

# PENNSTATE



## College of Agricultural Sciences

### *L.W. SCHATZ CENTER FOR TREE MOLECULAR GENETICS* ANNUAL REPORT

July 2019 – June 2020

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The Schatz Center over the years:



## L.W. SCHATZ CENTER FOR TREE MOLECULAR GENETICS ANNUAL REPORT, 2019-2020

The Louis W. Schatz Center for Tree Molecular Genetics at Penn State has played an important role in forest genetics and genomics research since its inception in 2003, due to the generosity and foresight of Dr. Schatz, and the continuing engagement of the Schatz family. The endowments have supported a wide array of research projects through funds for post-doctoral fellows, visiting scholars, undergraduate and graduate students, staff, field trips, travel and supplies. The Schatz Center endowments at the Mont Alto campus have also positively impacted the research community through sponsorship of colloquia on important forest genetics topics, and support for student projects. We are pleased to provide this update on activities and accomplishments in The Schatz Center for the 2019-2020 academic year.

### THE LOUIS W. SCHATZ CENTER FOR TREE MOLECULAR GENETICS ENDOWMENT:

This endowment supports crucial research and training activities in the Schatz Center at the University Park campus, including wages for undergraduate student researchers, visiting scientists, and technical staff, as well as publication costs, field support staff, travel expenses, research services, and research supplies.

Undergraduate Research: All three of the undergraduate students who worked with us during the 2018/2019 academic year continued with us in 2019/2020. Three Horticulture students were supported on hourly wages to assist with research in the Schatz Center. **Brian Betz**, who graduated May 2019, helped keep our poplar and green ash field trials in good growing condition. **Maureen Mailander**, who graduated in December 2019, continued to have responsibility for the regeneration of poplar plants from tissue culture and transplanting to greenhouse and field trials. Maureen also assisted with collection of data from our poplar bioenergy and green ash genetics field trials. After graduation she continued as a part-time research assistant and assumed the role of lab manager on July 1, 2020. **Adam Bettinger** also assisted in collecting data at our poplar bioenergy and green ash genetics field trials as well as lab upkeep, until as an undergraduate student he was required to leave campus in March 2020 due to covid concerns.



Maureen and Adam working together in the lab, pre-covid.

The endowment also supported the Center's lab manager, **Nicole Zembower**, who served this year on a part-time basis. Ms. Zembower provided administrative and research support to the Center's Director and Visiting Scholars, including arrangements for travel, housing, university appointments, safety training, ordering supplies, and research assistance. Ms. Zembower also helped supervise our undergraduate research assistants and organized the Schatz Center's extensive greenhouse and field trials, including transplanting of seedlings and endless mowing. Over the past year, Nicole was on medical leave until January 16, 2020, and then retired July 10, 2020. Her dedication and many contributions to the Schatz Center over the past 9 years were greatly appreciated and she will be missed.

Visiting Scientists: The endowment supported visits to the Schatz Center at Penn State by three renowned tree genetics research scientists with whom we collaborate. This greatly facilitated the review of our recent research results, the planning of future experiments, and the writing of manuscripts. Dr. Catherine Bodénès, a geneticist from the National Institute for Agricultural Research in Bordeaux, France, visited from July 14 to 27, 2019. We have collaborated with Dr. Bodénès for over 10 years on various oak genetics and genomics projects. Dr. Rita Costa, a geneticist at the Portuguese National Institute for Agricultural and Veterinary Research in Portugal, visited from August 4 to 13, 2019. We collaborate with Dr. Costa on chestnut genetics and genomics projects, with special emphasis on resistance for root diseases. Dr. Margaret Staton, bioinformatics professor at the University of Tennessee, visited from October 22-25, 2019. We have collaborated with Dr. Staton since 2006. She hosts The Hardwood Genomics website which is the public repository for all the genomic and genetic data which we have generated since the beginning of the Schatz Center. In addition, the endowment supported the salary of Research Associate Professor Tatyana Zhebentyayeva for a second year. Dr. Zhebentyayeva had another highly productive year in the center, publishing 5 major papers and submitting several grant proposals. Dr. Zhebentyayeva is playing an important role in maintaining the high profile and productivity of the Schatz Center during Director John Carlson's transition through part-times service and into retirement in 2021. In addition, Dr. Albert Abbott, part-time co-Director of the Forest Health Research and Education Center at The University of Kentucky, served a final year as a part-time consultant, assisting us in the preparation of numerous manuscripts and grant proposals.

