



# Niagara Rhodo



Newsletter of the Niagara Chapter, Rhododendron Society of Canada  
District 12, American Rhododendron Society  
Our website: [www.rhodoniagara.org](http://www.rhodoniagara.org)

## Special Edition!

**Our Purpose:** We are a non-profit organization whose aim is to promote, encourage, and support interest in the genus *rhododendron*. Our goal is to encourage gardeners to grow and appreciate these plants by providing educational meetings with knowledgeable speakers, access to topical publications, and hosting joint meetings with other chapters.

**Word of Caution:**

By becoming a successful grower, the reader will be exposed to a contagion for which there is no cure. Once infected with an appreciation of rhododendrons and azaleas, most gardeners spend a lifetime collecting these most beautiful of all plants.

*H. Edward Reiley*

## *The Secret Life of Rhododendron Roots – a dramatic tale of diversity, divergence and disease resistance*

Presented by Dr. Juliana S. Medeiros  
November 11, 2018 - SRS Niagara Chapter Fall Meeting  
Summarized by Dixie Szasz-Taylor

A fascinating, complex topic and yes, quite an eye-opener for most of us! In short, Juliana's exceptional talk, full of eye-catching visuals, was well received by a large Niagara Chapter audience at the November 2018 meeting. Based on a previous ground-breaking paper, Juliana presented the results of her work on the dramatic diversity of roots within genus *Rhododendron* from montane tropical forests to arctic tundra (Medeiros et al, 2017). As such, she discussed the ecological and evolutionary implications, followed by the preliminary results of her present research focus - the complex interactions or mutualism between rhododendron roots and specialist ericoid mycorrhizae, and other good and bad soil microbes.



Juliana is the principal investigator at the Holden Arboretum's Medeiros laboratory in Holden Forests and Gardens, Kirtland, Ohio, and lead for the 'ARS Rhododendron Research Network', designed to build liaisons between ARS members, international research scientists, and *Rhododendron* hybridizers. Her lab is now focused on *Rhododendron* as a model system to understand how plant traits evolve in response to the environment. She obtained her PhD in the physiology of desert shrubs from the University of Mexico, and is now a Professor at two American Universities, as well as a dynamic, popular speaker actively involved in Youth and Adult Outreach science education programs.

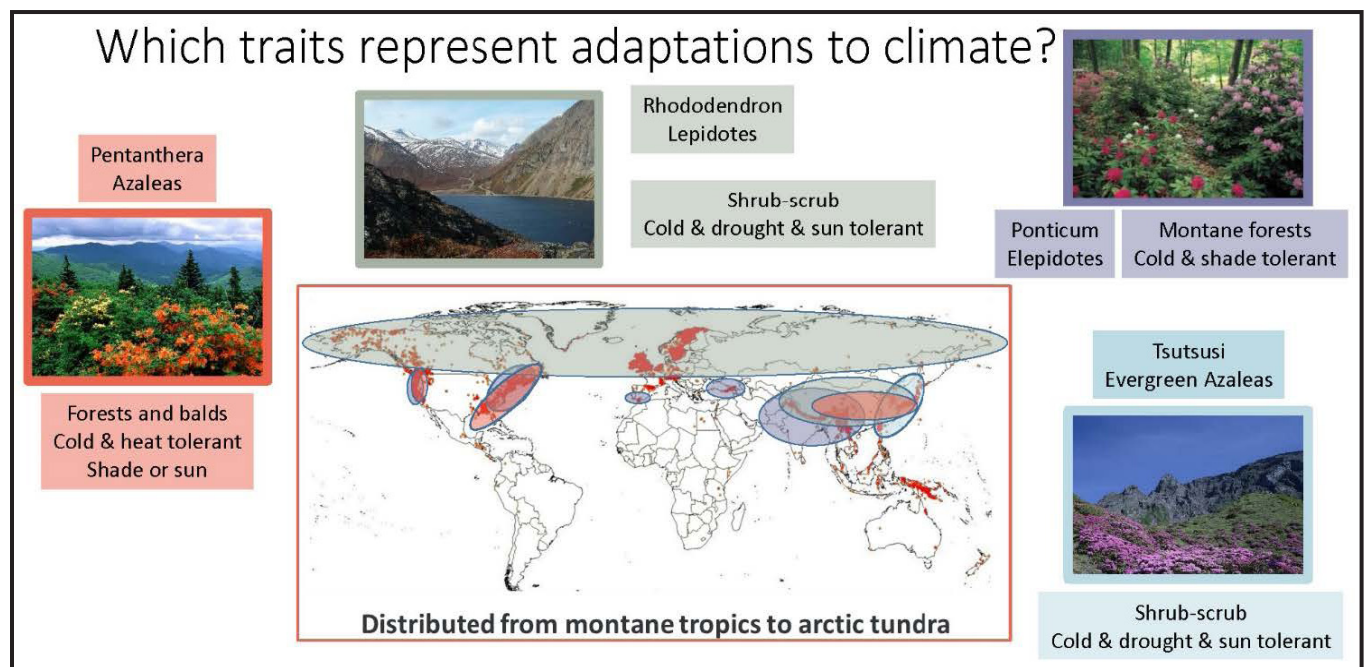
## Introduction:

The presentation addressed eight main themes: climatic diversity, root diversity? investment strategies, roots and climate? working with microbes, good guys and bad guys, roots and microbes? and why do we care? Highlights were summarized as follows:

- Are *Rhododendron* roots diverse?
- Do Rhody root investment strategies differ across climates?
- Do different Rhody roots host different microbes?
- What are the implications for disease resistance, propagation and breeding, conservation and restoration?

Genus *Rhododendron* has a global distribution of about 800 to 1,100 species with significant habitat diversity ranging from montane tropical forests to arctic tundra. This includes four major clades or evolutionary groups with unique climate and environmental associations:

*Ponticum* evergreen elepidotes - montane forests, cold and shade tolerant; *Tsutsusi* semi-evergreen to evergreen azaleas - shrub and scrub, cold, drought and sun tolerant; *Rhododendron* evergreen to semi-evergreen lepidotes - shrub and scrub, cold, drought and sun tolerant; *Pentanthera* deciduous azaleas - forests and mountain meadows, cold and heat tolerant, shade or sun.



## Are Rhody roots diverse? Yes!

As soil specialists which thrive in low pH and low nutrient environments, 27 species of rhododendron were studied to determine why Rhody roots are so diverse (Medeiros, et al, 2017). In general, roots are dependant on a complex soil ecosystem that includes nutrients, water, good and bad soil microbes, where climate seasonality and temperature are also extremely important.

## Investment strategies

Root structure can be characterized as an investment strategy, where roots represent the infrastructure for soil resource acquisition, and investment in roots determine uptake rates for nutrients and water. When nutrient or water supplies are high or rapid, carbon priority is for leaves, wood, flowers or seeds, but when supplies are low or slow, carbon allocation shifts back to roots, and more wisely to particular kinds of roots.

Absorption which happens at the root surface is facilitated by root diameter primarily. Thinner roots, for example, have a higher surface area to volume ratio. Root length, however, in the form of long thin roots can explore and absorb from larger areas, whereas root tip abundance is an adaption for exploring smaller soil volumes more efficiently. Roots also store and distribute photosynthesis-derived carbohydrates from which carbon, the ultimate building block for all plant proteins and cell walls, is derived. During climate stress or greater seasonality, root survival depends on extra carbon allocation to roots.

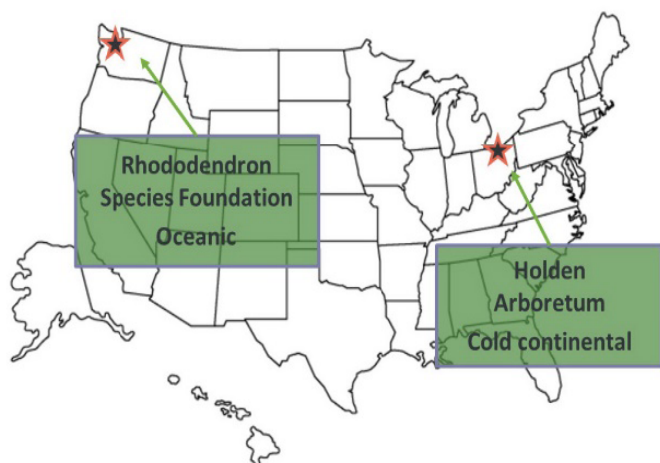
For example, with a warmer, wetter climate and constant supply of nutrients, faster growth is characterized by higher Specific root length, SLA; or, depending on Rhody species, greater Specific root tip abundance, SRTA, both designated as acquisitive growth traits. But under stressful colder conditions, different roots including the right kind of roots are needed for survival. Survival of the fittest may actually mean shorter, thicker roots, where higher LAL, root link average length, or greater FOD, first order root diameter are designated conservative traits linked to slower growth (Medeiros et al, 2017).

