Is Phosphorus More Limiting than Nitrogen to Foliar Production in Northern Hardwood Forests?

Max Charlamb, 9th Grade

Background

The Multiple Element Limitations in Northern Hardwood Ecosystems (MELINHE) project is a collaborative research project to study the effects of phosphorus and nitrogen on the growth of trees in northern hardwood forests. MELINHE is supported by the National Science Foundation. This specific study was performed by the author under the guidance of Dr. Ruth Yosef, one of the project’s principal investigators. MELINHE. (1)

While plants use phosphorus in various forms, they need nitrogen to allow this process to occur. Plants require a wide variety of nutrients to grow. Nitrogen and phosphorus are two of these nutrients. Both nutrients and phosphorus are classified as major nutrients because they are used by plants in relatively high quantities. Phosphorus is used in many processes that involve energy, including photosynthesis. The amount of available nutrients may affect the production of foliage and the subsequent litter mass in a forest. (1)

The purpose of this project is to determine the effect of application of nitrogen and phosphorus nutrients on the foliar production of trees in northern hardwood forests as indicated by the litter mass produced by those trees. Traditionally, foliar growth has been thought to be limited by the nitrogen available in the environment. However, with phosphorus application, it is possible that forest growth is now limited by phosphorus, so there may be adequate nitrogen available in the environment. If there is a surplus of a particular nutrient in the environment, supplementation would be needed in addition to foliage growth. Measuring foliage growth by measuring litter mass after application of nutrients can help to determine whether nutrients are limiting forest growth. (5)

If a forest is limited by a certain nutrient, it does not necessarily mean that there is less of that nutrient than other nutrients in the environment. Instead, it means that it is the rate of nutrient use is being measured. For example, if a forest has a ratio of phosphorus to nitrogen use of 2:1, and the forest had 7 parts phosphorus and 12 parts nitrogen, it would be phosphorus limiting the growth of the forest. (6)

Hypothesis

The hypothesis of this study is that the litter mass will increase with phosphorus application more than with nitrogen application.

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Materials and Methods

Material List: Ammonium Nitrate, Monosodium Phosphate, Electronic Scale, Paper Bags, Drying Oven, Hand Harvester, Plastic Bags, Vehicle for Transportation

Site Treatment and Litter Collection (by Dr. Yosef Yosef)

- The study was carried out in 3 northern hardwood forest sites that are part of the MELINHE project in the Suckers Brook White Mountains National Forest and the Hubbard Brook Experimental Forest in New Hampshire.
- Each of the three sites is divided into 4 plots. Starting in the spring of 2011, each plot of a site was treated with Nutrient (10 kg/ha as NO₃-N) and with Phosphorus (5 kg/ha as H₂PO₄). Phosphorus was applied to one of the 4 plots, or serving as a control. Each plot was divided into 3 equal parts, and the entire surface was covered with the same amount of litter mass. Each plot had a surface area of 126 m², or 2500 kg of forest floor mass within the 3 plots. Litter was harvested by the MELINHE project researchers at least three times a year: at the end of the growing season, or at August before the start of the next summer season.

Litter Processing and Analysis (by the author)

The harvested litter was washed and dried in a 40°C oven. The dried samples were stored in airtight containers.

Data Analysis (by the author)

- To determine the effects of the nutrient additions, each site was divided into 4 equal parts, and weights of the litter from these plots (C, N, P, and NO₃-N) were compared using one-way ANOVA analysis, Yosef and 2-way ANOVA analysis. Significant differences using Tukey’s honestly significant differences using sigmeData 4.0.

Results

- In the BBO site (late cut circa 1980), litter mass varied between treatment groups (p<0.01). One-way ANOVA analysis revealed that N treatment was associated with higher foliage than P treatment, and the difference was significantly different (10.67 g/m² vs. 9.31 g/m², p<0.05). Also, in this plot there was more foliage with the nutrient treatments than without treatment (average 9.22 g/m² vs. 7.84 g/m², p<0.05). The combined treatment (NP) produced a higher average than control in the BBO site, but the difference was not statistically significant using ANOVA (11.20 g/m² vs. 9.61 g/m², p<0.25).

- In the BBO site (late cut circa 1990), the difference between the litter mass of the treatment groups approached statistical significance (p<0.05). Similar to the BBO site, ANOVA analysis revealed that N treatment was associated with higher foliage than P treatment, with the difference statistically significant (10.55 g/m² vs. 7.75 g/m², p<0.05). In the BBO plot, both N and P treatments produced more foliage than control, but the difference was not statistically significant.

- Analysis of the data showed no treatment effect in the JBB site (late cut circa 1985), indicating that litter mass was similar among the different treatments in that plot (p>0.05).

Discussion

The findings at the two sites indicate that overall, nitrogen application as associated with more litter production than phosphorus or control. This suggests that the litter production growth at these sites is still limited by nitrogen. Therefore, the hypothesis is not supported by this data.

The lack of significant findings in the JBB plot could be due to multiple factors. This site is relatively new growth, and this difference in forest maturity could play a role in the effect of nutrient supplementation. It could be that there are adequate levels of both phosphorus and nitrogen in the environment in this plot, and the litter production may be limited by something else altogether. However, there are other possible explanations. There was a high variance of areas that each treatment group was subjected to, and the data may not accurately reflect the average litter in the plot. This could be due to the natural factors including human error and sampling error. It was noted that some of the analyzed samples had been crushed and had been mixed together, which could have affected the amount of usable data from these samples.

Applying the experiment with a higher number of samples from each treatment area of each plot, and allowing more time for the treatments to have an effect on the foliage may result in improved results in future experiments.

Conclusion

The data obtained did not support the hypothesis that nitrogen production would increase with phosphorus application more than with nitrogen application. At the older forest sites, litter production seemed to be limited by nitrogen availability.

References


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