Evaluation of Machine Learning for *Rhododendron* Identification

Jia Xu

August 2021

Thesis submitted in partial fulfilment for the MSc in Biodiversity and Taxonomy of Plants

Abstract

Rhododendron L. is the largest genus in the Ericaceae with 1,360 accepted species. It has important ornamental, medical and ecological values. However, many species are under extreme threat in the wild and in need of urgent conservation action. Throughout the history of its classification, there were many controversies and a recognized authoritative classification system has not been established yet. The identification of plants requires a high level of expertise and takes many time. To reduce the workload of experts, we set our sights on automatic image analysis tools, which use deep learning for plant identification. In this project, we trained the Pl@ntNet model twice by uploading (i) 1,478 images of 73 species, (ii) 7,913 images of 440 species, and compared the 3 different versions of Pl@ntNet with other plant identification apps. The results show that the identification accuracy of Pl@ntNet on each infrageneric taxa was significantly improved by the two training datasets. The problems that occured and their possible reasons were discussed. By the end of this project, Pl@ntNet had improved, and the latest version was considered a very useful tool to narrow down the possible identifications to subsections, and suggest illustrated species in that group.

Acknowledgements

First of all, I am very grateful to all the healthcare workers around the world who have saved many lives during the COVID-19 pandemic. Gratitude to the University of Edinburgh and Royal Botanic Garden of Edinburgh for giving me this opportunity to learn and improve myself. Thanks to all the teachers from RBGE for providing high-quality teaching in this very special academic year.

Many people kindly helped me with this thesis. I would like to thank Colin Pendry, one of my principal supervisors who led me to finish this project from the beginning to the end and provided many suggestions for the data evaluation and dissertation. Many thanks to my other principal supervisor, Pierre Bonnet who helped me to understand the whole structure of this project and the basics of machine learning. I would like to thank Alan Elliott, my subsidiary supervisor, he provided me with many useful references on *Rhododendron* taxonomy and helped me to finish the classification and characters. I would also like to thank Herv é Go ëau, my other subsidiary supervisor, together with other engineers from Pl@ntNet, whodid all the model training and the internal evaluation.

Finally, I want to thank my parents and my family for their support and encouragement, they helped me through the tough times.

Contents

List of Tables

List of Figures

Introduction

Rhododendron

Rhododendron L. in the Ericaceae has centres of its diversity in the Himalayas and South East Asia but is also distributed in North America, Europe and Australia. About 1,360 species have been described and recorded from its distribution. *Rhododendron* is an internationally famous flower, the gorgeous colour and graceful posture make it of high ornamental value. Many species such as *Rhododendron setosum* D.Don, *R. mucronulatum* Turcz., and *R. molle* (Blume) G.Don, etc. are widely used in many fields such as medicine, food and chemical industry (Klocke et al., 1991; Innocenti et al., 2010; Mok & Lee, 2013). *Rhododendron* also has an important ecological value, it plays a vital role in soil and water conservation in alpine areas and is an indispensable component of mountain ecosystems (Zhou et al., 2008). Most *Rhododendron* are short shrubs, with dense branches and well-developed roots, forming a large area of natural communities, that can withstand the extremely harsh alpine climate, playing an important role in maintaining alpine soil and preventing erosion and falling stones, especially for the screes formed by the strong mountain weathering. There are also some epiphytic *Rhododendron* species distributed in tropical and tropical rainforests of Southeast Asia, which grow on the trunks or branches of other trees and stones. They have soft and drooping branches and well-developed roots clinging to the bark or stones, which can absorb nutrients from the decay and decomposition of fallen branches and leaves in the forest. The strong ability of nutrient interception and water storage make them of great significance to the water and nutrient cycling of the rainforest ecosystem (Shi et al., 2018). In addition, they can provide food and habitat for insects and other important pollinators. Such importance in usage and conservation value makes *Rhododendron* a research focus. They are widely cultivated in temperate regions, but many species are under extreme threat in the wild due to habitat loss, global climate change, human activities etc. Forty-five species of *Rhododendron* are considered Critically Endangered, with only a few individuals remaining in the wild (Elliott et al., 2021). Conservation action is urgently needed for these *Rhododendron*.

The genus *Rhododendron* was originally proposed by Carl Linnaeus in *Species Plantarum* (Linnaeus, 1753), he divided the modern *Rhododendron* into two genera, *Rhododendron* and *Azalea*, and put the five species with 10 stamens into *Rhododendron*; and six species with five stamens into *Azalea* L. In 1796, R. A. Salisbury questioned Linnaean taxonomy regarding *Azalea* and *Rhododendron*, he maintained the genus *Azalea* but transferred some Linnaean

species to *Rhododendron* (Salisbury, 1796). Since then, the classification system of *Rhododendron* has undergone several far-reaching changes.

George Don established a new taxonomic system in 1834 (Don, 1834), he included new three genera, *Hymenanthes*, *Rhododendron* and *Vireya*, and formally merged the genera *Rhododendron* and *Azalea*, leaving only the *Rhododendron*. Hooker divided *Rhododendron* into nine series under the genus *Rhododendron* and then revised it to 14 series (Hooker, 1849). In 1870, Maximowicz published his work *Rhododendron Asiae Orientalis* (Maximowicz, 1870), which included 36 new species of *Rhododendron* collected from Siberia, Northeast China and Japan. The three genera in the classification system proposed by George Don were merged into one genus, and the genus *Rhododendron* was divided into eight subgenera according to the positional relationship between flower buds and leaves. In 1930, after synthesizing the new taxa described by researchers at several organizations including Royal Botanic Garden Edinburgh and Royal Botanic Garden Kew, The Rhododendron Society published *The Species of Rhododendron* (Stevenson, 1930). It was based on the Series concept for the genus by Professor Isaac Bayley Balfour, which was devised from the herbarium and living *Rhododendron* arriving in Edinburgh from SW China. They divide *Rhododendron* into 43 series and about 669 species. Subsequently, this classification system was widely used for more than half a century.

In 1949, after collating a large number of materials of *Rhododendron* from China and the tropics, the classification system of *Rhododendron* that was later adopted by most people was established (Sleumer, 1949). It divided *Rhododendron* into eight subgenera according to the positional relationship of flower buds and leaf buds, the existence of scales, the morphology of flower parts, fruits and seeds, and whether they are evergreen, and further divided the genera into subgenera, then sections, and then subsections. This way of classification laid the foundation for the establishment of the later classification systems of *Rhododendron*. Since then, advances in research of biochemistry, anatomy of vascular bundles of stem nodes and leaves, and differentiation of indumentum, scales, seeds and cotyledons have been used in the systematic classification of subgenera, sections and subsections of *Rhododendron*.

In 1996, an internationally recognized classification system was established after revising all the eight subgenera and lower taxa (Chamberlain et al., 1996). In 2005, a new classification framework of five subgenera based on the sequences of *RPB2* gene was proposed, dividing the plants of *Rhododendron* into Subgen. *Azaleastrum*, Subgen. *Choniastrum*, Subgen.

Hymenanthes, Subgen. *Rhododendron*, and Subgen. *Therorhodion* (Goetsch et al., 2005). And the original sect. *Vireya* of Subgen. *Rhododendron* group was elevated to a subgenus rank in 2006 (Argent, 2006). The classification we followed in this study is a combination of the classification by Chamberlain and the modification by Argent, including six subgenera.

The morphological diversity of *Rhododendron* and ability to produce hybrids in the wild has led to species inflation. Many of their key characters are homologous, the difficulty of traditional morphological classification is greatly increased by these features. The taxonomic status of individual species, especially the new species published in recent years, is still controversial. The inconsistency among phylogenetic markers also limits the accuracy of the classification at the molecular level (Khan et al., 2020). These problems seriously restrict the scientific classification and accurate identification of species in this genus and slows down the process of utilization and conservation of *Rhododendron* resources.

For a long time, scholars all over the world have done a lot of research in order to establish an accurate classification system of *Rhododendron*. However, most of them have struggled with the attribution of some subgenera, not only have they failed to draw conclusions that are generally recognized by the academic community but there are even some contradictory results and inferences. Controversies are still many and a recognized authoritative classification system has not been established yet. The taxonomic study of *Rhododendron* is far from complete.

Machine Learning

The identification and classification of plants requires a high level of expertise, which is long and difficult to acquire because an expert must often consider entire floras, of the order of several thousand species on the scale of a region or a country, which also leads to strong visual and morphological ambiguities, particularly between species of the same genus such as *Rhododendron*. In recent years there has been a growing interest from the general public in plant identification and ecology in general, notably through requests for help on social networks for example. However, traditional identification is very time-consuming and experts can no longer cope with the increasing flow of requests.

Thanks to advances in mobile technology, artificial intelligence and the growth of plant image databases on the web, more and more automatic image analysis tools are now available to help

users identify plants. A large part of the identification queries, especially for common plants, can thus be delegated to artificial intelligence, allowing experts to focus on the most difficult groups of species.

This success is largely due to the breakthrough of deep learning, in particular Convolutional Neural Networks (CNN) (Lawrence et al., 1997; LeCun & Bengio, 1998), which have completely changed computer vision and machine learning research. Before the advent of deep learning, traditional image classification techniques often consisted in transforming each image of a training set into relatively small “features” vectors where the values represent the most useful information (colour, texture, shape), then learning a classification model, and finally applying them to predict the class of a new image via the extraction of its features. These features are human engineered ("handcrafted") because the extraction of the values was done by algorithms manually designed by computer vision researchers based on image analysis of colour distributions, textures, shapes, detection of corners, etc. The accuracy and the reliability of the models directly depended on the extracted features and on the methods used for feature extraction.

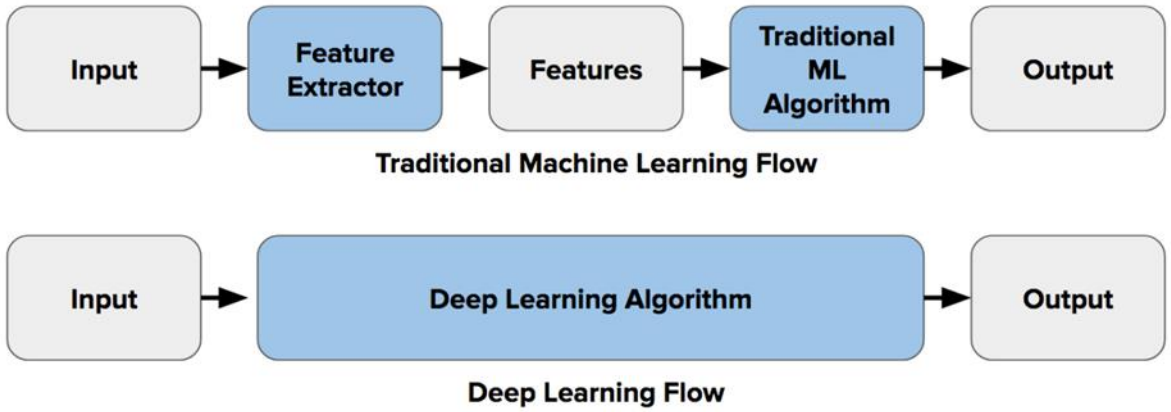

Figure 1 Comparison of the workflow between traditional learning and deep learning.

Deep learning introduced a concept of an end-to-end learning where both the extraction and classification of the features are learnt together. There is no longer the need of defining the features and doing features engineering, reducing the investment in manpower (Figure 1; LeCun et al., 2015), but under the need of having a huge amount of training data and the need of large computation power (GPU workstations). Since the incredible breakthrough in 2012 with the publication of the AlexNet architecture (Krizhevsky et al., 2012), numerous successful CNN architectures are constantly developed, always pushing the limits in terms of classification

performance, training speed, memory space while reducing the need of huge amounts of training data.

However, it may turn out that less recent architectures can still be very efficient, especially on very large data volumes in terms of number of images and number of classes. For instance, the Pl@ntNet system studied in this project, is still using an adaptation of the Inception-v3 architecture (Szegedy et al. 2015), even if new state-of-the-art CNN architectures are regularly evaluated and adapted to plant data in order to select the most efficient.

Plant identification apps

The past decade is a period of vigorous development of digital information technology, information technology has penetrated into all fields of society. With the popularity of smartphones, the emergence of plant identification apps provides a new alternative way to solve the difficult problem of plant identification. They can analyse and process plant images, extract the leaf shape, leaf edge outline, flower, fruit and other characters of plants with the help of the image identification technology, and compare these characters with plants from the database, so as to complete the identification of plant species. The operation of these apps is very simple. Users only need to take photos of the plants they want to identify and upload them with their mobile phones, and they can get the information they need such as the names and characteristics of the plants in a few seconds.

In an image-based plant identification competition, the accuracy of machines is found to be far from outperforming the best professional botanists, but significantly better than beginners and inexperienced test subjects (Bonnet et al., 2016). This result shows that the research on automatic plant identification systems can be promoted, which is likely to open a new chapter for a new generation of ecological surveillance systems.

Pl@ntNet

Pl@ntNet is a plant biodiversity research and education program supported by Agropolis Foundation since 2009 (Joly et al., 2014). This project creates an image-based interactive plant identification application that is constantly enriched by members of a social network specialized in botany (Bonnet et al., 2016). Its function of plant identification is completely free and open, and supports both web version (https://identify.plantnet.org/) and mobile version (PlantNet).

Currently, it can identify about 20,000 plant species, and this number has been increasing due to the contribution of users.

The basic data unit of Pl@ntNet are observations of living individual plants, including one to four images with their view type (flower, leaf, fruit, stem and habit) and the provenance data (location, author, date, etc.). The species names can be proposed by the contributor or other annotators or automated classifiers, and the determination will be tagged as valid when the confidence score exceeds some threshold. Image representations are then computed by a CNN that is periodically trained in a supervised manner on the observations with a valid determination name and an additional rejection class (containing mainly non-plant pictures taken by the users). The searched pictures are weighted depending on their view type to fuse the predictions and the values of the weights have been optimized empirically (Affouard et al., 2017).

Aims and objectives

Royal Botanic Garden Edinburgh (RBGE) has a long history of research on *Rhododendron* and maintains unrivalled living and preserved collections from around the world. In recognition of this unique resource Botanic Garden Conservation International has set up a Global Conservation Consortium on *Rhododendron* which is coordinated by RBGE. The conservation and management of biological resources depends on accurate identifications. However as with any large genus, identification of *Rhododendron* species is problematic, especially for the non-specialist. One potential answer is the use of the most recent advances in machine learning (and deep learning in particular) to identify taxa by images analysis. With the help of the image-analysing AI, the search can be narrowed down to subgenera, sections or even lower taxa, thus the number of species to be investigated can be reduced and make the identification to species easier. This project will work with Pl@ntNet consortium to test the accuracy of the latest version of the artificial intelligence's identification service for *Rhododendron* images.

RBGE has an archive of several thousand images of specialist-identified *Rhododendron* which are managed in the Image Repository, as well as images collected by David Purvis for his book on Chinese *Rhododendron* and the Padme database of the Flora of Nepal project. A selection of these images will be uploaded to Pl@ntNet platform to contribute to a new training of the AI-based identification service. This project will use archive images (including digitized

herbarium specimens as well as field observations) and images of the living collections to test the AI in various ways. Additional images of cultivated living plants taken from RBGE will also be archived and contribute to future training of plant identification models and other research.

Aims of this study are:

1. Find out the most accurate app in identification of *Rhododendron* species and infrageneric taxa by testing different plant identification apps.
2. Update the Pl@ntNet identification model by uploading images of organs (leaves, flowers, fruits) and model training.
3. Analyse the influences of the uploaded images on the accuracy of Pl@ntNet (especially the reliability of identification to infrageneric taxa) by testing different versions of the identification model.
4. Test the impacts of different numbers of images uploaded on producing reliable identifications by uploading different numbers of images for each model training.

Methods

Rhododendron classification

The classification of *Rhododendron* used in this project is derived from theon Ericaceae Resource Centre (Elliott et al., 2021), dividing *Rhododendron* into 6 subgenera, 15 sections and 60 subsections. This classification is as synthesis of *The Rhododendron Handbook 1998* (The Royal Horticultural Society, 1997), Argent's (2015) 2nd Edition Vireya monograph and recent generic realignment of *Diplarche* and *Menziesia* (Craven, 2011). This classification recognises 1,360 species, 1,340 placed within the sectional classification and a further 20 are *Incertae sedis.*

All the macroscopic characters listed (The Royal Horticultural Society, 1997; Argent, 2015) have been listedaccording to their ease of recognition by plant identification apps. Since the pictures used in this project cannot show in detail all the characters relating to indumentum (setose, glands, etc.) they are all described as 'hair'. Other characters that were not photographed or may not be captured by plant identification apps were not listed (inner structure of the ovary, seed appendages, etc.).

The relationship and main morphological characters of all the infrageneric taxa are listed as follows:

***Rhododendron* Subgen. *Azaleastrum* Planch. ex K. Koch**

Shrubs or small trees. Branches glabrous or with hairs. No scales. Inflorescences 1 to several flowered, below terminal or subterminal leaf axils. Calyx lobes large and broad or inconspicuously obsolete. Corolla 5-lobed, rotate to funnel-shaped. Stamens 5 or 10. Ovary glabrous or with hairs. Capsule ovoid to elongated cylindrical.

Accepted Species: 145 in 3 Sections

> **Sect. *Azaleastrum* Planch. ex Maxim.**
>
> Shrubs or small trees. Flowers solitary. Calyx lobes large and broad, glabrous or with hairs at the margins. Corolla rotate to broadly funnel-shaped. Stamens 5, exserted from the corolla. Ovary with short-stalked glands. Capsule cone-shaped ovoid, equalling the persistent calyx.

Accepted species: 10

Sect. *Sciadorhodion* Rehder & E. H. Wilson

Shrubs or small trees. Branches glabrous or with hairs. Inflorescences 1- to 15-flowered. Calyx minute. Corolla zygomorphic, rotate-funnel-shaped, outer surface glabrous. Stamens 10. Ovary and lower part of style glandular-hairy.

Accepted species: 15

Sect. *Tsutsusi* (Sweet) Pojark.

Shrubs, sometimes dwarf. Floral and vegetative shoots from same terminal buds, usually with rust-coloured hairs. Inflorescence terminal, umbellate, 1- to several-flowered. Calyx lobes small. Corolla rotate to funneliform-campanulate. Stamens 5-10(-12). Ovary with hairs. Capsule ovoid to conical, with hairs.

Accepted Species: 120 in 2 Subsections

Subsect. *Brachycalyces* (Sweet) Spethmann

Low shrubs. Leaves rhombic, monomorphic, glabrous or villous. Inflorescence 1- to several-flowered. Corolla rotate to funneliform-campanulate, pale rose to purple, with flecks inside, outer surface glabrous. Stamens 5-10, unequal.

Accepted species: 23

Subsect. *Tsutsusi* Sweet

Much-branched shrubs or low shrubs. Young twigs and leaves with densely coarsely flattened rusty strigose indumentum. Corolla rotate to tubular-campanulate, pink to maroon, usually glabrous. Stamens 5 or 10(-12). Ovary with hairs. Capsule conical to conical-ovoid, coarsely strigose.

Accepted species: 97

***Rhododendron* Subgen. *Choniastrum* Franch.**

Shrubs or small trees. Branches glabrous or with hairs. Scales absent. Inflorescence axillary or terminal, 1- to several-flowered. Calyx lobes minute or well developed. Corolla narrowly funneliform to campanulate shaped. Stamens 10. Style as long or longer than the stamens. Capsule oblong-cylindrical or cylindrical, glabrous or puberulent.

Accepted species: 20

***Rhododendron* Subgen. *Hymenanthes* (Blume) K. Koch**

Dwarf shrubs to large trees. Branches glabrous or with hairs. Scales absent. Leafe blades large and leathery, narrowly elliptic to suborbicular, abaxial surface glabrous or hairy. Inflorescence terminal, umbellate racemose, many-flowered, rhachis present or absent. Calyx absent to well-developed. Corolla 5- to 10-lobed, open to tubular campanulate, sometimes ventricose, white or red to maroon, with or without darker nectar pouches at base. Stamens 10-20, declinate, unequal. Ovary glabrous or hairy. Capsule cylindrical, glabrous or not, with hard woody valves.

Accepted Species: 585 in 3 Sections

Sect. *Pentanthera* G. Don

Erect shrubs or small trees. Branches glabrous or pubescent. Inflorescence shortly racemose umbellate, arising from an apical bud on the shoots from previous year, 1- to 15-flowered. Calyx lobes minute to well-developed. Corolla broadly funnel-shaped, or rotate to tubular-campanulate, sparsely pubescent on outer surface or glabrous, with or without flecks. Stamens 5-10, usually declinate. Ovary hairy. Style glabrous, usually declinate. Capsule ovoid to cylindrical, with woody carpopodium.

Accepted Species: 17 in 2 Subsections

Subsect. *Pentanthera* (G.Don) Kron

Shrubs. Leaves sparse. Corolla funnel-shaped, zygomorphic, outer surface with hairs. Stamens 5, exserted. Ovary hairy.

Accepted Species: 16

Subsect. *Sinensia* (Nakai) Kron

Corolla broadly funnel-shaped, outer surface hairy, upper corolla lobe spotted. Stamens 5, slightly exserted or not.

Accepted species: 1

Sect. *Ponticum* G.Don

Same as for subgen. *Hymenanthes*.

Accepted Species: 315 in 23 Subsections

Subsect. *Arborea* Sleumer

Trees. Bark rough. Leaves with hairs on lower surface, upper surface rarely hairy.

Inflorescence dense, 10- to 25-flowered. Calyx minute. Corolla 5-lobed, campanulate or tubular-campanulate, with nectar pouches. Stamens 10. Ovary with dense hairs. Style glabrous.

Accepted Species: 5

Subsect. *Argyrophylla* Sleumer

Shrubs or small trees. Leaves hairy on both sides. Inflorescence lax or dense, 4- to 30-flowered, with long and slender rhachis. Calyx usually minute. Corolla 5-lobed, open to funneliform-campanulate, white to purple, nectar pouches usually absent. Stamens usually 10(-20). Ovary hairy or glabrous. Style glandular to tip or glabrous. Capsule cylindrical.

Accepted Species: 23

Subsect. *Barbata* Sleumer

Shrubs or small trees. Bark smooth, peeling. Leaf blades elliptic, oblong to broadly obovate, lower surface glabrous or with hairs. Inflorescence dense, 10- to 20-flowered. Calyx minute to large, usually coloured, cup-shaped. Corolla 5-lobed, red, tubular-campanulate, with nectar pouches at base. Stamens 10. Ovary glabrous to densely hairy. Style glabrous.

Accepted Species: 5

Subsect. *Campanulata* Sleumer

Shrubs or small trees. Leaf blades broadly elliptic to ovate, abaxial surface hairy to (rarely) glabrous. Inflorescence lax or dense, 5- to 15-flowered. Calyx minute. Corolla 5-lobed, whitish to lilac-purple, broad to funneliform-campanulate, without nectar pouches. Stamens 10. Ovary and style glabrous. Capsule cylindrical, slightly curved.