Dr. Carlson's final Ph.D. student T. Casey Weathers completed and successfully defended his dissertation on conservation genetics of brook trout in July 2019. Casey graduated on August 5, 2019 and is employed as a Research Scientist with the US Fish & Wildlife Service's Southwestern Native Aquatic Resources and Recovery Center in Dexter, NM. The endowment supported attendance and travel for Dr. Carlson, students, and staff in the Schatz Center to present talks at several research meetings. Dr. Zhebentyayeva and visiting scientist Rita Costa attended the USDA multi-state research project NE-1833 annual meeting, along with Dr. Carlson, at Alpine Lake, WV, Aug 5-8, 2019. Dr. Carlson, Dr. Zhebentyayeva, former student Krystle Swartz and colleague Sara Fitzsimmons-Lingenfelt attended the Natural Areas Association conference in Pittsburgh, PA, Oct 7 – 10, 2019. Finally, the endowment assisted with expenses for Dr. Carlson's to attend the American Chestnut Foundation annual meeting in Gettysburg, PA, Oct 16-20, 2019.

**Plans for the 2020-21 fiscal year:** Approximately one-third of the endowment funds remained at the end of the 19/20 fiscal year. This resulted from shortfalls in anticipated expenses due to reduced staffing and research activities, curtailed travel plans, interruptions in the delivery of supplies, and temporary closure of facilities providing research services due to the covid pandemic and other issues. In addition, the current director conserved funds which carry over to the 2020/21 year to assist with expenses that may be incurred in transition to the new director. For the first 6 months of FY 2020/21, wages/salaries will continue for Dr. Zhebentyayeva and Maureen Mailander, along with their research project expenditures, under the direction of Dr. Carlson. The new Schatz Center Director will assume responsibility for the fund upon arrival in 2021.

### **SCHATZ FACULTY TRAVEL FUND:**

The Louis and Merry Schatz Faculty Travel Fund supported two trips in the 2019-2020 fiscal year by Dr. Carlson to participate conferences and research meetings relevant to the Schatz Center goals. Attending such meetings is an important national and international outreach component of

the Schatz Center, allowing members to inform the research community about results from the projects underway in the Schatz Center and to meet with colleagues to review and plan projects.

In October 2019, Dr. Carlson attended the annual meeting of The American Chestnut Foundation in Gettysburg, PA. The Schatz Tree Genetics Colloquium endowment fund (at Mont Alto) provided funding to assist the Pennsylvania Chapter of The American Chestnut Foundation to host the meeting. Dr. Carlson was asked to give a keynote address at the meeting, which reviewed the many activities and accomplishments of the Schatz Center during Dr. Carlson's 16 years as director. The Schatz Center students and staff have worked closely over many years with The American Chestnut Foundation, in the foundation's efforts to restore native chestnut trees to North American forests, including leading efforts to identify genes for chestnut blight resistance in Asian tree species. The new faculty member being recruited to replace Dr. Carlson will hold a position titled "Restoration Genetics." Being able to attend the annual meeting of The American Chestnut Foundation provided an important opportunity to inform the foundation membership of the ongoing shared interest of the Schatz Center.

The second trip for Dr. Carlson supported by the Faculty Travel Fund was to the Georg-August University of Göttingen in Germany, where Dr. Carlson started the prestigious Mercator Fellowship for 3 years as a Visiting Professor. The Department of Forest Genetics and Forest Tree Breeding at the University of Göttingen hosted a one month visit by Dr. Carlson, from mid-December 2019 to mid-January 2020. The Schatz Faculty Travel Fund supported Dr. Carlson's airfare, while his hosts provided food and lodging for this first visit. The Visiting Professorship is associated with a project to study the underlying genetics of hybridization among oak species in both Europe and North America. The Schatz Faculty Travel Fund's support for this trip allowed Dr. Carlson to contribute to an area of research that should continue to be of interest to the Schatz Center as it has been to forest biologists and managers around the world for many decades.

