INVASIVE PLANTS ADVERSELY AFFECT SOIL CHEMISTRY AND GROWTH OF NATIVE SEEDLINGS

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ABSTRACT

*Invasive plant species pose a grave threat to biodiversity worldwide. Two such species, Japanese knotweed (*Reynoutria japonica*) and porcelain berry (*Ampelopsis glandulosa *var.* brevipedunculata*) are common and widespread in the northeast United States, including on the campus of State University of New York (SUNY), Purchase College. We assessed the pH and critical nutrient levels in soil found under these invasive species and compared them to those of soil found under spicebush (*Lindera benzoin*), a native species, and soil found under a woodlot containing mature native trees. We grew pumpkins (*Cucurbita pepo*) from seed in each soil type and compared germination rates and growth. While our findings on the concentrations of nitrogen (N), potassium (K), and phosphorus (P) were mixed, we found that the knotweed and porcelain berry soil types were basic and acidic, respectively, in contrast to the native soil samples, which were both neutral. Additionally, both germination of pumpkin seeds and growth of the seedlings were significantly lower when planted in the invasive soil samples than when planted in the native soil samples, possibly due to the effects of pH differences or of allelochemicals.*

Keywords: invasive species, Japanese knotweed (*Reynoutria japonica*), plant growth, porcelain berry (*Ampelopsis glandulosa* var. *brevipedunculata*), soil chemistry

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INTRODUCTION

Invasive species often have negative effects on multiple fundamental features of a community, including community structure, species richness and evenness, and overall diversity of an ecosystem. As global commerce continues to grow, so do the numbers, ranges, and impacts of anthropogenically spread species (Brenton-Rule 2016). Previous work has shown that invasive plant species have the ability to alter soil chemistry and structure, thus limiting competition from native plant species (Weidenhamer and Callaway 2010, Stinson et al. 2014, Huangfu and Li 2019). They alter the soil conditions to their own benefit, which allows them to outcompete native species (Lavoie 2017). However, the effects of invasive plants on soil chemistry are highly species-specific, and Dassonville et al. (2008) show that their effects are often dependent on a site's pre-invasion soil chemistry. Possible impacts include decreasing nutrients available to native species (McEwan et al. 2012, Lavoie 2017, Stefanowicz et al. 2017, Paulauskiene et al. 2018), altering the mycorrhizal fungal communities upon which native species rely (Burke et al. 2019), and secreting allelochemicals (Weidenhamer and Callaway 2010, Dommanget et al. 2014).

At SUNY Purchase College, invasive plant species are widespread, often colonizing recently disturbed areas, and are altering community structures by outcompeting native species for space and resources. Two such species are Japanese knotweed (*Reynoutria japonica*) and porcelain berry (*Ampelopsis glandulosa* var. *brevipedunculata*). Both are common in various parts of campus, particularly areas disturbed by construction and the edges of woodlots. Japanese knotweed is a shrub-like perennial in *Polygonaceae*, the buckwheat family. It can grow to more than two meters tall, spreads extremely quickly in dense thickets that, once established, are very persistent, and can thrive in a wide range of conditions. Often found near sources of water, it poses a particular threat to riparian ecosystems (United States Department of Agriculture Forest Service 2017*a*). Lavoie (2017) found a marked pattern among various studies in which knotweed adversely impacted soil chemistry, and Dommanget et al. (2014) found allelopathic effects by knotwood on two other plant species. The porcelain berry vine is a deciduous, woody perennial in *Vitaceae*, the grape family. It can grow more than 5 meters in a single growing season. It thrives in edge habitats and recently disturbed areas, especially anthropogenically disturbed areas, preferring full sunlight or partial shade to the full shade of mature forests. While it is slow to initially colonize new areas, once established it spreads rapidly, shading smaller plants and generally outcompeting native species (United States Department of Agriculture Forest Service 2017*b*).

We measured the pH and relative levels of key nutrients in soil found under Japanese knotweed, soil found under porcelain berry, soil found under native spicebush (*Lindera benzoin*), and soil found under the leaf litter in a mature woodlot with native tree species. We also grew pumpkins (*Cucurbita pepo*) from seed in each soil type to determine the relative ability of this native plant species to grow in soil potentially altered by knotweed and porcelain berry. Pumpkins are native to North America and are good bioaccumulators (Echem 2014, Paulauskiene et al. 2018), making them an excellent model for our purposes. We hypothesized that the soil chemistry of the invasive soil types would differ significantly from that of the native soil types and that pumpkin would not germinate or grow as readily in the invasive soil types.