Accepted Species: 3

Subsect. *Campylocarpa* Sleumer

Shrubs or small trees. Leaves narrowly obovate to suborbicular, both surfaces glabrous. Inflorescences sparse or dense, 4- to 15-flowered. Calyx minute to well-developed, cup-shaped. Corolla 5-lobed, yellow, pinkish or white, funneliform-campanulate to saucer-shaped, without nectar pouches. Stamens 10. Ovary glandular. Style glandular or glabrous. Capsule slender and long, curved.

Accepted Species: 6

Subsect. *Falconera* Sleumer

Large shrubs or trees. Leaves large, broadly ovate to obovate-elliptic, lower surface hairy, upper surface glabrous. Inflorescence dense, racemose umbel, 10- to 25-flowered. Calyx minute. Corolla (5-)7-10-lobed, white, pale yellow to pink, funnel-formed to ventricose or obliquely campanulate, without nectar pouches. Stamens (10-)12-18. Ovary hairy or glabrous. Style glabrous. Capsule cylindrical.

Accepted Species: 15

Subsect. *Fortunea* Sleumer

Shrubs or trees. Leaves oblanceolate to orbicular, lower surface glabrous or with hairs on midrib, upper surface glabrous. Inflorescence lax or dense, 5- to 30-flowered, with well-developed rhachis. Calyx minute to well-developed. Corolla 5-7(-8)-lobed, white to purple, funneliform-campanulate to open-campanulate, nectar pouches usually absent. Stamens 10-16. Ovary glandular or glabrous. Style glabrous or hairy to tip.

Accepted Species: 39

Subsect. *Fulgensia* D. F. Chamb. ex Cullen & D. F. Chamb.

Shrubs or small trees. Leaves oblong-elliptic to broadly obovate, lower surface hairy. Inflorescence terminal, lax or dense, 4- to 14-flowered. Calyx minute to well-developed. Corolla 5-lobed, funneliform- to tubular-campanulate, with nectar pouches. Stamens 10. Ovary and style glabrous. Capsule straight or slightly curved.

Accepted Species: 3

Subsect. *Fulva* Sleumer

Shrubs or small trees. Leaves elliptic to oblong, lower surface hairy, upper surface usually glabrous. inflorescence dense, 6- to 30-flowered. Calyx minute. Corolla 5-lobed, white to pale pink, with crimson basal blotch and dark spots on upper lobes, campanulate. Stamens 10. Ovary and style glabrous. Capsule narrowly elongate-cylindrical, strongly curved to sickle-shaped.

Accepted Species: 2

Subsect. *Glischra* (Tagg) D. F. Chamb.

Shrubs or small trees with rough bark. Leaves ovate to oblanceolate, lower surface hairy, upper surface glabrous or with hairs. Inflorescence lax, 6- to 14-flowered. Calyx well-developed. Corolla 5-lobed, white to flushed pink, usually with purple basal blotch, campanulate to funneliform-campanulate, nectar pouches absent. Stamens 10. Ovary glandular-hairy. Style glabrous or glandular at base.

Accepted Species: 9

Subsect. *Grandia* Sleumer

Large shrubs to large trees. Leaves large, broadly elliptic to oblanceolate, lower surface hairy, upper surface usually glabrous. Inflorescence dense, 12- to 30-flowered, with stout rhachis. Calyx minute. Corolla 6-10-lobed, creamy-white to rosy-purple, tubular- to ventricose-campanulate, usually without nectar pouches. Stamens 12-18. Ovary hairy or glabrous. Style glabrous.

Accepted Species: 15

Subsect. *Griersoniana* Davidian ex D. F. Chamb.

Shrubs. Leaves elliptic, lower surface with dense hairs. Inflorescence lax, 5- to 12-flowered. Calyx minute. Corolla 5-lobed, deep rose to scarlet, tubular to funneliform-campanulate, without nectar pouches, outer surface densely hairy. Stamens 10. Ovary densely hairy. Style glabrous.

Accepted Species: 1

Subsect. *Irrorata* Sleumer

Shrubs or small trees. Leaves ovate to elliptic-lanceolate, lower surface usually glabrous. Inflorescence lax or dense, 4- to 20-flowered. Calyx minute or cup-shaped. Corolla 5-7-lobed, white or yellow to deep crimson, tubular- to open-campanulate, nectar pouches sometimes present. Stamens 10. Ovary glabrous or hairy. Style glandular to tip. Capsule oblong-cylindrical.

Accepted Species: 24

Subsect. *Lanata* D. F. Chamb.

Shrubs or small trees. Leaves elliptic to obovate, lower surface with light brown to rufous hairs. Inflorescence terminal, lax or dense, 3- to 15-flowered. Calyx minute.

Corolla 5-lobed, yellow or white to pink, campanulate to open-campanulate, nectar pouches absent. Stamens 10. Ovary densely hairy. Style glabrous.

Accepted Species: 6

Subsect. *Maculifera* Sleumer

Large shrubs or small trees. Leaves oblong-elliptic to obovate, lower surface hairy. Inflorescence lax or dense, 5- to 20-flowered. Calyx usually minute. Corolla 5-lobed, white to pink or deep red, basal blotch present or not, widely or narrowly campanulate, with nectar pouches. Stamens 10. Ovary usually hairy. Style usually glabrous.

Accepted Species: 16

Subsect. *Neriiflora* Sleumer

Shrubs, sometimes dwarf and creeping, or small trees, bark smooth. Leaves elliptic to orbicular, lower surface glabrous to densely hairy. Inflorescence lax or dense, 1- to 12(-20)-flowered. Calyx minute to well-developed, cupular, often coloured. Corolla 5-lobed, white or yellow to pink or deep red, tubular-campanulate to campanulate, nectar pouches present. Stamens 10. Ovary hairy or glabrous. Style glabrous.

Accepted Species: 29

Subsect. *Parishia* Sleumer

Shrubs or small trees. Leaves elliptic to oblong obovate, lower surface glabrescent or hairy. Inflorescence lax, 5- to 15-flowered. Calyx usually small. Corolla 5-lobed, deep red, tubular- to funneliform-campanulate, nectar pouches present. Stamens 10. Ovary hairy. Style glabrous.

Accepted Species: 8

Subsect. *Pontica* Sleumer

Shrubs or small trees. Leaves linear to broadly elliptic or obovate, lower surface glabrous or with hairs. Inflorescence lax or dense, 5- to 20-flowered. Corolla 5(-7)-lobed, white or yellow to pink or lilac-purple, campanulate or funneliform-campanulate, nectar pouches absent. Stamens 10. Ovary glabrous or hairy. Style glabrous.

Accepted Species: 17

Subsect. *Selensia* Sleumer

Shrubs or small trees. Leaves elliptic or long-obovate, lower surface glabrous or with hairs. Inflorescence lax, (1-)5- to 10-flowered. Calyx small. Corolla 5-lobed, white or pale yellow to rose-pink, funneliform-campanulate to campanulate, nectar pouches absent. Stamens 10. Ovary hairy. Style glabrous.

Accepted Species: 9

Subsect. *Taliensia* Sleumer

Dwarf shrubs or small trees. Leaves linear to broadly elliptic, lower surface densely or sparse hairy. Inflorescence usually compact, 5- to 20-flowered. Calyx minute. Corolla 5(-7)-lobed, white to pink or purplish, campanulate or funneliform-campanulate, without nectar pouches. Stamens 10(-14). Ovary glabrous to densely hairy. Style glabrous.

Accepted Species: 59

Subsect. *Thomsonia* Sleumer

Shrubs or small trees. Leaves orbicular to oblong-elliptic, both surfaces glabrous, sometimes with hairs on the lateral veins of lower surface. Inflorescence lax or dense, 1- to 15-flowered. Calyx usually well-developed and cup-shaped. Corolla 5-lobed, creamy-white to deep crimson, campanulate to tubular-campanulate, nectar pouches present. Stamens 10. Ovary glabrous to hairy. Style glabrous or glandular to tip. Capsule stout and short.

Accepted Species: 18

Subsect. *Venatora* D. F. Chamb.

Straggling shrub. Leaves elliptic, lower surface with hairs on the midrib. Inflorescence 7- to 10-flowered. Calyx with broad lobes. Corolla 5-lobed, crimson, tubular-campanulate, nectar pouches present. Stamens 10. Ovary densely hairy. Style glabrous.

Accepted Species: 1

Subsect. *Williamsiana* D. F. Chamb.

Small shrubs with smooth bark. Leaves broadly ovate-orbicular to broadly oblong, lower surface with hairs on midrib, upper surface glabrous. Inflorescences lax, 2- to 5-flowered. Calyx small. Corolla 5-lobed, pink to purplish, campanulate nectar pouches

absent. Stamens 10. Ovary hairy. Style glabrous or glandular to tip.

Accepted Species: 2

Sect. *Rhodora* (L.) G. Don

Corolla zygomorphic, 3-lobed, outer surface glabrous. stamens (5-)7-10.

Accepted Species: 1

Rhododendron* Subgen. *Rhododendron

Shrubs to trees. Scales always present. Inflorescence terminal or rarely in axil of upper leaves, 1- to many-flowered. Calyx absent to well-developed. Corolla rotate to funnel-shaped, campanulate or tubular. Stamen 5-10. Ovary scaly, glabrous, hairy and/or glandular. Capsule oblong or ovoid, densely scaly.

Accepted Species: 242 in 2 Sections

Sect. *Pogonanthum* G. Don

Dwarf Shrubs. Scales with lobed margin. Inflorescence a terminal, capitate, racemose umbel, dendroid hairs fringing inflorescence bud scales. Corolla white or yellow to red or purple, hypocrateriform. Stamen 5-10. Capsule small, scaly.

Accepted Species: 23

Sect. *Rhododendron*

Shrubs or trees. Scales entire, crenulate or undulate**.** Hairs fringing the inflorescences bud scales. Corolla rotate to funnel-shaped, campanulate or tubular, very rarely hypocrateriform. Capsule ovoid to cylindric, valves hard, not twisting.

Accepted Species: 219 in 28 Subsections

Subsect. *Afghanica* Cullen

Low shrubs. Leaves with scales on lower surface well-spaced. Inflorescence terminal, distinct and elongate raceme, many-flowered. Calyx conspicuously lobed. Corolla campanulate. Stamens 10. Style impressed sharply deflexed.

Accepted Species: 1

Subsect. *Baileya* Sleumer

Small shrubs. Leaves with scales on lower surface crenulate, overlapping and flaky.

Inflorescence terminal, racemose, with an elongate rhachis. Calyx well-developed. Corolla red to purple, rotate to campanulate, outer surface densely scaly. Stamens 10. Ovary densely scaly. Style short, sharply deflexed, glabrous. Capsule ovoid-cylindrical, densely scaly.

Accepted Species: 1

Subsect. *Boothia* (Hutch.) Sleumer

Epiphytic or free-growing shrubs. Lower surface of leaves whitish papillose, scales rimmed or vesicular, deeply sunk in pits. Inflorescence terminal, 1- to many-flowered. Calyx well-developed. Corolla broadly campanulate or rotate to saucer-shaped, outer surface scaly. Stamens 10, not declinate. Style short, thick, sharply bent. Capsule ovoid to cylindrical-ovoid, scaly.

Accepted Species: 8

Subsect. *Camelliiflora* (Hutch.) Sleumer

Shrubs, often epiphytic. Lower surface of leaves with broad-rimmed, overlapped scales. Inflorescence terminal, 1- to 2-flowered. Calyx conspicuous. Corolla broadly campanulate. Stamens 11-16. style shorter than stamens, stout, sharply deflexed, not scaly. Capsule ovoid or oblong, densely scaly.

Accepted Species: 8

Subsect. *Campylogyna* (Hutch.) Sleumer

Dwarf shrubs, usually prostrate. Lower surface of leaves whitish papillose, with sparse, small, deciduous, vesicular scales. Inflorescence terminal, umbellate, 1- to 3-flowered. Corolla pink to purple, broadly campanulate. Stamens 10. Ovary scaly. Style thick, bent or sharply deflexed, glabrous. Capsule ovoid, scaly.

Accepted Species: 1

Subsect. *Caroliniana* (Hutch.) Sleumer

Shrubs. Lower surface of leaves with dense small-rimmed scales. Inflorescence terminal, several-flowered. Calyx small. Corolla narrowly to openly funnel-shaped. Stamens 10, declinate. Ovary impressed below the declinate style.

Accepted Species: 4

Subsect. *Cinnabarina* (Hutch.) Sleumer

Shrubs. Lower surface of leaves with dense small scales, broadly or narrowly rimmed. Inflorescence terminal or axillary, 2- to 5-flowered. Calyx inconspicuous. Corolla tubular to narrowly or shortly campanulate. Stamens 10, declinate. Ovary impressed below the declinate style. Capsule cylindrical, scaly.

Accepted Species: 5

Subsect. *Edgeworthia* (Hutch.) Sleumer

Shrubs, often epiphytic or scrambling over rocks. Leaves often bullate on upper surface, lower surface hairy, scales distant and small. Inflorescence terminal, 2- to 3-flowered. Calyx well-developed. Corolla funneliform-campanulate or campanulate, outer surface scaly. Stamens 10. Ovary densely hairy. Style straight or sharply deflexed. Capsule scaly, densely hairy.

Accepted Species: 3

Subsect. *Fragariflora* Cullen

Small shrubs, upright to prostrate. Leaves minute, margin crenulated, lower surface with distant vesicular scales. Inflorescence terminal, 2- to 3-flowered. Corolla purple or pinkish purple, openly campanulate to almost rotate, outer surface usually glabrous. Stamens 10, declinate. Ovary impressed below the declinate style. Capsule ovoid.

Accepted Species: 1

Subsect. *Genestieriana* (Cowan & Davidian) Sleumer

Free-growing shrubs. Lower surface of leaves whitish papillose, with distant, small scales. Inflorescence terminal, racemose, many flowered. Calyx rim-like. Corolla campanulate, reddish purple, outer surface glabrous. stamens (8-)10. Ovary scaly. Style short, stout, sharply deflexed, glabrous. Capsule ovoid-cylindrical, scaly.

Accepted Species: 1

Subsect. *Glauca* (Hutch.) Sleumer

Shrubs to 2m. Lower surface of leaves whitish papillose, with dimorphic scales. Inflorescence terminal, umbellate or racemose, 3- to 10-flowered. Calyx well-developed. Corolla campanulate to tubular-campanulate. Stamens 10. Style impressed, usually sharply deflexed. Capsule ovoid to cylindrical-ovoid.

Accepted Species: 7

Subsect. *Heliolepida* (Hutch.) Sleumer

Shrubs or small trees. Lower surface of leaves with dense, large scales. Inflorescence terminal, umbellate, 4- to 10-flowered. Calyx usually disc-like. Corolla broadly funnel-shaped to campanulate. Stamens 10, declinate. Ovary impressed below the declinate or straight style. Capsule cylindrical.

Accepted Species: 6

Subsect. *Lapponica* (Balf.f.) Sleumer

Small shrubs. Lower surface of leaves papillose, with distant or dense scales, broadly rimmed. Inflorescence terminal, umbellate raceme, 1-several flowered. Calyx minute to conspicuous. Corolla usually broadly open-campanulate, outer surface not scaly. Stamens 5-10(-11). Style impressed, straight or declinate. Capsule ovoid to cylindrical-ovoid.

Accepted Species: 41

Subsect. *Ledum* (L.) Kron & Judd

Small shrubs. Leaves usually strongly revolute, lower surface with epidermis whitish papillate and hairy. Inflorescence terminal, corymb, many-flowered. Calyx obsolete or small. Corolla rotate. Stamens 7-12. Style straight.

Accepted Species: 7

Subsect. *Lepidota* (Hutch.) Sleumer

Small shrubs. Lower surface of leaves with distant or touching scales, with broad, translucent rims. Inflorescence terminal, 1- to 5-flowered. Calyx well-developed. Corolla campanulate, outer surface scaly. Stamens 10. Ovary impressed below the very short, sharply deflexed, glabrous style. Capsule small, densely scaly.

Accepted Species: 4

Subsect. *Maddenia* (Hutch.) Sleumer

Shrubs or small trees, epiphytic or terrestrial. Lower surface of leaves whitish or greyish papillose, with distant or dense scales, sometimes with crenulated margins. Inflorescence terminal, a broad and large umbel or short raceme, 1- to 7-flowered. Calyx usually conspicuous. Corolla funneliform- to tubular-campanulate, outer surface usually scaly, hairy in tube. Stamens usually 10, declinate. Style declinate. Capsule

often large, ovoid to cylindrical, densely scaly.

Accepted Species: 49

Subsect. *Micrantha* (Hutch.) Sleumer

Shrubs. Lower surface of leaves with contiguous or overlapping scales, broadly rimmed. Inflorescence terminal, racemose, many-flowered. Calyx small. Corolla funneliform-campanulate, outer surface scaly. Stamens 10. Ovary impressed below the straight, glabrous style. Capsule cylindrical, scaly.

Accepted Species: 3

Subsect. *Monantha* Cullen

Shrubs, sometimes epiphytic. Lower surface of leaves with dense, large, broadly rimmed scales. Inflorescence terminal, subumbellate, 1- to 3-flowered. Calyx minute. Corolla tubular- to funneliform-campanulate, outer surface scaly. Stamens 10. Style impressed, straight. Capsule oblong, densely scaly.

Accepted Species: 4

Subsect. *Moupinensia* (Hutch.) Sleumer

Epiphytic or free-growing shrubs. Lower surface of leaves with dense scales, medium to small. Inflorescence terminal, cymose, 1- to 2-flowered. Calyx conspicuous. Corolla broadly funneliform-campanulate. Stamens 10, declinate. Style declinate, without scales. Capsule oblong or ellipsoid.

Accepted Species: 3

Subsect. *Rhododendron*

Small shrubs. Lower surface of leaves with large scales, golden or reddish-brown. Inflorescence terminal, with conspicuous rhachis. Calyx small, lobed. Stamens 10, declinate. Style straight or declinate.

Accepted Species: 3

Subsect. *Rhodorastra* (Maxim.) Cullen

Small to moderately sized shrubs. Lower surface of leaves with dense or lax medium-sized scales. Inflorescence axillary, at the end of the branches, 1-flowered. Calyx rim-like. Corolla broadly funnel-shaped. Stamens 10, declinate. Style declinate.

Accepted Species: 3

Subsect. *Saluenensia* (Hutch.) Sleumer

Small shrubs, erect or prostrate. Lower surface of leaves with overlapping scales. Inflorescence terminal, umbellate, 1- to 3(-5)-flowered. Calyx large, deeply 5-lobed. Corolla broadly funneliform-campanulate. Stamens 10, declinate. Style declinate. Capsule ovoid, surrounded by persistent calyx.

Accepted Species: 4

Subsect. *Scabrifolia* (Hutch.) Cullen

Small shrubs. Lower surface of leaves sometimes whitish papillose, hairy, upper surface hairy. Inflorescence axillary, 2- to 3(-5)-flowered. Calyx rim-like or with lobes to 3mm, or tubular. Stamens (-8)10, declinate. Ovary impressed below the usually declinate style.

Accepted Species: 8

Subsect. *Tephropepla* (Cowan & Davidian) Sleumer

Small to moderately sized shrubs. Lower surface of leaves papillose, with broadly rimmed scales, sometimes sunk in pits. Inflorescence usually terminal, rarely axillary, (1-)3- to 9-flowered. Calyx conspicuous, deeply 5-lobed. Corolla tubular-campanulate to funneliform-campanulate, outer surface usually scaly, sometimes glabrous. Stamens 10, declinate. Style straight or declinate. Capsule cylindrical, scaly.

Accepted Species: 7

Subsect. *Trichoclada* (Balf.f.) Cullen

Small shubs. Leaves glabrous or with hairs, lower surface with distant, vesicular, large scales. Inflorescence terminal, 2- to 5-flowered. Calyx rim-like to clearly lobed. Corolla funneliform-campanulate. Stamens 10. Ovary impressed below the sharply deflexed style.

Accepted Species: 5

Subsect. *Triflora* (Hutch.) Sleumer

Shrubs, often large. Lower surface of leaves with lax or dense, rimmed or rimless

scales. Inflorescence terminal and axillary, 1- to 3-flowered. Calyx usually minute. Corolla strongly zygomorphic, broadly funneliform-campanulate. Stamens 10, declinate. Ovary impressed below the declinate style. Capsule cylindrical.

Accepted Species: 27

Subsect. *Uniflora* (Cowan & Davidian) Sleumer

Dwarf shrubs, often prostrate. Leaves revolute, margins sometimes crenulated, scales on lower surface dense, equal or unequal, rimless or with undulate rims. Inflorescence terminal, 1- to 3-flowered. Calyx with definite lobes, scaly. Corolla funneliform-campanulate, outer surface mostly densely hairy and sparsely scaly. Stamens 10, declinate. Style impressed, straight or declinate.

Accepted Species: 4

Subsect. *Virgata* (Hutch.) Cullen

Small shrubs. Lower surface of leaves papillose, with dense, unequal, flaky scales. Inflorescence borne in the axils of the upper leaves, terminal bud vegetative, 1(-2)-flowered. Calyx small. Corolla funnel-shaped. Stamens 10, declinate. Ovary impressed below the declinate style.

Accepted Species: 1

***Rhododendron* Subgen. *Therorhodion* A.Gray**

Dwarf shrubs**.** Scales absent**.** Inflorescent terminal, racemose**,** 1- to 3-flowered, peduncle with leaf like bracts**.** Calyx lobes well-developed**.** Corolla 5-lobed, rotate, divided to base on lower side**.** Stamen 10. Ovary hairy. Capsule ovoid.

Accepted Species: 2

***Rhododendron* Subgen. *Vireya* Clarke**

Small creeping shrubs to trees, scaly, branches glabrous. Inflorescence an umbel composed of many solitary flowers, rhachis never present. Calyx low disc. Corolla very variable, never with spots or pigment. Stamens 5 or 10-14. Ovary tapering gradually into the style.

Accepted Species: 346 in 7 Sections

Sect. *Albovireya* (Sleumer) Argent

Bracts fringed with scales. Lower leaf surface clearly visible between the well-spaced

scales. Scales dense, large, not markedly different in size, with small centre, deeply lobed, occasionally sub-dendroid or dendroid. Corolla various. Filaments hairy from base or glabrous. Fruit outer layer irregularly peeling before dehiscing.

Accepted Species: 14

Sect. Discovireya (Sleumer) Argent

Bracts fringed with simple white hairs. Lower leaf surface clearly visible between the well-spaced scales. Scales disc-shaped, swollen in centre, narrow rimmed. Corolla mostly tubular-cylindric, lobes distinctly shorter than tube. Filaments hairy from base or glabrous. Fruit outer layer does not peel before dehiscing.

Accepted Species: 26

Sect. *Hadranthe* Schltr.

Bracts with scales. Scales dendroid, from the top of a tubercle on lower leaf surface. Corolla various shapes. Filaments hairy from base or glabrous. Fruit outer layer irregularly peels before dehiscing.

