Mentored Undergraduate Summer Experience
Summer 2021

Name:
Email:
Title:
Tenure Statue:
Years at TCNJ:
Department: Biology

Project Title: CYP72A9 regulates the growth/defense tradeoff in Arabidopsis plants experiencing abiotic stress

Student collaborators:

Approvals: IACUC and IRB approval is not needed.

Most recent Award:

Project and Learning Plan

I) Intellectual Merit

My work on the chemical nature of plant stress responses relates to the broad question of global food security. External factors influencing plant success include light, temperature, water availability, and nutrient supply as well as attack from herbivore, bacterial and fungal pests. Stress from any one, or a combination, of these factors can decrease the growth and reproductive potential of the plant. A genetic understanding of plant-environment interactions helps plant breeders select the most beneficial crop varieties. I have made progress in identifying the role of several enzymes important for producing defensive chemicals. Enzymes are the proteins that all living organisms use to facilitate biochemical reactions. Most enzymes are encoded in the genes (DNA) of the organism and do not get "turned on" until the organism needs a particular chemical. This regulation of "gene expression" allows a balance between defense responses and using resources for normal growth. Defense chemicals are often made at the expense of nutrients needed for growth.

The enzymes I study are called cytochrome P450s (CYPs), which are involved in biochemical pathways in all organisms. I have historically used a small model plant to study a subset of the CYPs that appear to be important in all flowering plants, even though their biochemical function is largely unknown. I have expanded my work to include an important food plant, corn. I use of a combination of genetics and biochemistry to address two questions:

- Under what stress condition is each enzyme most needed by the plant?
- What is the specific chemical process that each enzyme facilitates?

My work at TCNJ includes both a small model plant, *Arabidopsis thaliana,* and an economically important plant, corn. All the genes in Arabidopsis and corn have been sequenced, which is important for identifying the connection between DNA and traits. I can also isolate mutations in those genes through a variety of techniques. This helps me determine the contribution of individual genes to plant stress responses in both plants.

Prior students helped me isolate several useful Arabidopsis and corn mutants from the stock I generated on sabbatical and recent students have been testing the mutants. Each student takes responsibility for one or two of the CYP72A genes so that they can study what is known about the normal gene expression to develop experiments for comparing the mutant and normal plants. The difference in plant stress responses helps explain the normal function of each CYP72A enzyme, and the enzymes appear to play slightly different roles in corn and Arabidopsis. I recently got funding from the US Dept. of Agriculture for the corn project. I can support a student with that funding and would like one MUSE student dedicated to the Arabidopsis project.

The mutant plants allow us to ask the plant what chemical pathways change when one of the CYPs is missing. In the past two years, we have performed plant stress experiments on a variety of mutants and found that the plants show little physical change under single stresses. We have performed chemical analysis of the mutant and normal plants to show that there are significant differences in the metabolites, supporting our hypothesis that the CYP is required. We are currently studying the literature to determine which combination of stresses makes the most sense for further stress experiments in each mutant, such as cold and bacterial infection.

We made some important progress on the project in the summer of 2019, but did not have enough funding in the fall to send the samples to Cornell for biochemical analysis. Then the pandemic hit and we ended up with lots of samples sitting in the freezer. We were able to conclude that combinations of salt stress and drought prevent the mutant plants from responding appropriately to caterpillar attack. Those results suggest that the genes we are studying balance the metabolism needed for plants to appropriately respond to multiple stresses.

Furthermore, another research lab published an important finding on one of the Arabidopsis CYPs at the end of 2019. They found that this enzyme inactivates a growth hormone in the seed. That study did not explore the connection between stress and inactivation of growth, which is what we are studying. Our experiments should be an appropriate follow up to the work that was recently published to show the mechanism of the growth/defense tradeoff during stress.

The scholarly outcome of this project will be publication in a scientific journal and presentation at a national conference. We need to collect a substantial body of evidence to connect each enzyme to a chemical function, so conferences allow me to get feedback from my colleagues until I have enough data for publication. MUSE will allow me to engage a student in polishing the final data sets that are needed to publish the Arabidopsis work, which is more than I can collect alone.

The eight weeks in the summer is important for doing multi-day experiments that are difficult during the academic year. We will plant seeds in May so that the plants are ready and at different growth stages when the student starts in June. I am training ____ this semester in important techniques that a graduating student helped me design during the remote semester. We will test all of the techniques this semester to prepare for robust replications in the summer.

II) Role of the Student and Mentor

This project will require _____ to work very closely with me in designing, performing, and analyzing the data from each procedure. I will be in the lab directly teaching and helping her become more independent. ______ studied the literature extensively during the remote semester and is analyzing data that we are producing in all of the trials this semester. My mentoring philosophy is based on the idea that my students are respected as my colleagues, yet I make a big effort to treat them as individual learners that need different kinds of support. I expect each student to read scientific papers and help develop our procedures. I help them understand the papers within the context of their coursework. Our progress is slowed by the "teaching moments" required to help the student understand, but those moments are crucial to the student's development.

For this MUSE project, ______ will gain experience performing plant environmental stress experiments that she has not yet performed. More importantly, she will hone critical thinking and analysis skills that will help with advance degree programs after leaving TCNJ. This type of deep scientific engagement, where the student is the scientist, cannot be found in the classroom with limited one-on-one mentoring from the professor. Finally, the community involvement of the MUSE program is an excellent opportunity for _____ to learn how to explain her work.

III) Broader Impacts

Participation in the MUSE program is very important for my career goals and for encouraging the intellectual development of my students. This project is key to moving my research program toward publication. The pandemic stalled my research productivity significantly, because I need to be in the lab to perform experiments required for publication. If we are not able to both be in person this summer, I could still use ______'s help in analyzing the results from pictures that I collect along the way. We did not have the experiments ready last summer, and ____ has had the last four months to study the literature to prepare for understanding the work.

An important aspect of working in my lab is learning how to be part of a research team. It is very important that my students establish a strong support structure that keeps them from feeling isolated in their science interests. ____ has learned from the students who are graduating this year, even though we were remote. Having ____ work alongside me over the summer will make her the student expert on the Arabidopsis project. She will then become a leader in mentoring the other students in the lab throughout the following year. Working full time on the project will help her develop independence and confidence in her scientific thinking.