The Effect of the Amount of Sunlight on Iron and Manganese

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Abstract

Both iron and manganese make significant contributions to essential synthetic processes in plants, most importantly photosynthesis. However, while plants use iron almost exclusively to produce carbohydrates in the carbon fixation process, manganese helps plants to both produce and break down carbohydrates. Given the potentially antagonistic roles that iron and manganese play in photosynthetic and metabolic tasks of plants, we inferred that sunlight could be a potential factor that influences the quantities of these minerals in the soil. In this study, we tested for the levels of iron and manganese in plants and their soils in different locations with varying amounts of sun exposure. We predicted that plants with higher percentages of sun exposure would have higher levels of iron than manganese in the plant tissue and that the soil directly underneath the plant would contain higher levels of manganese than iron. Likewise, we predicted that plants with lower percentages of sun exposure would have higher levels of manganese than iron in the plant tissue and that the soil directly underneath the plant would contain higher levels of iron than manganese. A densitometer was used to determine 5 locations with varying canopy cover (100%, 75%, 50%, 25%, and 0%), and each day for 6 days, one orange jewelweed plant was uprooted and collected from each location. Then, a 15 cm deep and 2.5 cm diameter soil core sample was extracted from the soil directly underneath the uprooted plant. Both plant tissue and soil were tested for levels of ferric iron (ppm) and manganese (ppm). The results from our experiment supported part of our hypothesis by showing that, as the percentage of sun exposure increased, the amount of manganese in the soil increased while the amount of manganese in the plant tissue decreased. Contrary to our hypothesis, however, our results show low statistical differences between varying amounts of sun exposure and the iron levels in the soil and the plants. We did observe a significant increase in iron levels in the plants between the location with 100% sun exposure and the sites with lower percentages of sun exposure, and for further investigation, we would repeat our experiment in a more controlled environment by growing the plant specimens indoors in order to control for any outside influences

Introduction

Both iron (Fe) and manganese (Mn) are essential metals found in the soil. Of the two, iron levels vary greatly depending on the soil composition and other sources of the mineral present in the surrounding environment, and the two most common forms of iron are ferrous (Fe^{+2}) and ferric (Fe^{+3}). The former, Fe^{+2}, is more soluble and therefore more bioavailable than its counterpart, Fe^{+3}. Ferrous iron is also more prevalent in acidic soil and reduced environments, such as lowland and waterlogged sites. Available manganese, too, is higher in more acidic soils, but like iron, the overall moisture levels in soils ultimately determine what forms of manganese are available or unavailable to the plant life that requires them (Spectrum Analytic, 2010).

Both iron and manganese are essential to soils because without them, plants would be incapable of photosynthesis and other synthetic processes. The efficiency of photosynthesis depends directly on iron nutrition in the soil because iron helps plants to form chlorophyll, the essential pigment plants use to produce their food through the carbon fixation process in which plants convert inorganic compounds into carbohydrates(Newton, 1975; Biology Online, 2005). In fact, both the rate of photosynthesis and nitrate uptake correlates with iron concentration (Reuler and Ades, 1887), and there is a positive correlation between iron content in the soil and chlorophyll content in leaves (Marsh et al, n.d).

The micronutrient manganese also plays a role in the process of photosynthesis by aiding in the splitting of water to produce oxygen molecules and the electrons required for the photophosphorylation process that leads to carbon fixation (Caspi, 2013). But the role of manganese in plant metabolism is more complex, and in addition to helping create carbohydrates, it also helps plants break down those same carbohydrates into useable energy (Kids World, n.d.). Thus, the micronutrients iron and manganese have potentially antagonistic roles in the life of a plant.

