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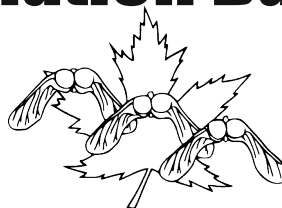
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The Canadian Botanical Association Bulletin



Bulletin de l'Association Botanique du Canada

September/Septembre 2015. Volume 48 N°2

Dear CBA/ABC members,

One of things I've always liked about CBA meetings is their laid back pace. There always seems to be time to chat with colleagues, meet new people, and with a limited number of sessions, learn about research in other fields. This year our annual meeting was like no other. Botany 2015 brought together 13 different societies from Canada and the US. The activities and needs of the different societies obviously created huge organization challenges, which were mainly taken care of by our colleagues at the Botanical Society of America. With 17 workshops, 22 field trips and up to 13 concurrent sessions taking place the meeting had a lot to offer to attendees. However, joint meetings can simply turn into parallel a number of meetings if the organizers don't make an effort to bring the different groups together. I think the CBA/ABC did a pretty good job in that respect. Our mycology section ran a joint symposium with the Mycological Society of America. Our development, ecology and teaching sections held joint symposia with their Botanical Society of America counterparts. Also, For the first time, Plant Canada put together a joint symposium of its Canadian societies.

I'd like to thank everyone that helped make this meeting a success, including, Diane Haughland for organizing field trips, Christine Peterson, Nicole Fenton, Moira Galway, Shannon Berch and Hugues Massicotte for organizing symposia, and Jocelyn Hall for acting as our local representative.

Finally, I'd like thank the board members who are stepping down and welcome our new board members. Our two new student reps are Pauline Catling and Warren M. Cardinal-McTeague. Julissa Roncal is our new board member from the east and Melanie Jones is our member from the West. Julia Nowak is taking over as our new Secretary.

John Markham, CBA President



John Markham

The Canadian Botanical Association Bulletin

The CBA Bulletin is issued three times a year (March, September and December) and is freely available on the CBA website. Hardcopy subscriptions are available for a fee.

INFORMATION FOR CONTRIBUTORS

All members are welcome to submit texts in the form of papers, reviews, comments, essays, requests, or anything related to botany or botanists. For detailed directives on text submission please contact the Editor (see below). For general information about the CBA, go to the web site: <http://www.cba-abc.ca>

Bulletin de l'Association Botanique du Canada

Le Bulletin de l'ABC paraît trois fois par année, normalement en mars, septembre et décembre. Il est envoyé à tous les membres de l'ABC.

SOUSSION DE TEXTES

Tous les membres de l'Association sont invités à envoyer des textes de toute nature concernant la botanique et les botanistes (articles, revues de publication, commentaires, requêtes, essais, etc.). Tous les supports de texte sont acceptés. Pour des renseignements détaillés sur la soumission de textes, veuillez consulter le rédacteur (voir ci-dessous). Infos générales sur l'ABC à l'URL suivant: <http://www.cba-abc.ca>

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NEXT ISSUE / PROCHAIN NUMÉRO

Texts for the next issue, 48(3), must be received by December 1, 2015
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The Shaw Conference Center in Edmonton, location of the 2015 CBA Meeting



Julian Starr (U. Ottawa, left) and his student Étienne Léveillé-Bourret (right), recipient of the 2015 Porsild-Consaul award for best student paper in systematics

PAST-PRESIDENT'S REPORT FROM THE 2015 AGM – UPDATED

Frédérique Guinel¹

Continuance Process

CBA has successfully continued under the Canada Not-for-Profit Corporations Act on July 14th, 2014; as such, Canada Revenue Agency has acknowledged the Continuance in a letter dated September 8th, 2014. Once the process was completed with the federal government, we applied for Charitable status in Ontario (because the Association was created in Ontario) and in Québec (because the office of the Association is in Montreal). With the help of our lawyer, Jennifer Leddy from Carters Professional Corporation, these two tasks have been completed. Ms. Leddy wrote to the CBA a final reporting letter which will be useful in the future for any new CBA officer. The (new) Operating Bylaw has been translated in French and will be posted soon on our web-site.

Archives

Our Archives are now in Library and Archives Canada (LAC) and we have been assigned an Archivist for our collection. All items deposited last year have now been processed by the Archivist Mélody Béland. Mélody has promised a report for the next issue of the Bulletin which will let the members know how the CBA materials have been organized. Members should be reminded that the documents that are in the Archives are now owned by LAC, and are accessible to any researcher interested in the CBA fund. Transferring ownership to LAC was one of the conditions that LAC had made before accepting to take the CBA materials. The next step for the CBA in the archiving will be to store all documents concerning the Continuance process; it has yet to be decided the form (electronic or hard copy) under which we have to store these documents. After a discussion at the Executive meeting in January 2015, it was decided that I would be the primary contact of the CBA for the collection. If you have anything related to CBA that you think would be interesting to the fund, please contact me at fguinel@wlu.ca

Future Meetings

I have compiled a list of all the locations where CBA met over the years since its inception. This list has been placed in the President's hands and should be consulted for planning the location of future meetings. The organization for the meeting in Victoria in 2016 is underway, and at the 2015 AGM the members have voted for Wilfrid Laurier University in Waterloo to host the annual meeting in 2017. We are still looking for a location for 2018 and are accepting bids for that year. In the meantime, we are also discussing the possibility for 2018 to meet with the Canadian Society of Zoologists in Newfoundland.

Manual Policy

With the help of previous officers, I have begun to update the Manual Policy of the Association, for which the last update was 2005. It is a good time to work on this task now that the Association has been newly incorporated. The duties of the President, President-Elect, Past-President, and Treasurer, and the planning of a meeting have all been reviewed and the corresponding sections just need to be fine-tuned. I will work on the other sections in the next 5 months so that the revised manual can be presented to the Board of Directors at the next Executive meeting in January. I will call through the Fall term on the appropriate (past) officers to help me revise the remaining sections.



Current CBA President John Markham delivering his report at the AGM in Edmonton

¹Past-President of the Canadian Botanical Association

MYCOLOGY SECTION NEWS

Mycena Workshop

First and foremost, many members of the Mycology section were able to participate to the *Mycena* workshop, held a day before the official opening of the Botany 2015 meeting in Edmonton. The full day workshop was expertly led by Roland Treu and Brian Perry, with Mary Berbee, and a clutch of future “mycenologists” had a great time giving their best taxonomic appraisal to them.



Weresub Lecture

A distinguished crowd was delighted to hear Dr. Lynne Sigler, professor-scientist at the University of Alberta and the Devonian Botanical Garden, deliver a wonderful Weresub presentation on the benefits and challenges of curating and maintaining the University of Alberta Microfungus Collection and Herbarium (UAMH).



Weresub Award

In other news, the winner of the Weresub Award for Best Student Publication in fungal biology was Santiago Sánchez-Ramírez, with his contribution in the *Journal of Biogeography* (see the details elsewhere in this issue). Congratulations and thank you to all Weresub contenders for their submissions.

Other News

At our section meeting, a group of us discussed themes and ideas that could be used for possible symposia in Victoria (2016) and beyond, and for potential Weresub lecturers. If anyone has further suggestions regarding any of these topics, forward these to either Shannon or me, as we will be discussing further during the coming months.

Respectfully submitted,
Hugues Massicotte and Shannon Berch
Co-Chairs of the Mycology Section

TEACHING SECTION NEWS

The Teaching Sections of the Canadian Botanical Association (CBA), the Botanical Association of America (BSA) and the Canadian Society of Plant Biologists (CSPB) recently hosted a very successful joint Teaching Symposium at Botany 2015 in Edmonton July 25–29, 2015, titled “Blended Learning and Educational Technology to enhance Biology”, a very current direction in education in both Canada and the USA. For your interest, here is a summary of the talks given by the international speakers, with their abstracts:

BEYOND BLENDED: MULTI-ACCESS AND CONNECTED LEARNING TO SUPPORT LEARNER ENGAGEMENT AND ACCESS **VALERIE IRVINE, UVic TIE RESEARCH LAB** ([HTTP://TIE.UVIC.CA](http://tie.uvic.ca)) VIRVINE@UVIC.CA

Major shifts in education are pushing instructors to consider best ways to support their learners and to meet them where they are at. Unfortunately, traditional structures often still exist to serve as barriers for change. In this session, evidence is presented to challenge why we have those traditional structures and strategies are shared to support truly learner-centred education. We will discuss multi-access learning, personalization, openness, connected learning, and assessment for learning.

STRATEGIES TO ENHANCE STUDENT LEARNING **PETER ARTHUR PETER.ARTHUR@UBC.CA**

The creation of pre-lab videos, open educational resources and two stage exams are strategies to enhance the learning experience for students. To fully utilize lab time, faculty are creating pre-lab videos that provide students with an asynchronous rich media experience that prepares students for labs and reduces the time needed for lab instructions. In addition, instructors are creating and sharing botany related resources with a creative commons licenses that provide instructors will valuable resources to enhance student learning in and out of the classroom. These open educational resources are slowly being adopted by instructors. Finally, two stage exams provide students with an alternative assessment experience that promotes learning!

THE LECTURE HALL AS AN ARENA OF INQUIRY: USING CINEMATIC LECTURES AND INVERTED CLASSES (CLIC) TO FLIP AN INTRODUCTORY BIOLOGY LECTURE COURSE **DAVID J MARCEY MARCEY@CLUNET.EDU**

Two sections of an introductory Biology lecture course (Introduction to Metabolism, Genes and Development) were run in parallel as a pedagogical experiment. One section was taught in a long-established, traditional manner, with lectures delivered during class, readings assigned in a textbook, and access to lecture graphics/slides provided via the online syllabus. The other, “flipped” section lacked both required reading assignments and in-class lectures.

Instead, students were assigned online cinematic lectures (cinelectures) for viewing outside of class. These cinelectures, delivered via YouTube, incorporate multiple presentation media. In class, students were broken into small groups and conducted learning activities that varied from building physical molecular models to constructing concept maps of key topics. Often, these groups were responsible for presenting material to the class as a whole. Accounting for all sources of content, the subject material covered was the same for both sections and assessments of learning were identical quizzes and examinations. Statistically significant differences in learning were observed during the first half of the semester, with the flipped-class students performing better on all tests and quizzes. These differences disappeared in the second half of the semester, coincident with a large increase in the number of views of cinelectures recorded on the course YouTube channel. Survey of the traditional class revealed that approximately 2/3 of the students had learned of the cinelectures at this time and had added viewing of these to their study, providing an internal, if initially unintended, control sample to the experiment. These results, along with other analyses to be presented, provide strong evidence that supports the conversion of traditional Biology lecture classes to a flipped model.

Web Links for a flipped Biology course: Introduction to Metabolism, Genes, and Development, a.k.a “The Flow of Life”: <https://www.youtube.com/user/dmflyboy>



The CBA Teaching Section in action at the 2015 CBA meeting in Edmonton

COUNTING THE FOREST AND THE TREES: QUANTITATIVE UNDERGRADUATE BIOLOGY EDUCATION AND SYNTHESIS (QUBES) IS A TOOL FOR VISION AND CHANGE
DOROTHY BELLE POLI POLI@ROANOKE.EDU

Vision and Change stressed the importance of quantitative skills for the future of science in the United States. In response to this plea, biologists and mathematicians came together to discuss quantitative education, and QUBES (Quantitative Undergraduate Biology Education and Synthesis) was born. QUBES was recently awarded a five-year grant from the Improving Undergraduate STEM Education (IUSE) Program at the National Science Foundation, and aims to improve learning opportunities for all students enrolled in undergraduate biology courses. This presentation will focus on how QUBES plans to achieve this goal (for example, through mentoring networks and an online Hub of collaborating educators) and how you can get involved in this new community.

Web Links: Quantitative Undergraduate Biology Education and Synthesis: <http://www.qubeshub.org>

BLENDED STRATEGIES FOR SCIENCE
MELISSA JAKUBEC MJAKUBEC@TRU.CA & MICHELLE HARRISON MHARRISON@TRU.CA

As instructional designers we face the challenge of providing laboratory experiences for our learners completing courses at a distance. We will describe our experiences creating opportunities for learners to engage in inquiry-based learning through online, field, and home-based laboratory experiences. Using blogs to document and share field studies in ecology, remotely accessing chemistry equipment, and completing experiments through lab kits while studying at a distance are all ways we can create engaging experiences that meet required learning outcomes for science. We will also share multi-media pieces developed for Plants and Society, as well as Immunology courses, which can enrich any learner's experience.

Sincerely,
Christine Petersen, CBA Teaching Section Chair.
Carina Anttila-Suarez, BSA Teaching Section Chair.
Santokh Singh on behalf of Madoka Gray-Mitsumune, CSPB.

Botany on the Edge / Botanique de Pointe

Canadian Botanical Association / L'Association Botanique du Canada
May 15th - May 18th, 2016
University of Victoria
Victoria, British Columbia

Join us next spring on beautiful southern Vancouver Island
Visit Garry Oak meadows, coastal rainforests, beaches & bogs on the wild west coast
Engage with exciting botanical and mycological research happening across Canada

More information coming soon at www.cba-abc.ca and in the CBA/ABC Bulletin

2015 CBA AWARD RECIPIENTS

Each year the CBA gives student awards for travel to an annual meeting, travel for research, publications in each of the CBA/ABC's sections, talks and posters at the annual meeting. We also give awards to established scientists for contribution to botany research, teaching and service to the association. Thanks to Ellen Macdonald, Line Rochefort and Jeff Saarela for sitting on the awards committee, and to our judges Paul Catling, Simon Chuong, Nicole Fenton, Jocelyn Hall, James Macklin, John Markham, Raf Offinowski, Larry Peterson, Mirwais Qaderi, and Line Rochefort.



Consaul Arctic Research Scholarship

This is the second year we have been able to offer this scholarship, due to the generous support of the late Laurie Consaul's husband, Mark Armstrong. This year's winners were Katy Alambo from the University of Ottawa and Cory Wallace from Wilfrid Laurier University. Both these students will be letting us know about their field season in upcoming editions of the Bulletin.



Awards For Student papers

PORSILD-CONSAUL AWARD FOR SYSTEMATICS AND PHYTOGEOGRAPHY

Étienne Léveillé-Bourret

Léveillé-Bourret, É., Gilmour, C.N., Starr, J.R., Naczi, R.F.C., Spalink, D., & Sytsma, K.J. 2014. Searching for the sister to sedges (*Carex*): resolving relationships within the Cariceae-Dulichieae-Scirpeae clade (Cyperaceae). *Botanical Journal of the Linnean Society* 176:1-21.

ROWE AWARD FOR ECOLOGY OR CONSERVATION

Alexandra Conway

Conway, A.J. and Danby, R.K. 2014. Recent advance of forest-grassland ecotones in southwestern Yukon. *Canadian Journal of Forest Research*. 44: 509-520.

Honorable mention: **Zoe Panchen**

TAYLOR STEEVES AWARD FOR PLANT STRUCTURE AND DEVELOPMENT

Teagen Quilichini

Quilichini, T. D., Douglas, C. J. & Samuels, A. L. 2014. New views of tapetum ultrastructure and pollen exine development in *Arabidopsis thaliana*. *Annals of Botany* 114: 1189-1201.

WERESUB AWARD MYCOLOGY

Santiago Sanchez-Ramirez

Sánchez-Ramírez, S., R. E. Tulloss, M. Amalfi & J.-M. Moncalvo. 2015. Palaeotropical origins, boreotropical distribution, and increased rates of diversification in a clade of edible ectomycorrhizal fungi (*Amanita* sect. *Caesareae*). *Journal of Biogeography*, 42: 351-363.

Annual CBA/ABC Meeting Awards

IAIN AND SYLVIA TAYLOR AWARD FOR THE BEST STUDENT POSTER

Dominic Smoluch

Honorable mention: **Jennifer Doering**

CINQ-MARS AWARD FOR THE BEST STUDENT ORAL PRESENTATION

Warren Cardinal-McTeague

Honorable mention: **Marion Barbe** and **Étienne Léveillé-Bourret**

MACOUN TRAVEL BURSARY FOR GRADUATE STUDENTS PRESENTING A PAPER OR A POSTER

Marion Barbe

Rebecca Bowler

Warren Cardinal-McTeague

Joelle Castonguay

Pauline Catling

Jennifer Doering

Dilukshi Fernando

Ian Girard

Sean Haughian

James Jones

Deidre Kahn

Etienne Léveillé-Bourret

Jenna Millar

Jocely Pender

Jianfei Shao

Domonic Smoluch

Kshitij Trivedi

WINTERHALDER TRAVEL BURSARY FOR UNDERGRADUATE STUDENTS PRESENTING A PAPER OR POSTER

David O'Leary-Ponzo



2015 Recipients of the Macoun Student Travel Bursary

REGIONAL AWARD WINNERS RECOGNIZED BY CBA/ABC IN 2015

At three student research conferences held across Canada during late winter and early spring of 2015, the CBA-ABC provided six awards (\$100 each) to CBA-ABC Regional Award winners. Recipients were senior undergraduate or graduate students who presented the best botanical talk or best botanical poster during those conferences. Details about the winning student presentations are given below.

