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Contents

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From the Editor

Dr. Glen Jamieson
Parksville, BC
Canada

Rhododendrons International (RI) is an online journal distributed free to all the world's known rhododendron associations for their internal distribution. It can also be accessed without charge on the American Rhododendron Society website at https://www.rhododendron.org/ri-index.htm. This ninth issue of RI is different from previous issues, which have had articles extracted from various rhododendron publications that I feel were worthy of wider world-wide distribution. I regularly search botanical publications for worthwhile rhododendron articles I deem to be of international significance for wider distribution through RI issues. I also welcome submissions from authors of such material that I might not be aware of, so please feel free in the future to bring such material to my attention at rhodojournal@gmail. com, and please put "Rhododendrons International" in the subject line.

Articles in this ninth volume are the abstracts from a 2025 convention organised by Dr. Juliana Mederios with contributions from world-wide researchers, many of whom are just starting their careers working on rhododendrons. It shows the great diversity of *Rhododendron* research that is presently underway, and the wide geographical range of active researchers.

Finally, I would like to express my big appreciation to Sonja Nelson, the past volunteer layout editor, for all her hard work in producing previous issues of *Rhododendrons International*. Without her involvement and support, this journal would not exist! Sadly, Sonja now has health issues and is no longer able to work on *Rhododendrons International*. However, Brenda Macdonald has kindly stepped in and has produced this issue, and for that I thank her very much.

Proceedings of the Rhododendron Research Network

2025 Virtual International Convention

Dr. Juliana S. Medeiros
Chair, American Rhododendron Society Research Committee

The Rhododendron Research Network (R-RN) is a collaborative working group of scientists, conservationists and community members seeking to advance *Rhododendron* as a model study system in biodiversity science. Led by botanical garden staff, academic researchers, and members of the American Rhododendron Society, the R-RN plans conventions, collaborative projects, and publications to support advancement of early career investigators, encourage more scientific interest in the genus as well as inspire community engagement in *Rhododendron* conservation and cultivation.

Rhododendron researchers and conservationists worldwide shared the results of their work at a convention hosted by the R-RN and held over Zoom, May 27-28, 2025. *Rhododendron* is an important study system across different scientific disciplines, and topic areas represented at the convention included investigations into climate impacts on plant physiology, symbiotic and pathogenic relationships with microbes and insects, the evolution of biodiversity, and conservation of species in living collections. Here we present abstracts of the talks, and talks can be viewed on the Rhododendron Research Network YouTube Channel at https://www.youtube.com/channel/UCnY4uCMGIBpYJoSYajkticQ

Temporality of Ice-formation and Ice-progression vs. Leaf Thermonasty during Natural Freeze in *Rhododendron maximum*, and Mechanistic Hypothesis for Leaf Rolling

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Evergreen leaves of *Rhododendron* species inhabiting temperate climates are typically exposed to high radiation and freezing temperatures during winter when photosynthetic biochemistry is severely inhibited. This leads to accumulation of excess energy (radiation) in photosynthetic reaction centers causing photoinhibition or photooxidative damage. Cold-induced "thermonasty" (lamina rolling and petiole curling/drooping) can reduce the amount of leaf area exposed to solar radiation and has been associated with photoprotection in overwintering rhododendrons (Fig. 1). The present study was conducted on natural, mature plantings of a cold-hardy thermonastic North American species (*R. maximum*) during winter freezes. Infrared thermography was used to determine initial sites of ice formation, patterns of ice propagation, and dynamics of the freezing process in leaves to understand the temporal and mechanistic relationship between freezing and thermonasty. Results indicated extracellular freezing in leaves preceded the initiation of leaf rolling or intensification of petiole curling; only the former is mainly discussed here. Ice initially formed in the vascular tissue of the midrib and propagated into other portions of the vascular system. Ice never started to form or was propagated into palisade, spongy mesophyll, or epidermal tissues. These observations, together with lamina-histology and a simulation of the rolling effect of dehydrated leaves using a paper-bilayer system, suggest that thermonasty occurs due to anisotropic [a physical property that has a different value when measured in different directions] contraction of cell wall cellulose fibers of adaxial [the upper surface of a leaf] versus abaxial [the lower surface of a leaf] surface as cell water freezes in vascular tissues.

Figure 1. Leaf curling and drooping of *Rhododendron maximum* in response to sub-freezing temperatures.

Rhododendron minus Seedlings Achieve Similar Performance across Light Environments with Anthocyanin Accumulation and Architectural Adjustments under High Light Intensity

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Rhododendron minus is an evergreen shrub native to the Southeast United States, spanning environments from high elevations and snowy winters in the Appalachian Mountains to warm, humid environments near the Gulf Coast. This species also grows across wide light environments, from shaded conditions of the forest understory to high light upon rock outcrops. Gardeners enjoy the red and pink hues of *R. minus* foliage and flowers. This coloration is from a pigment known as anthocyanin which provides protection from a range of environmental stressors including high light. *R. minus* is also known to display changes in leaf angle in response to the environment. To investigate the functional significance of anthocyanin and leaf movements in *R. minus*, we conducted two experiments at Holden Arboretum, in Kirtland, Ohio. First, we exposed *R. minus* seedlings from Hawksbill Mountain, a relatively cold, sun exposed location, to different light intensities in a greenhouse. Second, we studied mature *R. minus* plants originating from different locations to see whether climate and solar radiation in the location of origin influence anthocyanin concentration. For this project, we used a multispectral imaging device which photographs leaves under red and green LEDs to estimate anthocyanin concentration (Fig. 2). We found that plants in the high light treatment had more anthocyanin than plants under the shade and intermediate

Figure 2. Miranda operates the homemade multispectral imaging device to estimate the anthocyanin and chlorophyll content of *R. minus* leaves.

light treatments, suggesting that adjustment in this pigment helps *R. minus* grow in different habitats. Knowledge of pigment expression under contrasting environments can help us predict future patterns as climate change shifts the timing of canopy closure, affecting the light environment of understory plants. We also found that plants in the high light treatment had leaf movements to reduce direct light capture, helping to manage light absorption in stressful conditions.

