2021 Research Experience for Teachers (RET)
Switchgrass Nitrogen Fixation
with Carmella Vizza and Sarah Roley

Apply here! by Monday, May 31, 2021 (a word version of the application, to be used to preview and prewrite your application)
Who? Middle or High School STEM teachers
What? Research Experiences for Teachers (RET) are in-depth, authentic research experiences available to classroom K-12 teachers. These experiences often pair a teacher with a researcher to assist with an ongoing project or complete an independent, co-developed research project.
Where? W.K. Kellogg Biological Station, 3700 East Gull Lake Dr. Hickory Corners, MI 49060
When? Mid-June-August (8 weeks, full time (40 hours, week of July 5 off); attend the (virtual) KBS K-12 Partnership Summer Workshop June 22 -24, 2021, LTER Network RET Meetings (virtual), Dates TBD
Compensation:
$8000 stipend for 8 weeks of full time (40 hours/week)
$2000 supplies - for personal field gear (ex. waterproof boots and jacket) and/or student supplies for future experiments
$1500 for travel to professional conference (likely the LTER All Scientists Meeting in California, fall 2022)
Questions? email Kara and Carmella, karahaas@msu.edu and vizzacar@msu.edu

Research Experience for Teachers (RET) Overview

This research experience for teachers involves examining nitrogen (N_2) fixation in switchgrass (*Panicum virgatum*), which is a perennial grass native to North American prairies and a potential biofuel crop. N_2 fixation is the process by which microbes convert dinitrogen gas to a form of N that is available for plant uptake. Some microbes fix N_2 in a loose association with plants, a process known as associative N fixation (ANF). In contrast to the symbiotic relationship between certain microbes and legumes, many details of ANF remain unknown, including its ecosystem importance, the microbial taxa that fix N_2, and the ecological relationships driving its occurrence. The teacher will help researchers investigate this process in the field and the laboratory, by taking soil cores, preparing plant and soil samples for isotopic analysis, extracting soil nutrients, and participating in other field and laboratory work. In addition, the educator will help translate their research experience into the classroom by creating a Data Nugget, which is a set of classroom activities for K-12 students in which students use real scientific data to practice their quantitative skills.

2021 Research Experience for Teachers (RET)
Switchgrass Nitrogen Fixation
with Carmella Vizza and Sarah Roley

RET Logistics

This RET project is embedded within the Kellogg Biological Station Long-term Ecological Research (KBS LTER) program and the Great Lakes Bioenergy Research Center (GLBRC). The teacher will help with all elements of the 2021 research being conducted by post-doctoral researcher, Dr. Carmella Vizza under the guidance of primary investigators Drs. Sarah Roley (Washington State University), Phil Robertson (Michigan State University), and Dan Buckley (Cornell University). In addition, the RET teacher will present their research results in the KBS K-12 Summer Institute and at a state or national conference (e.g., the Michigan Science Teachers' Association conference).

In addition to the research experience, the educator will create a Data Nugget, which are free classroom activities, co-designed by scientists and teachers, that bring contemporary research and authentic data in the classroom. Specifically, the RET educator will use these existing resources along with first-hand knowledge from their research experience to develop a Data Nugget such as "Where do grasses get their food?", which would include data on N fixation rates and annual N requirements. Training and support, alongside other RETs developing their own Data Nuggets, will be incorporated into the experience.

RET Goals

1. Develop ecological research knowledge and skills related to teaching subject area;
2. Learn about current ecological research challenges, approaches, and opportunities;
3. Gain experience and skills in curriculum development aligned with Next Generation Science Standards and relevant state standards;
4. Develop a data nugget connected to the research experience to use with students during the school year and made available for other teachers to adapt for similar classes;
5. Present research summary and educational materials created at the K-12 Partnership workshop or summer institute and at a professional conference;
6. Connect with a community of LTER and KBS researchers, staff and fellow educators;
7. Have a fun, rewarding experience.

Research Background: Nitrogen is an element essential to life present in the genetic code (DNA and RNA), the building blocks of proteins, and the energy molecule (ATP)

used to drive biological processes. Although it is abundant in gaseous form (N_2) in the atmosphere, most organisms find N_2 inaccessible. N_2-fixing organisms, however, are able to break the powerful triple bond between N atoms, fixing it into biologically-accessible forms of N. Because N_2 fixation is an energetically costly process, N is a limiting nutrient in many environments.

With the combustion of fossil fuels and the advent of synthetic N fertilizers, humans have greatly altered the N cycle, resulting in water pollution, drinking water contamination, and greenhouse gas emissions (Galloway et al. 2004). Agricultural N fertilizer is particularly problematic. Fertilizer is necessary to achieve optimal plant growth, but excess N also leaches into groundwater and surface water. Soil microbes convert fertilizer to nitrous oxide (N_2O), a powerful greenhouse gas (Robertson and Vitousek 2009). Balancing these environmental consequences with the need for higher global food and energy production is vital to ensuring the flourishing of humanity and the planet (Galloway et al. 2008).

One such solution is the development of perennial grass crops. Perennial grasses require less fertilizer, leach less N, and emit lower amounts of greenhouse gases than annual crops (Oates et al. 2016; Sanford et al. 2016; Hussain et al. 2019). Perennial grasses can be converted to biofuels, or fuels recently derived from organic matter or plant material. They can also be grown on lands unsuitable for food production, thereby reducing environmental impacts of biofuels growth, while avoiding the food-fuel conflict (Robertson et al. 2017).