METHODS

Site selection. We collected soil samples from four locations on the SUNY Purchase College campus on October 16, 2019 and October 23, 2019 (Fig. 1). Samples for invasive soil types were collected from underneath thickets of invasive Japanese knotweed and porcelain berry, respectively. For the native soil type, we collected soil from under native spicebush and from a late succession forest floor. Samples from each site were collected in the same manner: We used shovels to dig down below topsoil layer and collected the samples from the same depth, close to the roots. We then transferred the samples to the lab using labeled cups to continue the experiment.

Soil testing and planting. On both dates we used "Rapitest" soil test kits to determine the soil pH of each sample and the relative levels of potassium (K), nitrogen (N), and phosphorus (P). To test for pH, we added soil to the included test vial up to the fill line, filled the vial with deionized water, and dissolved the included indicator. After shaking the tube for 1 minute and allowed the mixture to settle for 1 minute, we were able to compare the color of the mixture with the included indicator colors. The nutrient testing was conducted by mixing 1 part soil with 4 parts deionized water and leaving the mixture for 24 hours. After 24 hours we filled the corresponding test vial with liquid from the mixture and dissolved the corresponding included indicator. After shaking for 1 minute, we waited 10 minutes to allow the color to develop. After the alloted time, we were able to compare the color of the mixture to the included corresponding indicator colors and values. These values allowed us to determine if the soil nutrient levels were depleted, intermediate, or high for the corresponding nutrient type. After soil testing, we planted the pumpkin seeds, using 3 cups for each soil type. We planted four pumpkin seeds in each cup, approximately 1 inch below the surface. The cups were then set in an incubator at 23 °C. Our decision to collect again on October 23 was due to a total lack of germination and growth in the invasive soil types up to that point and possible overwatering. From October 16 to October 23, we watered each replicate with 40 mL of tap water each day. Due to possible overwatering, we reduced this to 20 mL of tap water every few days (depending on soil moisture) for the remainder of the study. We measured the height of each seedling that sprouted once per week for 4 weeks for the replicates planted on October 16 and 3 weeks for the replicates planted on October 23.

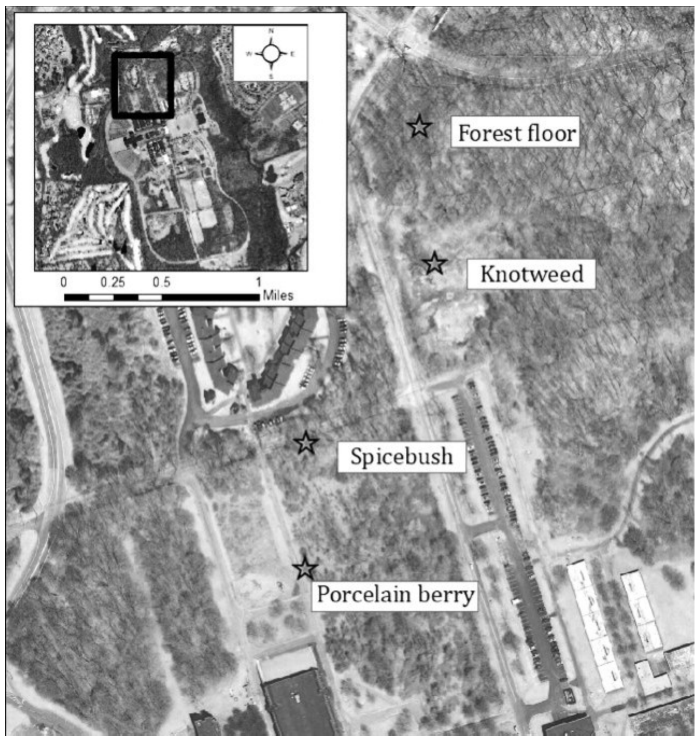

Figure 1. Study area: map of samples collected from four sites on SUNY Purchase College campus.

RESULTS

Seed Germination. Native soil types yielded greater germination rates than those of the invasive soil types (Fig. 2). The forest floor soil yielded the highest germination rate overall and spicebush yielded the next highest rate. The invasive soils took longer over the four-week period to germinate and were not as numerous as the native soil types used.