**The 2020/21 university fiscal year** will see a transition of the Directorship of the Schatz Center at the University Park campus from Dr. Carlson, who retires June 2021, to a new faculty member soon to be hired. It is anticipated that by January 2021 a new Director of the LW Schatz Center for Tree Molecular Genetics will be in place. At the time of this report, out-of-state travel is still curtailed until January 1, 2021, due to the covid-19 pandemic. Thus, travel funds to attend meetings should not be needed during the first 6 months of the 20/21 fiscal year. For the second 6 months of the 20/21 fiscal year, if when the new Director is in place, she/he may wish to attend conferences and visit new colleagues across PA and the US as initial steps in developing new research directions and visibility for the Schatz Center, if travel has opened up again.

#### **SCHATZ STUDENT FIELD TRIP FUND:**

The biennial field trip of Schatz Center faculty and students to visit Gordon and Karen Schatz and The L.W. Schatz Demonstration Tree Farm at Humboldt State University in California was planned for May 2020. However, that date and the re-scheduled field trip in August 2020, were not possible, due to continuing safety concerns from the covid-19 pandemic. In consultation with Mr. and Mrs. Schatz, the field trip was postponed to May 2021. Hopefully, travel will be possible then. The balance of funds from fiscal year 2019/2020 will be applied to the student field trip in 2021, which will support participation by more faculty and students in 2021, hopefully including the new faculty member hired to direct Schatz Center activities at the University Park campus.



## SCHATZ TREE GENETICS COLLOQUIUM FUND, MONT ALTO CAMPUS

The Schatz Center's Tree Genetics Colloquium Fund was a major sponsor of The American Chestnut Foundation's 36<sup>th</sup> annual meeting held October 18 and 19, 2019, in Gettysburg, PA. The meeting was hosted by the Pennsylvania Chapter of TACF and our faculty at the Penn State Mont Alto campus. Dr. Carlson presented an overview of the accomplishments of the LW Schatz Center for Tree Molecular Genetics since 2003. The slides presented by Dr. Carlson are attached to this report. The TACF membership expressed appreciation of the fund's support of the meeting, and for assistance provided by the Schatz Center in reaching their goals to become 'genomics-enabled'.

**For the 2020/21 fiscal year,** a Schatz Tree Genetics Colloquium is being planned around the theme of "Emerging Concepts in Tree Biology." This is anticipated to be a major event, bringing together experts to review a wide spectrum of research disciplines, and culminating in a special issue of the Forests journal featuring ground-breaking opportunities for collaborative tree research.

## SCHATZ CENTER RESEARCH PROGRESS UPDATE FOR 2019-2020

The Schatz Center made great progress during the past year, both in new ground-breaking research and the publication of 8 journal articles and one book chapter capping several of our completed research projects. The highlight for us was the publication of the complete genome of a Chinese chestnut cultivar, providing new insights into the genetics of chestnut blight disease resistance and of environmental adaptation that should assist efforts to restore American Chestnut to eastern forests. The American Chestnut Foundation is already integrating our genomics tools into their blight resistance breeding program and are now working themselves on sequencing the genomes of many remaining American Chestnut trees (or root sprouts) to learn more about how our chestnut species became such a vigorous, dominant forest tree prior to introduction of the blight.

