Comparison and Characterization of the Soil Microbiomes of *Delairea odorata* and California Native Plants

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Abstract

There is considerable evidence in the literature that rhizospheric microbes affect plant health, yet, we know very little about the impact of invasive plants on soil microbiomes. During the 1950s, *Delairea odorata* (Cape Ivy), a perennial vine from South Africa, was brought to California. Its population exponentially increased and significantly decreased native species richness, making it a serious ecological threat. Cape Ivy's impenetrable mats block light from reaching the native plants. The goal of this research is to investigate the soil microbiome of Cape Ivy to explain its high adaptability to a foreign environment, especially during drought. Through community level physiological profiling using Biolog Ecoplates, diversity of organisms in Cape Ivy-soil was compared to soil with native vegetation. Both soils contain microorganisms that use seven carbon sources, However, the functional diversity in the Cape Ivy-soil (83.9 % ± 0.1) is significantly ($p<0.05$) greater than the native plant-soil (29.0 % ± 0.1). The dense growth of Cape Ivy increases soil moisture by 5.4% compared to native plant-soil. Soil respiration, algae populations, and mycorrhizal association were measured to determine soil productivity and presence of symbiotic relationships. Results suggest Cape Ivy changes soil microbiota, which in return, aids its survival. This research may provide new targets to develop effective eradication measures.

Aim

To compare the soil microbiota of Cape Ivy to the soil microbiota of native plants.

Background

- Cape Ivy (Asteraceae: *Delairea odorata*) is one of the most invasive, plant species in California. It needs human intervention and management, otherwise it will reduce the biodiversity of an area (4).
- Cape Ivy expanded 87% between 1987 and 1997 in the Golden Gate National Recreation Area (GGNRA) and is continuing to increase (3).
- Plots invaded by Cape Ivy contain 36% fewer native plant species and 37% fewer non-native taxa. (1).
- Beneficial rhizospheric microbes can alter plant morphology, enhance plant growth, and increase soil mineral content (5).
- Plants and rhizosphere microbes mutually interact through rhizodeposition, production of regulatory compounds, decomposition, and nutrient cycling (5, 7).
- Plant–soil-microbe interactions play a large role in determining plant community structure and may strengthen an invasive's ability through complex feedback loops (2, 7).
- There are very few studies investigating the effects of invasive plants on the soil microbiome and the relationship of the soil microbiome to plant fitness.

