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Comparative Study of Photosynthesis Rates between Native Red Maple and Invasive Norway Maple in the Eastern Deciduous Forest

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Abstract

Invasive species, such as the Norway Maple, are often able to outcompete native species, such as the Red Maple by performing more efficiently in the environment compared to the native species. In this study, we examined if the Norway maple was able to outcompete the Red Maple in the Eastern Deciduous Forest because the Norway Maple had a higher rate of photosynthesis. The study found that the Norway Maple leaves had a slightly higher rate of carbon dioxide consumption than Red Maple leaves and that the Red Maple leaves had a higher rate of oxygen production compared to the Norway Maples. Since these differences were not statistically significant, the data suggested that the differences in the rate of photosynthesis between the two tree species is most likely very small. This suggests that the rate of photosynthesis is most likely not the advantage Norway Maples have over Red Maples that allows this invader to better compete for space in a forest.

Keywords

Photosynthesis rate, invasive species, Red maple, Norway maple, Eastern Deciduous Forest

Cover Page Footnote

Thank you to Professor William Maier for proofreading and suggesting that we submit our study to The Review.

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Evan Bourtis and Lindsey Heckman

ABSTRACT

Invasive species, such as the Norway Maple, are often able to outcompete native species, such as the Red Maple, by performing more efficiently in the environment than the native species. In this study, we examined if the Norway Maple was able to outcompete the Red Maple in the Eastern Deciduous Forest because the Norway Maple had a higher rate of photosynthesis. The study found that the Norway Maple leaves had a slightly higher rate of carbon dioxide consumption than Red Maple leaves and that the Red Maple leaves had a higher rate of oxygen production compared to the Norway Maples. Since these differences were not statistically significant, the data suggested that the differences in the rate of photosynthesis between the two-tree species is most likely very small. This suggests that the rate of photosynthesis is most likely not the advantage Norway Maples have over Red Maples that allows this invader to better compete for space in a forest.

Introduction

Performing photosynthesis, the process in which plants use solar energy to make sugar, is a fundamental aspect of a plant's ability to survive in an environment. A plant that performs more efficient photosynthesis can survive better in an environment, and therefore, can ultimately outcompete other plants.

Invasive plants are often able to outcompete native plants by becoming more efficient in the environment than the native plants. These plants can colonize areas of a forest and cause the decline of native species. For example, the Norway Maple (*Acer platanoides*), a common invasive species in the eastern deciduous forest, can outcompete native maples, such as the abundant Red Maple (*Acer rubrum*). According to a study (Martin 1999) that compared the species richness of tree saplings before and after the introduction of the Norway Maple, the mean sapling density for native species and mean species richness were both significantly lower after introduction of the Norway Maple.

It is important to study how invasive plants are able to outcompete native species because invasive plants can heavily damage the structure, composition, and food webs of biological communities (Martin 1999). Understanding how invasive species are able to outcompete native species will help to prevent their spread and create a more biodiverse ecosystem.

There are many factors, besides photosynthesis, that allow for a plant to outcompete other species, such as efficiency of water uptake, nutrient absorption, level of predation on the plant, and seed dispersal strategies. The purpose of this study is to determine if the Norway Maple is so effective at colonizing the eastern deciduous forests because it can perform more efficient photosynthesis than the Red Maple.

A recent study explored a similar question by comparing the rates of photosynthesis of the Norway Maple to the Sugar Maple (*Acer saccharum*), another common tree species in the eastern deciduous forest (Paquette et al. 2012). The experiment involved growing the two different tree species inside a

greenhouse using artificial light and similar levels of water and nutrients in the soil. The study found that the Norway Maple could perform photosynthesis at a faster rate than the Sugar Maple.

In our experiment, we chose to perform a laboratory study comparing the photosynthesis rates of Norway Maple to Red Maple, using leaf samples on the St. John Fisher College campus in Pittsford, NY. The photosynthesis rate was estimated using changes in oxygen and carbon dioxide concentrations inside the experimental chamber as indicators. Our predicted results, given the past research, was that the Norway Maple can perform photosynthesis at a faster rate than the Red Maple.

Methods

The rate of photosynthesis of Red Maple (*Acer rubrum*) and Norway Maple (*Acer platanoides*) were estimated using changes in oxygen and carbon dioxide concentrations inside the experimental chamber. The Red Maple was chosen from an adult tree and the Norway Maple was chosen from a sapling in the eastern deciduous forest. The leaves were collected on the St. John Fisher campus in Pittsford, NY in mid-fall (October). Green leaves were chosen for the experiment, and two individual leaves were used per tree sampled.

For each set of three runs, a leaf was placed in a plastic container with oxygen and carbon dioxide sensors in the two pores of the container. The light was directly above the leaf. Three trials were conducted per Red Maple leaf and three trials were conducted per Norway Maple leaf. The change in concentration of carbon dioxide and the change concentration of oxygen inside the plastic container were recorded. A T-test was utilized to compare average rates of

change of both O₂ and CO₂ gas concentrations for the two species.