Dr. Carlson was awarded a new grant for \$200,000 from the USDA's McIntire-Stennis program that runs from October 2019 to September 2021. This grant funds the completion and publication of the first reference genome sequences for Northern Red Oak and Green Ash. This project will provide a platform of genomic and genetic resources to encourage and facilitate many future research projects with these important forest tree species. The results should also contribute to applied forest health initiatives in state and national programs, including restoration of ash populations that are being devastated across the eastern US. At this point, the green ash genome DNA sequencing has been completed and the 23 ash chromosomes have been compiled and the location of all the genes identified. We had previously constructed a genetic map showing the relative locations of over a thousand genes based on inheritance within one green ash family (see photo). We found that order of genes in the new chromosome sequences matched up perfectly with the genetic map. The DNA sequencing of the northern red oak genome will also soon be completed. The US Department of Energy's Joint Genome Institute and the HudsonAlpha Institute offered to assemble the complete DNA sequences of the 12 northern red oak chromosomes, and to place the completed northern red oak genome on their plant genomes website (Phytozome) for the world to access.



During the 2019-2020 academic year, Dr. Carlson, Dr. Zhebentyayeva with our colleagues produced the following scientific papers and scientific conference presentations:

Peer-reviewed publications:

1. Staton ME, Addo-Quaye C, Cannon N, Yu J, **Zhebentyayeva T**, Huff M, Islam-Faridi N, Fan S, Georgi LL, Nelson CD, Bellis E, Fitzsimmons S, Henry N, Drautz-Moses D, Noorai RE, Ficklin S, Sasaki C, Mandal M, Wagner T, Zembower N, Bodénès C, Holliday J, Westbrook J, Lasky J, Hebard FV, Schuster SC, Abbott AG, **Carlson JE**. 2020. A reference genome assembly and adaptive trait analysis of *Castanea mollissima* 'Vanuxem', a source of resistance to chestnut blight in restoration breeding. *Tree Genetics and Genomes*, 16:57 (<https://doi.org/10.1007/s11295-020-01454-y>) 23 pages.
2. Tchatchoua TD, Poethig RS, Doody E, Weathers TC, Swartz K, Mathieson I, Zembower N, **Zhebentyayeva T**, **Carlson JE**. 2020. Genetic diversity of *Faidherbia albida* populations in the Sudano Sahelian region of Cameroon, using SSR (Simple Sequence Repeat) markers. *African Journal of Biotechnology*, 19(7): 415-425.
3. Guo L, Guo S, Xu J, He L, **Carlson JE**, Hou X. 2020. Phylogenetic analysis based on chloroplast genome uncover evolutionary relationship of all the nine species and six cultivars of tree peony. *Industrial Crops and Products*, 153: p.112567, (<https://doi.org/10.1016/j.indcrop.2020.112567>), 10 pages.
4. Soltani N, Best T, Grace D, Nelms C, Shumaker K, Romero-Severson J, Moses D, Schuster S, Staton M, **Carlson J**, Gwinn K. 2020. Transcriptome profiles of *Quercus rubra* responding to increased O<sub>3</sub> stress. *BMC Genomics*, 21(1): 1-18.
5. Yu, J., Conrad, A.O., Decroocq, V., **Zhebentyayeva, T.**, Williams, D.E., Bennett, D., Roch, G., Audergon, J.M., Dardick, C., Liu, Z. and Abbott, A.G., 2020. Distinctive gene expression patterns define endodormancy to ecodormancy transition in apricot and peach. *Frontiers in Plant Science*, 11, p.180.
6. Bourguiba, H., Scotti, I., Sauvage, C., **Zhebentyayeva, T.**, Ledbetter, C., Krška, B., Remay, A., D'Onofrio, C., Iketani, H., Christen, D. and Krichen, L., 2020. Genetic Structure of a Worldwide Germplasm Collection of *Prunus armeniaca* L. Reveals Three Major Diffusion Routes for Varieties Coming From the Species' Center of Origin. *Frontiers in Plant Science*, 11, p.638.
7. Bell TH, Kaminsky LM, Gugino BK, **Carlson JE**, Malik RJ, Hockett KL, Trexler RV. 2109. Factoring Ecological, Societal, and Economic Considerations into Inoculant Development. *Trends in Biotechnology*, 37(2): 140-151.
8. Conrad, A.O., Yu, J., Staton, M.E., Audergon, J.M., Roch, G., Decroocq, V., Knagge, K., Chen, H., **Zhebentyayeva, T.**, Liu, Z. and Dardick, C., 2019. Association of the phenylpropanoid pathway with dormancy and adaptive trait variation in apricot (*Prunus armeniaca*). *Tree Physiology*, 39(7), pp.1136-1148.

