RHS

Inspiring everyone to grow

RHS Science Strategy 2015–2019

What we have achieved

The RHS Vision

To enrich everyone's life through plants, and make the UK a greener and more beautiful place.

Welcome

Professor Alistair Griffiths, RHS Director of Science & Collections

2019 brings the first ever RHS Science Strategy to a close, and what a five years it has been! I am immensely proud of what we have achieved and excited about the prospects for the future.

Our successful bid for the National Lottery Heritage Fund is testament to the hard work of so many people across the RHS, in Fundraising, Education, Communities and Gardens as well as Science and Collections. Thanks to

Our four key themes

1. A global knowledge bank for gardening and garden plants
2. Plant health in gardens
3. Gardening in a changing world
4. Plant science for all: people, plants, planet

Above. Visualisation of the new National Centre for Horticultural Science & Learning at RHS Garden Wisley.

this effort, the building of the new National Centre for Horticultural Science & Learning is under way and on track for official opening in spring 2021. Preparations for the move now begin in earnest as we work to catalogue and safeguard our collections, plan for new ways of working and finalise designs and stories for the exciting new public areas of the building.

2019 has itself been a year of achievements – the publication of our third monograph, on *Wisteria*, completing the move from email to online for Gardening Advice enquiries, growing our PhD programme to train the next generation of horticultural scientists and kicking off the Innovate UK Knowledge Transfer Partnership in collaboration with Cranfield University on water use in gardens are just a few of this year's highlights. The Science and Collections team is going from strength to strength and our work is directly benefiting gardeners, growers and government with improved evidence-based information and advice about getting the most from gardens and gardening.

Our 2020 forward strategy will continue our work in plant health and in understanding and promoting the benefits of plants for people, a changing climate and the environment. Our ongoing work on cultivated plant diversity and conservation comes to the fore and our continued commitment to the Global Knowledge Bank on Gardening expands and grows. Our Collections will soon have their own strategy to ensure their conservation, management and sharing supports both our Science Strategy and the wider RHS vision to improve everyone's lives through plants and make the UK a greener and more beautiful place.

"The Science and Collections team is going from strength to strength and our work is directly benefiting gardeners, growers and government."

1 A global knowledge bank for gardening and garden plants

Gathering and sharing information

Horticultural monographs

Written with gardeners in mind, the RHS monographs provide a guide to identification of the species, hybrids and cultivars in a genus, with descriptions and images as well as a checklist of names. They are also a compilation of the latest practical information about the group of plants, their uses in the garden, their cultivation and breeding. The aim of the series is to raise awareness of the diversity in UK gardens and the potential for the development of new varieties.

Since the publication of *Kniphofia* in 2016, the RHS monograph programme has gone from strength to strength with *Hedera* (2017) and *Wisteria* (2019). Forthcoming monographs will include *Lathyrus* and *Colchicum*.

The Hillier Manual

Providing gardeners and landscapers with a key reference source for almost all woody plants grown in the UK, the *Hillier Manual of Trees & Shrubs* supports the growing diversity in gardens. By including features and growing requirements for a huge range of plants, some of which are rare or recently introduced, it encourages people to choose the right plant for the right place. The plant names are up-to-date and so the book provides an authoritative source for the nomenclature of woody plants in UK gardens.

The previous edition (2014) was the first which the RHS produced, and we published the 9th edition in 2019 with significant updates. This new edition contains:

- Over 1,200 new entries
- RHS hardiness ratings for all entries for the first time
- Latest published information on *Betula*, *Hedera* and *Wisteria* (the latter two tying in with our horticultural monographs)
- Tree ferns added for the first time; also many more acacias and palms, reflecting the increasing range of plants grown in UK gardens

> "Our work will make a difference by improving plant identification, informing effective management of invasive plants, safeguarding our important collections, and making them more accessible as a learning resource."
> RHS Science Strategy 2015–2019

Left. Rosalyn Marshall, RHS Monographer, who worked with leading authorities on the genera to produce the RHS monographs on *Hedera* and *Wisteria*. Above. *Wisteria sinensis* 'Prolific'. Far left. *Acacia baileyana*, which featured in the 9th edition of the *Hillier Manual*. Right. *RHS Plant Finder* supports UK nurseries and connects them with buyers.

Dianthus Register

The *International Dianthus Register and Checklist*, containing over 40,000 names, was published in 2016. The Register (published as part of our role as International Cultivar Registration Authority for nine plant groups) allows users to check *Dianthus* names to see if they have already been used, helping to prevent duplication of names. It also allows cross-referencing of cultivar names with trade designations, which are widely used in the *Dianthus* trade. The Register also supports identification of *Dianthus* and helps build a picture of the history of *Dianthus* cultivation and the individuals and nurseries involved in it.

RHS Plant Finder

RHS Plant Finder is the reference book and online resource for plant buyers and those looking for plant names. It supports UK nurseries by connecting them with buyers and showcases the diversity of plants available for your garden. The 2015–2019 strategy saw the 30-year anniversary of *Plant Finder*, a milestone that was celebrated with a special edition and a unique garden showcasing significant plants and people throughout the book's history.

The content of the book has been developed to include plant lists for pollinator support, AGM fruit and vegetables with descriptions, and cacti. The new colour section (introduced for the anniversary edition) included an editorial piece on new plants which proved so popular with both readers and nurseries that it has been made a regular feature.

Since 2015 the number of nurseries in *Plant Finder* had been steadily declining as smaller businesses merged or closed. Our programme of outreach and engagement with nurseries saw that trend turn the corner in 2019 with numbers both of nurseries and plants rising. Further efforts should see this rise continue in the 2020 edition, supporting more UK nurseries and bringing more plants to UK gardeners.

Identifying and understanding plants in our gardens

Genetic diversity in *Narcissus* (daffodils)

The RHS has had a prominent role in *Narcissus* classification since the first daffodil conference in 1884. More recently we have established a programme of research and PhD projects with the ultimate aim of producing a monograph of the genus, as well as informing breeding and conservation efforts and strengthening our advice on how to grow and care for daffodils in the garden. One of these projects has been to sequence the entire chloroplast genome of a number of species of *Narcissus*, the first being *N. poeticus*, which was published in 2018 and was the first time this had been done for the genus. We are using this data to improve our understanding of the evolution of the genus and to explore the possibility of genetic markers that can be used to identify daffodil cultivars in the absence of other distinguishing features, for instance when sold as dry bulbs.

Using genetic markers, we tested bulbs of cultivars 'Julia Jane' (top) and 'Atlas Gold' from different sources. Our results showed that two of the 'Julia Jane' plants grouped together, while the third was more similar to 'Atlas Gold'. This was confirmed when the plants flowered, revealing that the latter had been mislabelled.

Gunnera

The Brazilian giant rhubarb (*Gunnera manicata*; above) is a popular feature plant in waterside areas of gardens, but its close relative the Chilean *Gunnera tinctoria* is listed as a serious invasive plant in the UK and the Republic of Ireland. Both *Gunnera* species have been in cultivation in this country since the latter part of the 19th century, but it has in practice proved difficult to separate them on morphological characters.

Our project combines morphological and molecular methods to better understand the relationships between these two species to gain insights into the nature of the invasive plant and so support efforts to control it. Having completed a thorough survey of these two species in cultivation in the UK and Ireland, our current work is focusing on plants sourced from areas where these species are native and plants in cultivation in mainland Europe.

"As well as giving buyers assurance, our work in genomics will potentially help plant breeders speed up the process of selecting new cultivars with specific traits."