In the summer of 2013, the E.S.S.R.E. Biota Survey showed statistically anomalous levels of manganese between the four surveyed sites (E.S.S.R.E, 2013). Research shows that soil pH affects nutrient availability, and soil pH and manganese have an inverse relationship where lower levels of pH result in higher levels of available manganese in the soil. In comparison to the soil pH levels of the other three sites, Site 4 soil contained the highest average pH (6.675). Given this information, we would expect Site 4 to have the lowest ppm of manganese to correspond properly with the lower acidity. However, Site 4 soil also contained the highest average level of manganese (7.375 ppm) amongst the four sites. Meanwhile, though, iron levels in Site 4 soil followed their expected environmental pattern in which soil with more neutral levels of pH tend to have higher levels of iron. As noted above, Site 4 soil had the highest average pH (6.675), and the iron reading for Site 4 was in fact the lowest amongst the four sites (4.375 ppm). This discrepancy between the expected manganese and iron levels in Site 4 led us to wonder what key environmental factor might somehow be the source of this anomaly. Given the potentially antagonistic roles of iron and manganese in plant life, we wondered whether the difference in metabolic activities in the plants in Site 4 might explain this year's biota survey's findings. Based on the roles iron and manganese play in the process of photosynthesis, we suspect that differences in the amount of sunlight in Site 4 could potentially be influencing the anomalous amounts of iron and manganese levels found there. Since a plant located in direct sunlight requires more chlorophyll to perform photosynthesis to produce carbohydrates (Carter, 2004), a plant in sunlight should need more iron to create chlorophyll and less manganese to metabolize carbohydrates. However, when a plant is located in the shade, it needs more manganese to break down carbohydrates for sustenance and less iron to perform photosynthesis to create and store sugars. Our hypothesis was that plants in direct sunlight would have higher levels of iron than manganese in the plant tissue but that the soil directly underneath these plants would contain higher levels of manganese than iron. Similarly, plants in the shaded tree canopy would have higher levels of manganese and lower levels of iron in the plant's tissue, and the soil under these plants would contain higher amounts of iron and lower levels of manganese.

Methods

In ESSRE Site 4 (E.S.S.R.E., 2001) a densitometer was used to determine 5 locations with varying canopy cover (100%, 75%, 50%, 25%, and 0% respectively). Each location was chosen to control for plant species variation and density. Within a 20 centimeter diameter of the center of each location, 1 full orange jewelweed plant (*Impatiens capensis*) was uprooted and collected. Simultaneously, a soil core sample 2.5 centimeters in diameter and 15 centimeters deep was collected directly underneath the uprooted plant. All soil and plant samples were taken simultaneously and then both soil and plant samples were tested for ferric iron (ppm) and manganese levels (ppm) using the LaMotte Combination Soil chemical testing kit model number STH-14. Additional plant and soil samples were taken from each site for 6 days and tested for ferric iron (ppm) and manganese (ppm) using the same test kit.

Results

Figure 1: Impact of Sun Exposure on Manganese in Soil

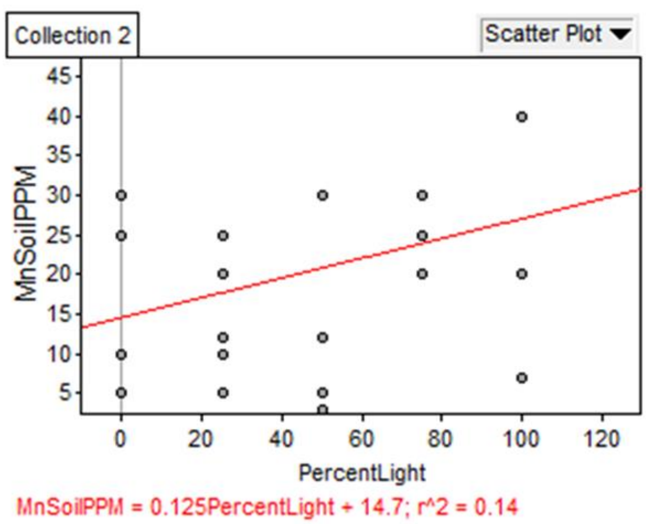

Figure one above shows the relationship between the percentage of sun exposure and the corresponding levels of manganese in the soil. As the percentage of sun exposure increases, the level of manganese in the soil also increases. The graph shows an r^2 value of 0.14, which shows a relatively strong positive correlation between the amount of sun exposure and manganese levels in the soil.