Atlantic Region

THE SCIENCE ATLANTIC BIOLOGY AND AQUACULTURE & FISHERIES JOINT STUDENT CONFERENCES, UNIVERSITÉ DE MONCTON FROM MARCH 6-8, 2015

Best Oral Presentation in Botany

Michael Buckland-Nicks, (Saint Mary's University, Halifax) for "GIS-Based Analysis to Understand the Effects of Environmental Variability on the Growth and Success of Native Plants on Green Roofs"

Green roofs have a number of realized benefits including reducing stormwater runoff, saving building energy costs, and reducing the urban heat island effect. However, more research is needed to understand the effects of environmental variability on plants growing in these dynamic systems. In this study, Geographic Information Systems were used in conjunction with statistical analysis to uncover some of these relationships. 69 *Sibbaldiopsis tridentata* plants and 72 *Solidago bicolor* plants were monitored across an extensive green roof located in Halifax, Nova Scotia, from June 5th to November 10th, 2014. Plants were measured based on growth, survival, and reproductive success, and environmental data were also collected. Spatial information was obtained from the plants by turning the roof into a grid system. A 3D model of the roof constructed in ArcGIS was used to generate a solar radiation model and was incorporated into the analysis. Both species achieved fastest growth, but had a greater risk of mortality, where there was low vascular plant cover. Plant growth and survival were also greater with higher moisture, lower temperatures, and deeper soil. The data show that significant spatial environmental variability occurred across the green roof system. Furthermore, certain building features created detectable microclimates that influenced many plant and environmental variables. Geographic Information Systems not only provided the ability to visualize important spatial relationships but it also contributed significantly to the data analysis and ultimately to an increased understanding of the dynamic nature of the green roof system.



Best Poster in Botany

Strom Hardy (University of PEI) for "Analysis of the salt pan marine fungal community"

Decomposition and nutrient cycling play a vital role in salt marsh ecology. Natural soil depressions in marsh systems create ecologically distinct microcosms, called salt pans, where adapted species such as the marine macrophyte *Ruppia maritima* thrives in the dynamic salinity of the pan. As primary decomposers of plant material, distinct fungal communities thrive in these small pockets of marsh, tolerating the changing saline conditions and using available metabolic resources in the microcosm. Although salt marsh fungi have been studied intensively, especially saprophytes of *Spartina alterniflora*, a fungal catalogue of species specifically associated with the salt pan, including saprophytes of *Ruppia* have not been documented. To identify key fungal species involved in the decomposition of cellulose within the salt pan microcosm, fungal isolates were obtained from submerged and senescent plant material (of *Ruppia maritima* and *Spartina alterniflora*) along with pan sediment. Fungal isolates were identified using micromorphology and sequencing the ITS rDNA barcoding gene and evaluated for their ability to degrade cellulose over a range in salinity. By assessing the source and rate of occurrence of fungal isolates from the various substrata along with their ability to tolerate and actively degrade cellulose at various salinities, the specific ecological roles of the isolated fungi was inferred, providing insight into the role of the various fungal species within the salt pan community.



Ontario

ONTARIO BIOLOGY DAY 2015, CARLETON UNIVERSITY, OTTAWA, MARCH 21-25, 2015

Best Oral Presentation in Botany

James Santangelo (University of Toronto) for “Fungal endophytes of red fescue (*Festuca rubra*) increase host survival but reduce plant tolerance to simulated herbivory”

Fungal endophytes – fungi that live within plant tissues – are ubiquitous in nature and can have profound effects on the ecology and evolution of plants. While they may improve host plant responses to both biotic and abiotic stresses, they can sometimes act as pathogens and often impose metabolic costs on hosts. Here we examine the role of fungal endophyte communities in mediating responses of the host grass red fescue (*Festuca rubra*) to salt and herbivore stress. We collected 4 red fescue genotypes from its native range on Akimiski Island, Nunavut, Canada, where it occurs in the intertidal region on the northern part of the island and is heavily grazed by nesting and brood-rearing Lesser Snow (*Chen caerulescens caerulescens*) and Interior Canada Geese (*Branta canadensis*). We then conducted a fully factorial greenhouse experiment where we crossed genotype (4 levels) with simulated grazing (clipped or unclipped), endophyte status (present or absent) and salinity (0, 32 or 64 ppt). Overall, the presence of endophytes reduced plant mortality by 42%, although this effect depended on salt concentration. On the other hand, endophytes reduced plant tolerance to simulated herbivory. Thus, our results suggest a potential endophyte-mediated trade-off in host plant survival and tolerance to herbivory and suggest this trade-off may be altered by stressful abiotic conditions.



Best Poster Presentation in Botany

Haley Wilcox (Wilfred Laurier University) for “Arogenate dehydratase: Import into *Arabidopsis thaliana* chloroplasts”

Plastids, especially chloroplasts, are essential organelles to the plants in which they reside, as well as all aerobic life on Earth. As the site of photosynthesis, they provide the O₂ and organic molecules that support virtually all life. Plastids are also the site of other essential biochemical processes, including the biosynthesis of essential amino acids such as L-Phenylalanine, which is produced by the enzyme Arogenate Dehydratase (ADT). There are six ADT isozymes in the model plant *Arabidopsis thaliana*. In previous studies, fluorescently labeled ADT isozymes were shown to localize to chloroplasts using microscopy and were found in isolated soluble sub-chloroplast fractions. There has not yet been a study on the import pathway used by ADTs. It is hypothesized that ADT isoenzymes 4 and 6 from *A. thaliana* use the Toc-Tic pathway to gain entry to the chloroplast and that they are targeted using a transit peptide which is cleaved following import to the stroma. Using 35S-Methionine labeled ADT enzymes and freshly isolated *A. thaliana* chloroplasts, in vitro protein import assays were performed to confirm that ADT4 and ADT6 are imported into chloroplasts. SDS-PAGE was used to confirm the import of the proteins and to confirm that the transit peptides were cleaved, which was evident by a molecular weight shift of the protein to a lower molecular weight, mature form.



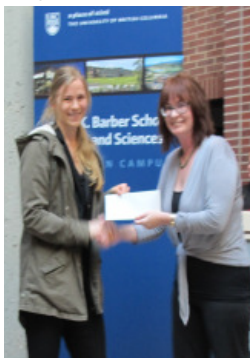
British Columbia

10TH ANNUAL IRVING K. BARBER SCHOOL REGIONAL UNDERGRADUATE RESEARCH CONFERENCE, UNIVERSITY OF BRITISH COLUMBIA, OKANAGAN CAMPUS, KELOWNA

Best Oral Presentation in Botany

Natasha Benson (UBC-O) for "The Effects of Sulphur Dioxide Addition on the Diversity and Composition of *Saccharomyces cerevisiae* Strains in Spontaneously Fermented Pinot Gris at Cedar Creek Estate Winery"

Sulphur dioxide (SO₂) is added to grape must at the beginning of winemaking to reduce the number of undesirable spoilage organisms. However, consumers often report symptoms including headaches and nausea when the concentrations of SO₂ are relatively high. Because *Saccharomyces cerevisiae* is the main yeast responsible for fermentation and because different strains produce unique sensory attributes, it is important to understand the effects of different concentrations of SO₂ on *S. cerevisiae* strain dynamics. This information may provide winemakers the confidence to reduce SO₂ levels in winemaking and to produce a more consumer friendly product. Research regarding the effects of SO₂ on *S. cerevisiae* at strain level is limited. The objectives of this study were to determine: (a) the total number of viable yeast cells (CFU/mL); (b) the diversity of *S. cerevisiae* strains; and (c) the composition of *S. cerevisiae* strains isolated throughout spontaneous fermentation of three concentrations of SO₂ addition (0, 20, and 40 mg/L). We predicted that: (a) CFU/mL and (b) strain diversity will decrease with increasing concentrations of SO₂ addition; and (c) the strain compositions will differ between the three concentrations of SO₂ addition. Pinot gris must was treated with 0, 20 or 40 mg/L SO₂ in French oak barrels (n=3 per treatment). Fermentation was allowed to progress spontaneously. Wines were sub-sampled in triplicate at three stages throughout the fermentation. Thirty-six yeast colonies from all samples were isolated. DNA was extracted and fragment analysis was conducted on eight microsatellite loci to identify DNA fingerprints of *S. cerevisiae* strains. The resulting fingerprints were compared with two existing databases of commercial *S. cerevisiae* strains. Preliminary results showed that higher concentrations of SO₂ yield a lower viable cell count throughout fermentation. This presentation will further discuss the results of this research.



Best Poster Presentation in Botany

Nicole Labine (Supervisor: Dr. Paul Shipley, UBC-O) for "A comparative analysis of *Acorus americanus* Morphotypes and their Application in Traditional Aboriginal Medicine"

Plants from the genus *Acorus* have historically been used as a traditional herbal remedy to treat throat and lung infections. This project focused on identifying the chemical differences between two morphotypes of *Acorus calamus* var. *americanus*, also known as Ratroot by the Cree people, collected in the Northwest Territories. Aboriginal traditional usage has identified one morphotype for medicinal usage and the other has been identified as poisonous. Under the guidance of a traditional knowledge holder, we have collected and prepared these two morphotypes using Aboriginal traditional methods. The rhizomes were extracted with an appropriate solvent, then nuclear magnetic resonance spectrometry was used to investigate the metabolome, or total small molecule chemical profile, of each morphotype. Multivariate statistical analysis allows us to identify specific chemical differences between the morphotypes. Recent results have shown that a significant difference between the morphotypes can be attributed to the stigmastane family of sesquiterpenes, which are known for their antiinflammatory, antimicrobial and antiulcer properties. It is our hypothesis that differences in chemistry between the morphotypes are responsible for the traditionally reported difference in medicinal properties, making the stigmastanes candidate molecules for further study.



NORTHERN RESEARCH AWARD REPORT

Katherine Alambo¹

After being awarded the Laurie Consaul Northern Research Scholarship I was able to travel to Yellowknife, NWT this August to conduct research for my masters' thesis. While in Yellowknife I sampled a number of lakes including Great Slave Lake, to collect water and sediments, which will be analysed for the presence of toxic, microcystin-producing cyanobacterial blooms.

In September of 2013, researchers from Environment Canada working in the Yellowknife Bay region of Great Slave Lake noticed what looked like a cyanobacterial bloom in the waters of Akaitcho Bay. This discovery sparked interest in the occurrence of blooms in Canada's north as few reports of such occurrences have been made for this region. Cyanobacterial blooms tend to occur in the warm, nutrient rich water bodies of temperate and tropical regions and are not commonly reported at polar latitudes.

In September of 2014 the same Environment Canada researchers travelled back to Yellowknife and collected a number of water samples and a sediment core from Yellowknife Bay for me to analyse. Additionally, I received sediment cores from Meretta Lake and Crazy Lake, both located in Nunavut. With the addition of these cores my research interests shifted focus from just Great Slave Lake to a broader study of cyanobacterial bloom occurrence at latitudes north of the 60th parallel. As such, and thanks to this award, I decided to add a few more lakes to my 2015 field season. I chose four lakes situated along the Ingraham Trail: Madeline Lake, Pontoon Lake, Pickerel Lake and Tibbit Lake. Due to forest fires in the region at the beginning of August, I was only able to sample the two lakes closest to the city of Yellowknife: Madeline Lake and Pontoon Lake with the help Nicole Dion of an aquatic scientist from the Government of Canada in Yellowknife.



Bloom forming off shore of Dettah. ©J. Chételat



Sampling Madeline Lake. ©N. Dion

My sampling protocol, along with general limnological procedures, involved collecting water samples and sediment cores from the lake bottom. Once in the lab I filtered the water samples for further analysis (including chlorophyll a concentrations, microcystin concentrations and DNA extractions) and sectioned the sediment cores for later DNA extraction. With the extracted DNA I will test for the presence of cyanobacterial 16S genes as well as the toxic *Mcy E* and *Mcy D* genes present only in toxin producing cyanobacterial species. The sediment sections will allow us to paint a picture of the historical cyanobacterial community within the lakes while the water samples will give a snapshot of the current state of the water.

While I was in Yellowknife the weather was beautiful! Most days had temperatures of at least 25°C (it even reached 29°C!), which made fieldwork even more enjoyable. However, these increased temperatures likely resulted in the increased surface water temperatures (an average of 20°C for all lakes sampled) that may have contributed to the bloom formations that we saw in a number of locations on Great Slave Lake. These blooms appeared to consist of *Anabaena Lemmermannii*, a potentially toxic cyanobacterium. As global temperatures increase, it is likely that we will see an increase in the number and duration of cyanobacterial blooms globally. As polar latitudes are often the most dramatically impacted by climate change it is thought that the occurrence of blooms will become more common in the North. My fieldwork in Yellowknife has provided me with a number of samples that I will be able to use to reconstruct the history of the lakes I visited as well as to provide more insight into the taxonomic composition of said blooms in the North. I hope that with my studies, I will be able to shed more light on this emerging topic and provide valuable information to the wonderful and welcoming people of Yellowknife.

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A TRIBUTE TO JOHN MONTAGUE GILLETT, 1918–2014

Erich Haber¹

John Montague Gillett, or “Jack,” as he was called by everyone, was born in Ottawa on 26 November 1918, the only child of Elizabeth and John C. Gillett, both of whom came from large families in England. Elizabeth left England as a lady’s handmaiden on a passenger liner bound for the United States. She subsequently moved to Ottawa, and John joined her there. John was a machinist and Elizabeth worked as a chef in her early career.

Jack grew up in the Westboro area of Ottawa, where he explored with like-minded friends such as Lloyd Francis, former member of the Canadian Parliament and Speaker of the House. Jack and friends spent their holidays at Constance Bay and occasionally would cross the Ottawa River in a rowboat equipped with a sail. They would climb the escarpment (“the mountain”) in an area that would become part of Gatineau Park, Quebec. For thrills, they would also dive into the turbulent waters at Hog’s Back Falls, Ottawa.

Jack completed his secondary school studies at Glebe Collegiate Institute in 1937. At Glebe, he also learned shorthand and typing. This bode well for Jack because, while working part time after school cleaning up in the chemistry lab, he was asked by a staff member to type out his doctoral thesis, which was on a botanical topic. This kindled in him a lifelong interest in botany and taxonomy.

Jack joined the Royal Canadian Air Force and served both in Canada and England between November 1940 and September 1945. He initially wanted to be a pilot and trained to fly fighter planes while at the Gander Airfield in Newfoundland. However, after episodes of blacking out during training, Jack became a mechanic instead. When he was transferred to the Kirmington Airfield (Humberside International Airport), Lincolnshire, England, Jack worked as a radar mechanic on Lancaster Bombers. Unfortunately, this resulted in a partial hearing loss from the noise of the bomber engines that were being serviced.

Following his military service, Jack enrolled in biology at Queen’s University, Kingston, Ontario (1945–1949). He used his veterans’ allowance to fund his initial postsecondary education. In the course of his studies at Queen’s, he served as an undergraduate assistant in general biology (1946–1947). During the summers of 1946–1948, Jack returned to Ottawa as a summer student planting trees in the Arboretum and working in the herbarium of the Division of Botany and Plant Pathology at the Central Experimental Farm (CEF), Agriculture and Agri-Food Canada (AAFC). In the summer of 1948, he was sent to Churchill, Manitoba, to assist in a northern survey project conducted for the Defence Research Board. After graduating from Queen’s in May 1949 with an honours B.A. (biology, chemistry),



Figure 1. John M. Gillett, 1974. Photo courtesy of the Canadian Museum of Nature.

Jack joined the staff at the CEF herbarium. In the fall of 1949, Jack took leave from his position and began studies for his doctoral thesis on the genus *Gentianella* at the Missouri Botanical Garden under the supervision of Robert E. Woodson. While conducting his research there and majoring in plant taxonomy and morphology, Jack also served as a herbarium assistant (1949–1951).