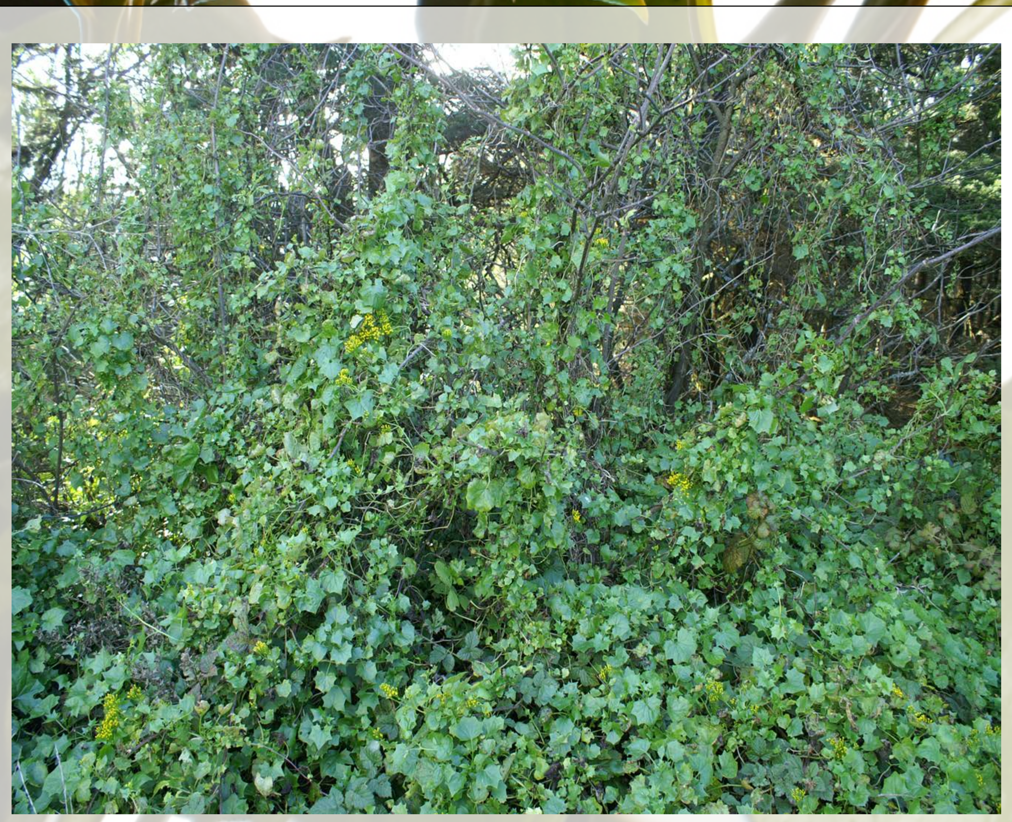

Figure 1. Cape Ivy in the Golden Gate National Recreation Area (GGNRA) forms large monocultures that block light from other plants.

Methods

- **Soil samples** were collected at a depth of 30.5 cm.
  - Test soil samples were taken from a Cape Ivy monoculture in the GGNRA in San Bruno, CA (**Figure 1**).
  - Control samples were taken in GGNRA in San Bruno, in a location without Cape Ivy. The predominate plants were *Baccharis pillaris* and *Eriophyllum staechadifolium*.
- **Soil moisture.** Soil samples were weighed before and after drying at 120°C for 18 hr.
- **Soil pH.** The pH of soil suspensions (20 g soil in 40 mL water) was measured using a calibrated pH meter.
- **Community-level physiological profiling (CLPP).** Soil was diluted in phosphate buffered saline. 100 µL of the 10^{-2} dilution was transferred to Biolog Ecoplates containing 31 different carbon sources. After three days incubation at 25°C, absorbance of each well was measured at 590 nm.
  - The average absorbance in the three control (water) wells was subtracted from the average absorbance of each substrate well, with the difference being the net change.
- **Soil Algae Population**. 10 g soil was diluted 10^{-1} to 10^{-6}. Five replicates of 5 mL Bristol's medium were inoculated with 1 mL of the respective dilution. Tubes were exposed to diffused light at 23°C for 8 weeks. Algae cells were counted microscopically to determine the most probable number (MPN).
- **Soil Respiration.** 100 g of soil was transferred to a closed container. CO_2 concentration was measured using a Vernier CO_2 sensor.
  - Respiration rates were measured in the presence and absence of light.
- **Mycorrhizal Association.** Roots were bleached using 10% KOH, H_2O_2 and 1% HCl. Roots were stained with acid fuchsin in lactic-acid glycerin. Presence of mycorrhizal vesicles and arbuscles were identified using light microscopy.

Results

- Cape-Ivy soil has more moisture (12.62%) than native-plant soil (7.19%) (**Table 1**).
- Cape-Ivy soil temperatures are lower (14.9°C) than native-plant soil (19.1°C).
- Functional diversity of the control soil is 29% with microbes using nine substrates, while the Cape-Ivy soil has 83.9% functional diversity with its microbes using 26 substrates.
- Cape-Ivy soil has a more diverse microbiota (**Figure 2**). Both soil samples used seven different carbon types, however the Cape-Ivy soil microbiome uses all carbon sources more efficiently.
- Cape-Ivy soil organisms had a 530% higher respiration rate in the presence of light compared to native plants' soil organisms (**Figure 3**).
- The algal population in Cape-Ivy soil was 83% higher than that of native-plant soil.
- Vesicles and arbuscles are present in Cape-Ivy roots denoting the presences of mycorrhizal association (**Figure 4**). Control-roots showed no signs of mycorrhizae.

Table 1. Soil comparisons. Average of two trials.

