Nitrogen fixation in Switchgrass with Sarah Roley and Carmella Vizza; Location: Kellogg Biological Station

Research Experience for Teachers 2020

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.

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 2020 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).

When - schedule is definitely flexible, typically 10 weeks at 30-40 hours per week between mid June through early August, 2020. Work on the Data Nugget or other classroom materials can take place in fall and winter.

Compensation - $10,000 + $1500 for travel to a professional conference

Where - Lab and field work will take place at W.K. Kellogg Biological Station (KBS) in Hickory Corners, MI; independent work to include reading, writing and Data Nugget creation can take place off-site.

In addition, the RET teacher will present their research results in the KBS K-12 Summer Institute (last week of June annually) and at a state or national conference (e.g., the Michigan Science Teachers' Association conference). KBS has strong connections to local science teachers via programs such as the KBS K-12 Partnership and hosts several RETs each summer.

Deliverables: the educator will create 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. They are freely available to K-12 teachers at http://datanuggets.org to supplement their science curriculum. Each nugget addresses a scientific question and includes data, background information, student graphing activities, and a grading rubric. They are flexible and have been used across grade levels. Data nuggets were developed at Michigan State University (MSU) as part of the National Science Foundation GK-12 and BEACON programs and are actively supported by the KBS LTER program, which hosts the website and provides templates for designing the nuggets. 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.

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 ground water 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 2020 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.

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