness and preventing a rest period resulted in a faster establishment of the seedlings. Once the plants had reached 18–25 cm, they were slowly weaned to cope with drier soil conditions. Regular liquid feeds were incorporated into the watering regime.

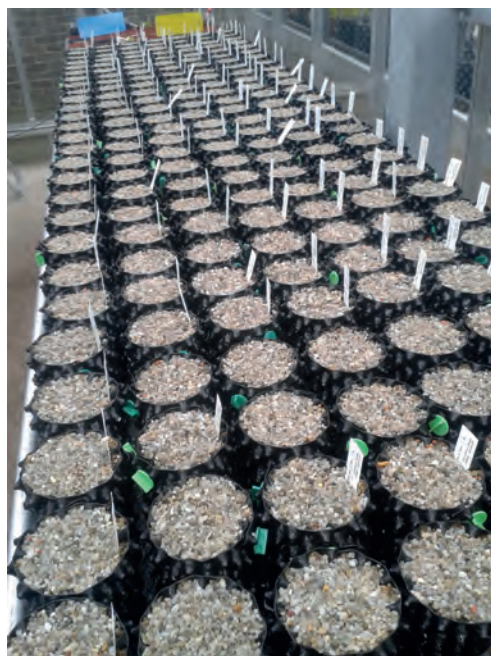


Fig. 13 In autumn 2015 various species of the Proteaceae family were sown for the Temperate House restoration in the Tropical Nursery. Photo: R. Hilgenhof.



Fig. 14 Six-month-old *Banksia* seedlings grown on behind the scenes at RBG, Kew. Photo: R. Hilgenhof.



Fig. 15 The Temperate Propagation Glasshouse, a purpose-built greenhouse to facilitate the propagation of the plant material for the Temperate House. Photo: R. Hilgenhof.

A non-phosphorus fertiliser with well-balanced amounts of nitrogen and potassium (4:0:4) plus trace elements was used to provide the main nutrients. Iron in the form of iron sulphate was provided on a regular basis as young seedlings often showed signs of deficiency in the new foliage which, in the absence of this element, simply died off. Air movement was also crucial for establishing the small *Banksia* seedlings, and once at least two to three pairs of true leaves were produced, the young plants were placed in front of a fan in order to expose them to constant air movement. Not only did this prevent etiolation and encourage a strong root system, it also kept the plants cool on even the hottest days.

Once the plants were well established in 3-litre Air-pots[®], they were planted out into the Temperate House. The earlier proteaceous plants can be established in their final location, the better it is for their healthy development into maturity.

CONCLUSION

The Temperate House Restoration Project was a great success and went as planned, with the House reopening its doors on Saturday, 5 May 2018. Despite a variety of challenges to propagate the range of plant material growing there, the horticulturists achieved the targets set to re-establish the earlier collections after restoration. Some of the challenges were: constraints in time available to produce large plants and the need for speedy

production; the limited plant material available; and, in some cases, limited information available about the plants and their culture. However, the project provided a great opportunity for all those involved to apply their knowledge and experience and exercise their propagation skills on a diverse range of plants, in order to rejuvenate a historic and scientifically significant collection. Of the 1,000 species that were originally growing in the Temperate House before the restoration, about 80 per cent were successfully propagated and replaced. These were complemented with new, high-value collections of core research interest, some of conservation concern, accompanied with wild collection data. This brought the total number of plants up to 1,400 species at the time of opening. An additional 100 accessions are still growing on at RBG, Kew's nursery facilities and once these have been planted, there will be a total of 1,500 species that can be admired, learned from and enjoyed in the Temperate House.

ACKNOWLEDGEMENTS

We would like to extend our gratitude to all those who have been involved with and supported the propagation of the plants for the Temperate House in the past six years. Without their help this mammoth undertaking would have not been possible. This includes the teams that make up the Palm House, Arboretum Nursery and the Tropical Nursery. Here, we would especially like to thank Dave Cooke (Supervisor, Temperate House) for sharing his vast knowledge on the collections. We would like to say a special thank you to Miranda Janatka (Botanical Horticulturist, Tropical Nursery) for proof-reading this article and providing valuable comments. Also, thank you to Kate Hughes (Editor of *Sibbaldia*) for editing the final version of this article before its publication.

REFERENCES

- AMERICAN CONIFER SOCIETY (2017). *Pinus roxburghii* (Chir pine). Available online: <http://conifersociety.org/conifers/conifer/pinus/roxburghii/> (accessed May 2018).
- FARJON, A. (2013). *Pinus roxburghii*. The IUCN Red List of Threatened Species 2013: e.T42412A2978347. Available online: <http://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T42412A2978347.en> (accessed June 2018).
- GRIMSHAW, J. & BAYTON, R. (2009). *New Trees: Recent Introductions to Cultivation*. Royal Botanic Gardens, Kew, Richmond.
- HARVEY, R. (1995). *Banksias – the genus Banksia*. Information about Australia's Flora. Based on an Australian National Botanic Gardens leaflet. Australian National Botanic Gardens and Centre for Australian National Biodiversity Research, Canberra. Available online: www.anbg.gov.au/banksia/index.html (accessed May 2018).
- HEATHCOAT AMORY, M. (2009). *The Oaks of Chevithorne Barton*. Adelphi Publishers, London.
- HITCHCOCK, A. (2013). *Erica verticillata*. Kirstenbosch National Botanical Garden. Available online: <http://pza.sanbi.org/erica-verticillata> (accessed April 2018).

-
- HITCHCOCK, A. & REBELO, A. (2017). The restoration of *Erica verticillata* – a case study in species and habitat restoration and implications for the Cape flora. *Sibbaldia*, 15: 39–64.
- IUCN LIST OF THREATENED SPECIES. Available online: <http://www.iucnredlist.org/details/42412/0> (accessed May 2018).
- LE HARDY DE BEAULIEU, A. & LAMANT, T. (2010). *Guide illustré des chênes*. Edilens, Geer.
- MANNING, J. (2012). *Plants of the Greater Cape Floristic Region. 1: the Core Cape Flora*. South African National Biodiversity Institute (SANBI), Pretoria.
- MCLEAN, R. (1991–1993). *The Propagation of Banksia*. Australian Plants Online. Available online: <http://anpsa.org.au/APOL24/dec01-1.html> (accessed May 2018).
- OLDFIELD, S. & EASTWOOD, A. (2007). *The Red List of Oaks*. Fauna & Flora International, Cambridge.
- SCHUMANN, D. & KIRSTEN, K. (1992). *Ericas of South Africa*. Fernwood Press (Pty) Ltd., Simon's Town.
- SINGLE, J. & SINGLE, S. (2010). Short Note: Good roots matter from day one. *Sibbaldia*, 8: 179–188.
- THE PLANT LIST (2018). *Erica*. Available online: <http://www.theplantlist.org/1.1/browse/A/Ericaceae/Erica> (accessed April 2018).
- TOOGOOD, A. (ed.) (1999). *Propagating Plants*. Dorling Kindersley, London.