Switchgrass (*Panicum virgatum*), a perennial C_4 bunchgrass native, is a potential biofuel candidate due to its widespread range across North America, high yield, and low fertilizer requirements. Specifically, switchgrass productivity is not enhanced by adding N fertilizer even in systems where N is repeatedly removed with the harvesting of aboveground biomass (Parrish and Fike 2005). We recently found that microbes associated with switchgrass roots and soil may be providing a substantial amount of N for the plant (Roley et al. 2018; Roley et al. 2019), but we still need to determine how much N_2 fixation is occurring and what factors influence this process.

Specifically, our 2021 research has both observational and experimental components. We will be monitoring N_2 fixation throughout the growing season as switchgrass N

demand and its relationship with microbial communities vary. In addition, we will examine how precipitation and drought affect N_2 fixation rates by manipulating drying and wetting cycles with rainout shelters and irrigation systems. We will also measure temperature, pH, soil carbon availability, and the amount of accessible N already in the soil to better understand how these factors influence N_2 fixation. Overall, the project aims to quantify annual N inputs from fixation, identify microbial taxa that fix N_2 in association with switchgrass, and characterize the plant-microbe interactions that promote N_2 fixation.

More about mentor, Dr. Vizza:

Dr. Carmella Vizza joined Dr. Sarah Roley's lab as a postdoc on the E-fix (episodic N fixation) project examining non-symbiotic nitrogen fixation in switchgrass in Fall of 2018. Before joining the lab, she received her B.S. in Ecology and Evolutionary Biology at Tulane University in 2008 where her honors thesis was about spider sperm competition. Next, she worked as a project manager for four years at the Northwest Fisheries Science Center (NOAA Fisheries) based in Seattle, WA, examining the effect of marine-derived nutrients brought by Chinook salmon to riparian ecosystems. In 2018, she received her PhD at the University of Notre Dame in the field of aquatic biogeochemistry with the guidance of advisors Drs. Gary Lamberti and Stuart Jones. Her dissertation investigated how physicochemical properties and microbial communities shape ecosystem function in Alaskan wetlands. Carmella is passionate about biogeochemistry and microbial communities! She loves being outdoors and enjoys playing ultimate frisbee and Crossfitting in her free time.

https://scholar.google.com/citations?hl=en&user=Y1NC4RoAAAAJ

Personal Interview for Women in Science

ESA 2020 talk

References

Galloway, J. N., F. J. Dentener, D. G. Capone, E. W. Boyer, R. W. Howarth, S. P. Seitzinger, G. P. Asner, C. C. Cleveland, P. A. Green, E. A. Holland, D. M. Karl, A. F. Michaels, J. H. Porter, A. R. Townsend,

and C. J. Vöosmarty. 2004. Nitrogen cycles: Past, present, and future. Biogeochemistry 70:153–226.

Galloway, J. N., A. R. Townsend, J. W. Erisman, M. Bekunda, Z. Cai, J. R. Freney, L. A. Martinelli, S. P. Seitzinger, and M. A. Sutton. 2008. Transformation of the nitrogen cycle: Recent trends, questions, and potential solutions. Science 320:889–892.

Hussain, M. Z., A. K. Bhardwaj, B. Basso, G. P. Robertson, and S. K. Hamilton. 2019. Nitrate Leaching from Continuous Corn, Perennial Grasses, and Poplar in the US Midwest. Journal of Environmental Quality 48:1849–1855.

Oates, L. G., D. S. Duncan, I. Gelfand, N. Millar, G. P. Robertson, and R. D. Jackson. 2016. Nitrous oxide emissions during establishment of eight alternative cellulosic bioenergy cropping systems in the North Central United States. GCB Bioenergy 8:539–549.

Parrish, D. J., and J. H. Fike. 2005. The biology and agronomy of switchgrass for biofuels. Critical Reviews in Plant Sciences 24:423–459.

Robertson, G. P., S. K. Hamilton, B. L. Barham, B. E. Dale, R. C. Izaurralde, R. D. Jackson, D. A. Landis, S. M. Swinton, K. D. Thelen, and J. M. Tiedje. 2017. Cellulosic biofuel contributions to a sustainable energy future: Choices and outcomes. Science 356:eaal2324.

Robertson, G. P., and P. M. Vitousek. 2009. Nitrogen in Agriculture: Balancing the Cost of an Essential Resource. Annual Review of Environment and Resources 34:97–125.

Roley, S. S., D. S. Duncan, D. Liang, A. Garoutte, R. D. Jackson, J. M. Tiedje, and G. P. Robertson. 2018. Associative nitrogen fixation (ANF) in switchgrass (Panicum virgatum) across a nitrogen input gradient. PLOS ONE 13:e0197320.

Roley, S. S., C. Xue, S. K. Hamilton, J. M. Tiedje, and G. P. Robertson. 2019. Isotopic evidence for episodic nitrogen fixation in switchgrass (Panicum virgatum L.). Soil Biology and Biochemistry 129:90–98.

Sanford, G. R., L. G. Oates, P. Jasrotia, K. D. Thelen, G. P. Robertson, and R. D. Jackson. 2016. Comparative productivity of alternative cellulosic bioenergy cropping systems in the North Central USA. Agriculture, Ecosystems & Environment 216:344–355.