Figure 2: Impact of Sun Exposure on Manganese in Plant Tissue

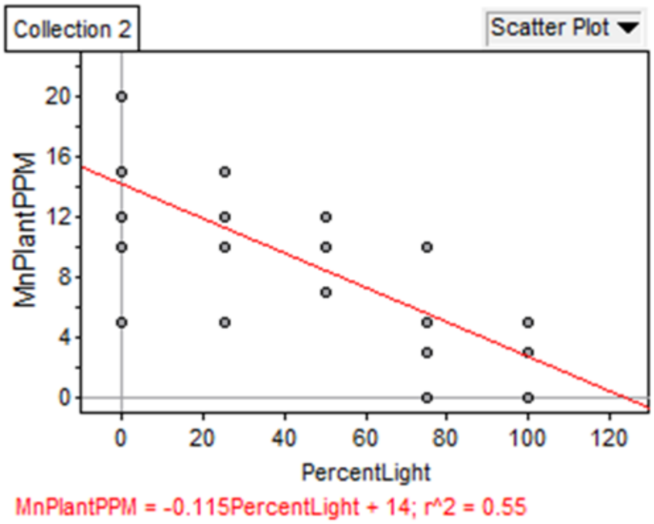

Figure Two displays the relationship between the percentage of sun exposure and the levels of manganese in the plant tissues. As the percentage of sun exposure increases, the level of manganese decreases. Shown in the graph of Figure 2, there is a high r^2 value which represents a strong correlation between the percentage of sun exposure and manganse levels in the plant tissues.

Figure 3: Impact of Sun Exposure on Ferrous Iron in Soil

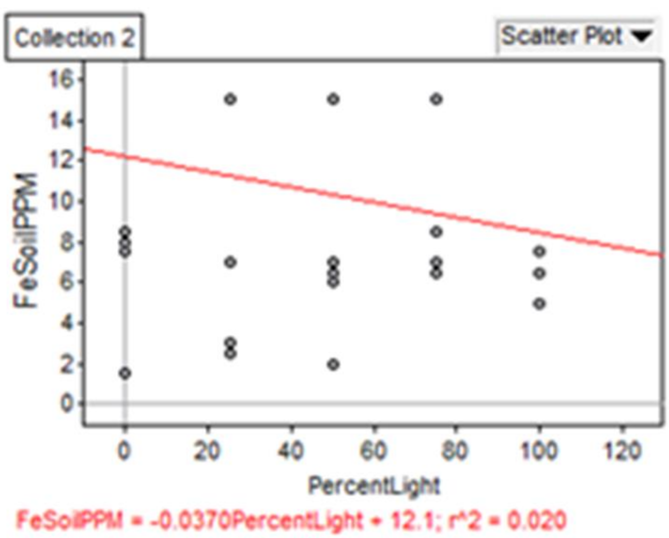

Figure 3 above shows the relationship between the percentage of sunlight and the levels of ferrous iron in the soil. As the percentage of sun exposure increases, the levels of ferrous iron decreases. The low r^2 value shows that there is no correlation between these two factors.

Figure 4: Impact of Sun Exposure on Ferrous Iron in Plant Tissue

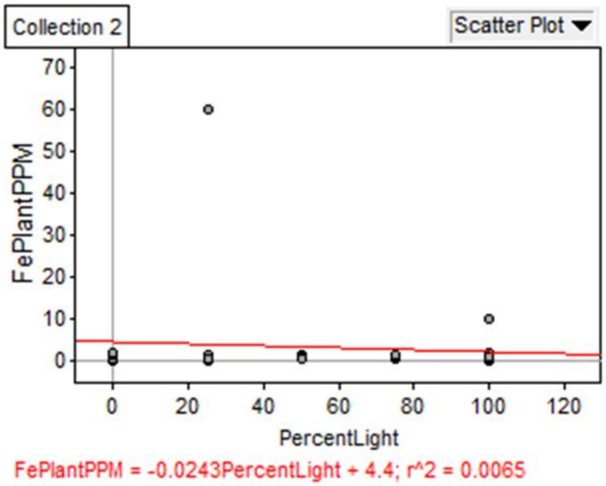

Figure 4 shows the data of the amounts of ferrous iron in plant tissue based on the percentage of sun exposure. As the percentage of sun exposure increases, the amount of ferrous iron in the plant's tissues decreases.

