The Effect of a Dominant Species on Iron Levels in Soil

A study by: Lili Fanua, Prabhnoor Kaur, and Emma Scherer

Abstract

Photosynthesis is a constant and crucial process for plant survival and growth. During the photosynthesis process, iron is consumed in order to turn light energy into chemical energy. However, the amount of iron consumption from the soil by a plant can depend on the rate at which that plant photosynthesizes. Consequently, it was proposed that the discrepancy between iron levels in sites 3 (N 39.35797; W 076.63836) and 4 (N 39.35733; W 076.63840) found in the E.S.S.R.E Biota Survey could be attributed to the hypothesis that the different dominant plant species and their respective photosynthesis process would impact the iron levels in soil. The dominant species studied in this investigation were rhododendron in Site 3 and spicebush and white grass in Site 4. 36 soil samples were taken in total using soil extractors 15 cm in length and 2.5 cm in diameter; 3 samples were taken from under each dominant species on the same day at the same time. In addition, leaves were taken from each of the respective plants from which soil was taken. On the same day and same time, each soil sample and leaf pair were extracted and tested for iron levels using the LaMotte model STH-14 test kit. The results showed that iron levels in the soil collected from under the rhododendron, spicebush, and white grass all stayed statistically consistent throughout the days of data collection, disproving the prediction of the inverse relationship between the iron levels in the soil and the iron levels in the plant. Therefore, no connection could be drawn between the species of plant and iron levels in the soil. However, it was found that the original discrepancy between iron levels in the E.S.S.R.E Sites 3 and 4 is still present. In addition, the iron level fluctuations did have statistical significance between subsequent days for spicebush and white grass. Consequently it was concluded that there were other environmental factors independent of the experiment affecting the photosynthesis process of a plant (corresponding with its iron uptake). Different environmental factors were considered; however, further research would include an experiment investigating the impact of the amount of sunlight on a plant's photosynthesis process.

Introduction

Photosynthesis is a crucial process for all plant life. Through it, plants use sunlight and several nutrients to synthesize food in order to grow and reproduce. One of the most significant of these nutrients is elemental iron, specifically, ferric iron (Fe^{+3}). This form of iron is used in the first stage of the photosynthesis process, photophosphorylation, to aid in the transfer of electrons to convert absorbed light energy into two chemical energy products: ATP and NADPH. One of the protein molecules that the electrons encounter in order to complete this process is the iron-sulfate protein, ferredoxin. (Jane Reece, 2011).

However, different species of plants undergo photosynthesis at different rates, which can result in varying amounts of Fe^{+3} being absorbed from the soil to meet an individual plants ferredoxin needs. Factors that can affect the rate of photosynthesis in a particular plant include leaf position, environmental heat, and levels of chlorophyll b. The position of a leaf on a tree affects its photosynthesis process, depending on the amount of sunlight it receives. As a leaf receives more sunlight, the rate at which the light energy is absorbed and converted into chemical energy increases (Steven R. Spilatro, 1998), creating a greater need for Fe^{+3} to build ferredoxin. Furthermore, because heat is needed for the biochemical reactions, air temperature affects the rate of photosynthesis, with a direct relationship between temperature and the rate of photosynthesis in a plant up to an optimal temperature, again impacting the amount of Fe^{+3} a given plant may need. Finally, the abundance of chlorophyll b (which absorbs more of the light spectrum than chlorophyll a) found in dark green leaves increases a plant's ability to capture light, resulting in a greater rate of photosynthesis (UCLA College of Life Sciences, 2011). Hence, plants with darker leaves in warm climates and bright sun microclimates are more likely to require additional Fe^{+3} to cope with the increase of photophosphorylation.

Because of its critical role in photosynthesis, any unusual variation in available Fe^{+3} in the soil can have a profound impact on the plant life in an ecosystem. Yet, as observed in the 2016 E.S.S.R.E Biota Survey Sites 3 (N 39.35797; W 076.63836) and 4 (N 39.35733; W 076.63840), the normal relationship between ferric iron levels and pH in the soil samples was not observed. Generally, the more acidic the soil, the more ferric iron should be present. However, in E.S.S.R.E Site 3, the soil had an average pH of 5.991, while the pH in E.S.S.R.E site 4 pH was 6.608 (E.S.S.R.E, 2016). Yet, the more acidic site had a lower ferric iron level (3.04 ppm) compared to the ferric iron level at the more alkaline site (24.2 ppm). Since the dominant species in each site is different (E.S.S.R.E 2016) and display color differences in their leaves indicative of the different quantities of chlorophyll b, we posited that perhaps the difference in the species of plants and their life cycles in the two sites might be contributing to the amount of ferric iron being absorbed in each location. For example, the low iron levels in Site 3 could be attributed to the dominant species present there, rhododendron. Rhododendron has the dark leaves indicative of chlorophyll b and should use more iron during its photosynthesis process compared to the lighter shade of the spicebush and white grass plants, the dominant plant species found in Site 4. Subsequently, we chose to study the dominant species of plant in Site 3 which was rhododendron, and in Site 4, which was spicebush and white grass. Because of the potentially different rates of photosynthesis in different plants, we hypothesized that the difference in each species of plant's structure is affecting the amount of iron uptake from the soil.