Papers Accepted (for publication in 2020):

1. Stanton BJ, Haiby K, Gantz G, Shuren R, Hall R, Johnson LJ, Weathers TC, Wu D, Islam-Faridi N; Best T, Stanish A, Staton M, **Carlson JE**. 2020. Inter-Specific Hybridization of *Alnus rubra* and *Alnus rhombifolia*: Preliminary Report of a New Taxon and DNA Marker Resources for Bioenergy Feedstock Production, Accepted July 22, 2020, *Tree Genetics and Genomes*, *In Press*.
2. Wang W, Carlson CH, Smart LB, **Carlson JE**. 2020. Transcriptome analysis of contrasting resistance to herbivory by *Empoasca fabae* in two shrub willow species and their hybrid progeny. *PLoS ONE In Press*.

## Book Chapters

1. Merkle SA, Vieitez FJ, Corredoira E, **Carlson, J.E.** 2020. 10.1 *Castanea* spp. Chestnut. In R. Litz, F. Alfaro, & J. Hormaza (Eds.), *Biotechnology of Fruit and Nut Crops* (2nd ed.). CAB International, published January 2020, pages 206 – 237.

## Presentations at Research Conferences

1. Jeremy Sutherland, Ryan Crawford, Ryan Trexler, Christopher Tkach, Terrence Bell, Stacy Bonos, Marvin Hall, Julie Hansen, Jesse Lasky, Donald Viands, **John Carlson**. 2019. Breeding resilient, disease-resistant switchgrass cultivars for marginal lands, DOE/USDA Genomic Sciences Program Annual Contractor-Grantee Meeting, Tyson's Corner, VA, Feb 24-26, 2020.
2. **John Carlson**, Kim Steiner, Charles Ray, Tetyana Zhebentyayeva, Sara Fitzsimmons. 2019. Pennsylvania State University Report, Multi-State Research Project NE-1833. Agriculture Experiment Station Update, NE-1833 Meeting, Pennsylvania State University, University Park, PA, September 6, 2019.
3. **John E. Carlson**. 2019. Genetic opportunities for restoring green ash and American beech, Natural Areas Conference, Station Square Sheraton, Pittsburgh, PA, October 8, 2019.
4. **John E. Carlson**, Penn State University Station Report, NE-1833 Multi-state Project Annual Meeting, Alpine Lake Resort, WV, September 6, 2019.
5. **Zhebentyayeva** et al. Genetic mapping the resistance/susceptible response in chestnut seedlings to *Phytophthora cinnamomi* infection. Annual Meeting, Forest Health Research and Education Center (FHC), University of Kentucky, Lexington, KY, April 23, 2019 - April 24, 2019.
6. **Zhebentyayeva** et al Integrated genomic and genetic approach for discovery candidate genes associated with resistance to *Phytophthora cinnamomi* in chestnut. Southern Forest Tree Improvement Conference (SFTIC), The Forest Health Research and Education Center and the Department of Forestry and Natural Resources and Forestry Extension at the University of Kentucky, Lexington, KY, June 2, 2019 - June 7, 2019.
7. **Zhebentyayeva** et al. Mapping the QTLs for *Phytophthora cinnamomi* resistance. The 37th annual meeting "NE1833: Biological Improvement of Chestnut through Technologies that Address Management of the Species and its Pathogens and Pests", Pennsylvania State University, University Park, PA, September 5, 2019 - September 9, 2019.
8. L. Gustavsson, K. Dalman, J-E. Englund, H. Véléz, I. Abreu, F. Odilbekov, J. Skytte af Sättra, I. Semashko, B. Canbäck, **T Zhebentyayeva**, E. van de Weg. Towards a better understanding of resistance to European canker in apple: a multidisciplinary approach. XV EUCARPIA Fruit Breeding and Genetics Symposium, Prague, Czech Republic, June 3 - 7, 2019.
9. **T. Zhebentyayeva**, S. Fitzsimmons and **J.E. Carlson**. Restoration of the American chestnut. The 2019 Natural Areas Conference (NAC), Natural Areas Association (NAA), Station Square Sheraton, Pittsburgh, PA, October 7, 2019 - October 10, 2019.
10. Yu J, Conrad A, Decroocq V, **Zhebentyayeva T**, Williams D, Bennett D, Roch G, Audergon J-M, Dardick C, Liu Z, Abbott A, Staton M. Distinctive gene expression patterns define endodormancy to ecodormancy transition in apricot and peach. Plant & Animal Genome XXVIII Conference, San-Diego, CA, January 11 - 15, 2020.

