Connecting the Allelopathic Effects of Invasive Garlic Mustard on Biodiversity of Invasive Wisteria in Northern Jersey

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Funded by the Thompson Family Foundation

Abstract

Wisteria is a highly invasive species known for its rapid growth and impact on native biodiversity, while garlic mustard is another invasive plant that releases allelopathic chemicals that suppresses nutrient intake for nearby plants. This study investigates the biodiversity of wisteria in Northern Jersey with the presence of garlic mustard. We collected 30 plant samples and soil samples from two locations: Location A, where both species were present, and Location B, with only wisteria. DNA barcoding identified types of wisteria, and soil tests were conducted to measure pH, nitrogen, phosphorus, and potassium levels. We found that wisteria in the presence of garlic mustard (Location A) had higher biodiversity (Simpson's Diversity Index = 0.714) than without (Location B, Diversity Index = 0.400). Our results suggest that garlic mustard's allelopathic chemicals may not suppress invasive biodiversity as expected. This opens new questions about how invasive species interact and compete in shared environments.

Introduction

- Wisteria are quick-growing, hard, tree-climbing vines which are extremely invasive to North Jersey [2], vigorously outcompete native species, and are an established threat to local plant diversity [1].
- Garlic mustard is a similarly aggressive invasive herb capable of stretching across dense patches on the forest floor [3]. It uses allelopathic chemical compounds released into the soil via its roots to hinder mycorrhizal fungi communities, and thus soil microbial health and native plant nutrient absorption [4].
- Our project's objective is to:
  a. Determine whether the presence of garlic mustard affects wisteria biodiversity, especially through allelopathic chemicals, through DNA barcoding and diversity index analysis
  b. Assess the soil conditions surrounding wisteria that corroborate the allelopathic effects from garlic mustard by measuring pH as well as N, P, and K levels
- Hypothesis: Due to its allelopathic compounds, garlic mustard will reduce the biodiversity of wisteria should it be in a 1m-by-1m radius.

Materials & Methods

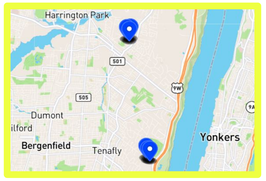

Figure 1: Sampling Sites (TNC and CNC)

Figure 1a: Wisteria girdling native trees

Figure 1b: Plot of garlic mustard at CNC

Figure 1c : pH test from Location A (TNC)

Sampling
Collect 30 wisteria and 3 soil samples per location → Test soil for pH, N, P, and K levels using Rapitest Soil Testing Kit → Obtain ¼ to ⅛ diameter sized fern samples for DNA isolation

DNA Isolation
Extra DNA from cell using lysis solution → Add silica resin to bind to DNA → Remove DNA from silica resin and add rbcL primer

PCR
Denaturation of DNA strands at 94°C → Annealing of DNA primer (rbcL) at 54°C → Extension of DNA at 72°C

Bioinformatics - DNA Subway (Blue Line)
Upload and trim sequences → Pair forward and reverse strands into a consensus sequence → Use BLASTN software to identify species

Data Analysis
Usage of Simpson and Shannon-Wiener Diversity Indexes → Usage of Bray-Curtis Dissimilarity formula → Tabulation and analysis of soil conditions from Rapitest kit

Results

Location	Sample #	Species	Soil pH	Levels of Nitrogen	Levels of Phosphorous	Levels of Potassium
A - TNC	KHT-02	Wisteria floribunda	Neutral pH 7.0	Low	Medium	Medium
	KHT-03	Wisteria sinensis				
	KHT-06	Wisteria sinensis				
	KHT-07	Wisteria sinensis				
	KHT-08	Wisteria floribunda	Neutral pH 7.7			
	KHT-011	Wisteria frutescens				
	KHT-012	Wisteria frutescens				
	KHT-013	Wisteria sinensis				
B - CNC	KHT-017	Wisteria sinensis	Acidic pH 6.2	Very Low	Very Low	Low
	KHT-021	Wisteria sinensis				
	KHT-022	Wisteria sinensis				
	KHT-027	Wisteria sinensis	Acidic pH 6.5			
	KHT-028	Wisteria brachybotrys				

Figure 4: Soil conditions for wisteria samples successfully barcoded. Highlighted groups of the same color represent identical species of wisteria. Nitrogen, phosphorus, and potassium levels are shown in single sets of numerical values for both A and C; they are averages of several soil sample tests.

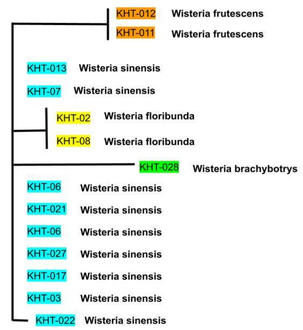

Figure 5: ML phylogenetic tree of the wisteria samples we collected at both the TNC and CNC. KHT-022 is the outlier group here.

$$D = 1 - \frac{\sum n(n-1)}{N(N-1)}$$

D = Simpson's Diversity Index (the probability that two randomly selected individuals belong to different species)
- Higher values of D represent higher levels of biodiversity

n = number of individuals of a particular species
N = Total number of individual organisms (all species combined)

$D_{Location\ A} = 0.714$
$D_{Location\ B} = 0.400$

Figure 6: Simpson's Diversity Index Formula. Information from Figure 4 was used to calculate the values of D for both locations.

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

H' = Shannon-Wiener Diversity Index (the calculated value representing biodiversity)
S = Total # of species (species richness)
p_i = proportion of total sample that belongs to the *i*th species
- $p_i = n_i / N$
  - n_i = # of individuals of species *i*
  - N = total # of individuals across all species

$H'_{Location\ A} = 1.0398$
$H'_{Location\ B} = 0.5004$

Figure 7: Shannon-Wiener Diversity Index Formula. Information from Figure 4 was used in calculating numerical values for biodiversity via this formula.

$$BC = 1 - \frac{2C}{A+B}$$

C = sum of shared species counts between two locations
A and B = total individuals in each location

Bray-Curtis = 0.385
0.385 = 38.5% dissimilarity, or 61.5% similarity

Figure 8: Bray-Curtis Dissimilarity Formula. Compares community composition for locations A and B.
0 = completely identical
1 = completely different

Discussion

- Wisteria biodiversity was higher in the presence of garlic mustard (Simpson's D = 0.714, Shannon-Wiener H = 1.0398 at Location A) than without it (D = 0.400, H = 0.5004 at Location B)
- Garlic mustard presence did not reduce wisteria biodiversity → resilience of wisteria to presence of allelopathic compounds from mineral cycling [5]
- Soil at Location A (with garlic mustard) had near-neutral pH (7.0–7.7) and higher mineral levels (medium phosphorus and potassium, low nitrogen)
- Location B had slightly acidic soil (pH ~6.2–6.5) and lower nutrient levels → linked to lower biodiversity
- Glucosinolates in garlic mustard are more active at higher pH → wisteria maintained biodiversity, suggesting resistance to allelopathy
- Wisteria may be less dependent on mycorrhizal fungi → able to absorb nutrients even if microbial communities are disrupted [6]
- Challenges included low plant health due to season, variable field conditions, and limits in PCR amplification and soil test precision
- Future studies → explore microbial communities in root soil, test allelopathic effects under controlled conditions, and examine interactions between

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Acknowledgements

We would like to thank the Harlem DNA Learning Center, Mr. Brandstaedter, and our upperclassmen for their continual support for their feedback.