SPACE GRANT 2023 SUMMER FELLOWSHIP
FINAL REPORT

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BACKGROUND

Permafrost-affected regions contain over 33% of global soil carbon stocks and are warming almost four times faster than the global average. There is serious concern that permafrost thaw will continue to result in significant greenhouse gas emissions through increased decomposition of soil organic matter (SOM). Permafrost thaw alters the soil environment by introducing nutrients and energy that were previously unavailable to microbes and plants, increasing microbial metabolism, as well as "awakening" previously dormant microbial communities.

Warming global temperatures are accelerating permafrost thaw and altering landscapes, displacing tussock-forming cotton grass with woody shrubs in a process known as shrubification. Tussocks and shrubs exhibit differences in their life history strategies, which influence belowground carbon dynamics and ecosystem function. For example, differences in root phenology, preference of soil horizon, mineralogical interactions, and mycorrhizal associations shape distinct root-associated, or rhizosphere, communities (Figure 1). As plant roots travel deeper in the soil profile following thaw, rhizosphere and permafrost microbial communities collide forming distinctly new communities. Understanding how these new communities will influence the formation and decomposition of SOM represents a knowledge gap that is critical to better understanding carbon fluxes from thawed permafrost systems.

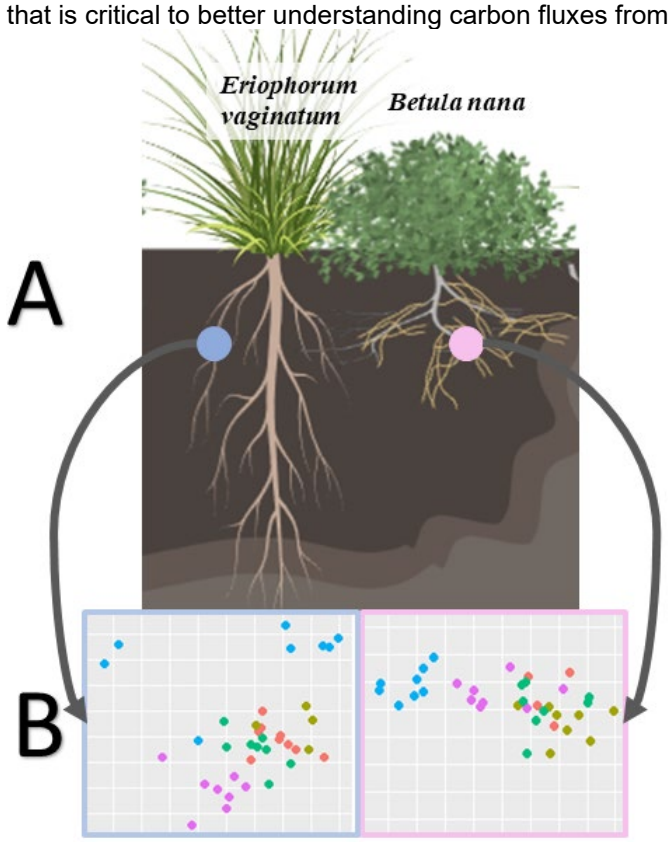

Figure 1. A) Comparison of aboveground and root growth patterns between *E. vaginatum* and *B. nana*. Yellow represents mycorrhizal association with B. nana roots. B) Differences in rhizosphere fungal community structures, as shown by non-metric multidimensional scaling 3. Each point is a different rhizosphere community (sample), with colors representing sites on the North Slope of AK.

METHODS

This semester I was able to conduct the laboratory portion of my qSIP experiment. The primary goal was to examine how distinct microbial communities from permafrost and rhizosphere coalesce and influence SOM dynamics. To accomplish this, I inoculated rhizosphere communities from the shrub *B. nana*, the sedge *E. vaginatum,* as well as a no-plant control, to native permafrost. To select for microbes associated with degrading root exudates or SOM, I added either an exudate cocktail (primed) or water (control) to the permafrost or permafrost-

rhizosphere samples daily. The samples were incubated at 4°C for 54 days, and CO_2 and CH_4 production were measured throughout the incubation at various time points (Figure 2). To identify specific taxa associated with SOM or exudate degradation from these microbial communities, I performed quantitative stable isotope probing (qSIP). To this end, I added isotopically enriched water (^{18}O-H_2O) or exudates (^{13}C glucose, oxalic acid, alanine) during the final 8 days of the incubation.

The next steps will be to extract and fractionate DNA from our samples at Lawrence Livermore National Laboratory (LLNL). Utilizing their high throughput qSIP pipeline, I will identify taxon-specific microbial traits, such as growth and exudate incorporation rates from different rhizosphere and permafrost microbial communities. From this I will determine how specific taxa influence the formation and decomposition of SOM in rhizosphere and permafrost soils. The findings of this experiment will then be used to help paramaterize the Microbial-MIneral Carbon Stabilization model (MIMICS), which will be used to predict SOM dynamics in the tundra.

RESULTS

Initial respiration results suggest differences in microbial community structure and biogeochemical function between the rhizosphere-inoculated permafost and native permafrost communities, as well as diverging functions for primed versus control groups (Figure 2). Further analysis from qSIP will allow us to identify guilds of microbes associated with degrading root exudates or SOM, as well as their growth rates in different communities and environmental conditions.

PRESENTATIONS AND OUTREACH

The work conducted this semester will be presented at the International Conference on Permafrost (ICOP) in June 2024 in Yukon, Canada. This presentation will feature the respiration readings I conducted in the Fall of 2023, as well as the work I will be conducting at LLNL in the spring of 2024.

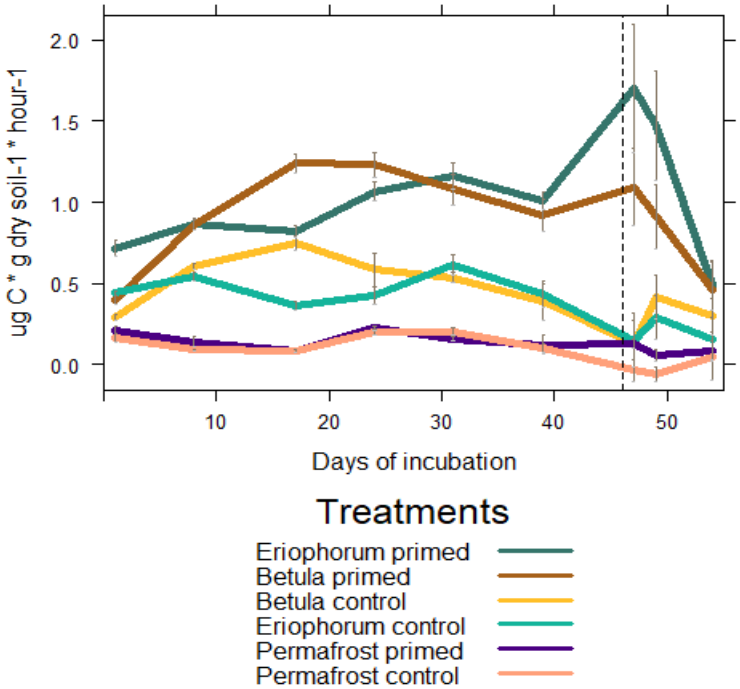

Figure 2. Respiration rates separated by the inoculant/ priming treatment combination where primed groups received 5 µL of exudate cocktail (5.7 µg/µL) daily while control groups received 5 µL of water. The dashed line signifies the point which isotopes were added and all treatments received 180 µL amount of exudate cocktail (5.7 µg/µL) or water.