The second experiment revealed that plants from colder temperatures, namely those in the northern region, had more anthocyanin. Interestingly, plants from locations with higher solar radiation, namely those in the southern region, had less anthocyanin. At first glance, this seems to contradict results from the first experiment. It is important to note, however, that plants in the south grow in warmer, less seasonal climates. These plants may require less anthocyanin despite increased solar radiation since photosynthesis is not limited by cold temperature, unlike plants in the north. This work helps us understand how environmental pressures shape pigment production in *R. minus*, revealing complexities in how light and temperature interact to influence anthocyanin.

Seasonal pigment variation among populations of *Rhododendron minus* var. *minus* from sites with different mean annual temperatures

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In evergreens, photoprotective pigments are utilized to prevent photooxidative damage during cold stress, particularly in response to extremely low temperatures and fluctuating light conditions during winters. To investigate how local adaptation may affect population responses to shifting climate, we observed intraspecific variation in pigment response to cold acclimation in the rhododendron *Rhododendron minus* var. minus. *R. minus* plants were grown from seeds collected from provenances across the species' natural range in the Eastern US, representing different long-term minimum temperatures, including three provenances that regularly experience minimum temperatures below 0° C, and three provenances which rarely experience frost (Fig. 3).

Looking at chlorophyll (both chlorophyll a and chlorophyll b) and carotenoid (violaxanthin, antheraxanthin, zeaxanthin, neoxanthin, and lutein) pigment concentrations for non-cold acclimated plants (leaves in the summer) and the concentration responses of pigments to frost (leaves in the winter) at both predawn (dark-exposed) and midday (light-exposed) light conditions, we compare the nocturnal retention of dynamic pigments across provenances. We found that xanthophyll cycle pigments in the photoprotective state (antheraxanthin and zeaxanthin) are retained at predawn during frost, displaying evidence for sustained photoprotection in winter. Similarly, predawn concentrations of neoxanthin and lutein, not directly involved in the xanthophyll cycle, increase during frost exposure. The increase of these carotenoids varies among provenances, with plants from lower latitudes which rarely experience frost more greatly upregulating neoxanthin and lutein upon frost exposure, suggesting that local adaptation to temperature minimums creates differential responses to cold acclimation within a species.

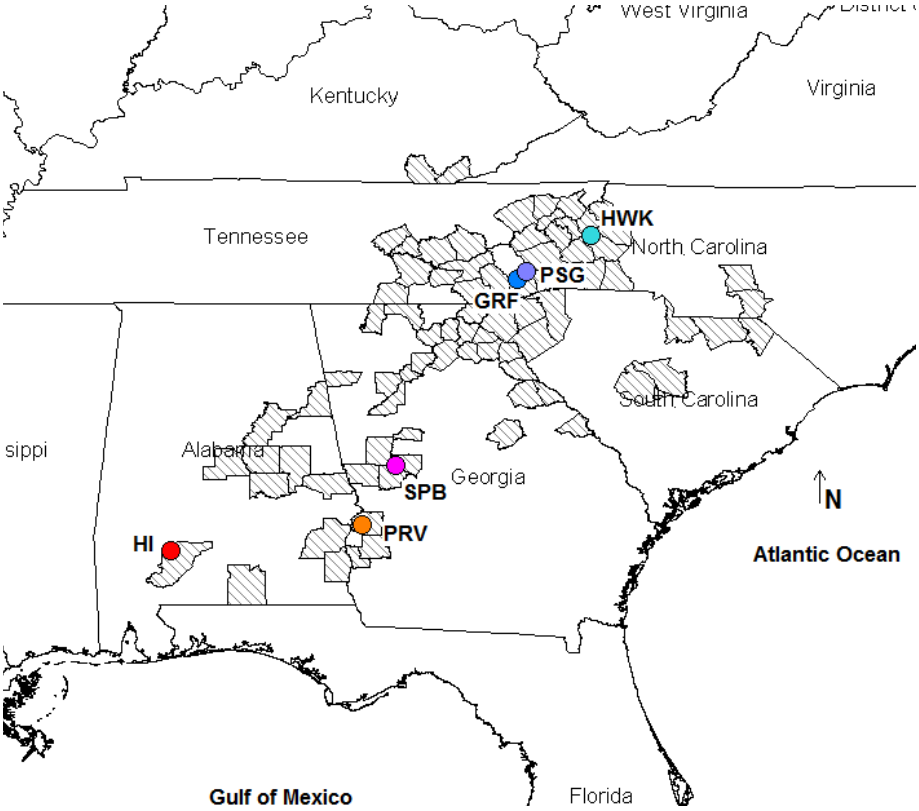

Figure 3. Geographic distribution and seed collection locations of *R. minus.* Counties where *R. minus* var. *minus* occurs are shown with white dashed lines, data based on USDA Plants database. Seed collection locations: Graveyard Fields, North Carolina (GRF), Hawksbill Mountain, North Carolina (HWK), Mt. Pisgah, North Carolina (PSG), Sprewell Bluff, Georgia (SPB), Haines Island, Alabama (HI) and Providence Canyon, Georgia (PRV).