More evidence of the effects of climate on resource use and availability can be seen with two widely separate Rhody species: *R. brookeanum* found in the warm, damp climate of Mt. Kinabalu, Borneo, where faster growth combined with rapid decomposition and nutrient recycling rates suggests less carbon investment in roots and shorter root life. In contrast, *R. groenlandicum* found in the cold, damp climate of Wedgemount Lake in B.C, Canada, where slow growth combined with slow decomposition and nutrient recycling rates suggests greater survival potential of more carbon investment in roots.

## Do *Rhody* root investments differ across climates?

### Study of two botanical collections

- 25 species - taxonomic and climate diversity
- Compare warm and cold sites



Medeiros et al. 2017

### Do *Rhody* root investment strategies differ across climates? Yes!

Further studies compared 25 species of rhododendron at two separate locations in the U.S. - the warmer, less seasonal climate on the west coast at the 'Rhododendron Species Foundation', in Washington State, and the cold continental climate of Holden Arboretum in Ohio. Observations of faster growth on the west coast and slower growth at Holden Arboretum confirmed that under good growth conditions where resource acquisition is fast, Rhody roots respond with increased, thinner root length (SRL), or higher root tip abundance (SRTA) per unit of carbon, but have shorter root life, in contrast to thicker roots and longer life at Holden Arboretum.



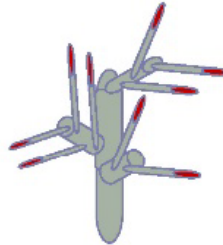
# Divergence! Root foraging strategy differs among clades

Ponticum  
Elepidotes



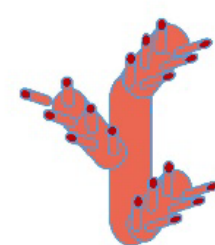
**No relation**  
to climate

Rhododendron  
Lepidotes



**Increase scale**  
More root length per carbon  
~ faster growth in warm climate

Pentanthera  
Azaleas



**Increase precision**  
More root tips per carbon  
= **faster** growth in warm climate

Medeiros et al. 2017

Interestingly, studies also showed different leaf-root relationships or divergence patterns between species in the Rhody clades in response to climate. For example, in the evergreen *Ponticum* elepidotes, observations suggested an evolutionary divergence or decoupling between root and leaf traits, and only a weak link to climate effects. But in the evergreen to semi-evergreen *Rhododendron* lepidotes, faster growth in warm climate resulted in increased specific root length, SRL, suggesting lepidote root traits are closely related to climate, not leaf traits. In contrast, deciduous *Pentanthera* azaleas showed increased specific root tip abundance, SRTA with faster growth, also suggesting strong links to climate, not leaf traits.

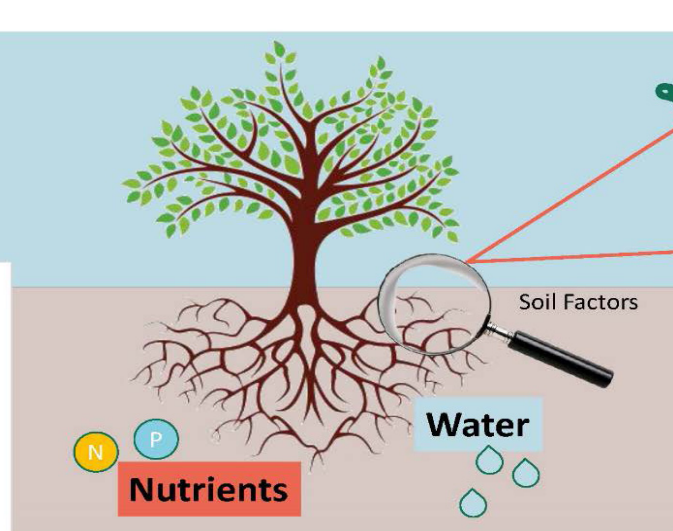
But as Juliana emphasized, observations don't always fit expectations when trying to compare various *Rhododendron* species' root adaptations to cold and warm environments. It does make sense, however, that the effect of climate differs among the Rhody clades, and that there are many distinctly different driving factors and foraging strategies between and within the various clades (Medeiros et al, 2017).