Overall, the total growth of germinated seedlings was greater in the native soil types, at 707.7 cm among the spicebush replicates and 609.7 cm among the forest floor replicates. The total growth among the knotweed replicates was 87.0 cm and was 69.0 cm among the porcelain berry replicates. Observing the mean height values (Fig. 3), forest floor and spicebush seedlings experienced greater growth with final mean heights of 22.2 cm and 21.4 cm, respectively, than those of porcelain berry at 8.4 cm and knotweed at 5.9 cm.

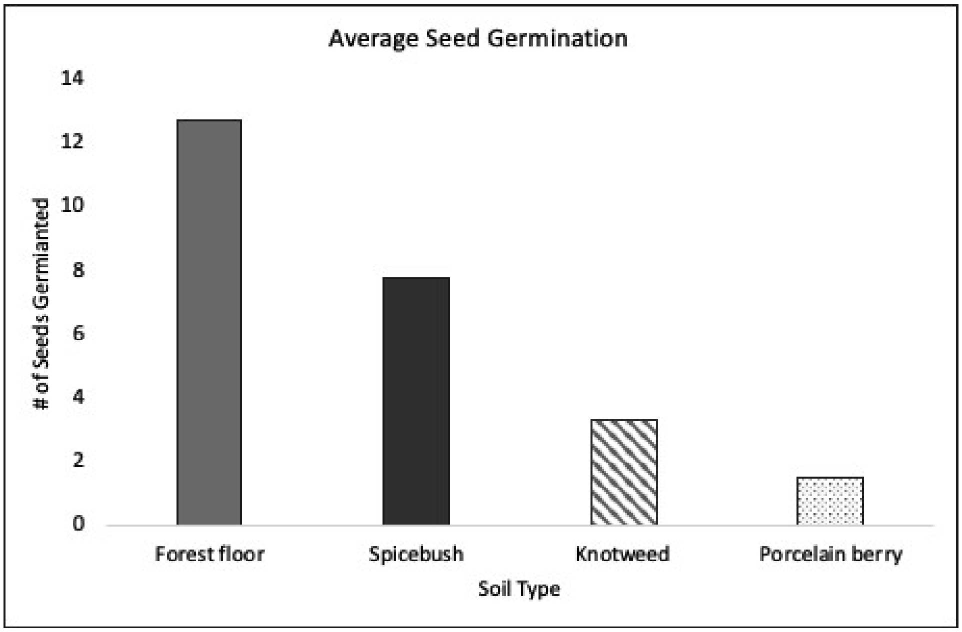

Figure 2. Average number of successfully germinated pumpkin seeds per soil type over the four weeks the experiment took place.

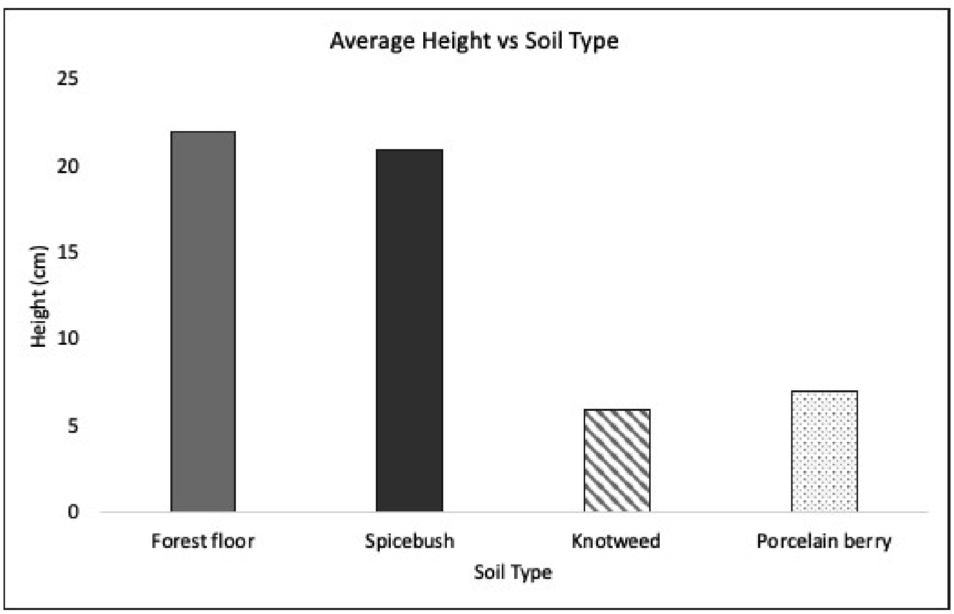

Figure 3. Average final height of pumpkin vs soil type.

