RURALS: Review of Undergraduate Research in Agricultural and Life Sciences

Volume 11 | Issue 1 Article 2

8-22-2017

# Soil Feedback of Garlic Mustard (*Alliaria petiolata*) on Oat (*Avena sativa*) Plants

Brook Morris
*Kansas State University*, brookm@ksu.edu

Johanna A. Dille
*Kansas State University*, dieleman@ksu.edu

# Soil Feedback of Garlic Mustard (*Alliaria petiolata*) on Oat (*Avena sativa*) Plants

**Cover Page Footnote**
Thank you to my co-author, Dr. Dille, for helping me every step of the way. Dr. Anita Dille is a Professor at Kansas State University teaching Weed Ecology in the Department of Agronomy. Her email address is dieleman@ksu.edu, and her phone number is 785-532-7240. Brook Morris recently graduated from Kansas State University from the Department of Agronomy with Summa Cum Laude Honors. She is currently pursuing her MBA.

## 1. Introduction

Garlic mustard [*Alliaria petiolata* (M. Bieb.) Cavara & Grande] is a biennial weed species that originated in western Eurasia and has found its way into the United States, being first introduced in mid-1800s (Davis et al. 2012; Rodgers et al. 2008a). As settlers took up residence in the eastern colonies of the US, they brought with them a plant that would, in the future, be one of the quickest non-native plants to spread across the eastern and Midwestern US. Garlic mustard is estimated to spread at a rate of 6400 $km^2$ per year (Rodgers et al. 2008a). Garlic mustard was originally used as a flavoring substitute for cultivated garlic (*Allium sativum* L.). Today, garlic mustard is a weed that threatens the ecology of native forests due to its lack of natural predators (Eschtruth and Battles 2014), presence of compounds making it unpalatable to herbivores (Waller and Maas 2013), and early germination in the spring and taking up space before other plants begin to leaf out in the spring under forest canopies that are virtually undisturbed (Davis et al. 2012; Eschtruth and Battles 2014). As a biennial plant, it establishes itself as a rosette seedling in its first year, and it bolts, flowers and sets seed in its second year.

This non-native plant has quickly spread across the country, and several researchers have explored the impact of garlic mustard presence on soil properties and other native plant species in locations where it occurs (Davis et al. 2012; Roberts and Anderson 2001; Rodgers et al. 2008a, 2008b). The documented impact of garlic mustard has ranged from no effect to modest negative effects or even positive effects on native plants. When Roberts and Anderson (2001) compared germination and root growth of sorghum (*Sorghum bicolor*) or tomato (*Lycopersicum esculentum*) in agar medium with or without garlic mustard leachates, they documented shorter root lengths in presence of garlic mustard. However, Davis et al. (2012) conducted a four-year study in eastern Minnesota and determined that the percent ground cover of garlic mustard did not affect surrounding plants nor did the soil affect growth of bur oak (*Quercus macrocarpa*) seedlings. In a greenhouse pot study, the emergence, survival and growth of first-year bur oak seedlings were not affected by being grown in soil from below garlic mustard patches or soil from areas without. It was observed, however, that first-year green ash (*Fraxinus pennsylvanica*) seedlings grown in garlic mustard soil were 12% shorter (Davis et al. 2012). Repeating this study and also imposing drought conditions, no differences were observed on growth of these two tree seedlings based on source of soil (Davis et al. 2014). Another study found abundance of garlic mustard (competition) had negative effects on abundance of tree seedlings and grass-like species, but that herbs or shrubs were not impacted (Stinson et al. 2007) when surveying forested areas in eastern US.

Garlic mustard occurrence in Kansas is thought to be limited to the eastern portion and more research is needed to understand where garlic mustard occurs, and how its presence could affect soil properties and subsequently, growth and survival of other plants. Several agencies in many states produce brochures advising land owners on how to remove and control garlic mustard (e.g., Wisconsin, Panke and Renz 2012). It will be important to know if such invasive weed management plans are needed for Kansas. The purpose of this study was to locate populations of garlic mustard in Riley and Pottawatomie Counties (Kansas) and to determine how garlic mustard affects the soil in which it grows using the indicator crop plant, oat (*Avena sativa*). If it is found that garlic mustard changes soil characteristics that could deter other plants from growing in and around it, then garlic mustard could significantly impact native plants in those environments, and warrant the need for more aggressive control.