## Stressed out? Build it stronger with more carbon

Specific root tip abundance

Specific root length

Absorbing root diameter



Short, fat roots with thick cell walls  
Less surface per sugar  
=  
Costly infrastructure  
Growth is slow  
**but**  
More resistant to stress  
Long-lived

## Working with soil microbes and ericoid mycorrhizae to leverage investments

According to microbial geneticists, a teaspoon of healthy soil can contain at least a billion invisible bacteria, several yards of invisible fungal hyphae, several thousand protozoa, and a few dozen nematodes, and they all need carbon to survive (Lowenfels & Lewis, 2010). Opportunistic soil microbes and specialist ericoid mycorrhiza certainly affect Rhody root function as well.

In a time of climate change, no surprise that mycology today is considered one of the fastest growing scientific fields. Mutualist mycorrhizae fungi which exchange soil- derived nutrients and water for plant-derived sugars or carbon, can grow on or inside roots - in the process increasing root surface area by 100X to 1000X.

There are three main types of mycorrhiza: Arbuscular mycorrhiza, at 80% the most common throughout the plant kingdom, growing into root cells or root hairs; Ectomycorrhiza growing on the surface of roots, and specialist Ericoid mycorrhiza in or on Rhody roots which may host up to six or eight different mycorrhizae. Some may even have evolved as opportunistic saprophytes with the ability to switch over to mutualistic roles with living plants under the right conditions (Vohnik et al, 2012).

## Good guys and bad guys

Rhododendron clades are known to form mutualistic relationships with many different specialized mycorrhizae and other soil microbes. For example, the ericoid mycorrhiza, *Oidiodendron* is commonly found associated with all four clades, whereas another ericoid mycorrhizae may be associated with only one clade. Elepidotes also form mutualistic relationships with Ectomycorrhizae, whereas species of Arbuscular mycorrhizae have only been observed in lepidote species.

In addition, there are many anti-microbes in the soil known to affect roots of certain *Rhododendron* lepidotes and evergreen *Tsutsusi* azaleas, including *Penicillium*, *Pseudomonas*, *Streptomyces*, and *Trichoderma*. Clades also have many soil enemies or pathogens such as *Armillaria*, *Rhizoctonia*, *Cylindrocladium*, *Pythium* and notably *Phytophthora*, a plant killer.

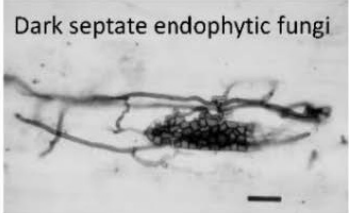
## The good, the bad and the unknown

Intriguing dark septate endophytic fungi (DSEF) with unknown functions have also been identified within Rhody roots, but many other potential root associations from mutualistic mycorrhizae to anti-microbes or pathogens have not been investigated to date, as seen in the Table below. Juliana stressed the importance of a multidisciplinary approach to successfully resolving all the many unknowns.

The good, the bad and <i>the unknown</i>					
Microbial genera	Putative function	Azalea	Elepidote	Lepidote	Ev. Azalea
Oidiodendron	Ericoid mycorrhizae				
Leotiomyce	Ericoid mycorrhizae	?	?		?
Meliniomyces, Rhizocyphus, Sebaciales	Ericoid mycorrhizae	?		?	?
Cenococcum, Russula, Thelephoraceae, Tricholoma, Helotiales	Ectomycorrhizae	?		?	?
Various sp.	AM mycorrhizae	?	?		?
Penicillium, Pseudomonas, Streptomyces, Trichoderma	Anti-microbial	?	?		
Armillaria, Rhizoctonia, Cylindrocladium	Pathogen	?		?	
Pythium	Pathogen		?	?	
Phytophthora	Pathogen	?			
Phialocephala, Cryptosporiopsis, Leohumicola, Neonectria, etc.	Unknown	?			?