Accepted Species: 52

Sect. *Malayovireya* (Sleumer) Argent

Bracts fringed with simple white hairs, rarely missed with scales. Lower leaf surface not clearly visible, scales overlap or at least touch forming a layer over the lower surface. Scales disc-shaped, variable in size, swollen in centre, rim lobed. Corolla various. Filaments hairy from base or glabrous. Fruit outer layer does not peel before dehiscing.

Accepted Species: 15

Sect. *Pseudovireya* (Clarke) Sleumer

Bracts fringed with simple white hairs, rarely missed with scales. Lower leaf surface clearly visible between the well-spaced scales. Scales disc-shaped, swollen centre, rim narrow. Corolla small, mostly campanulate, broader than long, lobes as long or longer than corolla tube. Filaments hairy from base or glabrous. Fruit outer layer does not peel before dehiscing

Accepted Species: 13

Sect. *Schistanthe* Schltr.

Bracts fringed with scales. Lower leaf surface clearly visible between the well-spaced

scales. Scales with small centre, moderately to deeply stellately lobed, occasionally sub-dendroid or dendroid. Corolla campanulate, tubular, mostly large funnel-shaped or trumpet-shaped. Filaments hairy from base or glabrous. Fruit outer layer irregularly peeling before dehiscing.

Accepted Species 213 in 5 Subsections

Subsect. *Euvireya* H.F.Copel.

Medium to large shrubs, small trees. Leaf size >4cm, with stomata on the lower surface only.

Accepted Species: 103

Subsect. *Linnaeopsis* (Schltr.) Sleumer

Small creeping or erect shrubs. Leaf size < 1cm, with stomata on the lower surface only.

Accepted Species: 14

Subsect. *Malesia* H.F.Copel.

Medium to large shrubs, small trees. Leaves 1-4cm, with stomata on the lower surface only.

Accepted Species: 59

Subsect. *Saxifragoidea* (Sleumer) Argent

Cushion forming plant. Leaves 1.6-3.4cm, with stomata on both surfaces.

Accepted Species: 1

Subsect. *Solenovireya* H.F.Copel.

Medium to large shrubs, small trees. Leaves 1-10cm, with stomata on the lower surface only. Corolla trumpet-shaped.

Accepted Species: 36

Sect. *Siphonovireya* Argent

Bracts with scales. Lower leaf surface clearly visible between the well-spaced scales. Scales disc-shaped, swollen centre, rim narrow. Corolla trumpet-shaped, lobes <25% of length of corolla. Filaments hairy from base or glabrous. Fruit outer layer irregularly peels

before dehiscing.

Accepted Species: 13

Photography

The photographs of *Rhododendron* accessions were taken at RBGE's Inverleith garden. Cultivars and hybrids were excluded. Photographs were taken of particular organs, and artificial objects, effects of humidity and other interferences were avoided. Individuals of the same species were photographed separately and an abundance of photos was taken in case some of them did not meet the requirements and could not be used for the following steps.

Each 'event' includes pictures of the label, habit and organs of an individual taken by one person on the same day. The organs photographed are stem/trunk, leaves, buds, inflorescences, flowers and fruits (if present, take a set from different stages of growth).

To simulate the differences of light and colour when different users take photos with different devices, iPhone12, RICOHGRII and SONYDSC-RX100M7 were used for the photographing process.

Names

The labels of each individual were photographed for identification (e.g. Figure 2).

Figure 2 The label of *R.galactinum.*

Habits

One to three pictures of the habits for each individual from different angles and/or different light conditions were taken (e.g. Figure 3).

Figure 3 The habit of *R.galactinum* taken from different angles.

Organs

Bark

One to three pictures of the bark of the stem/trunk in different heights were taken. Distant shots were avoided; the pictures were taken in a 'portrait' orientation and as close as possible (e.g. Figure 4). As the climate in Edinburgh is humid, special attention needs to be paid to avoiding part of the bark covered with too much moss or lichens.

Figure 4 The bark of *R.galactinum* at different height.

Leaves

Four to six pictures of both sides of each simple leaf were taken. Only one leaf contained in one picture and was kept in maximum size (e.g. Figure 5).

Figure 5 Both sides of the leaves of *R.galactinum*.

Buds

Two to three pictures of the buds in different angles were taken (e.g. Figure 6).

Figure 6 The buds of *R.galactinum* at different angles.

Inflorescences & flowers

Six to ten pictures of the inflorescences and flowers in different angles, distances, and/or light conditions (but not in mixed lights) were taken (e.g. Figure 7,8).

Figure 7 The inflorescences of *R.galactinum* at different angles and light conditions.

Figure 8 The flowers of *R.galactinum* at different angles and distances.

Fruits

Since only a few species had fruit appeared during the photographing period, new fruits and old fruits retained from the previous year were photographed (e.g. Figure 9).

Figure 9 Fruits of *Rhododendron.*
A: Old fruits of *R.wardii var. wardii*. B: New fruits of *R.montroseanum*

Arranging, processing and uploading of the photos

The photos taken were transferred to the computer and grouped into separate folders according to the name of the species. Then the individuals with different shooting dates and collection numbers were grouped into different folders for subsequent operations.

Photos that were out of focus and did not meet the requirements were deleted. The main parts of the photographs, namely the organs, which meet the requirements, were cropped to ensure that the organs are clear and centred. In order to achieve the best upload speed and effect, Pl@ntNet requires that either side of the image uploaded by the user must not exceed 1,200 pixels. In order to meet this requirement, the setting of the size of the picture in the camera was changed at first, but the size of the picture taken under this setting was too small, resulting in a very unclear picture, so the scheme was abandoned. Finally, we choose to change the setting of the picture size in the camera to the maximum to ensure the clarity of the picture. Then after cropping the image its size was changed to no more than 1,200 pixels for uploading.

On the Identify page of Pl@ntNet website (found through the menu at the right corner on the homepage), the images to be uploaded (up to four) are dragged into the uploading box. After selecting the organs for each picture, the *World flora* project was selected in the drop-down menu at the right of the ‘Contribute to’ button at the bottom of the page, and then the ‘Contribute

to' button was clicked. After the picture was uploaded successfully, a new page would appear. The species name was typed in the 'Species name' box on the new page. Note that the names must be chosen from the name list that is automatically displayed after the input to ensure the accuracy of the species name. If the name was not automatically displayed after typing the name in the box, the setting button on the right side of the box needs to be clicked to open the 'Search by species name - Options' window. In this window, 'Project' was left unchanged as *World flora*, 'Illustrated species only' was switched off and 'Include synonyms' was switched on, then the 'OK' was clicked. If the name of the uploaded species was still not automatically displayed after all the above operations (because the species list of Pl@ntNet is so outdated that many newly discovered species are not included), the full name of the species needs to be typed into the box manually. Since all the photos were taken at RBGE, the record of position is meaningless, so the 'Map' box was not filled in. The collection number of the uploaded species and other important information (if any) were added to the 'Comments' column of the 'Additional data' box. The 'Also publish this observation in groups' option at the bottom of the page was switched on, and after ticking the group that wants to share, an upload was to be completed by clicking on the 'Share' button below. All the pictures taken were uploaded to Pl@ntNet and the group in units of 'event'.

Observation validation

This step was performed by other members of the Pl@ntNet Rhododendron group. Validating observations upgrades the rank of the user, thereby increasing the weight given to these observations by the system. All the observations can be seen when entering the homepage of the group. The icon with a check mark in a circle at the upper right corner of each observation box was clicked to validate the name of the species. For the observations whose species name is not in the list, the group members clicked the 'Observation details' at the lower right corner, and then clicked the thumb up on the right of the species name in the 'Suggested names' column to vote for the names.

Identification accuracy tests

There were two types of tests conducted, the test of nine plant identification apps and the internal evaluation of Pl@ntNet. The app test is to compare the identification accuracy to the infrageneric taxa between different versions of Pl@ntNet models and other apps. The internal evaluation process of Pl@ntNet is to see the identification accuracy on a bigger scale, and the

progress of Pl@ntNet by the training process.

Training

The three model training sessions were conducted by computational engineers from Pl@ntNet consortium using deep learning frameworks. These trainings are conducted with the full validated dataset of the Pl@ntNet platform, available at the time of training. The volume of this training dataset has increased in the last few months due to three data sources. The dataset from the contributions of the Pl@ntNet users network was used for the training of the first model, including illustrated and unillustrated plant observations, so the quality and correct rate of these images cannot be guaranteed. The dataset produced during this project on cultivated living plants from RBGE was used for the training of the second model. These photos were taken in strict accordance with the requirements of Pl@ntNet to ensure this dataset is as informative as possible. However, due to the limitation of time, flowering season and image processing, only 1,478 images related to 406 observations and 73 *Rhododendron* species (species list and details see Results) were included. The dataset from the pictures reference library of RBGE for other projects was used for the training of the third model, including all types of images and some of them may not fit the requirements of PlantNet. However, this dataset has greater image numbers, including 7,913 images related to 2,200 observations and 440 *Rhododendron* species. The type of view for the living plant images was selected manually, and automatically predicted from a dedicated deep learning model for the pictures of the RBGE reference library. Types of views that were not adapted for field plant species identification such as microscopic pictures, pictures of landscapes, scans of herbarium sheets, etc. were not uploaded on Pl@ntNet platform for the training phases.

The total volume of data used during each training was:

Model 1: 6.14 millions of images, illustrating 35,643 species

Model 2: 6.43 millions of images, illustrating 36,154 species.

Model 3: 6.53 millions of images, illustrating 36,276 species.

The training of the Pl@ntNet deep learning model is based on two complementary steps:

the Image representation learning and extraction: Image representations are computed by a convolutional neural network (CNN) that is periodically trained in a supervised manner on the observations with a valid determination name and an additional rejection class (containing non-plant pictures taken by Pl@ntNet users, e.g. faces, animals, manufactured objects, etc.)

(Affouard et al., 2017). At the time of writing, the used CNN architecture is the inception the third version (developed by Szegedy et al. (2015), trained with PyTorch version 1.8.1-lts (with 70 epochs), extended with batch normalization developed Ioffe & Szegedy (2015). The network is pre-trained on ImageNet dataset Deng et al. (2009) and fine-tuned on Pl@ntNet data. 36,276 species (i.e. classes) are illustrated in August 2021, by 6.53 millions of images.

Internal evaluation of Pl@ntNet

As the number of *Rhododendron* species in Pl@ntNet has dramatically increased during the project, a dedicated test set has been established on the initial list of Rhododendron species in order to ensure the measurement of the performances on the same dataset all along the project. This test set has allowed two sets of data to cover (i) 203 species from 385 plant observations (that would be illustrated in Pl@ntNet after integrating new training data and matching ThePlantList), (ii) 52 species from 117 plant observations (already illustrated in Pl@ntNet and matching ThePlantList). Performance measurements were obtained from a computational script produced by H. Go ëau, which has allowed the direct obtaining of species prediction at the observation level from the Pl@ntNet API, using the following dedicated website: https://my.plantnet.org/. The identification accuracy on species level of the first predicted species (Top 1 results), and the five first predicted ones (Top 5 results) were recorded.

The evaluation was also conducted three times for the three models, the first test was tested by 25th April 2021, the second by 6th July, third by 16th August.

App test

Species selection

Images of 16 *Rhododendron* species (originally 21 species, details see Discussion) from all the six subgenera were selected from the image database collected by David Purvis for his book on Chinese Rhododendrons in 2015 and 2016 (it was believed that these images were not part of the RBGE image repository as they were materials for the book). These species covered 5 different sections and 11 subsections, which account for about 33% and 18% of all the sections and subsections of *Rhododendron* respectively. The database was accessed via the RBGE Virtual Office and downloaded to the cloud storage. The images were then downloaded to the computer from the cloud storage after logging out of the system of RBGE Virtual Office. The species list and their classification are shown in Table 1, all the infrageneric taxa covered are in bold.

Table 1 Species selected for the app test within the infrageneric classification.

Subgenus	**Section**	**Subsection**	**Species**
Azaleastrum	*Azaleastrum*		
	Sciadorhodion		
	Tsutsusi	*Brachycalyces*	
		Tsutsusi	*R. reticulatum*
Choniastrum			*R. huguangense*
Hymenanthes	*Pentanthera*	*Pentanthera*	
		Sinensia	
	Ponticum	*Arborea*	
		Argyophylla	*R. insigne var. insigne*
		Barbata	*R. erosum*
		Campanulata	
		Campylocarpa	*R. campylocarpum*
		Falconera	
		Fortunea	
		Fulgensia	
		Fulva	*R. fulvum ssp. fulvum*
		Glischra	
		Grandia	
		Griersoniana	
		Irrorata	
		Lanata	
		Maculifera	
		Neriiflora	
		Parishia	
		Pontica	
		Selensia	
		Taliensia	
		Thomsonia	
		Venatora	
		Williamsiana	
	Rhodora		
Rhododendron	*Pogonanthum*		
	Rhododendron	*Afghanica*	
		Baileya	
		Boothia	
		Camelliiflora	
		Campylogyna	
		Caroliniana	
		Cinnabarina	
		Edgeworthia	

Subgenus	**Section**	**Subsection**	**Species**
Rhododendron	***Rhododendron***	*Fragariflora*	
		Genestieriana	
		Glauca	
		Heliolepida	
		Lapponica	*R. fastagiatum*
			R. cuneatum
		Ledum	
		Lepidota	
		Maddenia	
		Micrantha	
		Monantha	
		Moupinensia	
		Rhododendron	
		Rhodorastra	*R. mucronulatum var. mucronulatum*
		Saluenensia	*R. calostrotum ssp. keleticum*
		Scabrifolia	*R. pubescens*
		Tephropepla	
		Trichoclada	*R. mekongense var. rubrolineatum*
			R. caesium
		Triflora	
		Uniflora	
		Virgata	
Therorhodion			*R. camtschaticum*
Vireya	*Albovireya*		
	Discovireya		*R. retusum*
	Hadranthe		
	Hadranthe		
	Malayovireya		
	Pseudovireya		
	Schistanthe	*Euvireya*	
		Linnaeopsis	
		Malesia	
		Saxifragoidea	
		Solenovieyea	*R. lambianum*
	Siphonovireya		

App selection

The plant identification apps which are easy to obtain and with relatively large numbers of users were found using search engines and the App Store. Nine apps were selected for the test. Of the four apps developed by Chinese institutions, three have only Chinese versions available. The identification model of Pl@ntNet was updated two times during the image uploading process, so three versions of PlantNet (name of the mobile version) were tested for the evaluation of the accuracy of infrageneric taxa.

Before the formal testing, all apps were simply tested and evaluated, and their main features and functions were recorded (Table 2). All the apps were tested using their free versions since there is no difference in the function of identification between the free version and the full version although several of the apps have paid options. All the apps were tested in their mobile version.

Table 2 Tested apps and their main features.

App	Organ selection	Images allowed	Result	Percentage	Language	Focus
PlantNet	Yes	4	＞3	Yes	English	Global plants
iplant	No	1	1	No	English	Global plants
PlantSnap	No	1	＞3	No	English	Global plants
LeafSnap	Yes	1	＞3	No	English	Global plants
HuaBangZhu (花帮主)	No	1	＞3	Yes	Chinese	More on gardening plants
PictureThis	No	1	1	No	English	Global plants
aiPlants	No	1	＞3	Yes	English	Chinese plants
iPlant (花伴侣 pro)	No	1	＞3	Yes	Chinese	Chinese plants
iNaturelist	No	4	＞3	No	English	Global plants & animals

Testing

Since only the two apps, PlantNet and iNaturalist, allow users to upload up to four pictures at one time, while other apps only allow the identification for one image, only the test results for one image were compared. The tests for all apps were conducted using the same image of flowers for each species, because the flower is the organ with most recognizable and with the

most obvious characters for identification.

The photos to be tested were uploaded to the photo album of the smart phone in advance. When testing, the photos to be tested were chosen from the album for the app to identify, and the three first predicted species (Top 3 results) and their confidence percentage (if any) identified by each app were recorded.

The first test of all the nine apps was conducted on 27th-28th June 2021, the test of the second version of PlantNet was conducted on 8th July and the test of the third version of PlantNet was conducted on 9th August.

Evaluation

The taxa of all the test results were listed according to the classification system we chose, the results were then divided into six levels by comparing the taxa of the tested species and their test results (Table 3) and marked with different colours to see a clearer change pattern. If a result and its tested species belong to the same infrageneric taxon with no sub-taxa (e.g. subgen. *Choniastrum*), it would be treated as a correct subsection. The accuracy of the test results in different taxonomy levels was then scored. The score was 1 when the taxon is the same as the test species and 0 when different. In the scoring of the Top 3 results, the lowest taxon which is the same as the test species was counted. For the species in the results that are hybrid or with names that are not accepted were ignored and not scored. Finally, the average scores of different taxa in the test results of each app were calculated and the bar statistics were drawn.

Table 3 Six levels of the test results and their marked colours.

Level	**Colour**
Correct Species	
Correct Subsection	
Correct Section	
Correct Subgenus	
Correct Genus	
Incorrect Genus	

Results

Training dataset for the second Pl@ntNet model

For the training of the second model, 1,478 images of 73 *Rhododendron* species were photographed and uploaded to Pl@ntNet as 406 observations. The infraspecies were uploaded using their species names (accession names) since Pl@ntNet only works at the species level. The species list and their accession names are shown in Table 4, all the infrageneric taxa covered are in bold.

Table 4 Photographed species and their accession names within infrageneric classification.

Subgenus	Section	Subsection	Species	Accession Name
Azaleastrum	*Azaleastrum*			
	Sciadorhodion		*R. schlippenbachii*	*R. schlippenbachii*
	Tsutsusi	***Brachycalyces***	*R. wadanum*	*R. wadanum*
		Tsutsusi	*R. simsii*	*R. simsii*
Choniastrum				
Hymenanthes	***Pentanthera***	***Pentanthera***	*R. canescens*	*R. canescens*
			R. luteum	*R. luteum*
			R. molle ssp. japonicum	*R. molle*
		Sinensia		
	Ponticum	***Arborea***	*R. arboreum*	*R. arboreum*
		Argyrophylla	*R. argyrophyllum ssp. Argyrophyllum*	*R. argyrophyllum*
			R. argyrophyllum ssp. hypoglaucum	*R. argyrophyllum*
			R. argyrophyllum ssp. nankingense	*R. argyrophyllum*
			R. insigne var. insigne	*R. insigne*
			R. pingianum	*R. pingianum*
		Barbata	*R. barbatum*	*R. barbatum*
			R. succothii	*R. succothii*
		Campanulata		
		Campylocarpa	*R. callimorphum var. callimorphum*	*R. callimorphum*
			R. campylocarpum	*R. campylocarpum*
			R. wardii var. wardii	*R. wardii*
		Falconera	*R. arizelum*	*R. arizelum*
			R. coriaceum	*R. coriaceum*
			R. falconeri ssp. falconeri	*R. falconeri*
			R. galactinum	*R. galactinum*
			R. hodgsonii	*R. hodgsonii*

Subgenus	Section	Subsection	Species	Accession Name
Hymenanthes	***Ponticum***	***Falconera***	*R. rex ssp. fictoliacteum*	*R. rex*
			R. rex ssp. rex	*R. rex*
			R. semnoides	*R. semnoides*
			R. sinofalconeri	*R. sinofalconeri*
		Fortunea	*R. decorum ssp. decorum*	*R. decorum*
			R. orbiculare ssp. orbiculare	*R. orbiculare*
			R. vernicosum	*R. vernicosum*
		Fulgensia	*R. fulgens*	*R. fulgens*
		Fulva	*R. fulvum ssp. fulvum*	*R. fulvum*
			R. uvariifolium var. uvariifolium	*R. uvariifolium*
		Glischra		
		Grandia	*R. grande*	*R. grande*
			R. kesangiae var. kesangiae	*R. kesangiae*
			R. macabeanum	*R. macabeanum*
			R. montroseanum	*R. montroseanum*
			R. pudorosum	*R. pudorosum*
		Griersoniana		
		Irrorata	*R. annae*	*R. annae*
			R. anthosphaerum	*R. anthosphaerum*
			R. irroratum ssp. irroratum	*R. irroratum*
			R. irroratum ssp. ningyuenense	*R. irroratum*
		Lanata		
		Maculifera		
		Neriiflora	*R. chamaethomsonii var. chamaethomsonii*	*R. chamaethomsonii*
			R. dichroanthum	*R. dichroanthum*
			R. forrestii ssp. forrestii	*R. forrestii*
			R. forrestii ssp. papillatum	*R. forrestii*
			R. mallotum	*R. mallotum*
		Parishia		
		Pontica	*R. makinoi*	*R. makinoi*
			R. maximum	*R. maximum*
		Selensia	*R. selense spp. dasycladum*	*R. selense*
			R. selense ssp. jucundum	*R. selense*
		Taliensia		
		Thomsonia	*R. cyanocarpum*	*R. cyanocarpum*
			R. meddianum var. atrokermesinum	*R. meddianum*
			R. thomsonii ssp. thomsonii	*R. thomsonii*
		Venatora	*R. venator*	*R. venator*
		Williamsiana		
			R × *peregrinum*	*R. peregrinum*
	Rhodora		*R. vaseyi*	*R. vaseyi*

Subgenus	Section	Subsection	Species	Accession Name
Rhododendron	*Pogonanthum*			
	Rhododendron	*Afghanica*		
		Baileya		
		Boothia		
		Camelliiflora		
		Campylogyna		
		Caroliniana		
		Cinnabarina		
		Edgeworthia		
		Fragariflora		
		Genestieriana		
		Glauca		
		Heliolepida	*R. rubiginosum var. rubiginosum*	*R. rubiginosum*
		Lapponica	*R. cuneatum*	*R. cuneatum*
			R. flavidum var. flavidum	*R. flavidum*
			R. hippophaeoides	*R. hippophaeoides*
			R. hippophaeoides var. hippophaeoides	*R. hippophaeoides*
			R. impeditum	*R. impeditum*
			R. orthocladum var. microleucum	*R. orthocladum*
			R. orthocladum var. orthocladum	*R. orthocladum*
			R. russatum	*R. russatum*
			R. yungningense	*R. yungningense*
		Ledum		
		Lepidota		
		Maddenia		
		Micrantha		
		Monantha		
		Moupinensia		
		Rhododendron		
		Rhodorastra	*R. dauricum*	*R. dauricum*
			R. mucronulatum var. mucronulatum	*R. mucronulatum*
		Saluenensia	*R. calostrotum ssp. calostrotum*	*R. calostrotum*
			R. saluenense ssp. chameunum	*R. saluenense*
			R. saluenense ssp. saluenense	*R. saluenense*
		Scabrifolia	*R. hemitrichotum*	*R. hemitrichotum*
			R. pubescens	*R. pubescens*
			R. racemosum	*R. racemosum*
		Tephropepla		
		Trichoclada		

Subgenus	Section	Subsection	Species	Accession Name
Rhododendron	***Rhododendron***	***Triflora***	*R. augustinii ssp. chasmanthum*	*R. augustinii*
			R. augustinii ssp. hardyi	*R. augustinii*
			R. davidsonianum	*R. davidsonianum*
			R. lutescens	*R. lutescens*
			R. polylepis	*R. polylepis*
			R. searsiae	*R. searsiae*
			R. siderophyllum	*R. siderophyllum*
		Uniflora		
		Virgata		
Therorhodion				
Vireya	*Albovireya*			
	Discovireya			
	Hadranthe			
	Hadranthe			
	Malayovireya			
	Pseudovireya			
	Schistanthe	***Euvireya***	*R. christi*	*R. christi*
			R. gracilentum	*R. gracilentum*
		Linnaeopsis		
		Malesia		
		Saxifragoidea		
		Solenovieyea		
	Siphonovireya			

Accuracy of the internal evaluation of Pl@ntNet models

By 18th May 2021, which is before the first uploading and training, Pl@ntNet had only 13,962 images of 79 *Rhododendron* species in its database (Appendix 1). And after the completion of the second model training, there were 23,543 images of 275 *Rhododendron* species in the database by 27th July 2021 (Appendix 2).

