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Common Buckthorn's *(Rhamnus cathartica)* Influence on Minnesota Soil Properties in Contrast to Native Black Cherry (*Prunus serotina*)

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Abstract
The invasion of common buckthorn (*Rhamnus cathartica*) into Minnesota has been altering native forests for over a hundred years. The invasive plant is known to compete with native flora for light and space, often successful in its efforts to beat out native plants. However, observations of the impact buckthorn is having on the below ground ecosystem is lacking. This study investigates the changes in soil properties following the invasion of common buckthorn in southern Minnesota forests. Soil characteristics including % organic matter, soil moisture, respiration and nitrate and ammonia levels were measured near buckthorn plants and compared to measurements taken near the native Minnesotan species, black cherry (*Prunus seroting*). Despite the limitation of this study, variations in soil quality among buckthorn and black cherry can be seen. Buckthorn exhibits slightly higher % organic matter and varying levels of nitrate and ammonium. Respiration measurements indicating microbial decomposition were significantly greater for buckthorn soils. The presence of macro invertebrates was also recorded and buckthorn soils supported significantly greater earthworm numbers. This information on differing soil conditions will be beneficial in designing comprehensive and effective forest restoration projects in the future.

Introduction

Buckthorn *(Rhamnus cathartica)* is a common invasive species that spread from its native European range into Minnesota in the mid-1800s (DNR 2016). The plant was introduced in greenhouses as a hedge or garden plant and quickly grew out of control in the area, invading forests. Growing to be a large shrub or small tree, the plant casts a large dense canopy of bright green leaves. Identification is aided by the retention of these leaves late into the season. A lack of natural predators or controls has lead to the prolific nature of these plants in Minnesota. Their spread into new areas is facilitated by avian dispersal of seeds, leading to rapid range extension (Gale 2000). Buckthorn has proven to be very competitive against native plants and has detrimental effects on forests.

The invasion of buckthorn in an area is followed by complete restructuring of the forest and a change in species composition. It has proven to inhibit success of native plants in a number of ways. One mechanism of its success is a dense canopy. This network of leaves outcompetes native plants for sunlight, thus eliminating a light starved understory. This restructuring of the forest leads to a barren forest floor, dense mid canopy and thinned upper canopy due to shading out of native seedlings, greatly reducing their survival and growth rate (Klionski et al. 2011). In addition, this canopy tends to persist late into the season, persisting nearly 2 months longer than native species. This extended growing season gives *R. cathartica* a competitive advantage of native plants and may cause phonological disjunction for certain species looking to capitalize on this late season period of light (Harrington et al. 1989). The inability for native species to cope with these changes leads to overwhelming success of buckthorn and a change in composition.

Efforts have been made to mitigate the effects of Buckthorn and reduce its numbers, primarily by listing it at as noxious weed in Minnesota but it is a difficult species to eliminate (DNR 2016). The efficient avian dispersal of its propagules necessitates complete regional removal to limit reestablishment (Gale 2000). Several methods of control are being used to eradicate *R. cathartica* but its persistent resprouting and capacity for dormancy require repetitive employment of control efforts. Mechanical, physical (use of fire), and chemical methods of control are all being used in an attempt to eradicate the species (Gale 2000). Mechanical control, or plant-by-plant removal from the soil, is the most widespread and environmentally friendly method but often the returns do not warrant the extensive effort required to pull plants. A Physical method, or controlled burning, is used to remove populations in areas adapted to fire but this method is only suited to areas with fire tolerant natives (Kline 1981). The last method, chemical, which has been recently gaining traction, involves applying herbicides to plants. This, however, must be done with caution due to significant environmental impacts of the herbicide. Prospective biological control methods have also been investigated but no sufficient organisms have been identified (Gassmann and Tosevski 2013). A combination of these efforts has successfully slowed the spread of buckthorn but it remains a prominent threat to most of Minnesota.

Restoration efforts following buckthorn eradication have showed variable results. Results of plantings and forest rebound following removal of buckthorn have not showed as great of success as hoped for. Flowering, growth, and overall survival of native plants in these ecosystems remain stunted for some time after eradication of the invasive buckthorn. These observations are reiterated by experiments analyzing growth following removal of buckthorn in plots (Klionsky et al. 2011). This legacy effect, or persisting inhibition of growth inherited by buckthorn, indicates there is an additional component to buckthorn's impact on native vegetation.