Jack received his Ph.D. on 8 May 1952 from Washington University, St. Louis, after completing his thesis entitled: *A Revision of the North American Species of Gentianella*. That same summer, he returned to Ottawa and began the first of his many field surveys (Cody et al. 1986), which included the vicinity of Marmora, Ontario (1952); along the proposed route of the St. Lawrence Seaway, with W.G. Dore (1952, 1953); Crater Lake, Labrador, in connection with the National Geographic Society and the Royal Ontario Museum (1953); Florida, with W. M. Bowden (1954); the area around Québec City (1955); southern Ontario (1957); Churchill, Manitoba (1958), to prepare for an International Botanical Congress field trip for which he was host (1959); along the Alaska Highway in northern British Columbia, southern Yukon, and the Ogilvie Mountains with J. A. Calder (1960); southern Ontario for studies on legumes (1961); western Canada and United States (1962, 1963, 1964, 1966, 1970); and a floristic study of Gatineau Park, Quebec (1967, 1968).

Jack’s early surveys, checklists, and plant collections serve as useful tools that now provide an insight into floristic changes that have occurred in areas explored decades ago. One such important survey conducted with Bill Dore in 1952–1953 along the proposed St. Lawrence Seaway, provides an in-the-nick-of-time inventory of a

¹Stittsville, Ontario. First Published in The Canadian Field-Naturalist 129(1):90-96



Figure 2. Windmill Fringed Gentian, a species studied by Jack Gillett and originally treated as *Gentianella detonsa* (Rottbøll) G. Don ssp. *nesophila* (T. Holm) J.M. Gillett. This was later transferred to the genus *Gentianopsis*. ©D. Brunton, Hawkes Bay, Newfoundland, Canada, 4 August 2014.

significant ecological corridor that no longer exists. This inventory remains as the most comprehensive ever conducted in southeastern Ontario.

Jack was an amiable field companion according to one of his colleagues from the former Plant Research Institute, AAFC (Ted Mosquin, personal communication). He recalled with much affection his time with Jack exploring the mountains of the American Great Basin collecting clovers (*Trifolium* spp.). Jack was a light-hearted and fun-loving companion on botanical collecting trips. He would take great delight when encountering a species he had not seen before, especially of rare native clovers, and would let out a boyish shriek of joy. At times of considerable risk, walking along the edge of a cliff, a steep slope, or in areas of bear signs, Jack would exclaim, "Never fear, Bullwinkle is here." This is in reference to an early animated TV show featuring Bullwinkle, a moose with large antlers, and his friend Rocky, a flying squirrel. Ted also benefitted, as others have, from Jack's helpful nature in providing assistance with plant identifications. He was always keen to chat with botanists and to provide encouragement and advice.

In 1972, Jack left the Plant Research Institute at CEF to become a curator and head of the vascular plant section of the herbarium at the National Museum of Natural Sciences (now Canadian Museum of Nature). In his new role, he undertook to reorganize species alphabetically within genera rather than follow the

existing scheme based on grouping species by presumed affinities. Over the course of his years at the museum, Jack continued his work on the local flora. This included preparing an extensive manuscript on the flora of Gatineau Park, which unfortunately was never published in its entirety. Several groups of plants from the manuscript, such as the clovers, asters, goldenrods, and violets, were published in *Trail & Landscape*, a quarterly newsletter of the Ottawa Field-Naturalists' Club. Jack also published a Checklist of the Vascular Plants of the Ottawa-Hull Region. The second, updated version of this checklist, revised with David White in 1978 (see bibliography), served, for decades, as an important tool for floristic work in the region and for landscape conservation and protection. Jack also continued with his taxonomic studies of various plant groups at the museum. He retired from the museum in 1983, but maintained his affiliation as curator emeritus.

Jack was a "field biologist," who applied knowledge gained in the field to his systematic studies. This approach provided a better understanding of the species in nature and helped in the recognition of new taxa. In his work with gentians (*Gentianaceae*), Jack described two new subspecies: Pribilof Dwarf Gentian (*Gentianella tenella* [Rottbøll] Börner ssp. *pribilofi* J.M. Gillett); and Yukon Fringed Gentian (*Gentianopsis detonsa* ssp. *yukonensis* [J.M. Gillett]).

Among other genera Jack studied, he specialized, in particular, in clovers (*Trifolium* spp.). His contributions to this important group, which includes many economically important species, focused on North American species but also extended worldwide. Jack described three new species and three new subspecies that are currently still recognized for North America: Dedecker's Clover (*Trifolium dedeckeriae* J.M. Gillett); Rollins' Clover (*Trifolium rollinsii* J.M. Gillett); Siskiyou Clover (*Trifolium siskiyouense* J.M. Gillett); Beatley's Clover (*Trifolium andersonii* A. Gray ssp. *beatleyae* J.M. Gillett); Cascade Clover (*Trifolium eriocephalum* Nuttall ssp. *cascadense* J.M. Gillett); Martin's Clover (*Trifolium eriocephalum* Nuttall ssp. *martinii* J.M. Gillett). (It is interesting, and potentially confusing, that another Gillett, unrelated to Jack (Jan B. Gillett, 1911–1985), has also published new species of clovers.) Jack also described as new the Great Lakes Wheatgrass (*Agropyron psammophilum* J.M. Gillett & H. Senn), which was subsequently transferred to the genus *Elymus* as a subspecies (*Elymus lanceolatus* ssp. *psammophilus* [J.M. Gillett & H. Senn] Å. Löve).

Over the years, Jack was a member of a number of scholastic and learned societies: Sigma Xi, International Association for Plant Taxonomy, American Society of Plant Taxonomists, the New England Botanical Club, the California Botanical Society, the Canadian Botanical Association, Société botanique du Québec, the Explorers Club of New York, and the Ottawa Field-Naturalists' Club (OFNC).

Jack was a long-time member of the OFNC, beginning in 1946 when he was a summer student at the CEF. He

served on its council from 1958 to 1970 in various capacities, including treasurer, auditor, and chair of the Publications Committee. He also compiled a comprehensive index to the Transactions of the Ottawa Field-Naturalists' Club and to The Ottawa Naturalist. In 1996, Jack received the Anne Hanes Natural History Award from the OFNC. This was given for his outstanding contributions to knowledge of the natural history of the Ottawa Valley through publications and long service on the OFNC council, club field excursions, and his friendly and open nature to both professional and would-be botanists. In 2000, he was awarded honorary membership in the OFNC (Brodo et al. 2001).

Jack met his first wife, Gladys Isabel Proulx (of Aylmer, Quebec, 1927–2001), while playing tennis and being soundly trounced. Her tennis skills apparently made a lasting impression on Jack. They were married 1 September 1956. Jack and Gladys had two children, Peter (1958), who became a visual artist and resides in Toronto with his partner Alma Roussy, and Kimberley (1960). Kimberley (Burnett) is a retired chartered professional accountant (CPA, CA) living in Ottawa with her husband François Gouin (CPA, CA). Kimberley has a daughter, Shannon Burnett, a Toronto special effects make-up artist for film and TV, who is married to Michael Echlin, also a visual artist. Gladys died on 20 July 2001 after a long battle with hepatitis C, contracted from a blood transfusion.

Jack was a man of many interests. He played piano, both classical and show tunes, and collected stamps and minerals. His “rock collection” was sufficiently extensive that his neighbours constructed a “mineral garden” with his collection when his house was sold and the garage was emptied of its contents. Jack was highly curious and fascinated by diverse topics, ranging from quantum physics to the politics of light-rail travel. He loved trains of all kinds and studying languages. His bookcase contained many instruction manuals, including French, Latin, Italian, Spanish, Chinese, Cree, Inuit, and Russian. He could nap readily, anywhere, anytime, and loved skinny-dipping, picnics in cemeteries, garage sales, and Saturday house shopping. Rain or shine, with kids in the back seat, “professional house shoppers” Jack and Gladys would head out on their weekly Saturday tours. In 45 years, they never did make another purchase (Kimberley Burnett, personal communication).

Jack met his second wife, Elizabeth Snowden in 2002, through his friend Michael Smithson, another model-train enthusiast, who was Elizabeth's brother. Jack, who often had dinner with Michael and his wife, met Elizabeth at such a gathering while she was visiting from New Zealand. They obviously took a shine to each other because when Elizabeth challenged Jack to visit her in New Zealand, he promptly did so, arriving several weeks later. Over the next 12 years, they spent six months a year there, avoiding Canadian winters, and six months of the warm seasons at Jack's home. The latter years, however, were spent at Riverpark Place Retirement Residence, Ottawa.



Figure 3. John M. Gillett, 1982. Photo provided by the Gillett family.

They married in 2007 under perhaps typical Jack-like circumstances. Jack, being a fun-loving individual, took Elizabeth one morning to the “post office,” actually the Ottawa City Hall, where he inquired where one could get married. When Jack was informed that he was at the right place, Elizabeth asked: “Who are you getting married to Jack?” You, of course, said Jack. So it was on the morning of 15 October 2007 that Jack and Elizabeth Snowden-Gillett were married and celebrated with a simple wedding breakfast — a cup of soup at Tim Horton's, Jack's favourite coffee shop chain (Elizabeth Snowden-Gillett, personal communication).

The passion for travel and exploring that was in Jack's blood had taken him, earlier in his career, beyond North America and Mexico, to such places as Columbia, Costa Rica, Venezuela, Hawaii, and Europe. He now continued his explorations with Elizabeth on a cruise around Australia, tours of New Zealand, and onward to Fiji, Bali, and Samoa. Their attempts at camping in New Zealand resulted in some memorable moments.

Elizabeth suggested they camp while touring New Zealand, but Jack said he was “too old for camping.” Nevertheless, they did buy a tent and, with considerable effort and time, managed to erect it on their first try. This occasion became a source of amusement for fellow campers at the site who set up their lawn chairs to watch the unfolding event that resulted in the tent, initially, being erected inside out. Putting their tea cups aside, the onlookers gave them a round of applause. Subsequent camping efforts went more smoothly with a notable exception. While visiting Rotorua, the thermal capital of

New Zealand, and not relishing being cold and uncomfortable at night, they pitched their tent in an area where the ground was warmed by a hot underground stream. Unfortunately, their inflated mattress collapsed in the dead of night from the excessive heat build-up under it. They couldn't find a thing in the dark, but got a great laugh out of it (Elizabeth Snowdon-Gillett, personal communication).

Jack died peacefully on Saturday, 27 December 2014 in his 97th year. He is survived by his wife Elizabeth Snowdon-Gillett, daughter Kimberley, son Peter, and granddaughter Shannon. Many fond memories were made and are cherished by Jack's immediate family and by his extended family in New Zealand. Jack's professional contributions to taxonomy and floristics and his amiable assistance to others reflect a life full of achievements. As Kimberley and Peter remarked at his memorial service (5 January 2015), their father was a great adventurer with a true zest for life and an eagerness to experience all that life has to offer.

Acknowledgements

Much of the personal history and anecdotes presented here, which reflect the contributions of Kimberley, Peter, and Elizabeth, are gratefully acknowledged. I am also indebted to local botanists and colleagues of Jack, especially Dan Brunton, Paul Catling, Stephen Darbyshire, and Ted Mosquin, for discussions and contributions related to Jack's activities with the Ottawa Field-Naturalists' Club, the timeline of his research activities, bibliographic compilation of his publications on file at the Central Experimental Farm, Agriculture and Agri-Food Canada, and anecdotes related to fieldwork. Thanks also to the Canadian Museum of Nature, and especially Chantal Dussault, head, archives and library, for providing a scan of Jack's 1974 photo, and to Stephen Haber for photoshop improvements of original black and white images. Comments on an earlier draft by reviewers George Argus, Daniel Brunton, Paul Catling, and Irwin Brodo are also appreciated.

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Figure 4. John M. Gillett. Family photo: 31 May 2014.

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A TRIBUTE TO PROFESSOR IAN SUSSEX - AN EMINENT PLANT DEVELOPMENTAL BIOLOGIST

Edward Yeung¹ and Vipen Sawhney²

It is with great sadness we inform the members of the CBA/ABC the passing of Professor Ian Sussex of Yale University, an internationally renowned and highly distinguished Developmental Botanist. Professor Sussex passed away on May 10th, 2015. He is survived by his wife, Nancy Kerk and his family in New Zealand. Professor Sussex was born on May 4, 1927 in Auckland, New Zealand. He obtained his B.Sc. and M. Sc. degrees from the Auckland University College in New Zealand and did his Ph.D. at Manchester University, England, under the supervision of Professor C. W. Wardlaw. After obtaining his Ph.D. in 1952, he went to Professor Ralph Wetmore's laboratory at Harvard as a junior research fellow where he met Professor Taylor Steeves. They became life-long friends. After a short stint at Harvard, he worked as a post-doctoral fellow at the Agriculture Research Center, Versailles in France. He then returned to New Zealand and served as an Assistant lecturer at the Botany Department, University of Victoria from 1954 to 1955. Professor Sussex returned to North America with an appointment as Assistant Professor, at the Biology Department, University of Pittsburgh from 1955 to 60. He was then appointed as Associate Professor at Yale University in 1960 and subsequently promoted to full Professor in 1973. In 1990, he joined the newly established Department of Plant Biology at UC, Berkeley, where he played a significant role in the establishment of the NSF Center for Plant Developmental Biology in the College of Natural Resources. He retired in June, 1997 and returned to Connecticut where he rejoined Yale University as a scientist and lecturer.

Professor Sussex had a diverse interest in different aspects of plant development. He was interested in how plant development is regulated. He used a combination of genetic, biochemical, and molecular methods in his studies, emphasizing the importance of an experimental approach to study a problem. This is clearly illustrated by the classical text, the "Patterns in Plant Development", co-authored with Professor Taylor Steeves. In this book, they identified key concepts in plant development, the importance of an experimental approach in one's experimentation, and how to ask questions. This book has been "The Bible" to developmental botanists and has been fully entrenched in the teachings and research activities of plant developmental biology.

Professor Sussex had a special interest in plant meristems, especially in how plant meristems are organized and the subsequent process of organogenesis. This most likely started while performing

experimental investigations on the shoot apex when he was a graduate student at Professor Wardlaw's laboratory. His focus on the meristem was clearly noted in the paper, "The Permanence of Meristems" presented at the Brookhaven National Laboratory Symposium in 1963. His love of meristems is clearly illustrated in his review in 1989 "Developmental Programming of the Shoot Apical Meristem" in the journal, *Cell*, with a simple and powerful statement, "The Meristems Make the Plant". Recent progress in meristem research, in part, is influenced by his research and writings.

From a personal side, what have we learned from Professor Sussex as his student? As Francis Hsu (one of his former students) wrote, "we learn how to ask questions, define a problem, and design an approach to answer the questions". In the 1970s, there were quite a number of graduate students working in the Sussex laboratory. However, everyone worked on totally different topics on plant development. Projects were not assigned or given, instead, we developed our research questions with his guidance. In hindsight, Professor Sussex trained us to be independent from the start and taught us to develop our own research program. This guaranteed successes in our future careers as scientists. This also clearly demonstrates his unselfishness in his guidance and supervision of students. Although excellent works had been generated, his approach to graduate supervision slowed his own personal research on meristems. In today's research environment, without a series of quality related publications, funding will not be possible. With many students in the laboratory, we did not have a lot of resources. We all learned that approaching and asking the right questions are more important than the high tech approach, and that we could still generate good quality, excellent research work; we had to think and work smarter. This is how one of us (EY) survived in pursuing his research career, as funding is always limited in the classical area of plant developmental studies.

Besides his immediate family, Professor Sussex is survived by many of his students, post-doctoral fellows, research associates and visiting scientists - his academic family. Professor Sussex was a very fine, generous, caring, and a humble human being. Certainly, we are all saddened to have lost a teacher, mentor, and a dear friend. However, his teaching and friendship will forever be remembered in our hearts.

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MAJOR INVASIVE ALIEN PLANTS OF NATURAL HABITATS IN CANADA

12. GARLIC MUSTARD, ALLIAIRE OFFICINALE: *ALLIARIA PETIOLATA* (M. BIEBERSTEIN) CAVARA & GRANDE

Paul M. Catling^{1,2}, Gisèle Mitrow¹ and Amanda Ward¹

Since 1979, when an article in the Biology of Canadian Weeds series was published, this plant has increased greatly in abundance in North America and hundreds of articles have been written about its impact and ecology. It is astonishing how much has been learned about the plant and about invasive plant science as a result of studies of Garlic Mustard in the 36 years since this early review. One recent article summarized the situation well: "Although no single mechanism appears to explain the success of Garlic Mustard, a combination of plant traits – all slightly different from those of native plants – seems to confer Garlic Mustard with tremendous success in the new habitats it invades. The domination of this new species in eastern forests is clearly changing the ecology of these systems. The consequences of Garlic Mustard invasion include the loss of biological diversity, ripple effects through higher trophic levels, and change in the function of soil microbial communities". The only observations to be added to this are: (1) facilitation by both invasive earthworms and increasing deer populations; (2) some evidence for declining impact in areas of long establishment; (3) promising biocontrol agents; (4) evidence for multiple introductions; (5) it is listed in weed legislation across Canada; and (6) the fact that it is still spreading in Canada and in the rest of North America. It was listed as no. 4 in the prioritized list of the invasive alien plants of natural habitats in Canada in 2005 (CBA/ABC Bulletin 38(4): 55-57).

