The Twin Ecosystems Project: A New Capability for Field and Laboratory Ecosystems Coupled by Sensor Networks and Autonomous Controls

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Project Goals: This project will develop 'twin' lab and field ecosystems to create a new capability that scales-down field observations inside fabricated ecosystems to uncover plant-microbial system responses to drought. The 'twins' will be integrated using sensor networks and interrogated through the development and application of novel in situ sensors, imaging, Omics analysis, and autonomous controls.

Discovering the fundamental biology that regulates ecosystem responses to changing climate is vital for predicting and managing ecosystem outcomes. To accurately identify biological drivers of ecosystem responses, technical approaches are needed to scale-down field observations to determine causal mechanisms. The goal of the TWIN ecosystem project ('TWINS') is to pilot laboratory and field 'twin' ecosystems that use sensors and autonomous controls to test the hypothesis that *compositional changes in root exudates during drought stress select for beneficial rhizosphere microbes.* The field 'twin' will define climate conditions and hyperspectral signatures of drought stress enabling the lab 'twin' to characterize the composition, localization, and dynamics of microbes and exudates. As such, the lab 'twin' will also provide powerful environmental controls and measurements which are not possible in the field. More specifically, TWINS is investigating molecular interactions in the rhizosphere to gain insights into the types of rhizosphere microbial communities that tall wheatgrass (*Thinopyrum ponticum*) exudates select in response to drought. Tall wheatgrass is a widely distributed species adapted to dry northern latitudes that is known to develop soil "resource islands" or "hot spots" that may impose heterogeneous spatial distribution of important plant exudates impacting the soil microbiome. These effects on the soil microbiome may be more prominent in response to drought when plants may differentially allocate photosynthates to roots.

To investigate microbiome selection and the formation of hot spots of microbial activity by wheatgrass we will integrate existing soil and environmental sensor technology at the laboratory (EcoFABs and EcoPOD) and the field irrigation trial of the PNNL soil SFA. Integrated technologies include multispectral imaging for the measurement of above-ground plant response, minirhizotrons for root imaging, and novel microbe-based biosensors for surveying below-ground microbial activity.

We have successfully excavated and relocated soil monoliths containing whole tall wheatgrass plants from PNNL's field site at Washington State University to the Berkeley Lab for incubation in the EcoPOD. Minirhizotrons were installed to enable imaging of the root system within the EcoPOD and the plants incubated under controlled conditions of photosynthetically available radiation (PAR), humidity, and temperature (Fig. 1). Hyperspectral cameras are being added into the EcoPOD to analyze plant responses to environmental manipulations, such as drought and changes in temperature. Next, and as part of the optimization of environmental sensors (PAR, T, atmospheric and soil humidity) we will simulate normal and drought conditions (50% vs 20% soil WHC) to analyze the differential recruitment and microbial network formation in the rhizosphere of the tall wheatgrass plants.

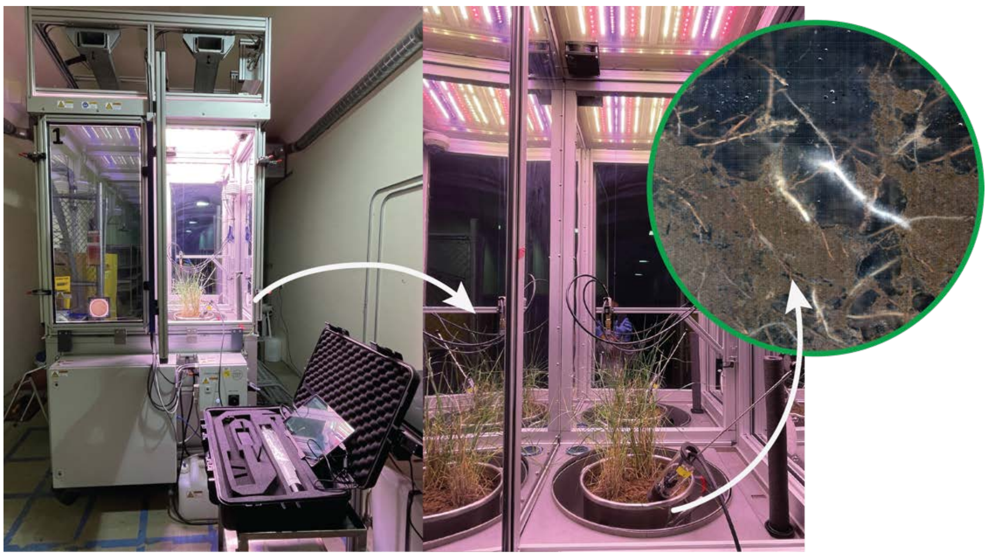

Fig. 1. Tall wheatgrass monoliths were excavated and relocated to the Berkeley Lab for incubation in the EcoPOD. The image shows the EcoPOD housing the plants with connected minirhizotrons. The upper inset image shows an image of roots photographed with the minirhizotron camera.

Funding Statement: This research is supported by the U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research, Genomic Science Program under contract number DE-AC02-05CH11231. Work at PNNL is under FWP 78814. A portion of this work was performed in the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), a national scientific user facility sponsored by Office of Biological and Environmental Research and located at PNNL. PNNL is a multi-program national laboratory operated by Battelle for the DOE under Contract DE-AC05-76RLO 1830.