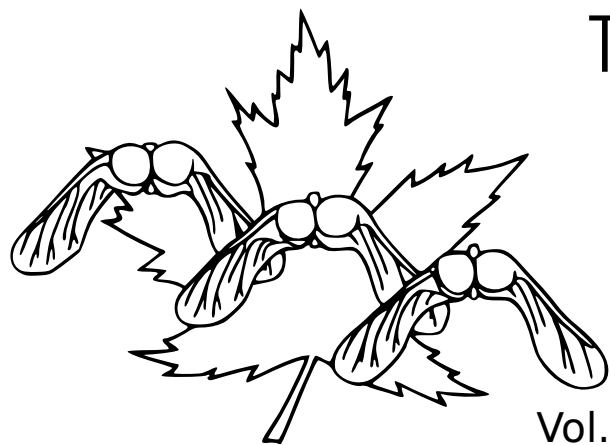




The Canadian Botanical Association Bulletin

Bulletin de l'Association Botanique du Canada

Vol. 49 Number 2, September/septembre 2016



Fall colours at the Queen's University Biological Station on Lake Opinicon, ©Greg Bulte. See article on page 63

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Major Invasive Plants:
Eurasian Water Milfoil

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Fall Colours Top Ornamental Plants:
Impatiens

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Diane Davis, CBA President Art Davis, and Christine Maxwell ©Hugues Massicotte



CBA members Olivera Gavric, Jarnail Chandi, Jason Wong, and Santokh Singh, celebrating "Fascination of Plants Day", May 18, 2016 at UBC. Host your own event in 2017 - for more details see fascinationofplantsday.org

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: www.cba-abc.ca

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NEXT ISSUE

Texts for the next issue, 49(3), must be received by December 1, 2016

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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: www.cba-abc.ca

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PROCHAIN NUMÉRO

La date de tombée des textes du prochain numéro, le no 49(3), est le 1 décembre 2016

PRESIDENT'S MESSAGE

Both geographically and scientifically, "Botany on the Edge" was a fitting theme for the CBA-ABC's annual meeting held May 15-18, 2016 at the beautiful University of Victoria on Vancouver Island. One hundred delegates participated in field trips (e.g., to Saltspring Island; the Garry Oak ecosystem), the annual banquet, the annual general meeting, plus viewed the 25 posters and attended the 50 talks, including one keynote symposium ("An Exploration of Biological Creativity and New Possibilities"), and a symposium on Tree Biology. Four Section Symposia (Plant Development, Ecology, Mycology, Teaching) rounded out the program. Thanks to the many participants for their important roles!

The Lawson Medal recipient was Luc Brouillet (Univ. de Montréal and Botanic Gardens - IBRV), and the CBA-ABC's inaugural Magister Teaching Award went to Arunika Gunawardena (Dalhousie Univ.). Bryce Kendrick (Univ. of Waterloo) presented the Weresub Memorial Lecture. Also, a connection was made with Linda le Geyt of the Botanical Artists of Canada, with plans to continue this relationship ahead. Various student awards for presentations and refereed scientific publications, plus several travel awards to assist their attendance at Victoria's meeting (see photos and details in this issue), were given at the banquet held at the wonderful Horticulture Centre of the Pacific. Another highly entertaining and financially successful live auction of botanically-related memorabilia, orchestrated by Hugues Massicotte and Linda Tackaberry (plus an accompanying silent auction), helped secure funds for student travel to future national meetings.

It is my pleasure, on behalf of the CBA-ABC, to thank the Local Organizing Committee (LOC) members Geraldine Allen, Erica Wheeler, Shannon Berch, Barbara Hawkins, Terri Lacourse, and Patrick van Aderkas, for their skillful planning and execution of the excellent meeting in Victoria.

That meeting also marked a turnover in several CBA-ABC executive positions. For their essential assistance during this transition, I thank John Markham for his 2-year term as President and continuation as Past-President, and to Frédérique Guinel for her term as Past-President. Frédérique remains on the executive as Vice-President, chairing the LOC for next year's meeting (July 4-8, 2017) at Wilfrid Laurier University, Waterloo. For their past service, we thank Gerry Allen (VP



and director, west), Pauline Catling (student rep, west), Deborah Metsger (director, east), and Moira Galway (chair of Development Section). Newly elected to the board of directors are Julian Starr (President-Elect), Nadia Cavallin (director, east), Rob Guy (director, west), and Dylan Ziegler (student rep, west). The full 2016-17 board of directors and section chairs is published in this issue.

Projecting forward from Victoria's meeting, I look forward to working with you as CBA-ABC President – a sort of "Botany on the PEdge". Currently the *ad hoc* Science Policy Committee is drafting the association's submission to the call by the Federal Minister of Science for a science-policy review of Canadian universities, due by the end of September. Also, we shall be unveiling the first competition of the CBA-ABC Special Projects Fund, an initiative begun during John's presidency. Please see the official call in the next issue of the Bulletin.

Until then, wishing you an enjoyable, rewarding, and beautiful autumn 2016. Remember ... plants have all the anthers!

Respectfully,

Art Davis, University of Saskatchewan

“Hidden World of Plants”

Wilfrid Laurier University

July 4th to July 8th, 2017

53rd Annual Meeting

Keynote Speaker

Dr. Jan Sapp, York University

Main Symposium Speakers

Taxonomy & Phytogeography

Dr. Julissa Roncal, MUN, St. John's

Mycology

Dr. Franck Stefani, AAFC, Ottawa

Ecology

Dr. Anna Hargreaves, UBC, Vancouver

Plant & Development

Dr. Ned Friedman, Harvard University, Boston

Teaching

Dr. Roger Hangarter, Indiana University, Bloomington

Field-trips

- Inglis Falls and Bruce Peninsula
- A ginseng farm and Backus Woods
- Rafting on the Grand River



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L'Association Botanique du Canada



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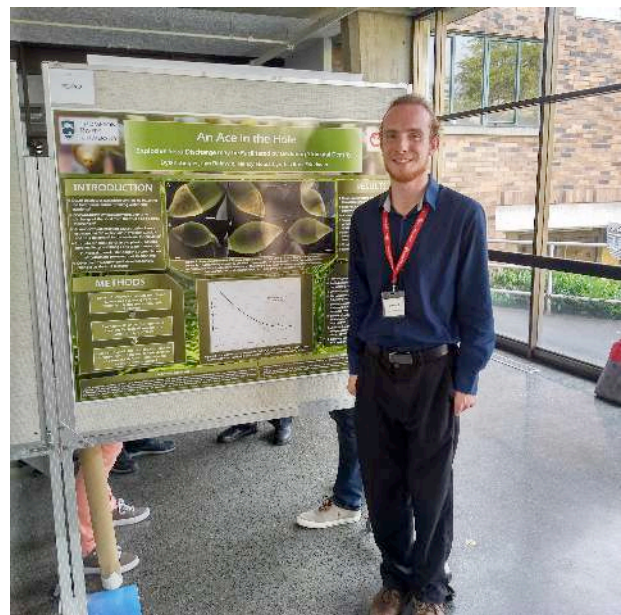
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Book For Review

"Stellar evolution and morphology in selected taxa based on the study of Vascuilotaxy (*studio nov.*), by Kevin Ross, published by Aulie Ink, is available for review. If you're interested, please contact the bulletin editor at cba.abc.bulletin@gmail.com.



Dylan Ziegler, Incoming CBA Student Rep, West

ANNOUNCEMENTS

Lecture Series in Honour of Margaret McCully



Margaret E. McCully

Carleton University has recently initiated an annual lecture series in honour of Dr. Margaret E. McCully who was an extraordinary teacher and faculty member in the Carleton Biology Department for more than 35 years. Following her retirement in 1999, she moved to Australia where she continued her work. She is currently an honorary research scientist at CSIRO and visiting fellow at the Australian National University in Canberra. Margaret is internationally recognized for her pioneering work in microscopy and root anatomy and physiology for which she was awarded a Lawson Medal in 1996. The annual McCully lecture in Plant Biology is held each year in April. The theme of this lecture series is "from the lab to the field". The next speaker will be Dr. Zhongmin Dong from St. Mary's University on April 21st, 2017 speaking on plant-microbe interactions in the rhizosphere. For more information, please contact shelley.hepworth@carleton.ca.

Emploi: professeure ou professeur en biologie cellulaire végétale, Université de Montréal

Le Département de sciences biologiques sollicite des candidatures pour un poste de professeure ou de professeur à temps plein au rang d'adjoint en biologie cellulaire végétale.

La personne retenue sera appelée à enseigner aux trois cycles, à encadrer des étudiants aux études supérieures, à poursuivre des activités de recherche, de publication et de rayonnement ainsi qu'à contribuer aux activités de l'institution. La personne retenue sera également responsable de la gestion et du développement de la plateforme de microscopie à l'Institut de recherche en biologie végétale (IRBV).

Pour en savoir plus, lisez la description complète en ligne: <http://bio.umontreal.ca/departement/nouvelles/une-nouvelle/news/emploi-professeure-ou-professeur-en-biologie-cel-37311/>.

Job: Professor in Plant Cellular Biology, Université de Montréal

The Département de sciences biologiques is seeking applications for a full-time tenure-track position at the rank of

Assistant Professor in Plant Cellular Biology.

The appointed candidate will be expected to teach at all three levels of the curriculum, supervise graduate students, engage in ongoing research and publication, and contribute to the academic life and reputation of the University. The appointed candidate will also be responsible for the management and development of the microscopy platform at the Plant Biology Research Institute (IRBV).

For more information, see the complete posting online: <http://bio.umontreal.ca/departement/nouvelles/une-nouvelle/news/emploi-professeure-ou-professeur-en-biologie-cel-37311/>.

Job: Assistant Professor, Plant Biology, University of Ottawa

A higher rank will be considered under exceptional circumstances.

The Department of Biology, University of Ottawa, is seeking a plant scientist with research expertise in one or more of the following areas: plant physiology, plant molecular biology, genetics and plant genomics, and plant-microbe interactions. The successful candidate will be expected to teach plant science courses at the undergraduate and graduate levels; to conduct research and academic service activities, and to supervise graduate students. The candidate will join an active department of over 40 professors that maintains strong collaborative links with the numerous governmental and academic institutions that characterise Canada's Capital Region.

To learn more, read the complete job description online: <https://www.uottawa.ca/vice-president-academic/faculty-affairs/faculty-recruitment/openings>

Emploi: Professeur adjoint, Biologie végétale, Université d'Ottawa

Des rangs supérieurs seront envisagés dans des circonstances exceptionnelles.

Le département de Biologie de l'Université d'Ottawa est à la recherche d'un chercheur en biologie végétale dont le champ de recherche touche un ou plusieurs des domaines suivants: physiologie végétale, biologie moléculaire végétale, génétique et génomique végétale, et interactions plantes-microorganismes. Il est entendu que le(la) candidat(e) choisi(e) donnera des cours en biologie végétale de premier cycle et de cycles supérieurs, mènera des activités de recherche et de service académique, et supervisera des étudiants diplômés. Le(la) candidat(e) se joindra à un département dynamique comptant plus de 40 professeurs, maintenant des liens collaboratifs forts avec plusieurs organismes gouvernementaux et institutions académiques qui caractérisent la région de la Capitale nationale du Canada.

Pour en savoir plus, lisez la description complète en ligne: <https://www.uottawa.ca/vice-recteur-etudes/affaires-professorales/recrutement-facultaire/postes-pourvoir>

CBA Meeting Videos Available

Connie Nozzolillo has produced three short (5-10 minute) videos of past CBA meetings. If any CBA member is interested in viewing them, she would be happy to send a copy by mail or dropbox. They're too big to be sent by e-mail. One was made from movies and slides she took in 1972 at the joint CBA-CSPP meeting in Halifax and is mainly devoted to the post-meeting Cape Breton field trip. A second one she

recorded at the recent CBA meeting in Montreal during the field trip to the McGill Biology Station and at the "history" sessions at the jardin botanique. The third one I made following the BSA organized meeting in Edmonton last year at which I participated in the field plots tour north of Edmonton. If you're interested in seeing these, please send a message to the Bulletin Editor via cba.abc.bulletin@gmail.com, and I'll put you in touch with Connie.