Soil	Soil Moisture, %	Temp, °C	pH	Microbial Functional Diversity, %	Algae Population (MPN/mL)
Cape Ivy	12.62	14.9	5.71	83.9	2.03×10^5
Native Plants	7.19	19.1	5.13	29.0	8.41×10^4

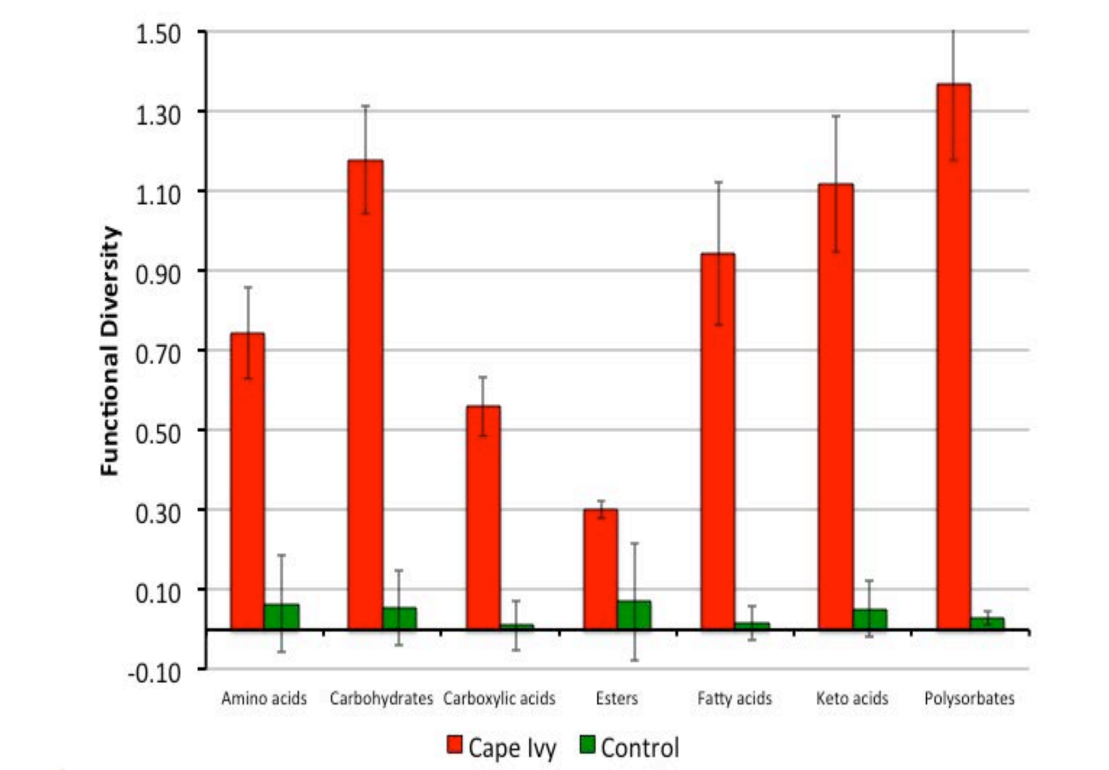

Figure 2. Cape-Ivy soil microbes used more different carbon sources than native-plant soil microbes. 31 carbon sources were tested. Data are averages of three trials. Error bars = 1 S.D.