RHS Botanist Kálmán Könyves

A single source for naming and classification of garden plants

Launch of online registration for orchids and dahlias

As International Cultivar Registration Authority (ICRA) for nine different groups of plants, the RHS provides a resource for breeders and raisers of new varieties, as well as for researchers seeking information about these plants. It also enables the RHS to promote the stability of cultivated plant names. The groups the RHS is responsible for include orchids, daffodils, lilies, rhododendrons and dahlias. The system has been largely paper-based, which increasingly is becoming an impediment to registration. Thanks to a joint project between Science, IT and Digital, it is now possible for people worldwide to register new plant names for both orchids and dahlias using our newly developed online system. This simple and secure system has made plant registration more accessible to registrants around the world, a fact which is reflected in the high uptake. It is planned to make this possible for other plant groups the RHS is ICRA for.

Above. **From field to cabinet: the RHS Herbarium preserves the nation's gardening heritage by creating and curating dried specimens of ornamental plants.** Top right. ***Dahlia*** **'Kelsey Annie Joy' was the first dahlia to be registered using the online registration form. This colourful collerette dahlia originated in the USA.**

Digital Herbarium

Our ambition to make digital versions of all our herbarium specimens available online for researchers and gardeners alike reached a critical milestone in 2018 with the completion of the imaging of the 87,600 specimens. With the support of the National Lottery Heritage Fund, work now continues to catalogue these images in preparation for making them available to search and view online and to develop the means to deliver this. High-quality cataloguing combined with a user-friendly portal to the collection will be critical to ensuring maximum exposure for this unique reference collection of UK garden plants. Of course the herbarium continues to grow, at a rate of around 1,000 specimens a year, working towards our goal of a comprehensive representation of the UK garden flora.

The RHS horticultural database

Our project to safeguard and make shareable our plant knowledge and data has delivered a brand-new approach to managing our plant names that ensures that what we know about a plant stays with that plant even if its accepted name changes. This new "entity"-based approach will soon form the basis of improved search facilities on rhs.org.uk, helping gardeners to find plant information whether they search on the accepted name, a synonym or historic name or a common name. The next step is to connect this approach to our herbarium and living collections data as well, making it possible to search and find everything that the RHS has recorded about a particular plant.

2 Plant health in UK gardens

The RHS plant health policy

There has been an increase in the rate at which harmful plant pests have become established in the UK. Pests such as ash dieback and box tree moth are causing significant changes to our landscape and horticultural practices.

In 2017 we revised our approach to plant health and adopted six principles to guide plant health practice across the Society (see panel, right).

To implement these principles, we are making changes to our horticultural, retail and shows activities. For example, we have banned plants that are particularly susceptible to the bacterium *Xylella* from being exhibited at RHS Shows (unless UK-sourced and grown), and all imported semi-mature trees must be held in quarantine prior to planting or exhibition.

These issues were discussed and presented in a plant health garden at RHS Chatsworth Flower Show in 2018.

Above. **The new RHS Plant Reception facility at RHS Garden Wisley. Plants received are assessed for risk according to source and type of plant material. The higher the risk, the longer plants are held in reception.**

The six principles of RHS plant health practice

- **Provide guidance** on plant health issues to protect the sustainability of gardens and horticulture in the UK.
- **Assess plant health risks** prior to undertaking activities that are likely to have phytosanitary implications and identify what mitigations are required.
- Adopt **practices across RHS activities** that minimise plant health risk, while balancing that risk with horticultural benefit.
- Prioritise and **undertake research** to generate the knowledge necessary to manage plant health risks to UK horticulture.
- Communicate and **exchange knowledge** to enable informed decisions to be made to manage plant health risks to UK horticulture.
- **Work collaboratively**, internally and with external organisations, to contribute to the management of plant health risks in the UK and to help develop the skills necessary to manage such risks.

> "Our work will make a difference by improving plant health in gardens, enabling better detection, identification and control of plant pests and diseases, and safeguarding biodiversity through improved stewardship of nature."
> RHS Science Strategy 2015–2019

Advancing management strategies

Honey fungus

Honey fungus (*Armillaria*) is a major concern for gardeners, as it can kill high-value woody plants then use the dead wood and roots as a food source to survive on until it finds a new host. Improving the practicality and effectiveness of the advice we give to gardeners dealing with honey fungus will help avoid unnecessary and time-consuming actions wherever possible and support gardeners to respond appropriately to an outbreak.

Our portfolio of research on honey fungus, established under this strategy and continuing under the next one, involves long-term investigations of the interactions between the strongly pathogenic *Armillaria mellea* and the weaker *Armillaria gallica* and the potential of beneficial *Trichoderma* fungi to protect plants from honey fungus infection. Achievements during the last strategy period include:

- Discovery that *A. mellea* is by far the most prevalent and impactful honey fungus species in gardens (occurring in 83% of cases). This key understanding was reached by analysing data from samples received by RHS Gardening Advice during 2004–2007 and then again 10 years later in 2017. Results also showed that only three of the seven UK species of honey fungus occur in UK gardens and that species distribution is unchanged over a ten-year timescale.

- Responses to our citizen science mushrooms survey revealed that mushrooms are most often associated with dead and dying plants. Our online resources for mushroom identification proved successful as over 90% of records correctly identified honey fungus mushrooms.

- A new molecular test has been developed that can both identify the species of honey fungus present in a sample and quantify how much of each is present. This test may in future be offered as a service for gardeners, enabling accurate identification and tailored advice on management of honey fungus.

- Our honey fungus host plant list has been completely overhauled, with 300 genera reviewed, greatly improving the accuracy of our advice on what gardeners can safely replant in affected gardens. This review was based on a new analysis of host plant resistance based on experimental observations and evidence from member enquiries.

Slugs and snails

Slugs and snails hit the top of gardeners' pet peeves year on year, and yet until recently there has been little scientific evidence around which species live in our gardens, which species are damaging our plants and what can be done to control them. RHS research is improving understanding of the role of these maligned creatures in the garden ecosystem, and in conjunction with BASF providing an evidence base for gardeners on what is effective in minimising the impact of those species that are pests.

Having already shown that organic slug pellets (ferric phosphate) or nematode biological control can perform as well as metaldehyde pellets when paired with mulch, work is continuing to find sustainable ways in which gardeners can manage slugs and snails.

A project in collaboration with Liverpool John Moores University is investigating the currently available nematode biological control system, testing its efficacy in different soils and temperatures, so we can give more tailored advice to gardeners on application and use. The RHS is also using a citizen science approach, in collaboration with Newcastle University, to study which species of slugs and snails are present in UK gardens. This will challenge gardeners' perceptions by exploring and highlighting which species are beneficial in the garden and which species are responsible for eating our plants.

Above. **Round-backed slug (*Arion* species) on young lettuce plant. RHS research will highlight which species of slugs and snails are beneficial in the garden.**

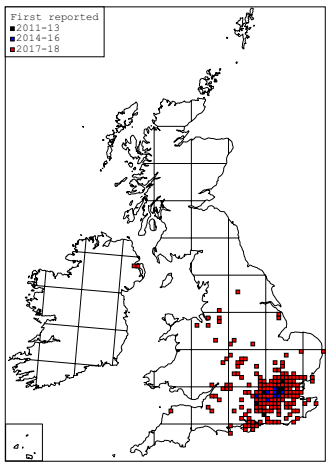
Box problems

Despite new pest and disease problems, box (*Buxus*) remains a garden staple and represents a significant investment for many gardens. This strategy has seen the rapid expansion of our research on integrated pest management of box including dealing with the box tree moth caterpillar (*Cydalima perspectalis*) and management of box blight. Work in conjunction with BASF resulted in Nemasys® Natural Fruit & Veg Protection, a nematode treatment, being recommended as an additional tool for use against box tree moth. Further work is needed to optimise application recommendations to give gardeners the best chance of success.