Fungal Communities Driven by *Rhododendron* Species Correlate with Pathogen Protection against *Phytophthora cinnamomi*

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Plant interactions with soil microbial communities are critical for understanding plant health, improving horticultural and agricultural outcomes, and maintaining diverse natural communities. In some cases, disease suppressive soils enhance plant survival in the presence of pathogens. However, species-specific differences and seasonal variation complicate our understanding of the drivers of soil fungal communities and their consequences for plants. Here, we aim to describe soil fungal communities across *Rhododendron* species and seasons as well as the test for fungal indicators of *Rhododendron* species in the soil. Further, we test possible mechanisms governing disease suppressive soils to the oomycete pathogen *Phytophthora cinnamomi*. Variation in disease susceptibility to this pathogen across species and clades allows us to test for possible fungal drivers of disease suppressive soils. We conducted high throughput sequencing of the fungal communities found in soil collected under 14 *Rhododendron* species and across two seasons (April, October) at two sites in Ohio, USA. Phylogenetic analyses were used to determine whether fungal community composition correlated with increased plant survival with the addition of whole soil communities from a prior greenhouse experiment.

Effects of *Rhododendron* species (R2 = 0.13), season (R2 = 0.01) and their interaction on fungal communities (R2 = 0.11) were statistically significant. Fungal community composition was negatively correlated with plant survival following exposure to whole soil microbial communities, though this result depended on the presence of *R. minus*. Forty-five *Trichoderma* [a genus of fungi in the family Hypocreaceae that is present in all soils, and which are the most prevalent culturable fungi] taxa were identified across our soil samples, and some *Trichoderma* were significantly associated with particular *Rhododendron* species

(e.g., *Trichoderma atroviride* was associated with *R. molle*) in indicator species analyses. The correlation between plant responses to soil biotic communities and fungal community composition, as well as the presence of potential beneficial taxa such as *Trichoderma* and mycorrhizal fungi, are consistent with fungal-mediated survival benefits in the presence of the pathogen *Phytophthora cinnamomi*.

This work has been published: Ahmad S., D.J. Burke, S.R. Carrino-Kyker, J.S. Medeiros and J.H. Burns. In Press. Fungal communities driven by *Rhododendron* species correlate with pathogen protection against *Phytophthora cinnamomi*. *Plant & Soil.* 516: 2051-2062

Phytophthora cinnamomi Threatens *Rhododendron* Species: Could *Trichoderma* be the Next Sustainable Solution?

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Cleveland, Ohio

Phytophthora cinnamomi is a devastating pathogen responsible for root rot in *Rhododendron* species, causing significant economic and ecological impacts. While fungicides have been the traditional method for managing such diseases, the emergence of fungicide resistance has highlighted the need for sustainable and environmentally friendly alternatives. *Trichoderma* species are well-known for their biocontrol potential and plant-growth-promoting abilities, and their application as a biocontrol agent against *Phytophthora* offers a promising solution. This study explored the role of *Trichoderma* species in enhancing *Rhododendron* resistance to *Phytophthora cinnamomi*, testing whether individual and combined species of *Trichoderma* could mitigate the pathogen's impact on plant performance. Specifically, the research sought to assess the effects of *Trichoderma* species on *Rhododendron* growth and survival and determine whether a combination of *Trichoderma* species exhibited a non-additive effect on *Rhododendron* survival under pathogen pressure.

Rhododendron seedlings were grown under controlled greenhouse conditions using a factorial design involving three *Rhododendron* species, four *Trichoderma* species treatments (control, *Trichoderma harzianum*, *T. asperellum*, and a combination of both *Trichoderma* species), two pathogen treatments (with and without) and 15 replicates. Key plant metrics, including relative growth rate, survival rates, shoot biomass, root biomass, and specific root length (SRL) were measured. Preliminary findings suggest that *Trichoderma* treatments, particularly the combined application of *T. harzianum* and *T. asperellum*, enhanced survival rates and growth compared to untreated controls (Fig. 4). Additionally, *Trichoderma* influenced root traits, with specific root length showing higher values in the absence of the pathogen and lower values under pathogen stress.

These results indicate a potentially synergistic effect of *Trichoderma* treatments in mitigating pathogen-induced stress, enhancing plant resilience.

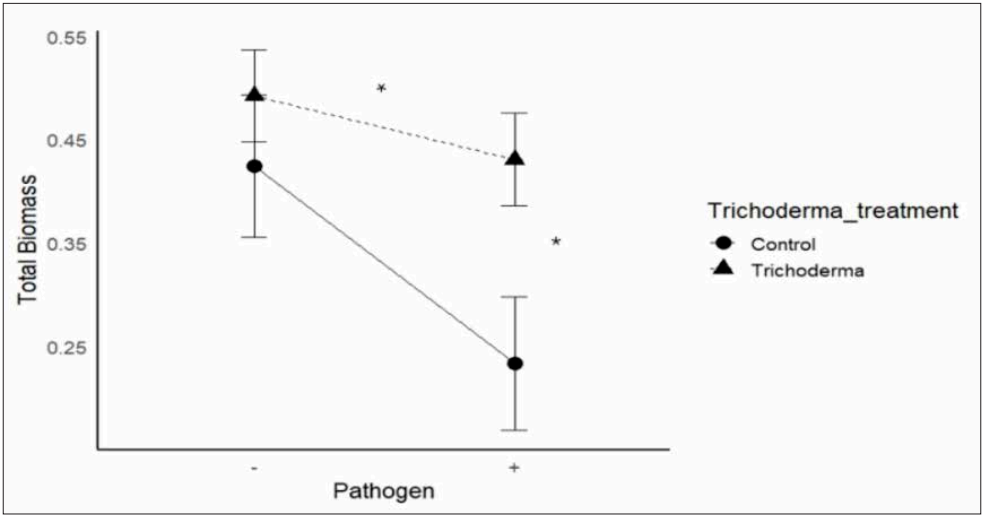

Figure 4. Effects of *Trichoderma* inoculation on total biomass (a measure of growth) under pathogen presence and absence. Points represent means (+/- standard error) across *Rhododendron* species. Asterisks indicate significant differences between treatments ($P < 0.05$).