TEACHING SECTION NEWS

In lovely Victoria, BC at CBA 2016, the Teaching Section held an inspiring Symposium "**Teaching in the Field: Outdoor Classroom**" which examined the broad meaning of teaching in the field and learning outside the traditional classroom. This included field courses, outdoor ecology labs, field trips, ecology of "Place" and ethnobotany. The three dynamic speakers were: Dr. J. Hugo Cota-Sanchez (University of Saskatchewan) who gave us "*Experiential learning al-fresco*" showcasing his Field courses in Saskatchewan, Kananaskis, and in Latin America, as well as his multicultural & food filled Plants & People labs; Dr. Shailesh Shukla (University of Winnipeg) who shared "*Indigenizing the Sciences within Academy: Lessons from Summer School on Field Ethnobotany*" with wonderful stories about elders and students; and finally, Dr. Lyn Baldwin (Thompson Rivers University) took us on a journey

to "*In the Field: Teaching as a path to Place*" with her Terrestrial Ecology field course and Plants & People community based project "How Close Can You Stay".

Plans are underway to prepare a hands-on symposium to explore student-centered learning at our next conference at Wilfred Laurier University in Waterloo, ON. We look forward to seeing you again next year!

Sincerely,

Christine Petersen, Thompson Rivers University, BC
cpetersen@tru.ca
Rafael Otfinowski, University of Winnipeg, MB
r.otfinowski@uwinnipeg.ca
Teaching Section Co-chairs

MYCOLOGY SECTION NEWS

To begin, we should mention that the 52nd CBA meeting participants, held this last May, were greeted by a wonderfully blooming UVic campus and Finnerty gardens. The meeting was motivating, informative and fun and our heartfelt gratitude must go to the organizers for a flawless proceeding.

On the mycological scene, one of the field trips was devoted to hunting native mushrooms and truffles. While I (SB) organized and led the foray, the true leaders were Oluna and Adolf Ceska and Brooke Fochuk and her amazing truffle dog, Dexter. Despite the unusually warm and dry spring, an array of interesting fungal finds was made including some truffles.

The Mycology Symposium (Fungi at the Edge) organized by Shannon Berch and Yolande Dalpé was well received with four eager presenters (Kranabetter, Chagnon, Massicotte & Piercey-Normore) and additional contributed papers were also given enthusiastically as part of the Tree Biology Symposium (Hawkins, Feldman) and the Ecology Symposium (Shay, Chen).

In other news, the winner of the Weresub Award for Best Student Publication in fungal biology was Jaclyn Dee (UBC) for her contribution: Dee JM, Mollicone MRN, Longcore JE, Roberson RW, Berbee ML. 2015. Cytology and molecular phylogenetics of Monoblepharidomycetes provide evidence for multiple independent origins of the hyphal habit in the Fungi. *Mycologia* 107:710-728. Congratulations and thank you to all Weresub contenders for their submissions.

We were privileged to hear Dr. Bryce Kendrick (Prof

Emeritus, U of Waterloo) deliver the Memorial Weresub ("Beneath the surface") lecture this year to a delighted audience and recollect, among other things, his scientific encounters with Luella Weresub.

There was also a first at the Auction this year, where superb specimens of *Agaricus augustus* (The Prince! See pict page 43) were offered to an always-benevolent audience and bid successfully by Mary Berbee, delighted as she was to be able to put them to good use right away for an incoming show-and-tell!

We are now focusing our energies to the meeting in 2017, to be held in Waterloo at Wilfrid Laurier University. We are now considering potential candidates for our Weresub Lecturer, and debating if we should sponsor a mycology-based symposium. At our section meeting, a group of us discussed themes and ideas that could be used for possible symposia, and for potential Weresub lecturers. If anyone has further suggestions regarding any of these topics, forward these to either Shannon or me. As always, the announcement of the next Luella K. Weresub Memorial Award for the best paper in Fungal Biology will appear early in the new year, so students and supervisors can expect to hear more over the next few months!

Respectfully submitted,

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

REFLECTIONS ON CBA-ABC 2016, VICTORIA BC

It was a great pleasure to see the familiar faces of our CBA-ABC friends and colleagues in Victoria in May for the 52nd annual conference. Thank you to everyone who participated and contributed to its success! Here are a few highlights and some photos of the event contributed by the membership.

We had a good turnout with 100 registrants, including 35 students. Nearly half of the attendees were from BC but people also traveled to Victoria from each of the other nine Canadian provinces, several US states (New York, California, Washington DC), and Norway! We hope this broad geographic representation will continue at future meetings.

The LOC was keen to broaden the public outreach component of the annual meeting by including an evening plenary lecture to which the general public was invited. Dr. Karl Niklas from Cornell University delivered an excellent talk outlining his career-long fascination with the intersection of mathematics and botany. A number of people from the broader community attended the lecture, a trend that we can continue to encourage.

Despite an early spring on the West Coast, the local flora was still in good shape and people on field trips to Trial Island and Saltspring Island were treated to some of the best that southern Vancouver Island has to offer. Truffle-hunting

at Royal Roads University was a great success, thanks to Dexter the truffle dog who put all of the human sniffers to shame!

The botanical auction, skillfully hosted by Hugues Massicotte, brought in nearly \$700 for the Macoun Travel Bursary fund which supports students attending the annual meetings. For maybe the first time in the history of the CBA-ABC, some beautiful specimens of the 'Prince' (*Agaricus augustus*) hastily plucked from the undergrowth on the University of Victoria campus, were auctioned off. They were clearly the favourite auction item of the evening!

The CBA-ABC Banquet, held at the Horticulture Centre of the Pacific, was a highlight of this year's meeting. Attendees had the opportunity to stroll through the gardens for an hour, before sitting down to an excellent buffet dinner in a beautiful botanical setting.

Thanks again for joining us in Victoria. It was a pleasure to have you here and we look forward to seeing you all next year in Waterloo ON, at Wilfrid Laurier University.

Best wishes,

Erica Wheeler and Geraldine Allen
On behalf of the LOC



Arbutus ©Hugues Massicotte



Truffle Hunting Party ©Linda Le Geyt



Receiving Instruction in Truffle Hunting ©Rafael Otfinowski



Dexter the Truffle-Dog ©Rafael Otfinowski



The Prey ©Rafael Otfinowski



Mary Berbee's Prince Mushrooms, *Agaricus augustus* ©Hugues Massicotte



Botanizing on Saltspring Island ©Hugues Massicotte



All together under a Garry Oak on Vancouver Island ©Hugues Massicotte



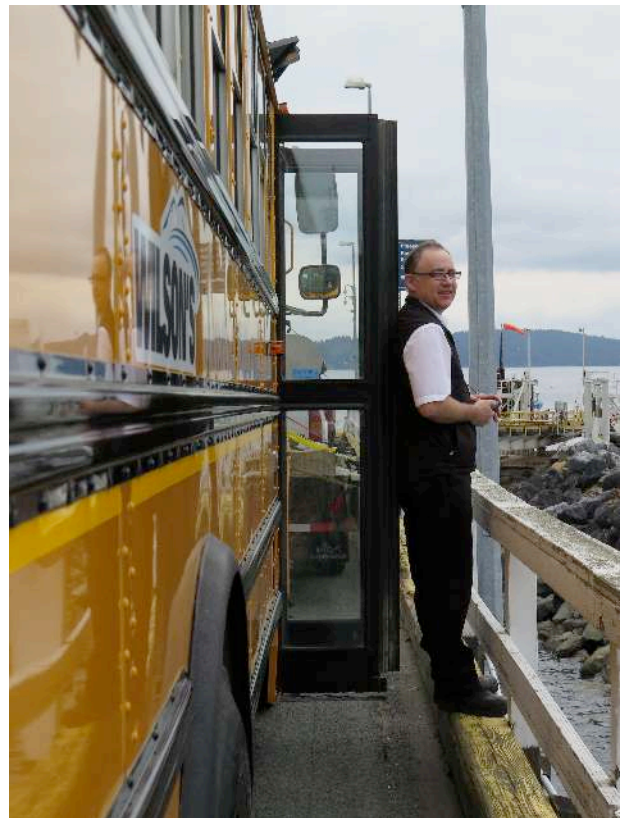
Camassia ©Hugues Massicotte



Vancouver Island ©Hugues Massicotte



After Botanizing on Saltspring Island ©Hugues Massicotte



The Excellent Driver ©Hugues Massicotte

2016 CBA AWARDS

Student Awards

PORSILD-CONSAUL AWARD.

This award, named in memory of the eminent botanists Alf Erling Porsild (1901-1977) and Laurie Consaul (1960-2012), recognizes the best paper in systematics and phytogeography published by a student.

2016 WINNER: EDELINE GAGNON

Gagnon, E., Hughes, C.E., Lewis, G. P. and Bruneau, A. 2015.

A new cryptic species in a new cryptic genus in the *Caesalpinia* group (Leguminosae) from the seasonally dry inter-Andean valleys of South America. *Taxon* 64: 468-490.

Nomination: This work represents one of the major contributions for furthering our understanding of the systematics of Caesalpinioidea and identification of cryptic taxa in the tropical Andes, one of most important biodiversity hotspots in the world. This study describes a new genus, *Arquita* and a new species, *Arquita grandiflora*. The methodology and suite of analyses used for addressing well articulated questions were impressive. This work will provide a basis for further research on recognition of cryptic species and documenting species diversity and endemism in biodiversity hotspots contributing to the development of effective conservation strategies to preserve biodiversity.

ROWE AWARD

This award, named in memory of John Stanley Rowe, recognizes the best scientific paper recently published by a student in the field of Ecology or Conservation.

2016 WINNER: BENOIT GENDREAU-BERTHIAUME

Gendreau-Berthiaume, B., Macdonald, S.E. Stadt, J. and Hnatiuk, R. 2015. How dynamic are understory communities and the processes structuring them in mature conifer forest? *Ecosphere* 6:27.

Nomination: The author made use of a long term data set, combined with their own data to examine change in boreal understory communities over time. The analysis was both elegant and comprehensive, examining both temporal and spatial trend in community structure. The awards committee consisted of Nicole Fenton, Richard Caners, Art Fredeen and myself.

WERESUB AWARD

This award, named in memory of Luella K. Weresub, recognizes the best paper in mycology published by a student in the year preceding the CBA/ABC annual meeting.

2016 WINNER: JACLYN DEE

Dee, Jaclyn M., Mollicone, M., Longcore, J.E., Roberson, R.W., Berbee M.L. 2015. Cytology and molecular phylogenetics of Monoblepharidomycetes provide evidence for multiple independent origins of the hyphal habit in the Fungi. *Mycologia*. 107:710-28.

LIONEL CINQ-MARS AWARD



Yunfei Jiang, University of Saskatchewan with co-supervisors Rosalind Bueckert and Art Davis, co-winner of the Lionel Cinq-Mars Presentation Award. ©Marlynn Mierau



Marion Barbe, UQAT, with supervisor Nicole Fenton, co-winner of the Lionel Cinq-Mars Presentation Award

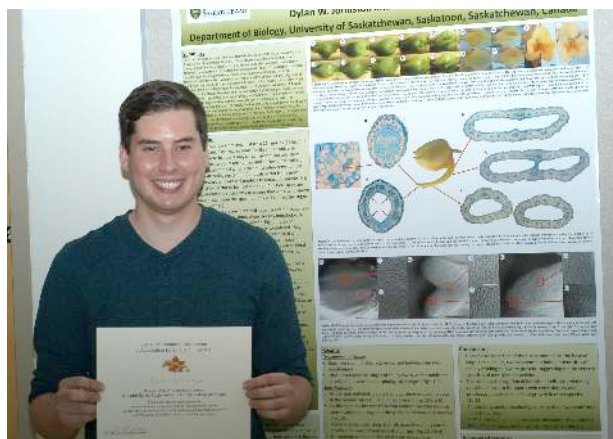
The Lionel Cinq-Mars award recognizes the best oral presentation by a student delivered at the annual CBA conference.

2016 WINNERS: YUNFEL JIANG AND MARION BARBÉ

M. Barbe, E.E. Chavel, N.J. Fenton, L. Imbeau, M.J. Mazerolle, P. Drapeau, and Y. Bergeron. "Not always gone with the wind: cryptogam dispersal by small mammals".

Y. Jiang, A.R. Davis, T. Warkentin, and R.A. Bueckert. "Effect of ovule, pod and node position on patterns of seed formation in field pea plants exposed to heat stress"

Iain and Sylvia Taylor Award



Dylan Johnston, University of Saskatchewan, winner of the Taylor Poster Award. ©Marlynn Mierau



Lucas Hampel, TRU, honourable mention in the Iain and Sylvia Taylor Poster Award competition

The Taylor Award recognizes the best student poster presented at the annual CBA conference.

2016 WINNER: DYLAN JOHNSTON

Winner: Dylan Johnston (University of Saskatchewan) for his poster "Growth of the bifurcated floral nectar spur of *Impatiens hybrida* (Balsaminaceae)".

Honourable Mention: Lucas Hampel (Thompson Rivers University, BC) was runner up (honourable mention) with his poster "Plants, fungi, and freeloaders: examining fungal species richness in *A. americanum* throughout its growing season".