## 2. Materials and Methods

In order to know where to search for garlic mustard populations in Riley and Pottawatomie Counties, local agencies were contacted such as the county noxious weed directors, county extension agents, and Kansas State University Herbarium records, as well as distribution maps in the EDDMapS database (www.eddmaps.org/). A roadside survey of the southern portions of these two counties was conducted to identify populations of garlic mustard and these were documented using an iPhone with a map feature, dropping a pin at each location, as well as marking locations in a road atlas.

From two of the locations where garlic mustard populations were found, soil samples were taken and consisted of removing the top 8 to 10 cm of soil with a garden trowel from several places within the population and compositing the samples in a bucket. A soil sample was also taken from a nearby location (within 30 m) where there was no garlic mustard plants observed. Sampling was done in the spring of 2013, and repeated in the spring of 2014 from same general location. Soil samples were placed in plastic bags and stored in a freezer until the fall of each year. Enough soil was collected from each location and history of garlic mustard to provide a sample for the soil testing lab and to fill greenhouse pots for the greenhouse study.

Before initiating the greenhouse study each fall, soil was allowed to thaw at room temperature and 20 g of soil was submitted to the Kansas State University Soil Testing Lab. Soil was analyzed for pH, Mehlich-3 phosphorus (ppm), potassium (ppm), nitrate-nitrogen (ppm), and organic matter content (%). In 2013, one sample from each location and history was tested, while in 2014, two samples from each location and history were tested. The lab also conducted internal replications for some samples to ensure accuracy of the analysis.

The greenhouse experiment was initiated in the fall of 2013, and repeated in the fall of 2014 with new soil. The remaining thawed soil was evenly divided among 0.5-L plastic pots. In 2013, there were four pots for each location and history of garlic mustard, for a total of 16 pots, while in 2014, there were six pots for each location and history of garlic mustard, for a total of 48 pots.

Three oat seeds were planted in 2013 and two oat seeds planted in 2014 in each pot to be used as indicator plants that would respond to differences in soil characteristics. Pots were placed in a greenhouse with 25/15 C day/night temperatures in a 14/10 h day. Pots were watered twice each week. On a weekly basis, plant height, leaf number, tiller number, and florets number were recorded for each oat plant. Data were collected until the oat plants in each pot had lost all green color and had ceased growing. Data from 56 days after planting were used to compare among treatments.

The main effects and interactions of location and history of garlic mustard on oat plant height, leaf number, tiller number, and floret number per plant were tested using SigmaPlot (v.12) using a two-way analysis of variance (ANOVA). Least squared means and standard errors were calculated and are reported for those interactions or main effects that were significant at $P \leq 0.05$ for each year separately.

## 3. Results and Discussion

*Garlic mustard in Riley and Pottawatomie Counties, KS.*

When contacting various organizations, it was found that garlic mustard was not considered a noxious weed or even an invasive weed in Pottawatomie and Riley Counties, so county information was extremely limited. Based on records in the Kansas State University Herbarium database, there were 21 records of garlic mustard in Kansas with 11 records for Riley County and none for Pottawatomie County. The first sample verified was in 1937. Based on information in the EDDMapS database, garlic mustard populations have been observed in several KS counties (Figure 1). Through the roadside survey, no garlic mustard populations were found in Riley County, but at least 10 locations with garlic mustard populations were found in Pottawatomie County. These locations were near creeks (permanent or intermittent) and usually below a forested canopy.