The identification accuracy of different Pl@ntNet models tested by the two datasets of 203 and 52 species had improved during the three model training (Table 5; Figure10), but the patterns of the improvements are a bit different between the two tests. For the test of 203 species, the accuracy of both Top 1 and Top 5 results was not much improved after the first model update but significantly improved after the second model update. For the test of 52 species, the accuracy improvements of the Top 1 results after the two updates do not have many differences, the accuracy of the Top 5 results was not much improved after the first model update but significantly improved after the second model update.

Table 5 Identification accuracies of the three models tested by the two datasets.

Model version	Tested end of	Test species	Top 1	Top 5
Model 1	25th April	203	0.055	0.075
		52	0.179	0.248
Model 2	6th July	203	0.094	0.195
		52	0.308	0.641
Model 3	16th August	203	0.400	0.660
		52	0.462	0.744

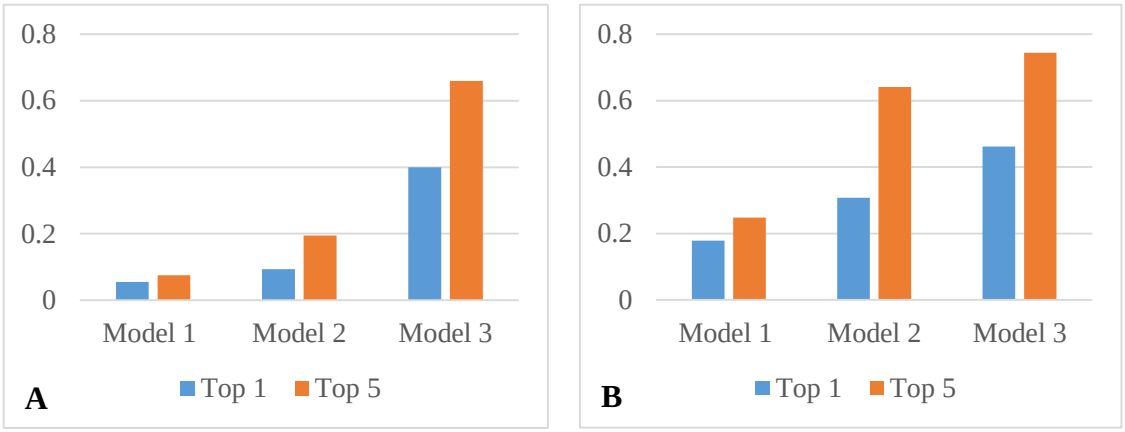

Figure 10 Comparison of the accuracies of the three models tested by the two datasets.

A: identification accuracies of the three models tested by 203 species dataset.

B: identification accuracies of the three models tested by 52 species dataset

Identification accuracy evaluation of plant identification apps

For the overview of the full test results of all the nine apps with 16 *Rhododendron* species and their classification, see Table 6, and for the details, see Appendix 3. The scores of all test results are shown in Appendix 4.

The evaluation of the Top 1 results of the test for 16 species (Table 7; Figure 11) shows that the identification accuracy of the PlantNet model for all infrageneric taxa was improved after each training. Before the first model training, the app with the highest identification accuracy at species, subsection and genus level was iPlant, and the app with the highest identification accuracy at subgenus and section level was PlantSnap. After the first model update, the identification accuracy of PlantNet v2 for four of the infrageneric taxa was basically consistent with the highest accuracy of other apps, and slightly lower than iPlant only at the species level. After the completion of the second model update, the identification accuracy of PlantNet v3 for all the five infrageneric taxa was significantly higher than other apps.

Compared with the Top 1 results, the evaluation of the Top 3 results of the test for 16 species (Table 8; Figure 12) shows that the identification accuracy of each app for each infrageneric taxa of the Top 3 results was higher than that of the Top 1 results (except for iplant and

PictureThis, they only generate one result, their results of the two evaluations were exactly the same), but the difference between all apps did not change significantly. The identification accuracy of PlantNet of all five infrageneric taxa was improved after the first model update. And the accuracy at species and subsection level has been significantly improved after the second model update, while no significant difference at section, subgenus and genus level.

Table 6 Test results of all the nine apps with 16 *Rhododendron* species

Species		PlantNet v1		PlantNet v2		PlantNet v3		iplant	PlantSnap	LeafSnap	PictureThis	HuaBangZhu (花帮主)		aiPlants		iPlant (花伴侣pro)		iNaturelist
R. retusum	1	*Kechiella corymbosa*	3%	*Teucrium heterophyllum*	3%	*R.retusum*	12%	*Aeschynanthus palcher*	*R.praetervisum*	*Bouvardia ternifolia*	*Epilobium canum*	*Aeschynanthus radicans*	63%	*Aeschynanthus radicans*	55%	*R.spinuliferum*	8%	*Bouvardia ternifolia*
	2	*Fuchsia microphylla*	2%	*R.molle*	1%	*R.cinnabarinum*	7%	\	*Epilobium canum*	*Woodfodia fruticosa*	\	*Aeschynanthus palcher*	16%	*Aeschynanthus palcher*	16%	*R.vialii*	7%	*Burchellia bubalina*
	3	*Xanthostemon francii*	1%	\	\	*R.forrestii*	4%	\	*Woodfodia fruticosa*	*Fuchsia microphylla*	\	*Aeschynanthus bracteatus*	5%	*Aeschynanthus buxifolius*	9%	*R.oldhamii*	5%	*Lonicera sempervirens*
R. erosum	1	*R.arboreum*	48%	*R.arboreum*	48%	*R.erosum*	58%	*R.delavayi*	*R.barbatum*	*R.arboreum*	*R.macrophyllum*	*R.delavayi*	89%	*R.delavayi*	89%	\	\	*R.ponticum*
	2	*R.ferrugineum*	17%	*R.kaempferi×kiusianum*	<1%	*R.argipeplum*	23%	\	*R. 'Rubicon'*	*R.ferrugineum*	\	*R.rex*	4%	\	\	\	\	*R.macrophyllum*
	3	*R.barbatum*	3%		\	*R.barbatum*	8%	\	*R.protistum*	*R.barbatum*	\	*R.lapponicum*	1%	\	\	\	\	*R.catawbiense*
R. fastagiatum	1	*R. impeditum*	48%	*R. impeditum*	55%	*R.impeditum*	78%	*R.capitatum*	*R. impeditum*	*R. impeditum*	*R.simsii*	*R.capitatum*	97%	*R.capitatum*	99%	*R.capitatum*	60%	*R.lapponicum*
	2	*R.hippophaeoides*	30%	*R.hippophaeoides*	27%	*R.fastigiatum*	8%	\	*R.augustinii*	*R.hippophaeoides*	\	*R.lapponicum*	3%	\	\	*R.intricatum*	11%	*R.ponticum*
	3	*R.saluenense*	2%	*R.augustinii*	<1%	*R.orthocladum*	5%	\	*R.hippophaeoides*	*R.lapponicum*	\	*Corydalis benecincta*	0%	\	\	*R.fastigiatum*	4%	*R.mucronulatum*
R. pubescens	1	*R.scabrifolium*	46%	*R.pubescens*	35%	*R.pubescens*	73%	*R.racemosum*	*R.racemosum*	*R.scabrifolium*	*R.maximum*	*R.capitatum*	45%	*R.capitatum*	44%	*R.pubescens*	42%	*R.canadense*
	2	*R.impeditum*	18%	*R.hemitrichotum*	18%	*R.scabrifolium*	14%	\	*R.hippophaeoides*	*R.impeditum*	\	*R.racemosum*	34%	*R.racemosum*	33%	*R.yungningense*	37%	*Kalmia microphylla*
	3	*R.racemosum*	10%	*R.scabrifolium*	10%	*R.racemosum*	6%	\	*Haemanthus humilis*	*R.racemosum*	\	*R.spiciferum*	11%	*R.spiciferum*	11%	*R.spiciferum*	5%	*R.groenlandicum*
R. fulvum ssp. Fulvum	1	*R.calophytum*	16%	*R.galactinum*	53%	*R.fulvum*	62%	*R.rex*	*R.hyperythrum*	*R.calophytum*	*R.maximum*	*R.phaeochrysum*	97%	*R.phaeochrysum*	98%	*R.fulvum*	30%	*R.catawbiense*
	2	*R.oreodoxa*	13%	*R.pudorosum*	20%	*R.uvariifolium*	19%	\	*R.ovatum*	*R.oreodoxa*	\	*R.rex*	1%	\	\	*R.hypoglaucum*	18%	*R.ponticum*
	3	*R.sutchuenense*	12%	*R.rex*	6%	*R.galactinum*	8%	\	*R.hypoglaucum*	*R.maximum*	\	*R.oreodoxa*	1%	\	\	*R.phaeochrysum*	7%	*R.macrophyllum*
R. calostrotum ssp. keleticum	1	*R.simsii*	29%	*R.saluenense*	70%	*R.saluenense*	48%	*Rhododendron*	*R.lapponicum*	*R.simsii*	*R.simsii*	*R.hybrida*	40%	*R.hybrida*	33%	*R.saluenense*	85%	*R.lapponicum*
	2	*R.lapponicum*	27%	*R.calostrotum*	11%	*R.calostrotum*	38%	\	*R.williamsianum*	*R.lapponicum*	\	*Diapensia purpurea*	18%	*D. purpurea*	17%	*R.rupicola*	2%	*R.indicum*
	3	*R.saluenense*	7%	*R.lapponicum*	3%	*R.camtschaticum*	1%	\	*R.camtschaticum*	*R.saluenense*	\	*R.redowskianum*	9%	*R.×pulchrum*	8%	*R.nivale*	2%	*R.catawbiense*
R. mekongense var. rubrolineatum	1	*R.maximum*	16%	*R.maximum*	16%	*R.mekongense*	6%	*Rhododendron*	*R.carolinianum*	*R.maximum*	*R.occidentale*	*R.aureum*	50%	*R.aureum*	54%	*R.mucronatum*	81%	*R.viscosum*
	2	*R.columbianum*	13%	*R.columbianum*	13%	*R.columbianum*	3%	\	*R.maximum*	*R.columbianum*	\	*R.pachypodum*	21%	*R.pachypodum*	17%	*R.schlippenbachii*	1%	*R.occidentale*
	3	*R.albiflorum*	5%	*R.albiflorum*	8%	*R.rigidum*	3%	\	*R.albiflorum*	*R.albiflorum*	\	*R.siderophyllum*	7%	*R.siderophyllum*	8%	*R.ovatum*	1%	*R.albiflorum*
R. caesium	1	*Crossosoma californicum*	8%	*R.cinnabarinum*	5%	*R.trichocladum*	22%	*R.chunienii*	*Clematis cirrhosa*	*C.californicum*	*Euphorbia milii*	*Hypericum patulum*	75%	*Hypericum patulum*	73%	*R.lutescens*	9%	*Hypericum crux-andreae*
	2	*Hypericum hypericoides*	4%	*R.wardii*	3%	*R.valentinianum*	7%	\	*Helleborus odorus*	*Hypericum hypericoides*	\	*Hypericum monogynum*	9%	*Hypericum monogynum*	7%	*Hyoscyamus niger*	3%	*Clutia*
	3	*Acridocarpus austrocaledonicus*	1%	*Xanthostemon pubescens*	1%	*R.lepidostylum*	6%	\	*R.rarilepidotum*	*Lycium pallidum*	\	*Euphorbia sieboldiana*	5%	\	\	*R.mucronatum*	2%	*Brachystelma*
R. insigne var. insigne	1	*R.balfourianum*	46%	*R.argyrophyllum*	17%	*R.insigne*	81%	*R.longipes var. chienianum*	*R.protistum*	*R.balfourianum*	*R.macrophyllum*	*R.longipes*	55%	*R.maculiferum*	48%	*R.praevernum*	20%	*R.macrophyllum*
	2	*R.maximum*	7%	*R.rex*	9%	*R.traillianum*	2%	\	*R.pingianum*	*R.maximum*	\	*R.maculiferum*	32%	*R.longipes var. chienianum*	33%	*R.longipes*	17%	*R.catawbiense*
	3	*R.hunnewellianum*	5%	*R.arboreum*	9%	*R.beesianum*	2%	\	*R.hyperythrum*	*R.hunnewellianum*	\	*R.simiarum*	8%	*R.simiarum*	12%	*R.adenopodum*	16%	*R.pseudochrysanthum*
R. reticulatum	1	*R.lapponicum*	30%	*R.canadense*	22%	*R.dauricum*	13%	*R.dauricum*	*R.kaempferi*	*R.lapponicum*	*R.canadense*	*R.dauricum*	86%	*R.dauricum*	86%	*R.mucronulatum*	40%	*R.mucronulatum*
	2	*R.ponticum*	24%	*R.lapponicum*	9%	*R.canadense*	3%	\	*R.reticulatum*	*R.ponticum*	\	*R.mucronulatum*	7%	*R.mucronulatum*	9%	*R.schlippenbachii*	24%	*R.indicum*
	3	*R.dauricum*	11%	*R.dauricum*	8%	*R.setosum*	3%	\	*R.racemosum*	*R.dauricum*	\	*R.mariesii*	3%	\	\	*R.dauricum*	8%	*R.canadense*
R. mucronulatum var. mucronulatum	1	*R.dauricum*	71%	*R.dauricum*	30%	*R.mucronulatum*	90%	*R.mucronulatum*	*R.mucronulatum*	*R.dauricum*	*R.catawbiense*	*R.capitatum*	61%	*R.capitatum*	38%	*R.mucronulatum*	95%	*R.mucronulatum*
	2	*R.catawbiense*	12%	*Kalmia polifolia*	17%	*R.dauricum*	6%	\	\	*R.catawbiense*	\	*R.dauricum*	22%	*R.dauricum*	27%	*R.dauricum*	4%	*R.catawbiense*
	3	*R.lapponicum*	3%	*R.saluenense*	3%	\	\	\	\	\	\	*R.concinnum*	8%	*R.mucronulatum*	13%	*R.huadingense*	0%	*R.lapponicum*
R. huguangense	1	*R.viscosum*	17%	*R.maximum*	25%	*R.augustinii*	30%	*R.stamineum*	*R.viscosum*	*R.viscosum*	*R.occidentale*	*R.stamineum*	98%	*R.stamineum*	98%	*R.stamineum*	88%	*R.occidentale*
	2	*R.arborescens*	10%	*R.augustinii*	13%	*R.arborescens*	17%	\	*R.atlanticum*	*R.alabamense*	\	*R.championiae*	1%	\	\	*R.championiae*	4%	*R.viscosum*
	3	*R.atlanticum*	8%	*R.latoucheae*	8%	*R.maximum*	8%	\	*R.carolinianum*	*R.atlanticum*	\	*R.hancockii*	0%	\	\	*R.augustinii*	0%	*R.columbianum*
R. campylocarpum	1	*R.campylocarpum*	29%	*R.campylocarpum*	73%	*R.campylocarpum*	66%	*R.wardii*	*Dombeya burgessiae*	*R.campylocarpum*	*R.maximum*	*R.wardii*	92%	*R.wardii*	91%	*R.liliiflorum*	56%	*R.albiflorum*
	2	*R.maximum*	26%	*R.sinofalconeri*	12%	*R.wardii*	18%	\	*R.maximum*	*R.wardii*	\	*R.irroratum*	5%	\	\	*R.campylocarpum*	10%	*Verbascum lychnitis*
	3	*R.wardii*	16%	*R.wardii*	1%	*R.wightii*	2%	\	*R.williamsianum*	*R.maximum*	\	*R.decorum*	1%	\	\	*R.simiarum*	6%	*R.pseudochrysanthum*
R. cuneatum	1	*R.impeditum*	26%	*R.hippophaeoides*	31%	*R.cuneatum*	22%	*Rhododendron*	*R.lapponicum*	*R.lapponicum*	*R.ferrugineum*	*R.lapponicum*	81%	*R.lapponicum*	68%	*R.concinnum*	44%	*R.lapponicum*
	2	*R.hippophaeoides*	25%	*R.cuneatum*	28%	*R.hippophaeoides*	22%	\	*R.hippophaeoides*	*R.hippophaeoides*	\	*R.capitatum*	15%	*R.capitatum*	26%	*R.hippophaeoides*	22%	*R.catawbiense*
	3	*R.lapponicum*	24%	*R.impeditum*	7%	*R.yungningense*	11%	\	*R.racemosum*	*R.impeditum*	\	*R.racemosum*	2%	\	\	*R.capitatum*	8%	*R.ponticum*
R. lambianum	1	*R.maximum*	71%	*R.pingianum*	18%	*R.latoucheae*	18%	*R.latoucheae*	*R.polyanthemum*	*R.maximum*	*R.maximum*	*R.moulmainense*	41%	*R.moulmainense*	49%	*R.simiarum*	18%	*R.macrophyllum*
	2	*R.minus*	8%	*R.minus*	18%	*R.zaleucum*	15%	\	*R.rarilepidotum*	*R.minus*	\	*R.latoucheae*	33%	*R.latoucheae*	27%	*R.latoucheae*	11%	*R.viscosum*
	3	*R.catawbiense*	1%	*R.argyrophyllum*	7%	*R.minus*	10%	\	*R.orbiculatum*	*R.macrophyllum*	\	*R.cavaleriei*	10%	*R.cavaleriei*	7%	*Luculia pinceana*	5%	*Weigela*
R. camtschaticum	1	*R.camtschaticum*	34%	*R.camtschaticum*	17%	*R.camtschaticum*	19%	*Rehmannia chingii*	*R.camtschaticum*	*R.camtschaticum*	*R.indicum*	*Pelargonium graveolens*	36%	*Pelargonium graveolens*	47%	*Malus × scheidecheri*	62%	*Geranium phaeum*
	2	*Rubus odoratus*	11%	*Geranium phaeum*	7%	*Geranium phaeum*	3%	\	*Dianthus glacialis*	*Rubus odoratus*	\	*Rehmannia chingii*	18%	*Rehmannia chingii*	19%	*Cydonia oblonga*	6%	*Phacelia parryi*
	3	*Rosa pendulina*	1%	*Geranium macrorrhizum*	3%	*Verbascum phoeniceum*	2%	\	*Dianthuspavonius*	*Rosa pendulina*	\	*Rehmannia glutinosa*	6%	\	\	*Tradescantia sillamontana*	2%	*Cuphea aequipetala*

Correct species
Correct subsection
Correct section
Correct subgenus
Same genus
Incorrect genus

Table 7 Average scores of the Top 1 results of the nine apps in different infrageneric taxa.

App	Genus	Subgenus	Section	Subsection	Species
PlantNet v1	0.875	0.625	0.625	0.375	0.125
PlantNet v2	0.938	0.75	0.75	0.5	0.188
PlantNet v3	1	0.813	0.813	0.813	0.625
iplant	0.875	0.563	0.563	0.375	0.063
PlantSnap	0.875	0.813	0.75	0.4375	0.125
LeafSnap	0.938	0.688	0.688	0.375	0.125
PictureThis	0.875	0.313	0.313	0	0
HuaBangZhu	0.813	0.563	0.563	0.313	0
aiPlants	0.813	0.563	0.563	0.25	0
iPlant (花伴侣 pro)	0.929	0.643	0.643	0.429	0.214
iNaturelist	0.813	0.438	0.438	0.188	0.063

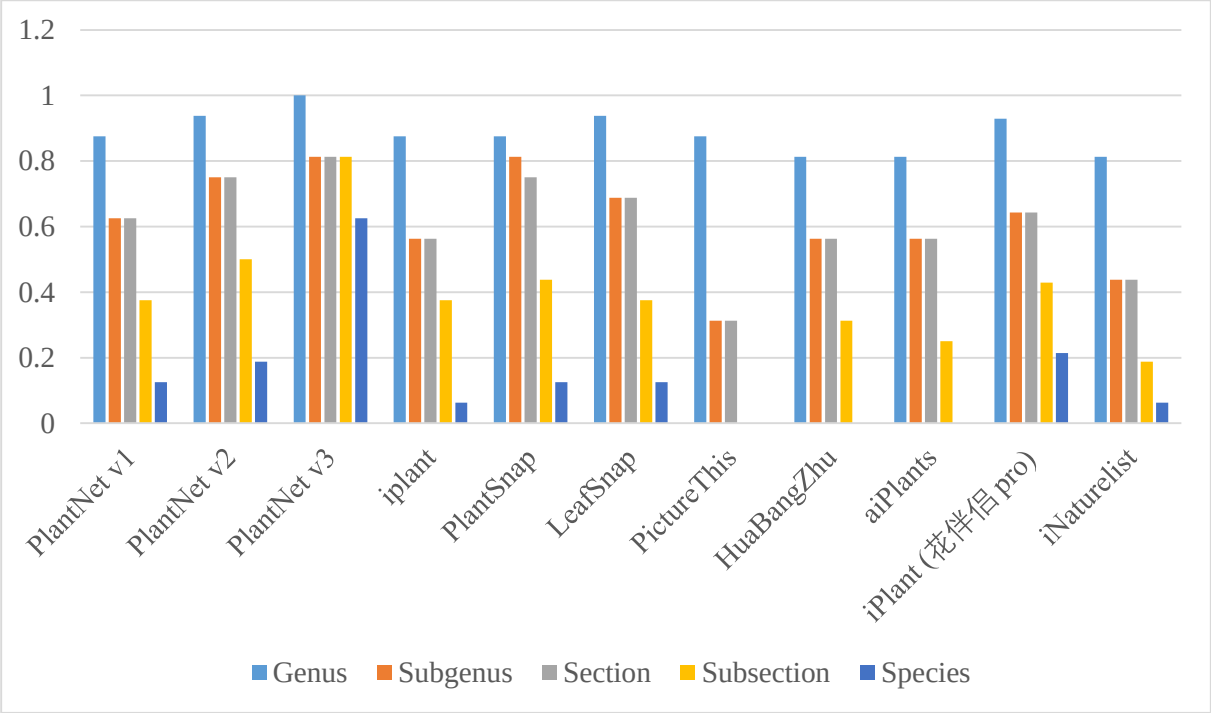

Figure 11 Accuracy distribution of the Top 1 results of the apps in different infrageneric taxa.