MACOUN TRAVEL BURSARY



Macoun Winners with CBA Past-President John Markham (left), left to right: Conrad Yiridoe, Jacob Fletcher, Dawn Wood, Yunfei Jiang, Haoran Chen, and Zoe Panchen

Awarded to assist with travel costs to the annual CBA meeting, to students presenting a paper or poster.

2016 RECIPIENTS

Conrad Yiridoe, Dalhousie University
Jacob Fletcher, Dalhousie University
Dawn Wood, University of Manitoba
Yunfei Jiang University of Saskatchewan
Haoran Chen, University of Manitoba
Zoe Panchen, Carleton University

WINTERHALDER TRAVEL AWARD



Winterhalder Recipients Paige Anderson and Dylan Johnston, with Past-President John Markham (left)

Awarded to an undergraduate student presenting a paper or poster at the annual CBA meeting.

2016 RECIPIENTS

Dylan Johnston, University of Saskatchewan
Paige Anderson, University of Manitoba

Magister teaching award



Arunika Gunawardena receiving the Magister Award from John Markham, CBA Past-President

This awards recognizes mid- or late-career plant biologists who have demonstrated a consistently high level of teaching excellence and teaching-related activities over at least 10 years as a faculty at a Canadian post-secondary institution. This is the first time we have given the award. The inaugural winner is Dr. Arunika Gunawardena.

Arunika started teaching at University of Peradeniya, Sri Lanka in 1994 where she taught both graduate and undergraduate courses. As a postdoctoral researcher in the Dengler lab and as a sessional lecturer, she taught a number of courses at the University of Toronto. Since 2006 she has been a faculty member in the Biology department at Dalhousie University where she has taught a number of course at the graduate and under graduate level.

Arunika's teaching is consistently described by her peers and students as being supportive and caring of students, whether this be through her open door policy, the interactive nature of her lectures or for fostering student presentation skills. Her teaching excellence has been formally recognized by Dalhousie University a number of times. She has received the Dalhousie Alumni Association Award for Excellence in Teaching, the Dalhousie Student Union Teaching Excellence Award and the Outstanding Graduate Student Advisor Award. As one supporting letter stated, this is an unprecedented level of recognition for teaching at Dalhousie. Another testament to her teaching is the fact that her students have been recognized for their work at the Atlantic Undergraduate Biology Conference and here at the annual CBA meeting. In addition to having a stellar teaching record, Arunika has also been able to keep up an excellent research program, and was awarded an Killam Science Prize in 2011.

Lawson award



Luc Brouillet receiving the Lawson Medal from CBA Past President John Markham

The Lawson Medal, the most prestigious award of the Canadian Botanical Association. The medal is given for either a lifetime contribution to botany or for a single major contribution

2016 WINNER: LUC BROUILLET

Luc is receiving the Lawson medal for his contribution to both the Flora of North America Project as well as his related contribution to the VASCAN project.

Luc received a BSc in 1975 and MSc. in 1977 from the University of Montreal, and a PhD from Waterloo in 1981. He has been a Professor at the University of Montreal since 1982. He has been a member of COSEWIC, WWF Scientific Committee, the International Compositae Alliance, President of the Friends of the Montreal Botanical Garden as well as President of the CBA and chair of our Systematics and Phytogeography section.

Since 1984 Luc has been a driving force behind the Flora of North America project, which is the definitive reference for the taxonomy of native plants of North America. Luc is a founding member of the project, has been the President of the Board of Directors, has served on the editorial board, is regional coordinator for reviewers from eastern Canada, and has played a key role in publishing 6 of the 19 volumes and is lead editor for a 7th volume. His treatment of the 3 Asteraceae volumes has been described a "heroic job". To quote another letter of support, "As you use these volumes you realize the amazing quality and quantity of information and the passion of dedication of the multitude of people [including Luc] involved in producing three magnificent volumes". No other Canadian has contributed as much to the Flora of North America Project as Luc. To quote Nancy Morin, the Flora of North America Convening Editor "Luc has been a wonderful ambassador for Flora of North America from the very beginning of the project. He has given presentations at national and international meetings, written popular articles, and represented FNA in conferences with potential funders. He is an inspiring and visionary advocate for plants,

plant conservation, and the study of plants in Canada and throughout North America.”

In Addition to his with the Flora of North America, Luc is being honored for with work on VASCAN. VASCAN is the online database of Canadian Vascular plants run in conjunc-

tion with the Candensys project. The VASCAN database is a remarkable tool for outreach of botanical of knowledge in Canada. It one year it received over 620 000 views and is the go to source for information on plant distribution in Canada.



Luc Brouillet, Hugues Massicotte, Bryce Kendrick, and Iain Taylor ©Hugues Massicotte

REGIONAL AWARD WINNERS RECOGNIZED BY CBA-ABC IN 2016

Arthur R. Davis, CBA-ABC President, University of Saskatchewan, Saskatoon, Saskatchewan

At three student research conferences held across Canada during late winter and early spring of 2016, the CBA-ABC provided four awards (\$100 each) to CBA-ABC Regional Award winners. Recipients were senior undergraduate students who presented the best botanical talk or 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* were held at Saint Mary's University in Halifax, NS, from March 11-13, 2016. Ms. Emily Corkum (Dalhousie University) received a CBA-ABC Regional Award for *best botanical talk*. Her abstract follows:

FLORAL SEX ALLOCATION IN THREE SPECIES OF *LOBELIA*

Emily Corkum, Department of Biology, Dalhousie University

Sex allocation theory predicts that hermaphrodite organisms will display an optimal pattern of investment in each sex function in order for each individual to maximize its reproductive success. Plants of the genus *Lobelia* (Campanulaceae) provide an ideal system in which to study floral sex allocation as their flowers are protandrous (sequentially male and then female) with no overlap. Because flowers open acropetally, reproductive opportunity for a given sex changes with flowering position within an inflorescence. Under negative frequency-dependent selection, early (basal) flowers are expected to have higher relative female allocation, while late (apical) flowers are expected to have higher male allocation. This effect is expected to be strongest in highly outcrossing species, and weak or nonexistent in self-fertilizing species. Three related *Lobelia* species with different mating systems were used to test this theory: *L. cardinalis*, (primarily outcrossing), *L. inflata*, (completely self-fertilizing),

and *L. dortmanna*, whose mating system falls somewhere in between. In order to quantify absolute and relative sex allocation, all pollen grains (male allocation) and ovules (female allocation) were collected from 60 flowers of each species. Pollen grains and ovules were counted using image analysis of photos taken through a stereomicroscope. In agreement with sex allocation theory, self-fertilizing *L. inflata* showed no relationship between position along the flowering stem and relative femaleness, while the more outcrossing *L. dortmanna* showed a negative relationship. No relationship was found in highly outcrossing *L. cardinalis*; potential explanations for this result are discussed.

Ontario

Ontario Biology Day 2016 was held at Ryerson University in Toronto from March 19-20, 2016. Recipient of a CBA-ABC Regional Award for the *best botanical talk* at this conference was Mr. Michael Ostrander of Wilfrid Laurier University. His abstract follows:

GROWTH OF CORN (*ZEА MAYS*) IN SOIL SUPPLEMENTED WITH SPANISH RIVER CARBONATITE: EFFECTS OF LOCAL ENVIRONMENTAL CONDITIONS OF ROOT-ASSOCIATED MICROBES

Michael Ostrander, Department of Biology, Wilfrid Laurier University

Spanish River Carbonatite (SRC) is a liming agent mined from an igneous deposit rich in plant macro-, except nitrogen, and micro-nutrients. The consumer product comes directly from the mine without any chemical treatment before packaging. However, the mined product is left exposed to natural weather conditions on an offsite location (up to 2 years) before packing. Because using SRC as a soil supplement has the potential to reduce chemical fertilizers application, how this exposure affects soil microbes in SRC and subsequent plant growth was determined. *Zea mays* were grown in an artificial soil mixed with Wendigo soil, supplemented with either; SRC from the deposit, SRC from the offsite storage pile, or sterile SRC. In this latter case, plants were inoculated with the arbuscular mycorrhizal (AM) fungus, *Rhizophagus irregularis*. AM root colonization, plant dry weight, and the amount of cultural microbes in the soil were measured. As expected, increased phosphorous-solubilizing microbes were found in treatments where plants had been grown with AM fungi. However, the number of total microbes was reduced in treatments grown with SRC from the storage pile. The results suggest that the microbial community of SRC is different at the deposit and at the offsite storage pile.

Also at the *Ontario Biology Day 2016* conference in Toronto, Ms. Kristen Van Gelder (University of Guelph) received a CBA-ABC Regional Award for the *best botanical poster*. Her abstract follows:



Ms. Emily Corkum, Dalhousie University, receiving her award from Dr. Alyre Chiasson (Université de Moncton, right), who served as Chair of the *Science Atlantic Biology and Aquaculture & Fisheries Joint Student Conferences* and kindly supplied the photo and presentation information.



Kristen Van Gelder, University of Guelph, receiving her award for Best Botanical Poster from Dr. Joe McPhee, Ryerson University, at Ontario Biology Day.

EVIDENCE FOR SALICYLIC ACID CATABOLISM IN THE FLOWERS OF *SILENE LATIFOLIA*

Kristen Van Gelder, Taylor Forrester, Colleen Murphy, Matiy Ojehomon, Tariq Akhtar, University of Guelph

Silene latifolia (white campion) is a dioecious plant that emits an array of volatile compounds from both its male and female flowers. Among these volatiles is 1,2-dimethoxybenzene (veratrole), an important pollinator attractant to the moth, *Hadena bicruris*. The biosynthetic route to veratrole is believed to involve a novel branch point from the general phenylpropanoid pathway. Here we utilized substrate and stable isotope feeding experiments to provide evidence that veratrole is derived from the plant hormone, salicylic acid. *S. latifolia* flowers that were fed a solution of [2H6]-salicylic acid emitted veratrole that contained the benzene ring-bound deuterium atoms. Possible intermediates in the conversion of salicylic acid to veratrole were also investigated. Using gas chromatography coupled to tandem mass spectrometry in selected reaction monitoring mode identified catechol as a precursor to veratrole. After feeding flowers with [2H6]-catechol, the stable isotope was recovered in veratrole as well as its precursor, guaiacol. Addition of a trapping pool of guaiacol in combination with [2H6] salicylic acid resulted in the accumulation of the label into catechol. Finally, we provide evidence for catechol o-methyltransferase enzyme activity in *S. latifolia* flowers thereby implying the catabolism of salicylic acid to veratrole in the following reaction sequence: salicylic acid > catechol > guaiacol > veratrole.

This information was kindly provided by Dr. Roberto Botelho of Ryerson University, Chair of the Ontario Biology Day 2016 conference.

British Columbia

At the BC Undergraduate Research Conference held April 7, 2016 at University of the Fraser Valley in Abbotsford, BC, Ms. Abigail Guthrie of Trinity Western University received a CBA-ABC Regional Award for the best botanical poster. Her abstract follows:



Abby Guthrie (Trinity Western University) receiving her award from Dr. Brad Whittaker (Director, Research Services and Industry Liaison, University of the Fraser Valley).

CHARACTERIZING THE EFFECTS OF HERBIVORY AND COMPETITION ON NATIVE *CAMASSIA QUAMASH* IN GARRY OAK ECOSYSTEMS

Abigail Guthrie, Jennifer Adhika, David Clement, Department of Biology, Trinity Western University

Introduction: Garry oak (*Quercus garryana*) ecosystems are of the most endangered and diverse habitats in Canada, found amongst the Gulf Islands and southern Vancouver Island, British Columbia. The relatively open canopies of these meadow habitats supports and encourages the growth of diverse plant species. These include many wildflower indicator species such as *Camassia quamash*, more commonly known as common camas (Liliaceae). The presence, absence, and/or well-being of this wildflower is indicative of the health of the ecosystem as a whole. Herbivory is one of the main factors that limits plant success, where herbivores, such as rabbits, rodents, and deer feed on vegetation. This is generally known as grazing when meadow vegetation is consumed by mammal herbivores. Competition is another main factor that limits plant success, affecting plant community structure and diversity. This occurs when members of a species (intraspecific competition) or members of different species (interspecific competition) compete for vital resources including territory, nutrients, water, and/or sunlight. Fencing was used to inhibit herbivory, and mowing to mimic historical control burnings by First Nations, reducing competition. It was hypothesized that *C. quamash* growth and flowering will be inhibited in the plots where herbivory is prevented and competition is reduced.

Conclusions: Herbivory has more serious impacts on the success of *Camassia quamash* than competition and can therefore be deemed a more limiting factor on growth of the plant. This signifies that preventing herbivory should be the focus in restoration efforts for *C. quamash* rather than reducing plant competition. Repeating the 2013 monitoring methods in 2015 increased the understanding of the impacts of herbivory and competition on *C. quamash* growth.