Methods

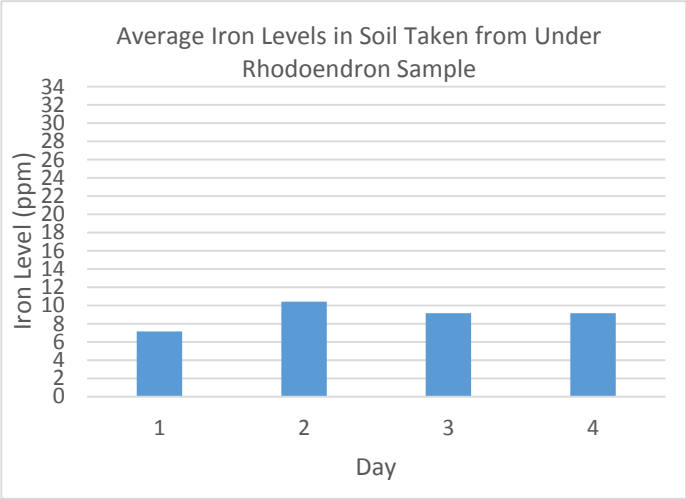
In the E.S.S.R.E. microclimates, 3 soil samples 2 cm in diameter and 15 cm deep were simultaneously collected under rhododendron plants *(Rhododendron ferrugineum)* in Site 3 (N 39.35797; W 076.63836) and under white grass *(Leersia virginica)* and spicebush plants *(Lindera benzoin)* in Site 4 (N 39.35733; W 076.63840). Each individual soil sample was taken from three different rhododendron plants in three different locations in Site 3, and a leaf sample was collected from the rhododendron plant rooted at each location where a soil sample was collected. The exact same process was followed on the

same day at the same time in Site 4 for spicebush (3 samples of soil and leaves) and white grass (3 samples of soil and leaves). Each leaf sample was stored with its respective soil sample.

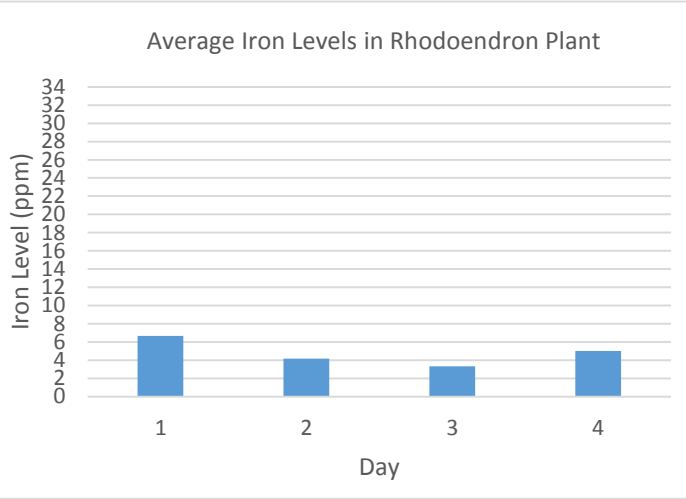
Each soil sample and its corresponding leaf sample were tested for iron (ppm) on the same day of collection using the LaMotte Model STH-14. Both collecting and chemical testing was repeated each morning for a total 4 more days in July 2016.

Results:

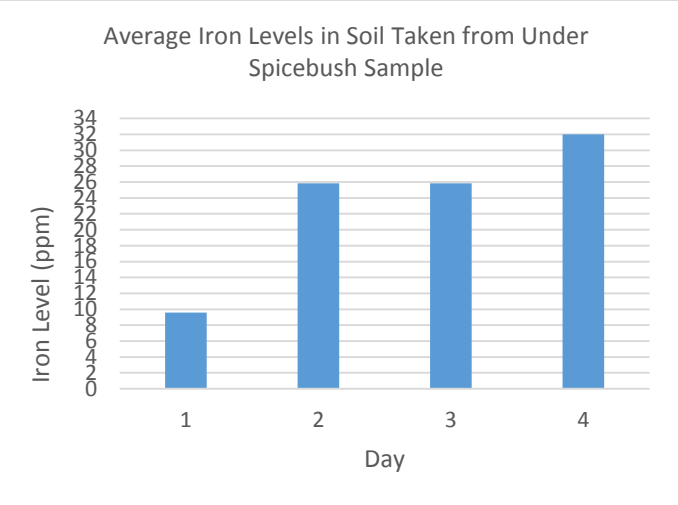
Graph 1:



Graph 2:



Graph 3:



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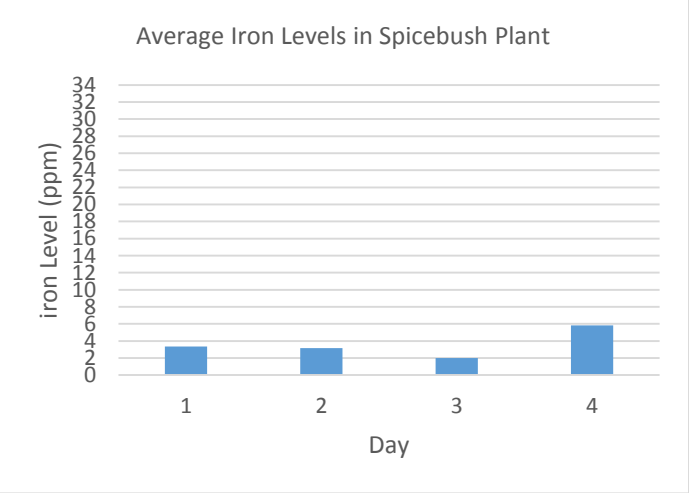
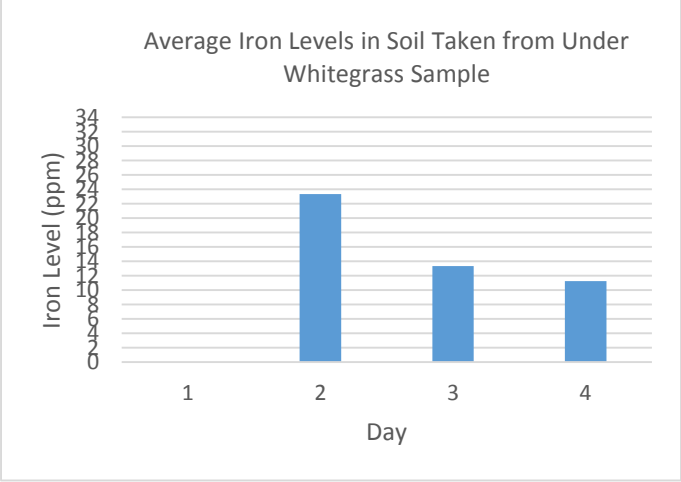


Graph 5:



Graph 6:

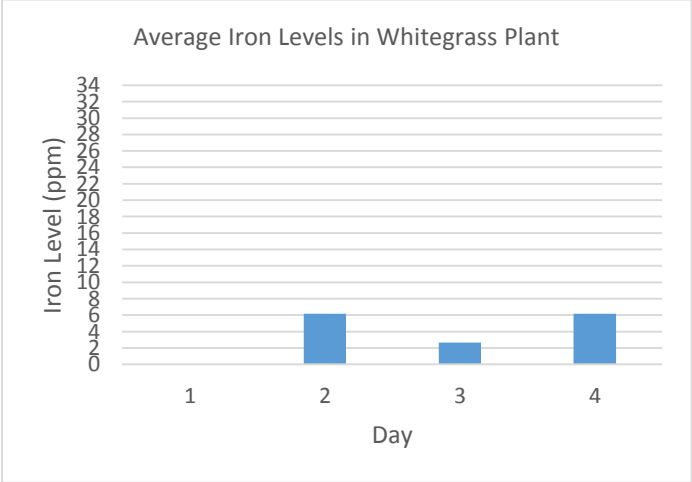


Table 1: T-test of Iron Levels in Soil and Plants between Different Species.

Plant Species Compared	P-value of soil	Mean 1	Mean 2	P- value of plant	Mean 1	Mean 2
Rhododendron(1) to Spicebush(2)	.05	8.98	21.94	.19	4.79	3.58
Rhododendron (1) to White Grass (2)	.11	8.98	15.94	.84	4.79	5

Table 2: T-test of Iron Levels in Rhododendron Soil and Plant between Different Days of Collection.

Days Compared	P-value of soil	P-value of plant
1-2	.38	.38
2-3	.72	.52
3-4	1	.39

Table 3: T-test of Iron Levels in Spicebush Soil and Plant between Different Days of Collection.

Days Compared	P-value of soil	P-value of plant
1-2	.47	.87
2-3	1	.16
3-4	.78	.02

Table 4: T-test of Iron Levels in White Grass Soil and Plant between Different Days of Collection.