Understanding the impact that gardeners can have on the spread of box blight using cultural methods has been a key aspect of our work to improve our guidance on box management. Identified beneficial practices include:

- Keeping stems as dry as possible by avoiding overhead watering during summer to reduce the viability of the fungus in infected stems and thereby reduce the risk of new infections in autumn
- Employing good garden hygiene
- Pruning during dry conditions
- Maintaining good ventilation with appropriate plant architecture to reduce the humidity that box blight enjoys

This improved understanding means we are now offering gardeners a more positive outlook on the future of box in their gardens. Further work on partially resistant box cultivars and alternatives will continue alongside the existing box research portfolio under the next strategy.



Top. **The box blight management assessment at the John MacLeod Field Research Facility, Wisley. Understanding the impact gardeners can have on the spread of box blight is a key aspect of our research. Above, left. Box tree moth is a worrying new problem for UK gardeners. It has also been the subject of one of our Citizen Science surveys, with reports of the pest increasing rapidly since it was first reported in 2011 (right; red dots are reports received 2017–2018). Other pests which we track through surveys include berberis sawfly, lily beetle, hemerocallis gall midge and rosemary beetle.**

Carrot root fly

Carrot root fly is a bothersome pest for growers of carrots, parsnips and celeriac, among other popular Grow Your Own crops. Following the publication of our research in *Journal of Applied Entomology* in August 2019, our advice on carrot root fly has been updated to advise gardeners to completely cover their carrot crop to attain an acceptable level of control of carrot root fly, especially for carrots harvested later in the season. This new advice has been included in the seeds sent out to community groups that are growing carrots as part of the Big Soup Share 2019.

Monitoring plant pests and diseases

New discoveries

The RHS Plant Health team has identified several species new to the UK through samples sent to RHS Gardening Advice and from RHS Gardens.

Since 2015 discoveries have included:

- **Bamboo white scale** (*Kuwanaspis howardi*), 2015, and a **felt scale** (*Acanthococcus pohutukawa*), 2017, neither of which had previously been confirmed as being present in Europe.
- **Cotton stringy scale** (*Takahashia japonica*), 2018, which had only recently been added to the UK plant health risk register. 1
- **Webspinners** (Embioptera: *Aposthonia ceylonica*), 2018. Previously no other species of webspinner was known to be resident in the UK and there were very few reports of this insect order in Britain. However, no action needed to be taken as it is not harmful to its orchid hosts and is unlikely to survive outside glasshouse conditions. 2
- **Aquilegia downy mildew** (*Peronospora aquilegiicola*), 2013. Since then the disease has become widespread in the UK, causing significant losses in gardens including destruction of the National Aquilegia Collection in Swansea. RHS scientists collaborated with researchers from Germany and South Korea to produce two papers highlighting the significance of the disease and naming the pathogen as a new species of *Peronospora*. 3
- ***Alternaria thunbergiae***, 2017. *Thunbergia alata* (black-eyed Susan vine) is used as an annual climber in bedding schemes and hanging baskets in UK gardens. In 2017 plants at RHS Garden Wisley were affected by a leaf spot caused by *Alternaria thunbergiae*. The unsightly foliage causes a reduction in plant quality and could have significant negative implications for growers. A report of the finding has been published by RHS scientists to raise awareness of the problem. 4
- ***Phytophthora palmivora***, 2019. RHS scientists diagnosed a case of *Phytophthora palmivora* on *Prunus* trees imported from Italy; this was reported to the Animal and Plant Health Agency (APHA), as it is a regulated pathogen. The affected trees were removed and destroyed by the member, who had raised the issue through RHS Gardening Advice.

HOMED – Holistic Management of Emerging Forest Pests and Diseases

The RHS is working as part of the consortium of 22 global partners in this EU Horizon 2020 research and innovation grant-funded programme. RHS scientists will play a key role in delivering public engagement and awareness aspects of the programme, which will develop approaches to identify and manage the pests and diseases affecting our forests. The programme is currently in its early stages and the majority of the work will come under the next RHS Science Strategy.

BRIGIT: enhancing surveillance and response preparedness for *Xylella fastidiosa*

Xylella fastidiosa is a bacterial plant pathogen that is already estimated to have caused €1.2 billion worth of damage to plants such as olive in mainland Europe and is spreading across southern Europe from its origins in the Americas. Although *Xylella* has not yet been detected in the UK, an outbreak would be devastating for gardeners and the horticulture industry.

As part of the BRIGIT consortium, the RHS is focusing on delivering citizen science, outreach and knowledge exchange. Through "Biosecurity and *Xylella*" training days in Wales, England and Scotland (in collaboration with Forest Research and the University of Sussex) and our new disease symptom guides (below) for the top nine high-risk hosts in the UK we are raising awareness and vigilance about the disease and the pathways through which it might be introduced into the UK.

Throughout the year we have also been promoting *Xylella* awareness with our BRIGIT stand and leaflets at RHS flower shows and other trade events. The RHS Plant Health team worked with young garden designer Kristian Reay and APHA and BSPP colleagues on the Phytosanctuary Garden at Tatton Flower Show to highlight *Xylella* and the risk it poses to UK horticulture and the wider environment. The garden won the Young Designer award leading to significant interest among the public and in the press.

Our recent survey on xylem-feeding insects, including spittlebugs (major vectors of *Xylella fastidiosa* overseas), received over 14,000 responses thanks to an initial exclusive with the BBC (including coverage on *BBC One Breakfast*, the BBC News Channel, BBC News Online and BBC Radio 4's *Broadcasting House*), followed by coverage in *The Times*, *The Guardian*, *The Telegraph*, *The i*, *The Independent*, *Gardeners' World* magazine, *Amateur Gardening* and local and regional papers. The data collected contributes to the development of a model for how the disease may spread if it reaches the UK, which in turn will inform UK-wide response planning.

The BRIGIT consortium is funded by UK Research and Innovation through the Strategic Priorities Fund, by a grant from the Biotechnology and Biological Sciences Research Council with support from the Department for Environment, Food and Rural Affairs and the Scottish Government. It is made up of 12 research organisations including the RHS. Further information can be found at the website www.jic.ac.uk/brigit

Encouraging good garden stewardship

Plants for Bugs

With major impacts on the advice that we give on maximising garden biodiversity, Plants for Bugs has been one of the most significant and wide-reaching research studies ever undertaken at the RHS. Over four years, the field experiment known affectionately as "P4B" considered whether the geographic origin of garden plants affected the abundance and diversity of invertebrates they could support.

The results have promoted discussion about the role of native and non-native plants in the garden both in the UK and further afield with findings prompting pieces in publications in Germany and the USA. At an amenity level, beneficiaries of the advice developed on the basis of P4B research include BREEAM (Building Research Establishment Environmental Assessment Method), TDAG (Tree Design Action Group) and the Defra / UK National Pollinator Strategy.

With general news reports of the decline in insect populations in the UK, gardeners, landscapers and designers are benefiting from this robust, reliable information on how best to support invertebrates in the garden, and with three peer-reviewed publications now translated into clear and practical advice on what gardeners can do, the future looks a little brighter for the UK's garden invertebrates.

Green walls and biodiversity

Using techniques developed as part of Plants for Bugs, our current project investigates the role of green walls (often grown as they achieve greening in areas where ground space is at a premium and have a role in air quality improvement) in supporting invertebrate life.

Comparing the abundance of invertebrates that four common climbing green wall plants support – common ivy (*Hedera helix*), a variegated ivy (*H. helix* 'Glacier'), a Boston ivy (*Parthenocissus tricuspidata* 'Veitchii') and climbing hydrangea (*Pileostegia viburnoides*) – this work will enable us to strengthen our advice to gardeners and landscapers looking to maximise biodiversity benefits where spaces in cities to grow are decreasing.

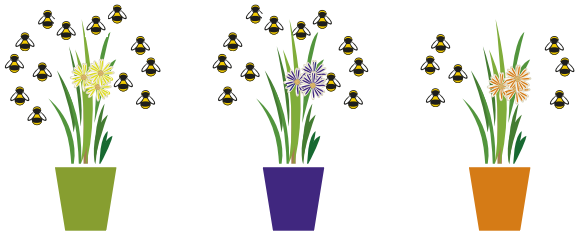


Fig. 1. Gardens as habitats for pollinators.