Ms. Deborah Block (Graduate Studies, University of the Fraser Valley) kindly supplied this information and photograph.

LAURIE CONSAUL NORTHERN RESEARCH SCHOLARSHIP

REPORT: MY JOURNEY TO THE NORTH

Mélina Guéné-Nanchen, B. Sc., Biologie, Candidate au doctorat en Biologie végétale (Ph.D),
Département de phytologie (FSAA), Université Laval, GRET (Groupe de Recherche en Écologie des
Tourbières)



©Mélina Guéné-Nanchen

There is definitely something unique about the north, and for those who have not been there, let me paint a picture for you, as I experienced it with the help of the Laurie Consaul Northern Research Scholarship. The north is wonderful, with unique landscapes and wild territories wherever you look. The north can also be quite unexpected. For example, you may have to rethink the schedule of your day when there is a herd of wood bison in your research site. One day, you can cross hundreds of kilometres of burned forests, the other, encounter black bears on the side of the road and yet another harvest wild fire morels for supper.

One thing is sure, the north is a luxurious place, with tons of untouched rivers, forest, peatlands... But still, there is so much to learn from it. This is why I have spent two months in the Northwest Territories this summer trying to learn more about the ecological succession of burnt peatlands. Fire is the most important disturbance for the northern ecosystem. For many ecologists, the wetter and richer peatlands (fens) were long considered not at risk of burning. But still, during an early site prospecting trip in June 2015, my supervisor (Line Rochefort) and I have found fens that have burned during a fire in 2014. The questions that came to us afterward were, how do fens regenerate themselves? Will the plants that were there before, still be there after? Which plant will be the first to come after a disturbance? Will these peatlands still be able to play their role in carbon sequestration after the fire?

For that, we needed to look at the plant succession in burned fen ecosystems. This summer, I have built a chronology of burned fens, with fires from 2014, 2013, 2011 and 2008. With those, I will be able to construct the plant succession, and hopefully answer these questions. So, I have been travelling along these peatlands (35 research sites in total) with quadrats for vegetation surveys. I have looked at plant succession in terms of the percentage cover of vascular

plants and moss species. Species diversity and community structuration were also investigated. Furthermore, I have looked at other abiotic factors that could have an influence on the plant regeneration (hydrology, soil conditions, adjacent landscape, intensity of the fire). Natural peatlands that have never burned were also inventoried. Long days of work have passed (thanks to the northern summer) and already it was time to come back.

Back at Laval University, all this data is now being compiled and analyzed, and soon it will reveal more about plant succession in burned fen peatlands. I hope this work will improve our knowledge of the effects of northern disturbances on the landscape. This project will also have an impact on the restoration of disturbed fens, by guiding us on how to improve restoration methods.

I would like to thank the Canadian Botanical Association for their help in making this project possible. It is now clear to me that northern research is essential. I will certainly miss the north scenery and people (with the small exception of the mosquitos), and I knew even before leaving that I will definitely be back soon...



©Mélina Guéné-Nanchen

MAJOR INVASIVE ALIEN PLANTS OF NATURAL HABITATS IN CANADA

14a. Eurasian Water Milfoil, myriophylle en épi, *Myriophyllum spicatum* Linnaeus

14b. Hybrid Water Milfoil, *Myriophyllum spicatum* Linnaeus
× *Myriophyllum sibiricum* Komarov

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

In the 1970s this species invaded many lakes in the Kawartha region of Ontario. It grew in profusion causing the loss of native species, oxygen deficit, massive fish kills, loss of recreation and blockage of water flow. Since it was overlooked until the 1970s, it did not appear in manuals and guides and was confused with the native Siberian Water milfoil. Even after recognition, the identification keys to milfoils based on flowering material were not very helpful in distinguishing it. Following its explosive spread, it declined in many areas to much lower biomass, but was often still dominant or subdominant. Its impact on native aquatic habitat may have exceeded that of any other Canadian invasive plant. An apparent increase in the hybrid *M. sibiricum* × *M. spicatum*, which is difficult to recognize morphologically, and its potentially increased invasiveness are among many current concerns.



Figure 1: *Myriophyllum spicatum*. © L.J. Mehrhoff, University of Connecticut. UGA 547206 (CC-BY-3.0 US).

becoming leafless toward the base, branched near the water surface, whitish or pinkish, 0.5-7 m long; growing apices forming a tassel, often reddish; leaves, feather-like, 1.5-4 cm long, acute or broadly flattened at the tip, 1-several cm apart on the stem, in whorls of 3-4(5) with (12)14-17(27) segments (filiform divisions) up to 1.5 cm long and 1 mm apart; winter buds (turions) absent; flowering spikes emergent, erect 5-20 cm long, often pink, lying on the surface when the fruit are set; stem 5-20 nodes below the spike is almost double the width of the same stem lower down and is rigid; flowers in whorls of 4 in axils of bracts of which the upper are inconspicuous and the lower slightly longer than the flowers and comb-like or pointed; flowers at the base of the spike are pistillate (female), those in the middle bisexual and those at the tip staminate (male); petals present only on the male flowers reddish, dropping early, approximately 3 mm long; stamens 8; fruits round or subglobose, 2-3 mm across, with two wrinkled warty ridges.

Classification and Identification

Eurasian Water Milfoil is a member of the Water-milfoil family, Haloragaceae. There are approximately 40 species in the genus worldwide. As well as Eurasian Water Milfoil, the best known is likely the now cosmopolitan but barely temperate Brazilian Water Milfoil (myriophylle aquatique, *Myriophyllum aquaticum* (Vellozo) Verdcourt) which has an emergent leafy stem and is dioecious. As well as being a pest, the latter is sometimes cultivated and eaten as a vegetable.

DESCRIPTION OF EURASIAN WATER MILFOIL

Submersed aquatic plants, most often in water 1-3.5 m deep, but up to 10 m deep; perennial from rhizomes; stems smooth,

EWM = Eurasian Water Milfoil and Hybrid Water Milfoil

On account of the difficulty of separating the two taxa we consider it appropriate to include some hybrids of EWM with *M. sibiricum*. We do separate them in the key to the best of our ability. It is unclear to which taxon various observations and published research apply. Thus the reader should bear in mind that EWM can refer to both. Since there is less indication of Siberian Watermilfoil being a problematic invasive, it is not necessary to make "EWM" a threesome.

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

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Ideas on identification from some recent studies

“leaf segment/leaf length measurements can effectively distinguish *M. spicatum* and *M. sibiricum*; however, hybrids are intermediate for these characters and such measurements frequently overlap with respect to their parental taxa.” (Moody and Les 2007)

“The two types can be separated with 70 % effectiveness by determining whether the specimen has more or

less than 14 pairs of leaflets.” (Nichols 1975).

“Hybrid *M. spicatum* × *M. sibiricum* can only be confirmed using molecular techniques ...”. (Graf et al. 2014)

As if the identification difficulties are not already enough, it has been observed that *M. spicatum* under the influence of the herbicide 2,4-D develops relatively few leaf divisions.

IDENTIFICATION

Although Eurasian Water Milfoil was first discovered in North America in the late 19th century, it was not widely noticed as a significant invader until the middle 20th century. Since it was overlooked, it did not appear in manuals and guides and was confused with the native Siberian Water milfoil, then called *M. exalbescens*, but now correctly called *Myriophyllum sibiricum*. Even after Eurasian Water Milfoil became widely known as a major aquatic pest, the identification keys to milfoils based on flowering material were not very helpful in distinguishing it.

Of 13 species of *Myriophyllum* in Canada, none has 14-17 (24) leaf segments on most leaves. The spikes are almost naked (without leaves or bracts). The only species likely to be confused with Eurasian Water Milfoil is Siberian Watermilfoil (myriophylle de Sibérie, *Myriophyllum sibiricum* Komarov). This species has 5-11 (14) leaf segments and produces turions (a tight mass of overwintering leaves) late in the season. It also differs in having the stem diameter below the inflorescence the same as that of the lower stem, and the stem tips are usually green. In *M. spicatum*, the stem diameter below the inflorescence is greater than that of the lower stem, and the stem tips are usually reddish. This seems very simple, but there are hybrids of *M. sibiricum* and *M. spicatum* to consider. The key below places the three taxa in the context of Canadian *Myriophyllum* species.

Hybrids involving *M. spicatum* and *M. sibiricum* were considered rare a decade ago, but recently they have received a lot of attention and may have become more common. Much of this attention has involved molecular characterization and has not included quantitative biological data, morphological analyses, nor even based on the preservation of voucher specimens. Differences among authors in establishing limits and some overlap have led some authors to suggest that hybrids can only be confirmed by using molecular techniques (see text box).

The hybrids have generally been identified by an intermediate number of leaf segments. As evidence of the capability of sexual reproduction in these hybrids, one recent study reports backcrosses. If a backcross had more characteristics of one parent and few of the other, then it may be quite difficult to identify. For example, it may have the numerous segments of *M. spicatum* and other unseen characters of *M. sibiricum*. Thus a hybrid could look like *M. spicatum*. This is still speculative because a satisfactory study of morphology has not accompanied the molecular work and genetic variation within and among EWM and its hybrids requires more study. One recent article noted that “a small fraction of internal transcribed spacer (ITS) identifications incorrectly identified hybrid watermilfoils as Eurasian or Northern Water Milfoil.” Apparently EWM consists of two distinct lineages in North America that were introduced to different parts of the continent on separate occasions.



Pl. 118. *Myriophylle en épi*. *Myriophyllum spicatum* L.

Figure 2: *Myriophyllum spicatum* by Amédée Masclef from Atlas des plantes de France, 1891

PARTIAL KEY TO CANADIAN TAXA OF *MYRIOPHYLLUM* (FOR VEGETATIVE MATERIAL)

1. Leaves scale-like or absent, alternate

M. tenellum Bigelow

1. Leaves conspicuous and with filiform segments, alternate or opposite

2. Leaves alternate

M. farwellii Morong

M. heterophyllum Michaux

M. hippuroides Nuttall ex Torrey & A. Gray

M. humile (Rafinesque) Morong

M. pinnatum (Walter) Britton, Sterns & Poggenburgh

2. Leaves opposite

3. Plants robust, with emergent stems with feathery leaves similar to those below

M. aquaticum (Vellozo) Verdcourt

3. Plants not robust, with emergent stems less leafy than submersed portions below

4. Mature submersed leaves with 2-7 segments

M. ussuriense (Regel) Maximowicz

M. alternifolium deCandolle

4. Mature submersed leaves with 6-20+ segments

5. Stems and foliage brownish or greenish and flaccid; bracts usually twice as long as the pistillate flowers and pectinate or pinnatifid; clavate winter buds (turions) well formed in some plants

..... *M. verticillatum* L.

5. Stems and foliage pale, whitish or pink rigid; bracts as long or longer than the pistillate flowers and with various margins; winter buds present or not

6. Young shoots with one or several pairs of entire leaves at the base

M. quitense Kunth

6. Young shoots without entire leaves at the base

7. Submerged leaves with 7-12 pairs of segments, rounded at the apex; stems at the base of the spike equal to lower stems in width; stem tips green; turions developing later in the season; bracteoles ovate, longer than, or as long as broad; anthers 1.2-1.8 mm long

M. sibiricum Komarov

7. Submerged leaves with 14-24 pairs of segments, truncate (flattened) at the apex; stems at base of spike almost double the width of the lower stems; stem tips reddish; without turions developing later in the season; bracteoles reniform to suborbicular, broader than long; anthers 1.8-2.2 mm long

M. spicatum L.

The hybrid *M. sibiricum* Komarov $\times$ *spicatum* L. may possess characters of both of the parents on the same plant and/or a character varying across the range of both parents on the same plant.

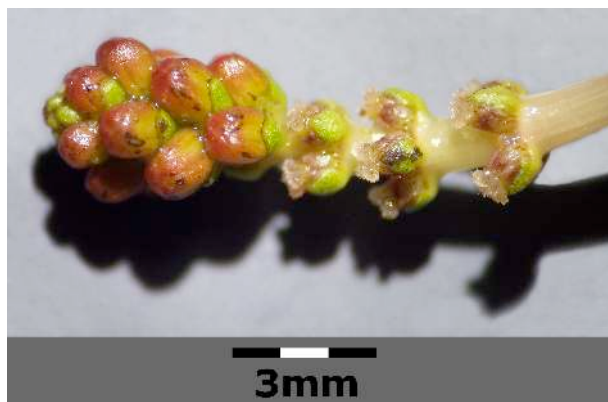


Figure 3: Female flowers of *Myriophyllum spicatum*. © Stefan Lefnaer (CC BY-SA 4.0).



