IMPACT OF PINE ALLELOPATHY ON SEED GERMINATION

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ABSTRACT

Allelopathy is an environmental augmentation by an organism in which it produces a biochemical agent that influences germination, growth, survival, and reproduction of other organisms. This experiment was designed to test the effects of soil allelopathy on various types of seeds. This was tested with five different types of soil and four different types of seeds keeping temperature, humidity, light, and amount of water constant. The results yielded that the seeds did poorly in the red pine soil (allelopathic soil) compared to the other soil types. The data also shows that seeds grown in the forest floor soil had the highest seed germination. Independent of seed species, the red pine soil on campus was shown to have the biggest impact on seed germination.

Keywords: Allelopathy, Germination, Invasive Species, Red pines, White pines

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INTRODUCTION

Growth and development of flora in any environment is important to the overall health of that area. Without proper development of a variety of trees, grasses, and shrubs, other organisms could not sustain themselves (Tilman and Downing 1994). These are the primary producers of an ecosystem; therefore, they provide their environment with the first level of energy needed to support every other organism. Plants also support animals by providing habitat. Before plants can begin to take root, one major factor has to be accounted for, which is soil. These groups need a suitable location to grow, meaning they need adequate soil to have a chance to grow to maturity. Inadequate soil could lead to a decrease in plant growth and germination (Gong et al. 2001). The quality of soil can be altered because of some factors, including salinity, acidity, the ability to retain water, and nutrient content. Soil health is a very important factor in determining how many seeds will germinate, how tall the plant will grow, and what types of species can grow there. Changes in acidity, in particular, can have some positive and negative impacts on seed germination and seedling growth (Redmann and Abouguendia 1979).

The acidity of soil can be affected by many features near the soil, one of which is pine trees, specifically Red and White Pines. These trees will drop their needle-shaped leaves on the ground around them which can acidify the soil around the tree. This is known as an allelopathic effect, an effect by an organism in which it produces a biochemical agent that influences germination, growth, survival, and reproduction of other organisms. The allelopathic effect from the Timor white gum (*Eucalyptus urophylla*) plant has a restraining factor on native woody communities (Qin et al. 2018). In this case, the pine needles have acidic properties that change the pH of the soil near the tree making it harder for other plants to grow there. This adaptation can be observed visually; as the plant life under large groups of pine trees is often more sparsely located than in open fields.

Both Red and White Pine are native to North America (Cook et al. 1952), so native species have had a long evolutionary history of dealing with the allelopathic effects of pine needles. This may give these native species more adaptations that make it better suited than other species to germinate in pine needle soil. However, in the past two centuries, human movement has led to an increase in invasive species. This has introduced an array of species to our forests, and many have become dominant. On the Purchase College campus, we can find a long list of invasives, such as Multiflora Rose, Tree of Heaven, Norway Maple, and Porcelain Berry. Successful removal of these species, especially those that take over the undergrowth of our wooded areas, would require long and tenuous effort. The most effective method for removal is to go in and cut back all of the invasive undergrowth, then to repeat the process constantly for several years. If this is not done constantly the area is likely to return to how it was before by the next year (Flory and Clay 2009).

Another method of removal is to introduce a species that is a natural predator of the first species. In this case, this would mean introducing Asian species that naturally predate on Porcelain Berry and the Multiflora Rose. However, past efforts to use this method of population control have had low success, with the possibility of making the situation worse (Baldwin et al. 1952). Some other methods to control these invasive species would also look at chemicals to help the situation, but the side effects of these chemicals are not completely known. One potential method of controlling invasive species without introducing a new species or using new chemicals is to reintroduce a native species that is known for using chemicals for its benefit.

We looked at how different soil samples from different locations, two pine soils and two non-pine soils, around the Purchase College campus would cause different species of seeds to germinate or not to germinate. Our hypothesis is that fewer seeds, independent of species, will germinate in the pine soils than in any other soil.