This research highlights the potential of *Trichoderma* species as sustainable biocontrol agents against *Phytophthora cinnamomi* in *Rhododendron* cultivation. Further studies are necessary to explore the underlying mechanisms of these interactions and their broader applications in horticultural management, paving the way for alternative, eco-friendly disease management practices.

This work has been published: Folorunso AE & JH Burns (2026) The enemy of my enemy is my friend: Trichoderma fungi reduce root rot disease symptoms caused by Phytophthora cinnamomi in Rhododendron. *Plant Ecology* 227: 56.

From Petals to Pests: the Multifaceted Role of Volatile Organic Compounds in *Rhododendron* Species

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Volatile organic compounds (VOCs) have been reported in some *Rhododendron* species distributed in Asia and were determined to be of significant importance, primarily due to their bioactive effects and ecological roles in pollination and pest control. The analysis of VOCs to date has largely focused on Asian *Rhododendron* species, and it remains understudied in North American species, particularly within the Azalea group.

In the United States, approximately 17 native deciduous azalea species are found, ranging in flower color from white to pink-orange and characterized by their extraordinary fragrances. We propose characterizing the VOCs emitted by leaves and flowers of various azalea species and examining their relationships with pollinators and phenology. Pollinator visitors and the phenology of the plants involved in the study will be described based on flower morphology and field observations.

The project will be conducted at Holden Arboretum, focusing on the azalea collection, in collaboration with the Gardner Lab at Case Western Reserve University for mass spectrometry (MS) sample analysis. Understanding the VOCs of American azalea species could shed light on their biological and medicinal significance, as well as their value for ornamental purposes

Effects of *Rhododendron* Removal on Bees in the Southern Appalachians

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Rhododendron maximum is an evergreen shrub native to the Appalachian Mountains of North America that has expanded in recent decades due to past disturbances and land management. The purpose of this study was to explore how bees and plants were affected by the experimental removal of *R. maximum* followed by a prescribed fire in one forested watershed compared to a neighboring reference watershed in North Carolina, U.S.A. Bees and plants were sampled for three years in both watersheds. Comparisons were based on the rarefaction and extrapolation sampling curves of Hill numbers as well as multivariate methods to assess effects on community composition.

Bee richness, Shannon's diversity and Simpson's diversity did not differ between watersheds in the year after removal but were all significantly higher in the removal watershed in year two, following the prescribed fire. Bee Shannon's diversity and Simpson's diversity, but not richness, remained significantly higher in the removal watershed in the third year. Similar but weaker patterns were observed for plants. Comparisons of community composition found significant differences for bees in the second and third year and significant differences for plants in all three years. For both groups, significant indicator taxa were mostly associated with the removal watershed. Because bees appeared to respond more strongly to the prescribed fire than to the removal of *R. maximum* and these benefits weakened considerably one year after the fire, clearing *R. maximum* does not appear to dramatically improve pollinator habitat in the southern Appalachians. This conclusion is underscored by the fact that about one quarter of the bee species in our study area were observed visiting *R. maximum* flowers. The creation of open areas with wildflowers may be a better way to benefit bees in this region, judging from the high diversity of bees captured in the small roadside clearings in this study.

This work has been published: Ulyshen, M., K. Elliott, J. Scott, S. Horn, P. Clinton, N.Liu, C.F. Miniat, P. Caldwell, C. Oishi, J. Knoepp, and P. Bolstad. 2022. Effects of Rhododendron removal and prescribed fire on bees and plants in the southern Appalachians. *Ecology & Evolution* 12(3): e867.

A Novel Method for Identifying Suspected Triploids in Interploidy Contact Zones of Diploid *Rhododendron canescens* and Tetraploid *Rhododendron austrinum*

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For over 75 years, triploids have been documented in interploidy contact zones involving tetraploid *Rhododendron calendulaceum*. The most common method of finding suspected triploids in an interploidy contact zone containing *R. calendulaceum* was to search for plants that had flower color atypical for both *R. calendulaceum* and the co-located diploid deciduous azalea species. This atypical flower color method worked well for finding triploids at Audra State Park near Buckhannon, West Virginia, Hurricane Creek near Dawsonville, Georgia, and Chattahoochee River National Recreation near Roswell, Georgia. However, flow cytometry also showed that triploids in such populations could have physical characteristics and flower colors typical for *R. calendulaceum*.

In 2006, Dr. Ranney's team determined using flow cytometry that *R. austrinum*, *R. atlanticum*, and *R. colemanii*, as well as *R. calendulaceum*, were tetraploids. Shortly thereafter, Ron Miller discovered that *R. austrinum* could have pink flowers. Moreover, given populations of *R. austrinum* on the Escambia, Blackwater, and Yellow Rivers could have a range of flower colors from typical gold and yellows to combinations of yellow and pink to pink, as well as white (Figs. 5, 6). Identifying populations using solely the atypical color rule is thus impractical for finding triploids in interploidy contact zones involving *R. austrinum* and diploid pink *R. canescens*.

However, our experience hand-crossing diploid deciduous azaleas with tetraploid deciduous azaleas showed us the following:

1) Diploid x tetraploid normally produces viable seed;
2) Tetraploid x diploid does not normally produce seed pods;
3) Seedlings from diploid x tetraploid normally have the physically characteristics of the tetraploid pollen parent including flower color;
4) Seedlings from diploid x tetraploid are normally seed sterile triploids;
5) Some seedlings from diploid x tetraploid can be fertile triploids or fertile tetraploids, but both are rare occurring possibly one in every 100 seedlings.