Figure 4: Male flowers of *Myriophyllum spicatum*. © Stefan Lefnaer (CC BY-SA 4.0).



Figure 5: *Myriophyllum spicatum* foliage. © G. Lovell, Alabama Dept. of Conservation (CC-BY-3.0).



Figure 6: Seeds of *Myriophyllum spicatum* from USDA-NRCS Plants Database. © Steve Hurst used with permission.

M. AQUATICUM (VELLOZO) VERDCOURT (BRAZILIAN WATER-MILFOIL; MYRIOPHYLLE AQUATIQUE)

An introduced species of garden ponds in southwestern B.C. and rarely elsewhere. It has not spread into natural habitats in Canada.

M. USSURIENSE (REGEL) MAXIMOWICZ (RUSSIAN WATER-MILFOIL; MYRIOPHYLLE DE L'OUSSOURI)

This dioecious species is native in southwestern B.C. It has emergent leaves on the inflorescence that are serrate or with very short segments. The submersed leaves have less than 7 segments. Interestingly, most populations in B.C. are reported to be female.

M. ALTERNIFOLIUM DECAUDOLLE (ALTERNATE-FLOWERED WATER-MILFOIL; MYRIOPHYLLE À FLEURS ALTERNES)

The uppermost flowers are distinctly alternate. Leaves usually less than 12 mm long. Native in Northwest Territories, Manitoba, Saskatchewan, Ontario, Québec, New Brunswick, Nova Scotia and Newfoundland.

M. VERTICILLATUM L. (WHORLED WATER-MILFOIL; MYRIOPHYLLE VERTICILLÉ)

The bracts are usually twice as long as the pistillate flowers and are pectinate or pinnatifid. Clavate winter buds are well formed in some plants. Native in all provinces and territories except Labrador.

The foliage is often greenish or brownish and the leaves and leaf divisions quite long and soft forming a flaccid mass in contrast to the green and more rigid foliage of *M. sibiricum* (with which it is otherwise difficult to separate).

M. QUITENSE KUNTH (ANDEAN WATER-MILFOIL; MYRIOPHYLLE DE QUITO)

The bracts of the upper portion of the inflorescence are characteristically deltoid. In Canada believed to be native only in B.C. and possibly introduced in New Brunswick. Native in South America and Western North America.

M. SIBIRICUM KOMAROV (SIBERIAN WATER-MILFOIL; MYRIOPHYLLE DE SIBÉRIE)

Native in all provinces and territories in Canada. Previously *M. exalbenscens* Fernald

M. SPICATUM L. (EURASIAN WATER-MILFOIL; MYRIOPHYLLE EN ÉPI)

Introduced in British Columbia, Ontario, Québec and New Brunswick.

M. SIBIRICUM KOMAROV × *SPICATUM* L.

Possibly a relatively more recent hybrid (last decade) that is becoming more abundant. A reason for increased numbers of hybrids may be that they are superior to their parents in resistance to predators, pathogens and/or poisons. While some articles have provided evidence for increased invasiveness of hybrids, others have not. One recent study has proposed a relatively simple polymerase chain reaction – restriction fragment length polymorphism (PCR-RFLP) method to facilitate hybrid identification so that hybrid adaptation can be studied in more depth (see also text box).

Distribution

EWM is native to Eurasia and North Africa, but has now been spread by humans to most continents of the world (except Australia and Antarctica). It is believed to have been introduced in many widely separated locations in North America from home aquaria as long ago as 1881. Its early appearance in the US Chesapeake Bay area has been linked to introduction by release from ship ballast. The earliest Canadian records are from Rondeau Provincial Park on Lake Erie in 1961 and along the St. Lawrence River later in the 1960s.

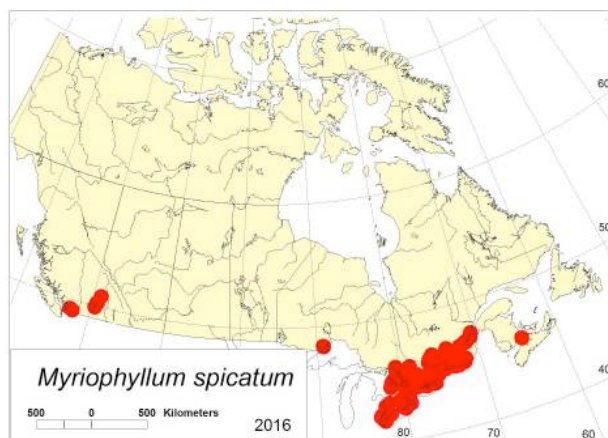


Figure 7: Distribution of *Myriophyllum spicatum* in Canada.



Figure 8: Distribution of *Myriophyllum spicatum* × *M. sibiricum* in Canada based on DNA analysis.

A Hybrid Advantage

If we cannot be sure about identifying the hybrid, how can we control it? This is a good question because early detection and control is recommended as a major strategy for dealing with invasives. A hybrid can have an advantage of being difficult to separate from its less noxious parent. In this case there is identification help in the form

of molecular methods. It still may be a happy place for a hybrid due to the other potential advantages of (1) novel genotypes (more adapted to extreme conditions than either parent), (2) greater genetic variation, (3) beneficial heterozygous genotypes, or (4) an opportunity to dump deleterious alleles.

It was first recognized as a serious problem in Canada in the Ontario Kawartha Lakes in in the early 1970s. It was first found in British Columbia in Okanagan Lake in 1970. Currently it is found in British Columbia, New Brunswick, Ontario and Quebec. A report from PEI is considered incorrect.

The hybrid may be more abundant than Figure 8 suggests because hybrids may have increased recently and the map is based largely on older collections made prior to recent increase. Some hybrids may be difficult to recognize morphologically and some more recently collected specimens attributed to *M. spicatum* on the basis of traditional morphological characters may be hybrids. A recent study, including genetic analysis, in central Ontario lakes with EWM revealed hybrids present in 5 of 20 lakes (25%). Thus "*M. spicatum*" on the map may be true *M. spicatum* but also some hybrids, especially backcrosses with the *M. spicatum* parent. See also notes on identification above.

The accompanying map showing *M. spicatum* (*sensu lato*, Figure 7) distribution in Canada is based on collections from ACAD, ALTA, CAN, DAO, HAM, LKHD, MT, NBM, OAC, QFA, QK, QUE, TRT, TRTE, UAC, UBC, UNB, UWO and V. The following were without any specimens of *M. spicatum* or the

hybrid: MMMN, NFM, NSAC, NSPM, PMAE, SASK, UPEI, and WIN. MTMG, UVIC, WLU and NFLD were unable to assist. The additional map of hybrid distribution is based entirely on published reports of plants confirmed as hybrids with DNA analysis.

Ecology

EWM invades almost all kinds of communities of submerged aquatic plants and displaces most other plants. In the process it forms dense beds of aquatic vegetation larger than those originally present. EWM and the hybrid may or may not grow together. The plants can grow in water up to 6-10 m deep. They thrive in eutrophic or oligotrophic lakes, with various substrates and pH ranging from 5-10. Although some studies have provided some evidence for an allelopathic effect of EWM on phytoplankton, it appears that more research is needed in this area. It has been suggested that the growth form, low requirements of N and P, and high vegetative reproductive capacity are among the factors determining its success as an invasive.

Insect herbivory in EWM induces five different resistance and defensive traits in grazed apices: changed appearance, increased plant toughness, delocalization of N-containing metabolites, increased polyphenols, and reduced nutritional value. In a low nitrogen environment, more energy is devoted to autofragmentation than to root crown production, thus favouring dispersal.

POLLINATION

Stigmas become receptive before stamens on the same spike shed pollen. Pollen is carried by wind, water and insects.

DISPERSAL

By far the most common mode of dispersal of EWM is by people on boats and boat trailers, dumping bait buckets, or by dumping aquarium contents. Plant parts may also be distributed by waterfowl or by mammals using them as building materials. Both seeds and plant parts are distributed by water and seeds may also be distributed by adhesion to waterfowl.

An extensive recent survey shows that 8 aquatic invasive vascular plants are kept in aquaria. Some of these originate in aquarium supply shops while others are gathered from natural habitats. Dumping out the aquarium (often to preserve the fish) at a new location results in dispersal of the aquatic plants.

Seeds from some populations may have to pass through the digestive system of waterfowl and/or be subjected to cold before germination, whereas they may germinate soon



Figure 9: Sign suggesting actions to prevent aquatic plant spread in New York State. Wikipedia Commons (CC BY-SA-3.0).

after formation in other populations. Seedlings are rarely encountered and most dispersal of EWM is thought to be by plant fragments.

Detrimental Aspects

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

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

Many studies have shown substantial declines in native species richness and abundance with the development of dominance by EWM. It overgrows and shades out other aquatic plants by extensive branching at the surface to produce a thick enough mass to support the weight of wading birds. It can reach the surface in water 5 m deep in one season.

(2) REDUCED PROPERTY VALUES *****

EWM invasion can reduce lakefront property values by up to 20%. This affects property taxes and reduces revenue.

(3) REDUCED WATER-BASED RECREATION *****

Plants reach the water surface where they produce dense mats that interfere with swimming and fishing, and also prevent boat traffic. The diverse native aquatic plant flora that precedes invasion does not produce surface mats, and may be restricted to shallower water. The reduced recreational opportunity impacts both the experience and local income.

(4) GENERAL CHANGES TO THE AQUATIC ENVIRONMENT ***

There is lower dissolved oxygen and lower temperature in the lower parts of EWM beds. This changes the aquatic ecosystem.

(5) CLOGGING AND ACCUMULATING ***

EWM clogs water supply systems. The broken stems also accumulate on beaches. Sometimes removal is costly.

(6) REDUCES WATERFOWL FOOD ***

The native species that are more valuable as waterfowl foods may be eliminated by dense beds of EWM.

(7) LARGE CONTROL COSTS***

EWM has a larger impact on human activity than some other invasives in this series (which have a relatively greater impact on other species) and therefore more is generally spent on control.

(8) MOSQUITO DEVELOPMENT*

By replacing open water with a dense aquatic mass, it has been reported that EWM produces an environment conducive to the development of mosquitos. This requires more study.

Beneficial Aspects

(1) USED AS FOOD BY NATIVE ANIMALS *

Although EWM is used by ducks, many other species which it displaces are preferred.

(2) HABITAT *

The habitat produced by EWM may be beneficial to some species but not to others. It has been associated with a decline in fisheries based on fewer and smaller fish.

(3) WATER CONTENT AND CLARITY *

Plants may remove nutrients from water preventing algal blooms and may also remove heavy metals.



Figure 10: Diver emerges from bed of *Myriophyllum spicatum* (CC BY NC-2.0).

(4) USE AS A FERTILIZER *

Use of harvested plants as fertilizer, animal feed, and soil conditioner is limited.

(5) MEDICINAL USE

In China *M. spicatum* has been used to break fever and to treat flu and dysentery. This potential value requires more study.

Management

LEGISLATION AND REGULATIONS

Myriophyllum spicatum is considered an invasive in all provinces where it occurs within Canada. The "Environment and Climate Change of Canada" report lists it as an "Invasive Alien Species" and it is targeted by the "Invasive Alien Species Partnership Program Projects". The Canadian Food Inspection Agency also has it listed as an "invasive alien species". In the Atlantic Maritime ecozone, it has only been discovered in small lake in New Brunswick. In Quebec, it is considered an "Exotic Aquatic Plant". In Ontario, it is listed in Ontario's "Invading Species Awareness Program" and the "Invasive Species Centre" lists it under "Invasive Aquatic plants posing a serious threat to all water bodies". In Manitoba, the "Water Protection Act" includes the "Aquatic Invasive Species" legislation, and here EWM is listed as one of the prohibited plant species. In Saskatchewan, it is listed in the Schedule 1 ("Prohibited Weeds"). In Alberta it is listed with "Prohibited Noxious Weeds". In British Columbia it is legislated and listed by the Invasive Plant Council of British Columbia as a "Fresh Water / Riparian Vascular Plant, alien invasive species". In the United States, because of the serious problems caused by Eurasian watermilfoil, large-scale management programs have been implemented to stop the continued spread.

MANUAL AND MECHANICAL METHODS

Mechanical harvesting in some situations has had the impact of improving the fishery by increasing the number of larger fish. Most harvesting is done with boats that pull aquatic vegetation onto a conveyor and pile it onto barges. Sometimes driver-operated dredges are used.