Fig. 2. Gardens as habitats for plant-dwelling invertebrates.

■ British native plants ■ Northern Hemisphere plants
■ Southern Hemisphere plants

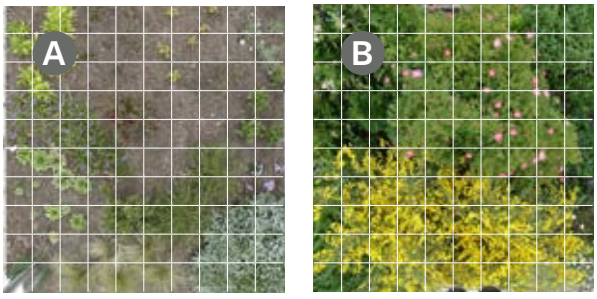


Fig. 3. Vegetation density in two of the 3 x 3m Plants for Bugs plots, with a grid of 30 x 30cm squares superimposed. Plot A is sparsely planted: approximately 50% of the squares show soil and 50% show vegetation. By contrast, Plot B is densely planted, with 90–100% of the squares filled with plants. We would expect plot B to support more ground-active and plant-dwelling invertebrates than plot A.

What did we do?

It's often assumed that insects and other invertebrates that live in gardens are best supported by native plants. But is this true, especially in the UK, where the number of plants classed as "native" are relatively few?

To make a comparison between native and non-native garden plants and the invertebrates they support, two sites were chosen for a field experiment at RHS Garden Wisley. Each site was divided into eighteen 3 × 3m plots. Every plot contained 14 species of plants from one of three geographical regions (Britain, Northern Hemisphere excluding Britain and Southern Hemisphere). Invertebrates were recorded from all plots by several methods: from the ground using pitfall and gastropod (slug and snail) traps, from foliage using a Vortis suction sampler and from flowers (pollinators) by visual observation. Findings from the study, supported by the Wildlife Gardening Forum, have shed new light on the plantings British invertebrates prefer.

What did we find?

Our first paper, published in 2015 in the *Journal of Applied Ecology*, looked at gardens as habitats for aerial insects (pollinators such as bees, wasps, butterflies and hoverflies). We concluded that If a garden contained flowering plants from a single region, the number of pollinators that visited British native plants would differ only marginally from the number found in a garden consisting solely of plants from the Northern Hemisphere, but would be almost double the number in a garden with only Southern Hemisphere plants (Fig. 1).

Paper 2, published in *Biodiversity and Conservation* in 2017, looked at plant-dwelling invertebrates such as caterpillars, ladybirds, earwigs and springtails. In a typical garden there is usually a mix of plants from different regions. We concluded that if you were to choose plants from a specific region (as we did in this experiment), to obtain the same number of invertebrates as from a plot of British native plants, you would need about a fifth more vegetation from the Northern Hemisphere, and about a quarter more from the Southern Hemisphere (see Fig. 2).

Paper 3, also published in *Biodiversity and Conservation*, in 2019, looked at ground-active invertebrates such as wingless weevils and carnivorous ground beetles. We found that, overall, regardless of plant origin, the denser the vegetation, the higher the ground-active invertebrate abundance (Fig. 3). A notable exception was ground-active spiders, which were found in greater numbers among sparser plantings. However, planting schemes based on exotic plants may support more ground-dwelling active invertebrates in winter than British native or near-native planting schemes, perhaps because of the greater use of evergreens.

"The power of a garden lies in its very smallest inhabitants. Gardeners who look after them will have the greatest positive impact for biodiversity, helping to forge a new generation of wildlife champions."
RHS Principal Entomologist Dr Andrew Salisbury

3 Gardening in a changing world

Understanding the vital role of plants

What hedge should I plant?

In 2015 the RHS Greening Grey Britain garden at Hampton Court Flower Show promoted the positive benefits of hedges and other garden plants and features – noise mitigation, air quality improvement, rainfall mitigation and biodiversity support, to name just a few. As an important design feature within gardens which can also deliver environmental and health benefits, our next challenge was to guide gardeners to choose hedging plant types that maximise the benefits they are looking for. Through an extensive literature review and experimentation, we have now developed practical guidance for members and industry practitioners on the combinations for hedges which are likely to have the most positive environmental impact.

How plants contribute to drainage systems

Our investigations into different hedge species also revealed that little is known about the differences in rainfall and flood mitigation provision between plant types. With flooding high on the agenda as weather patterns change in the UK, our research (carried out both outdoors and in the lab) has shown that planting the right plants can play a positive role in alleviating pressure on the already stretched drainage systems during rainfall events, particularly in the urban context where there is little permeable ground to absorb water.

In the experiment set up by RHS researchers on outdoor field plots at the University of Reading in 2017 (left), simulated rainfall was applied to hedges and bare substrate (a commercial mix of coir, pine bark and fibre) in troughs.

The results showed that rainfall run-off from species such as *Cotoneaster* and *Crataegus* with larger canopies and high water use rates was delayed by as much as 15 minutes, compared with bare substrate. The volume of rainfall run-off was also reduced.

Maximising the health benefits of gardening

Office and house plants for improved indoor air quality

Houseplants are frequently marketed as "air cleaners", and with interest in houseplants on the rise, better understanding of which plants, under what conditions, can best deliver this sought-after benefit is needed. The RHS's own work alongside two PhD projects (Universities of Birmingham and Reading) has unravelled the impact of plant choice and conditions on aspects of indoor air quality, including relative humidity and concentrations of CO_2 and NO_2. Our research shows that more vigorous and active species such as peace lily and indoor ivies do remove more gases from the air. However, environmental conditions in the room (e.g. light levels) have a greater impact on how effective they are in doing so. Additionally, we found that even in the dark (e.g. at night) plants don't contribute significantly to the elevation of CO_2 at a room scale – dispelling the popular myth that plants in the bedroom will suffocate you at night.

Front garden landscapes for health and wellbeing

One in three UK front gardens contain no plants. Through a collaborative PhD with the Universities of Sheffield and Virginia, we aim to understand the social and cultural value of front gardens. We are investigating if increasing the vegetation in front gardens has a positive impact on residents' well-being and other cultural ecosystem services such as social cohesion. Using a low-cost "greening" intervention on a typical terraced street, this work will help us understand the role that vegetated front gardens can play in supporting individuals and communities. This work supports the broader RHS Greening Grey Britain campaign and is raising the profile of the consequences of paved front gardens. Results are expected in early 2020. This work will be followed up with a new Fellowship on Gardening for Wellbeing in collaboration with Sheffield University to commence in 2020.

Left. The research involves installing plants and containers in gardens along a typical suburban street and assessing the impact on residents' wellbeing, as well as cultural aspects such as social cohesion. It also aims to establish how achievable these local interventions are, in relation to cost, timescale, and other resources, and to identify factors that encourage and discourage residents in maintaining front gardens.

> "Our work will make a difference by improving understanding of the health benefits of plants and gardening, promoting the use of plants for their ecosystem services, reducing resource use and equipping gardeners to meet the challenges of a changing climate."
> RHS Science Strategy 2015–2019

Promoting environmentally responsible gardening

Gardening in a Changing Climate report

2017's launch of our Gardening in a Changing Climate report and the events that accompanied it represent a significant achievement under this strategy and an example of the importance of collaboration with our university partners.

In 2018, we ran three events sharing region-specific detail on climate change predictions, what they mean for gardeners in terms of what they can grow, and how gardeners might adapt to the challenges. These events, run in collaboration with the Royal Metrological Society (RMetS), took our findings to diverse audiences in Manchester, Bristol and Birmingham. A joint gardeners' event programme is planned for spring 2020.