Ron Miller had observed based on field observations that tetraploid pink *R. austrinum* as well as tetraploid yellow *R. austrinum* have glands on the new growth whereas normally diploid pink *R. canescens* do not. From these observations our team formulated a method for finding triploids in interploidy contacts zones of diploid pink *R. canescens* with tetraploid *R. austrinum* that can be summarized as follows: Seedless triploids looking similar to typical glandular on the new growth *R. austrinum* will be found near large groups of typically nongranular on the new growth diploid pink *R. canescens*. The smaller the ratio of typical *R. austrinum* types to diploid pink *R. canescens* types, the more likely the typical looking *R. austrinum* types are triploids, especially if all the *R. austrinum* types are seedless whereas most of the diploid pink *R. canescens* have seed. This method allowed our team to locate triploids between *R. canescens* and *R. austrinum* in eight locations in the Blackwater River State Forest, Yellow River Management area, and near Albany, Georgia. Triploids were also located in two additional interploidy contact zones involving *R. austrinum* using a combination of the above method with atypical flower color. All triploids were confirmed using flow cytometry.

Figure 5. Pink *R. canescens* x *R. austrinum* triploid.

Figure 6. Yellow *R. canescens* x *R. austrinum* triploid

An Efficient Micropropagation Protocol for the Endangered *Rhododendron chapmanii*

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Rhododendron chapmanii is an endangered species endemic to Florida, with only 32 known populations in three counties of Florida. Logging and clear cutting as well as over-collection have negative impacts on this species. Current-year spring shoots were used as explants, disinfected by 0.1% HgCl2 (Fig. 7). Anderson Rhododendron Media [a tissue culture medium that was specially designed for the challenges of *Rhododendron* and other ericaceous plants] was used as the basal cultivation media, supplemented with zeatin for the multiplication stage

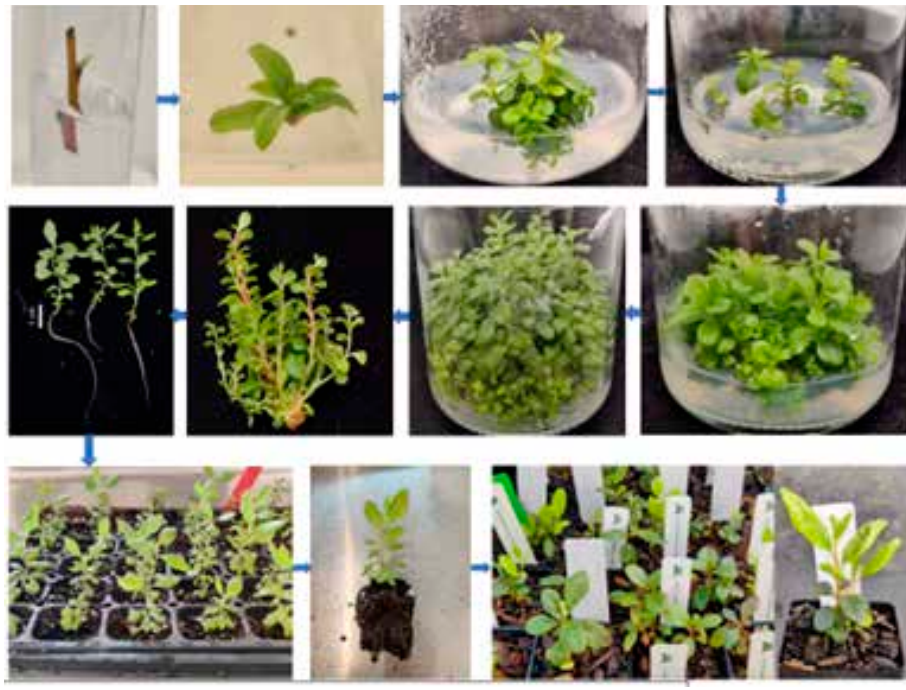

Figure 7. Plants in the micropropagation process stages for *R. chapmanii*

[subculturing shoots on new medium to increase the number of shoots]. Both *in vitro* [container cultivation] and *ex vitro* [natural environment] rooting were tested. About 20% success in initiation culture with 2-3 nodes segments.

Axillary buds were emerged 2 weeks after initiation on media with 0.5 mg/L zeatin. Highest shoot proliferation was achieved with 1 mg/L zeatin, multiplication rate can reach to 12. Elongated shoots can rooted one month both *in vitro* (1 mg/L IBA) and *ex vitro* (quick dip with 1g/L IBA). Rooted shoots have 100% survival rate after transplanted in cell tray with Pro-mix. After two month in cell tray, plants were transplanted into 6-inch pots filled with coarser potting mix. All the plants survived and grew vigorously. This protocol can produce large number of plants in a short time, and thus avoid over-collection of this endangered species to protect the wild populations. It also provides an efficient safe *in vitro* conservation method without abiotic and biotic stress.

Susceptibility of *Rhododendron* to the Azalea Lace Bug, *Stephanitis pyrioides* (Scott)

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The invasive azalea lace bug, *Stephanitis pyrioides* (Scott), is one of the most serious insect pests of the genus *Rhododendron*, especially azaleas. Feeding by nymphs and adults damages the foliage and thus reduces the aesthetic value of infested plants. *Rhododendron* spp. (L.) and cultivars are a major component of public and private landscapes in the Pacific Northwest. Variability in the susceptibility of *Rhododendron* to *S. pyrioides* has been previously examined but generally on a limited number of *Rhododendron* species and cultivars. We measured the susceptibility of 71 *Rhododendron* species, varieties, and cultivars to the azalea lace bug over two years, selecting plants across the phylogenetic tree of *Rhododendron*, and quantified the proportion of leaf damage caused by *S. pyrioides*.

To examine if evolutionary history had an effect, we analyzed damage in comparison with trichrome presence, as well as by subgenera and section of the selected *Rhododendron* plants. We observed that trichome presence did not predict *S. pyrioides* damage. Plants from the subgenus Azaleastrum were the significantly most susceptible subgenus, and all sampled plants from this subgenus had measurable damage. In contrast, plants from the subgenus Hymenanthes were the significantly least susceptible to damage, with most plants having no measurable damage. This study provides a guideline for using host plant resistance to *S. pyrioides* in plant selection, and emphasizes the potential for *S. pyrioides* management if azaleas susceptible to *S. pyrioides* are to be used in the landscape.