Table 8 Average scores of the Top 3 results of the nine apps in different infrageneric taxa.

App	Genus	Subgenus	Section	Subsection	Species
PlantNet v1	0.875	0.688	0.688	0.563	0.125
PlantNet v2	1	0.813	0.813	0.563	0.25
PlantNet v3	1	0.813	0.813	0.813	0.75
iplant	0.875	0.563	0.563	0.375	0.063
PlantSnap	1	0.875	0.813	0.5	0.125
LeafSnap	0.875	0.688	0.688	0.563	0.125
PictureThis	0.875	0.313	0.313	0	0
HuaBangZhu	0.813	0.688	0.688	0.438	0
aiPlants	0.813	0.625	0.625	0.438	0.063
iPlant (花伴侣 pro)	0.929	0.714	0.714	0.643	0.357
iNaturelist	0.813	0.625	0.625	0.25	0.063

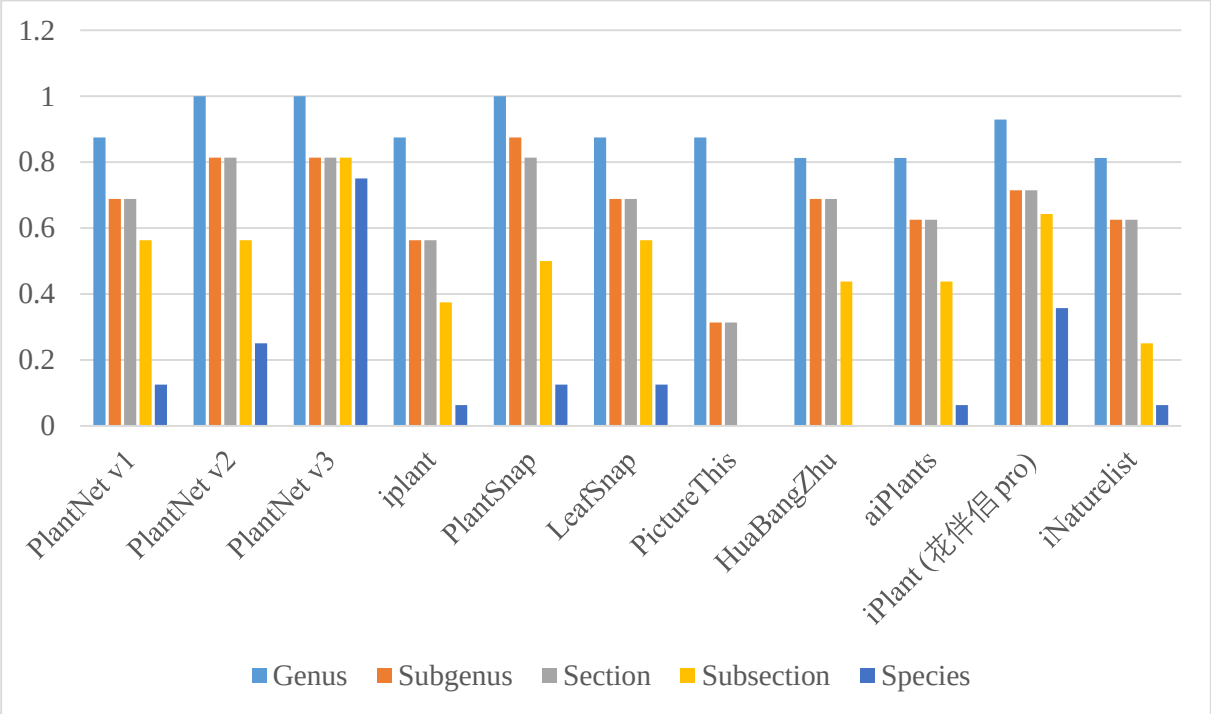

Figure 12 Accuracy distribution of the Top 3 results of the apps in different infrageneric taxa.

Discussion

Improvements of Pl@ntNet and comparison with other apps

The two tests of 203 and 52 *Rhododendron* species show us the identification accuracy of Pl@ntNet models on bigger scales. The test dataset of 203 species was not illustrated in Pl@ntNet, which means the users are less familiar with them, and the identification accuracy improvements of these 'harder' species are just what we want to see. The results of this 203-species test can also show us the entire scale of the diversity of Rhododendron across Pl@ntNet. The test dataset of 52 species was illustrated in Pl@ntNet, indicating that these species are more common species. The results of this 52-species test can show us the progress of the identification accuracy by the model training using the training data like the 16-species test. Comparing the identification accuracies of the two test datasets, the improvement of Model 3 in the 203-species test is more significant than that in the 52-species test (Figure 10), suggesting that the training data has made a great contribution to the improvement of the identification accuracy of the species that are more difficult to identify. However, the final identification accuracies of the 52 species for both Top 1 and Top 5 are higher than that of the 203 species dataset, indicating that the Pl@ntNet model is more familiar with the common species.

As mentioned in the Methods, the test dataset we picked was originally composed of images from 21 species. But during the test of the PlantNet v3, five species were found to have their test images in the latest database of Pl@ntNet (never found in former databases, for some reason these images were in the RBGE repository and were uploaded with other training images), so these biased species were deleted from the test data set and their results from other apps were also deleted and not evaluated. To show the impact of these biased species on the evaluation of identification accuracy, their test results of the three versions of PlantNet were put in Table 9. These results show that these biased species can always be identified to the correct species by PlantNet v3 in the Top 3 results and usually with very high confidence percentages. The identification accuracies of PlantNet v3 would be higher than their actual values if these results were used for the evaluation.

Table 9 Test results of the five biased species.

Species		PlantNet v1		PlantNet v2		PlantNet v3	
R. roxieanum var. oreonastes	1	*R.calophytum*	29%	*R.rex*	34%	*R.roxieanum*	86%
	2	*R.maximum*	11%	*R.galactinum*	7%	*R.alutaceum*	2%
	3	*R.rex*	10%	*R.pudorosum*	5%	*R.hyperythrum*	2%
R. arboreum var. cinnamomeum	1	*R.arboreum*	45%	*R.arboreum*	18%	*R.arboreum*	74%
	2	*R.catawbiense*	3%	*R.ferrugineum*	2%	*R.delavayi*	22%
	3	*R.sutchuenense*	2%	*R.maximum*	<1%	\	\
R. coriaceum	1	*R.pseudochrysanthum*	35%	*R.pudorosum*	47%	*R.coriaceum*	72%
	2	*R.calophytum*	12%	*R.rex*	18%	*R.pudorosum*	17%
	3	*Prunus serrulata*	10%	*R.coriaceum*	9%	*R.rex*	4%
R. anthosphaerum	1	*R.rex*	21%	*R.rubiginosum*	21%	*R.anthosphaerum*	20%
	2	*R.sutchuenense*	18%	*R.pudorosum*	12%	*R.davidii*	19%
	3	*R.oreodoxa*	17%	*R.argyrophyllum*	8%	*R.oreodoxa*	12%
R. mallotum	1	*R.ferrugineum*	25%	*R.arboreum*	34%	*R.sperabile*	28%
	2	*R.simsii*	15%	*R.ferrugineum*	18%	*R.barbatum*	25%
	3	*R.arboreum*	12%	*R.simsii*	6%	*R.mallotum*	12%

In the test of nine apps, the test dataset of 16 species from six different subgenera was used to represent the whole genus of *Rhododendron*. It shows the identification accuracy on the infrageneric taxa of several plant identification apps commonly used and the improvements of the identification accuracy of PlantNet on each infrageneric taxa in the process of model training. However, the current classification of *Rhododendron* is still not very clear, the analysis results can be different according to different classification systems, so this process can only be completed manually and cannot be conducted on a big scale.

The test results of PlantNet v1 and other apps (Table 7; Figure 11) show that the identification accuracy of iPlant in subsection and species level is much higher than that of other apps. This may be due to the fact that Southwest China is the distribution centre of *Rhododendron*, and this app was developed by the Institute of Botany, Chinese Academy of Sciences (IB-CAS), the image data used by this app came from Plant Photo Bank of China, which covers a relatively

large number of images of *Rhododendron* species. So that the identification model of iPlant is more familiar with the characters of Rhododendron species, which caused the result of its higher identification accuracy than other apps. Pl@ntNet can also cooperate with other plant image databases more actively in the future to increase the training datasets and the number of species that can be identified therefore to improve its accuracy of identification.

After the first model update, the identification accuracy of PlantNet v2 in each infrageneric taxon was improved, indicating that the image quality of the training data is high and has a positive impact on the improvement of the identification model. However, due to the relatively small number of images of *Rhododendron* (1,478) uploaded as the training dataset, the identification accuracy of PlantNet v2 was not significantly improved and still lower than that of iPlant at subsection and species level.

During the second model training, the dataset included images of 56 species that had erroneously been labelled as *Rhododendron*. This may have a certain impact on the identification accuracy of the new model. However, the test results show that the accuracy of the PlantNet v3 model was significantly increased after the second update, especially in subsection and species level, with the respective accuracy about 2.2 and 6 times higher than PlantNet v1, indicating that the errors mentioned above did not cause a great impact on the accuracy of the identification model. This may be due to the large amount of image data (7,913 images of 440 species) used in the second training, in which the 56 wrong species accounted for a relatively small proportion, and their negative impact can be ignored.

The confidence percentages produced with the results by PlantNet (Table 6; Appendix 3) may also show the improvements of the Pl@ntNet models. For some tested species, if all the three models identified them to a same species, the percentage of these results may increase as the model update. But this trend did not appear frequently since the confidence percentages are also related to the ambiguity between species. This means that if more images of species look similar to each other were uploaded for the model training, the confidence percentages would be lower than that of the former models. So for the current Pl@ntNet models, the changing trend of their

confidence percentages may not be very useful for the evaluation of the model improvements. Only when the species number and the images for each species in the database are sufficient, the confidence percentage may be an effective parameter to evaluate the progress of the models.

As of the last test (9th August 2021), the identification accuracy of PlantNet v3 on all the infrageneric taxa was the highest of the nine tested apps. Its accuracy at the species level was about 63% and for the higher infrageneric levels it was reliable for more than 80% of tests (Table 7). This suggests that PlantNet v3 would give the correct subsection more than 8 times out of 10 in the first results, so it is usually reliable to use for identifying an unknown *Rhododendron* species to the subsection level and narrowing down the possibilities of the correct species. The first three results of PlantNet v3 (Table 8) contain the correct species at a 75% possibility, and the identification accuracy of the subsection level is also more than 80%. This fully suggests that when the first result did not get to the correct species or subsections, the second and third results also have a high reference value, which can also be used to narrow down the possibilities of the correct species. If PlantNet narrows down the possibilities to taxa (containing only species, no lower taxa, usually subsections, sometimes sections and subgenera) with a small number of species (e.g. Subsect. *Arborea* in Subgen. *Hymenanthes* Sect. *Ponticum*, with 5 species), then it is a useful tool to identify an unknown *Rhododendron* species, but if the taxa are very large (e.g. Subsect. *Tsutsusi* in Subgen. *Azaleastrum* Sect. *Tsutsusi*, with 97 species), then it does not help so much.

We can say that the current Pl@ntNet model is better than experts on the identification of Rhododendron because it has a relatively high identification accuracy on species and subsections which can narrow down the possibilities of the correct species and saves much more time than the manual identification.

Possible reasons of why some species cannot be identified correctly

Hair is one of the important distinguishing characters of *Rhododendron*, the different types of indumentum play an important role in the classification of subgenera, sections, subsections and interspecies. The variety of indumentum makes the leaves of *Rhododendron* diverse. For the main types of *Rhododendron* indumentum see Figure13. However, in this project, these very detailed characters cannot be accurately recognized by the identification models, which may lead to the inaccurate identification of some species. Although they cannot be used for the identification by apps, these characters can be used as an important basis for judging the accuracy of the results produced by the apps, and also play an important role in further identification of subspecies and varieties.

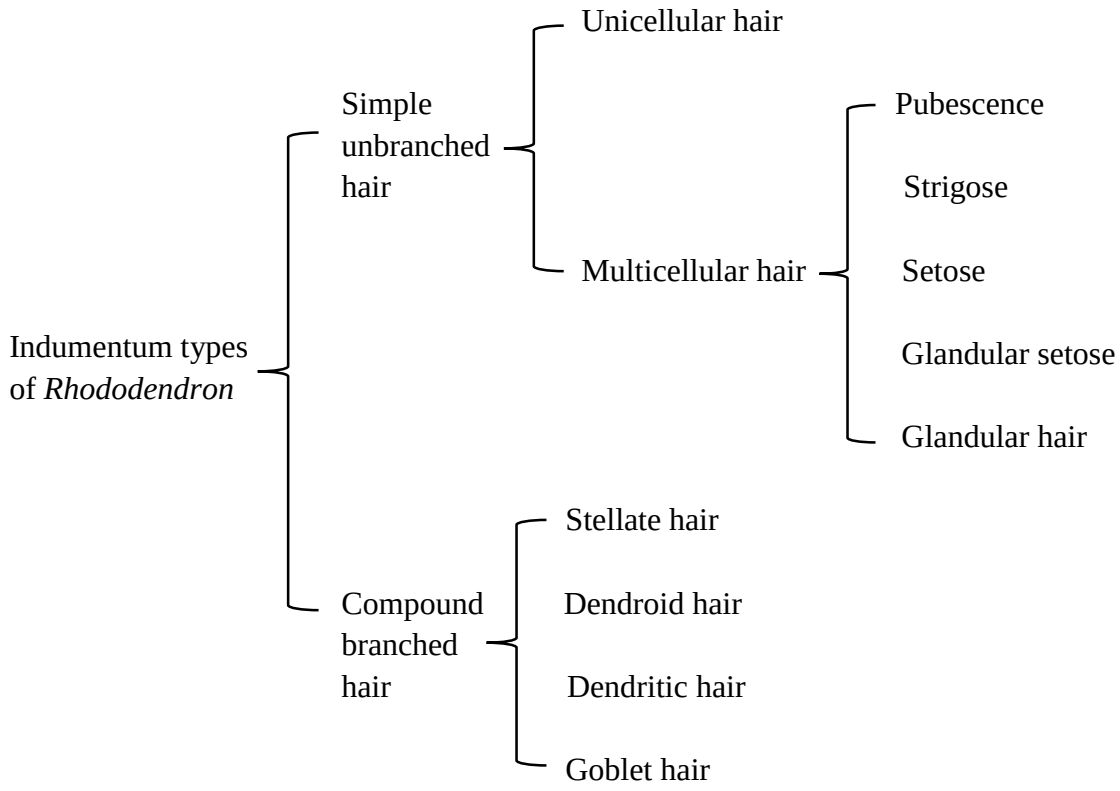

Figure 13 Main indumentum types of *Rhododendron* and their classification.

The differentiation of the characters of *Rhododendron* seeds is also very diverse, which is one of the important indexes of classification. The seeds can be winged, or with appendages, fringes or tails. However, this project was conducted from spring to summer, the seeds were not photographed, and Pl@ntNet does not use seeds for its type of views, so these useful characters

of the seeds were not able to use for the testing and training.

Species that do not exist in the database can never be correctly identified, this is a major factor limiting the identification accuracy of Pl@ntNet. Although we have updated the identification model of Pl@ntNet for several times, and the number of species that can be identified has been greatly improved, but still, only 275 *Rhododendron* species were contained in its latest database (species list and classification see Appendix 5), which is far from enough for such a large genus like *Rhododendron* of more than 1,000 species. More images of different *Rhododendron* species are needed for the model training to further improve the identification accuracy of Pl@ntNet.

The number of pictures is also one of the factors that have influence on the identification accuracy of Pl@ntNet. The number of pictures of a certain species determines the familiarity of the Pl@ntNet identification model to the character of this species, which therefore affects the identification results. As can be seen in Appendix 1 and 2, in the current image database of Pl@ntNet, some species have more than 4,000 images, while some species have only one image. The identification accuracy of the species with a small amount of image data is likely to be lower than that of the species with a large amount of image data. Similarly, the number of images of different organs for each species also affects the accuracy of identification. The flowers of Rhododendron have a great variety in characters and are the most important organs for species identification. It can be seen in Appendix 2 that there are more than 3,000 images of flowers in some species, while some others even have none, which may make a huge difference between their identification accuracies. Therefore, a large volume of data, especially the images of organs with important characters for identification, is an important basis to improve the identification accuracy of Pl@ntNet.

During the process of this project, the Pl@ntNet model was trained twice using two sets of different training data. Both the two training datasets had improved the identification accuracy of the Pl@ntNet model but to different extents. As can see from Table 5, 7, and 8, Figure 10, 11 and 12, the accuracy improvements after the training by the first dataset of 1,478 images were not significant (usually no more than two times higher), although these images were

targeted photographed and fit the requirements of Pl@ntNet. The accuracy improvements after the training by the second dataset of 7,913 images were significant (usually more than three times higher, but might lower than it should be since only 275 out of the 440 species matched ThePlantList), although these images were from the RBGE repository for other projects and many of them might not meet the requirements of Pl@ntNet. This difference suggests that large numbers of images are more useful than the smaller numbers of targeted photography for the model improvement in this case. But if the volumes of the training data are the same, the training dataset with more informative images should be more effective for the improvement of Pl@ntNet's identification accuracy.

Recommendations for further improvements

Since Pl@ntNet is a fully open access platform, many non-professional users also contribute a lot to the training data. However, we found errors in the previous observation uploaded by other users, which may be one of the reasons for the low accuracy of the identification model before the first update. If Pl@ntNet can develop a user authentication system in the future, increasing the weight of observations uploaded by professional users and reducing that of the non-professional users, then the error rate of the training data can be reduced, thus the identification accuracy of the model can be more effectively improved after the training.

When uploading a large number of images to the plant observations, the limitation of four images greatly increases the working time. If Pl@ntNet can provide a platform for users to upload a large number of plant observations at once in the future, some professionals can contribute to the image database of Pl@ntNet more efficiently, thus making the identification model progress more rapidly.

Before the first model training, the number of illustrated species for *Rhododendron* in the database of Pl@ntNet was very small. During the contributing process, many uploaded species were not illustrated in Pl@ntNet, so the option ‘Illustrated species only’ needed to be switched off when selecting their species names. However, this option is set to switch on by default, so

it needed to be switched off frequently during the process of uploading species observations, which took a certain amount of time. If Pl@ntNet can change the default setting of this option to remember the last choice of the users in the future, it can reduce the time wasted in the process of multiple uploads and improve the working efficiency.

Since Pl@ntNet do not have a specific project on Rhododendron, than plant name data derived ThePlantList was used, but the number of species it contains is relatively small. For the second training dataset with 440 species, only 275 species matched ThePlantList names. This makes the data of the remaining species useless for the improvement of identification accuracy. If Pl@ntNet can update the World Flora project with a more complete list of species names, or to have a dedicated project on *Rhododendron* or dedicated to the Nepalese flora to exploit more *Rhododendron* species and so more data that we have yet uploaded.

Conclusion and future research

Conclusion

Through the test of the nine plant identification apps, iPlant was found to be the most accurate app before the second update of PlantNet, with the highest accuracy at both subsection and species level. After all the model training process, the latest version PlantNet became the most accurate app, with the highest accuracy of all infrageneric taxa. The identification accuracy of Pl@ntNet at all infrageneric taxa has been improved by the model training using the uploaded images, but this influence is most obvious at the subsection and species level, with the respective accuracy about 2.2 and 6 times higher than the original Pl@ntNet identification model. The identification model of Pl@ntNet had improved, especially for the species that are more difficult to identify, and was considered to be a very useful tool for *Rhododendron* identification, especially for narrowing down the possibilities of correct species.

Future research

This study has improved the identification model of Pl@ntNet greatly, and explained the influence of the training data on identification accuracy to some extent, but there are still a lot of details that worth further studying:

1. Test how many images are needed to produce reliable identifications by uploading different numbers of images for different organs (leaves, flowers, fruits, etc.) of different species.
2. Find out which organs/characters are useful and which are not for the identification model of Pl@ntNet by the model training and accuracy test carried out for a particular organ/character.
3. Test the impacts of different numbers of images (up to 4 per identification) submitted on the identification accuracy.
4. Determine which combinations of different views (e.g. upper and lower leaf surface, face and profiles of flowers) is most effective for the identification.
5. Evaluate at what level of accuracy the identification of species illustrated by digitized herbarium specimens is possible using the approach developed in the framework of Pl@ntNet by testing images of herbarium specimens as well as living plants.

References

Affouard, A., Go ëau, H., Bonnet, P., Lombardo, J., & Joly, A. (2017). Pl@ntNet app in the era of deep learning. *ICLR*.

Argent, G. (2006). *Rhododendrons of subgenus Vireya*. London: Royal Horticultural Society.

Argent, G. (2015). *Rhododendrons of subgenus Vireya*, 2nd edition. Royal Botanic Garden Edinburgh.

Bonnet, P., Joly, A., Go ëau, H., et al. (2016) Plant identification: man vs. machine. *Multimedia Tools and Application* **75**(3): 1647–1665.

Chamberlain, D. F., Hyam, R., Argent, G., Fairweather, G. & Walter, K. S. (1996). *The genus Rhododendron: its classification and synonymy*. Edinburgh: Royal Botanic Garden Edinburgh.

Craven, L. A. (2011) *Diplarche* and *Menziesia* transferred to *Rhododendron* (Ericaceae). *Blumea - Biodiversity, Evolution and Biogeography of Plants* **56**(1): 33–35.

Don, G. (1834) *A general history of the dichlamydeous plants: 3 vol.* London, UK: Rivington, J. G & F. 843–851.

Elliott, A. C., Purvis, D. & Pullan, M. (2020–). Ericaceae Resource Centre. <https://padme.rbge.org.uk/ericaceae/> (accessed 28th June 2021)

Goetsch, L., Andrew, J. E. & Benjamin, D. H. (2005) The Molecular Systematics of *Rhododendron* (Ericaceae): A Phylogeny Based Upon RPB2 Gene Sequences. *Systematic Botany* **30**(3): 616–626.

Hooker, J. D. (1849) *The Rhododendrons of Sikkim-Himalaya*. London: Reeve, Benham, and Reeve.

Innocenti, G., Dall'Acqua, S., Scialino, G., et al. (2010) Chemical Composition and Biological Properties of *Rhododendron anthopogon* Essential Oil. *Molecules* **15**(4):2326–2338.

Joly, A., Goeau. H., Bonnet, P., et al. (2014) Interactive plant identification based on social

image data. *Ecological Informatics* **23**: 22–34.

Khan, G., Nolzen, J., Schepker, H. & Albach, D. C. (2020) Incongruent phylogenies and its implications for the study of diversification, taxonomy and genome size evolution of *Rhododendron* (Ericaceae). *BioRxiv* 2020.07.27.216218.

Klocke, J. A., Hu, M. Y., Chiu, S. F. & Isao, K. (1991) Grayanoid diterpene insect antifeedants and insecticides from *Rhododendron molle*. *Phytochemistry* **30**(6):1797–1800.