Lessons learnt from a trial run of conditions that are likely to become more common in the UK, and which were experienced in the hot summer of 2018, were published in partnership with RMetS in *The Garden* magazine.

Contributors included Dr Ross Cameron (University of Sheffield), Dr Alastair Culham (University of Reading), Kathy Maskell (Walker Institute, University of Reading), Dr Claudia Bernardini (KTP Research Associate). Dr Mark McCarthy (Met Office) and Prof. Tim Sparks (Coventry University) provided expert advice on climate projections and phenology. The project was also supported by Innovate UK and the Trustees of Spencer Horticultural Trust. Richard Bisgrove and Prof. Paul Hadley, authors of the Gardening in a Global Greenhouse report (2002), built the foundations for this updated report.

Top. The Garden for a Changing Climate at RHS Chatsworth Flower Show in 2017 showcased the garden adaptations suggested in the report as a response to changing climate in the north of England. For instance, the central rill transports water captured during extreme weather events to ponds or rain gardens (above), while *Primula vialii* (left) thrives in wet conditions.

Sustainable growing media

Between 2012 and 2017, funded by an RHS / AHDB Fellowship, Dr Gracie Barrett (above) worked on identifying and assessing environmentally sound alternatives to traditional growing media components. Although there has been an interest in renewable materials from agricultural, industrial and municipal waste streams, and many of these show promise at an experimental level, few have been taken up on a significant scale. Gracie's work highlighted the extreme complexity of "sustainability" in the growing media context and the need to take into account a broad range of factors, including human health, ecosystem impacts, pollution potential, irrigation requirements and pest and disease management when considering "alternative" components for growing media, including those that come from waste streams. This work also identified the need for better understanding of the costs of such components for industry, including the costs of processing, transport and plant management, consistency of product and the need for a stable and large supply.

Responsible Sourcing Scheme (RSS) for growing media

We are continuing our contributions to an industry group working to produce an audit scheme for sustainability and employment ethics in the growing media industry. The launch is planned for the end of 2019.

Above. **Research into sustainable growing media at the Field Research Facility, Wisley.**
Above right. **Research on optimal watering strategies for hanging baskets forms part of the KTP project to improve water management in the RHS and the wider horticultural community.**

Improving water management in the horticultural community

Water management specialist Janet Manning joined the RHS in November 2018 to work towards addressing the challenge of sustainable water use by gardeners and research the best water management products and techniques. "I am hoping to change behaviours to not only achieve savings in water use, but also help gardeners grow better plants by managing their water resources more effectively," says Janet, seen above at the RHS irrigation trial. "Every drop saved in the garden makes more available for the environment and people to use." Janet's recent knowledge gap survey revealed that gardeners want to know how to cope with the changing climate as well as getting better advice on how much to water and how often. Irrigation and water companies have been identified as key stakeholders and are keen to work with the RHS.

The project is a three-year Knowledge Transfer Partnership (KTP) between Cranfield University and the RHS, which is funded jointly by Innovate UK and the RHS. KTPs facilitate learning between academic and industry partners, for mutual benefit, and the project continues under the next strategy.

Soil health and the long-term organic matter trial

A further five years of testing different soil amendments on our organic matter plots has found no appreciable differences in yield between a 2.5cm green waste compost application and a 5cm application, suggesting that our existing understanding of annual soil input requirements may be excessive. In addition, high organic matter loss (mineralisation) has shown that organic matter inputs are not an effective way to sequester carbon in sandy soils. Further work is now planned to investigate the potential of "living fertilisers" as an alternative to organic matter amendments for both carbon sequestration and plant nutrition with both "dig" and "no dig" approaches being investigated in order to provide definitive guidance for gardeners.

4 Plant science for all: people, plants, planet

Involving people of all ages

Science week

Science week has built over the course of this strategy into a key way in which RHS Science involves Wisley visitors in our research and engages them in the world of plant science.

In 2019 Prof. Alistair Griffiths partnered with scent manufacturer Givaudan and RHS Garden Wisley visitors to explore the emotions triggered by a variety of scents, as part of our developing research on how gardens can affect mental health and wellbeing.

In addition, the Plant Health team worked with the Events and Education teams to deliver workshops for school groups on slug identification and plant CSI – helping bring our work to life for children, teachers and parents alike.

Rocket Science

In the summer of 2016, 600,000 children became space biologists as they began a 35-day experiment to sow and grow rocket seeds that has spent six months on board the International Space Station (ISS) with astronaut Tim Peake. The results varied from group to group but overall they suggest that, on average, the space seeds grew less well than the seeds that had remained on Earth. Prof. Alistair Griffiths said of the experience, "Rocket Science has been a great way to engage school children with plant science and to get them thinking about the future of our food".

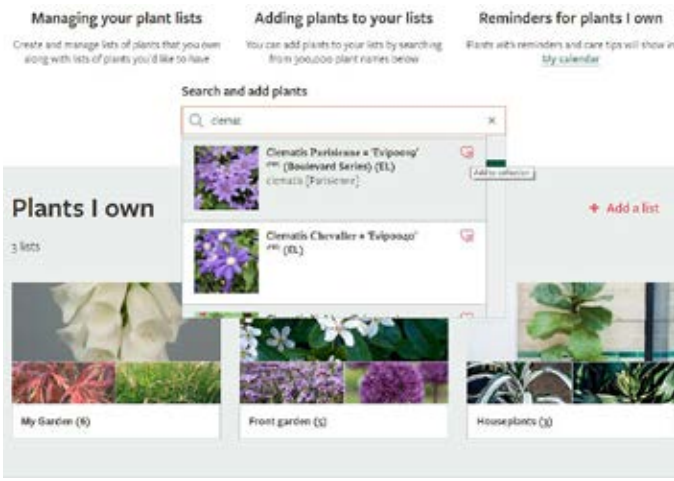
"Rocket Science has been a great way to engage school children with plant science and to get them thinking about the future of our food."

Director of Science & Collections
Prof. Alistair Griffiths

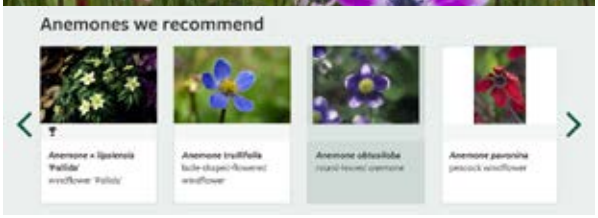
Inspiring and informing

My Garden – refreshing our approach to online gardening information

Based on extensive user research in 2016–2017, My Garden launched on rhs.org.uk in spring 2019 and is proving tremendously popular with users. Users can now add the plants they have (or would like to have!) in their garden to their online account and receive monthly alerts on how best to care for them. This free service supports gardeners at all levels of experience in gardening more successfully and involved the creation of a huge new body of content for care calendars that links to our gardening advice content. To date (October 2019), 21,000 My Garden users have added over 300,000 plants to their My Garden profiles – a great start, but there is more to do to create care calendars and profiles for more plants to maximise what people can add to their lists.



Above. The Rocket Science exhibit in the Discovery Zone in the Great Pavilion at the RHS Chelsea Flower Show 2015. Left. Astronaut Tim Peake with packets of rocket seed that spent six months on the International Space Station in summer 2016 before being distributed to schoolchildren throughout the UK to grow and then compare with seeds that had stayed on Earth.



Popular Plants: exploring the diversity of garden plants

The brand-new Popular Plants section on rhs.org.uk gives users over 260 freshly designed pages that delve deep into the looks, likes, uses, types and cultivars of some of the most popular garden genera. Users can now explore the huge variety of plants available for the garden whatever their knowledge level and can benefit from the know-how of our experts in choosing the right plants for them and growing them successfully.

Further work to connect this content to the wealth of cultivation and botanical information in our horticultural database and to build on the number of genera available will continue under the next strategy – helping to raise awareness among gardeners of the diversity of plants available and to get gardeners of all levels of confidence to the information they need as quickly and easily as possible.