Investigation of Flower Characteristics and Pollinator Guilds across Elevational and Longitudinal Gradients

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We investigated the floral characteristics of equatorial *Rhododendron* species (commonly referred to as vireyas) across the Malesian Archipelago [a biogeographical region straddling the Equator and the boundaries of the Indomalayan and Australasian realms], with analyses informed by use of a detailed phylogenetic tree. Floral characteristics of interest included metrics of size or categorization of scent, as described in botanical monographs and global herbarium records, as well as quantification of shape and color based on photographs, for approximately a hundred species. From a list of potential pollinators that we compiled from natural history observations, we found that *Sphingid* (hawkmoth) and *Apis* (bee) diversity was highest at lower elevations, whereas nectivorous birds occurred across a broader elevational gradient, but with variation in beak shape depending on clade and biogeographic history. We found a correlated evolution between flower color and scent, with red flowers tending to be scentless whereas white flowers were most often strongly scented. Flower shape changed along an elevational gradient, shifting from larger, deeply lobed flowers at lower elevations to smaller, more tubular fused flowers at higher elevations.

From a multi-trait perspective, four distinct pollination guilds emerged.

1) Generalist flowers with a campanulate shape and a range of colors, most likely attracting a mix of insects such as bees, flies, or butterflies; similar to flowers of temperate *Rhododendron* species.

2) Specialized sphingophilus [adapted for pollination by hawkmoths (sphinx moths)] flowers, characterized by white or light pink corollas, and fragrant, narrow, trumpet-shaped tubes held vertically or semi-erect.

3) Specialized ornithophilous [adapted for pollination by birds] flowers, characterized by scentless red, yellow, or dark pink corollas curved downwards with bilateral symmetry, or narrowly strait with fused or minimalist petals, and held hanging downwards.

4) Within the Sahul bioregion [the ancient continent that existed during the Pleistocene Epoch, when sea levels were lower and Australia, New Guinea, and Tasmania were connected by land bridges], a subset of flowers had extremely large and relatively broad corollas held horizontally, pale in color with more than five deeply lobed petals and a unique scent, most likely to attract lory parrots [lorikeets] or fruit bats.

This study offers a unique perspective on how flower form changes across elevational and longitudinal gradients, while recognizing the need for additional field-based observational studies to test predictions of pollinator specificity.

Bridging Taxonomy and Conservation: *ex situ* Gap Analysis and Phylogenetic Studies of Subsection Maddenia Rhododendrons

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Here I present my PhD research on *Rhododendron* taxonomy and the diversity of *ex situ* collections for conservation, using subsection Maddenia as a case study (Fig. 8). This group is widely cultivated in temperate regions worldwide, yet

Figure 8. Some subsection Maddenia Rhododendron species:
(A) *Rhododendron coxianum*, (B) *R. maddenii* subsp. *crassum*, (C) *R. fletcherianum*,
(D) *R. nuttallii*, (E) *R. lindleyi*, (F) *R. formosum* var. *formosum*,
(G) *R. dalhousiae* var. *rhabdotum*, (H) *R. burmanicum*, and (I) *R. valentinioides*.

seldom studied for conservation, and its complex taxonomy hinders effective decision making. An *ex situ* conservation gap analysis was undertaken, using ecogeographical representation as a proxy for genetic representation in botanic garden collections worldwide. Of the 61 taxa in subsection Maddenia, 51 are in cultivation, but the number, origin, and diversity of wild-sourced accessions remain unclear, and 33 taxa are Threatened or Data Deficient. To address this, we surveyed global living collections across 73 sites, assessed provenance of wild-sourced material, and compared *ex situ* coverage to wild distributions (Fig. 9).

Complementary studies included determination of ploidy level, as polyploidy may affect phylogenetic analysis; the molecular phylogeny of 40 taxa using target capture sequencing; and trials of controlled pollination for safeguarding germplasm of prioritised species. Together, these analyses reveal significant gaps in representation and provenance data, while providing taxonomic resolution and practical strategies for strengthening conservation. Outcomes such as the taxon checklist, distribution data, and updated conservation status directly inform ongoing IUCN Red List publication for subsection Maddenia and offer a framework for wider *ex situ* conservation planning of the genus.

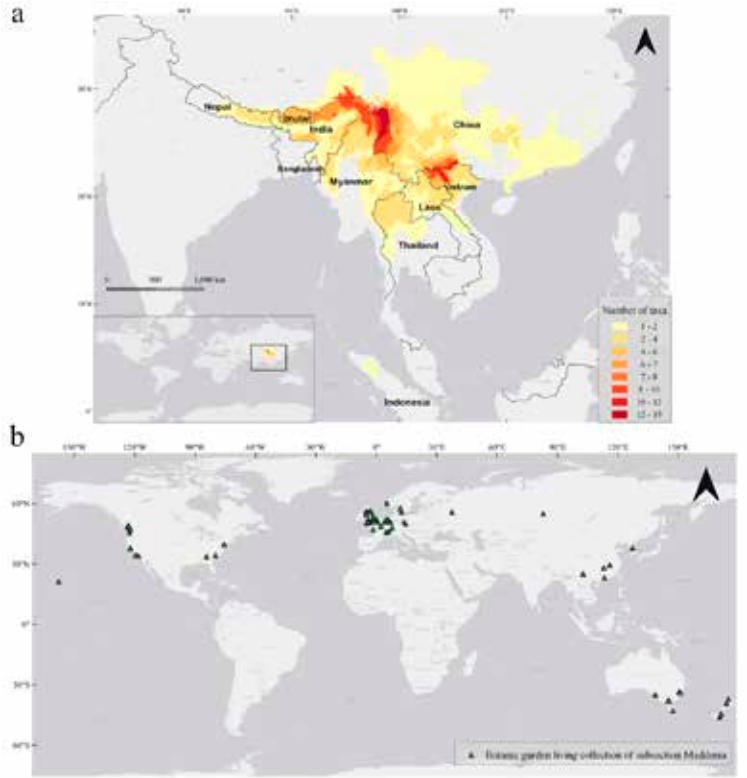

Figure 9. Subsection Maddenia species locations in a) their native countries and b) *ex situ* collections.