Results

The rates of CO₂ production/consumption and O₂ production/consumption in Norway Maple leaves and Red Maple leaves were compared through quantitative analysis. The rate of CO₂ production/consumption of Norway Maple and Red Maple leaves were individually determined experimentally and the averages for each species are displayed in Figure 1, respectively (-8.35×10^{-5} ppm/s, -4.17×10^{-5} ppm/s). After a t-test, the calculated p-value for the Norway Maple vs. Red Maple Average Rate of CO₂ Production/Consumption indicated that the results were not statistically significant (p-value > 0.05).

The rate of O₂ production/consumption of Norway Maple and Red Maple leaves were individually and experimentally determined. The averages for Norway Maple (4.48×10^{-4} ppm/s) and Red Maple (9.90×10^{-4} ppm/s) are displayed in Figure 2. After a t-test, the calculated p-value for the Norway Maple vs. Red Maple Average Rate of O₂ Production/Consumption indicated that the results were not statistically significant (p-value > 0.05).

Discussion

We hypothesized that the invasive Norway Maple leaves would have a faster rate of photosynthesis when compared to the native Red Maple leaves. Specifically, we examined the rates of CO₂ and O₂ production/consumption and compared the results from both species. Our results do not support our hypothesis because the results were not found to be statistically significant, however, the results also do not disprove our hypothesis. A more robust test, with a larger

sample size, is needed to fully investigate this question.

Figure 1 shows us that Norway Maple leaves had a faster rate of CO₂ consumption than Red Maple leaves, which means that the overall rate of photosynthesis was faster for the Norway Maple. The average rate of CO₂ consumption/production was found to be negative for both species, indicating that more CO₂ was consumed in photosynthesis than was produced by cellular respiration. However, this data was not statistically significant based on a t-test conducted that compared the average rates of CO₂ production/consumption for Norway Maple leaves vs. Red Maple leaves (p-value = 0.672 > 0.05). In other words, even though the results of our analysis of the average rate of CO₂ consumption/production from figure 1 suggested that the Norway Maple had a faster rate when compared to the Red Maple, the results are not statistically significant.

Figure 2 shows that the Red Maple leaves had a faster rate of oxygen production compared to the Norway Maples, indicating that the Red Maple had a higher rate of photosynthesis. Both species had a positive rate of O₂ production/consumption, indicating that more O₂ was produced in photosynthesis than was consumed by cellular respiration. This data was also not statistically significant, based on a t-test conducted that compared the average rates of O₂ production/consumption for Norway Maple leaves vs Red Maple leaves (p-value = 0.787 > 0.05). In other words, even though the results of our analysis of the average rate of O₂ consumption/production from figure 2 suggested that the Red Maple had a faster rate when compared to the Norway Maple, the results are not statistically significant.

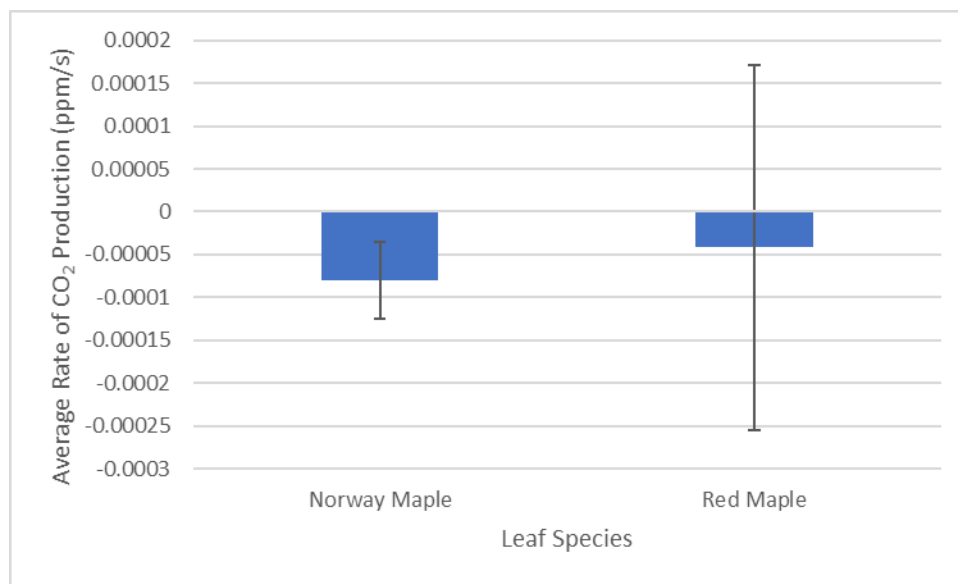


Figure 1: Average rate of CO₂ Production/Consumption (ppm/s) for Norway Maple and Red Maple leaves.