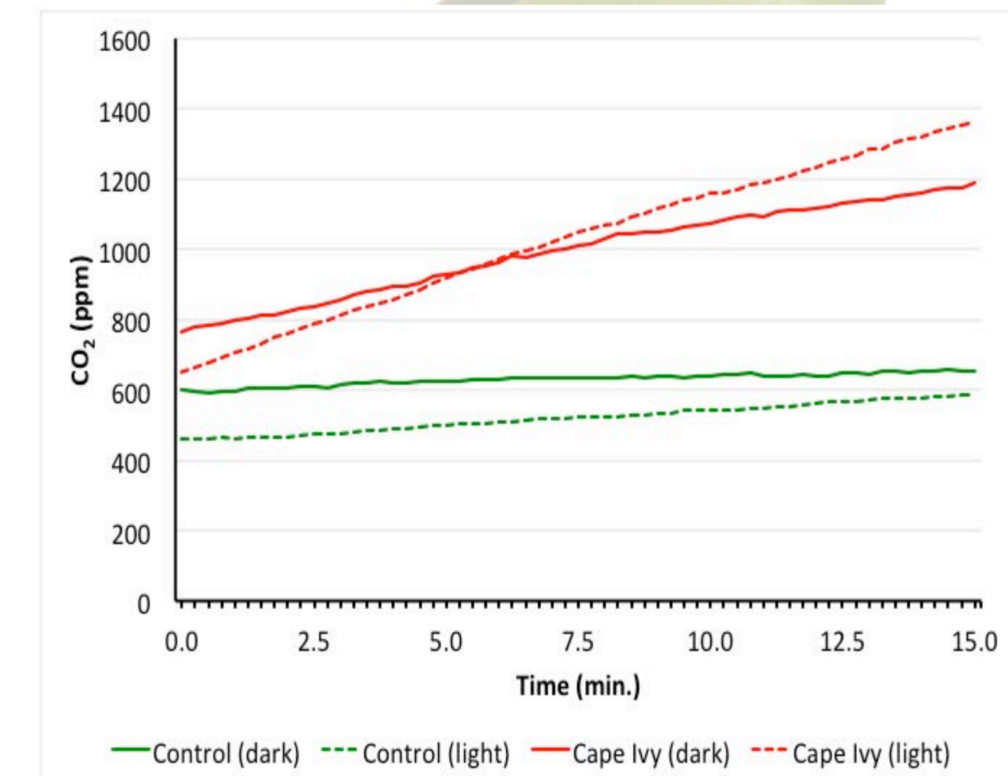

Figure 3. Soil respiration rates. The microbial respiration rate in Cape-Ivy soil was 780% and 530% greater than control soil in absence and presence of light respectively.

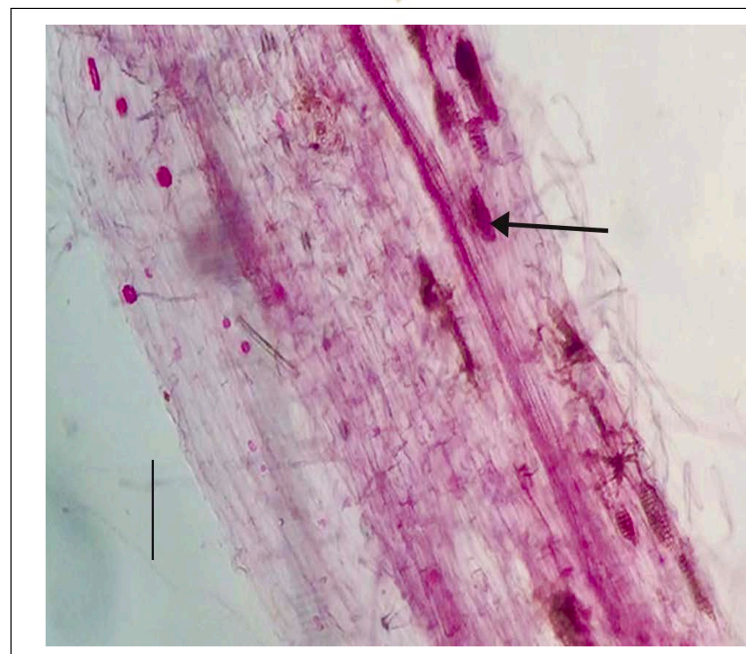

Figure 4. Arbuscular mycorrhiza (at arrow) in Cape Ivy root. Scale bar = 100 µm.

Discussion & Conclusion

- Cape-Ivy soil retains more moisture compared with the native-soil control, which may increase plant growth and organic matter in the soil by decreasing the temperature of the soil.
- The increased moisture increased microbial diversity, which in turn, may benefit Cape Ivy.
- Mycorrhizae may promote Cape-Ivy growth by regulating nutritional and hormonal balance, producing plant growth regulators, solubilizing nutrients, and inducing resistance against plant pathogens even under stress conditions like drought (6).
- The absence of the fungi in native plant roots makes the mycorrhizae–Cape Ivy symbiosis a potential eradication target.
- The significant differences between Cape-Ivy and native-soil microbiomes suggest that control through microbiome manipulation is possible.

Future Studies

- Further research is needed to identify not just the metabolic diversity, but also the taxa of bacteria present in the soil.
- Specific roles such as growth factors or nutrient absorption of the Cape-Ivy soil organisms need to be explored to identify whether a specific plant-microbe interaction is commensal, mutualistic, or parasitic.
- Relationships between Cape-Ivy symbionts and other invasive species can be explored.

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