Some studies hypothesize that buckthorn's impact on the forest ecosystem go beyond effects due to canopy cover. Variation in Buckthorn leaf litter is believed to change soil properties such as pH, percent organic matter, soil moisture and general soil fertility (such as the presence of Nitrogen) (Heneghan et al. 2006). The dense leaf litter of Buckthorn has also shown to be positively correlated with the presence of invasive earthworms further affecting soil quality and the success of native plant species (Madritch and Lindroth 2009). These alterations to soil properties would subsequently affect the growth of native plants even after removal of buckthorn from the area.

Understanding the extent to which soil conditions have changed would provide critical information for designing effective forest restoration plans following buckthorn eradication. Plants that may have thrived in pre buckthorn soils may no longer be able to cope the altered conditions. Consideration of soil amelioration or particular species establishment would be necessary to increase success of restoration efforts (Heneghan 2004). A comprehensive understanding of how soils are affected allows for consideration of specific soil properties in forest management plans.

Through a multi proxy approach this study analyzed soil properties in the presence of buckthorn, with a comparison to soil properties of native black cherry (*Prunus serotina),* which occupies a similar ecological niche as that of buckthorn. The study measured soil moisture, percent organic matter, soil respiration, as well as nitrate and ammonia levels. To further analyze the below ground environment of buckthorn and its impact on the local ecosystem, macro invertebrates, particularly earthworms, were counted. The acquisition of this information aids in moving towards more comprehensive management and restoration strategies.

Methods

Sampling for this project was forest fragment in Northfield, MN. 12 sites were chosen, 6 near buckthorn and 6 near black cherry plants. 2 soil cores were taken 15 cm from the base of the plant at each site, one for soil density, percent organic matter and soil moisture and one for nutrient testing. Earthworms were counted at 3 of each types of site in a 30cm x 30cm plot using mustard powder to bring the invertebrates to the surface. Soil respiration was also measured at each site using a Li-COR soil respiration chamber.

Following sample collection further soil analysis was carried out in the lab. Soil mass was measured upon return to the lab and the sample was set to dry 48 hours at 105 degrees C. The sample was then massed again following dehydration in order to calculate the following characteristic:

$$\%\, moisture = \frac{weight\ of\ water}{dry\ weight\ of\ soil}\, x\ 100$$

To determine percent organic matter the same dried sample was passed through a 2mm sieve followed by drying in an oven at 105 degrees C and then 500 degrees C, massing the samples before and after each drying stint.

$$\% \; organic \; material = \frac{weight \; after \; 105 \; C - weight \; after \; 500 \; C}{weight \; after \; 105 \; C}$$

The remaining core that was not dehydrated was used to test for nutrient levels. Nitrate and ammonia levels were measured using the smartchem at St. Olaf College.

Statistical analysis was carried out using RStudio version 1.0.44 and R commander. Microsoft Excel version 14.6.3 we used to compile data and graph results.
were created using Microsoft Excel version 14.6.3. Analyses of variance (ANOVAs) were completed for organic matter, nitrate and ammonium levels, worm density, and respiration measurements between buckthorn and black cherry. A linear regression was used to analyze any relationship between earthworm density and respiration. Significance was established according to $p \leq 0.05$.

Results

An analysis of variance (ANOVA) analyzing % organic matter for buckthorn and black cherry indicated no significant relationship ($p=0.817$) between plant type and organic matter (Table 1). Significance was also absent for differences in % moisture between the two plants. Nitrate and ammonium levels in the 2 soil types displayed standard deviations too large to show any significance. Both nitrate and ammonium ANOVAs had p values > 0.1 (Tables 2 & 3). This indicates that, as far as our results show, plant type was not affecting nitrate and ammonium levels.

An ANOVA analyzing respiration in the absence and presence of buckthorn indicated a significant relationship ($p=0.0021$) between type of plant and respiration of

CO_2 (Figure 2). This indicates that plant type was affecting the flux of CO_2, indicative of microbial activity. Significance was also found ($p=0.0059$) for differences in earthworm densities between plant types (Figure 1). Buckthorn soils were found to support greater densities of earthworms than black cherry soils. A linear regression test indicated a nearly significant relationship ($p=0.0599$) between earthworm density and soil respiration. Due to a p-value above 0.05 we are unable to draw conclusions about the relationship between earthworm density and respiration but a larger sample size may lead to a significant positive correlation.