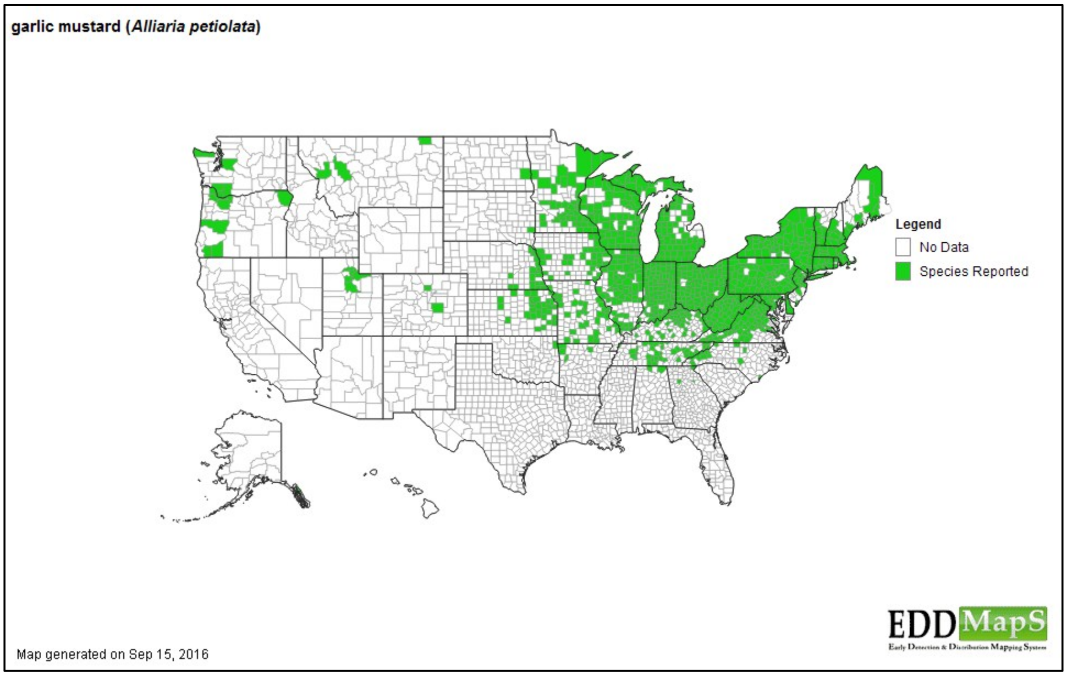


**Figure 1.** Distribution of reports indicating presence of garlic mustard (*Alliaria petiolata*) in each county as of September 2016 based on EDDMapS database.

*Soil characteristics with and without garlic mustard history.*

The sample from the Mt. Zion location (39.22564 N, 96.46773 W) was from a Reading (fine-silty, mixed, superactive, mesic pachic Argiudolls) or Clime-Sogn (fine, mixed, active, mesic udorthentic Haplustolls) silty clay loam soil, (NRCS 2016) while the sample from the St. George location (39.19133 N, 96.42368 W) was from a Wann (coarse-loamy, mixed, superactive, mesic fluvaquentic Haplustolls) fine sandy loam soil in 2013 and from a Thurman (sandy, mixed, mesic udorthentic Haplustolls) loamy fine sand soil in 2014 (NRCS 2016). Thus, the Mt Zion location had a loamy texture compared with the St. George location that was dominated by sandy texture. Each location was situated near a creek and under a forested canopy.

There were differences between the two locations in regards to soil pH, nutrient availability, and organic matter (Table 1). In general, soil pH was greater at Mt. Zion than at St. George in each year, irrespective of garlic mustard history. Also, potassium, Nitrate-N, and organic matter content were greater at Mt. Zion than at St. George in each year. Within a year and location, both the phosphorus and potassium concentrations were greater when garlic mustard was growing in the soil in each location (Table 1). The differences were not significant for St. George soils in 2013 for phosphorus concentration and were not different for Mt. Zion soils in 2014 for potassium concentration.

In general, the soils from Mt. Zion had more nutrients and greater organic matter content, which may translate into greater growth by the indicator oat plants.