Left. The Popular Plants facility gives gardeners at every level an easy route into a particular genus or group of plants. With *Anemone*, for instance, the user is presented with a carousel of recommended plants, and can then access specific advice on the plant selected (e.g. *Anemone trullifolia*, left) as well as supplier details.

Providing excellent advice

New face to face advice services

With the launch of a pilot service at Rosemoor in spring 2019, RHS Gardening Advice is now offering regular advice services at all RHS gardens for the first time. The Rosemoor service has built on the success of the services at Hyde Hall (from 2018) and Harlow Carr (from 2016). Over 12,000 people have now used the services at gardens other than Wisley and plans are under way to extend the service to RHS Garden Bridgewater.

Gardening Advice online

In May 2019 we completed work to overhaul how we deliver members' advice online with the full roll-out of our new My Advice service. Providing more support to members to give Advisors the information needed to answer their questions and routing of enquiries direct to the relevant experts have improved the customer experience and opened up the service to new members who were previously put off asking for advice. Since the full launch, over 16,000 have used My Advice, 25% up on the same period in the previous year, when only an email service was available.

Right. **RHS Gardening Advice includes videos and podcasts on all aspects of plant cultivation, pests and diseases.**

First quality monitoring for advice

Since 2016 we have been monitoring RHS Gardening Advice customer satisfaction levels to ensure that as the numbers of questions answered rose (from 82,500 in 2015–2016 to an estimated 105,000 in 2019–2020) the quality of the customer experience was maintained. With an initial very high customer service rating of 9.46/10, making improvements was always going to be a challenge. However, by 2018–2019 we had reached 9.59 and we continue to set ambitious targets to deliver the kind of service wanted by both current and prospective members.

> "Our work will make a difference by fostering greater understanding of plants and gardens, training the next generation of horticultural scientists, enabling more people to benefit themselves and their communities through gardening, inspiring young people to garden, and providing evidence for effective policy-making."
> RHS Science Strategy 2015–2019

The RHS supported 16 PhD students during 2019, working on the following:

- The accumulation of regional diversity in the Anthropocene: insects on plants (University of York)
- Pathogen-induced changes in plant–insect interactions for crop and ornamental species in the genus *Solanum* (University of Cambridge)
- Benign enhancement of natural defences: BEYOND (University of Sheffield)
- Plant resources for pollinating insects (University of Bristol)
- Mycorrhizae II (Royal Holloway, University of London)
- Varietal & environmental factors optimising rosemary quality (Royal Holloway, University of London)
- The impact of climate change on UK garden plants – can we avoid a new Japanese knotweed? (University of Reading)
- *Armillaria* (University of Bristol)
- *Rose rosette virus* (Newcastle University / Fera)
- Nematodes other than *Phasmarhabditis hermaphrodita* as slug biocontrol agents (Liverpool John Moores University)
- Gastropod diversity in UK gardens (Newcastle University)
- Improving soil biology-derived ecosystem services through organic material applications (Cranfield University)
- Leaf surface micro-organisms & bacterial – potential for pollution degradation (University of Warwick)
- Investigating the impact of plants on indoor air quality: a multi-scale cross-disciplinary approach (University of Reading)
- Climate and speciation in the Mediterranean biome (University of Reading)
- Do front garden landscapes Influence wellbeing? (University of Sheffield)

Training the next generation of horticultural scientists

RHS support for new PhD students

Training and developing the horticultural scientists of the future has been a key objective of this strategy, with significant successes around new ways of supporting early career scientists and building on successful existing programmes such as our PhDs.

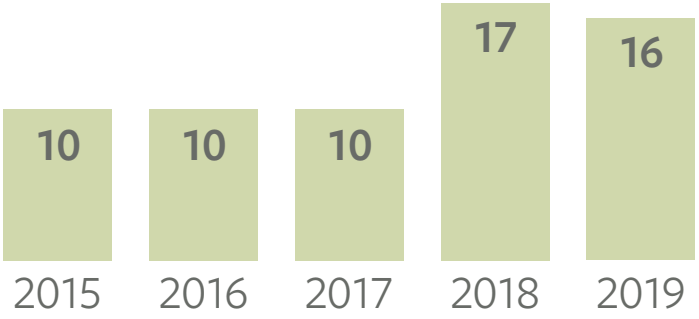
Over the last five years, the RHS has welcomed back Dr Kálmán Könyves (Horticultural Taxonomist) and Dr Stephanie Bird (Plant Health Scientist), both of whom are graduates of the RHS PhD programme and are now working as part of our research teams.

Plant Health team members Anna Platoni and Imogen Cavadino are also completing their PhDs while working part-time in RHS Science. "I'm thrilled to be able to continue working for the RHS," says Anna. "It means I can carry on doing the job I love, especially public engagement at RHS Shows, and continue to produce papers from my previous RHS research projects while I study."

Former colleagues and students have also made an impact across horticulture, including Dr Lionel Smith (RHS-supported PhD with Reading University 2010–2014), who now lectures at Myerscough College while continuing his research on grassless lawns, and Dr Gracie Barrett (RHS / AHDB Fellowship on sustainable resources in horticulture 2012–2017), who moved on to an industry role in trials at Tristram Plants. Recent PhD graduate Dr Sarah Duddigan (RHS and Reading University 2013–2017) is now a research fellow at Reading University.

The strategy has also seen the development of a strong summer student programme providing undergraduate students with an opportunity to work alongside RHS scientists and contribute to our research. In 2019 we hosted four summer placement students in Plant Health (Julie Lin on *Agapanthus* gall midge, Colleen Sellwood on box tree moth, Clare Hurst on box blight and Louise Ager on *Phytophthora*); this built on programmes in 2017 and 2018.

PhD students supported by the RHS



The RHS works with a wide range of universities on supported PhDs, which can include financial support, access to RHS research facilities, the support of RHS Media and Shows teams and supervision by senior RHS scientists.

Promoting RHS Science through RHS Shows and the media

The Bug Hub, RHS Flower Show Tatton Park 2019

The Bloomin' Healthy Garden, RHS Chatsworth Flower Show 2018

The Gardening for a Changing Climate Garden, RHS Chatsworth Flower Show 2017

Rocket Science

RHS Science in the media

RHS scientists have been spreading the word about their work far and wide by communicating their research and commenting on issues in the media. Notable coverage has included:

- Prof. Alistair Griffiths appeared on the Royal Society Christmas Lectures in 2015 talking about growing food in space.
- The Gardening in a Changing Climate report launch in 2017 with Baroness Brown.
- Dr Hayley Jones appeared on **BBC One's *The One Show***, revealing the results of her research on slug control home remedies. The findings were also discussed on ***BBC One Breakfast*** and BBC Radio 4 ***Today*** as well as the front page of the ***Daily Telegraph***. In total, more than 200 publications / media outlets ran the story including the ***Times***, ***Daily Mail***, ***Daily Express*** and ***Guardian***.
- Water scientist Janet Manning discussed her tomato plant water experiment with **BBC Radio 4's *Inside Science*** (May 2019).
- We launched a search for the elusive Ms Harrison with the **BBC**, calling on the public to share information about the first female to win the horticultural scholarship, in 1897 (September 2018). ***BBC One Breakfast***, **BBC Radio 4** ***Today*** and **BBC News Online** ran the initial story with the ***Daily Telegraph*** and the ***Observer*** also reporting on the search.
- Dr Matthew Cromey appeared on ***Gardeners' World*** discussing integrated box (*Buxus*) management with Monty Don.
- Dr Tijana Blanuša appeared on **BBC Radio 4's *You and Yours*** talking about hedges as a way of mitigating air pollution.
- The discovery of webspinners (*Embioptera*) at Wisley, an insect order new to the UK, featured first on the **BBC News website** (March 2019), followed by the ***Daily Telegraph***, ***Daily Mail***, **BBC Radio Surrey**, **BBC Radio Wales**, **BBC Radio 5 Live**, **RTE** and **BBC Radio 4** ***Today***. Entomologist Dr Andrew Salisbury was also the star of **BBC *Wildlife*** magazine's 'Meet the Scientist' feature, discussing his discovery and broader RHS work.
- We warned gardeners about *Xylella fastidiosa* and detailed how we're attempting to mitigate the threat via our new plant health policies. Coverage appeared in nine national newspapers, including the ***Times***, the ***Daily Telegraph***, the ***Daily Mail*** and the ***Sun*** (December 2017).

