Assessing the Allelopathic Effects of Thirteen Plant Species in Northeastern Pennsylvania

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Abstract

To determine the allelopathic effects of 13 plant species in Northeastern Pennsylvania, extracts from each species were applied to 100 red onion seeds and allowed to germinate over 2 weeks. The germination counts and shoot length means were compared and three species (*Juglans nigra*, *Berberis thunbergii*, and a *Solidago* species) were found to have significant effects. While these species were expected to show allelopathy, several others in the study were also expected to, but did not show significant effects. The absence of allelopathy in these species may be due to the lack of soil, the wrong season, chemicals present in the roots but not leaves, or due to specialization.

Introduction

Allelopathy is a process by which a plant can inhibit the germination or growth of another plant through the release of chemicals into the surrounding environment. Some plants may release chemicals from the roots, while others may build up chemicals in the leaves. Many studies have been done on the allelopathic effects of several species (such as Butcko and Jensen 2002; Eppard et al. 2005; Jose and Gillespie 1998; Stewart 1975). Studies ~~have also been done to~~ assess how to counter allelopathic effects (for example, Engelman and Nyland 2006).

This study focuses on the allelopathic chemicals found in the leaves, stems, and in one case, the fruit of thirteen plant species found in Northeastern Pennsylvania. These species include American Beech (*Fagus grandifolia*), Japanese Barberry (*Berberis thunbergii*), Hay-scented fern (*Dennstaedtia punctilobula*), Ground Ivy (*Glechoma hederacea*), Mountain Laurel

(*Kalmia latifolia*), Garlic mustard (*Alliaria petiolata*), Common Mullein (*Verbascum thapsus*), Bracken Fern (*Pteridium aquilinum*), a Goldenrod species (*Solidago*), New York Fern (*Thelypteris noveboracensis*), Small White Wood Aster (*Aster divaricatus*), Black Walnut (*Juglans nigra*), and one unidentified species. The goal of this study is to determine which species show allelopathic effects on red onion (*Allium haematochiton*) seeds, and which do not. In this paper, I describe the differences between germination counts and shoot length means of onion seeds treated with extracts and those treated with water, and I discuss the reasons for these differences.

Materials and Methods

Thirteen plant species from northeastern Pennsylvania were selected during the last week of October, and any available leaves, flowers, and fruits were harvested. Extracts were obtained from each species by homogenizing the harvested parts with water. Each extract was applied to 100 red onion seeds, and a control was treated with water only. The seeds were allowed to germinate over 2 weeks, and the lengths of the shoots were measured to the nearest half millimeter. Germination counts were compared with the z test, and shoot length means were compared with the ANOVA test and the t test.

Results

The germination count of the control group was 90 out of 300 seeds. A z test was performed for each group of extract-treated seeds, and the germination counts of the seeds treated with a Goldenrod species (z = -2.96) and Black Walnut (z = 2.40) were found to be significantly lower than the control. The remaining 11 extracts did not show a significant difference (Table 1).

A one-way ANOVA test was performed on the data, and the results showed a significant difference between shoot length means of one or more groups (df = 13, MS = 1354.943, F = 5.230363, $p = 1.47 \times 10^{-8}$) and the control (mean = 20.906). A two-tailed t test was also performed on the shoot length means for each extract-treated group. Twelve of the 13 extracts showed a significant difference from the control group ($p < 0.05$), but only Japanese Barberry and Black Walnut had means lower than the control (Table 2).

Table 1. Germination counts of onion seeds treated with plant extracts and z test results

Extract Species	**Germination out of 100**	**Z Value**
American Beech	23	-1.35
Japanese Barberry	25	-0.95
Hay-scented Fern	20	-1.93
Ground Ivy	22	-1.54
Mountain Laurel	21	-1.74
Garlic Mustard	29	-0.19
Common Mullein	28	-0.38
Bracken Fern	25	-0.96
Goldenrod Species	15	-2.96
New York Fern	34	0.93
Small White Wood Aster	22	-1.54
Black Walnut	12	2.40
Unknown	25	-0.95

Table 2. Shoot length means of onion seeds treated with plant extracts and t test results

Extract Species	**Mean**	**Std. Deviation**	**T value**	**Df**	**P value**
American Beech	38.70	26.723	3.194	22	0.004
Japanese Barberry	15.380	10.5250	-2.622	24	0.015
Hay-scented Fern	38.375	19.6314	3.981	19	0.001
Ground Ivy	28.364	14.7254	2.377	21	0.027
Mountain Laurel	31.905	19.4420	2.594	20	0.017
Garlic Mustard	31.121	18.8394	2.922	28	0.007
Common Mullein	30.015	14.7254	3.213	26	0.003
Bracken Fern	26.800	12.7380	2.316	24	0.029
Goldenrod Species	29.033	12.7173	2.477	14	0.027
New York Fern	28.132	15.6362	2.697	33	0.011
Small White Wood Aster	20.750	9.6006	-0.070	19	0.945
Black Walnut	10.000	5.0181	-7.524	11	0.000
Unknown	31.420	12.4906	4.211	24	0.000

should have same number of sign. figures

Discussion

The data analysis clearly shows that there are significant differences between the germination counts and shoot length means of several groups of treated seeds and the control group. For germination counts, it would appear that the Goldenrod species and Black Walnut both have an allelopathic effect on red onion seeds by reducing the seed's ability to germinate. For shoot length means, it would appear that Japanese Barberry and Black Walnut both have an allelopathic effect on red onion seeds by impairing the growth of seedlings.

