Iron-reducing bacteria impact on iron uptake in plants

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Introduction:

Though iron is the fourth most abundant nutrient in soil, many plants still suffer from iron deficiency because iron is usually present in insoluble forms, ferric hydroxide, ferric oxide, and ferric phosphate. That said, ferric iron (Fe^{3+}) must be reduced to ferrous iron (Fe^{2+}) through redox reactions before it can become useful for plants. Iron solubility is dependent on soil factors, such as pH, calcium carbonate content, presence of organic matter, soil moisture, as well as non-soil factors, such as plant-microbial interactions, productions of phytosiderophores, root reductase activity, and agricultural methods. This nutrient is vital for plant nutrition because it is needed for enzyme structure, chlorophyll synthesis, and chloroplast function. Fe uptake in plants is also of major concern since crops suffer from iron-deficiency across the globe, particularly in semi-arid locations with alkaline or calcareous soils. It has been questioned if iron-reducing bacteria (IRB) can aid in the uptake of iron in crops. The goal of this research was to assess the impact that IRB have on Fe uptake in spinach plants and determine if different soil conditions affect the abundance and diversity of the bacteria present in the soil.

Methods:

To assess the impact that soil conditions have on the microbial community, four treatments were used.

1. Control Treatment – normal soil conditions
2. Bacteria Treatment – addition of wastewater
3. Organic Matter Treatment – addition of wastewater, woodchips, and sucrose
4. Barley Treatment – addition of wastewater and barley

16 samples were used to allow 4 replicates for each treatment. Treatments were added 2 weeks after seed germination. The wastewater was collected from 14 Mile Run Wastewater Treatment Plant and was inoculated with 8 g/L fumarate, 1.4 g/L acetic acid, and 5 g/L sodium bicarbonate and served as a source of IRB. Leaves were collected from each sample, dried, and weighed to prepare for digestion procedure. Acid digestions of the leaves were done in Teflon containers with 9 ml nitric acid 2 ml HCl and were filtered before being diluted to a known volume. To measure Fe concentrations in the digested leaves, the digested samples were run through the ICP-AES. eDNA analysis was also conducted on soil samples using Qiagen Dneasy Power Soil Pro Kit, and the soil samples were sent to Jonah Ventures lab for sequencing and identification.

Results:

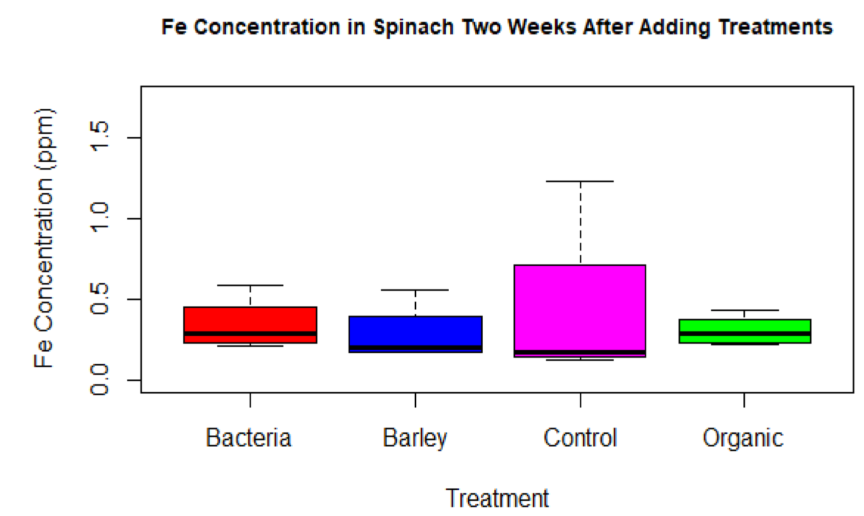

Figure 1:

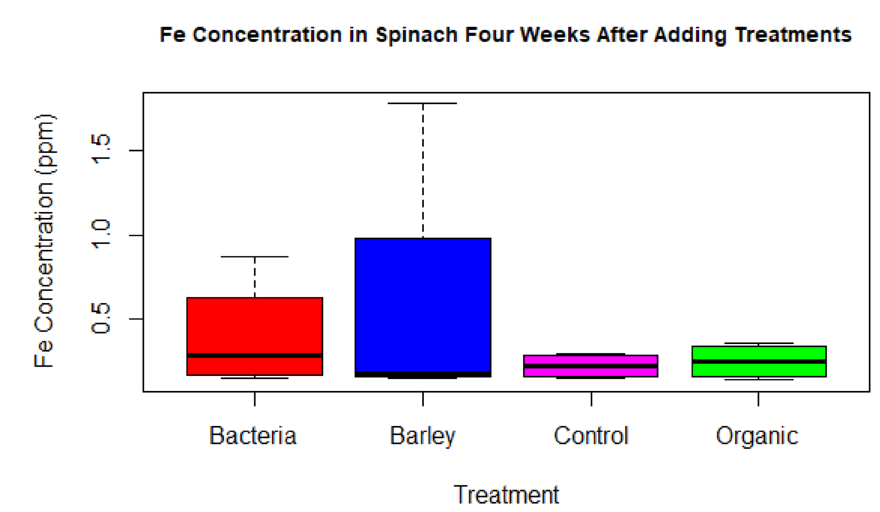

Figure 2:

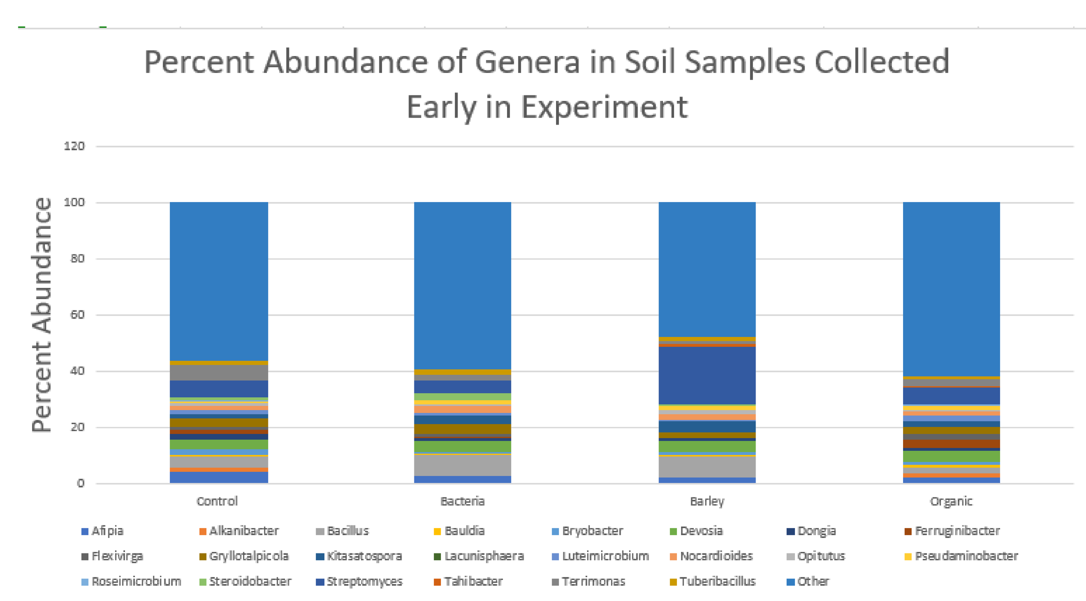

Figure 3:

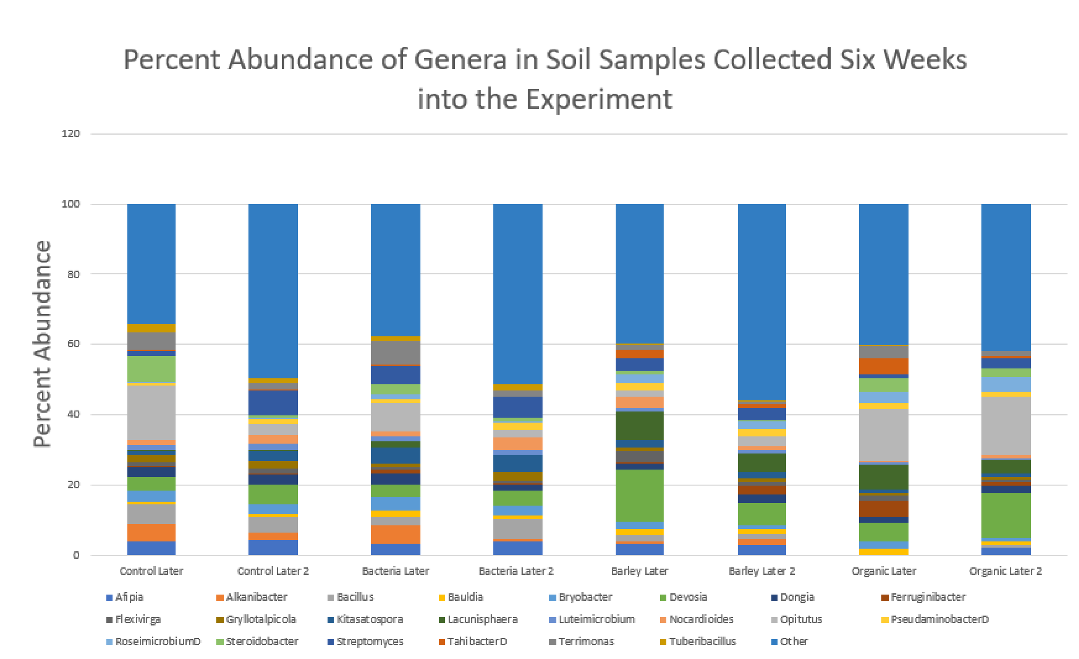

Figure 4:

- One-way ANOVA tests were run to determine the difference in Fe concentrations among treatment groups.
- No significant differences in Fe concentrations were found between any treatments.
- A genus with iron-reducing capabilities, *Bacillus*, was found in all treatments, including the Control.
- There was little variation in the genera present throughout treatments.

Discussion:

The results made clear that there were no significant differences in the Fe concentrations across treatment groups, but they also show that there was not a large variation in the abundance and diversity of IRB present. Similar research by Valencia-Cantero et al. (2007) studied the effect that IRB have on iron concentrations in plants. Results from the study found that plants grown in soil containing bacteria were larger and contained a 1.8 to 3.3-fold increase in iron uptake. The study by Valencia-Cantero et al. (2007) differed in design because the soil was autoclaved before the bacteria isolates were added into the soil. However, this study assessed the natural enhancement of bacteria into soil, therefore, iron-reducing bacteria was unintentionally present in the Control treatment. In addition, it is possible that iron was not a limiting nutrient in this reaction. Healthy spinach leaves contain Fe concentrations of 0.036 mg Fe/g, and the Fe concentrations measured in the samples were as high as 0.044 mg Fe/g. Consequently, the abundance of nutrients and diverse microbial community present in the soil could have contributed to the similarity of Fe concentrations measured across treatments.

Conclusion:

There are a vast variety of factors that can impact iron assimilation in plants and the effect that iron-reducing bacteria have on this process. Unfortunately, iron-deficiency is a major problem experienced by crops and people worldwide. Nearly fifty percent of all anemia cases result from iron-deficiency, making iron-rich crops vital for the health of many individuals. With that said, more research must be conducted to better understand the numerous factors impacting iron uptake in plants.

Sources:

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