Krizhevsky, A., Sutskever, I. & Hinton, G. E. (2012) Imagenet classification with deep convolutional neural networks. *Advances in neural information processing systems* **25**: 1097–1105.

Lawrence, S., Giles, C. L., Tsoi, A. C., et al. (1997) Face recognition: A convolutional neural-network approach. *IEEE transactions on neural networks* **8**(1): 98–113.

LeCun, Y. & Bengio, Y. (1998) *Convolutional Networks for Images, Speech, and Time Series*. Cambridge, MA: MIT Press 255–258.

LeCun, Y., Bengio, Y. & Hinton G. (2015) Deep learning. *Nature* **521**: 436–444.

Linnaeus, C. (1753) *Species Plantarum.* London.

Maximowicz, C. J. (1870) Rhododendreae Asiae Orientalis. *Mem. Acad. Imp. Sci. St.-Pétersbourg Sér* **7** (16): 1–53.

Mok, S. Y. & Lee, S. (2013) Identification of flavonoids and flavonoid rhamnosides from *Rhododendron mucronulatum for. albiflorum* and their inhibitory activities against aldose reductase. *Food Chemistry* **136**(2): 969–974.

Salisbury, R. A. (1796) *Prodromus stirpium in horto ad Chapel Allerton vigentium*. London.

Shi, W., Long, G., Yang, S., et al. (2018) Advance in Researches on Eco-physiological Adaptability of Epiphytes. *Journal of Tropical and Subtropical Botany* **26**(1): 92–106. [In standard Chinese]

Sleumer, H. (1949). Ein System der Gattung *Rhododendron* L. *Bot. Jahrb. Syst*. **74**: 511–553.

Stevenson, J. B. (1930) *The Species of Rhododendron*. Rhododendron Society.

Szegedy, C., Vanhoucke, V., Ioffe, S., Shlens, J. & Wojna, Z. (2016) Rethinking the inception architecture for computer vision. *Proceedings of the IEEE conference on computer vision and pattern recognition* 2818–2826.

The Royal Horticultural Society (1997) *The Rhododendron Handbook: Rhododendron Species in Cultivation*. The Royal Horticultural Society, London.

Zhou, L., Wang, Y. & Zhang, L. (2008) Pollen Morphology and Its Taxonomy of Twenty-Six Species in *Rhododendron*. *Scientia Silvae Sinicaev* **2**: 55–63. [In standard Chinese]

Appendices

Appendix 1

Species	Images	Species	Images
Rhododendron alabamense Rehder	7	Rhododendron macrophyllum D. Don ex G. Don	14
Rhododendron albiflorum Hook.	16	Rhododendron maddenii Hook. f.	4
Rhododendron anthopogon D. Don	3	Rhododendron maximum L.	2679
Rhododendron arborescens (Pursh) Torr.	41	Rhododendron micranthum Turcz.	2
Rhododendron arboreum Sm.	11	Rhododendron minus Michx.	4
Rhododendron atlanticum (Ashe) Rehder	16	Rhododendron molle G.Don	7
Rhododendron augustinii Hemsl.	8	Rhododendron mucronatum (Blume) G. Don	2
Rhododendron aureum Georgi	1	Rhododendron nakaharae Hayata	2
Rhododendron auriculatum Hemsl.	3	Rhododendron neriiflorum Franch.	3
Rhododendron balfourianum Diels	7	Rhododendron niveum Hook. f.	4
Rhododendron barbatum Wall. ex G. Don	1	Rhododendron obtusum Hort. ex Wats.	10
Rhododendron bureavii Franch.	1	Rhododendron occidentale (Torr. & A. Gray) A. Gray	6
Rhododendron calendulaceum (Michx.) Torr.	960	Rhododendron ochraceum Rehder & E.H. Wilson	4
Rhododendron calophytum Franch.	15	Rhododendron oligocarpum W.P. Fang	4
Rhododendron campylocarpum Hook. f.	5	Rhododendron orbiculare Decne.	1
Rhododendron camtschaticum Pall.	6	Rhododendron oreodoxa Franch.	4
Rhododendron canadense (L.) Torr.	35	Rhododendron oreotrephes W.W. Sm.	1
Rhododendron canescens (Michx.) Sweet	72	Rhododendron periclymenoides (Michx.) Shinners	168
Rhododendron catawbiense Michx.	819	Rhododendron ponticum L.	1513
Rhododendron cinnabarinum Hook. f.	1	Rhododendron prinophyllum (Small) Millais	92
Rhododendron columbianum (Piper) Harmaja	58	Rhododendron prunifolium (Small) Millais	3
Rhododendron dauricum L.	8	Rhododendron pseudochrysanthum Hayata	1
Rhododendron davidsonianum Rehder & E.H. Wilson	4	Rhododendron racemosum Franch.	2
Rhododendron decorum Franch.	7	Rhododendron redowskianum Maxim.	2
Rhododendron fauriei Franch.	3	Rhododendron rex H. L év.	14
Rhododendron ferrugineum L.	4057	Rhododendron saluenense Franch.	1
Rhododendron fortunei Lindl.	2	Rhododendron scabrifolium Franch.	4
Rhododendron griffithianum Wight	2	Rhododendron schlippenbachii Maxim.	5
Rhododendron hemitrichotum Balf. f. & Forrest	4	Rhododendron simsii Planch.	2178
Rhododendron hippophaeoides Balf. f. & W.W. Sm.	6	Rhododendron sinogrande Balf. f. & W.W. Sm.	3
Rhododendron hirsutum L.	406	Rhododendron sutchuenense Franch.	9
Rhododendron hunnewellianum Rehder & E.H. Wilson	8	Rhododendron thayerianum Rehder & E.H. Wilson	1
Rhododendron impeditum Balf. f. & W.W. Sm.	12	Rhododendron vaseyi A. Gray	23
Rhododendron indicum (L.) Sweet	403	Rhododendron virgatum Hook. f.	2
Rhododendron keysii Nutt.	2	Rhododendron viscosum (L.) Torr.	38
Rhododendron lapponicum (L.) Wahlenb.	61	Rhododendron wardii W.W. Sm.	4
Rhododendron latoucheae Franch.	1	Rhododendron williamsianum Rehder & E.H. Wilson	1
Rhododendron lepidostylum Balf. f. & Forrest	2	Rhododendron wiltonii Hemsl. & E.H. Wilson	7
Rhododendron lutescens Franch.	9	Rhododendron yuefengense G.Z. Li	2
Rhododendron luteum Sweet	55	Total	13962

Appendix 2

Species	Images	Flower	Fruit	Leaf	Bark	Habit	Scan	Branch	Sheet	Other	Drawing	Bud	Anatomy
Rhododendron × hemigymnum (Tagg & Forrest) D.F. Chamb.	2	0	0	0	0	0	0	0	0	0	0	2	0
Rhododendron aberconwayi Cowan	3	2	0	0	0	1	0	0	0	0	0	0	0
Rhododendron adenogynum Diels	48	30	0	4	0	8	0	0	0	0	0	6	0
Rhododendron adenosum Davidian	28	23	0	0	0	1	0	0	0	0	0	4	0
Rhododendron aganniphum Balf. f. & Kingdon-Ward	14	3	0	4	0	5	0	0	0	0	0	2	0
Rhododendron alabamense Rehder	7	2	0	1	2	2	0	0	0	0	0	0	0
Rhododendron albiflorum Hook.	21	8	0	7	1	4	0	0	0	1	0	0	0
Rhododendron alutaceum Balf. f. & W.W. Sm.	18	12	0	0	1	4	0	0	0	0	0	1	0
Rhododendron ambiguum Hemsl.	6	5	0	0	0	1	0	0	0	0	0	0	0
Rhododendron amesiae Rehder & E.H. Wilson	10	10	0	0	0	0	0	0	0	0	0	0	0
Rhododendron annae Franch.	17	8	0	4	2	2	0	0	0	1	0	0	0
Rhododendron anthopogon D. Don	33	18	1	6	1	5	0	0	0	0	0	1	1
Rhododendron anthosphaerum Diels	29	23	0	1	1	2	0	0	0	0	0	2	0
Rhododendron araiophyllum Balf. f. & W.W. Sm.	6	5	0	0	0	0	0	0	0	0	0	1	0
Rhododendron arborescens (Pursh) Torr.	48	31	1	6	0	10	0	0	0	0	0	0	0
Rhododendron arboreum Sm.	255	140	5	38	12	33	0	6	0	0	0	21	0
Rhododendron argipeplum Balf. f. & R.E. Cooper	12	5	0	0	0	7	0	0	0	0	0	0	0
Rhododendron argyrophyllum Franch.	145	85	2	19	8	26	0	0	0	3	0	2	0
Rhododendron arizelum Balf. f. & Forrest	97	62	0	10	9	16	0	0	0	0	0	0	0
Rhododendron atlanticum (Ashe) Rehder	21	11	0	1	0	9	0	0	0	0	0	0	0
Rhododendron augustinii Hemsl.	79	45	0	14	4	14	0	0	0	2	0	0	0
Rhododendron aureum Georgi	12	8	0	0	0	4	0	0	0	0	0	0	0
Rhododendron auriculatum Hemsl.	8	4	0	3	1	0	0	0	0	0	0	0	0
Rhododendron auritum Tagg	5	4	0	0	0	0	0	0	0	0	0	1	0
Rhododendron balfourianum Diels	26	10	0	6	0	9	0	0	0	0	0	1	0
Rhododendron barbatum Wall. ex G. Don	67	29	4	9	2	18	0	0	2	0	0	3	0
Rhododendron basilicum Balf. f. & W.W. Sm.	4	1	0	1	0	2	0	0	0	0	0	0	0
Rhododendron beanianum Cowan	30	23	0	4	1	1	0	0	0	0	0	1	0
Rhododendron beesianum Diels	7	5	0	0	0	2	0	0	0	0	0	0	0
Rhododendron brachyanthum Franch.	9	3	0	1	0	5	0	0	0	0	0	0	0
Rhododendron bureavii Franch.	75	48	0	10	1	12	0	1	0	0	0	3	0
Rhododendron calendulaceum (Michx.) Torr.	1226	996	1	168	10	47	0	0	0	4	0	0	0
Rhododendron callimorphum Balf. f. & W.W. Sm.	37	18	0	6	2	4	0	1	0	3	0	3	0
Rhododendron calophytum Franch.	95	60	2	5	3	17	0	0	0	0	0	8	0
Rhododendron calostrotum Balf. f. & Kingdon-Ward	56	30	0	4	0	19	0	0	0	0	0	2	1
Rhododendron camelliiflorum Hook. f.	1	0	0	0	0	0	0	0	1	0	0	0	0
Rhododendron campanulatum D. Don	123	67	2	24	3	14	0	4	3	0	0	6	0
Rhododendron campylocarpum Hook. f.	87	55	2	10	2	17	0	1	0	0	0	0	0
Rhododendron campylogynum Franch.	5	3	0	1	0	0	0	0	0	0	0	1	0
Rhododendron camtschaticum Pall.	7	5	0	0	0	2	0	0	0	0	0	0	0
Rhododendron canadense (L.) Torr.	55	40	0	9	0	6	0	0	0	0	0	0	0
Rhododendron canescens (Michx.) Sweet	92	54	0	26	3	9	0	0	0	0	0	0	0
Rhododendron capitatum Maxim.	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron catacosmum Balf. f. ex Tagg	17	9	0	3	1	0	0	0	0	0	0	4	0
Rhododendron catawbiense Michx.	1122	915	8	127	11	54	0	0	0	7	0	0	0
Rhododendron cephalanthum Franch.	4	4	0	0	0	0	0	0	0	0	0	0	0
Rhododendron cerasinum Tagg	14	8	0	0	0	5	0	1	0	0	0	0	0
Rhododendron chamaethomsonii (Tagg) Cowan & Davidian	9	8	0	1	0	0	0	0	0	0	0	0	0
Rhododendron championiae Hook.	2	0	0	0	0	1	0	1	0	0	0	0	0
Rhododendron charitopes Balf. f. & Farrer	15	4	0	1	0	2	0	0	0	0	0	8	0
Rhododendron chrysodoron Tagg ex Hutch.	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron ciliatum Hook. f.	58	37	1	14	0	3	0	0	0	0	0	3	0
Rhododendron ciliicalyx Franch.	4	2	0	2	0	0	0	0	0	0	0	0	0
Rhododendron ciliipes Hutch.	4	3	0	0	0	0	0	0	0	0	0	1	0
Rhododendron cinnabarinum Hook. f.	47	37	0	1	0	8	0	1	0	0	0	0	0
Rhododendron citriniflorum Balf. f. & Forrest	22	13	0	5	0	2	0	0	0	0	0	2	0
Rhododendron clementinae Forrest	6	3	0	2	0	1	0	0	0	0	0	0	0
Rhododendron coelicum Balf. f. & Farrer	1	0	0	0	0	1	0	0	0	0	0	0	0
Rhododendron coeloneurum Diels	6	3	0	1	0	2	0	0	0	0	0	0	0
Rhododendron collettianum Aitch. & Hemsl.	10	7	0	0	0	2	0	0	0	0	0	1	0
Rhododendron columbianum (Piper) Harmaja	59	40	1	5	0	13	0	0	0	0	0	0	0
Rhododendron complexum Balf. f. & W.W. Sm.	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron concinnum Hemsl.	9	5	0	0	0	4	0	0	0	0	0	0	0
Rhododendron coriaceum Franch.	33	19	0	8	1	3	0	0	0	0	0	2	0
Rhododendron crinigerum Franch.	20	12	0	0	0	8	0	0	0	0	0	0	0
Rhododendron cuneatum W.W. Sm.	41	22	3	1	2	4	0	0	0	1	0	8	0
Rhododendron cyanocarpum (Franch.) Franch. ex W.W. Sm.	29	19	0	3	1	3	0	0	0	0	0	3	0
Rhododendron dalhousieae Hook. f.	30	25	0	4	0	0	0	0	1	0	0	0	0
Rhododendron dauricum L.	23	15	0	3	0	5	0	0	0	0	0	0	0

Species	Images	Flower	Fruit	Leaf	Bark	Habit	Scan	Branch	Sheet	Other	Drawing	Bud	Anatomy
Rhododendron davidii Franch.	60	41	0	0	0	6	0	0	0	0	0	13	0
Rhododendron davidsonianum Rehder & E.H. Wilson	45	29	0	7	2	7	0	0	0	0	0	0	0
Rhododendron decorum Franch.	150	108	1	11	4	15	0	0	0	2	0	9	0
Rhododendron delavayi Franch.	79	50	1	1	0	18	0	0	0	0	0	9	0
Rhododendron dendricola Hutch.	5	5	0	0	0	0	0	0	0	0	0	0	0
Rhododendron dendrocharis Franch.	2	0	0	0	0	2	0	0	0	0	0	0	0
Rhododendron denudatum H. L év.	1	0	0	0	0	1	0	0	0	0	0	0	0
Rhododendron detonsum Balf. f. & Forrest	9	7	0	0	0	2	0	0	0	0	0	0	0
Rhododendron dichroanthum Diels	17	10	0	2	0	2	0	0	0	0	0	3	0
Rhododendron dignabile Cowan	2	1	0	0	0	1	0	0	0	0	0	0	0
Rhododendron eclecteum Balf. f. & Forrest	7	7	0	0	0	0	0	0	0	0	0	0	0
Rhododendron edgeworthii Hook. f.	14	14	0	0	0	0	0	0	0	0	0	0	0
Rhododendron emarginatum Hemsl. & E.H. Wilson	11	3	0	1	0	6	0	1	0	0	0	0	0
Rhododendron erosum Cowan	5	4	0	0	0	1	0	0	0	0	0	0	0
Rhododendron euchroum Balf. f. & Kingdon-Ward	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron eudoxum Balf. f. & Forrest	10	4	0	1	0	2	0	0	0	0	0	3	0
Rhododendron excellens Hemsl. & E.H. Wilson	15	8	0	3	0	4	0	0	0	0	0	0	0
Rhododendron facetum Balf. f. & Kingdon-Ward	9	4	0	2	0	3	0	0	0	0	0	0	0
Rhododendron fastigiatum Franch.	8	2	0	0	0	5	0	0	0	0	0	1	0
Rhododendron faucium D.F. Chamb.	4	2	0	0	0	2	0	0	0	0	0	0	0
Rhododendron fauriei Franch.	7	4	0	2	0	1	0	0	0	0	0	0	0
Rhododendron ferrugineum L.	4714	3187	72	1117	39	245	0	19	2	32	1	0	0
Rhododendron flavidum Franch.	17	11	0	2	1	2	0	0	0	0	0	1	0
Rhododendron fletcherianum Davidian	11	10	0	0	0	1	0	0	0	0	0	0	0
Rhododendron floccigerum Franch.	44	33	0	4	0	5	0	0	0	0	0	2	0
Rhododendron floribundum Franch.	10	8	0	0	0	2	0	0	0	0	0	0	0
Rhododendron forrestii Balf. f. ex Diels	38	24	1	4	2	7	0	0	0	0	0	0	0
Rhododendron fortunei Lindl.	36	23	0	1	0	12	0	0	0	0	0	0	0
Rhododendron fulgens Hook. f.	20	12	1	4	1	2	0	0	0	0	0	0	0
Rhododendron fulvum Balf. f. & W.W. Sm.	101	66	0	9	1	19	0	0	0	0	0	6	0
Rhododendron galactinum Balf. f. ex Tagg	74	41	0	12	5	6	0	0	0	4	0	6	0
Rhododendron glanduliferum Franch.	4	4	0	0	0	0	0	0	0	0	0	0	0
Rhododendron glischrum Balf. f. & W.W. Sm.	4	0	0	3	1	0	0	0	0	0	0	0	0
Rhododendron grande Wight	48	20	3	19	2	4	0	0	0	0	0	0	0
Rhododendron griersonianum Balf. f. & Forrest	2	2	0	0	0	0	0	0	0	0	0	0	0
Rhododendron griffithianum Wight	8	3	0	2	1	2	0	0	0	0	0	0	0
Rhododendron habrotrichum Balf. f. & W.W. Sm.	7	6	0	0	0	1	0	0	0	0	0	0	0
Rhododendron haematodes Franch.	73	47	1	2	1	14	0	0	0	0	0	8	0
Rhododendron hanceanum Hemsl.	1	0	0	0	0	1	0	0	0	0	0	0	0
Rhododendron heliolepis Franch.	6	2	0	2	0	2	0	0	0	0	0	0	0
Rhododendron hemitrichotum Balf. f. & Forrest	49	27	0	8	6	3	0	0	0	4	0	1	0
Rhododendron hemsleyanum E.H. Wilson	6	2	0	3	0	1	0	0	0	0	0	0	0
Rhododendron hippophaeoides Balf. f. & W.W. Sm.	115	53	1	25	7	20	0	0	0	2	0	7	0
Rhododendron hirsutum L.	497	332	4	102	8	47	0	0	2	1	1	0	0
Rhododendron hirtipes Tagg	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron hodgsonii Hook. f.	91	54	1	18	5	13	0	0	0	0	0	0	0
Rhododendron hongkongense Hutch.	3	2	0	0	0	1	0	0	0	0	0	0	0
Rhododendron hookeri Nutt.	19	11	0	0	1	7	0	0	0	0	0	0	0
Rhododendron huanum W.P. Fang	2	0	0	1	0	1	0	0	0	0	0	0	0
Rhododendron hunnewellianum Rehder & E.H. Wilson	12	8	0	3	0	1	0	0	0	0	0	0	0
Rhododendron hyperythrum Hayata	7	5	0	0	0	0	0	0	0	0	0	2	0
Rhododendron impeditum Balf. f. & W.W. Sm.	52	33	1	6	2	9	0	0	0	1	0	0	0
Rhododendron indicum (L.) Sweet	436	309	0	115	3	8	0	0	0	1	0	0	0
Rhododendron inopinum Balf. f.	2	2	0	0	0	0	0	0	0	0	0	0	0
Rhododendron insigne Hemsl. & E.H. Wilson	37	24	0	8	0	3	0	0	0	2	0	0	0
Rhododendron intricatum Franch.	6	4	0	0	0	2	0	0	0	0	0	0	0
Rhododendron irroratum Franch.	63	41	0	5	1	0	0	0	0	1	0	15	0
Rhododendron kendrickii Nutt.	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron keysii Nutt.	23	18	0	3	0	2	0	0	0	0	0	0	0
Rhododendron kyawii Lace & W.W. Sm.	4	0	0	4	0	0	0	0	0	0	0	0	0
Rhododendron lacteum Franch.	52	38	0	0	2	5	0	0	0	0	0	7	0
Rhododendron lanatoides D.F. Chamb.	1	0	0	0	0	1	0	0	0	0	0	0	0
Rhododendron lanatum Hook. f.	11	8	0	0	0	3	0	0	0	0	0	0	0
Rhododendron lanigerum Tagg	55	34	0	2	0	12	0	2	0	0	0	5	0
Rhododendron lapponicum (L.) Wahlenb.	73	48	0	9	2	13	0	0	0	1	0	0	0
Rhododendron latoucheae Franch.	1	0	0	1	0	0	0	0	0	0	0	0	0
Rhododendron lepidostylum Balf. f. & Forrest	2	0	0	1	1	0	0	0	0	0	0	0	0
Rhododendron lepidotum Wall. ex G. Don	75	46	4	10	0	13	0	2	0	0	0	0	0
Rhododendron leptothrium Balf. f. & Forrest	3	1	1	1	0	0	0	0	0	0	0	0	0