It was expected that the Goldenrod species and Black Walnut would have an allelopathic effect on the onion seeds, as the effects of both species have previously been documented. Butcko and Jensen (2002) found that leaf extracts from two Goldenrod species, *Euthamia graminifolia* and *Solidago canadensis*, inhibited the germination of radish and lettuce seeds. Jose and Gillespie (1998) found that juglone, a chemical released by walnut trees, can inhibit shoot growth in corn and soybeans.

Japanese Barberry has been less documented in terms of its allelopatic effects. However, Kourtev, Ehrenfeld, and Häggblom (2003) found that the invasive plant significantly alters the microbial community in the soil beneath it. This suggests that the plant releases some sort of chemical into the soil. If this chemical is capable of altering the community of microbes in the soil, it may also be capable of inhibiting the growth of seedlings.

There were a number of species that were expected to show allelopathic effects, but did not significantly affect germination or inhibit shoot growth. Stewart (1974) found that communities dominated by Bracken fern had both fewer herbaceous species and fewer woody species than sites without Bracken. Engelman and Nyland (2006) also reported that Bracken can inhibit germination and growth. Extracts from decaying leaves of Ground Ivy have been found to both inhibit germination and shoot growth (Hutchings 1999). American beech leaf extracts have also been found to inhibit the growth of Sugar Maple seedlings (Hane et al. 2003).

One possibility for these species' lack of allelopathy in this study could be that soil was not involved. Muller (1969) stated that the allelopathic effects of a plant species may be evident in some soil and climatic conditions but not in others. Perhaps soil is a necessary component for allelopathy in these species. Another possibility is that the plants were harvested during the wrong season. It is possible that allelopathic chemicals are stronger during the spring or summer than during late fall, which would affect the results. It is also possible that the chemicals would become stronger or their more evident as the plant decayed, so harvesting fallen leaves later in the season may produce different results.

A third possibility is that the chemicals responsible for the allelopathic effects are not found in the leaves, but instead in the roots. Extracts prepared from the leaves of Garlic Mustard, for example, do not affect radish or lettuce seed germination, but extracts prepared from the roots do have an effect (Butcko and Jensen 2002).

It is also possible that the allelopathic chemicals are specialized for certain species or genera. For example, the extracts from American Beech leaves that impaired the growth and development of Sugar Maple seedlings did not have an affect on American Beech seedlings (Hane et al. 2003). Hutchings (1999) also found that Ground Ivy affected radish and cheatgrass, but not standing crops. This suggests that allelopathic chemicals are not formulated to affect all plant species, but may be specialized. This would be adaptive to a species by preventing it from poisoning its own offspring, and may also help conserve energy by producing only a few chemicals that affect local competitors, rather than producing several chemicals that can affect all plants. If this is the case, then onions may not be affected by several of the species in this study since they do not normally grow in the same environments.

There is also the possibility that since the study was not carried out in the natural environment, the allelopathic effects were not as strong as they would have been in the field. Eppard at al. (2005) found that seedlings grown in soil from beneath Mountain Laurel had slight differences from the control, but these differences were not significant. They suggest that these effects could be exacerbated in nature when the seedlings face multiple stressors in addition to allelopathic chemicals. American Beech, Hay-scented fern, Ground Ivy, Small White Wood Aster, and Mountain Laurel all had germination counts that were lower than the control but were not significant ($z < 1.96$), but had z values that were close enough to the critical value that if the effects were amplified in the field, then the effects may have been significant.

Ten of the 13 species showed a significant difference in shoot length means from the control and had higher means than the control. This suggests that these extracts may have stimulated the growth of the red onion seeds rather than inhibited it. Eppard et al. (2005) suggested that the water given to the control group has no nutritional value, while the extracts do, and would therefore stimulate growth if no allelopathic chemicals are present. Butcko and Jensen (2002) found that some extracts have stimulatory effects in low concentration and inhibitory effects at high concentrations, which further supports the concept that the extracts may provide some nutrition. Hutchings (1999) suggested that allelopathic chemicals may increase the uptake of minerals, which would also lead to growth.

Clearly, there is still much to learn about allelopathy. Species that have previously been documented to show allelopathic effects may not behave as predicted, and it is unclear whether extracts work the same in the lab as they do in nature. However, developing an understanding of allelopathy is an important component in the successful management of plant communities, even if the results are not always consistant.

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Wow! This may be the best student paper I have ever read! It is well-written, & thoroughly researched.
Frankly, this is better than anything I've written myself!

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