METHODS

Field site. The site we studied from was SUNY Purchase College. Purchase College has different types of biomes located on the campus. First, we collected soil samples from a forest biome; two soil samples from the forest edge and two soil samples from the center of the forest. Second, we collected soil samples from an open grassland biome; called the “Great Lawn”. We collected soil samples from the center area, the northern area, the western area, and the eastern area of the Great Lawn. Third, we collected soil samples from a semi-urbanized biome; next to a road and a walkway where white pine trees are planted. Soil samples were collected next to four different white pine trees. Fourth, we collected soil samples from a heavily urbanized biome; located in front of the Big Haus dorm on the campus and next to a parking lot. Four soil samples were collected next to four different red pine trees.

We used a hand trowel to collect our soil samples on October 12th, 2018 and stored them in labeled ziplock bags. In total, we collected 16 bags of soil samples. These sample locations are marked on the map below (Figure 1). We took four samples from each location. These soil samples were left in the Ecology Lab over a weekend to dry out.

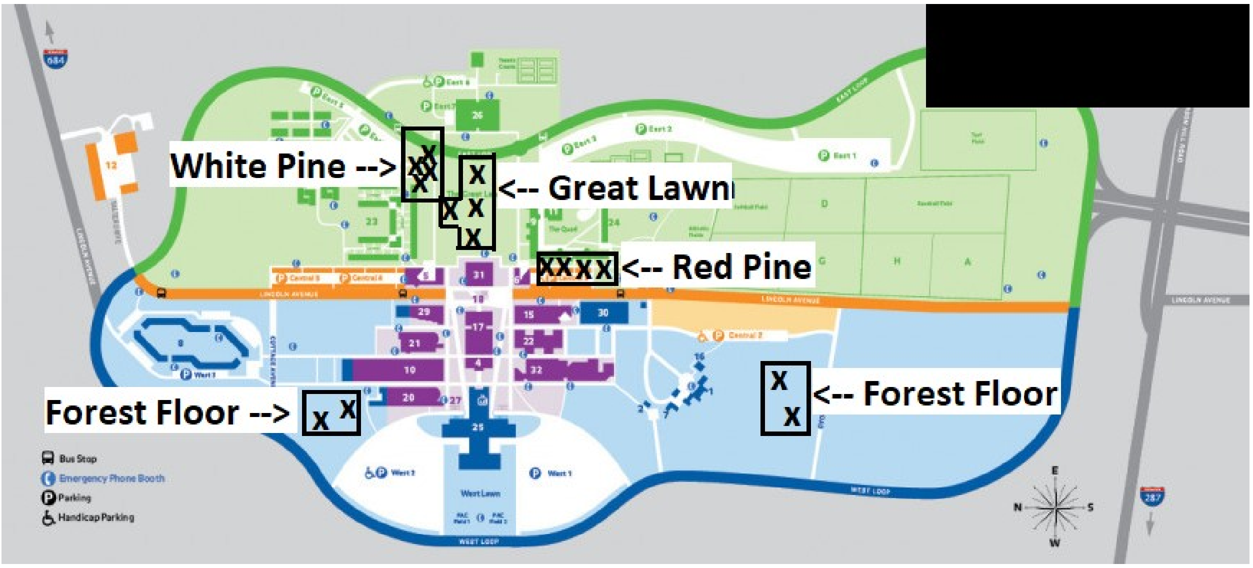

Figure 1. Soil Collection Sites on SUNY Purchase College Campus (X indicates each collection site).

We selected 4 different types of seeds to plant in our soil samples. The seeds were: Sweet Peas, Basil, Cosmos, and Catnip. We put our dry soil in pots and planted one type of seed in each pot. Four pots filled with potting soil were added as a control. We labeled each pot according to seed type and soil type. The potting array is shown below (Figure 2). These pots were then watered to saturation and placed in an incubator at 80 degrees Fahrenheit.