Vinyl-coated fiberglass panels were used in a Washington state lake. They were immediately effective in providing a plant-free water column. Coverage for a 2 month period resulted in a 75% reduction in EWM biomass with limited

It's Against State Law

"The transport of all aquatic plants or plant parts and aquatic invasive species is illegal in Vermont. A person who violates this law may be subject to a penalty of up to \$1,000 per violation. Invasive species, such as Eurasian watermilfoil and Zebra mussels, are typically spread by "hitchhiking" on boat trailers, propellers and fishing gear that isn't cleaned, or in bilge water, bait buckets, or livewells that aren't drained before moving to a different water body. It often takes only a tiny fragment of an invasive plant, sometimes less than an inch, to start a whole new infestation." ...Shadow Lake Association, Vermont



Figure 11: Eurasian Water Milfoil inspection areas for boaters. With permission, Shadow Lake Association, Vermont.

regrowth after panel removal. These panels are well-suited for control in limited areas.

Hand harvesting can be effective but requires a large financial investment. In one example six crews of divers harvested EWM in the entire littoral zone of Upper Saranac Lake in New York State. Harvests took place twice per summer for three years and cost \$150,000-350,000 per year. EWM cover was reduced to <5%.

BEHAVIOUR

Although surveys have indicated that anglers using boats have the most complete knowledge of aquatic invasives, surveys have shown that 25% return unused live bait directly back into the waterbody where they were fishing. This bait may have come from a lake far away that was contaminated with invasives. **Do not introduce plants to a new location by dumping a bait bucket.** Of course more EWM may also be spread around by releasing the contents of an aquarium into a natural habitat (at the lake by the cottage). That may have very serious and costly results (see "Believe It or Not").



Figure 12: *Acentria ephemerella*, male. © Robert L. Johnson, Cornell University (CC BY-3.0 US).

Attachment to boats and trailers is a particularly important method of dispersal. Boaters often visit two or three lakes over the same number of days. EWM plants can survive up to 18 hours out of water. **Do not introduce plants to a new location on a boat and trailer.** Not only is it illegal to transport nuisance aquatic plants over dry land in Vermont (see text box), some lakes have a free boat wash. The free, high pressure, hot water boat wash at Shadow Lake was funded by the state and a local town.

BIOCONTROL

The Milfoil Weevil (*Euhrychiopsis lecontei*) is a North American native that has been associated with EWM declines across the continent. It is highly specific to *Myriophyllum* species and has a preference for exotic EWM over natives. Studies have shown that this weevil "is an example of a native biological control agent that can reduce the abundance of an exotic species without a significant negative impact on closely related non-target species." It has been "introduced" or has simply increased at the sites of invasions resulting in declines of 50-95%. In Ontario, in 2009, Milfoil Weevils were introduced by the Scugog Lake stewards at a cost of \$30,000 which was followed up with 3 years of scientific research on effectiveness, all paid for through local fundraising. The introduction was reported to be "very successful." The effectiveness of the weevils may be reduced by predation by fish in some situations.

The other significant biocontrol agent is the Watermilfoil Moth (*Acentria ephemerella*), which was accidentally introduced to North America in the 1920s. Large unassisted declines in EWM have been attributed to this species alone (see text box). The small moths are less than 1 cm long. Males have white wings but most females are wingless.

A number of lab studies have suggested a potential for use of fungi in biocontrol. Pathogens have not yet been employed successfully under natural circumstances.

CHEMICAL METHODS

The development of resistance to herbicides by some aquatic invasives as well as the environmental impacts have increased interest in other methods of control, particularly

biocontrol and harvesting. There is an extensive literature on control of EWM with herbicide, much of it in the form of annual reports. Some of the published results are promising. For example, Triclopyr has provided up to two seasons of control of EWM without reducing the overall distribution and abundance of native plants. Chemical treatment reduced EWM in a Utah Lake by 90% over seven years. Integrated pest control with the herbicide Endothall and the pathogenic fungus *Colletotrichum gloeosporioides* has been recommended. Chemical methods usually require applications from government natural resource departments and local landowner groups, both of which often have extensive experience with costs, application rates, consequences and expectations.

REDUCTION OF POLLUTION

EWM can absorb nutrients through the foliage. Reduction of stream loading of nutrients by employing agricultural best practices has reduced growth of EWM. Some of the best practices include preventing direct run-off from fields into streams, preventing cattle from entering streams, and preventing fertilizer drift from entering any waterbodies.

WATER LEVEL DRAWDOWN

Lab studies have suggested that EWM can be killed by freezing at -5 C or desiccation at 4 C in as short a time as 48 hours. Interannual variability in response to drawdowns may be due to variability in annual climate conditions. An overwinter drawdown of 1.5 m has rarely killed plants at the 1 m depth in a lake at Ottawa, but effective use of drawdowns during cold weather has been reported elsewhere.

Prospects

EWM is still invading new areas in parts of North America. Regardless of the decline pattern, management will be necessary for a period to reduce losses. It may be invading lakes that were passed by in an initial invasion due to a change in water chemistry. It may also become a more serious invasive due to the increased invasive ability of Hybrid Water Milfoil. Extensive regions of Canada in BC, the maritimes and especially the southern prairie provinces are within a climatic region that would support EWM.

Believe It or Not

- It is possible to identify EWM patches in a lake without entering the water by using hydroacoustics.
- EWM is one of the four most studied invasive aquatic macrophytes. The others are *Hydrilla verticillata*, *Phragmites australis* and *Eichornia crassipes*.
- A biologist was walking across a beach of one of the Kawartha Lakes. A lady in a bikini met him coming the other way. She said "Do you know why we cannot swim here?" He explained that EWM was so dense in the water that swimmers were likely to get entangled and drown. She said "Wow, that must have reduced property values." He agreed, but said that it would be almost gone in a few years. "How do you know that she said." As he walked away, overwhelmed with the environmental damage, he said: "I have a crystal ball." Later, he felt badly about not explaining that he had biological information. Five years later he was surprised to meet the same lady at a scientific conference. She told him that she had bought all the properties on the lake during the infestation and

What Is ... "Native Biological Control"



Figure 13: Milfoil Weevil (*Euhrychiopsis lecontei*). © R.L. Johnson, Cornell University (CC BY-3.0 US).

In "classical biological control" we have an invasive that is doing well as a result of having arrived without its enemies. We go back to the source of that invasive and find a "safe enemy" that will attack it here. By a "safe enemy" we mean an alien species that will not destroy native species. "Native biological control" involves the use of a native enemy. Sometimes an invasive species arrives and is related to a group of natives with a predator to which they have developed a degree of resistance. The new arrival is suddenly in the presence of that predator but does not repel it as well as its native relatives (that are adapted to it). The result may be that the new invasive is a favourite of the native predator (in this case, the Milfoil Weevil) and that native predator always selects and most damages the new invasive (in this case Eurasian Water Milfoil). All we have to do is help it. We do that by bringing a large number to a new infestation where it can multiply quickly and encouraging sunfish tournaments for a few years (to reduce predation on the helpful weevil by small fish). ... And we study it to find other ways we can assist. This may sometimes be done at relatively low cost (see below).

Natural Decline – Will It Happen?

The decline of EWM at Chesapeake Bay in 1965 was believed to be a result of pathogens, particularly Northeast Disease, and it had the interesting effect of stimulating discussion of the potential use of pathogens for biocontrol, but there is a much bigger question. In 1977 there was a substantial decline of EWM in the Kawartha and Rideau Lakes of Ontario. Here it was attributed to grazing by an aquatic moth, *Acentria* sp. The moth was probably the Watermilfoil Moth (*Acentria ephemerella*), which was accidentally introduced to North America in the 1920s. It prefers EWM over other aquatic plants and has been used for biocontrol. However, the decline in the Kawartha and Rideau Lakes of Ontario was not clearly due to any purposeful introduction of this moth. The moth has also been associated with declines of EWM in the Finger Lakes of New York in the 1990s. All of these cases of decline of EWM,

and many others elsewhere, raise the interesting question of whether or not many invasive plants will increase to the point of complete dominance but then succumb to their enemies (insects and pathogens) that quickly or slowly catch up and reduce the invasive population. Different plants may have different periods of time for completion of this process. "A typical invasion of milfoil is characterized by a pattern of explosive growth, persisting for 5 or 10 years, followed by declining abundance." What if we just wait for this process to complete rather than trying to manage it to some degree. We will lose species, experience biodiversity decline, and lose money (at least) due to a variety of negative impacts. Some degree of management will have costs but will enable reduced losses until the "process" restores an acceptable balance.

sold them again when it disappeared with a 20% profit making an unrepeatable amount of money, and she had decided to become a biologist. He did not know that she was wealthy, nor did he think of biological information in terms of money.

- EWM contributed to the local popularity of weedless fishing lures in the 1970s but that was shortlived as fishing declined where it occurred.
- One in 72 Great Blue Herons rising from the water have attached invasive aquatic plant material sufficient to start a new infestation.

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Figure 14: *Myriophyllum spicatum*, scientific illustration from DAO 01-000618311, specimen collected September 7, 1961 in The Eau, Rondeau Provincial Park, Lake Erie, ON, by J.H. Soper 9281A, R.D. Ussher & M. Eddy and determined by J.H.S. Drawing by Marcel Jomphe

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THE ANNUAL SHOW OF TREE LEAF COLOUR

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As the end of summer nears, the green leaves of our deciduous trees undergo a change in colour. Those of some become a brilliant red like the red maple while others change to a yellow or golden colour like the birch and all of them ultimately become a brown colour. Despite the economic importance to our tourist industry of the autumnal display of colour of the trees in our forests, relatively little scientific study has been made of this annual phenomenon. As a result, we are subjected in the newspapers and on websites to an imaginative description of the process too often only distantly based on established facts. Of the many websites turned up by a Google search of "autumn color", few explanations conform entirely to the present incomplete state of knowledge. However, in the past two decades, ground-breaking work in the north-east USA and in northern Sweden has yielded a deeper understanding of the coordinated processes ongoing in the leaves as deciduous trees prepare for winter.

The reason for the autumnal change is variously attributed to lower light, cool temperatures, or various other environmental factors, although many descriptors have now grasped the fact that daylength is significant. In point of fact it is not the daylength itself that is important. The trees and shrubs recognize the increasing length of time between sunset and sunrise, i.e. the dark period, as the summer progresses and thus begin to make preparations for winter survival. They are able to do this because of an invisible blue-green pigment called phytochrome in their cells. This pigment serves as a timepiece, enabling the plant to ignore the suggestion of warm autumn days that summer may never end and to realize that ambient temperature is not a reliable marker of the seasons. Thus the process called leaf senescence is begun.

The colour change of the leaves is only one of many processes going on as the leaf senesces but it is the one most obvious to us. The green leaf of the maple and other trees contains several pigments in addition to phytochrome. Most visible are the two green chlorophylls present in tiny intracellular structures called plastids. These pigments are the key to our survival on earth because of their ability to trap the energy of sunlight for food production by the leaf. Also present in the plastids, but masked by the chlorophylls, are several kinds of orange and yellow pigments called carotenoids, a name derived from the Latin name of the orange carrot root. Over the course of a few days or weeks, the green of chlorophyll disappears. The carotenoids also are destroyed but not so rapidly as the chlorophylls, thus the leaf becomes a yellow colour. They are yellow, not orange, because the xanthophylls, the yellow carotenoids, are five times more abundant than the carotenes, the orange carotenoids, as a result of their slower breakdown.

At the same time, the leaves of some species begin to produce red-coloured pigments called anthocyanins. (These are the same class of pigments that are in the healthful blueberry and cranberry fruits we are encouraged to eat and



A hazel shrub showing the variation in leaf colour on the same plant.
©Constance Nozzolillo

they are not normally present in the leaf all summer, as many reports in the past have stated. Leaves of trees that produce anthocyanins in the summer, such as horticultural varieties of the Norway maple, appear almost black in colour because the green of the chlorophylls and the red of the anthocyanins absorb nearly all the light that passes through the leaf.) If nearly every cell of the leaf contains these pigments in high concentration, the leaf will be a brilliant red colour like those of the red maple, the carotenoids again masked from view. If the concentration is low, the leaf will appear orange like those of the sugar maple because we see the red of the anthocyanins mixed with the yellow of the carotenoids. Thus the orange colour seen in sugar maple leaves is not due to orange carotenoids as frequently stated, even in some botanical textbooks, but to the mixing of the primary red and yellow colours. Newly formed carotenoids do result in a red colouration in some species that retain their leaves in winter, red cedar being an example.