The Vireya Rhododendrons of Vogelkop, Papua, Indonesia

Yasper Michael Mambrasar
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New Guinea is one of the islands with the highest biodiversity in the world, hosting more than 150 species of *Rhododendron*. The island formed from uplift from the collision of the Australian and Pacific Tectonic Plates, while the Vogelkop region in Papua has a distinct tectonic history, having originally been part of Australia before separating and merging with New Guinea. To explore the biogeographic history of New Guinea through plant distribution, an inventory of *Rhododendron* species in the Vogelkop region was conducted (Fig. 10). The distribution pattern of *Rhododendron* species in the Vogelkop region of Papua provided insight into the biogeographic history of the area. Of the 27 species and one subspecies recorded, 12 are endemic to Vogelkop, indicating a high level of local endemism. This suggests that the Vogelkop region has acted as a center of speciation, likely due to its long-term geological isolation and complex topography, which create diverse microhabitats and ecological niches.

Figure 10. Author conducting surveys of Vireya species in Vogelkop

Six species occur throughout Papua, reflecting a broader ecological tolerance and dispersal capacity within the island. Seven species are shared between Papua, Indonesia, and Papua New Guinea, highlighting historical connections and biotic exchange across the central mountain ranges that

separate the two regions. The presence of one species shared between Vogelkop and Papua New Guinea, and one species distributed in both New Guinea and Maluku [Maluku Islands (Moluccas)], indicates that some taxa have broader dispersal mechanisms, potentially facilitated by past land bridges or long-distance seed dispersal events. Notably, the occurrence of one species endemic to Waigeo Island [in the Raja Ampat Island Archipelago of Papua] demonstrates that even nearby islands harbour unique lineages of *Rhododendron*, likely resulting from island isolation and limited gene flow. Overall, the observed distribution patterns support the hypothesis that the Vogelkop region has a distinct floristic composition shaped by both historical geological processes and contemporary ecological factors. The high endemism and varied distribution of *Rhododendron* species underscore the importance of this region as a biodiversity hotspot and as a natural laboratory for studying plant evolution and biogeography in New Guinea.

Conservation status varies among the recorded taxa:

1) Six species are classified as Data Deficient (DD) due to limited information on population size, distribution, and ecology, including *R. proliferum*, *R. brentelii*, *R. cornu-bovis*, *R. porphyranthes*, *R. mulyaniae*, and *R. engelbertii*.

2) Eighteen species are considered of Least Concern (LC), such as *R. lindaueanum* var. *lindaueanum*, *R. pulleanum* var. *maiusculum*, *R. erosipetalum*, *R. konori* var. *konori*, *R. konori* var. *phaeopeplum*, *R. asperum*, *R. phaeochristum*, *R. syringoideum*, *R. brachypodarium*, *R. inconspicuum*, *R. papuanum*, *R. laetum*, *R. macgregoriae*, *R. arfakianum*, *R. angiense*, *R. glabrifillum*, *R. zoelleri*, and *R. porphyranthes*.

3) Three species are considered Vulnerable (VU): *R. hatamense*, *R. hirtolepidotum*, and *R. englerianum.*

4) *R. bullifolium* is classified as Critically Endangered (CR), reflecting its extremely high risk of extinction in the wild.

The diversity of conservation statuses underscores the need for continued field surveys, population monitoring, and conservation efforts to improve understanding and protection of *Rhododendron* species in Vogelkop and adjacent regions.

Effect of Climatic Factors on Root Metabolites of *Rhododendron anthopogon*, an Alpine Himalayan Shrub

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Climate change profoundly impacts plants, which as a result have developed sophisticated adaptation strategies, primarily through metabolic adaptability. This involves primary metabolites like carbohydrates and proteins, and secondary metabolites like alkaloids and flavonoids, which support stress responses and biotic interactions. These metabolites are influenced by changes in temperature and moisture. The effects of temperature and moisture occur in combination as well. In our study, we are trying to understand how temperature, moisture and their interactions affect plant root metabolome [the total number of metabolites present], using the alpine Himalayan dwarf shrub *Rhododendron anthopogon* (Ericaceae) as a focal species. This species, native to Himalayan high-altitude environments, occurs along a wide climatic gradient and thus provides an ideal model for examining root metabolic responses to climate.

Our study design comprised of five sites along a precipitation gradient and at each site, we selected three elevations, giving a total of 15 populations. In each population, three plots were selected from a vegetation patch dominated by *R. anthopogon*. From each plot, three root samples from three individuals were collected. This resulted in nine samples per population. In addition, we also collected three soil samples from each population to study the confounding effects of soil chemistry on root metabolites, as that also changes along a climatic gradient. We used an untargeted metabolomics approach using LC-MS [a two-part technique that first uses liquid chromatography (LC) to separate metabolites in a sample and then uses mass spectrometry (MS) to identify and quantify them]. Our results showed that root metabolic profiles were most strongly affected by moisture, followed by the interactive effects of temperature and moisture in both the ionization modes. Both primary and secondary metabolite classes were affected by temperature, moisture, and their interaction. Amongst the primary metabolite classes, fatty alcohols, organic acids, and medium-chain fatty acids

were most affected. Secondary metabolite classes affected include triterpenoids, flavonoids, o-glycosides, and hydroxybenzaldehydes. Our results showed only soil electrical conductivity and soil nitrogen level impacted the root metabolic profiles significantly. Accounting for the soil chemistry did not modify the climate effects. This research highlights the effect of changing climatic factors on plant root metabolites using a metabolomics approach, as metabolic changes help plants fight against climatic stress.