8 Sweet Pea Seeds Red Pine Soil	8 Sweet Pea Seeds White Pine Soil	8 Sweet Pea Seeds Forest Floor Soil	8 Sweet Pea Seeds Great Lawn Soil	8 Sweet Pea Seeds Potting Soil
10 Basil Seeds Red Pine Soil	10 Basil Seeds White Pine Soil	10 Basil Seeds Forest Floor Soil	10 Basil Seeds Great Lawn Soil	10 Basil Seeds Potting Soil
10 Cosmo Seeds Red Pine Soil	10 Cosmo Seeds White Pine Soil	10 Cosmo Seeds Forest Floor Soil	10 Cosmo Seeds Great Lawn Soil	10 Cosmo Seeds Potting Soil
10 Catnip Seeds Red Pine Soil	10 Catnip Seeds White Pine Soil	10 Catnip Seeds Forest Floor Soil	10 Catnip Seeds Great Lawn Soil	10 Catnip Seeds Potting Soil

Figure 2. Potting Matrix. Number of seeds placed in each soil type.

RESULTS

We checked on our plants every day for 17 days. The plants were watered every day and the number of seeds germinated per pot per day was recorded (Figure 3).

8 Sweet Pea Seeds (6 germinated) Red Pine Soil	8 Sweet Pea Seeds (8 germinated) White Pine Soil	8 Sweet Pea Seeds (7 germinated) Forest Floor Soil	8 Sweet Pea Seeds (6 germinated) Great Lawn Soil	8 Sweet Pea Seeds (8 germinated) Potting Soil
10 Basil Seeds (6 germinated) Red Pine Soil	10 Basil Seeds (8 germinated) White Pine Soil	10 Basil Seeds (8 germinated) Forest Floor Soil	10 Basil Seeds (8 germinated) Great Lawn Soil	10 Basil Seeds (8 germinated) Potting Soil
10 Cosmo Seeds (4 germinated) Red Pine Soil	10 Cosmo Seeds (3 germinated) White Pine Soil	10 Cosmo Seeds (3 germinated) Forest Floor Soil	10 Cosmo Seeds (3 germinated) Great Lawn Soil	10 Cosmo Seeds (2 germinated) Potting Soil
10 Catnip Seeds (1 germinated) Red Pine Soil	10 Catnip Seeds (2 germinated) White Pine Soil	10 Catnip Seeds (4 germinated) Forest Floor Soil	10 Catnip Seeds (0 germinated) Great Lawn Soil	10 Catnip Seeds (0 germinated) Potting Soil

Figure 3. Total number of seeds germinated in each soil type.

The soil found under the red pine trees yielded lower germination rates than almost all other soil types. The forest floor soil yielded the highest germination rate out of all other types- even higher than the control. The different amounts of seeds grown per soil type can be seen in (Figure 4).