Days Compared	P-value of soil	P-value of plant
2-3	.47	.08
3-4	.62	.08

Several factors independent of our actual experiment research could have contributed to the statistical status of our data. Primarily, the span of data collection only lasted for 4 days, limiting the ability to interpret the patterns. In addition, our small time period of data collection placed additional importance on each data point, and the missing data point for day 1 of white grass limited the amount of data that could be analyzed.

Discussion

When comparing the average iron levels found in the soil and plants sampled over a four day period, our hypothesis that the difference in the type of dominant species of plants present in Microclimates 3 and 4 was affecting the iron levels in the soil in these sites was not supported. As Graphs

1 and 2 show, there was no statistically significant difference in iron levels from one day to the next in the soil under the rhododendron, disproving our original supposition that the abundance of chlorophyll b would cause the rhododendron to absorb more of the light spectrum, thereby photosynthesizing faster—with the consequent result that the rhododendron would need to consume more iron from the soil (p_{soil}=0.38-1.0; p_{plant}= 0.38-0.52; see Table 2). Therefore, it cannot be concluded that the type of plant present in Microclimate 3 was having any direct impact on the iron levels in the soil there. Furthermore, as shown in graphs 3 and 5, the iron levels of the soil under the spicebush (p=0.47-1.0; see Table 3) and white grass (p= 0.47-0.62; see Table 4) located in Microclimate 4 also failed to show any statistically significant differences from one day to the next. Hence the lack of any statistical support undermines the original reasoning that led to our prediction that the different type of species were affecting iron levels in Microclimates 3 and 4.

In addition, Graphs 1, 2, 3, and 5 show that during the individual comparison between plants and their respective soils in this study, the original anomaly present during the 2016 ESSRE Biota Survey is still present. The survey had revealed that given the pH observed in these sites that the average levels of iron in Site 3 were uncharacteristically low (3.04 ppm), while Site 4 had unusually high iron levels (24.2 ppm) (ESSRE, 2016). If one compares the iron levels between the soil under the rhododendron plant (8.98 ppm) with the soil under the spicebush (21.94 ppm) (p= 0.05) and the soil under the rhododendron with the soil under the white grass (15.94 ppm) (p= 0.11), there is still statistically a significant difference between the two sites similar to that observed during the survey. Since the initial anomaly that catalyzed the current investigation is still present, this suggests that there are still factors that are contributing to the disparity of iron levels in these two microclimates other than the differences in the plant species.

Interestingly, Graph 4 and Graph 6 illustrate statistically significant fluctuations of iron levels in the spicebush and white grass leaves over the course of three consecutive days (July 21, 2016- July 23, 2016). From July 21st to July 22nd, there was a significant decrease in iron levels of the spicebush plants (p=0.16) and then a significant increase from July 22nd to July 23rd (p= 0.02). Furthermore, this exact same variation was present in white grass plants (p=.08 from July 21 to July 22nd; p=0.08 from July 22nd to July 23rd). Given this statistical significance, further research was conducted to investigate the possibility of other environmental factors, independent of our experiment that could have affected the photosynthesis rates in these plants, including possible variations in the sunlight, temperature, precipitation (Steven R. Spilatro) that occurred during the dates of our investigation. We determined that on July 21st and July 22nd the ablative cover increased from 45% to 75% and then decreased from 75% to 50% between July 22nd and July 23rd (National Oceanic and Atmospheric Association, 2016). Given the inverse relationship between the ablative cover and the photosynthesis rates in the plants (and the corresponding level of need for iron), we can postulate that the varying amount of sunlight over the days of our data collection had an impact on the iron levels in the plant because of the consequent effect on the rate of photosynthesis.

In addition, we determined when researching the possible impact of precipitation on the experiment that the miniscule amount of rain on July 21st (0.05 cm) as well as the total absence of precipitation on July 22nd and July 23rd led us to eliminate the possibility that precipitation was influencing the photosynthesis rates of the plants. However, temperature fluctuations during the data collection period did follow the direct relationship expected between temperature and photosynthesis rates (decreasing 5.55 ºC from July 21st to July 22nd, and then increasing by 4.44 ºC from July 22nd to July 23rd). Hence, the changes in this environmental factor could also be influencing photosynthesis rates. But, the tiny differences in the temperatures compared to the significant changes of ablative cover lead us to conclude that light more likely had a larger impact on the photosynthesis rates of the plants.

Therefore, in the future, we would conduct an experiment manipulating the amount of sunlight provided to the plants in Microclimates 3 & 4. For example, large trees heavily shade the rhododendron in Site 3; while Site 4 is completely exposed to sunlight. Hence, in order to observe the impact of different amounts of light on the photosynthesis process of the plants in these locations (and the potentially consequent impact on their iron uptake), tents could be used to manipulate artificially the amount of sunlight reaching the ground

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