Growth Dynamics of the Himalayan Alpine Shrub *Rhododendron anthopogon* across Climatic Gradients

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Global climate change is having significant effects on plant growth patterns, and mountain plants can be particularly vulnerable to accelerated warming. Rising temperatures are releasing plants from cold limitation, such as at high elevations and latitudes, but can also induce drought limitation, as documented for trees from lower elevations and latitudes. Here we test these predictions using a unique natural experiment with the Himalayan alpine shrub *Rhododendron anthopogon* (Fig. 11) and its growth responses to changing climate over a large portion of its latitudinal and elevational ranges, including steep precipitation and temperature gradients. We determined growth dynamics during the last three decades, representing period of accelerated warming, using annual radial growth increments (Fig.12) for nine populations growing on both wet and warm southern localities and drier and cold northern localities in the Himalayas along elevation gradients encompassing the lower and upper species range limits.

Figure 11. *Rhododendron anthopogon*

A significant growth increase over the past decades was observed after controlling for confounding effect of shrub age and microsites. However, the magnitude of

increase varied among populations. Particularly, populations situated in the lower elevation of its northernmost (cold and dry) distribution exhibited most substantial growth enhancement. The relationship between growth variability and climate varied among populations, with the populations from the coldest location displaying the strongest responsiveness to increasing minimum temperatures during July. Minimum temperatures of April and August were the most important factor limiting growth across most populations. Potential warming-induced drought limitation had no significant impact on growth variation in any part of the species geographic range. Overall, our findings indicate that plant growth has continuously increased in the recent decades and growth-climate relationships are not consistent across populations, with populations from the coldest and wettest localities showing stronger responses. The observed patterns suggest that these dwarf shrubs are benefiting from ongoing warming, leading to the increased shrubification of high elevation alpine ecosystems.

Figure 12. A wood cross-section of *R. anthopogon*. The wood is stained to show the cell walls in purple, and the xylem vessels are open holes in the cross-section. The dark purple material at the top of the image is bark, including the phloem. The growth rings are visible as arcs crossing the image horizontally, with the oldest growth rings at the bottom. Thicker rings indicate years with more growth, thinner rings represent years where the plant grew less. The image shows ten growth rings, indicating ten years of growth for this plant, and this information was used to determine the growth dynamics of the plants over time.

Rhododendrons and their Association with Climate and Pollinators

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Mountains are recognized as biodiversity hotspots, supporting a substantial proportion of the world's flowering plant species. The high biodiversity is largely attributed to the strong variations in environmental conditions along the elevation gradient, which leads to variations in plant ecology - including species composition, phenology, lifeforms, leaf and flower traits. Among these, floral characteristics are often shaped by the selection imposed by pollinators whose composition and diversity also shift with the elevation. I provide insights into how rhododendrons function as a model system within mountain ecosystems to help understand the influence of abiotic and biotic factors in maintaining plant diversity on the local, regional and global scales. At the local scale, I describe a case study from the Sikkim Himalaya (Fig. 13, 14), highlighting how phenology (e.g.,

Figure 13. Monitoring *R. wightii* phenology at 3100 m (10,170 ft) in the Indian Sikkim Himalaya

flowering, fruiting) and community assembly of rhododendrons are closely linked to climate and evolutionary history. Further, at the regional level, I compare the pollinator visitation, pollination syndrome and their interaction with climate in rhododendrons from the Appalachian and Indian Himalayas. At the global level, I share our preliminary findings on the evolution of floral traits in *Rhododendron* species. Finally, I provide future perspectives on the limitations and knowledge gaps in *Rhododendron* research.

Figure 14. *Rhododendron* in full bloom in the subalpine forest at 3700 m (12,140 ft), Sikkim India.

Vireyas in Culture in a Recreated Landscape and as a Container Plant under North German Climate Conditions

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The Stiftung Bremer Rhododendronpark has the world largest collection of rhododendrons, including species, hybrids, vireyas, azaleas, etc. My responsibilities are both to maintain plants in the Borneo and New Guinea greenhouse of the Botanika Science Centre and to propagate and cultivate both nonwinter-hardy and winter-hardy rhododendrons from seeds, cuttings and graftings to flowering size at the propagation centre of the Stiftung Bremer Rhododendronpark. Vireyas (tropical rhododendrons) are cultivated as terrestrials, epiphytes and lithophytes in a recreated landscape in the Borneo and New Guinea greenhouse with its concrete rock monument of "Mt. Kinabalu".

In this landscape, vireyas are being grown with trees, tree ferns, shrubs, grasses and other companion plants to create a natural perspective, i.e., not just a collection status. In the propagation centre, vireyas are cultivated from seeds and cuttings in different substrates in special containers and boxes from small to large-sized plants. Two different climate rooms are used for the cultivation of vireyas, one for the warm-loving (lowland species) and one for the colder-loving ones (highland species). Needed technical equipment makes the cultivation of vireyas successful under North German weather conditions.

I also give an overview of my breeding program, which has been running since 1999 and how it has changed over time. Using peat in plant substrates will no longer be allowed in Germany after 2030, and so I am now assessing whether vireyas from seedlings can be grown in a mineral substrate. I will show what happened during the last three years. The Stiftung Bremer Rhododendronpark has the mission to save diversity within the genus *Rhododendron*. The Bremen Rhododendronpark is thus a "living-collection".