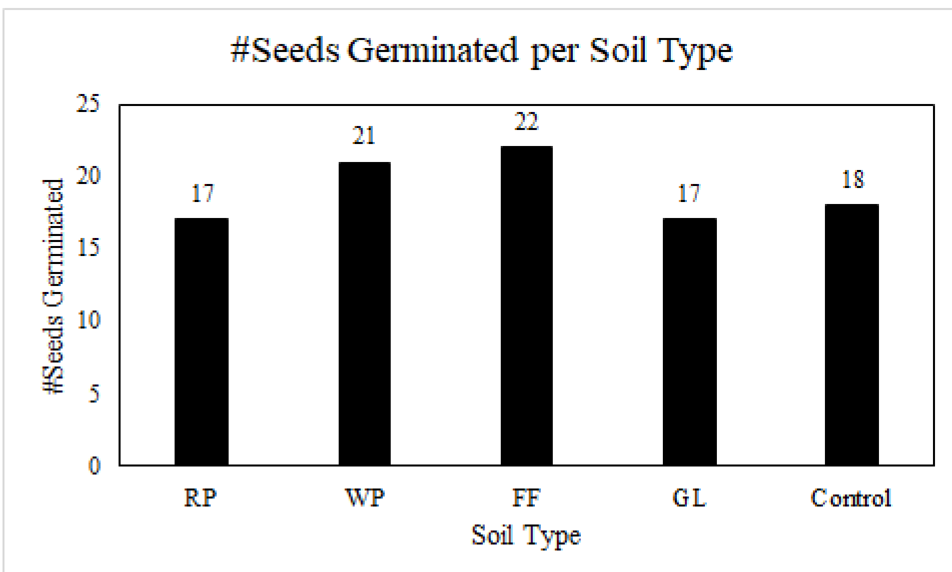

Figure 4. Total number of seeds germinated in each soil type. RP=red pine, WP=white pine, FF=forest floor, GL=great lawn

The seed growth array can be further broken down into a "per pot" view (Figure 5). This data is good for showing that not all seeds grew equally throughout the soil types. The Sweet Peas preferred the WP and Control soil and did worse in the RP and GL samples. The Basil did poorly in the RP soil, but did equally well throughout the other four samples. The cosmos preferred the RP soil and did poorly in the control. The catnip only did well in the FF sample and suffered everywhere else; so much so that it didn't even grow in the GL or Control samples.

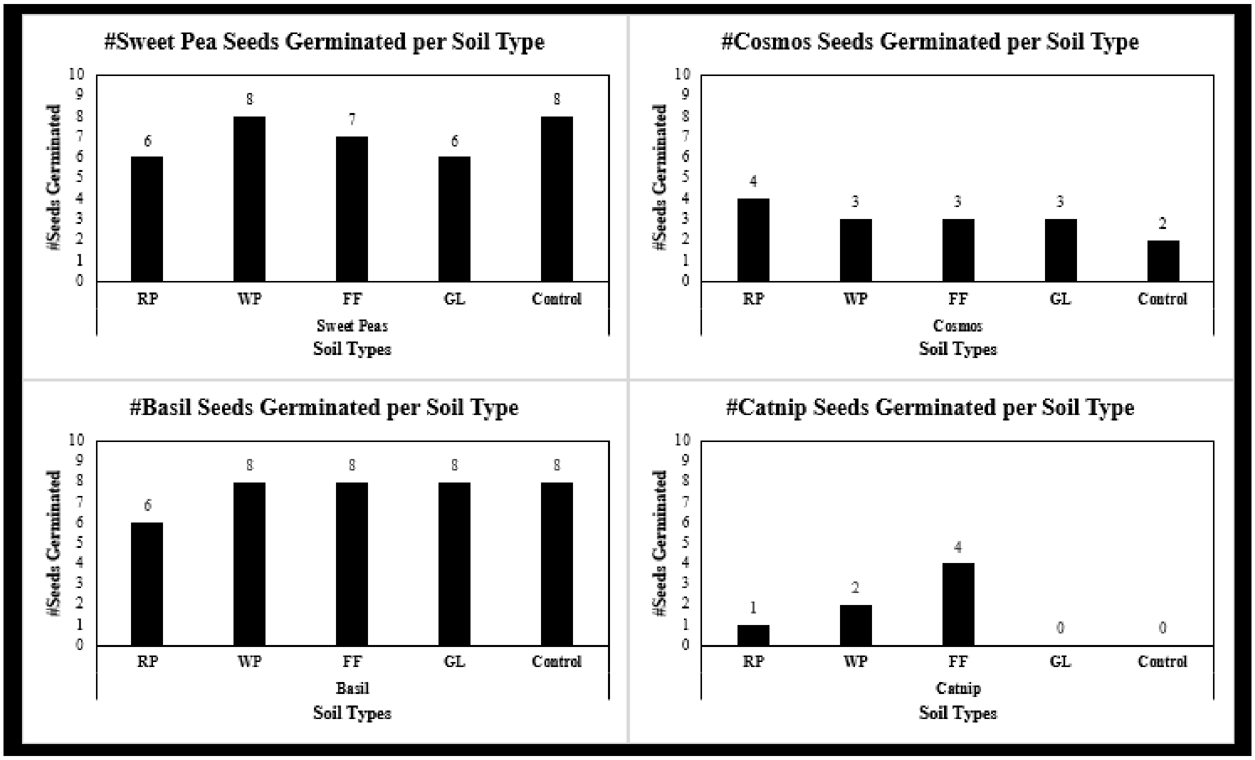

Figure 5. Total number of Sweet Pea, Basil, Catnip, and Cosmos seeds grown per pot.