RHS Chelsea Flower Show 2016

Working with industry and government

OHRG and the Oxford Economic Report

As part of the Ornamental Horticulture Roundtable Group (OHRG), the RHS has been championing the value and benefits of ornamental horticulture for the nation. OHRG is a body of industry leaders and innovators, including retailers, gardening charities and industry bodies, who are working with government to raise awareness of and grow the value of ornamental horticulture in the UK.

In 2015 the first cross-sector action plan was launched at the RHS Chelsea Flower Show in order to increase growth and competitiveness for the ornamental horticulture industry. The plan addresses 12 priority areas where government help could encourage the long-term growth of the sector and focuses on those areas where growth will also benefit the health and wellbeing of people and the environment.

Organisations involved in the OHRG include:

- Agriculture and Horticulture Development Board (AHDB)
- Arboricultural Association (AA)
- British Association of Landscape Industries (BALI)
- Chartered Institute of Horticulture (CiH)
- Defra
- Horticultural Trades Association (HTA)
- Landex
- National Farmers' Union (NFU)
- Royal Horticultural Society (RHS)

Left. **Begonia grading machine at Bordon Hill Nurseries, Warwickshire.** Opposite. **Gardens and landscapes help to preserve biodiversity, particularly within urban areas.**

In October 2018 the OHRG published its groundbreaking report *The Economic Impact of Ornamental Horticulture and Landscaping in the UK*, in conjunction with Oxford Economics (opposite). The report draws attention to the almost 570,000 jobs, £24.2 bn GDP footprint and £5.4 bn in revenue that the industry generates in the UK despite little in the way of financial support from Government.

The Ornamental Horticulture Roundtable Group is now calling on Government to:

- Create opportunities for the industry to scale up UK production in the light of Brexit
- Nurture innovation funding in horticultural science for environmental resilience and health benefits
- Support the development of a skills roadmap, to ensure a pipeline of talent to meet current and future workforce needs

APPGHG and innovation in horticulture

Prof. Alistair Griffiths (RHS Director of Science & Collections) and Dr Gerard Clover (Head of RHS Plant Health) gave evidence at the All Party Parliamentary Gardening and Horticulture Group (APPGHG) in spring 2019 alongside members of the RHS Science Committee.

Prof. Griffiths spoke about the potential of innovation to boost UK horticultural production in light of Brexit and Dr Clover gave comments on the potential for improving and safeguarding plant health.

Ornamental horticulture in the UK

568,700
Total jobs contribution of ornamental horticulture in 2017

24.2 billion
Total GDP footprint of ornamental horticulture industries in 2017

5.4 billion
UK tax revenues in 2017 attributable to ornamental horticulture

RHS Libraries

Investing in our Libraries

This period has seen the benefits of the RHS Strategic Investment Programme beginning to have a major impact on the RHS Library service and its ability to share its collections more widely.

In May 2016 the Lindley Library reopened after a programme of refurbishment which included a more welcoming entrance and reception and the creation of a small display area in the reading room.

The next major investment will be the opening of the new National Centre for Horticultural Science & Learning at the Wisley Hilltop in 2020 which will be an amazing opportunity to improve access to our library collections. With bespoke accommodation that will help keep collections in the best conditions to ensure they survive for future generations, the new building will also provide the public and researchers with greatly improved facilities for visiting and using the collections. This investment gives us an opportunity to create a new library and deliver an outstanding resource for horticultural scientists, students and gardeners of all levels. We are also undertaking an ambitious programme of conservation and collection care, focusing on collections which will help us interpret the fascinating history of RHS Garden Wisley and its long association with horticultural science and learning.

Left. 'Larger than life – dried clematis'. Watercolour on paper by Julia Louise Trickey, acquired by the RHS Lindley Library in 2012.

RHS Libraries: the last five years in numbers

1 + 1

library refurbished + library under construction

325,561

library users

40%

increase in annual visitor figures for all our libraries (from 50,020 in 2015/16 to 70,290 in 2018/19)

65,000

detailed library enquiries dealt with

54,000

book loans to RHS members

90,000

catalogue records created or enhanced

16,500

items digitised

4 online exhibitions, 19 Lindley Library exhibitions, and 7 outdoor displays touring 4 RHS Gardens

Bringing our collections to life

Our programme of exhibitions at the Lindley Library and outdoor displays at RHS Gardens has allowed us to showcase our collections and stories to thousands of people.

The 'Potted' display at the Lindley Library in 2017 presented a series of ceramic designs by students from Central Saint Martins college. Inspired by the Library collections, the students created made-to-measure pots for a variety of well-known and well-loved house plants.

The 'Collecting in the Clouds' exhibition explored the stories of plant collectors who travelled to China in the early 20th century. This display, produced with material from the archives and the RHS Herbarium, was very popular and attracted strong media interest which has helped to raise the profile of the collections. Over the past five years Library staff and collections have appeared in regional, national and international media.

In May 2019, working with Google Arts and Culture, the Library shared 165 images from the collection, arranged in four online exhibitions. In just eight weeks, these attracted nearly 10,000 unique users. To further share our collections and events with new audiences we have created the RHS Libraries twitter account @RHSLibraries, which has over 2,200 followers.

Preserving our gardening heritage

The library has a rolling programme of conservation, aiming to protect our most vulnerable and significant items for future generations.

A generous grant from the Foyle Foundation and an appeal to RHS members has allowed RHS Libraries to conserve, document and digitise papers relating to RHS plant-collecting expeditions dating from the early 1820s. This important collection, which includes the papers of David Douglas and Robert Fortune, will be a valuable resource for botanists, taxonomists and historians all over the world.

In 2015 we launched an Adopt-a-Book appeal to members and by the end of 2016 generous donations allowed the Library to clean and treat 2,250 volumes.

In 2017 funding from the Charles Hayward Foundation and the Pilgrim Trust enabled the Library to conserve, digitise and exhibit its collection of watercolour paintings of fruits commissioned by the Society in the early 19th century. These paintings, known as Hooker's Fruit Drawings, after the main artist William Hooker, are a unique and beautiful record of many varieties of fruit no longer in existence.

Our unique collection of over 7,500 RHS orchid portraits was fully catalogued and good progress has been made to digitise this collection in readiness for sharing it online.

> "The Library collections provide a unique global knowledge bank on gardening, gardens and cultivated plants, underpinning the RHS's status as a learning and research-based society."
> RHS Libraries Strategy 2016

Significant acquisitions by the collections over the past five years have included:

- *The Profitable Arte of Gardening* by Thomas Hill, published in 1568
- 16 RHS gold medal-winning botanical artworks
- Yokohama nursery catalogues 1900–1910
- *Fritillaria gibbosa* (1976), watercolour on vellum, by Rory McEwen
- Letters from Sir Thomas Hanbury, relating to the donation of Wisley to the RHS

Informing and inspiring all gardeners

Our libraries in the RHS Gardens are the main way we support general gardeners with inspiration and information. Over this period the lending and reference collections have been kept up to date with over 3,000 books purchased or donated for the collections. The Library teams at RHS Gardens Wisley and Harlow Carr have run a programme of attractive book displays. Highlights have included beautiful displays at the Harlow Carr Garden Library created with members of the Embroiderers' Guild who created pieces inspired by seasonal scenes in the garden. The library teams post details of their "book of the week" on social media and have participated in a number of national initiatives such as Science Week and National Gardening Week. Both Harlow Carr and Wisley Garden libraries offer popular "story time" sessions for under-fives.