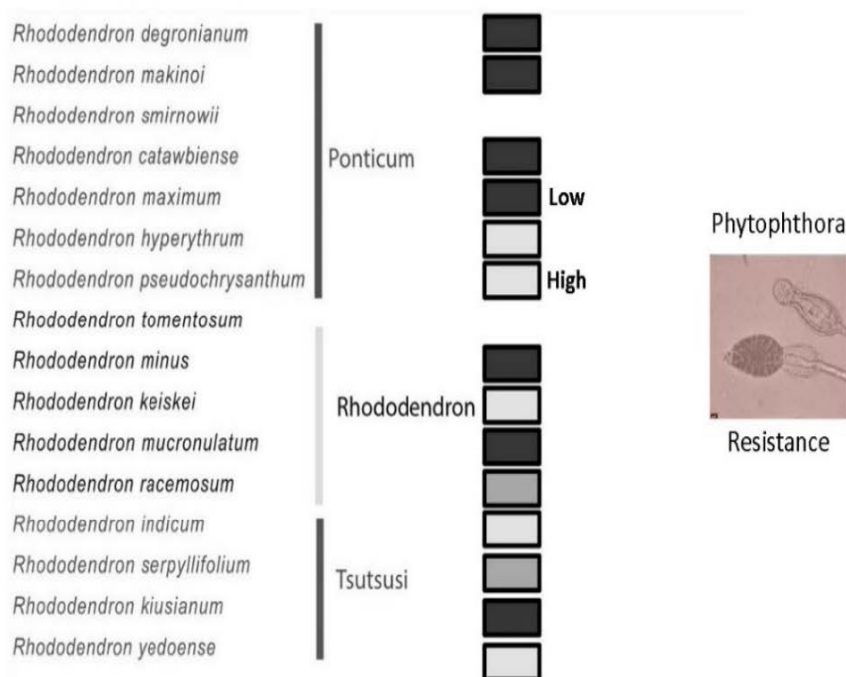
Soil decomposer?  
Inhibit disease microbes?  
Assist stress response?

Dark septate endophytic fungi



Truth is, most possibilities have not been investigated!

## Disease resistance also varies within clades



As seen in the above diagram, disease resistance to *Phytophthora* also varies within clades.

## Do different Rhody roots host different microbes? Yes!

This was confirmed when 12 species from the four clades were studied for taxonomic and climate diversity, as well as *Phytophthora* resistance in Washington State at the warmer west coast, and colder, continental Holden Arboretum sites. State-of-the-art DNA sequencing scores identified communities of unidentified root microbes, including possible mycorrhizae. One of the main observations, however, was that not only different types of Rhody roots host different communities of microbes, but also *Phytophthora*-resistant species have different root traits with different communities of microbes compared to susceptible species. In conclusion then, differences in root and soil microbial communities have an impact on plant health and survival (Medeiros pers. com., 2018, & Medeiros et al, in Prep.).

## What are the implications of ericoid root mycorrhizae and soil microbes?

1. **Propagation** – factors affecting plants such as climate and soil conditions also affect soil microbes. Combined with poor planting or horticultural practises, many soil amendments such as excessive organic or inorganic fertilizers and pesticides can kill or discourage good microbes.
2. **Disease resistance** – encouraging good microbes like ericoid mycorrhiza *Oidiodendron*, or anti-microbes like *Penicillium* or *Trichoderma* can make it harder for bad guys like *Phytophthora* and *Armellaria* to get a foot-hold.
3. **Breeding** – capitalize on variation within clades and selection of disease resistant species such as *R. hyperythrum* to create disease resistant, hot and cold tolerant hybrids. But also capitalize on the as yet poorly understood interactions of Rhody roots with specialist ericoid mycorrhizae, and other good and bad soil microbes.
4. **Conservation and restoration** – understand the unique and complex soil ecosystems in which genus *Rhododendron* thrives, and use this as a model for 're-wilding,' or restoration of biodiversity in other damaged natural environments, forests and wildlife habitats.

## But what we do know is...a lot more remains to be discovered!

**Special thanks** to Martin Taylor for his invaluable technical support in organizing the selection of pictures and figures.

## Selected References:

Lowenfels, J, Lewis, W, 2010. Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web, 220pp. Publishers, Timber Press, Inc., Portland, Oregon.

Medeiros, J.S, Burns, J.H, Nicholson, J, Rogers, L, & Valverde-Barrantes, O., 2017. Decoupled leaf and root carbon economics is a key component in the ecological diversity and evolutionary divergence of deciduous and evergreen lineages of genus *Rhododendron*. American Journal of Botany 104: 1-14.

Vohnik, M, Sadowsky, J, Kohot, P, Lhotakova, N, & Kolarik, M., 2012. Novel Root-Fungus Symbiosis in Ericaceae: Sheathed Ericoid Mycorrhiza formed by a hitherto undescribed Basidiomycetes with affinities to Trechisporates. PLOS 1: 7(6).