**Table 1.** Soil properties for Mt. Zion and St. George, Kansas locations based on history of garlic mustard presence (yes) or absence (no) in 2013 (n=1 soil sample) and 2014 (n=2 soil samples).

| | | Garlic Mustard History | Soil properties | | | | |
|---|---|---|---|---|---|---|---|
| Year | Location | | pH | Phosphorus | Potassium | Nitrate-N | Organic matter |
| | | | | ppm | ppm | ppm | % |
| 2013 | Mt. Zion | Yes | 8.1 | 57 | 720 | 20 | 5.8 |
| | Mt. Zion | No | 8.0 | 28 | 450 | 23 | 5.6 |
| | St. George | Yes | 7.7 | 48 | 300 | 16 | 3.3 |
| | St. George | No | 7.3 | 48 | 169 | 10 | 3.7 |
| 2014 | Mt. Zion | Yes | 7.7 | 33 | 474 | 33 | 6.3 |
| | Mt. Zion | No | 8.0 | 22 | 427 | 16 | 5.1 |
| | St. George | Yes | 7.2 | 41 | 195 | 13 | 2.3 |
| | St. George | No | 6.3 | 15 | 91 | 4 | 0.9 |

*Oat productivity in soil with or without garlic mustard history.*

A significant interaction between location and history of garlic mustard influenced the height of oat plants and number of florets at 56 days after planting in 2013, while main effects of location or history of garlic mustard influenced oat height and floret number in 2014 (Table 2). In general, using oat as an indicator plant of soil characteristics, the oat was always taller in soil from Mt. Zion across both years irrespective of garlic mustard history. Oat was taller in each soil with history of garlic mustard except for St. George in 2013, where oat heights were not different from each other. In 2013, more florets were produced in soil from Mt. Zion with history of garlic mustard compared to soil with no history or both soils from St. George. In 2014, more oat florets were produced in soil from Mt. Zion than St. George, as well as more in soil with history of garlic mustard than no history by 56 days after oat planting.

**Table 2.** Mean oat height (cm) and floret number (± standard error) after 56 days of growth in soil with (yes) or without (no) garlic mustard history in 2013 and 2014. Means followed by the same lowercase or uppercase letter were not different at $P \leq 0.05$. Significant interaction was observed in 2013 while main effects were significant in 2014.

| Year | Location | Garlic mustard history | Oat height | Florets |
|---|---|---|---|---|
| | | | cm | # plant$^{-1}$ |
| 2013 | Mt. Zion | Yes | 45.6 (2.5) a | 4.8 (0.4) a |
| | Mt. Zion | No | 35.6 (2.9) b | 2.0 (0.5) b |
| | St. George | Yes | 17.9 (2.5) c | 0.6 (0.4) b |
| | St. George | No | 23.0 (2.5) c | 1.1 (0.4) b |
| | | | | |
| 2014 | Mt. Zion | -- | 38.1 (1.0) A | 4.5 (0.3) A |
| | St. George | -- | 31.7 (1.0) B | 2.7 (0.3) B |
| | -- | Yes | 40.8 (1.0) A | 5.3 (0.3) A |
| | -- | No | 29.0 (1.0) B | 2.0 (0.3) B |

No significant differences in oat leaf production were observed in 2013 with 5.1 (± 0.6) leaves per plant on average, while in 2014 more leaves were produced per plant when grown in soil with a history of garlic mustard (5.4 leaves plant$^{-1}$ ± 0.1) across both locations in 2014 as compared to no history of garlic mustard (4.8 ± 0.1).

No significant differences in oat tiller production were observed in 2013 with an average of 0.3 (± 0.4) tillers per oat plant, while the main effect of location was significant in 2014. Oat plants grown in either soil from Mt. Zion had more tillers per plant (0.8 ± 0.1) compared to plants grown in either soil from St. George (0.5 ± 0.1) in 2014.

