METER
ENVIRONMENT

DO SOIL MICROBES INFLUENCE PLANT RESPONSE TO HEAT WAVES?

Rachel Rubin, PhD candidate at Northern Arizona University, is interested in the intersection of extreme climate events and disturbance, which together have a much greater impact on plant communities. She and her team at Northern Arizona University are investigating the role soil microbes play in plant response to heat waves, including associated impacts to microbial-available and plant-available water. Because heat waves threaten plant productivity, they present a growing challenge for agriculture, rangeland management, and restoration.

CAN SOIL MICROBES INCREASE HEAT RESISTANCE?

Many plants maintain mutualistic associations with a diverse microbiome found within the rhizosphere, the region of soil that directly surrounds plant roots. These "plant growth-promoting rhizobacteria" and arbuscular mycorrhizal fungi provision limiting resources including water, phosphorus and nitrogen in exchange for photosynthetically derived sugars. However, we understand very little about whether extreme events can disrupt these interactions.

Rachel and her team exposed rhizosphere communities to heat stress and evaluated the performance of native grasses both in the greenhouse, and transplanted under an artificial heat wave. They hypothesized that locally-sourced inoculum (a sample of local soil containing the right microbes) or even heat-primed inoculum would help alleviate water stress and improve survival of native grasses.

THE EXPERIMENTS

Rubin started in the greenhouse by planting Blue Grama (Bouteloua gracilis, C4 grass) and Arizona Fescue (Festuca arizonica, C3 grass) and assessed their responsiveness to locally collected soil inoculum that had either been left intact, pre-heated or sterilized (Fig. 1). Rubin says, "We expected that our plants would benefit the most from having intact soil microbe communities. But, we were surprised to find very large differences between plant species. Blue Grama performed the best with intact inoculum, whereas Arizona Fescue performed better with pre-heated or sterilized soil". This could mean that Blue Grama is more dependent on its microbiome, whereas Arizona Fescue engineers a rhizosphere that contains more parasitic microbes rather than mutualistic microbes. Rachel says that understanding this relationship is important for tailoring plant restoration projects to local conditions. Plants that exhibit high levels of mutualisms with their rhizosphere might require an extra inoculum "boost" in order to successfully establish in highly degraded soil, whereas we should not bother to inoculate plants that tend to harbor parasites within their rhizosphere.

After the team studied these responses, they planted the grasses into a degraded section of a grassland and installed an array of 1000-Watt ceramic infrared lamps mounted on steel frames (Fig. 2) to address whether inoculation influenced plant performance and survival. With help from a savvy undergraduate electrical engineering major (Rebecca Valencia), Rubin simulated a two-week heat wave while monitoring soil temperature and soil moisture using METER water content and water potential sensors, and METER data loggers. She also measured plant performance (height, leaf number and chlorophyll content) before, during, and after the event. Control plots had aluminum "dummy lamps" to account for shading.

METER ZL6 data logger

SOIL MICROBES

Data obtained from soil sensors helped Rachel to measure heating treatment effects as well as rule out a potential cause for plant mortality: soil moisture. “Soil temperature was on average 10 degrees hotter in heated plots than control plots, but water potential and soil water content were completely unaffected by heating. This tells us that the grasses died from reasons other than water stress– perhaps a top-kill effect.” Although growing concern over heat waves in agriculture is centered around accompanying droughts, this experiment demonstrates that heating can produce negative effects on some species even when water is in plentiful supply.

TEROS 21 water potential sensor

CHALLENGES

Rachel says the experiment was not without its difficulties. After devoting weeks towards custom wiring the electrical array, the team had to splice heat-resistant romex wire leading from the lamps to the dimmer switches, because the wires inside the lamp fixtures kept melting. Also, automation was not possible with this system. She explains, “We were out there multiple times a day, checking the treatment, making sure the lamps were still on, and repairing lamps with our multi-tools. We used an infrared camera and an infrared thermometer in the field, so we could constantly see how the heating footprint was being applied to keep it consistent across all the plots.”

SOME GRASS WAS HEAT RESISTANT

Rachel says her biggest finding was that all of the C4 grasses survived the field heat wave, whereas only a third of the Arizona Fescue plants survived. She adds that the initially strong inoculum effects in the greenhouse diminished after outplanting, with no differences between intact, heat-primed inoculum or sterilized inoculum for either plant species in the field. "It may be related to inoculum fatigue," she explains, "the microbes in the intact treatment may have become exhausted by the time the plants were placed in the field, or maybe they became replaced, consumed, or outcompeted by other microbes within the field site". Rachel emphasizes that it's important to conduct more field experiments on plant-microbe interactions. She says, "Field experiments can be more difficult than greenhouse studies, because less is under our control, but we need to embrace this complexity. In practice, inoculants will have to contend with whatever is already present in the field. It's an exciting time to be in microbial ecology because we are just starting to address how microbes influence each other in real soil communities."

WHAT'S IN STORE?

Now that the team has collected data from the greenhouse and from the heat wave itself, they have started looking at mycorrhizal colonization of plant roots, as well as sequencing of bacterial and archaeal communities from the greenhouse study. Rachel says, "It's quite an endeavor to link 'ruler science' plant restoration to bacterial communities at the cellular level. I'm curious to see if heat waves simply reduce all taxa equally or if there is a re-sorting of the community, favoring genera or species that are really good at handling harsh conditions."