Advancing learning and research

We have supported researchers, RHS apprentices, students and staff to access the RHS heritage and library collections. Our Library collections and staff provide a unique physical and electronic global knowledge bank on gardening, gardens and cultivated plants. Over the past five years we have greatly improved the range of electronic resources available to students at RHS gardens and candidates on the RHS Master of Horticulture (MHort) course.

In 2016 the Library was able to support a great deal of new research into gardens and landscapes associated with Lancelot 'Capability' Brown. Following a conservation and digitisation project, the Library shared online a digital version of the manuscript account book of Capability Brown. This unique record of the monies paid to the landscape designer is a key resource for researchers hoping to understand exactly what work was undertaken and sharing it resulted in several important discoveries. An exhibition at the Lindley Library was a significant element of the Capability Brown festival held that year to celebrate the 300th anniversary of his birth.

In 2017 the Lindley Library launched a programme of popular short courses for gardeners and garden enthusiasts, using our collections to explore different garden history themes and topics. We have also piloted study days at the Lindley Library on topics including historic book bindings and Victorian glasshouses. We are looking to expand this programme to our other libraries over the coming years.

Selected recent RHS Science publications

Books

Annual

- **Armitage, J., Cubey, J., Edwards, D., Könyves, K., Lancaster, N., Marshall, R.** *RHS Plant Finder*. London: RHS.

2019

- **Brooks, C.** *RHS Botanical Illustration: The Gold Medal Winners*. Woodbridge: ACC Art Books.
- **Compton, J., & Lane, C.** *Wisteria: The Complete Guide*. London: RHS.
- **Davison, F.** *The Hidden Horticulturists*. London: RHS.
- **Edwards, D., & Marshall, R.** *The Hillier Manual of Trees and Shrubs*. 9th edn. London: RHS.

2018

- **Blanuša, T., & Vaz Monteiro, M.** Green streets: classifications, plant species, substrates, irrigation and maintenance. In: Perez, G. and Perini, K. (eds) *Nature Based Strategies for Urban and Building Sustainability*. Oxford: Butterworth-Heinemann Elsevier.
- **Donald, D.** *The International Clematis Register & Checklist*, Sixth Supplement. London: RHS.
- **Greenwood, P., Halstead, A.** with the RHS Plant Health team. *RHS Pests & Diseases*. London: Dorling Kindersley.
- **Leslie, A.C.** *The International Dianthus Register and Checklist 2016*. London: RHS.

- **McAllister, H. & Marshall, R.** *Hedera. The Complete Guide*. London: RHS.

2017

- **Shaw, J.M.H.** *Sander's List of Orchid Hybrids*: 3-year addendum, 2014–2016. London: RHS.

2016

- **Armitage, J.** *RHS Practical Latin for Gardeners*. London: Mitchell Beazley.
- **Brickell, C.** (ed), incl. contributions from RHS staff (J. Armitage, J. David, D. Donald, D. Edwards, S. McDonald, J. Shaw). *RHS A–Z Encyclopedia of Garden Plants*. 4th edn. London: DK.
- **Ingram, D.S., Vince-Prue, D & Gregory P.J.** (eds), including chapters written or revised by RHS staff (P. Alexander, J. Armitage, G. Barter, G. Clover, J. David). *Science and the Garden: The Scientific Basis of Horticultural Practice*. UK: Wiley-Blackwell.

2015

- **Blanuša, T., Vaz Monteiro, M., *et al*.** Planting Choices for Retrofitted Green Roofs. In: *Green Roof Retrofit: Building Urban Resilience*. UK: Wiley.
- **Whitehouse, C.M.** *Kniphofia: a Complete Guide*. London: RHS.

Major papers

Plant Health 2019

- **Cromey, M., Drakulic, J., Beal, L., Waghorn, I., Perry, J. and Clover, G.** Susceptibility of garden trees and shrubs to Armillaria root rot. *Plant Disease* (in press).
- **Falk, S., Foster, G., Comont, R., Conroy, J., Bostock, H., Salisbury., A, Kilbey., D, Bennett, J. & Smith, B.** Evaluating the ability of citizen scientists to identify bumblebee (*Bombus*) species. *PLoS ONE* **14**.
- **Platoni, A., Bird, S., Waghorn, I., Perry, J., Collier, R. and Clover, G.** Using physical barriers to prevent carrot fly (*Psila rosae*) damage in domestic production. *Journal of Applied Entomology* (in press).
- **Salisbury, A., Al-Beidh, S., Armitage, J., Bird, Bostock, H., Platoni, A., Tatchell, M., Thompson, K. and Perry, J.** Enhancing gardens as habitats for soil surface-active invertebrates: should we plant native or exotic species? *Biodiversity and Conservation*.
- **Thines, M., Denton, G.J., Beal, E.J., Kilty, A., Denton, J.O., Shin, H.-D. and Choi, Y.J.** *Peronospora aquilegiicola* sp. nov.: the downy mildew affecting columbines in the UK is an invasive species from East Asia. *European Journal of Plant Pathology* (in press).
- **Vazquez-Iglesias, I., Adams, I., Hodgetts, J., Fowkes, A., Forde, S., Ward, R., Buxton-Kirk, A., Kelly, M., Santin-Azcona, J., Skelton, A., Harju, V., Boonham, N., Robinson, R., Clover, G. and Fox, A.** High throughput sequencing and RT-qPCR assay reveal the presence of rose cryptic virus-1 in the United Kingdom. *Journal of Plant Pathology* (in press).

Horticultural Taxonomy 2019

- **Könyves, K., David, J.C. & Culham, A.** Jumping through the hoops: the challenges of daffodil classification. *Botanical Journal of the Linnean Society* **190**: 389–404.
- **Compton, J.A., Könyves, K., Forest, F., Malakasi, P., Mattapha, S., Sirichamorn, Y. & Schrire, B.D.** The *Callerya* Group redefined and the Tribe Wisterieae (Fabaceae) emended based on morphology and data from nuclear and chloroplast DNA sequences. *PhytoKeys* **125**: 1–112.

♦ **Shaw, J.M.H.** *Petrocosmea thermopuncta* – a new identity for cultivated *Petrocosmea 'grandiflora'* Gesneriaceae. *Curtis's Botanical Magazine* **36**(2): 124–143.

Environmental Horticulture 2019

♦ **Blanuša, T., Garratt, M.P., Catchart-James, M., Hunt, L., Cameron, T.** Urban hedges: A review of plant species and cultivars for ecosystem service delivery in north-west Europe, *Urban Forestry & Urban Greening*, **44**: 1–16.

♦ **Gush, M., Dzikiti, S., van der Laan, M., Steyn, M., Manamathela, S. and Pienaar, H.** Field quantification of the water footprint of an apple orchard, and extrapolation to watershed scale within a winter rainfall Mediterranean climate zone. *Agricultural and Forest Meteorology*, **271**: 135–147.

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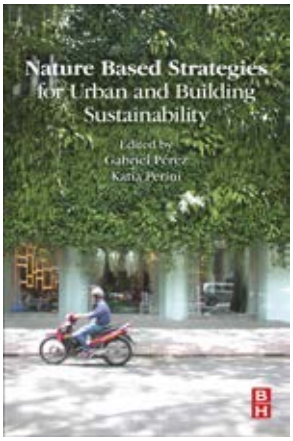

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- Increasing accuracy of powdery mildew (Ascomycota, Erysiphales) identification using previously untapped DNA regions (University of Reading, 2017)

For currently supported PhDs, see p.21.

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