Classification and Identification

Garlic Mustard is a member of the Mustard Family (Brassicaceae, formerly Cruciferae). There is one other species in the genus *Alliaria*, *A. brachycarpa* which is endemic to Caucasus in Azerbaijan and Georgia. This family is characterized by four petals in the form of a cross and a pungent watery juice. In the case of Garlic Mustard, the crushed leaves and stems often produce a strong odour of Garlic which is said to be helpful in distinguishing vegetative plants and rosettes from those of Creeping Charlie (*Glechoma hederacea*), White Avens (*Geum canadense*), Toothworts (*Cardamine* spp.) or Violets (*Viola* spp.), but the leaves are also more rounded and more evenly toothed than in these genera. Creeping Charlie smells minty when crushed and the leaves grow from runners. The common English name may lead to confusion with real Garlic (*Allium sativum*) which is a kind of onion.

SCIENTIFIC SYNONYMS

Alliaria alliaria, *Alliaria officinalis*, *Arabis petiolata*, *Sisymbrium officinalis*, *Erysimum alliaria*

OTHER COMMON NAMES (MOSTLY BRITISH ISLES)

Hedge-garlic, Sauce-alone, Jack-by-the-Hedge, Poor-man's-mustard, jack-in-the-bush, Garlic Root, Garlicwort, Mustard-root.

DESCRIPTION

Biennial or winter annual herbs 0.1-2 m tall, branching above and often from the root crown and with a slender white taproot with an "s" curve at the top. Stems and basal petioles with long hairs, mostly smooth above, arising from a first-year (overwintering) rosette of rounded or kidney-shaped leaves with regular coarse

teeth or crenate or scalloped and with long petioles. The stem leaves are 2-15 cm long, deltoid or heart-shaped and coarsely toothed with the terminal teeth larger and those higher on the stem with long pointed tips. They also differ from the basal leaves in having short petioles. Inflorescence one or more, racemose, few-50-flowered. White

flowers are 6-7 mm across and the four petals are 3-6 mm long and spatulate. The 6 stamens include four long and two short (tetradynamous). A nectar gland is present at the base of each stamen. The fruit is a

silique (a dry dehiscent fruit of 2 carpels separated by a persistent partition with seeds on both sides) with one to many arranged alternately on thick stalks 4-6 mm long and widely spaced along the stem when mature. Siliques are 2-7(8) cm long, 1-2(2.5) mm wide and contain 10-20 black or brownish-black seeds arranged on both sides of the chamber partition. The shiny seeds are ridged, 2.5-



Figure 1. Garlic Mustard, Beaver Meadow Conservation Area, Prince Edward County, Ontario. 11 May 2015. ©P.M. Catling & B. Kostjuk.

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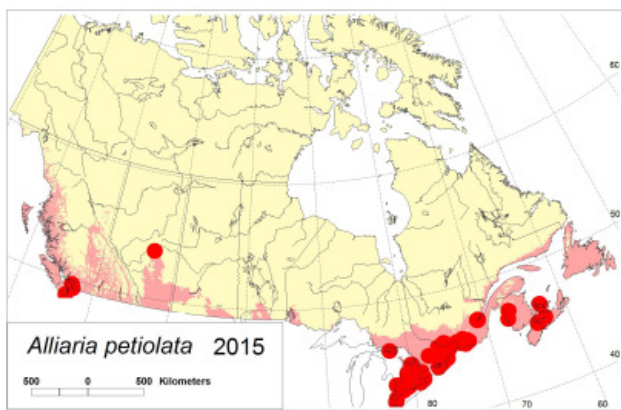


Figure 2. Distribution of Garlic Mustard in Canada from herbarium specimens (red dots) as described in the text up to 2015. The red shaded area is potential climatic range in Canada based on current distribution records and it includes hardiness zones (2000) 3b to 6b inclusive.

3.5(4.5) mm long and 1 mm wide and with one or both tips, often oblique.

Distribution

Garlic Mustard is native to Eurasia and introduced in southern Canada and the United States. North American plants may have originated primarily from the British Isles, northern Europe and central Europe based on molecular evidence. The first North American plants found growing in native vegetation in North America were on Long Island, New York in 1868. It is said to have been introduced by early colonists who valued it for medicine and food. The first Canadian collection of a presumably wild plant was from Moss Park in Toronto, Ontario in 1879 by James Fletcher, the first Dominion Entomologist and Botanist. Not long after (1891) it was found growing outside of cultivation at Beechwood Cemetery in Ottawa by William Scott who was well known as the Principal of the Normal School in Toronto.

In 1950 Garlic Mustard was more or less confined to urban centres. By 2015 it had expanded to occupy much of the natural landscape between urban centres in southwestern Ontario. Since a 1979 distribution map it has expanded into Prince Edward Island, Nova Scotia and Alberta. It has probably still not reached its full invasion potential in Canada, as has been suggested for much of the Midwestern United States. In 2008 it was estimated to be spreading across the North American landscape at a rate of 6400 km² per year. The pink zone on the 2015 distribution map includes current plant hardiness zones in which it has already been recorded (north to zone 3b). It presumably could spread throughout these zones and this is a very conservative prediction of its potential range where appropriate woodland habitat exists throughout Canada. Although it occurs in Alaska at Juneau, this location is much milder than parts of Yukon, NWT and NU and does not suggest spread to the Canadian territories in the near future any more than its occurrence in Scandinavia. Spread into much of southern Canada is suggested by occurrence in

the adjacent US. where it has been reported from the following states: AK, AR, CO, CT, DC, DE, GA, IL, IN, IA, KS, KY, ME, MD, MA, MI, MN, MO, NE, NH, NJ, NY, NC, ND, OH, OK, OR, PA, RI, SC, SD, TN, UT, VT, VA, WA, WV, and WI.

The accompanying maps showing distribution in Canada are based on collections from ACAD, ALTA, CAN, DAO, MT, NSAC, QK, QUE, TRTE, UBC, UWO and WIN.

Due to few founding individuals, some populations suffer founder effects (genetic drift), but with continued introduction of genetically diverse individuals, this disadvantage is lost and a local population of an invasive becomes genetically diverse. Some North American populations of Garlic Mustard have been found to have been exposed to founder effect, another study suggests high genetic diversity established by multiple introductions, and a notable lack of inbreeding depression in this highly selfing species. This probably has contributed to genetic diversity and invasion success in North America.



Figure 3. Garlic Mustard by Swedish Botanist and artist Carl Axel Magnus Lindman in Bilder ur Nordens Flora, vol. 1: t190 (1922-1926).

Ecology

POLLINATION

Flowers produced from April to May and into June are self-pollinated but pollination by a variety of insects also occurs (facultative xenogamy). Most pollinators are short-tongued bees (Apidae, Andrenidae, Halictidae) or flies but Lepidoptera may also be important. The flowers remain open for two days. Pollinators were shown to be effective in one study and fruit set and seed production usually exceeded 90%. Flowers provide pollinators with nectar and/or pollen. Aspects of the breeding system that contribute to success are: (1) almost every flower produces fruit and seeds; (2) flowers are adapted to widespread generalist pollinators; and (3) local adaptation may occur quickly due to outbreeding.

DISPERSAL

Dry seeds readily adhere to damp surfaces and the main method of dispersal is by adhesion to humans, other animals and vehicles. As well as simple adherence, seeds may be trapped in clods of wet soil on boots and vehicles and travel great distances in this way. Seed dispersal begins in June and continues to October. Seeds germinate in the second spring. Without additions, a seed bank of Garlic Mustard may be exhausted within 5 years. Maximum reported viability is up to 10 years. The dispersal mechanism is likely very effective as anticipated for a rapidly spreading invasive.

OTHER

Garlic Mustard usually occurs in moist or mesic woodland or woodland edges on sand, loam or clay soils of variable pH. Death of high-nutrient-content (first year) rosette leaves of Garlic Mustard “may change soil nutrient availability in such a way as to create a positive feedback between site occupancy and continued proliferation”.

The frequent tree associates are various Maples (*Acer* spp.), Oaks (*Quercus* spp.), Red Ash (*Fraxinus pennsylvanica*), Balsam Poplar (*Populus balsamifera*), Elms (*Ulmus* spp.), and Basswood (*Tilia americana*).

Oh my deer!

White-tailed Deer (*Odocoileus virginianus*), which have increased in North America over the past few decades, have been shown to facilitate Garlic Mustard and increase its impact in some situations, but not in others. One study noted that “deer are required for the success of *Alliaria*: its projected population trajectory shifted from explosive growth in the presence of deer ... to decline toward extinction where deer are excluded”. Another study reported that the “selective herbivory (by deer) drove the high exotic dominance (of Garlic Mustard) at our site, suggesting that a shift in focus from invasive plant removal to combined native plant restoration and herbivore control is need to maximize recovery of this degraded forest understory”.



Figure 4. Garlic Mustard, inflorescence, Beaver Meadow Conservation Area, Prince Edward County, Ontario. 11 May 2015. ©P.M. Catling & B. Kostiuk.

The herb layer may be diverse, especially before invasion, including various species of Asters and Goldenrods, Jewelweeds, and spring ephemerals, especially in the Lily family (Liliaceae). Garlic Mustard thrives in disturbed sites such as cutover woodlands, areas of soil disturbance by building, flooded areas (floodplains) and gardens.

Most Canadian earthworms (family Lumbricidae) are introduced from Europe. It has been suggested that alien earthworm invasion, rather than non-native plant invasion, is the driving force behind changes in forest plant communities in northeastern North America. This seems likely but requires more study. In an interesting example of one invasive with profound impact exercising a degree of control over another, also with profound impact, the European Nightcrawler (*Lumbricus terrestris*) ate and digested more seeds of Garlic Mustard than of those of native plant species. Since European Nightcrawler and other alien earthworms create bare soil (by eliminating the organic layer) which benefits Garlic Mustard, and they may also disperse some seed (if digestion was incomplete), their effect may be more positive than realized. On the other hand the introduced slug, *Deroceras reticulatum*, avoids Garlic Mustard at the expense of native forest herbs. See also text box for “Consumer-facilitated Invasions”.

Powdery Mildew (*Erysiphe cruciferarum*) is one of few natural enemies of Garlic Mustard in its introduced range. Another is a mosaic virus that does relatively little damage and is not transmissible to commercial Brassicaceae species. Other viruses on Garlic Mustard do also attack a variety of cultivated plants. See also under “biocontrol”.



Figure 5. Seeds of Garlic Mustard in the silique with one wall gone and mature seeds along the inner partition. The robust basal stalk of the silique is evident. Winchester County, New York. ©S.A. Mori. (CC BY-SA 3.0).

Detrimental Aspects

Significance is suggested by the number of asterisks to 5 for highly significant

(1) NEGATIVE EFFECTS ON BIODIVERSITY *****

Garlic Mustard is widely reported to displace native herbs and inhibit tree seedling growth and survival through the production of allelochemicals. Its extreme dominance in many ecosystems alone provides strong evidence of these effects. In addition, declines have been experimentally documented along with competition and allelopathic effects. As is often the case, some studies have reported little impact. There are situations where plants are present but not damaging, as with all invasives, but this does not mean that there are still huge areas of landscape that are not profoundly affected. Just as a native butterfly appears to have adapted to Garlic Mustard, so does at least one native plant, Jewelweed (*Impatiens capensis*), or they may be benefitting from a decline in toxicity.

Garlic Mustard's capability to invade relatively undisturbed forest habitat might be explained by disruption of belowground mutualisms. This is not a surprise since mustard plants (Brassicaceae) are often used as "break crops" in agriculture to inhibit the activity of unwanted soil organisms. The suppression of North American mycorrhizal fungi mutualists by Garlic Mustard has been found to be much greater in North American than in European soils where Garlic Mustard is native. Phytochemicals benign to resistant European mycorrhizal symbionts in the home range are lethal to naïve native mutualists in the introduced range. Despite some strong evidence in some studies, there are others that have provided little evidence that allelopathy or mutualism disruption are important in invasive success. In one case many indigenous arbuscular mycorrhizal fungi communities appeared tolerant to allelopathic effects (or perhaps those effects varied). Regardless of these varying results, it seems clear as a result of many studies, that Garlic Mustard does have a distinct phytochemical profile, and that this has contributed to invasive success.

(2) UNPALATABILITY TO LIVESTOCK *

It is a good question how a plant eaten by humans can be unpalatable to livestock, yet there are a number of references to this. Both farmers in Ontario and references have reported tainted milk as a result of cows eating this Garlic Mustard. By dominating large areas it could lead to a substantial loss of forage. Goats are said to be unaffected.

(3) WEED OF GARDENS *

Garlic Mustard is a common weed of gardens. Although it can be easily controlled in these situations by pulling, the problem is that these occurrences enhance its ability to colonize natural areas in an urban setting. It may also have negative effects on garden plants as described for native plants above.

(4) HOST OF PESTS

Garlic Mustard is host to a number of viruses that attack other cultivated plants and to introduced insect pests that feed on a variety of plants in the family Brassicaceae. This concern has not been evaluated.



Figure 6. Specimen in the AAFC National Collection of Vascular plants collected by William Scott in 1891.



Figure 7. Domination by Garlic Mustard is sometimes very complete and native species are entirely absent over extensive areas. Anoka County, Minnesota. ©Steven Katovich, USDA Forest Service, Bugwood.org (CC BY-SA 3.0).

Beneficial Aspects

(1) USE BY WILDLIFE *

Garlic Mustard provides pollen and nectar to a variety of pollinators over a relatively long flowering period. It provides food for some native animals. Springtails were reported to increase in Garlic Mustard invaded forest possibly due to pH modulation. See text box concerning Mustard White Butterfly. This aspect requires more study.

(2) USE AS A FOOD FOR HUMANS *

A recent article in the Journal of Chemical ecology noted that Garlic Mustard “produces levels of cyanide in its tissues that can reach 100 ppm fresh weight, a level considered toxic to many vertebrates”. This cyanide content may vary among populations. Elsewhere it is considered toxic to grazing animals. Contrary to such negative indications, there is much information supporting it as a human food resource. The uses are partially due the three main flavors: bitter, garlic and peppery. All of the plant parts are said to be edible and to have an extremely high nutritional value. The leaves are said to be “often” added to other greens making a “delicious salad”, and the whole plant, or selected plant

parts can be chopped and added to pasta, bean, cheese and egg dishes for flavoring. In England, the plant is known as “sauce-alone” for its use as a sandwich filling; additionally it was used for a spice in sausages and a side for salt-fish. Seeds of this plant are used to make mustard in some parts of Europe. The leaf provides a taste of garlic without the strong odour associated with real Garlic. It is said that the root can be used as an alternative to Horseradish. It would score higher as a human food, but some additional research on chemical content is required.

(3) MEDICINAL USE

Potentially medical plants contain active phytochemicals and should be used with caution. Herbalists used the leaves of Garlic Mustard for dropsy and to induce sweating. It was recommended that they be boiled with honey to make a syrup as a remedy for coughs and hoarseness. The leaves were also believed to have antiseptic properties and were applied as dressings to open sores and ulcers. Other medicinal uses include fighting cancer and heart disease, expelling worms, removing mucous from the sinuses, preventing scurvy, treating asthma, and purifying the blood.

(4) USE AS A DYE

The plant was used for a yellow dye, mostly in Europe for woolen goods.

Management

A useful Canadian document is Anderson (2012). See also the stewardship abstract (Nuzzo 2000).

LEGISLATION AND REGULATIONS

In 1979 Garlic Mustard was not mentioned in any Canadian or American weed legislation. That has changed. In Canada it is listed by Environment Canada as an “Invasive Species of High Threat in Canada”. It is listed as one of 35 top priority invasive plants in category 1 (= Top priority control, Aggressive invasive exotic species that can dominate a site to exclude all

Native Butterfly Saved ... by Garlic Mustard?