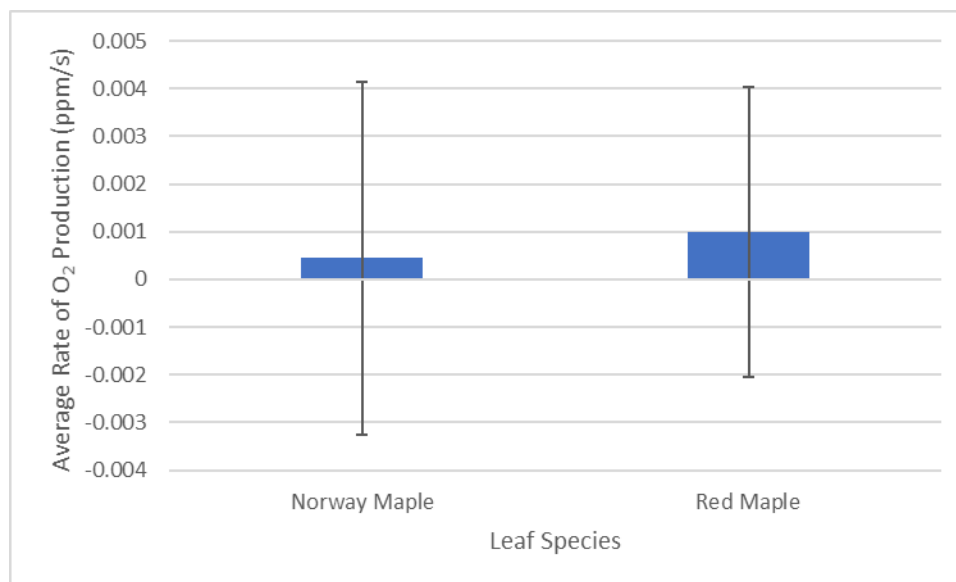


Figure 2. Average Rate of O₂ Production/Consumption (ppm/s) for Norway Maple and Red Maple leaves.

The data suggests that differences in the efficiency of photosynthesis between Red Maple and the Norway Maple are most likely very small. Therefore, the rate of photosynthesis is most likely not the advantage that Norway Maples have over Red Maples that allows them to outcompete the Red Maple trees. The other advantages that Norway Maples could have over Red Maples could include better seed dispersal, more efficient nutrient uptake, or how many predators the tree has. To further test this conclusion, a larger sample size is needed.

Invasive species of organisms outperforming their native counterparts has a huge effect on the ecosystems in which the two organisms live. In our situation, it is inferred that the invasive Norway Maple trees are outperforming the native Red Maple trees in the Eastern Deciduous Forest ecosystem at St. John Fisher College. For example, the predators that regulate the Red Maple population may be different than the predators that keep the Norway Maple population in check. Over time, this could lead to an overpopulation event for the Norway Maple trees on campus. This could

lead to the Red Maple tree population going extinct on campus because the Norway Maple is more efficient in utilizing nutrients for biochemical processes. The extinction of the Red Maple could be detrimental to its ecosystem, for example, animals that eat its seeds would no longer have a food source.

One source of error could have been the position of the leaf in relation to the sensor. Since the top and bottom of a leaf have different function, placing the top of the leaf closer to the sensor could yield different results than placing the bottom of the leaf closer to the sensor. In addition to this, when a leaf that is placed closer to the sensor, the sensor would be most likely to pick up changes in O₂ and CO₂ concentration compared to a leaf placed farther away from the sensor. In addition, the age of the trees from which leaves were collected could have had an impact on our results. A leaf from an older tree could be slightly different in terms of leaf composition that results from aging, which could impact the rate of photosynthesis. In other words, older leaves may not be able to perform photosynthesis as efficiently as a younger leaf because of

chlorophyll A deficiency when the two are compared. The Norway Maple leaf sample used in the experiment was from sapling, while the Red Maple leaf sample used was from a fully-developed adult tree. One study that used conifers, deciduous, and tropical trees found that the rate of photosynthesis for many of the tree species surveyed increased and occasionally decreased throughout the trees' lifetime, a phenomenon called ontogenetic change (Thomas and Winner 2002). If an adult Norway Maple Tree was to be used instead of a sapling, the results may have been more statistically significant.

The placement of the light could have also impacted our results. If the light is placed farther away from the leaf or hitting the leaf at an angle instead of directly on top of the leaf, the rate of photosynthesis would most likely be lower. In our experiment, we tried to prevent this by having both groups

conduct three trials with one Red Maple leaf and one Norway Maple leaf. This way, any influence that light placement had on the rate of photosynthesis would be accounted for in each species once an average value was calculated.

In addition to this, the small sample size could have contributed to the lack of statistically significant data collected. We conducted three trials per leaf with two different leaf species and another group conducted three trials per leaf with two different leaf species, for a total of twelve trials between the two groups. Twelve trials overall on four total leaves seems like a small sample size when attempting provide evidence of a hypothesis about a species of tree. If more leaves were tested, rather than just two samples, and more trials were conducted, we may have acquired more statistically significant results.

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