How the annual disappearance of an amount estimated to be a billion tons of the green chlorophylls is brought about has been subjected to rigorous study only in the past three decades. During the growing season, as reported on some websites, the levels of chlorophylls in the chloroplasts tend to decrease and increase to an extent dependent on growing conditions, with chlorophyll breakdown resulting from environmental stresses that tax the protective functions of the carotenoids beyond their capacity to prevent damage, and biosynthesis of chlorophyll to repair the damaged photosynthetic systems. The fact that chlorophyll is easily destroyed

is evidenced by the rapid bleaching of the leaves of an overwintered houseplant abruptly put out into bright spring sunshine, but a leaf properly adjusted to bright light conditions rarely, if ever, bleaches. Once the process of senescence is underway, chlorophyll biosynthesis ceases and a regimented, enzymic process of chlorophyll breakdown is begun. It is now known to be a highly controlled, multi-step process associated with major changes in the structure of the plastids.

The purposes of this process are twofold. An important result for the tree is the release of nitrogen, the most essential element for plant growth, from the proteins to which the chlorophylls had been attached. The removal of this nitrogen from the leaf for storage in the trunk or other parts of the tree before the leaf falls off is a significant activity. Results available to date demonstrate that trees vary considerably in their ability to do this. Some are able to remove as much as 80%, whereas others remove relatively little before the leaves fall. A second function is to transfer any potentially toxic breakdown products into the vacuole of the cell. Interestingly, the N in the chlorophyll itself thus remains in the leaf.

And what is the purpose, if any, of synthesizing new complex chemical structures like the anthocyanins? Scientific study directed to answering this question has begun only in the past few decades and provides some evidence to indicate that the red pigmentation may protect the leaf from the damaging effects of light so that more of the valuable nitrogen and other nutrients can be transferred to the trunk. In addition, it has been shown experimentally that leaves that are red are retained on the tree longer than those on the same tree that do not produce anthocyanins. Another question frequently asked is "Won't anthocyanin synthesis require energy that the leaf will no longer have freely avail-

able because of the loss of chlorophyll?" Of course energy will be required both to make the anthocyanins and also to transport the nutrients but this energy can be provided by "burning" the residual sugars in the cells of the leaf in the tiny "furnaces" called mitochondria, a process called respiration. These bodies provide the energy necessary for the activities of every living cell, plant or animal. Accumulation of sugars and starch in autumn leaves is well documented. Photosynthesis in those cells that retain intact plastids may continue but at levels that cannot compensate for energy lost due to respiration.

And how are the red pigments made? Contrary to statements frequently made in the past and as noted above, these red pigments are not present in the leaf blade during the summer in a green leaf blade, although the leaf stalk may be red in some species, but are made anew in the autumn in those species equipped with the necessary genetic information. That fact is now recognized in most popular explanations. The answer usually provided for the "how" question, however, completely ignores the current state of knowledge of the process by stating that the sugars remaining in the leaf as a product of photosynthesis are converted into anthocyanins. This may sound reasonable, especially since some sugars are incorporated into the final structure.

However, innumerable studies over the past several decades have shown that building of the part of the anthocyanin molecule that is responsible for the red colour involves sugars only as a source of energy to drive the process. There is increasing evidence, however, that sucrose, the sugar we put in our coffee and the form in which sugars are transported in a plant, acts as a signal for anthocyanin synthesis to begin. It occurs in the cytoplasm of the cell in a tightly coordinated multi-enzyme process, the final step of



Fall Colours in Gatineau, QC. ©Constance Nozzolillo

which is to add one or more sugars. Only then is the molecule so formed called an anthocyanin. It does not leave the cell in which it is made but is deposited into the vacuole, a large sac filled with a slightly acidic watery solution that occupies most of the cell volume.

The amounts of anthocyanins subsequently produced depend on many factors, including temperature, light exposure, and nutrient status. Scientific studies back up the observation that bright sunny days and chilly nights result in the best display of colour. A current “fashion” in popular explanations is to add that “chilly” cannot include sub-zero temperatures, but a touch of “jack frost” overnight does wonders to enhance the colouration of our hardy native species! It is true that freezing will kill the leaf cells, but most temperate plants develop frost hardiness to an extent that enables them to endure a few degrees of sub-zero temperatures with no ill effect. Surely so do the leaves on a native tree as the woody tissues and dormant buds of the stem to which they are attached prepare for winter. On the other hand, in warm weather, especially if the days are overcast, much of the chlorophyll remains and little of the red pigments is made. As any casual observer may note, more red colour is present in parts of the tree fully exposed to sunlight. It is important to keep in mind that a typical leaf is comprised of many individual cells each responding more or less independently to its environment. Although the overall process of preparing for winter is synchronized and ultimately leads to leaf fall, some cells may retain normal functioning much longer than others. Thus the colour of the leaves is not the same in all parts of the tree or even in all parts of the same leaf.

While all these colour changes are ongoing, the leaves are prepared for the phenomenon familiar to us as leaf fall. Preparation for separation from the tree is done so as not to leave an open wound at the point of attachment. An impermeable corky layer, called an abscission layer, is gradually built across the base of the leaf stalk. Such a layer is obviously incompatible with the already-mentioned desirability of removing as much as possible of the valuable nutrients in the leaf for storage in the trunk; how can nutrients be moved past an impermeable layer? The statement usually made in popular explanations is that the sugars are trapped in the leaf by this layer and are thus available for conversion to anthocyanins. But is it true that sugars are indeed “trapped” or are they there for the specific purpose of providing energy when photosynthesis is no longer occurring? In fact the tissues through which the nutrients are moved, the vascular tissues which make up the veins of the leaf, are the last part of the leaf stalk to be cut off. Questions that have yet to be answered include: “How long into the autumn is water carried into the leaf? And how long does the part of the veins, the phloem tissue, responsible for moving nutrients out of the leaf remain functional?” All we know for certain is that finally the leaf is held onto the tree only by the veins which ultimately break off to allow it to float away. Its point of departure is marked by a characteristic leaf scar that can be used to identify the tree in winter, its smooth corky surface marred by the broken remnants of the lignified xylem tissues of the vascular system.

And now we come to the matter of the final brown colour seen in the fallen leaves and also in leaves of some species that are still attached as in the white oak, for example. Again, explanation of the brown colour on websites is highly variable and mostly unrelated to the probable truth. There is no brown pigment already present in the tree leaves under discussion, or at least none that any phytochemist has isolated and reported on. The most likely cause of browning is the phenomenon familiar to anyone who has left a slice of apple or potato exposed to air. The exposed surface soon becomes brown because the tissues of apple and potato contain an abundance of colourless phenolic substances that are polymerized by enzymes to yield a brown shade. (There is now a genetically engineered variety of apple and another of potato that do not brown when cut.) Tree leaves also contain a complex mixture of phenolics, most of them formed at various steps of the same pathway that leads to anthocyanins as well as the enzymes noted above. Notable among them are two classes of vegetable tannins, condensed tannins (proanthocyanidins), polymers of catechins, whose synthesis branches off at a late stage of the pathway to anthocyanins and hydrolysable tannins that are polymers of gallic acid combined with glucose. (The chemistry of these compounds is exceedingly complex but that has not prevented their use over countless centuries in the production of leather from animal skin!) Thus there are ample compounds available for the browning phenomenon to occur in senescing leaves.

Our trees must maintain the delicate balance of retaining normal functioning of the leaves for as long as possible consistent with making adequate preparations for winter! Beginning the process of leaf senescence too soon will rob the tree of the ability to make food during the warm days of autumn but, on the other hand, starting too late may result in an abrupt cessation of all metabolic activity due to a killing frost before the tree has time to recover nutrients from its leaves.

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TOP CANADIAN ORNAMENTAL PLANTS. 14. IMPATIENS

Ernest Small^{1,2}

UNTIL about 2012, the patience plant (*Impatiens walleriana*) was one of the most important bedding plants in the world, and the premier floral annual for shady locations. As described in this review, a devastating, virulent mildew has substantially reduced its popularity, although there are efforts underway to breed resistant cultivars. Today, New Guinea impatiens (*I. hawkeri*) has become the most important *Impatiens*, while many of the other species (most notably balsam – *I. balsamina*) are occasionally grown. Even with the current difficulties experienced by *I. walleriana*, the genus *Impatiens* remains a leading source of easily grown, economical, colourful, garden ornamentals suited for shadier areas.

Names

Scientific names: The genus name *Impatiens* is based on the idea that the plants are explosively impatient to distribute their seeds (see “touch-me-nots,” explained below).

English names: *Impatiens*: the most frequent general English name for the genus is “impatiens,” followed by “balsam.” The species are also known as “touch-me-nots” for the way ripe pods explosively disperse their seeds when touched. For the same reason, they are also often termed “snapweed.” The name “balsam” (commonly applied to plants used as topical balms) reflects widespread historical use of the plants as skin ointments. Some species are called “jewel weed” (for rationale, see “Curiosities of Science and Technology”).

I. hawkeri: New Guinea impatiens.

I. walleriana: patience (plant), garden impatiens, busy Lizzie (a popular name in the U.K.; “busy” because the plant is “busily” setting flowers for a very long season; “Lizzie” is a variant of “Lucy,” explained next), patient Lucy (“Lucy” for the scientific name *I. lujai*), Japanese balsam, shady lady, sultana (for the scientific synonym *I. sultanii*, coined in honour of the sultan of Zanzibar), sultan’s balsam, sultan’s flower, Zanzibar balsam.

I. balsamina: bush balsam, garden balsam, garden jewelweed, rose balsam, spotted snapweed.

French names: *Impatiens*: balsamine, impatience, impatiens, impatiente, n’y touches pas, n’y touchez pas.

I. hawkeri: impatience de Nouvelle-Guinée, impatiens de Nouvelle Guinée, impatiente de Nouvelle-Guinée.

I. walleriana: balsamine de Waller, impatiens du Sultan, impatiens des jardins, impatiente des jardins.

I. balsamina: balsamine des jardins, balsamine cultivée.

Wild *Impatiens* species

Impatiens is one of the largest angiosperm genera, with over 1,000 species. Together with the monotypic genus *Hydrocera*, *Impatiens* makes up the family Balsaminaceae. *Impatiens* species are predominantly native to the tropics and subtropics of Asia and Africa, and most are local endemics. The distribution is mainly northern hemisphere, nearly all



Figure 1: A display of New Guinea impatiens (*Impatiens hawkeri*) at Kew Gardens, U.K. This species has become the most important commercial ornamental of the genus *Impatiens*. ©Leonora (Elle) Enking (CC BY SA 2.0).

species occupying elevations between 1000 and 3000 m, where cooler temperatures prevail, albeit in warmer regions of the world. Major centers of diversity include the Indian subcontinent, Southeast Asia, and the highlands and mountains of tropical and sub-tropical Africa. The plants are annual or perennial herbs or subshrubs. Most species occur in damp, shady environments near rivers or streams. Although very few species of *Impatiens* are grown, the huge number represents an invaluable store of germplasm for future development of improved cultivars.

Domesticated *Impatiens* species

A few cultivars of so-called “ornamental jewelweed” (*I. glandulifera*) are available. This species was indeed once cultivated as a garden ornamental until it became evident that it is extremely invasive. This native of northern India is a serious weed of North America (including Canada). To avoid confusion with the desirable ornamental species (which are very rarely invasive, at least in Canada), *I. glandulifera* is better termed by its alternative names “Himalayan balsam” or “policeman’s helmet.”

The following three “species” are the most important ornamentals in *Impatiens*. Although traditionally identified by the binomials *I. balsamina*, *I. walleriana*, and *I. hawkeri*, advanced cultivars are hybrids, with at least some parentage of other species.

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Figure 2: *Impatiens glandulifera*, an alien invasive threatening wetland habitats in Canada. ©Maja Dumat (CC BY 3.0).

GARDEN BALSAM (*IMPATIENS BALSAMINA*)

Garden balsam is an annual, native to southern Asia, including India, Bangladesh, and Myanmar, and has become widely naturalized in tropical, subtropical, and warm-temperate regions. This is the first *Impatiens* species to have been cultivated, and has been grown for centuries. It was introduced into Europe in the 16th century, where it was once a cottage-garden favourite. It grows to 1 m in height, although dwarf varieties have been bred. The species is available in a wide variety of flower colours and double-flowered forms. On the whole, garden balsam has limited popularity today.

GARDEN IMPATIENS (*IMPATIENS WALLERIANA*)

Impatiens walleriana (frequently misspelled *I. wallerana*) is a perennial, native to Eastern Africa (Kenya, Tanzania) and Equatorial (South Tropical) Africa (Malawi, Mozambique, Zambia, and Zimbabwe). It has also been widely naturalized in tropical, subtropical and warm-temperate regions. In its indigenous areas it occurs in or on the margins of moist, shady forests, and along river margins, while in introduced locations it is often found along roadsides and in disturbed sites. The species was named for Horace Waller, a missionary, member of the Royal Geographic Society, and publisher of the journals of David Livingston, the famous explorer of Africa. Physician and naturalist John Kirk, who travelled with Livingston, appears to have first brought the species to



Figure 3: Garden balsam (*Impatiens balsamina*). ©Xin (CC BY SA 2.0).



