Photochemical Responses of Sugar Maple and Red Maple to Excess Manganese in Contrasting Light Environments

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INTRODUCTION

Over the last few decades health decline in sugar maple and other sensitive tree species has been observed in the eastern forests of North America. Symptoms include leaf chlorosis, reduction in growth, crown dieback, tree mortality, and low rates of seedling regeneration. Manganese (Mn) toxicity may be an important factor contributing to these decline symptoms. Trees and seedlings growing on acidic non-glaciated soils in the eastern forest commonly accumulate high levels of foliar Mn. We hypothesize that excessive accumulation of foliar Mn may induce photo-oxidative stress in sensitive tree species particularly in high light environments.

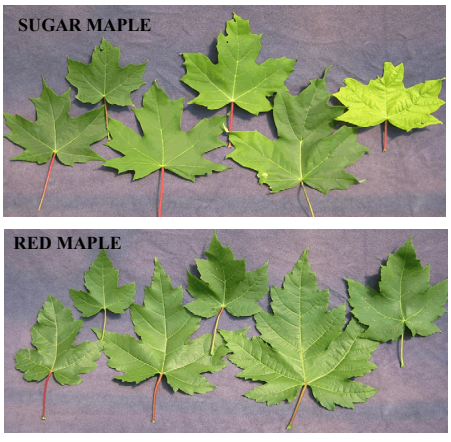
Sugar maple on the Allegheny Forest exhibiting health decline symptoms

STUDY 1

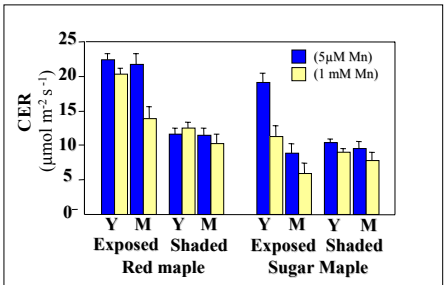
METHODS

In glasshouse conditions, 2nd year sugar maple and red maple seedlings were grown in a sand culture system irrigated with nutrient solution containing either 5 or 1000 µmol/L Mn. Leaves were exposed to either full sunlight or 20% of full sunlight using filter paper. Gas exchange measurements were made on young and mature leaves after 70 days.

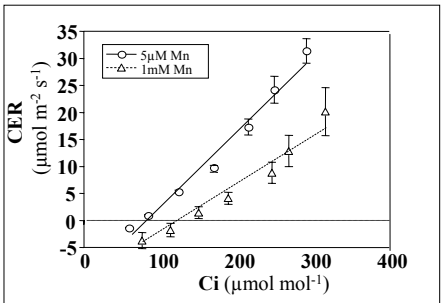
RESULTS



Excess Mn reduces leaf size at all stages of development. Leaves are younger as you moved to the right in the photos. Leaves from seedlings exposed to excess Mn treatment are along the top. Excess Mn reduced seedling growth by 33% in both species.



Excess Mn significantly decreased photosynthesis in mature red maple leaves and young sugar maple leaves under high light but not low light conditions. Y=young leaves, M=mature leaves on x-axis



Excess Mn significantly inhibits carboxylation efficiency in young sugar maple leaves

DISCUSSION

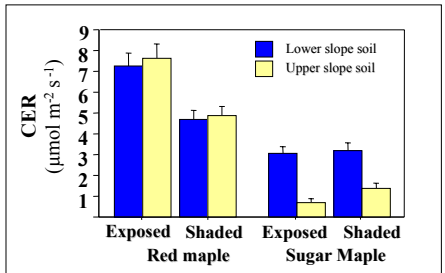
Rubisco appears to be a key target of Mn toxicity, as indicated by decreases in carboxylation efficiency of leaves treated with excess Mn. The observed interaction between excess Mn and high light in this study suggests that photo-oxidative stress may be a mechanism of toxicity underlying the observed physiological responses. Biochemical and molecular analysis of leaf tissues from this study are being analyzed to more thoroughly test this hypothesis.

STUDY 2

METHODS

This second study tests the same hypothesis as the first study but in more natural experimental systems. Soil cores from three field sites on the Allegheny Plateau were collected from upper slope and lower slope positions where a natural contrast in Mn availability exists. Sugar maple and red maple seed was collected from single parent trees and grown in the soil cores in a glasshouse. Factor combinations in this study include the natural contrast in Mn availability, and two light levels, full sunlight and 20% of full sun using shade boxes (see photo below). Gas exchange measurements were taken on leaves. Data presented here represents the first of four measurements that are currently being conducted this summer.
Measurements of overstory sugar maple leaves at the sites from which soil cores were collected are also being taken. Tree branches from the sun exposed upper canopy crown are shot down using a shotgun. Gas exchange are then made on the leaves.

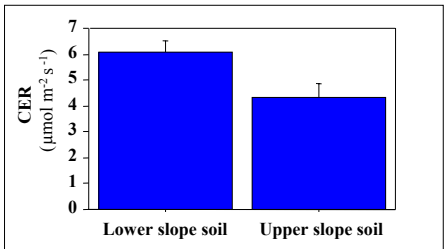
RESULTS



Upper slope soils prone to Mn toxicity decrease sugar maple photosynthesis under both light environments. Red maple appears to be tolerant.

Shooting down canopy foliage for photosynthesis measurements

Photosynthesis measurements on sugar maple foliage



Photosynthesis in trees growing on upper slope soils prone to Mn toxicity were 34% lower than trees growing on lower slope soils

DISCUSSION

Germinating seedlings and overstory trees sugar maple appear to be photochemically sensitive to the nutrient conditions of non-glaciated upper slope soils. Although Mn is one factor that differs among the soils at the different slope positions, there are other variables of interest that may contribute to the effects that are being observed. Further analysis of leaf tissue will be required to more appropriately test our hypothesis in this study.

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