Overall, oat plants grown in soils from Mt. Zion were taller and had more florets produced across both years. This corresponds to the greater nutrient concentration and organic matter content in soils from this location. The influence of history of garlic mustard at Mt. Zion was opposite to what was expected, in that oat plants were taller and had more florets in soil with previous history of garlic mustard. Rodgers et al. (2008b) were also surprised to observe that field populations of garlic mustard were associated with increased soil N and P availability, soil pH, and base cation availability compared to adjacent, uninvaded soils. The process by which garlic mustard presence might increases these soil properties was unclear. It was suggested that garlic mustard might increase N availability by accelerating the rate of litter decomposition of other plants, while changes in soil pH lead to the increase of P availability (Rodgers et al. 2008b). Understanding these processes would be an important area of future research.

This study determined that garlic mustard populations were found in the southern part of both Riley and Pottawatomie Counties, occurring near creeks and below forested areas. Soil nutrient concentration and organic matter content were greater in soils from Mt. Zion as compared to St. George, which likely contributed to the taller and larger oat plants when grown in soil sampled from Mt. Zion compared to St. George. Additionally, it was found that oat plants grown in soil with a history of garlic mustard presence were taller and produced more florets than soils with no garlic mustard history. These research results corresponded to those reported by Davis et al. (2012, 2014) in that garlic mustard did not have a negative effect on bur oak or green ash tree seedlings planted in soils with and without garlic mustard.

## 4. Conclusions

This study in Kansas found that soil with a history of garlic mustard did not have negative feedback effects on oat plant growth. It is still important to note that garlic mustard is spreading from east to west in Kansas because of no active management plans in place, and few natural predators that are present to deter its growth. Next steps would be to investigate control practices for garlic mustard in Kansas.

## 5. References

Davis MA, Colehour A, Daney J, Foster E, MacMillen C, Merrill E, O'Neil J, Pearson M, Whitney M, Anderson MD, Dosch JJ. 2012. The population dynamics and ecological effects of garlic mustard, *Alliaria petiolata,* in Minnesota Oak Woodland. Am. Midl. Nat. 168: 364-374.

Davis MA, MacMillen C, LeFebre-Levy M, Dallavalle C, Kriegel N, Tyndel S, Martinez Y, Anderson MD, Dosch JJ. 2014. Population and plant community dynamics involving garlic mustard (*Alliaria petiolata*) in a Minnesota Oak Woodland: a four year study. J Torrey Botanical Soc 141(3):205-216.

Eschtruth AK, Battles JJ. 2014. Ephemeral disturbances have long-lasting impacts on forest invasion dynamics. Ecology 95:1770-1779.

Kansas State University Herbarium. Retrieved from http://biodis.kstate.edu/collections/herbarium/ Accessed 25 Jan 2015, and http://www.k-state.edu/herbarium/database.html Accessed 10 Sept 2016

[NRCS] United States Department of Agriculture - Natural Resources Conservation Service Web Soil Survey. Retrieved from http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx Accessed 25 Jan 2015.

Panke B, Renz M. 2012. Management of Invasive Plants in Wisconsin: Garlic Mustard (*Alliaria petiolata*). A3924-07. University of Wisconsin-Extension: Madison, WI.

Roberts KJ, Anderson RC. 2001. Effect of garlic mustard [*Alliaria petiolata* (Bieb. Cavara & Grande)] extracts on plants and arbuscular mycorrhizal (AM) fungi. Am. Midl. Nat 146:146-152.

Rodgers VL, Stinson KA, Finzi AC. 2008a. Ready or not, garlic mustard is moving in: *Alliaria petiolata* as a member of eastern North American forests. BioScience 58:426-436.

Rodgers VL, Wolfe BE, Werden LK, Finzi AC. 2008b. The invasive species *Alliaria petiolata* (garlic mustard) increases soil nutrient availability in northern hardwood-conifer forests. Oecologia 157:459-471.

Stinson KA, Campbell SA, Powell JR, Wolfe BE, Callaway RM, Thelen GC, Hallet SG, Prati D, Klironomos JN. 2006. Invasive plant suppresses the growth of native tree seedlings by disrupting belowground mutualists. PLoS Biology 4, e140.

Waller DM, Maas LI. 2013. Do white-tailed deer and the exotic plant garlic mustard interact to affect the growth and persistence of native forest plants? Forest Ecology and Management 304:296-302.