The native Mustard White butterfly (*Pieris oleracea*) declined as a result of: (1) woodland habitat loss; (2) parasitoids introduced to control the introduced Cabbage White Butterfly (*Pieris rapae*); and (3) Garlic Mustard which attracts some Mustard White females to lay eggs, but inhibits growth of larvae. This inhibition is a result of a cyanoalyl glucoside which acts as a feeding deterrent. Garlic Mustard has been referred to as a “population sink” for Mustard Whites. However, since 1994 it has been noticed that in some places the larvae have begun to survive on Garlic Mustard. Thus a native butterfly that once appeared “on the road to nowhere” (headed for extinction) has apparently been saved (at least in part) by rapid adaptation to a widespread alien species or by reduced toxicity that has been reported to be occurring already due to natural selection (or both). Regardless, some models predict a strong recovery for the Mustard White.



Figure 8. The native Mustard White Butterfly, Elk Island National Park, 7 June 2009. ©dfaulder (CC BY-SA 2.0).

other species and remain dominant indefinitely), for control in Ontario by the Ontario Invasive Plant Council, Ontario's Invading Species Awareness program, Ministry of Natural Resources and Credit Valley Conservation. It is regulated (provincial designation covered by weed Control Act) in: Saskatchewan (Prohibited); Alberta (Prohibited Noxious Weed); and British Columbia (Noxious Weed). In Quebec, the planting of Garlic Mustard is prohibited under borough by-laws in Montreal, and it is listed as an invasive species by le Ministère de l'Environnement du Québec. In Prince Edward Island it is listed as an invasive alien species and if found, it is to be reported to the Island Nature Trust. In Nova Scotia it is also listed as an invasive species and sightings are expected to be reported to Invasive Species Alliance of Nova Scotia. In New Brunswick it is also listed as an invasive plant by the Petitcodiac Watershed Alliance.

In the US it is regulated (covered by the Federal and State Noxious weed list) in: Alabama (Class A Noxious Weed); Connecticut (Invasive and Banned); Massachusetts (Prohibited); Minnesota (Prohibited Noxious Weed); New Hampshire (Prohibited Invasive Species); New York (Prohibited and Regulated); in Oregon ("B" designated Weed Quarantine); Vermont (Class B noxious weed); and in Washington (Class A Noxious Weed, Noxious weed seed and plant quarantine). It is considered one of the most threatening of invasive plants in many other states.

MANUAL AND MECHANICAL METHODS

Pulling Garlic Mustard before fruit initiation, which occurs in summer, will reduce seed production. This is an effective control for small areas regardless of whether or not the pulled plants are left on site, and regardless of whether or not the roots are left intact. With a single plant producing hundreds of seeds (up to 62,000 per m²), this may seem a waste of time, but not all of those seeds remain viable since some are lost to disease or become food for various animals. The entire "s" shaped root should be removed in pulling to avoid re-sprouting from buds on the root system. Flowering stems can also be cut with a scythe or weed whip or by clipping. Any process other than pulling may have to be repeated in late summer to prevent new growth from lower stems and root crowns. The seed bank is short-lived (two to five years), so control methods should be continued for a maximum period of five years to deplete the seed bank. One study found pulling to be more effective than Glyphosate application.

BIOCONTROL

In its native range, Garlic Mustard has at least 70 insect species and seven fungi that control its growth. In North America only some leaf mining and "windowpane" damage has been observed with the exception of three native insects, a weevil (*Ceutorhynchus erysimi*), Diamondback Moth (*Plutella xylostella*), and Meadow Spittlebug (*Philaenus spumarius*), have been observed proceeding successfully through their different stages of

Once an Invader – Always an Invader?

Do invaders, released from forces that limit native populations, maintain their dominant status over long time spans ... or do ecological and evolutionary forces eventually develop to limit their populations? How long is "eventually"? In the case of Garlic Mustard, decreased phytotoxin production over 50 years of invasion has been attributed to natural selection. It is speculated that North American populations may already be developing evolutionary limits. There is also the idea that fungi, and/or viruses and/or bacteria may "eventually" catch up with an invader and reduce it to a "background level". Various kinds of biocontrol are a human-aided process similar to this concept that reduces the huge losses associated with initial outbreak. Regardless of whether or not it is happening naturally with Garlic Mustard or not, the limiting of invasive dominance can be complex and attributable to a number of causes.

development on introduced Garlic Mustard. To these may be added the native Mustard White Butterfly (see text box).

Several predators from its native range have been identified as potential biocontrol agents including five weevils (*Ceutorhynchus allariae*, *C. constrictus*, *C. roberti*, *C. scrobicollis* and *C. theonae*). A flea beetle, *Phyllotreta ochripes* (Curtis) (Coleoptera: Chrysomelidae) was also investigated. As a result of determining low genetic variation in a population of *C. scrobicollis*, host specificity tests were supported. In experiments, this root crown-mining weevil has significantly reduced biomass and seed production, and has increased mortality of Garlic Mustard. It has been recommended for release.

In the US grazing by Goats has been used to control Garlic Mustard, and several herds have been rented for this purpose in the midwest. This may not help the native flora and fauna unless it was implemented as part of a cautious restoration program.



Figure 9. *Ceutorhynchus scrobicollis*, a weevil with significant potential for biocontrol of Garlic Mustard. Switzerland, ©H. Hinz and E. Gerber (CC BY-SA 3.0).

BURNING

Several studies have reported no significant effect of burning on Garlic Mustard. It does sometimes occur in habitats, such as savanna, that have to be burned to control woody vegetation but with varying effects on Garlic Mustard. In one 17-year study of Oak forest management, Garlic Mustard quickly recolonized burned areas and was never removed by fire, but numerous other management goals were achieved. Use of fire should follow safe burning practices and be applied with the necessary permits.

CULTURAL METHODS

Some native plants have been shown to out-compete Garlic Mustard when planted in higher densities than are usually found in forests, as for example Bloodroot (*Sanguinaria canadensis*) and Mayapple (*Podophyllum peltatum*). If planted at densities of 9 or 11 plants/m², they can successfully outcompete Garlic Mustard. This method is best used in combination with other control measures, or as a restoration measure in areas where Garlic Mustard has been removed and the high-density planting can out-compete any growth from the seed bank. There are also other native species which can be used for this purpose such as Zigzag Goldenrod (*Solidago flexicaulis*), Canada Anemone (*Anemone canadensis*), Virginia Waterleaf (*Hydrophyllum virginianum*), Canada Waterleaf (*Hydrophyllum canadense*), White Avens (*Geum canadense*), Ostrich Fern (*Matteucia struthiopteris*), Woolly Blue Violet (*Viola sororia*), Woodland Sedge (*Carex blanda*), Starry False-Solomon's-Seal (*Maianthemum stellatum*), Lady Fern (*Athyrium filix-femina*), American Currant (*Ribes americanum*) and Bush Honeysuckle (*Diervilla lonicera*). Planting of the browse-tolerant, native, matrix grass, Virginia Wildrye (*Elymus virginicus*) proved successful in one experimental study.

CHEMICAL METHODS

It is more effective, based on the life cycle and physiology of Garlic Mustard, to do spot application of herbicide in the early spring or late fall. At this time, many native plants are dormant, but biennial rosettes of Garlic Mustard are still green. This process will need to be repeated for several years when the seed bank persists.



Figure 10. Using blow torches for control of Garlic Mustard in the US. ©J.H. Miller (CC BY-SA 3.0).

Since most herbicides currently used for Garlic Mustard control are non-selective, extreme precautions must be taken to avoid surrounding plants of importance. The most frequently recommended herbicide is Roundup® (active ingredient is Glyphosate). Herbicide use, storage, transport and disposal is regulated under provincial Pesticide Acts.

Prevention Here/Elsewhere

In Canada Garlic Mustard is recognized as an invasive in all provinces where it occurs and as a potential invasive in some where it does not yet occur. In Prince Edward Island, it is listed as an invasive by the Invasive Species Council. It is well established in Prince Edward Island National Park at Cavendish. In New Brunswick, The Petitcodiac Watershed Alliance (PWA Inc.) has listed it as invasive. It is abundant locally in the central Saint John River Valley. In Nova Scotia, Parks Canada, the NS Department of Transportation and Infrastructure Renewal, and Clean Annapolis River Project (CARP), made a commitment to work with each other and the local community to develop an action plan for managing the NS population. In Quebec, le Ministère de l'Environnement du Québec has listed Garlic Mustard as an invasive species. In Ontario, it is considered the most invasive exotic plant of the province. In Manitoba, Saskatchewan, Alberta and British Columbia it is on the Invasive Species Council list.

Consumer-Facilitated Invasion (CFI)

CFI has been proposed as an alternative to direct competitive exclusion to explain displacement of native plants by exotics. A few studies have documented the way in which competition from the unpalatable Garlic Mustard reduced survival of palatable native herbs in the presence of exotic slugs. In the absence of slugs, there was no deleterious competition effect. Whether this is a common phenomenon, or not, is unclear, but at least it requires some reconsideration of the simple competition model. Another way in which Garlic Mustard research has influenced our thinking about the action of invasives is through disruption of below-ground mutualisms (see text). As well as CFI, there are other hypotheses designed to explain the success of invasives. These include: the **Novel weapons hypothesis** – production of novel metabolites to which native species have little resistance; **Enemy release hypothesis** – absence of co-evolved enemies in the introduced range; **Optimal Allocation theory** – decreased allocation for defence in favour of competition, etc. For a useful consideration of how these apply to Garlic Mustard, see Rodgers et al. (2008).

In all adjacent areas to Canada where Garlic Mustard occurs (including Alaska, Washington, Montana, Minnesota, Wisconsin, Michigan, New York, Vermont, New Hampshire and Maine), management programs are in place. In some states, such as Washington, eradication by landowners is required. In others, such as Montana, infestations are being controlled as soon as discovered. In Michigan, "The Garlic Mustard Challenge" is an annual competitive event. In 2015 it was aimed at pulling 200,000 pounds of garlic mustard and to have 50 Garlic Mustard-free sites.

Prospects

Whether Garlic Mustard is a driver of ecological change, or a passenger, or both, in different situations may not really matter (except that people are willing to pay more for drivers). The fact is that it has hugely usurped natural habitats formerly occupied by a variety of native species and has at least contributed to a changed ecosystem. This justifies management to protect some native biodiversity from extinction, until such time as natural controls and directed biocontrol reduce impact allowing native flora and fauna, now becoming overwhelmed, to survive. Garlic Mustard will likely spread into currently unoccupied but available territory throughout southern Canada. Localized control will be possible but substantial reduction on the landscape is unlikely until biocontrol is implemented.

Believe it or not

- Although we are not recommending it as a food pending further study, Garlic Mustard is used in some gourmet recipes, has a higher vitamin C content than oranges and is available from some seed companies.
- Europeans used the seeds of Garlic Mustard as a spice 7000 years ago following a transition from a hunter-gatherer lifestyle to farming. This was revealed by phytoliths preserved in carbonised food.
- The rate of expansion of Garlic Mustard is faster than that of Purple Loosestrife

Selected References

We draw attention to one article which provides a very useful conceptual diagram illustrating the mechanisms for the success and impacts of Garlic Mustard, as well as a useful synthesis (Rodgers et al. 2008).

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TOP CANADIAN ORNAMENTAL PLANTS. 11. PEONY

Ernest Small^{1,2}

Peonies in bloom are stunning, so much so that many consider them the most attractive of all garden ornamentals. Reflecting their astonishing beauty, they have been called the “king of flowers” in China, the “queen of flowers” in ancient Greece, and the “prime minister of flowers” in Japan. Most herbaceous cultivars are well adapted to Canadian climates, and new gorgeous semi-woody varieties suited to Canada have recently been created that are significantly more beautiful than traditional cultivars.

Names

Scientific names: The genus name *Paeonia* is based on the Greek *paionia*, apparently derived from Paion, the physician of the classical gods, who employed peonies medicinally. Greek legend holds that Zeus transformed Paion into a peony flower to save him from his jealous teacher Asclepius.

English name: peony.

French name: pivoine.

Official symbols

The peony (no particular species) was adopted as the state flower of Indiana in 1957. In 1903, the tree peony (*P. suffruticosa*) was recognized as the official flower of China, but the modern People's Republic of China has not recognized an official national plant (the peony and the plum blossom, traditional emblems of China, are considered to be leading candidates for this honour).

Description

Paeonia species are stout branching perennial herbs and diffuse shrubs. Most of the herbaceous species are rhizomatous or have tuberous roots, which serve as the overwintering phase. The leaves are large and compound, occasionally finely dissected. The flowers are large, in the cultivated species often 15–30 cm (6–12 inches) across. Doubled blooms are common. The range of colors includes cream, peach, pink, purple, red, yellow, white, two-colored (“bicolor”) and multi-coloured.

Classification and distribution

Paeonia, the only genus in the family Paeoniaceae, has about three dozen species. These occur in four disjunct north-temperate areas of Eurasia (eastern Asia, central Asia, the western Himalayas and the Mediterranean region), with two endemics, *P. brownii* in northern California, adjacent states, and British Columbia, and *P. californica* in California and adjacent Mexico. These two western North American species constitute section *Onaepia*. Section *Moutan*, notable for *P. suffruticosa* (tree peony) discussed in detail later, includes six to nine species of shrubs of central and western China. Several of these are rare and are considered endangered due to overcollection for ornamental and medicinal purposes. The remaining species, all herbaceous, are in section *Paeonia*, occurring in Europe, North Africa and Asia – from Japan to Portugal and Morocco – but mainly in the



Figure 1. Paintings showing the beauty of peony flowers. **Left:** “Peonies” by American painter Charles Courtney Curran (1861–1942), famous for depicting women in various settings. **Right:** Peony flowers, painted by Jane Loudon in 1841. (Both illustrations are in the public domain.)

Mediterranean region and eastern Asia. Three species of this section, *P. lactiflora*, *P. officinalis*, and *P. tenuifolia*, are discussed in detail later.

The overwhelming majority of peony cultivars grown in Canada belong to *P. lactiflora* and its hybrids. Peony specialists artificially classify these into various groupings on the basis of flower form: 1) Single – with one or two rows of petals and a centre of functional stamens. 2) Semi-Double – with three or more rows of petals (rarely less) and with a centre of functional stamens. 3) Japanese and Anemone – with a centre of non-functional stamens – staminodes (stamens partially transformed into petals) in the Japanese category, petalodes (stamens more dramatically transformed into petals) in the Anemone category. 4) Double – fully double with many petals and often showing no stamens,



Figure 2. Geographical distribution of *Paeonia* species. ©Ninjatacoshell (CC BY SA 3.0).

¹Science and Technology Branch, Agriculture and Agri-Food Canada, Saunders Bldg., Central Experimental Farm, Ottawa ON, K1A 0C6

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Figure 3. *Paeonia brownii*, Canada's only native peony species. Left photo ©Jeff Moser (CC BY 2.0), right photo ©Cassandra Skinner (released to public domain).

or with hidden ones. Cultivars with doubled flowers are sometimes called French peonies. In a sub-type of the double category, known as the “bomb” form, the central petals appear as a sphere while the outer petals look like a plate.

Ecology

Most wild peonies grow in mild temperate climates, although the overall range extends from subtropical to subarctic. Peony species are adapted to overwintering in a dormant state, during which they are exposed to a period of cold temperatures. Flowering occurs in the spring and early summer. Peonies are usually quite drought resistant, and in nature often survive dry spells by going dormant. Wild peonies and the cultivars are sun-loving plants, although many of the wild forms occur in open woodland or the edges of forests (no species is found in deep shade). Most of the species grow in moderately fertile, circumneutral, well-drained soils that are not compacted. Many are long-lived, capable of persisting for decades. They are naturally resistant to deer and rabbits, presumably because of bitter-tasting phenolic compounds in the foliage and flowers.

Origin of cultivated peonies

Most but by no means all peony cultivars are of hybrid derivation, tracing the majority of their ancestry to China, where the plants have been grown for over 4,000 years. Since most cultivars are of interspecific hybrid origin, they are best recognized by hybrid names (*P. ×lactiflora*, *P. ×suffruticosa*, *P. ×officinalis*, etc.) but this convention is rarely followed.

Paeonia lactiflora (Chinese peony, common garden peony), is the dominant herbaceous species that has been domesticated. More than 5,000 cultivars have been recognized. This native of China, Tibet and Siberia is the main parent of most cultivated peonies, including the vast majority of those grown in Canada. It was not

introduced into Europe from China until the late 18th century.