Discussion

Soil Characteristics

Buckthorn's expansive canopy is known to produce greater amounts of leaf litter. However, this is accompanied by rapid decomposition due to high nitrogen content in leaves (Larkin et al. 2013). The combination of these two characteristics allows for a lack of significant difference between % organic matter in buckthorn and black cherry soils (Table 1). Despite this high nitrogen content previous studies have not found significant and repeated patterns in nitrate and ammonium levels, which is supported by our results (Tables 2 & 3). This may be due to the rapid cycling of leaf litter through the system and accompaniment of % organic matter patterns. Measures of total nitrogen however may produce different results.

Earthworm density results indicate a preference for buckthorn soils (Figure 1). This pattern has been found in previous studies as well. Though the verdict is still being discussed it believed that a high concentration of calcium in buckthorn litter attracts earthworm activity (Burtelow et al. 2008). These two organisms interact in a positive feedback loop to facilitate their success in the area. This exotic co-facilitation, both earthworms and buckthorn being invasive species, compounds the their negative impacts on native species and forest ecosystems.

Earthworms degrade organic matter, therefore facilitating decomposition. This increase in decomposition in the presence of higher earthworm densities leads to faster nutrient cycling of buckthorn's high quality leaf litter, thus affecting one of the core characteristics defining soil quality. Passage through the earthworm's digestive track is also known to leave soil with more easily mineralizable nitrogen and carbon (Burtelow et al. 2008). Easily mineralizable N and C is more readily available to microbial degradation.

Respiration results indicate greater microbial activity in buckthorn plots (Figure 2). A combination of buckthorn's high N leaf litter and the increased presence of earthworms are likely the reasons for this (Heneghan et al. 2004). The greater microbial activity of buckhorn soils compounds the rapid degradation in the presence of earthworm activity leading to rapid nutrient cycling.

Consequences for Soil and Vegetation

An increase in degradation components to the soil such as earthworms and microbial activity changes soil quality, primarily through inputs of high quality leaf litter (Miller 2010). This rapid turnover of nutrients increases soil fertility. Altered buckthorn soils, thus, disrupt the natural balance of conditions that native species thrive in (Klionsky et al. 2011). Enhanced fertility, as well as alteration to other soil chemistry properties such as pH and soil moisture, eliminates the competitive edge of native plants in Minnesota ecosystems. Native plants are unable to cope adequately with these new conditions and are thus negatively impacted by soil conditions following the invasion of buckthorn.

Application to Restoration

Because alterations to soil properties directly affect the success of vegetation in the area, it is critically important include this variable when assessing forest management. Personnel involved in restoration of a following the eradication of buckthorn are faced with designing a plan to best establish the native forest of the area. For the greatest success in restoration it is necessary to consider to what extent soils are affected and how to compensate for these changes. Oversight of these variables may lead to decreased growth, reproduction, or survivorship of native plants following buckthorn's removal (Klionsky 2010).

Armed with knowledge regarding changes to soil, managers are able to design effective plans incorporating selective plantings of certain species or soil amelioration allowing for a successful and prolific native forest.

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Literature Cited

Burtelow, A. E., P. J. Bohlen, and P. M. Groffman. 1998. Influence of exotic earthworm invasion on soil organic matter, microbial biomass and denitrification potential in forest soils of the northeastern United States. Applied Soil Ecology **9**:197-202.

DNR, M. 2016. MN DNR Buckthorn.

Gassmann, A., and I. Tosevski. 2014. Biological control of Rhamnus cathartica: is it feasible? A review of work done in 2002–2012. Journal of Applied Entomology **138**:1-13.

Gale, Samuel W. 2000. Control of the Invasive Exotic Rhamnus cathartica in Temperate North American Forests. Restoration and Reclamation Review 6(5).

Heneghan, L., F. Fatemi, L. Umek, K. Grady, K. Fagen, and M. Workman. 2006. The invasive shrub European buckthorn (Rhamnus cathartica, L.) alters soil properties in Midwestern U.S. woodlands. Applied Soil Ecology **32**:142-148.

Heneghan L, Rauschenberg C, Fatemi F, Workman M. 2004. European buckthorn (Rhamnus cathartica) and its effects on some ecosystem properties in an urban woodland. Ecological Restoration 22: 275–280.

Iannone, B. V., L. Heneghan, D. Rijal, and D. H. Wise. 2015. Below-ground causes and consequences of woodland shrub invasions: a novel paired-point framework reveals new insights. Journal of Applied Ecology **52**:78-88.

Klionsky, S. M., K. L. Amatangelo, and D. M. Waller. 2011. Above- and Belowground Impacts of European Buckthorn (Rhamnus cathartica) on Four Native Forbs. Restoration Ecology **19**:728-737.