Soil Nutrients. The pH values for both native soil types were neutral, while the porcelain berry soil type was slightly basic acidic a pH of 6.5 and the knotweed soil type was basic with a pH of 7.5 or greater (Fig. 4). Potassium and nitrogen varied greatly depending on the sample type (Fig. 5). A value of "1" = soil depleted of nutrient (lowest nutrient level), "2" = soil deficient of nutrients (intermediate nutrient level), and "3" = adequate amount of nutrient (highest nutrient level). Potassium was highest in both knotweed ("3") and porcelain berry ("3") soil type. These levels were lower in the native soil types, presenting as "2.5" in the forest floor sample and "2" in spicebush sample. Nitrogen levels were lowest in the invasive soil types, presenting as "1" in porcelain berry and knotweed samples. Phosphorus held constant across all native and invasive soil types.

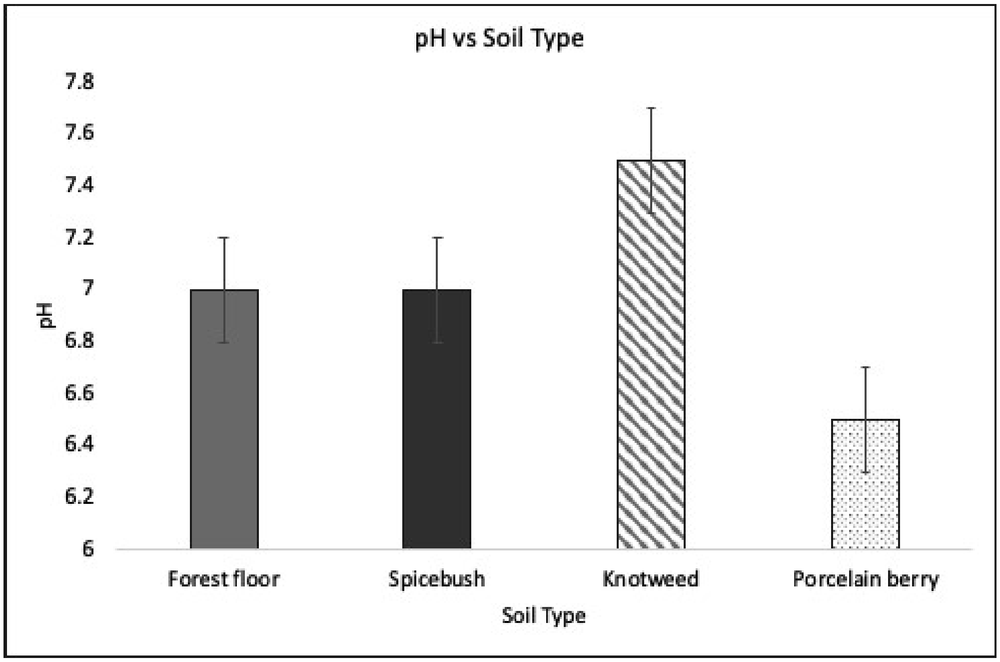

Figure 4. pH vs Soil Type. Results from October 16 were consistent with those from October 23. Error bars represent one standard deviation.