In horticulture, less commonly cultivated herbaceous peony species are often called “species peonies.” The two most widely cultivated kinds of species peonies (in the world, as well as in Canada) are *P. officinalis* (European peony, native to Europe) and *P. tenuifolia* (cutleaf peony, also native to Europe). Several dozen cultivars of both species have been bred.

The parental species of cultivars of “tree peonies” have been difficult to ascertain, and it seems that several species are ancestral, and that there has been repeated domestication of them. In China, there appear to be cultivated groups of tree peonies that are taxonomically traceable to different wild species. In particular, “flare tree peonies” (so-named because there is an obvious flare at the petal base) are often recognized as representing hybrid cultivars of *P. suffruticosa*, but actually trace much of their parentage to *P. rockii*. However, in Western nations, available cultivated tree



Figure 4. A Japanese peony garden. ©Higashimatsuyama Peony Garden (CC BY SA 3.0).



Figure 5. Representative cultivars of the common Chinese peony, *Paeonia lactiflora*. **Top left:** 'Coral Charm', ©Poupou l'quourouce (CC BY SA 2.5). **Top right:** 2-year-old girl beside 'L'Etincelante', ©Hinton Ampner (CC BY 2.0). **Bottom left:** 'Illini Belle' (public domain photo). **Bottom right:** 'Neon', ©Andrey Korzun (CC BY SA 3.0).

peonies are usually recognized as "*P. suffruticosa*," and called "tree peony" or sometimes "moutan," a name of Chinese origin. This species, a native of China and neighboring regions of Asia, is a main parent of cultivated peonies that grow as woody shrubs, and about a thousand cultivars have been bred. Buddhist monks introduced tree peonies into Japan between the 5th and 8th centuries, where they became second in popularity only to the chrysanthemum. The Japanese bred varieties of exceptional beauty, concentrating on flowers that are not as doubled as are most Chinese varieties (and hence less prone to flower drooping). Tree peonies were introduced into Europe in the late 18th century, shortly after the importation of herbaceous peonies. Most tree peony cultivars were bred in China, a considerable number also in Japan, and a few in Western countries.

Itoh or intersectional peonies are intermediate between herbaceous species (mostly *P. lactiflora*) and tree species (often identified as *P. suffruticosa* or *P. lutea*). Toichi Itoh, a Japanese hybridizer, produced the first intersectional hybrid in 1948.

Horticultural advantages & disadvantages

Ornamental plants are predominantly grown for attractive flowers, and in this respect peonies are virtually unsurpassed. Cultivars are available that produce huge flowers in a wide range of colours, and the flowers of many varieties have very attractive odours. Peony flowers are the basis of a substantial cut-flower industry, as well as being a favourite vase flower of home gardeners. The foliage of some cultivars is quite attractive in texture and colour. Peonies are small to medium-sized shrubs that are adaptable to a wide range of landscaping applications. Most cultivars are relatively resistant to diseases, pests, drought and northern climates. They are very long-lived, and once established require only a moderate degree of maintenance.

There are a few problems associated with peonies. Compared to annuals, they are slow to establish (especially if grown from seed). Compared to some perennials, peonies (especially the herbaceous kinds) have a relatively short flowering period. The flowers of most cultivars of the herbaceous kind (which dominate the peony world) often have weak stems, requiring support to prevent bending over to the ground. Peony breeders regularly produce exceptionally attractive cultivars that gardeners want, but these are often alarmingly expensive and often in short supply.

Paeonia lactiflora (Chinese peony, common garden peony)

This is the "standard" peony most often encountered. The wild *P. lactiflora* is a native from Tibet to China and Siberia, and has many relatively small flowers on given stems. Thousands of cultivars have been produced by hybridization and selection. These range from 45 to 150 cm (1.5–5 feet) in both height and diameter. Cultivars usually have only a few flowers per stem, and there has been selection for stems bearing just one large flower.

Paeonia suffruticosa (tree peony, moutan)

The name "tree peony" is somewhat of a misnomer. The plants can take on the appearance of miniature trees (i.e. by developing a single main stem analogous to a tree trunk), but usually are multi-stemmed, and grow into small to medium shrubs. Although woody ("woody peonies" would have been a better name than "tree peonies"), the stems are relatively brittle, especially when young. Some tree peonies can grow to a height of 3 m (10 feet), but some cultivars are dwarfs, as short as 90 cm (3 feet). Most mature to 1.2–2 m (4–6.5 feet) in height (and about the same width). Unlike herbaceous peonies, the above-ground stems are perennial,



Figure 6. Representative illustrations of the tree peony, *Paeonia suffruticosa*. **Top left:** ©Leonisha (CC BY 2.0). **Top right:** Painting from The Yokohama Nursery, Japan, 1900 (public domain image). The Yokohama Nursery exported peonies and other ornamentals to the U.S. from the early 1900s to the start of the Second World War. Its beautifully illustrated catalogues are collector's items, selling for thousands of dollars. **Bottom left:** Painting from H.C. Andrews, 1806–1807, The botanist's repository, vol. 7, plate 448 (public domain image). **Bottom right:** ©Jesse W900 (CC BY SA 4.0).



Figure 7. The Itoh hybrid 'Bartzella'. As noted in the text, a single propagating division of this once sold for over \$1,000.00. ©F.D. Richards (CC BY 2.0).

although the leaves are deciduous. There are hundreds of cultivars, but tree peonies are much less popular in North America compared to herbaceous peonies. Tree peonies are relatively tender, and are not suitable for much of Canada.

Itoh (intersectional) hybrids

Itoh or intersectional peonies are intermediate between herbaceous and tree species. They have larger, more numerous flowers, a longer flowering period, and stems that do not droop by comparison with most herbaceous peonies. Itoh cultivars produce overwintering buds above ground (like tree peonies), but in most of Canada it is too cold for above-ground peony meristems to survive. However, Itoh hybrids also produce buds underground (like herbaceous peonies), and these serve for overwintering in colder climates. Thus Itoh cultivars are harder than tree peonies. Indeed, they perform exceptionally well in the large peony collection at Ottawa's Central Experimental Farm. During the 20th century, Itoh cultivars were in short supply but high demand. In the 1990's 'Bartzella', an improved yellow form, sold for over \$1000.00 for a single division. Subsequent propagation by tissue culture has made Itoh hybrids much more affordable.

***Paeonia officinalis* (European peony)**

Aside from the principal ornamental peonies, *P. officinalis* is the most popular of the (so-called) "species peonies" grown in Canada. The European peony, indeed a native of Europe, has been cultivated there for 500 years, initially for medical purposes. Quite hardy cultivars are available, most with red or crimson flowers, several with moderately large doubled flowers up to 10 cm (4 inches) in diameter.

***Paeonia tenuifolia* (cut-leaved peony, fern-leaved peony)**

This is the second-most popular "species peony" grown in Canada. It is an early-flowering plant that grows only to about 50 cm in height, and dies back to the ground a few weeks after flowering (depending on location, this may be in later summer or early fall). Despite its limited size and display, the cut-leaved peony is an old-time favourite. It has very attractive, lacy, finely-cut, fern-like foliage and fragrant blood-red flowers. A few cultivars

with doubled flowers are available. The species is ideal as a rock garden specimen or in gardens where the surrounding areas can be supplemented with annuals.

Cut flowers

As cut flowers, peonies are very popular wedding, corsage and special event flowers because of their spectacular size, colours and attractive smell. Peonies are extremely important in the international cut flower trade. Leading commercial producers of cut peonies include Chile, Israel, the Netherlands, the U.S., New Zealand, France and Italy. In the Netherlands, it is not uncommon for a million peony stems to be sold in a single day. Christmas and the wedding season months of June and July are major sales periods. In the U.S., peonies have become a traditional flower of Memorial Day (observed on the last Monday of May in honour of those who died while serving in the military). Although all peonies can be employed as cut flowers, traditionally *P. lactiflora* flowers that are large, doubled, and on long stems are preferred in the retail trade.

For those wishing to harvest their own garden flowers, the stems should be cut just before the buds open (the buds become noticeably softer at this stage). Flowers can be floated in water or harvested with a long stem and placed in water in a vase (after removing the leaves below the water line).

Medicinal uses

The bark of the root of tree peonies (especially *P. suffruticosa*) has been employed in traditional Chinese medicine as a tonic, wound healer, preventer of fungal infections, analgesic, liver cleanser and treatment for spasmodic conditions. The root of the common peony (*P. lactiflora*) has also been used frequently, in herbal medicine of China, Japan and Korea. During the Middle Ages in Europe, the seeds and roots of peonies, especially of the European peony (*P. officinalis*) were employed to cure many conditions, including bladder stones, diarrhea, epilepsy, jaundice, labour pains, lunacy, nightmares and stomach ache. Today, peony bark continues to be widely used in traditional medicine of eastern Asia. The major constituents paeonin and paeoniflorin have been found to be useful in relieving inflammation and itching, and these and other glycosides of *Paeonia* roots are under investigation for use in new pharmaceuticals.



Figure 8. *Paeonia officinalis*. Left: plants. Right: dehiscent seed pods. ©H. Zell (CC BY SA 3.0).



Figure 9. *Paeonia tenuifolia*. Left photo ©Drew Avery, right photo ©Clivid (both CC BY 2.0).

Toxicity & Food usage

The literature and the internet often claim that oral consumption of peonies is toxic to humans, pets and livestock, but research documenting this does not seem to be available, and authoritative guides to toxic plants rarely list peonies. Very rarely, dermatitis from handling the plants has been reported. In ancient China, peony roots and flowers were consumed both for medicinal and culinary purposes. In the Middle ages of Europe, peony (*P. officinalis*) seeds were crushed and used as a seasoning, and peony roots were occasionally baked as a vegetable for the very rich. Today, the petals of *P. lactiflora* are sometimes consumed in salads or beverages. In China they are parboiled and served as a sweet tea. The Chinese also employ the flowers of tree peonies in casseroles, cakes, teas and drinks. Given the uncertainty about peony toxicity and the fact that the plants have medicinal constituents, they are best not consumed in significant amounts, either by humans or animals (pets or livestock).

Cultivation notes

PURCHASING

The best option for buying peonies from commercial sources is to purchase potted plants sold and guaranteed by a local reputable nursery. They can be planted at any time of the season. It is also very advisable to have researched information on cultivars offered, since some can outlive the average human, and buying a peony can represent a life-long commitment. Often the most attractive cultivars will only be available from specialist peony suppliers. They normally ship bare-root planting stock in the fall, after the material has been divided. The best time to plant these is before freeze-up

in the fall, allowing time to establish feeder roots.

Supermarket chains commonly (and inappropriately) supply bare-root material in the spring to address consumer demand for early-season planting. Offerings are often accompanied by photos of spectacular flowers, which frequently turn out to be misleading. Peony specialists have a very unfavorable opinion of the quality of much commercial bare-root peony stock (including herbaceous, tree and Itoh classes), because there is a high rate of failure. Although often sold at “bargain” prices, the stock is generally too small, is often dried out, or the shoot buds have started developing foliage (all signs that the material should not be purchased).

Paeonia lactiflora and its hybrids are readily available from nurseries, garden outlets and specialty mail-order sources, although some rare or new cultivars may require special order. In Canada, Itoh and tree cultivars



Figure 10. Left: Painting of vase of peonies by Pierre Auguste Renoir (1841–1919). (Public domain figure.) Right: A real vase of peonies. ©Andrey Korzum (CC BY SA 3.0). In addition to Renoir, numerous renowned artists, including Frédéric Bazille, Eugène Delacroix, Henri Fantin-Latour, Paul Gauguin, Édouard Manet and Conrad Gesner, produced peony paintings. Do such masterpieces compare with the natural beauty of the flowers?

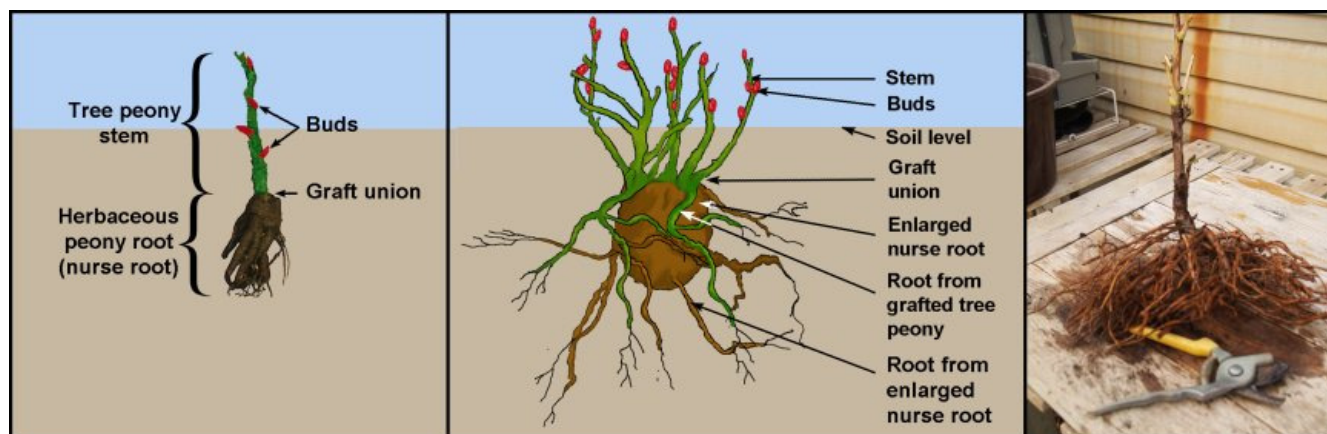


Figure 11. Development of the underground portion of a tree peony (*P. suffruticosa*), from planting to maturity. **Left:** Diagram showing how planting stock should be positioned in the soil. A young stem of a tree peony (in green; buds shown in red) has been grafted to a “nurse root” (in brown) of a herbaceous peony (*P. lactiflora*). As discussed in the text, the graft union should be 10–15 cm below soil level. **Centre:** After several years, the grafted stem has developed its own roots and has produced new stems (all parts of the tree peony are shown in green). The old nurse root (shown in brown) has persisted but is no longer needed. **Right:** Excavated root system and portion of aerial stem of a well-established tree peony. ©F.D. Richards (CC BY 2.0). Diagrams by B. Brookes.

are considerably more difficult to obtain and are more expensive (sometimes hundreds of dollars for Itoh cultivars).

PROPAGATION

The several dozen species of peonies that are grown mostly by enthusiasts, specialists and researchers are often reproduced by seeds. Seeds are occasionally employed to establish the principal horticultural peonies, but of course seeds will rarely reproduce the beautiful flowers of cultivars that have been maintained as clones. Peony seeds may have complex dormancy requirements, and if purchased it should be from a reliable source that provides germination instructions. Collecting, conditioning and storing peony seeds can be a demanding exercise, for which information is available in the references provided later. Herbaceous peonies usually produce flowers in their third year following seeding. When established from seeds, tree peonies generally require 5 to 7 years to produce flowers.

The horticultural industry and indeed most amateur gardeners usually reproduce herbaceous peony cultivars by division of the underground portion. This is best done when the plants have gone dormant in the autumn. The entire plant may be dug up. Herbaceous peonies should be divided into portions each of which has several “eyes” (i.e. buds or meristems) as well as several storage roots. The same is true for tree peonies, but each division should also have a vigorous stem or two of the current season’s growth. Herbaceous peony divisions are very widely available commercially in Canada as bare-root stock, and as young, potted plants (which can be established at any time of the season).