Species	Images	Flower	Fruit	Leaf	Bark	Habit	Scan	Branch	Sheet	Other	Drawing	Bud	Anatomy
Rhododendron leucaspis Tagg	15	8	0	1	0	1	0	0	0	0	0	5	0
Rhododendron liliiflorum H. L év.	3	3	0	0	0	0	0	0	0	0	0	0	0
Rhododendron lindleyi T. Moore	6	6	0	0	0	0	0	0	0	0	0	0	0
Rhododendron longesquamatum C.K. Schneid.	8	7	0	0	0	1	0	0	0	0	0	0	0
Rhododendron lukiangense Franch.	1	0	0	0	0	1	0	0	0	0	0	0	0
Rhododendron lutescens Franch.	45	25	3	6	0	11	0	0	0	0	0	0	0
Rhododendron luteum Sweet	186	114	4	38	3	25	0	0	0	2	0	0	0
Rhododendron macrophyllum D. Don ex G. Don	16	9	0	2	0	2	0	0	0	3	0	0	0
Rhododendron maculiferum Franch.	7	5	0	0	0	0	0	0	0	0	0	1	1
Rhododendron maddenii Hook. f.	55	21	2	20	1	10	0	0	0	0	0	1	0
Rhododendron mallotum Balf. f. & Kingdon-Ward	10	5	0	3	1	1	0	0	0	0	0	0	0
Rhododendron maximum L.	3132	1648	18	1249	63	131	0	0	0	21	0	2	0
Rhododendron meddianum Forrest	25	13	2	2	2	6	0	0	0	0	0	0	0
Rhododendron mekongense Franch.	4	1	0	0	0	2	0	1	0	0	0	0	0
Rhododendron micranthum Turcz.	5	2	0	0	0	0	0	0	0	0	0	3	0
Rhododendron microgynum Balf. f. & Forrest	16	8	0	0	0	3	0	0	0	0	0	5	0
Rhododendron mimetes Tagg & Forrest	3	3	0	0	0	0	0	0	0	0	0	0	0
Rhododendron minus Michx.	8	5	0	2	0	1	0	0	0	0	0	0	0
Rhododendron molle G.Don	65	42	0	5	4	10	0	0	0	3	0	1	0
Rhododendron montroseanum Davidian	54	14	3	8	0	26	0	1	0	0	0	2	0
Rhododendron morii Hayata	65	55	0	0	0	9	0	0	0	0	0	1	0
Rhododendron moulmainense Hook.	11	2	0	5	0	4	0	0	0	0	0	0	0
Rhododendron moupinense Franch.	2	1	0	0	0	1	0	0	0	0	0	0	0
Rhododendron mucronatum (Blume) G. Don	2	0	0	2	0	0	0	0	0	0	0	0	0
Rhododendron mucronulatum Turcz.	40	35	0	0	0	2	0	0	0	1	0	2	0
Rhododendron nakaharae Hayata	2	1	0	1	0	0	0	0	0	0	0	0	0
Rhododendron neriiflorum Franch.	76	52	0	1	0	15	0	1	0	0	0	7	0
Rhododendron nivale Hook. f.	19	10	0	3	0	6	0	0	0	0	0	0	0
Rhododendron niveum Hook. f.	68	46	1	8	0	7	0	0	0	1	0	5	0
Rhododendron nuttallii Booth ex Nutt.	6	0	0	2	0	3	0	0	0	0	0	1	0
Rhododendron obtusum Hort. ex Wats.	10	6	0	3	0	1	0	0	0	0	0	0	0
Rhododendron occidentale (Torr. & A. Gray) A. Gray	25	20	0	1	0	4	0	0	0	0	0	0	0
Rhododendron ochraceum Rehder & E.H. Wilson	4	2	0	2	0	0	0	0	0	0	0	0	0
Rhododendron oldhamii Maxim.	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron oligocarpum W.P. Fang	4	2	0	1	0	1	0	0	0	0	0	0	0
Rhododendron orbiculare Decne.	48	28	2	7	2	6	0	0	0	0	0	3	0
Rhododendron oreodoxa Franch.	191	141	0	6	0	28	0	1	0	0	0	15	0
Rhododendron oreotrephes W.W. Sm.	13	7	0	1	0	3	0	0	0	0	0	2	0
Rhododendron orthocladum Balf. f. & Forrest	56	30	0	6	4	13	0	0	0	3	0	0	0
Rhododendron ovatum (Lindl.) Planch. ex Maxim.	3	0	0	2	0	1	0	0	0	0	0	0	0
Rhododendron pachysanthum Hayata	4	4	0	0	0	0	0	0	0	0	0	0	0
Rhododendron pachytrichum Franch.	73	65	0	2	0	5	0	0	0	0	0	1	0
Rhododendron parmulatum Cowan	1	0	0	0	0	1	0	0	0	0	0	0	0
Rhododendron pemakoense Kingdon-Ward	5	1	0	2	0	2	0	0	0	0	0	0	0
Rhododendron pendulum Hook. f.	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron peregrinum Tagg	34	18	0	6	2	8	0	0	0	0	0	0	0
Rhododendron periclymenoides (Michx.) Shinners	178	124	0	22	6	26	0	0	0	0	0	0	0
Rhododendron phaeochrysum Balf. f. & W.W. Sm.	19	12	0	2	0	5	0	0	0	0	0	0	0
Rhododendron piercei Davidian	3	3	0	0	0	0	0	0	0	0	0	0	0
Rhododendron pingianum W.P. Fang	69	42	0	16	4	5	0	0	0	1	0	1	0
Rhododendron pleistanthum E.H. Wilding	2	1	0	0	0	1	0	0	0	0	0	0	0
Rhododendron pocophorum Balf. f. ex Tagg	18	8	0	2	0	4	0	1	0	0	0	3	0
Rhododendron polycladum Franch.	4	2	0	1	0	1	0	0	0	0	0	0	0
Rhododendron polylepis Franch.	16	5	0	7	2	1	0	0	0	1	0	0	0
Rhododendron ponticum L.	1807	1347	8	359	22	54	0	2	0	15	0	0	0
Rhododendron praestans Balf. f. & W.W. Sm.	6	0	0	0	1	3	0	0	0	0	0	2	0
Rhododendron praevernum Hutch.	77	64	0	1	0	7	0	0	0	0	0	5	0
Rhododendron preptum Balf. f. & Forrest	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron primuliflorum Bureau & Franch.	5	0	1	3	0	1	0	0	0	0	0	0	0
Rhododendron principis Bureau & Franch.	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron prinophyllum (Small) Millais	99	71	0	15	3	8	2	0	0	0	0	0	0
Rhododendron protistum Balf. f. & Forrest	8	0	0	1	1	5	0	0	0	0	0	1	0
Rhododendron prunifolium (Small) Millais	3	0	0	0	0	3	0	0	0	0	0	0	0
Rhododendron przewalskii Maxim.	12	7	0	0	0	2	0	0	0	0	0	3	0
Rhododendron pseudochrysanthum Hayata	35	23	0	2	1	5	0	0	0	0	0	4	0
Rhododendron pubescens Balf. f. & Forrest	85	52	3	7	4	11	0	3	0	4	0	1	0
Rhododendron pudorosum Cowan	76	47	2	15	3	9	0	0	0	0	0	0	0
Rhododendron pumilum Hook. f.	3	2	0	0	0	1	0	0	0	0	0	0	0
Rhododendron racemosum Franch.	134	83	3	10	1	27	0	0	0	0	0	10	0

Species	Images	Flower	Fruit	Leaf	Bark	Habit	Scan	Branch	Sheet	Other	Drawing	Bud	Anatomy
Rhododendron redowskianum Maxim.	2	2	0	0	0	0	0	0	0	0	0	0	0
Rhododendron retusum (Blume) Benn.	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron rex H. L év.	165	84	0	36	6	18	0	0	0	6	0	15	0
Rhododendron rigidum Franch.	23	6	2	2	0	10	0	0	0	0	0	3	0
Rhododendron ririei Hemsl. & E.H. Wilson	13	8	0	0	0	5	0	0	0	0	0	0	0
Rhododendron rothschildii Davidian	2	1	0	1	0	0	0	0	0	0	0	0	0
Rhododendron roxieanum Forrest	54	25	0	15	4	5	0	0	0	0	0	5	0
Rhododendron rubiginosum Franch.	144	88	0	10	2	33	0	0	0	3	0	8	0
Rhododendron rubropilosum Hayata	2	2	0	0	0	0	0	0	0	0	0	0	0
Rhododendron rufum Batalin	16	11	0	0	3	2	0	0	0	0	0	0	0
Rhododendron rupicola W.W. Sm.	8	7	0	0	0	0	0	0	0	0	0	1	0
Rhododendron rushforthii Argent & D.F. Chamb.	1	0	0	1	0	0	0	0	0	0	0	0	0
Rhododendron russatum Balf. f. & Forrest	56	31	0	5	2	13	0	0	0	1	0	4	0
Rhododendron saluenense Franch.	58	29	0	8	2	13	0	0	0	5	0	1	0
Rhododendron sanguineum Franch.	62	45	2	4	0	5	0	0	0	0	0	6	0
Rhododendron scabrifolium Franch.	12	7	0	3	0	2	0	0	0	0	0	0	0
Rhododendron schlippenbachii Maxim.	65	41	0	5	1	17	0	0	0	1	0	0	0
Rhododendron scopulorum Hutch.	13	10	0	1	0	0	0	0	0	0	0	2	0
Rhododendron searsiae Rehder & E.H. Wilson	37	16	0	4	2	8	0	1	0	6	0	0	0
Rhododendron selense Franch.	35	17	0	8	3	3	0	0	0	1	0	3	0
Rhododendron semnoides Tagg & Forrest	25	14	0	8	2	1	0	0	0	0	0	0	0
Rhododendron setosum D. Don	58	43	1	7	0	7	0	0	0	0	0	0	0
Rhododendron shweliense Balf. f. & Forrest	1	0	0	0	0	1	0	0	0	0	0	0	0
Rhododendron sidereum Balf. f.	4	3	0	0	0	1	0	0	0	0	0	0	0
Rhododendron siderophyllum Franch.	42	22	3	8	2	5	0	0	0	2	0	0	0
Rhododendron sikangense W.P. Fang	16	9	0	0	0	3	0	0	0	0	0	4	0
Rhododendron simsii Planch.	2459	1854	4	486	23	79	0	0	0	13	0	0	0
Rhododendron sinofalconeri Balf. f.	70	34	2	17	4	9	0	0	0	2	0	2	0
Rhododendron sinogrande Balf. f. & W.W. Sm.	49	19	1	14	0	15	0	0	0	0	0	0	0
Rhododendron souliei Franch.	37	28	0	2	0	5	0	0	0	0	0	2	0
Rhododendron sperabile Balf. f. & Farrer	48	32	1	0	1	3	0	0	0	0	0	11	0
Rhododendron spinuliferum Franch.	5	3	0	2	0	0	0	0	0	0	0	0	0
Rhododendron stewartianum Diels	4	4	0	0	0	0	0	0	0	0	0	0	0
Rhododendron strigillosum Franch.	53	34	1	3	1	8	0	0	0	0	0	6	0
Rhododendron sutchuenense Franch.	11	6	0	2	0	3	0	0	0	0	0	0	0
Rhododendron taggianum Hutch.	2	2	0	0	0	0	0	0	0	0	0	0	0
Rhododendron taliense Franch.	14	6	0	4	0	2	0	0	0	0	0	2	0
Rhododendron tanastylum Balf. f. & Kingdon-Ward	3	1	0	1	0	1	0	0	0	0	0	0	0
Rhododendron tatsienense Franch.	4	2	0	0	0	2	0	0	0	0	0	0	0
Rhododendron telmateium Balf. f. & W.W. Sm.	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron temenium Balf. f. & Forrest	17	12	0	4	0	0	0	0	0	0	0	0	1
Rhododendron tephropeplum Balf. f. & Forrest	5	3	0	0	0	0	0	0	0	0	0	2	0
Rhododendron thayerianum Rehder & E.H. Wilson	2	2	0	0	0	0	0	0	0	0	0	0	0
Rhododendron thomsonii Hook. f.	89	45	4	5	1	23	0	0	0	1	0	10	0
Rhododendron traillianum Forrest & W.W. Sm.	25	22	0	0	0	2	0	0	0	0	0	1	0
Rhododendron trichanthum Rehder	6	2	0	0	0	4	0	0	0	0	0	0	0
Rhododendron trichocladum Franch.	8	8	0	0	0	0	0	0	0	0	0	0	0
Rhododendron trichostomum Franch.	6	4	0	0	0	1	0	0	0	0	0	1	0
Rhododendron triflorum Hook. f.	1	1	0	0	0	0	0	0	0	0	0	0	0
Rhododendron tsariense Cowan	4	4	0	0	0	0	0	0	0	0	0	0	0
Rhododendron uvariifolium Diels	58	47	0	2	2	5	0	0	0	0	0	2	0
Rhododendron vaccinioides Hook.	5	4	1	0	0	0	0	0	0	0	0	0	0
Rhododendron valentinianum Forrest ex Hutch.	3	1	0	1	0	1	0	0	0	0	0	0	0
Rhododendron vaseyi A. Gray	83	56	1	0	3	18	0	0	0	4	0	1	0
Rhododendron venator Tagg	61	31	0	10	5	6	0	0	0	4	0	5	0
Rhododendron vernicosum Franch.	158	107	1	9	4	30	0	0	0	0	0	7	0
Rhododendron virgatum Hook. f.	2	2	0	0	0	0	0	0	0	0	0	0	0
Rhododendron viscosum (L.) Torr.	51	27	0	12	2	10	0	0	0	0	0	0	0
Rhododendron wallichii Hook. f.	66	36	4	7	0	13	0	2	0	0	0	4	0
Rhododendron wardii W.W. Sm.	113	72	5	11	2	14	0	0	0	3	0	6	0
Rhododendron westlandii Hemsl.	15	13	0	0	0	0	0	0	0	0	0	2	0
Rhododendron wightii Hook. f.	16	12	0	0	0	2	0	0	0	0	0	2	0
Rhododendron williamsianum Rehder & E.H. Wilson	29	18	0	2	0	8	0	0	0	0	0	1	0
Rhododendron wiltonii Hemsl. & E.H. Wilson	13	3	0	6	3	0	0	0	0	0	0	1	0
Rhododendron yuefengense G.Z. Li	3	1	0	2	0	0	0	0	0	0	0	0	0
Rhododendron yungningense Balf. f. ex Hutch.	11	5	0	0	1	3	0	0	0	2	0	0	0
Rhododendron yunnanense Franch.	34	23	1	1	0	6	0	0	0	0	0	3	0
Rhododendron zaleucum Balf. f. & W.W. Sm.	3	3	0	0	0	0	0	0	0	0	0	0	0
Total	23543												

Appendix 3

Species		PlantNet v1		PlantNet v2		PlantNet v3	
R. retusum	1	*Kechiella corymbosa*	3%	*Teucrium heterophyllum*	3%	*R.retusum*	12%
	2	*Fuchsia microphylla*	2%	*R.molle*	1%	*R.cinnabarinum*	7%
	3	*Xanthostemon francii*	1%	\	\	*R.forrestii*	4%
R. erosum	1	*R.arboreum*	48%	*R.arboreum*	48%	*R.erosum*	58%
	2	*R.ferrugineum*	17%	*R.kaempferi ×kiusianum*	<1%	*R.argipeplum*	23%
	3	*R.barbatum*	3%		\	*R.barbatum*	8%
R. fastagiatum	1	*R. impeditum*	48%	*R. impeditum*	55%	*R.impeditum*	78%
	2	*R.hippophaeoides*	30%	*R.hippophaeoides*	27%	*R.fastigiatum*	8%
	3	*R.saluenense*	2%	*R.augustinii*	<1%	*R.orthocladum*	5%
R. pubescens	1	*R.scabrifolium*	46%	*R.pubescens*	35%	*R.pubescens*	73%
	2	*R.impeditum*	18%	*R.hemitrichotum*	18%	*R.scabrifolium*	14%
	3	*R.racemosum*	10%	*R.scabrifolium*	10%	*R.racemosum*	6%
R. fulvum ssp. Fulvum	1	*R.calophytum*	16%	*R.galactinum*	53%	*R.fulvum*	62%
	2	*R.oreodoxa*	13%	*R.pudorosum*	20%	*R.uvariifolium*	19%
	3	*R.sutchuenense*	12%	*R.rex*	6%	*R.galactinum*	8%
R. calostrotum ssp. keleticum	1	*R.simsii*	29%	*R.saluenense*	70%	*R.saluenense*	48%
	2	*R.lapponicum*	27%	*R.calostrotum*	11%	*R.calostrotum*	38%
	3	*R.saluenense*	7%	*R.lapponicum*	3%	*R.camtschaticum*	1%
R. mekongense var. rubrolineatum	1	*R.maximum*	16%	*R.maximum*	16%	*R.mekongense*	6%
	2	*R.columbianum*	13%	*R.columbianum*	13%	*R.columbianum*	3%
	3	*R.albiflorum*	5%	*R.albiflorum*	8%	*R.rigidum*	3%
R. caesium	1	*Crossosoma californicum*	8%	*R.cinnabarinum*	5%	*R.trichocladum*	22%
	2	*Hypericum hypericoides*	4%	*R.wardii*	3%	*R.valentinianum*	7%
	3	*Acridocarpus austrocaledonicus*	1%	*Xanthostemon pubescens*	1%	*R.lepidostylum*	6%
R. insigne var. insigne	1	*R.balfourianum*	46%	*R.argyrophyllum*	17%	*R.insigne*	81%
	2	*R.maximum*	7%	*R.rex*	9%	*R.traillianum*	2%
	3	*R.hunnewellianum*	5%	*R.arboreum*	9%	*R.beesianum*	2%
R. reticulatum	1	*R.lapponicum*	30%	*R.canadense*	22%	*R.dauricum*	13%
	2	*R.ponticum*	24%	*R.lapponicum*	9%	*R.canadense*	3%
	3	*R.dauricum*	11%	*R.dauricum*	8%	*R.setosum*	3%
R. mucronulatum var. mucronulatum	1	*R.dauricum*	71%	*R.dauricum*	30%	*R.mucronulatum*	90%
	2	*R.catawbiense*	12%	*Kalmia polifolia*	17%	*R.dauricum*	6%
	3	*R.lapponicum*	3%	*R.saluenense*	3%	\	\
R. huguangense	1	*R.viscosum*	17%	*R.maximum*	25%	*R.augustinii*	30%
	2	*R.arborescens*	10%	*R.augustinii*	13%	*R.arborescens*	17%
	3	*R.atlanticum*	8%	*R.latoucheae*	8%	*R.maximum*	8%
R. campylocarpum	1	*R.campylocarpum*	29%	*R.campylocarpum*	73%	*R.campylocarpum*	66%
	2	*R.maximum*	26%	*R.sinofalconeri*	12%	*R.wardii*	18%
	3	*R.wardii*	16%	*R.wardii*	1%	*R.wightii*	2%
R. cuneatum	1	*R.impeditum*	26%	*R.hippophaeoides*	31%	*R.cuneatum*	22%
	2	*R.hippophaeoides*	25%	*R.cuneatum*	28%	*R.hippophaeoides*	22%
	3	*R.lapponicum*	24%	*R.impeditum*	7%	*R.yungningense*	11%
R. lambianum	1	*R.maximum*	71%	*R.pingianum*	18%	*R.latoucheae*	18%
	2	*R.minus*	8%	*R.minus*	18%	*R.zaleucum*	15%
	3	*R.catawbiense*	1%	*R.argyrophyllum*	7%	*R.minus*	10%
R. camtschaticum	1	*R.camtschaticum*	34%	*R.camtschaticum*	17%	*R.camtschaticum*	19%
	2	*Rubus odoratus*	11%	*Geranium phaeum*	7%	*Geranium phaeum*	3%
	3	*Rosa pendulina*	1%	*Geranium macrorrhizum*	3%	*Verbascum phoeniceum*	2%

Species		iplant	PlantSnap	LeafSnap	PictureThis
R. retusum	1	*Aeschynanthus palcher*	*R.praetervisum*	*Bouvardia ternifolia*	*Epilobium canum*
	2	\	*Epilobium canum*	*Woodfodia fruticosa*	\
	3	\	*Woodfodia fruticosa*	*Fuchsia microphylla*	\
R. erosum	1	*R.delavayi*	*R.barbatum*	*R.arboreum*	*R.macrophyllum*
	2	\	*R. 'Rubicon'*	*R.ferrugineum*	\
	3	\	*R.protistum*	*R.barbatum*	\
R. fastagiatum	1	*R.capitatum*	*R. impeditum*	*R. impeditum*	*R.simsii*
	2	\	*R.augustinii*	*R.hippophaeoides*	\
	3	\	*R.hippophaeoides*	*R.lapponicum*	\
R. pubescens	1	*R.racemosum*	*R.racemosum*	*R.scabrifolium*	*R.maximum*
	2	\	*R.hippophaeoides*	*R.impeditum*	\
	3	\	*Haemanthus humilis*	*R.racemosum*	\
R. fulvum ssp. Fulvum	1	*R.rex*	*R.hyperythrum*	*R.calophytum*	*R.maximum*
	2	\	*R.ovatum*	*R.oreodoxa*	\
	3	\	*R.hypoglaucum*	*R.maximum*	\
R. calostrotum ssp. keleticum	1	*Rhododendron*	*R.lapponicum*	*R.simsii*	*R.simsii*
	2	\	*R.williamsianum*	*R.lapponicum*	\
	3	\	*R.camtschaticum*	*R.saluenense*	\
R. mekongense var. rubrolineatum	1	*Rhododendron*	*R.carolinianum*	*R.maximum*	*R.occidentale*
	2	\	*R.maximum*	*R.columbianum*	\
	3	\	*R.albiflorum*	*R.albiflorum*	\
R. caesium	1	*R.chunienii*	*Clematis cirrhosa*	*C.californicum*	*Euphorbia milii*
	2	\	*Helleborus odorus*	*Hypericum hypericoides*	\
	3	\	*R.rarilepidotum*	*Lycium pallidum*	\
R. insigne var. insigne	1	*R.longipes var. chienianum*	*R.protistum*	*R.balfourianum*	*R.macrophyllum*
	2	\	*R.pingianum*	*R.maximum*	\
	3	\	*R.hyperythrum*	*R.hunnewellianum*	\
R. reticulatum	1	*R.dauricum*	*R.kaempferi*	*R.lapponicum*	*R.canadense*
	2	\	*R.reticulatum*	*R.ponticum*	\
	3	\	*R.racemosum*	*R.dauricum*	\
R. mucronulatum var. mucronulatum	1	*R.mucronulatum*	*R.mucronulatum*	*R.dauricum*	*R.catawbiense*
	2	\	\	*R.catawbiense*	\
	3	\	\	*R.lapponicum*	\
R. huguangense	1	*R.stamineum*	*R.viscosum*	*R.viscosum*	*R.occidentale*
	2	\	*R.atlanticum*	*R.alabamense*	\
	3	\	*R.carolinianum*	*R.atlanticum*	\
R. campylocarpum	1	*R.wardii*	*Dombeya burgessiae*	*R.campylocarpum*	*R.maximum*
	2	\	*R.maximum*	*R.wardii*	\
	3	\	*R.williamsianum*	*R.maximum*	\
R. cuneatum	1	*Rhododendron*	*R.lapponicum*	*R.lapponicum*	*R.ferrugineum*
	2	\	*R.hippophaeoides*	*R.hippophaeoides*	\
	3	\	*R.racemosum*	*R.impeditum*	\
R. lambianum	1	*R.latoucheae*	*R.polyanthemum*	*R.maximum*	*R.maximum*
	2	\	*R.rarilepidotum*	*R.minus*	\
	3	\	*R.orbiculatum*	*R.macrophyllum*	\
R. camtschaticum	1	*Rehmannia chingii*	*R.camtschaticum*	*R.camtschaticum*	*R.indicum*
	2	\	*Dianthus glacialis*	*Rubus odoratus*	\
	3	\	*Dianthuspavonius*	*Rosa pendulina*	\