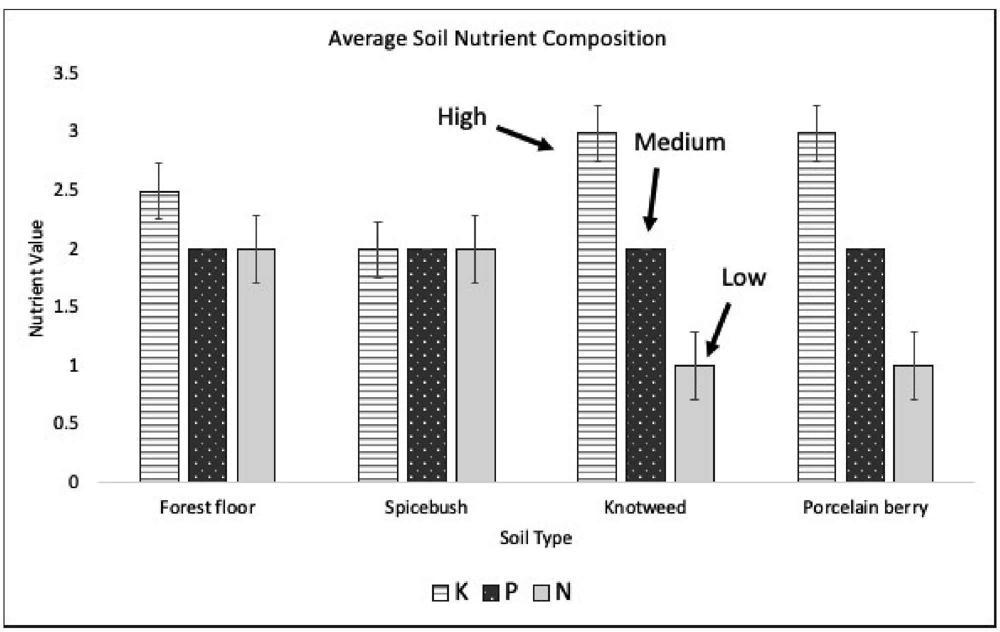

Figure 5. Average soil nutrient composition. Error bars represent one standard deviation. These results are an average of our findings from October 16 and October 23. A value of "1" = soil depleted of nutrient (lowest nutrient level), "2" = soil deficient of nutrients (intermediate nutrient level), and "3" = adequate amount of nutrient (highest nutrient level).

DISCUSSION

Germination rates for the native soil types proved to be more successful than those in the invasive soil types. The number of seeds germinated and the resulting height were both greater in native soil type while invasive types were not as numerous or successful. While the results for nutrient composition were mixed, the results of the pH tests show a clear difference between the native soil types, which were consistently neutral with a pH of 7, and the knotweed and porcelain berry soil types, which were basic and slightly acidic, respectively, with pH values of 7.5 or greater for knotweed and 6.5 for porcelain berry.

Our findings that knotweed and porcelain berry alter the soil pH are consistent with studies of other invasive plant species (Weidenhamer and Callaway 2010, Stinson et al. 2014, Huangfu and Li 2019) that have found alterations in soil chemistry, and with previous studies of knotweed (Stefanowicz et al. 2017, Lavoie 2017). Studies evaluating the impact of porcelain berry on soil chemistry were not readily available at the time of writing. It is possible that the changes in the invasive soil types account for some, if not all, of the discrepancy between germination and growth rates compared to the native soil types. Altering the soil pH may have dual benefits — it may be that knotweed grows better in basic conditions and porcelain berry grows better in slightly acidic conditions, that altering the soil pH reduces the relative fitness of competing native plants, or both.

It is also possible that one or both of the invasive species we tested secretes allelochemicals into the soil, like other successfully invasive plants have been shown to do (Lankau 2009; Silva et al. 2014; Li et al. 2015; Zheng et al. 2015). This is another potential explanation for our results regarding pumpkin germination and growth. Allelochemicals would be harmless to the plant that secretes them but would confer to that plant a marked advantage in competition for space by chemically limiting the ability of other plants to survive and grow in the area immediately surrounding the invasive plant.

Our largest potential sources for error are the imprecise nature of the tests we used to determine soil pH and nutrient levels and the irregularity of our watering regime. Though our results show clear trends, further testing with more standardized and precise protocols would lend much more certitude to our conclusions. The “Rapitest” soil test kit does not measure pH above 7.5, so it is possible that the pH of the knotweed soil sample was higher than 7.5. Though these results were confounded by variable watering regimes, the pumpkin seeds show a clear trend of higher germination rates correlated with the native soil types, and we measured significantly lower growth rates in the pumpkin plants grown in invasive soil types. Further testing with more precise equipment is especially needed to determine the exact pH of soil affected by knotweed. Additional studies could also examine other elements of soil chemistry or the makeup of soil microbial communities. Another potential for further study is the effects of these two invasives on mycorrhizal fungal communities. Studies of this manner are important for understanding soil composition on our campus, to hopefully advise management strategies for invasive species removal and the important conservation of native flora.

CONCLUSION

If confirmed by future studies, our findings indicate that both Japanese knotweed and porcelain berry alter soil chemistry and composition to their own benefit and to the detriment of neighboring native plants, one factor among many that makes them highly successful invaders. As with many other invasive plants, the ability to change the chemistry of the surrounding soil is a powerful advantage for these species, one which contributes to their ability to outcompete their rivals by reducing the relative fitness of the surrounding species. Invasive species ecology is highly variable, and our proposed explanations for our findings are just a few possibilities. Further studies are needed to explore the complex reasons for the success of these invasive plants.

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