The horticultural industry reproduces tree and Itoh peonies almost entirely by grafting cuttings onto the portions of underground organs of herbaceous peonies, a process that is slower than reproduction by divisions, and requires skill. Micro-propagation is currently becoming established, and is expected to lower the price of these classes of peonies. In Canada, almost all tree

peonies are supplied as bare-root, imported material, but potted stock is sometimes available. It is possible to import plants from specialty horticultural suppliers. Guaranteed potted plants sold within Canada are the best option, but availability is limited within the country. Tree peonies are a gamble, and represent an investment in dollars and effort that primarily attract peony

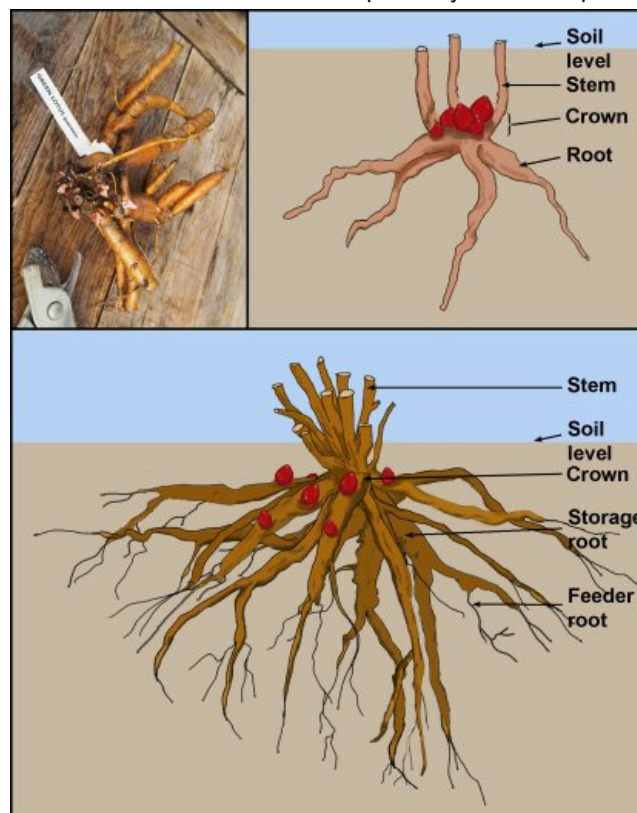


Figure 12. Planting a division of a herbaceous peony (*Paeonia lactiflora*). **Upper left:** A propagation division. ©F.D. Richards (CC BY 2.0). **Upper right:** Diagram showing an appropriately planted division (buds are shown in red). The top of the highest bud should be 2.5–5 cm below the soil surface. **Bottom:** The underground portion of a plant that has been established for several years. Diagrams by B. Brookes.

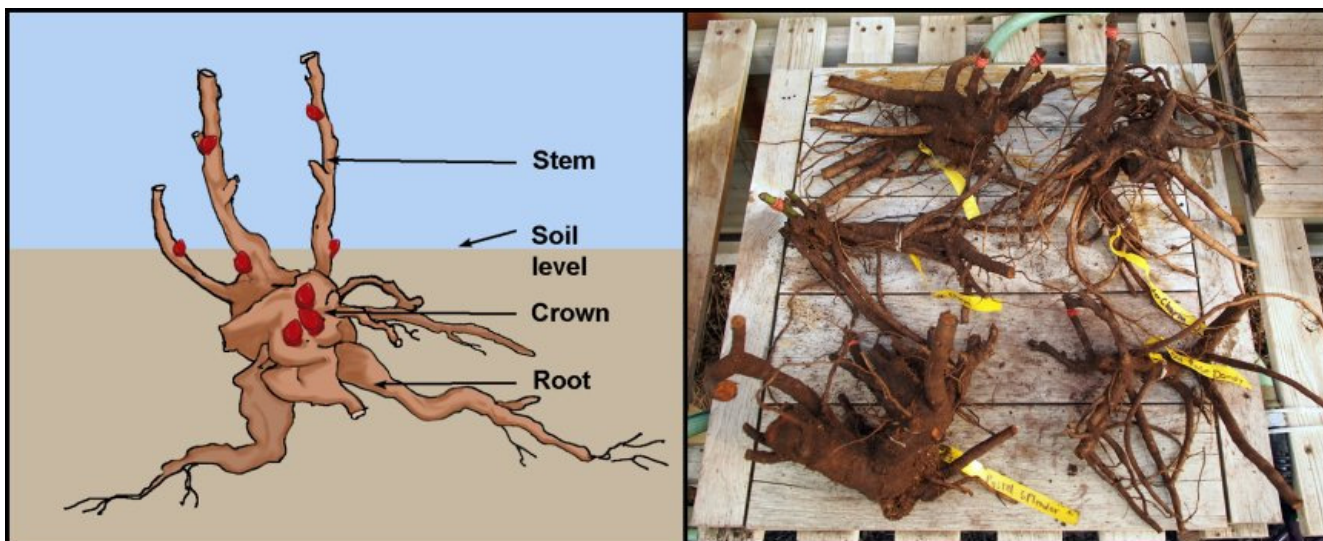


Figure 13. Propagation divisions of Itoh hybrids. **Left:** Diagram (by B. Brookes) showing an appropriately planted division (buds are shown in red). **Right:** ©F.D. Richards (CC BY 2.0).

enthusiasts in Canada. The hardier Itoh hybrids are a better choice for most Canadians.

PLANTING

Herbaceous peonies often do not respond well to transplanting, unless dormant, and in any event the deep, brittle roots are easily damaged, and up to 3 years may be required for an excavated plant to recover from the trauma. Because they can live for many years, planting sites should be carefully chosen and prepared well. They are best planted away (3 m or 10 feet) from competing roots of trees and shrubs. To avoid disease build-up, avoid planting where peonies have recently grown. Some peony specialists recommend preparing a “\$100 hole” – one that will nurture the plants for decades (such a hole could be 45 cm or 18 inches deep and 60 cm or 2 feet across). In hot climates, peonies benefit from some shade, but in most of Canada sites should be sunny (at least 6 hours of full sun daily) although some shade is tolerated (however, shade inhibits flowering). Peonies need excellent drainage. They are intolerant of waterlogging and, if available sites are overly moist, planting in raised beds should be considered. Divisions should be planted shallowly – the highest buds not more than 50 mm (2 inches) below the soil surface (both shallower and deeper planting can retard or prevent production of flowers). Potted plants should be removed from the pot and planted so that the top of the soil from the pot is level with the soil in the planting site.

Planting stock of tree peonies is typically grafted onto a base of *P. lactiflora*. When planted, the graft union should be 10–15 cm (4–6 inches) below soil level, enabling the tree peony stem to develop its own roots. The stem/root graft union usually appears as a root bulge just below the graft union (caused by the root growing much faster than the grafted stem). To form a hedge, tree peonies can be planted 0.9 m (3 feet) apart. Guidebooks often recommend that tree peonies be planted in somewhat shady areas (to prevent bleaching

of the flower colours by strong sunlight; to lower the risk of frost damage in early spring because the warmth prematurely stimulates growth; and to prevent excess drying) and in areas protected from wind (to prevent the petals from being blown away). However, in Canada it is usually more important to provide an open area where good exposure to sunlight is available.

Itoh hybrid (between herbaceous and tree peonies) planting stock will have erect basal stems with several buds, attached to a crown which will usually have more buds than on the stems. The crown buds should be 5–10 cm (2–4 inches) below soil level and (if possible) the lowest bud on the erect stems should be at soil level.

CONTAINERS

Peonies grow very well in large containers, and indeed in Asia potted tree peonies are popular. However, most cultivars develop roots that are too large for standard-sized pots. Peonies acquired in pots from stores are meant to be planted soon.



Figure 14. Hoops supporting peonies in a Japanese botanical garden. ©Tatebayashi Karino Botanen (CC BY SA 3.0).



Figure 15. Ants on a peony flower bud. ©Lee Bonnifield (CC BY 2.0).

SOIL & FERTILIZATION

Peonies can grow in infertile soils, but fertile loams are best. Both clay and sandy soils can be used, but supplementary fertilization is desirable in the latter case. Preferred pH varies from slightly acidic to slightly basic, although many peonies have a preference for slightly alkaline soil. Peonies are heavy feeders, benefitting from soil that has been fertilized with well-rotted (never fresh) manure worked well into the ground, and from annual top-dressing with well-rotted manure (avoiding contact with the plant). Some growers recommend adding inorganic fertilizers, but never high-nitrogen fertilizers; the level of nitrogen should never be higher than the levels of potassium or phosphorus (e.g., 10-15-10 would be suitable). The fertilizer should be applied away from the main crown and distributed on the soil around the drip-line of the foliage. Spring application as shoots emerge is desirable, although some gardeners also apply fertilizer in the autumn after the plants have gone dormant.

PEONY HOOPS

The flowers of most cultivars of the common peony (*P. lactiflora*) are notorious for flopping over and lying on the ground (tree peonies are quite resistant to this problem). This is because the flowers are poorly supported by their relatively weak stems (peduncles). Wind and rain may cause the flowering stems to bend over, but often large double-flowered blooms, especially of old-fashioned cultivars, droop to the ground simply because of their own weight. Bamboo stakes set around the plant and tied together by garden twine woven around the plants can be employed to support the plants. However, rust-resistant wire “hoops” or “rings” are widely employed to support the flowers in an erect position, installed in the spring at least before the plants have reached half their

height. Peony hoops (“wire cages”) designed for the purpose are usually employed. Tomato ring supports should not be substituted because their diameter is too small.

PRUNING & REMOVING FOLIAGE IN THE AUTUMN

Some gardeners deadhead peonies after the flowers senesce, but this isn't necessary, and some cultivars develop attractive seed heads. Peonies (both herbaceous and woody) don't require pruning, except for damaged stems or branches. Foliage or branches that become senescent during the growing season should be removed to lessen the chances of fungal infection. The most serious disease is botrytis (gray mould), which thrives in cool humid conditions; diseased portions should be cut away (using pruners dipped in a 10% bleach solution), and discarded. All senescent above-ground material can be removed after significant frost damage in late fall. Herbaceous peonies should be cut about 2.5 cm (1 inch) above ground. Itoh hybrid peonies should be cut 5–10 cm (2–4 inches) above ground. To avoid accumulation of disease organisms, the harvested material should be discarded.

WINTER SURVIVAL AND PROTECTION

Where winter temperatures fall below -20°C (-4°F), especially where snow cover is limited, an insulating mulch layer (hay and evergreen boughs are suitable) might be necessary to prevent loss of herbaceous peonies. Mulching is advisable in colder areas of Canada during the first year of establishment, removing the mulch when the shoots emerge. However, *P. lactiflora* peonies usually survive well with minimal or no winter care in most of the large urban areas of Canada. Some tree peonies can survive in the warmest parts of eastern Canada (Ontario to Newfoundland) and in British Columbia. They are occasionally grown in the Prairie Provinces, with limited success, because tree peonies are not adapted to very cold winter temperatures (Itoh hybrids are preferable). A burlap wrap can be helpful. In areas that are marginal for growth, the shrubs can simply be cut off at ground level (this will lower the viability of the plants but some may survive).

Curiosities of Science and Technology

- Ants (and indeed other insects) are commonly observed on peony flower buds. Tiny extra-floral nectaries produce a sweet liquid along the outside edges of the bracts covering the developing buds. Apparently the ants and peonies have established a symbiotic relationship, the peonies furnishing a sweet carbohydrate to the ants which in turn often drive off other insects. There is a common misconception that ants are necessary for peony flowers to open. To get rid of ants on peony buds to be used indoors as cut flowers, simply leave the cut stems in a vase outdoors for a period for the ants to leave.
- According to Chinese legend, the Empress Wu Zetian (ruled 690–705) banished the peony from her imperial

gardens because it refused to bloom in winter. The eccentric empress was so incensed that she ordered all peonies of the capital, Chang'an (present-day Xi'an), the most populous city in the world at the time, to be destroyed.

- In the mythology of classical Rome, the woodpecker was viewed as sacred, and under the protection of the god Mars, who guarded the peony because it had cured him when he had been wounded. ("Woodpecker of Mars" has certain meanings, including the poisonous and hallucinogenic mushroom fly agaric.) According to some ancient Greeks and Romans, peonies could be collected easily at night because they gave off light. This was desirable because it was thought that peonies should only be dug up during darkness for fear that if seen by a woodpecker the bird might peck their eyes out. This belief persisted into the Middle Ages in Europe, when people collecting peony roots for medicinal purposes were terrified that this might occur.
- Demons were one thought to fly to the spot where blood-red peony flowers bloomed, but a bit of the root worn around the neck was believed to avert enchantment.
- The fourth month of the traditional Chinese calendar was called "Moon of the Peony."
- "Paeonia" is not only the genus name of peonies, it is also an ancient kingdom, located mainly in the modern Republic of Macedonia, as well as part of northern Greece and western Bulgaria. In 168 B.C., Paeonia was taken over and incorporated into the classical Roman Empire. The Paeonian language is extinct, and today the old country of Paeonia is known mainly for ancient coins which are frequently offered by the collector's trade.

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Figure 16. Canadian stamps issued in 1952 showing Canadian-bred cultivars of herbaceous peonies ("Elgin" at left, 'Coral 'n Gold' at right). Based on photographs by Isabelle Toussaint.

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Key Websites

American Peony Society (APS) –

<http://www.americanpeonysociety.org/> [The APS is the international registrar for peony cultivars, and information on thousands of cultivars is available in

APS publications which can be purchased from this website. In particular, Jakubowski et al. (2007) list the names and descriptions of 7995 peony cultivars worldwide (many more have since been recognized).]

Canadian Peony Society – <http://www.peony.ca/>

[Especially note

<http://canadianpeonysociety.blogspot.ca/>. These are very informative websites on peonies suitable for Canada, and provide links to other sites where information on peonies is available.]

Peonies at the Central Experimental Farm –

<http://www.friendsofthefarm.ca/peonies.htm> [Good information on peonies hardy in Ottawa, and the contributions of the Saunders family to peony development.]

Peony Organizations and Links –

<http://mbgna.umich.edu/peony/peony-organizations-and-links>

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Figure 17. Peony exhibition in St. Petersburg, Russia. ©Olga (CC BY 2.0).

POLYKETIDE PRODUCTION AND GENE TRANSCRIPTION VARIES AMONG THALLUS STRUCTURES AND TIME IN STORAGE FOR *CLADONIA CARIOSA*

Jared Field^{1,2} and Michele D. Piercey-Normore^{1,3}

Cladonia cariosa is a widespread desiccation tolerant lichen in Manitoba consisting of a primary thallus of squamules at the soil surface, an upright podetium, and apothecia at the apex. Herbarium specimens of different ages were used to determine the feasibility of gene transcription and polyketide production in three thallus structures of *C. cariosa*. Specimens were dissected, rehydrated, and total RNA was subjected to semi quantitative PCR. Transcription of a housekeeping gene, β -tubulin, and two polyketide synthase genes was detected. The level of transcription was greatest in the apothecia and lowest in the squamules. The presence of two polyketides showed the opposite trend where the frequency of their presence was highest in the squamules and lowest in the apothecia. Transcription of all three genes corresponded with the length of time in storage where transcription was lower in the thallus samples collected 14 years ago than the more recently collected samples. This proof of concept paper shows preliminary evidence to suggest that gene transcription occurs in 14 year old specimens and it illustrates the feasibility of studying gene transcription in separate thallus structures.

Keywords: atranorin, β -tubulin gene, fumarprotocetraric acid, lichen structures, polyketide synthase genes

Introduction

Most lichens can tolerate desiccated conditions and they return to normal metabolic levels when they are rehydrated. Tolerance to desiccation depends on the length of time in the desiccated state, constitutive transcription levels, production of antioxidants, and other factors (reviewed in Kranner et al. 2008) in addition to some phenolic secondary metabolites. Lichens produce over 800 known secondary metabolites, some of which are thought to allow lichens to tolerate adverse environmental conditions (Huneck 1999) contributing to the overall fitness of the lichen (Asplund et al. 2010). Secondary metabolites produced in the cortex may influence light reception (Armaleo et al. 2008; Gauslaa and Solhaug 2001; Gauslaa and Ustvedt 2003; Solhaug et al. 2010) while some produced in the medulla are hypothesized to have different functions such as increasing tolerance to acidic substrata (Hauck and Jürgens 2008; Hauck et al. 2009) or reducing the excessive uptake of certain heavy metals (Mn²⁺ & Cu²⁺; Hauck and Huneck 2007). However, the production of secondary metabolites in specific thallus structures such as the apothecia, has been shown in only two species (Culberson et al. 1993a; Liao et al. 2010).

The lichen *Cladonia cariosa* (Ach.) Sprengel is a desiccation tolerant lichen that grows on thin soil (Hauck et al. 2009) and produces two major secondary metabolites, atranorin and fumarprotocetraric acid (Culberson et al. 1993b). The morphology of *C. cariosa* consists of small squamules found at the surface of the soil; the upright podetium which grows from the squamules; and the apothecia at the apex of the podetium (Fig. 1A). The squamules and podetia contain

the algal photobiont, which provides carbon through photosynthesis for growth and metabolism of both symbionts. The apothecia result from sexual reproduction and do not contain algae. Therefore, these structures in *Cladonia cariosa* may be expected to produce secondary metabolites for protection of the algae and the spores from adverse conditions.

Since longer time periods in the desiccated state may damage protective mechanisms, it is hypothesized that specimens stored for long time periods would have low levels of gene transcription, but it is not known how long *C. cariosa* may be viable. Additionally, if thallus structures show differences in polyketide production, differential gene transcription among thallus structures would be expected for PKS genes but not for housekeeping genes. In this proof of concept paper we illustrate the feasibility of examining gene transcription in three lichen structures of *C. cariosa* and discuss some of the limitations.