Figure 5: Average Ferrous Iron Levels in the Soil from Day 4 to Day 6

	Average Fe (ppm) in Soil		
Amount of Sun exposure	Day 4	Day 5	Day 6
100%	5.75	6.1	9.25
75%	7.25	8.8	9.83
50%	10.6	9.9	8.58
25%	6.8	6.9	9.9
0%	6.3	6.6	13.8

Figure Five shows a table of the averages of ferrous iron on days four, five, and six. All percentages expect for 50% show a steady increase in average.

Figure 6: Average Levels of Ferrous Iron in Plant Tissue from Day 4 to Day 6

	Average Amount of Fe (ppm) in Plants		
Amount of Sunlight Exposure	Day 4	Day 5	6
100%	1.12	2.9	2.58
75%	0.87	0.9	1
50%	1	1	0.916
25%	1	0.8	0.75
0%	0.375	0.6	0.83

Figure 6 displays data from days four, five, and six. The data shows the average amount of ferrous iron in plant tissue. There is a steady increase for 100%, 75%, 25%, and 0%, but 50%, and 20% steadily decrease.

Discussion

We originally hypothesized that higher exposure to sunlight would result in higher levels of iron than manganese in the tissue of the plants located in site 4 and that the inverse would be found in the soil from which these plants were extracted. As figures 1 and 2 show, there is support for our predictions about manganese. There is a definite direct correlation between the amount of sun exposure and the amount of manganese in the soil (r^2 =0.14) and an inverse correlation with the amount of manganese in plants (r^2 =0.55). This supports our claim that plants do not need as much manganese when there is more sunlight present because the plant is meeting its energy needs through photosynthesis (in which manganese plays a minimal role).

On the other hand, as figures 3 and 4 indicate, support for our claims about iron is tenuous at best. While figure 3 would seem to support our claim that the amount of iron in the soil would decrease as the amount of sunlight exposure increases, the statistical significance is extremely low (r^2 = 0.02). Furthermore, figure 4 discredits our claim entirely, showing that as the sunlight exposure amounts increase, the amount of iron in the plants decreases - if it changes at all (r^2=0.0065). In fact, we found that the average iron levels in the soil in nearly all sunlight conditions continuously increased on days 4, 5, and (see figure 5).

However, while figures 3 and 4 fail to prove our hypothesis, we did observe that iron in the plants in the 100% condition appeared to contain significantly more iron (2.58 ppm) than the other sun exposure locations (about 1 ppm – See Figure 6). Indeed, we have a reason to be confident that the difference in sun exposure was what affected the levels of iron between the 100% sun exposure site and

3the other sites (p=0.312). Hence, there is support for our claim that when there is more sunlight available, the plants extract more iron to aid in the photosynthesis process.

The real mystery that our data reveals, then, is the failure of our predictions about the degree of sunlight exposure and its impact on iron levels in the soil. There is clearly an unknown source releasing iron into the soil of all of our sites (see figure 5), leaving us to wonder why only the plants with 100% exposure have higher iron levels in their tissues. Perhaps because there were more orange jewelweed plants in the 100% sun exposure, there is increased competition for iron among these plants than in the 0%, 25%, 50%, and 75% sun exposure plants, and therefore the 100% sun exposure plants need to absorb iron at a faster rate. In the future, we would control for iron and manganese inputs into the soil by growing our test plants indoors under supervised conditions.

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