Larkin, D. J., J. F. Steffen, R. M. Gentile, and C. R. Zirbel. 2014. Ecosystem Changes

Following Restoration of a Buckthorn- Invaded Woodland. Restoration Ecology **22**:89-97.

Madritch, M. D., and R. L. Lindroth. 2009. Removal of invasive shrubs reduces exotic earthworm populations. Biological Invasions **11**:663-671.

Miller, S. 2011. Effects of Rhamnus cathartica (common buckthorn) stand age on decomposition.

Roth, A. M. 2015. Common buckthorn (Rhamnus cathartica), European earthworms, and ecosystem management: Invasion and restoration in Minnesota's deciduous forests. UNIVERSITY OF MINNESOTA.

Table 1. ANOVA comparing means of organic matter for buckthorn and black cherry soils. The p-value is 0.817, so the difference in means in not significant. Results indicate that the presence of buckthorn does not affect the % organic mater of the soil.

	n	Mean	Standard Deviation
Buckthorn	6	0.101	0.018
Black cherry	6	0.099	0.015

Table 2. ANOVA comparing means of nitrate (NO3) concentrations in buckthorn and black cherry soils. The p-value is 0.12. This indicates there is no significant difference between buckthorn and black cherry nitrate levels.

	n	Mean	Standard Deviation
Buckthorn	6	1.09	0.49
Black cherry	5	2.09	1.33

Table 3. ANOVA comparing means of ammonium (NH4) concentrations in buckthorn and black cherry soils. The p-value is 0.158. This indicates there is no significant difference between buckthorn and black cherry ammonium levels.

	n	Mean	Standard Deviation
Buckthorn	6	13.29	13.72
Black cherry	6	4.7	1.44

Table 4. ANOVA comparing means for respiration (CO2) in parts per million for buckthorn and black cherry soils. The p-value is 0.0021, so the relationship is significant. Soils near buckthorn displayed greater respiration, a proxy for microbial activity.

	n	Mean	Standard deviation
Buckthorn	6	632.83	13.88
Black cherry	6	592.33	19.73

Table 5. ANOVA comparing means for worm density (#worms/square foot) in soils near buckthorn and black cherry. The p-value is 0.0059, so the relationship is significant. Buckthorn soils support a greater density of earthworms than black cherry soils.

	n	Mean	Standard Deviation
Buckthorn	3	49	7.21
Black cherry	3	26.67	0.58

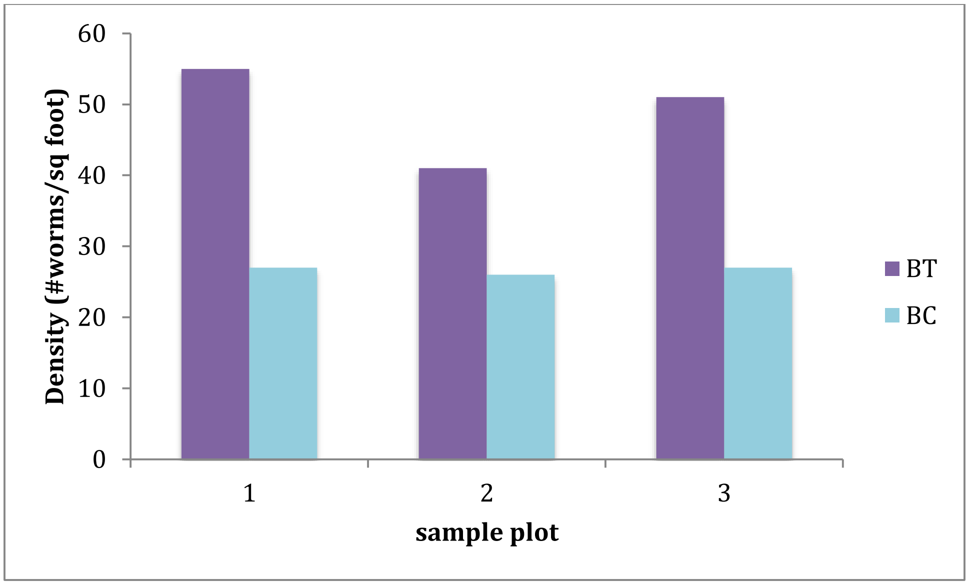

Figure 1. Graph depicting earthworm densities for sites 1-3 at buckthorn (BT) and black cherry (BC) plants. An ANOVA (Table 5) indicates there is a significant difference ($p=0.0059$) in worm density for buckthorn and black cherry. Buckthorn soils support a greater density of earthworms than black cherry.