## Manuscripts written during 2019/20 academic year, and submitted to journals for publication:

1. **John E. Carlson**, Margaret E. Staton, Charles Addo-Quaye, Nathaniel Cannon, **Tetyana Zhebentyayeva**, Nurul Islam-Faridi, Jiali Yu, Matthew Huff, Shenghua Fan, Anna Conrad, Stephan C. Schuster, Albert G. Abbott, Jared Westbrook, Jason Holliday, C. Dana Nelson, Laura Georgi, FV Hebard, "An Improved Chinese Chestnut Genome", Extended abstract, Submitted May 9, 2020, to Proceedings of the IUFRO 6th International Workshop on the Genetics of Tree-Parasite Interactions: Tree Resistance to Insects and Diseases: Putting Promise into Practice, Mt. Sterling, Ohio, USA, 5-10 August 2018, to be published as a General Technical Report by the USDA Forest Service Southern Research Station.
2. **John E. Carlson**, Irina Čalić, Jennifer Koch, David Carey, Charles Addo-Quaye, Donghwan Shim, David B. Neale, "Candidate Genes from GWAS was RNAseq for Beech Bark Disease Resistance in

- American Beech”, Extended abstract, Submitted May 9, 2020, for the Proceedings of the IUFRO 6th International Workshop on the Genetics of Tree-Parasite Interactions: Tree Resistance to Insects and Diseases: Putting Promise into Practice, Mt. Sterling, Ohio, USA, 5-10 August 2018, to be published as a General Technical Report by the USDA Forest Service Southern Research Station.
3. Krystle A. Swartz, T. Casey Weathers, Nicole M. Zembower, Di Wu, John W. Wenzel, **John E. Carlson**, "Genetic Variation and Conservation Implications for the Rare and Imperiled Buffalo Nut (*Pyralaria pubera*)" Submitted January 5, 2020 to the Diversity journal.
  4. T. Casey Weathers, Matt A. Kulp, Jacob M. Rash, Aaron W. Aunins, Mike Eackles, Jesse R. Lasky, David C. Kazyak, **John E. Carlson**, “Riverscape Genetic Analyses Identify Biotic and Abiotic Factors that Shape Patterns of Genetic Structure in Appalachian Brook Trout Populations”, Submitted October 31, 2019 to North American Journal of Fisheries Management..
  5. T. Casey Weathers, Matt A. Kulp, David C. Kazyak, Jacob Rash, **John E. Carlson**, “Implications of fine-scale genetic differentiation for the conservation of southern Appalachian brook trout (*Salvelinus fontinalis*)” Submitted September 12, 2019 to Conservation Genetics.
  6. Perkins M.T., **Zhebentyayeva T.N.**, Sisco P., Craddock H. Genome-wide sequence-based genotyping supports a nonhybrid origin of *Castanea alabamensis*. Systematic Botany (submitted), BioRxiv.org, preprint <https://www.biorxiv.org/content/10.1101/680371v1>.
  7. Callahan AM., **Zhebentyayeva TN**, Humann JL, Saski CA, Galimba KD, Georgi L.L, Scorza R., Main D, Dardick CD. Defining the ‘HoneySweet’ insertion event utilizing NextGen sequencing and a de novo genome assembly of plum (*Prunus domestica*). Horticulture Research (HORTRES-02202, submitted).