Figure 4: Garden impatiens (*Impatiens walleriana*). **Top:** A window box. ©geraldbrazell (CC BY ND 2.0). **Bottom:** A double-flowered form. ©Forest and Kim Starr (CC BY 2.0).

England in 1896 from the island of Zanzibar. The species was grown primarily as a potted plant until the 1970s, when breeding of cultivars expanded considerably. A very wide range of flower colours became available, as well as striped flowers and doubled flowers, and forms with different sizes and habits. Sales of *I. walleriana* underwent a spectacular increase in the early 1970s, and by 1977 it ranked third as a bedding ornamental in North America. In some recent years, annual sales of the species exceeded \$100 million in the U.S. alone. However, because of a serious disease problem, discussed next, *I. walleriana* has very recently undergone a catastrophic reduction in popularity. *Impatiens hawkeri* (New Guinea impatiens) has largely replaced *I. walleriana*, although the overall market value of *Impatiens* has decreased.

DOWNY MILDEW AND THE DEMISE OF *IMPATIENS WALLERIANA*

Although recorded for centuries, impatiens downy mildew emerged as a devastating foliar disease of *I. walleriana* in the 21st century on different continents (in 2011 in North America). The disease is caused by *Plasmopara obducens*, which is not a true fungus, but a member of the “water moulds” (Oomycota, which affect numerous economically important plants around the world, most famously the pathogen that caused the Irish potato famine). Some pathologists suspect that the sudden recent emergence of virulence of *P. obducens* is due to mutation. Reminiscent of true fungi, branched thread-like structures (sporangiophores) bearing reproductive sacs (sporangia, in which spores are generated) develop



Figure 5: Lower leaf surfaces of *Impatiens walleriana* infected by impatiens downy mildew. **Left:** Early development of sporangiophores and sporangia (spore-bearing structures). ©Don Ferrin (CC BY 3.0). **Right:** Advanced development of infection. ©Bruce Watt (CC BY NC 3.0).

inside the foliage. These sporangiophores emerge through stomates on the lower surface of the leaves, producing a white, downy growth on the leaf undersides. The sporangia on the sporangiophores are easily dislodged, and can be distributed by air currents or splashed by rain to other plants. Zoospores released from the sporangia swim in moisture on leaf surfaces, and they penetrate leaves by means of germ tubes which enter through the stomata. In addition to the zoospores, *Plasmopara* produces “oospores” inside infected plants. As the plants decay, these thick-walled, long-lived resting spores are released into the soil. Accordingly, infected plants should be discarded in garbage, not placed in compost.

Impatiens downy mildew thrives in cool, wet weather. Initially, leaves may curl downward at the edges and become yellow or stippled, and eventually plants become stunted. A light, gray fluffy coat of sporangiophores appears on the underside of the foliage, and many of the leaves and flowers fall away. Several fungicides can protect the plant from infection, but no cure is available once a plant is infected. The disease appears confined to *Impatiens*. All cultivars of *I. walleriana* as well as some wild species of *Impatiens* are susceptible. *Impatiens balsamina* is also considered susceptible, but significantly less so than *I. walleriana*, usually only exhibiting a yellow leaf spot. (In any event, it is much less popular than the other two major ornamental species of *Impatiens*.) Some hybrid combinations between *I. walleriana* and other species of *Impatiens* are relatively resistant, but a large percentage of *I. walleriana* in the parentage of a hybrid generally is associated with susceptibility.

Impatiens downy mildew changed the bedding plant business in North America by drastically reducing the most popular bedding plant, *I. walleriana*, from the market. New Guinea impatiens (*I. hawkeri*) is very resistant to the disease, and so has replaced *I. walleriana* as the leading ornamental species of *Impatiens*. However, it is not as shade tolerant as *I. walleriana*, and has not become as popular. Alternative shade-tolerant ornamentals such as begonias and coleus are often recommended, but none of these has proven as satisfactory to consumers. Breeding is underway to create hybrids of *I. walleriana* with other *Impatiens* species (particularly *I. hawkeri*) that are resistant to impatiens downy mildew. “Bounce” impatiens and “SunPatiens” (which is tolerant of full sun) are relatively resistant hybrids that have recently appeared on the market.



Figure 6: “Sunpatiens Compact Orange,” a recent *Impatiens* hybrid with *I. walleriana* and *I. hawkeri* parentage. Such varieties are resistant to downy mildew, but not as tolerant of deep shade as older *I. walleriana* cultivars that are susceptible to the disease. ©Serres Fortlier (CC BY 2.0).

NEW GUINEA IMPATIENS (*IMPATIENS HAWKERI*)

New Guinea impatiens (*I. hawkeri*) is a perennial, native to Papua New Guinea and the Solomon Islands. It was collected in Papua New Guinea by Lt. Hawker in 1884, and brought into cultivation. However, it did not become popular until 1970, after which extensive hybridization produced numerous attractive cultivars. In very recent times it has become the principal commercial species of *Impatiens*.

The species is generally larger than *I. walleriana*, up to 1 m in height, with leaves arranged in distinct whorls. New Guinea impatiens is available in about as wide a range of flower colours as was *I. walleriana* (including white, purple red, pink, salmon and orange) and many of the new cultivars have flowers that are larger (sometimes 7 cm or 2.8 inches across) and more numerous. Moreover, the foliage of New Guinea impatiens is available in a wide range of variegated patterns, exceeding what was available in *I. walleriana*. However, New Guinea impatiens has proven to be more expensive than *I. walleriana* (particularly because hybrids are



Figure 7: New Guinea impatiens (*Impatiens hawkeri*). ©Forest and Kim Starr (CC BY 2.0).



Figure 8: Garden impatiens (*Impatiens walleriana*) grown in boots. Container cultivation of this species, which is very susceptible to impatiens downy mildew, is advisable to avoid the disease. ©Forest and Kim Starr (CC BY 2.0).

reproduced by cuttings, not by seeds) and not as tolerant of deep shade.

Edibility and toxicity of *Impatiens*

Impatiens walleriana has been alleged to have sweet-tasting, edible flowers, which can be added to salads or mixed into fancy drinks. The flowers, seeds, foliage and young shoots of *I. balsamina* have been consumed in Asia. In Nepal, the seeds of *I. glandulifera* are harvested for food, and also pressed for their edible oil. However, *Impatiens* plants are generally bitter-tasting, and should be considered to be slightly poisonous. Preparations of the leaves and roots of *I. walleriana* have been employed as an abortifacient, suggesting that the plants are potentially toxic. As noted in the next section, constituents are present in *Impatiens* species that affect human metabolism, perhaps therapeutically, which also raises suspicion that there is danger of toxicity. Consumption of the species can cause vomiting, diarrhea and other intestinal disturbances, so caution is necessary in using the plants as food. The ornamental species of *Impatiens* are usually not considered to be hazardous for dogs and cats, and wild species are not thought to be significant hazards for most livestock. However, a turtle website provided the information that oxalates are present and so feeding of impatiens should be avoided.

Medicinal uses of *Impatiens*

In Asia, *I. balsamina* has been employed as a folk medicine to treat numerous conditions, such as rheumatism, fractures, inflammation, tuberculosis, snakebite, and menstruation. The plant is cathartic (purgative), diuretic (promoting urination), emetic (causing vomiting), and antibiotic, and these properties may provide a rationale for some of the traditional

usages. Moreover, a variety of chemical constituents are under investigation for possible medical applications.

Throughout the indigenous areas of *Impatiens* species, the plants have often been employed as topical salves to treat skin irritation. In particular, North American Indians widely employed a plant mash of jewelweed (*I. capensis*) to reduce development of poison ivy dermatitis. It has long been known that soaps are useful for this purpose by acting as a detergent to remove oily urushiol, the causative agent of poison ivy inflammation. It has recently been demonstrated that saponins (soap-like chemicals) in jewelweed act like soaps to alleviate poison ivy rash. In various parts of the world, similar preparations of *Impatiens* species have been employed to treat comparable skin conditions, but chemical constituents that could explain therapeutic effects have not been reliably identified.

Miscellaneous uses of *Impatiens*

Impatiens balsamina flowers are employed to prepare a red dye which is used as a substitute for henna (*Lawsonia inermis*) for colouring finger and toenails, and in cosmetics. Tubers of a species termed "*I. tinctoria*" were allegedly employed as a source of a black pigment used in Ethiopia for the ritual dying of hands and feet. In North America, Amerindians used the floral pigments of *I. capensis* as a food dye (to colour dried salmon), and they as well as European colonists also employed the plant to dye fabrics. The seed oil of *Impatiens* species has been used as a lamp fuel and in the surface-coating industry.

Cultivation

Impatiens walleriana until recently was the chief ornamental grown as a bedding annual in quite shady locations, but be-

cause of its susceptibility to impatiens downy mildew, it is no longer recommended. Until breeders produce a wide range of *I. walleriana* hybrids suited to deep shade, hybrids based primarily on New Guinea impatiens are the wisest choice for



Figure 9: Guttation in western jewelweed (*Impatiens noli-tangere*), a native of western Canada. Notice the exuded drops of liquid on the leaf margins. ©Hans Schneider (CC BY SA 2.0).

gardeners. *Impatiens walleriana* is still available from some nurseries, and as seed, and those interested in cultivating it are more likely to be successful if it is grown in a hanging basket or pot in a protected situation, where the mildew is less likely to infect the plants.

PURCHASING AND PROPAGATING

Seeds are available for the dominant ornamental species, but for the most part the plants are established from young established plants purchased from nurseries or garden centres. Commercially grown plants are frequently propagated from cuttings. *Impatiens* are often treated as houseplants, and can be obtained as potted plants to be maintained indoors as perennials.

PLANTING

Young plants are usually set out in beds or borders after danger of frost has passed. They are also sometimes employed as a groundcover in shady locations, particularly at the base of trees. The plants are also popular in hanging baskets, patio containers, window boxes, and pots. The species discussed here grow best in moist, well-drained soil rich in humus.

LOCATION

Impatiens walleriana until recently was the chief ornamental grown as a bedding annual in quite shady locations. New Guinea impatiens (*I. hawkeri*) is a reasonable alternative, but most hybrids and cultivars are better suited to semi-shade areas or areas that receive sun for part of the day.

MAINTENANCE

The species noted in this review are drought- and frost-intolerant (they are said to be “half-hardy”), and generally

will not thrive in full sun. *Impatiens hawkeri* requires regular watering to keep the soil moist, and regular fertilizing (or the use of a slow-release fertilizer).

Curiosities of Science and Technology

- The flowers of jewelweeds are very attractive (some sparkle in sunlight like jewels), and have been interpreted as the inspiration for the name jewelweed. However, the term is based on the foliage, which in the morning often has beads of water on the leaf edges, which sparkle like jewels. At night, the leaf edges expel excess water by guttation (exudation of xylem sap through special pores called hydathodes or water glands). This secretion of drops of water is an adaptation to the moist habitat, and compensates for the lack of transpiration at night when the stomates are closed. The drops of water are present in early morning, but evaporate quickly in sunlight.
- A slight touch of the ripe fruits of *Impatiens* results in contraction of elastic valves of the capsule, and an ejection of their seeds with great force. A study of explosive seed dispersal in *Impatiens capensis* (Hayashi et al. 2009) showed that the seeds could travel at up to 4 m/sec (9 miles/hour) and be dispersed up to 1.8 m (5.9 feet) from the plant.
- Unlike almost all other plant species, the number of chromosomes of *Impatiens* can be quickly determined from pollen grains on herbarium sheets. Angiosperm pollen typically contains a vegetative cell, responsible for producing an elongated tube in a stigma on which the pollen grain is deposited, and a generative cell, which divides by mitosis to produce two sperm cells which migrate down the tube to achieve the characteristic double fertilization of flowering plants. In *Impatiens*, the chromosomes go into a prolonged resting stage at the first mitotic metaphase of the generative cell, and in this state the chromosomes can be easily visualized (Gill and Chinnappa 1977).
- Like many other genera, species of *Impatiens* often have extrafloral nectaries, located on the stipules (small leaflike bracts, typically borne in pairs at the base of the leaf stalk). The nectar produced is especially attractive to ants, which have been hypothesized to symbiotically protect the plants against other insects in return for the sweet liquid.



Figure 10: A display of *Impatiens walleriana* planted on a sphere, representing a baseball. Much smaller ornamental *impatiens* “flower balls” have been made simply by wiring two perforated hanging baskets together (young plants placed in the perforations), with a pipe inserted for watering the interior. Photographed in Tokyo, Japan in 2005 by Mom the Barbarian (CC BY 2.0).

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