Species		HuaBangZhu (花帮主)		aiPlants		iPlant (花伴侣pro)		iNaturelist
R. retusum	1	*Aeschynanthus radicans*	63%	*Aeschynanthus radicans*	55%	*R.spinuliferum*	8%	*Bouvardia ternifolia*
	2	*Aeschynanthus palcher*	16%	*Aeschynanthus palcher*	16%	*R.vialii*	7%	*Burchellia bubalina*
	3	*Aeschynanthus bracteatus*	5%	*Aeschynanthus buxifolius*	9%	*R.oldhamii*	5%	*Lonicera sempervirens*
R. erosum	1	*R.delavayi*	89%	*R.delavayi*	89%	\	\	*R.ponticum*
	2	*R.rex*	4%	\	\	\	\	*R.macrophyllum*
	3	*R.lapponicum*	1%	\	\	\	\	*R.catawbiense*
R. fastagiatum	1	*R.capitatum*	97%	*R.capitatum*	99%	*R.capitatum*	60%	*R.lapponicum*
	2	*R.lapponicum*	3%	\	\	*R.intricatum*	11%	*R.ponticum*
	3	*Corydalis benecincta*	0%	\	\	*R.fastigiatum*	4%	*R.mucronulatum*
R. pubescens	1	*R.capitatum*	45%	*R.capitatum*	44%	*R.pubescens*	42%	*R.canadense*
	2	*R.racemosum*	34%	*R.racemosum*	33%	*R.yungningense*	37%	*Kalmia microphylla*
	3	*R.spiciferum*	11%	*R.spiciferum*	11%	*R.spiciferum*	5%	*R.groenlandicum*
R. fulvum ssp. Fulvum	1	*R.phaeochrysum*	97%	*R.phaeochrysum*	98%	*R.fulvum*	30%	*R.catawbiense*
	2	*R.rex*	1%	\	\	*R.hypoglaucum*	18%	*R.ponticum*
	3	*R.oreodoxa*	1%	\	\	*R.phaeochrysum*	7%	*R.macrophyllum*
R. calostrotum ssp. keleticum	1	*R.hybrida*	40%	*R.hybrida*	33%	*R.saluenense*	85%	*R.lapponicum*
	2	*Diapensia purpurea*	18%	*D. purpurea*	17%	*R.rupicola*	2%	*R.indicum*
	3	*R.redowskianum*	9%	*R.* ×*pulchrum*	8%	*R.nivale*	2%	*R.catawbiense*
R. mekongense var. rubrolineatum	1	*R.aureum*	50%	*R.aureum*	54%	*R.mucronatum*	81%	*R.viscosum*
	2	*R.pachypodum*	21%	*R.pachypodum*	17%	*R.schlippenbachii*	1%	*R.occidentale*
	3	*R.siderophyllum*	7%	*R.siderophyllum*	8%	*R.ovatum*	1%	*R.albiflorum*
R. caesium	1	*Hypericum patulum*	75%	*Hypericum patulum*	73%	*R.lutescens*	9%	*Hypericum crux-andreae*
	2	*Hypericum monogynum*	9%	*Hypericum monogynum*	7%	*Hyoscyamus niger*	3%	*Clutia*
	3	*Euphorbia sieboldiana*	5%	\	\	*R.mucronatum*	2%	*Brachystelma*
R. insigne var. insigne	1	*R.longipes*	55%	*R.maculiferum*	48%	*R.praevernum*	20%	*R.macrophyllum*
	2	*R.maculiferum*	32%	*R.longipes var. chienianum*	33%	*R.longipes*	17%	*R.catawbiense*
	3	*R.simiarum*	8%	*R.simiarum*	12%	*R.adenopodum*	16%	*R.pseudochrysanthum*
R. reticulatum	1	*R.dauricum*	86%	*R.dauricum*	86%	*R.mucronulatum*	40%	*R.mucronulatum*
	2	*R.mucronulatum*	7%	*R.mucronulatum*	9%	*R.schlippenbachii*	24%	*R.indicum*
	3	*R.mariesii*	3%	\	\	*R.dauricum*	8%	*R.canadense*
R. mucronulatum var. mucronulatum	1	*R.capitatum*	61%	*R.capitatum*	38%	*R.mucronulatum*	95%	*R.mucronulatum*
	2	*R.dauricum*	22%	*R.dauricum*	27%	*R.dauricum*	4%	*R.catawbiense*
	3	*R.concinnum*	8%	*R.mucronulatum*	13%	*R.huadingense*	0%	*R.lapponicum*
R. huguangense	1	*R.stamineum*	98%	*R.stamineum*	98%	*R.stamineum*	88%	*R.occidentale*
	2	*R.championiae*	1%	\	\	*R.championiae*	4%	*R.viscosum*
	3	*R.hancockii*	0%	\	\	*R.augustinii*	0%	*R.columbianum*
R. campylocarpum	1	*R.wardii*	92%	*R.wardii*	91%	*R.liliiflorum*	56%	*R.albiflorum*
	2	*R.irroratum*	5%	\	\	*R.campylocarpum*	10%	*Verbascum lychnitis*
	3	*R.decorum*	1%	\	\	*R.simiarum*	6%	*R.pseudochrysanthum*
R. cuneatum	1	*R.lapponicum*	81%	*R.lapponicum*	68%	*R.concinnum*	44%	*R.lapponicum*
	2	*R.capitatum*	15%	*R.capitatum*	26%	*R.hippophaeoides*	22%	*R.catawbiense*
	3	*R.racemosum*	2%	\	\	*R.capitatum*	8%	*R.ponticum*
R. lambianum	1	*R.moulmainense*	41%	*R.moulmainense*	49%	*R.simiarum*	18%	*R.macrophyllum*
	2	*R.latoucheae*	33%	*R.latoucheae*	27%	*R.latoucheae*	11%	*R.viscosum*
	3	*R.cavaleriei*	10%	*R.cavaleriei*	7%	*Luculia pinceana*	5%	*Weigela*
R. camtschaticum	1	*Pelargonium graveolens*	36%	*Pelargonium graveolens*	47%	*Malus* × *scheidecheri*	62%	*Geranium phaeum*
	2	*Rehmannia chingii*	18%	*Rehmannia chingii*	19%	*Cydonia oblonga*	6%	*Phacelia parryi*
	3	*Rehmannia glutinosa*	6%	\	\	*Tradescantia sillamontana*	2%	*Cuphea aequipetala*

Appendix 4

		Top 1 results					Top 3 results				
	Test species	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**
PlantNet v1	1	0	0	0	0	0	0	0	0	0	0
	2	1	1	1	0	0	1	1	1	1	0
	3	1	1	1	1	0	1	1	1	1	0
	4	1	1	1	1	0	1	1	1	1	0
	5	1	1	1	0	0	1	1	1	0	0
	6	1	0	0	0	0	1	1	1	1	0
	7	1	1	1	0	0	1	1	1	0	0
	8	0	0	0	0	0	0	0	0	0	0
	9	1	1	1	0	0	1	1	1	1	0
	10	1	0	0	0	0	1	0	0	0	0
	11	1	1	1	1	0	1	1	1	1	0
	12	1	0	0	0	0	1	0	0	0	0
	13	1	1	1	1	1	1	1	1	1	1
	14	1	1	1	1	0	1	1	1	1	0
	15	1	0	0	0	0	1	0	0	0	0
	16	1	1	1	1	1	1	1	1	1	1

		Top 1 results					Top 3 results				
	Test species	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**
PlantNet v2	1	0	0	0	0	0	1	0	0	0	0
	2	1	1	1	0	0	1	1	1	0	0
	3	1	1	1	1	0	1	1	1	1	0
	4	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	0	0	1	1	1	0	0
	6	1	1	1	1	0	1	1	1	1	1
	7	1	1	1	0	0	1	1	1	0	0
	8	1	1	1	0	0	1	1	1	0	0
	9	1	1	1	1	0	1	1	1	1	0
	10	1	0	0	0	0	1	0	0	0	0
	11	1	1	1	1	0	1	1	1	1	0
	12	1	0	0	0	0	1	1	1	1	0
	13	1	1	1	1	1	1	1	1	1	1
	14	1	1	1	1	0	1	1	1	1	0
	15	1	0	0	0	0	1	0	0	0	0
	16	1	1	1	1	1	1	1	1	1	1

		Top 1 results					Top 3 results				
	Test species	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**
PlantNet v3	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	0	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1
	6	1	1	1	1	0	1	1	1	1	1
	7	1	1	1	1	1	1	1	1	1	1
	8	1	1	1	1	0	1	1	1	1	0
	9	1	1	1	1	1	1	1	1	1	1
	10	1	0	0	0	0	1	0	0	0	0
	11	1	1	1	1	1	1	1	1	1	1
	12	1	0	0	0	0	1	0	0	0	0
	13	1	1	1	1	1	1	1	1	1	1
	14	1	1	1	1	1	1	1	1	1	1
	15	1	0	0	0	0	1	0	0	0	0
	16	1	1	1	1	1	1	1	1	1	1

		Top 1 results					Top 3 results				
	Test species	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**
iplant	1	0	0	0	0	0					
	2	1	1	1	0	0					
	3	1	1	1	1	0					
	4	1	1	1	1	0					
	5	1	1	1	0	0					
	6	1	0	0	0	0					
	7	1	0	0	0	0					
	8	1	1	1	0	0					
	9	1	1	1	1	0					
	10	1	0	0	0	0					
	11	1	1	1	1	1					
	12	1	1	1	1	0					
	13	1	1	1	1	0					
	14	1	0	0	0	0					
	15	1	0	0	0	0					
	16	0	0	0	0	0					

		Top 1 results					Top 3 results				
	Test species	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**
PlantSnap	1	1	1	0	0	0	1	1	0	0	0
	2	1	1	1	1	0	1	1	1	1	0
	3	1	1	1	1	0	1	1	1	1	0
	4	1	1	1	1	0	1	1	1	1	0
	5	1	1	1	0	0	1	1	1	0	0
	6	1	1	1	0	0	1	1	1	0	0
	7	1	1	1	0	0	1	1	1	0	0
	8	0	0	0	0	0	1	0	0	0	0
	9	1	1	1	0	0	1	1	1	1	0
	10	1	1	1	1	0	1	1	1	1	0
	11	1	1	1	1	1	1	1	1	1	1
	12	1	0	0	0	0	1	0	0	0	0
	13	0	0	0	0	0	1	1	1	0	0
	14	1	1	1	1	0	1	1	1	1	0
	15	1	1	1	0	0	1	1	1	0	0
	16	1	1	1	1	1	1	1	1	1	1

		Top 1 results					Top 3 results				
	Test species	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**
LeafSnap	1	0	0	0	0	0	0	0	0	0	0
	2	1	1	1	0	0	1	1	1	1	0
	3	1	1	1	1	0	1	1	1	1	0
	4	1	1	1	1	0	1	1	1	1	0
	5	1	1	1	0	0	1	1	1	0	0
	6	1	0	0	0	0	1	1	1	1	0
	7	1	1	1	0	0	1	1	1	0	0
	8	1	1	1	0	0	0	0	0	0	0
	9	1	1	1	0	0	1	1	1	1	0
	10	1	0	0	0	0	1	0	0	0	0
	11	1	1	1	1	0	1	1	1	1	0
	12	1	0	0	0	0	1	0	0	0	0
	13	1	1	1	1	1	1	1	1	1	1
	14	1	1	1	1	0	1	1	1	1	0
	15	1	0	0	0	0	1	0	0	0	0
	16	1	1	1	1	1	1	1	1	1	1

		Top 1 results					Top 3 results				
	Test species	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**
PictureThis	1	0	0	0	0	0					
	2	1	1	1	0	0					
	3	1	0	0	0	0					
	4	1	0	0	0	0					
	5	1	1	1	0	0					
	6	1	0	0	0	0					
	7	1	0	0	0	0					
	8	0	0	0	0	0					
	9	1	1	1	0	0					
	10	1	0	0	0	0					
	11	1	0	0	0	0					
	12	1	0	0	0	0					
	13	1	1	1	0	0					
	14	1	1	1	0	0					
	15	1	0	0	0	0					
	16	1	0	0	0	0					

		Top 1 results					Top 3 results				
	Test species	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**
HuaBangZhu	1	0	0	0	0	0	0	0	0	0	0
	2	1	1	1	0	0	1	1	1	0	0
	3	1	1	1	1	0	1	1	1	1	0
	4	1	1	1	0	0	1	1	1	1	0
	5	1	1	1	0	0	1	1	1	0	0
	6	1	0	0	0	0	1	0	0	0	0
	7	1	0	0	0	0	1	1	1	0	0
	8	0	0	0	0	0	0	0	0	0	0
	9	1	1	1	1	0	1	1	1	1	0
	10	1	0	0	0	0	1	1	1	0	0
	11	1	1	1	0	0	1	1	1	1	0
	12	1	1	1	1	0	1	1	1	1	0
	13	1	1	1	1	0	1	1	1	1	0
	14	1	1	1	1	0	1	1	1	1	0
	15	1	0	0	0	0	1	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0

		Top 1 results					Top 3 results				
	Test species	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**
aiPlants	1	0	0	0	0	0	0	0	0	0	0
	2	1	1	1	0	0	1	1	1	0	0
	3	1	1	1	1	0	1	1	1	1	0
	4	1	1	1	0	0	1	1	1	1	0
	5	1	1	1	0	0	1	1	1	0	0
	6	1	0	0	0	0	1	0	0	0	0
	7	1	0	0	0	0	1	1	1	0	0
	8	0	0	0	0	0	0	0	0	0	0
	9	1	1	1	0	0	1	1	1	1	0
	10	1	0	0	0	0	1	0	0	0	0
	11	1	1	1	0	0	1	1	1	1	1
	12	1	1	1	1	0	1	1	1	1	0
	13	1	1	1	1	0	1	1	1	1	0
	14	1	1	1	1	0	1	1	1	1	0
	15	1	0	0	0	0	1	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0

		Top 1 results					Top 3 results				
	Test species	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**
iPlant (花伴侣 pro)	1	1	0	0	0	0	1	0	0	0	0
	2										
	3	1	1	1	1	0	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1
	6	1	1	1	1	0	1	1	1	1	0
	7	1	0	0	0	0	1	0	0	0	0
	8	1	1	1	0	0	1	1	1	0	0
	9	1	1	1	0	0	1	1	1	1	0
	10	1	0	0	0	0	1	0	0	0	0
	11	1	1	1	1	1	1	1	1	1	1
	12	1	1	1	1	0	1	1	1	1	0
	13	1	0	0	0	0	1	1	1	1	1
	14	1	1	1	0	0	1	1	1	1	0
	15	1	0	0	0	0	1	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0

		Top 1 results					Top 3 results				
	Test species	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**	**Genus**	**Subgenus**	**Section**	**Subsection**	**Species**
iNaturelist	1	0	0	0	0	0	0	0	0	0	0
	2	1	1	1	0	0	1	1	1	0	0
	3	1	1	1	1	0	1	1	1	1	0
	4	1	0	0	0	0	1	1	1	0	0
	5	1	1	1	0	0	1	1	1	0	0
	6	1	1	1	0	0	1	1	1	0	0
	7	1	0	0	0	0	1	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0
	9	1	1	1	0	0	1	1	1	0	0
	10	1	0	0	0	0	1	1	1	1	0
	11	1	1	1	1	1	1	1	1	1	1
	12	1	0	0	0	0	1	0	0	0	0
	13	1	0	0	0	0	1	1	1	0	0
	14	1	1	1	1	0	1	1	1	1	0
	15	1	0	0	0	0	1	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0

Appendix 5

Subgenus	Section	Subsection	Species
Azaleastrum	***Azaleastrum***		*R. hongkongense*
			R. leptothrium
			R. ovatum
	Sciadorhodion		*R. schlippenbachii*
			R. albiflorum
	Tsutsusi	*Brachycalyces*	
		Tsutsusi	*R. simsii*
			R. indicum
			R. mucronatum
			R. nakaharae
			R. oldhamii
			R. rubropilosum
Choniastrum			*R. championiae*
			R. latoucheae
			R. moulmainense
			R. westlandii
Hymenanthes	***Pentanthera***	***Pentanthera***	*R. alabamense*
			R. arborescens
			R. atlanticum
			R. calendulaceum
			R. canescens
			R. luteum
			R. molle
			R. periclymenoides
			R. prinophyllum
			R. prunifolium
			R. viscosum
		Sinensia	
	Ponticum	***Arborea***	*R. arboreum*
			R. delavayi
			R. lanigerum
			R. niveum
		Argyrophylla	*R. argyrophyllum*
			R. denudatum
			R. floribundum
			R. hunnewellianum
			R. insigne
			R. pingianum
			R. ririei
		Barbata	*R. argipeplum*
			R. barbatum
			R. erosum
		Campanulata	*R. campanulatum*
			R. wallichii
		Campylocarpa	*R. callimorphum*
			R. campylocarpum
			R. souliei
			R. wardii
		Falconera	*R. arizelum*
			R. basilicum

Subgenus	Section	Subsection	Species
Hymenanthes	***Ponticum***	***Falconera***	*R. coriaceum*
			R. galactinum
			R. hodgsonii
			R. preptum
			R. rothschildii
		Falconera	*R. rex*
			R. semnoides
			R. sinofalconeri
		Fortunea	*R. calophytum*
			R. davidii
			R. decorum
			R. fortunei
			R. glanduliferum
			R. griffithianum
			R. hemsleyanum
			R. hirsutum
			R. orbiculare
			R. oreodoxa
			R. praevernum
			R. sutchuenense
			R. vernicosum
			R.auriculatum
			R. huanum
			R. yuefengense
		Fulgensia	*R. fulgens*
		Fulva	*R. fulvum*
			R. uvariifolium
		Glischra	*R. adenosum*
			R. crinigerum
			R. glischrum
			R. habrotrichum
		Grandia	*R. grande*
			R. montroseanum
			R. praestans
			R. protistum
			R. pudorosum
			R. sidereum
			R. sinogrande
		Griersoniana	*R. griersonianum*
		Irrorata	*R. aberconwayi*
			R. annae
			R. anthosphaerum
			R. araiophyllum
			R. irroratum
			R. kendrickii
			R. lukiangense
			R. tanastylum
		Lanata	*R. lanatoides*
			R. lanatum
			R. tsariense

Subgenus	Section	Subsection	Species
Hymenanthes	***Ponticum***	***Maculifera***	*R. longesquamatum*
			R. maculiferum
			R. pseudochrysanthum
			R. morii
			R. ochraceum
			R. oligocarpum
			R. pachysanthum
			R. sikangense
			R. strigillosum
		Neriiflora	*R. beanianum*
			R. catacosmum
			R. chamaethomsonii
			R. citriniflorum
			R. coelicum
			R. dichroanthum
			R. euchroum
			R. eudoxum
			R. floccigerum
			R. forrestii
			R. haematodes
			R. mallotum
			R. microgynum
			R. neriiflorum
			R. parmulatum
			R. piercei
			R. pocophorum
			R. sanguineum
			R. sperabile
			R. temenium
			R × *hemigymnum*
		Parishia	*R. facetum*
			R. kyawii
		Pontica	*R. aureum*
			R. catawbiense
			R. hyperythrum
			R. macrophyllum
			R. maximum
			R. ponticum
			R. fauriei
		Selensia	*R. hirtipes*
			R. selense
		Taliensia	*R. adenogynum*
			R. aganniphum
			R. alutaceum
			R. balfourianum
			R. beesianum
			R. bureavii
			R. clementinae
			R. dignabile
			R. lacteum

Subgenus	Section	Subsection	Species
Hymenanthes	***Ponticum***	***Taliensia***	*R. mimetes*
			R. phaeochrysum
			R. principis
			R. przewalskii
			R. roxieanum
			R. rufum
			R. taliense
			R. traillianum
			R. wightii
			R. wiltonii
			R. coeloneurum
			R. detonsum
		Thomsonia	*R. cerasinum*
			R. cyanocarpum
			R. eclecteum
			R. faucium
			R. hookeri
			R. meddianum
			R. stewartianum
			R. thomsonii
		Venatora	*R. venator*
		Williamsiana	*R. williamsianum*
			R. peregrinum
	Rhodora		*R. canadense*
			R. vaseyi
			R. inopinum
Rhododendron	***Pogonanthum***		*R. anthopogon*
			R. cephalanthum
			R. collettianum
			R. primuliflorum
			R. trichostomum
	Rhododendron	*Afghanica*	
		Baileya	
		Boothia	*R. chrysodoron*
			R. leucaspis
		Camelliiflora	*R. camelliiflorum*
		Campylogyna	*R. campylogynum*
		Caroliniana	*R. minus*
		Cinnabarina	*R. cinnabarinum*
			R. keysii
		Edgeworthia	*R. edgeworthii*
			R. pendulum
		Fragariflora	
		Genestieriana	
		Glauca	*R. brachyanthum*
			R. charitopes
			R. shweliense
		Heliolepida	*R. heliolepis*
			R. rubiginosum
		Lapponica	*R. capitatum*

Subgenus	Section	Subsection	Species
Rhododendron	***Rhododendron***		*R. complexum*
			R. cuneatum
			R. fastigiatum
			R. flavidum
			R. hippophaeoides
			R. impeditum
			R. intricatum
			R. lapponicum
		Lapponica	*R. nivale*
			R. occidentale
			R. orthocladum
			R. polycladum
			R. rupicola
			R. russatum
			R. setosum
			R. telmateium
			R. yungningense
		Ledum	*R. columbianum*
		Lepidota	*R. lepidotum*
		Maddenia	*R. ciliatum*
			R. fletcherianum
			R. ciliicalyx
			R. ciliipes
			R. dendricola
			R. excellens
			R. liliiflorum
			R. lindleyi
			R. maddenii
			R. nuttallii
			R. scopulorum
			R. taggianum
			R. valentinianum
			R. dalhousieae
		Micrantha	*R. micranthum*
		Monantha	
		Moupinensia	*R. dendrocharis*
			R. moupinense
		Rhododendron	*R. ferrugineum*
		Rhodorastra	*R. dauricum*
			R. mucronulatum
		Saluenensia	*R. calostrotum*
			R. saluenense
		Scabrifolia	*R. hemitrichotum*
			R. pubescens
			R. racemosum
			R. scabrifolium
			R. spinuliferum
		Tephropepla	*R. auritum*
			R. hanceanum
			R. tephropeplum
Rhododendron	***Rhododendron***	***Tephropepla***	*R. tephropeplum*
		Trichoclada	*R. lepidostylum*
			R. mekongense
			R. trichocladum
		Triflora	*R. ambiguum*
			R. amesiae
			R. augustinii
			R. concinnum
			R. davidsonianum
			R. lutescens
			R. oreotrephes
			R. pleistanthum
			R. polylepis
			R. rigidum
			R. searsiae
			R. siderophyllum
			R. tatsienense
			R. trichanthum
			R. triflorum
			R. yunnanense
			R. zaleucum
		Uniflora	*R. pemakoense*
			R. pumilum
		Virgata	*R. virgatum*
Therorhodion			*R. camtschaticum*
			R. redowskianum
Vireya	*Albovireya*		
	Discovireya		
	Hadranthe		
	Hadranthe		
	Malayovireya		
	Pseudovireya		*R. emarginatum*
			R. retusum
			R. rushforthii
			R. vaccinioides
	Schistanthe	*Euvireya*	
		Linnaeopsis	
		Malesia	
		Saxifragoidea	
		Solenovieyea	
	Siphonovireya		
Cultivar			*Rhododendron* obtusum