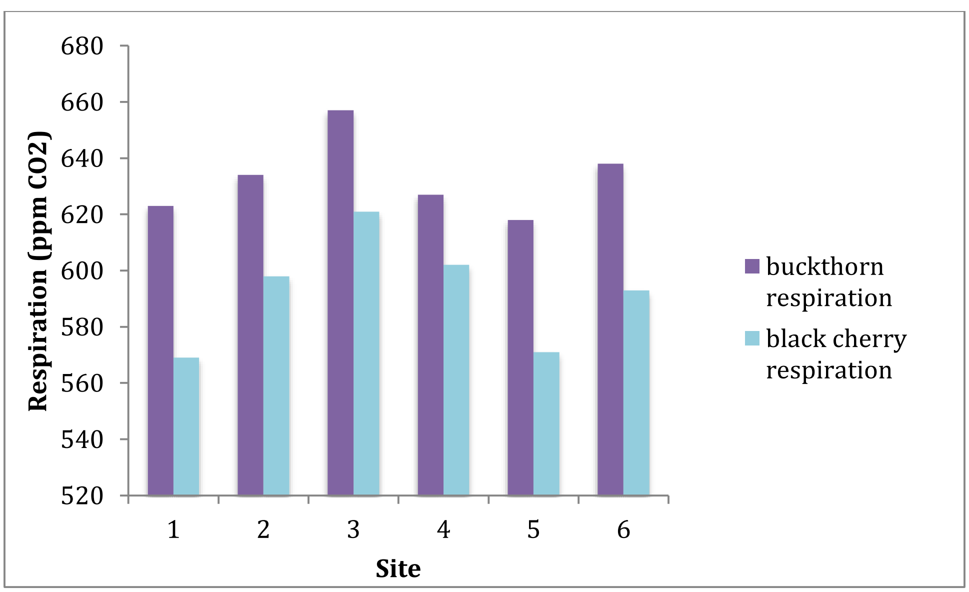

Figure 2. Graph depicting respiration (ppm) of soils near buckthorn and soils near black cherry plants. An ANOVA (Table 4) indicates there is a significant difference (p=0.0021) in respiration for buckthorn and black cherry environments. Buckthorn has greater respiration, indicating more microbial decomposition.

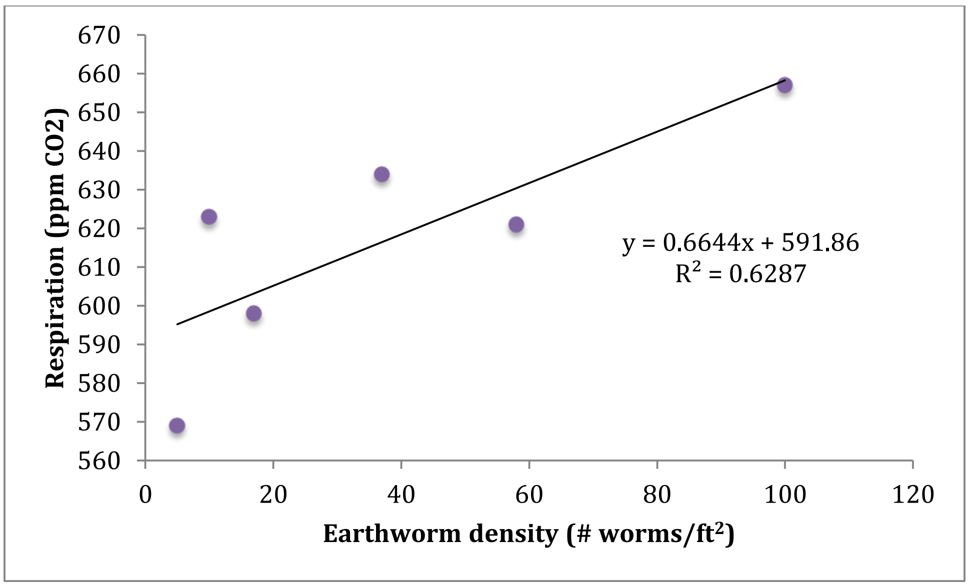

Figure 3. A linear regression analysis of earthworm density compared to respiration displays a nearly significant positive correlation (p=0.059) but sample size remains too small with too large of variation to draw definitive conclusions.