Materials and methods

Thirteen herbarium specimens of *Cladonia cariosa* were collected from different geographic locations and stored in the University of Manitoba Herbarium (Table 1). *Cladonia cariosa* has been selected for this study because it is commonly found in a dry habitat and the potential variability of secondary metabolite composition (Culberson et al. 1993b; Piercey-Normore 2003). Three structures (apothecia, podetia and squamules) were separated and cleaned of soil and other debris (Fig. 1A). Secondary metabolites were extracted from lichen structures by acetone following the procedure of Orange et al. (2001) using solvent A (toluene, dioxane and acetic acid; 180:45:5 mL). Approximately 10 mg (dry weight;

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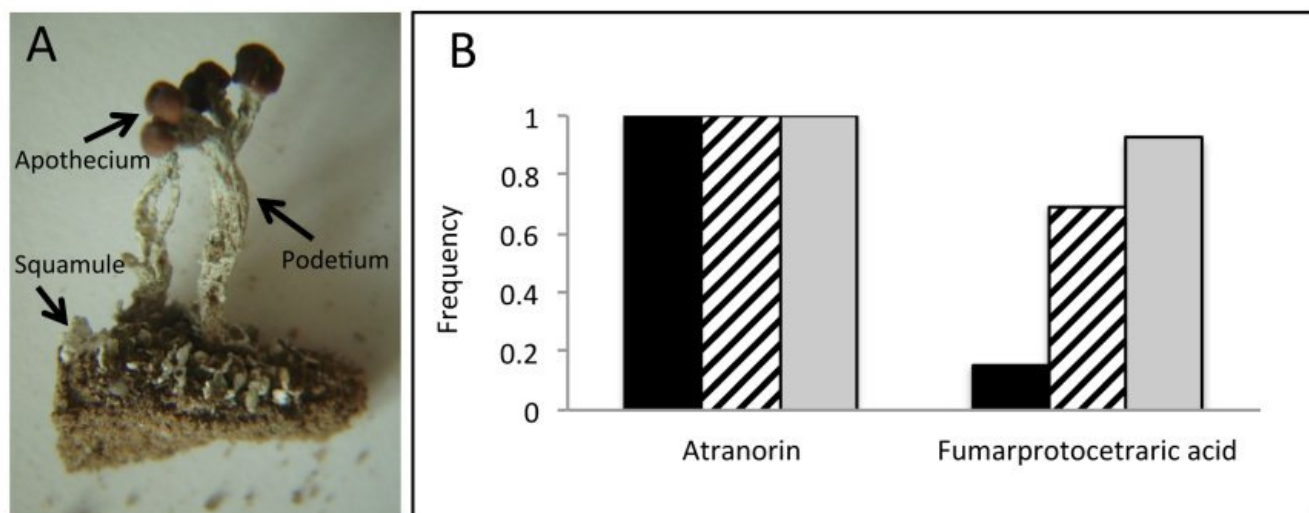


Figure 1: A) Photograph of *Cladonia cariosa* showing brown apothecia at the apex of the upright podetia, and the leaf-like squamules, which are in contact with the soil. **B)** Frequency of occurrence (n=13) of atranorin and fumarprotocetraric acid in each of apothecia (solid black bars), podetia (diagonal bars), and squamules (solid gray bars).

DW) of isolated tissue was used in 100 μ L of acetone and incubated at room temperature for 1 hour before spotting onto aluminum back silica coated plates (Thermo Fisher Scientific, Burlington, Ontario).

Semi-quantitative polymerase chain reaction (qPCR) was used to compare the level of transcription of two fungal PKS gene paralogs (PKS3 and PKS7; Timsina et al. 2013) and the fungal β -tubulin gene. The separated lichen structures were rehydrated for two hours (Doering et al. 2014). RNA was extracted using TRIzol (ThermoFisher Scientific) following the manufacturer's instructions and treated with DNase I (ThermoFisher Scientific). Complementary DNA (cDNA) was synthesised using the Maxima First Strand cDNA Synthesis Kit (Thermo Fisher Scientific). The PCR conditions for all three genes consisted of 1.5 μ L of cDNA sample, 1x PCR buffer (50 mM KCl; 100 mM Tris-HCl [pH 8.3]), 2.0 mM $MgCl_2$, 150 μ M each dNTP, 0.3, μ M each primer and 1 unit of Taq DNA polymerase (BioFrogga, Toronto, Ontario). The PCR cycle started with initial denaturation at 95 $^{\circ}$ C for 5 minutes followed by 28 cycles of denaturation at 95 $^{\circ}$ C for 1 minute, annealing at 58 $^{\circ}$ C for 1 minute and extension at 72 $^{\circ}$ C for 1 minute. PKS primers from Timsina et al. (2013) were screened and two sets of PKS primers that gave PCR product were used; PKS3-DA-F (GGTGAGCTATGAAGCGCT), PKS3-DA-R (GGCATCGTAATACCAGCAGT), PKS7-DA-F (AAGCCCTTGAGAATGCT), and PKS7-DA-R (AGAGTCTCCATCTCGGAT). The β -tubulin primers were BT-F (CTCGTGCCGTCGTCGAT) and BT-R (TCAGAGTTGAGTTGGCCAGG) (designed from product obtained by BT3 and BT10 from Myllys et al. (2001). The PCR product was then run on 1.5% agarose gels and quantified using a 1 Kb DNA ladder (ThermoFisher Scientific).

Statistical analyses were performed using the statistical software JMP (Version 10.0.2, 64 bit edition,

SAS Institute Inc, Cary, North Carolina, 2014). The normality of the data and residuals collected from PKS gene transcription (mass (ng) estimated from the gel) was tested using a normal probability plot (histogram selection in JMP). The data collected from TLC were in the form of frequencies for the presence of atranorin and fumarprotocetraric acid in each of the three thallus structures. To test the hypothesis that gene transcription varies among apothecium, podetium and squamule, a one-way ANOVA was used for the three genes together. To test the hypothesis that gene transcription varies with time in a desiccated state, a correlation was performed using Spearman's ρ correlation on all genes combined.

Results

The frequency of atranorin and fumarprotocetraric acid differed among apothecia, podetia and squamules. Fumarprotocetraric acid was detected in 12/13 squamule samples, 9/13 podetia and 2/13 apothecia but atranorin was present in all samples (Figure 1B).

The number of PCR cycles was compared with band intensity to determine the threshold cycle in the exponential phase, which was determined to be 28 cycles. Rehydrated thalli of *C. cariosa* produced gene transcripts from β -tubulin and the two PKS genes (Figure 2). The transcription levels did not significantly differ between structures for each gene alone (PKS3 $p=0.4418$; PKS7 $p=0.3629$; β -tubulin $p=0.1363$) but when data from all genes were combined the apothecia and podetia produced significantly more transcripts than the squamules ($df=2$; $F=7.8526$; $p=0.0011$).

The thalli that were collected and stored since 2001 and 2002 produced weaker products than those that were collected and stored since 2009 and 2012. There was a positive correlation between the time in storage and band intensity ($p=0.0226$; Spearman $\rho=0.4373$).

Discussion

The constant presence of atranorin in the three thallus structures was expected since the cortical compound atranorin plays a role in light regulation (Rao and LeBlanc 1965; but see Rundel 1978) and in reflecting excess light (Solhaug et al. 2010), which may protect the developing spores in the apothecium and the algae in the podetium and squamules from light exposure. Usnic acid, a light screening secondary metabolite, was more concentrated in apothecia of *Ramalina siliquosa* (Culberson et al. 1993a) and the apothecia, pycnidia, and around green algal cells in *Cladonia uncialis* (Liao et al. 2010), suggesting its location may be related to its function. The more frequent presence of fumarprotocetraric acid in the squamules (Fig. 1) may be linked to the extent of soil contact encountered by the squamules compared with the podetium and apothecium which are elevated above the soil. The accumulation of fumarprotocetraric acid may be necessary to maintain suitable moisture conditions within the squamules, since carbon acquisition is limited by the lower diffusion rate of carbon dioxide in water than air (Palmqvist 2000). Additionally, the localization of fumarprotocetraric acid in the squamules may also be related to the role of the compound in tolerating pH changes or heavy metal toxicity (Hauck and Huneck 2007; Hauck and Jürgens 2008; Hauck et al. 2009). Alternatively, degradation of fumarprotocetraric acid in the apothecia may explain its absence since usnic acid was thought to be degraded by UV light (Begora and Fahselt 2001).

This study showed that rehydrated lichen thalli of *C. cariosa* from older collection dates (2001 to 2002) produced weaker and inconsistent PCR product, but the more recent collections (2009-2012) produced stronger and more consistent results. Gene transcription from rehydrated thalli has been shown to be successful for *Lobaria pulmonaria* (Doering et al. 2014) and *Cladonia rangiferina* (Juntilla et al. 2009) but the thalli were recent collections. The finding that transcription of both PKS genes was similar to that of β -tubulin may imply that all three genes are constitutively expressed. The ability to obtain transcripts from thalli that are up to 14 years old provides potential for further physiological studies in this species utilizing the transcriptome.

The finding that transcription was higher in the apothecia than the squamules is intriguing and may be explained in at least two ways. First, the three genes examined are fungal specific genes and the apothecium contains all fungal tissue with no algal tissue. Even though the thallus mass was the same for all treatments, the mass of fungal tissue was proportionately higher in the apothecium than the vegetative structures and therefore more fungal RNA in the total RNA isolated. The podetia and squamules have both algal and fungal tissue present resulting in less fungal RNA than in the apothecia available for the reactions. A second explanation for this finding is that the higher transcription levels in the apothecia may be the result of low transcription levels in the squamules. The squamules are exposed to soil factors that affect the RNA quality,

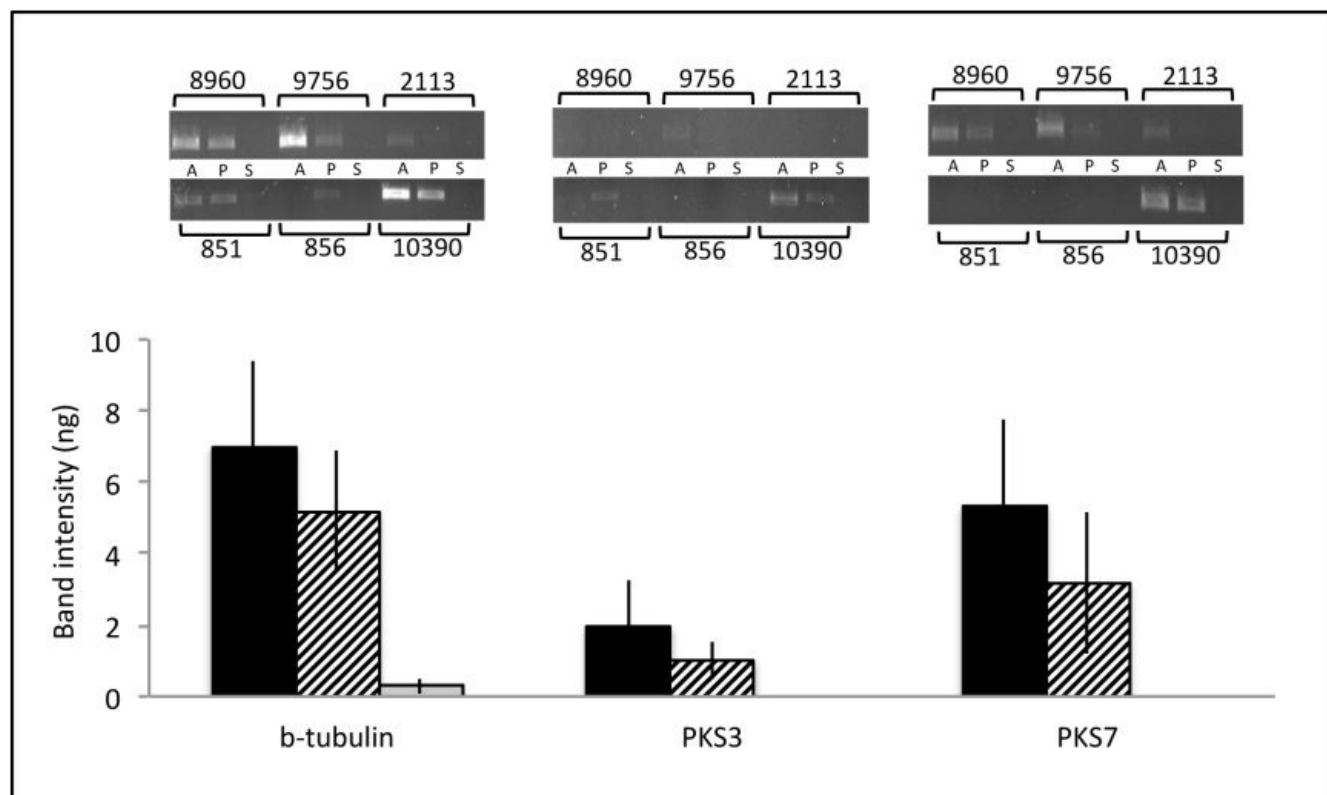


Figure 2: Transcription of three genes, β -tubulin, PKS3, and PKS7 for each of apothecia (A; solid black), podetia (P; diagonal), and squamules (S; solid gray). The numbers above and below the gel images refer to sample numbers (see Table 1).

Collection Number and Date	Location and Habitat
Normore 851, May 2001	Manitoba, Grass River Provincial Park; Hwy 39; roadside with exposed limestone outcrop; small shrubs, Jack pine, and aspen
Normore 856, May 2001	Manitoba, Goose Lake; Hwy 10; roadside with exposed limestone outcrop; aspen, balsam fir, white spruce, young Jack pine, and shrubs
Normore 1067, July 2001	Manitoba, Marble Ridge Road, Route 17; limestone cliff; birch, black spruce, aspen; lightly grazed pasture, limestone tables, and scattered oak
Normore 1074, July 2001	Manitoba, Marble Ridge Road, Route 17; limestone cliff; birch, black spruce, aspen; lightly grazed pasture, limestone tables, and scattered oak
Normore 2113, July 2002	Manitoba, Twin Lakes near Churchill; open lichen woodland with spruce; many ground dwelling lichens and epiphytes
Normore 2369, August 2002	Manitoba, Sherridon road; granite ridge dominated by Jack pine
Normore 3607, May 2004	Manitoba, Clearwater Provincial Park; disturbed roadside
Normore 8960a, July 2009	Manitoba, Wapusk National Park; burned black spruce plateau and forest near stream; low lying willow and dwarf birch
Normore 8960b, July 2009	Manitoba, Wapusk National Park; black spruce dominated peat plateau with some aspen, willow, and dwarf birch
Normore 9756, July 2010	Manitoba, Wapusk National Park; vegetated beach ridge near lake and spruce-larch fen
Normore 10390, July 2012	Manitoba, Simon House Road; roadside near margin of mature spruce forest; moist
Normore 10706, May 2013	Manitoba, Athapap Road; limestone tables with a thin layer of sand; juniper, aspen, spruce, and Jack pine
Normore 10719, May 2013	Manitoba, Athapap Road; limestone tables with a thin layer of sand; juniper, aspen, spruce, and Jack pine

Table 1. *Cladonia cariosa* specimens used in this study

such as free ribonucleases (RNases), humic acid and soil particles (Allison 2006; Carvalhais and Schenk 2013) (Fig. 1), resulting in less RNA available for cDNA synthesis. Additionally, the polyketides may also inhibit reactions (Juntilla et al. 2009). Therefore, both housekeeping and PKS gene transcription may be high in the natural lichen, but the detection after isolation of RNA would have been reduced because of lingering RNAases and other inhibitors. This problem might be avoided by immediately preserving the RNA complement when field collections are made.

In conclusion, this proof of concept study showed a differential production of atranorin and fumarprotocetraric acid in apothecia, podetia, and squamules of *C. cariosa* and the opposite pattern for gene transcription (of PKS and β -tubulin genes) in the same structures. It also showed that gene transcription could be detected from thalli that had been stored in a desiccated state for 14 years. While there were some limitations to this study, the study provided some of the first insights into gene transcription in separate thallus structures highlighting some of the potential problems with RNA isolation from each type of structures. For example, the proportion of fungal and algal cells that comprised the apothecia, podetia, and squamules may differ, which would influence the level of gene transcription detected. Additionally, RNA degradation and inhibition of reactions needs to be addressed for squamules, which are in contact with soil. Nevertheless, the study illustrates the feasibility of studying gene transcription in separate thallus structures, it highlights some of the limitations encountered, and provides the foundation for further hypothesis development.

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