DISCUSSION

In this study, we found that the soils collected from under the red pine trees had less seed germination than the soils that were collected at the other sites. The dropped needles of red pine trees inhibit the growth of plants (Kato-Noguchi et al. 2009). While we were collecting our pine soil samples, we observed that there was very little grass growth under the red pine trees. The allelopathy of red pine forests is involved in forming sparse understory vegetation (Kato-Noguchi et al. 2017). In the case of our pine soil samples, this would be tested for in the seeds ability to germinate compared to other soil types. A clear pattern can be noted as the red pine soil samples produced fewer seedlings than most other soil types (Figure 5).

Some seed types preferred specific soils over others. Pine needles, through defoliation and the breakdown of resin acids, alter the pH of soils by making them more acidic (Kato-Noguchi et al. 2017). It was listed on the seed packet that Cosmos can grow in a slightly acidic soil which is atypical of flowering plants. Sweet peas, the other type of flowering plant that we tested with, have the opposite preference- basic soil. This explains why the Sweet Peas didn't grow well in the acidic RP soil and why the Cosmos grew the best in this soil type. This may explain why the cosmos were the only seed type to show good growth in the RP soils- all other seed types grew poorly. The other soil type that we saw poor growth for was the GL soil. Grasses typically require a slightly acidic pH to thrive which is likely what the grounds crew for SUNY Purchase has been keeping the Great Lawn around. This slight acidity would yield similar results to the RP soil. This is evident with the Sweet Pea seeds, as their worst soil types are both RP and GL.

Analyzing environmental factors for the sample sites may yield additional hypotheses for why some plants did better than others. If we were to redo this experiment, it might be worth taking salinity values for the soil samples to test the osmotic stress values of the soil that we're about to plant in. If a soil is too salinated it may not allow for any seed germination as is the case for 7% of the earth's soils

(Flowers et al. 1997). Soil salinity has two likely effects on seeds: it can decrease the ease at which a seed gets water (osmotic stress) or it can facilitate the entry of ions into the seed which can be fatal in large doses to the fragile seedlings (ionization) (Ayers 1952).

Soil salinity as a whole is a major abiotic stress factor for already established plants (Zhu 2001). The same aforementioned stress factors (osmotic stress and ionization) can occur to a plant's root systems while the plant is fully developed as well as while it's still developing or in germination. This can be a major problem when it comes to agriculture worldwide. High soil salinities tend to yield poor crop qualities (Chinnusamy et al. 2004). This can be used as a tool to make certain soils unfavorable for certain plants to grow in. This may be useful in formatting a plan to combat invasive species.

There are many different ways that we could have approached this project or could re-approach it in the future. If we increased our sample size from 20 pots to 100, it would certainly yield more concrete results. In addition, if we ran the project for longer than 17 days, we may be able to test the allelopathic effects of pine needles on already established plants and not just seedlings. This might prove effective if we were to test the pine needle allelopathy as a method of eradicating the campus' invasive plant species. Our current experiment, if done with invasive plant seeds, may be good for determining whether or not said seeds would be inhibited by the pine allelopathy.

CONCLUSIONS

The red pine soil samples had the least amount of seedlings than the other soil types we tested. Soil allelopathy can hinder plant health, this can allow invasive plant species to move in and push out all of the native plants. With landscapes changing due to urbanization, the health of our native forests are being put under stress and are more vulnerable to allelopathy.

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