

An investigation into the effects of arbuscular mycorrhizal fungi (AMF) to dark septate endophytes (DSE) ratio on the coarse root to fine root ratio at varying elevation in the rocky mountains

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Abstract

Belowground systems are crucial for sustaining ecosystem function, but often remain unseen. Not very much is known about these systems and improving knowledge of them can aid understanding of ecosystems. Elevational gradients can be good places to test how above- and belowground systems respond to changes in climate. In this study I wanted to see how the relationship between mycorrhizal fungi and plants changes in response to elevation by observing changes in root and shoot biomass. I sampled from three sites of varying elevation and collected aboveground biomass and root biomass. The latter was divided into coarse root and fine root biomass. I then compared changes in biomass across the elevation gradient. I found that both fine and coarse root biomass tended to increase with elevation. The ratio of fine to coarse root biomass decreased with increasing elevation. Therefore, plants at high elevation produce fewer fine roots relative to coarse roots. This indicates a greater reliance on mycorrhizal relationships at high elevation which are dominated by DSE. This study shows the influence of underground biomes on the physiology of plants and showcases the diversity of these biomes across elevation.

Introduction

Ecologists tend to focus on what they can see aboveground, but interactions in the soil can be important for the structuring of ecosystems. In fact, roots and their associated fungi can make up most of the biomass in grassland ecosystems. Roots and their associated fungi are important for nutrient and water acquisition, anchor plants in stressful environments, and store carbon and nutrients of perennials over the winter. Thus, understanding how roots and their associated fungi respond to changes in ecosystems is important if we want to understand how biodiversity and ecosystem productivity will respond to perturbations like climate change.

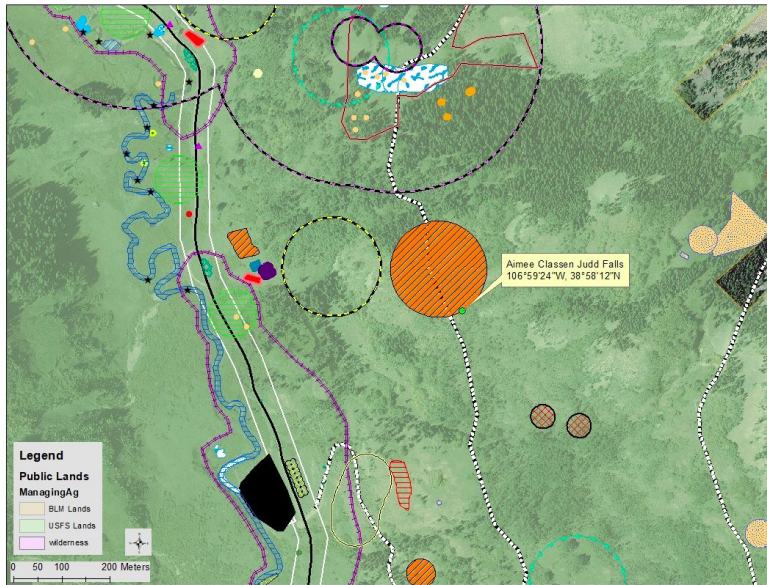
Environmental gradients are good places to explore how plants -- above- and below-ground -- respond to variation in the environment. A study by Sudqvist et al. (2013) determined that elevational gradient studies are useful for predicting ecosystem wide responses to climate change. A previous study in the arctic tundra by Blume-Werry et al. (2018) found that total plant biomass was greater at low elevation but that the ratio of below to above ground plant biomass remained consistent. This study also found that plants increased fine root biomass relative to coarse root biomass with increasing elevation. This means plants at high elevation in the arctic tundra have to produce more fine root to acquire the nutrients they need. This pattern is not universal and indicates the diversity of mountain ecosystems.

Clearly, roots are important below-ground structures. Generally, roots are divided into two categories based on their structure and function. Coarse roots are larger and provide structural support. Fine roots are associated with nutrient uptake and mycorrhizal relationships. The resource allocation of plants into producing either one type of root or the other could be an indication of the relative importance of either task for the survival of the organism. The type of mycorrhizal fungi can also influence the interspecies relationship. AMF or arbuscular mycorrhizal fungi are symbiotic fungi. DSE or dark septate endophytes can be mutualistic or parasitic. Some evidence suggests that DSE may be more prevalent at higher elevation in the rocky mountains. (Schmidt et al. 2008) Mutualistic relationships are able to maintain soil quality as plant populations shift. Additionally mycorrhizal root relationships may help ecosystem resistance to invasion and increase resilience to disturbance, (Henning, J. A., Q. D. Read, N. J. Sanders, and A. T. Classen. 2019) Data on mycorrhizal community composition in mountains collected by Dr. Jeremiah Henning found a fungal population shift across elevation in the rocky mountains. AMF dominates low elevations while DSE dominates high elevation. It is unclear why this change occurs. In this study I will be examining change in coarse root, fine root and shoot biomass to determine the effects of this change in soil biome across elevation.

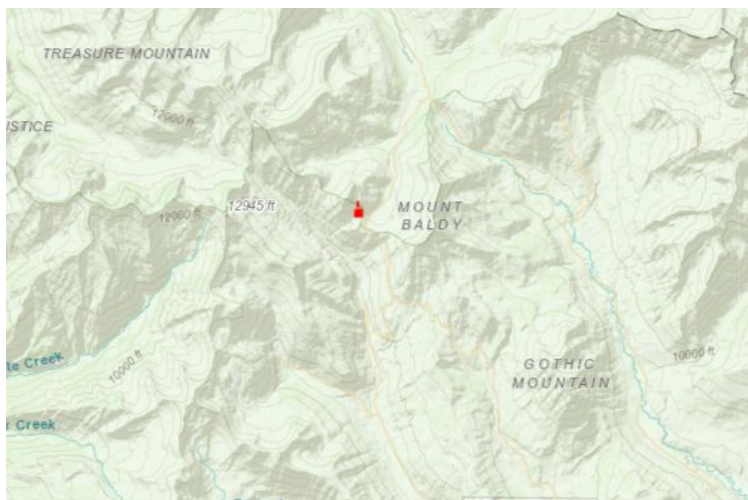
I hypothesise that coarse and fine root biomass will change to reflect changing conditions across elevations. A reduction in fine roots signals an increase in reliance on a mycorrhizal partner for obtaining nutrients. I expect to find an increased reliance on mycorrhizae as growing conditions become harsher. Therefore I expect to find a relative decrease in fine roots at high elevation. In this study I used three sites in montane meadows along an elevational gradient to explore the effects of changing climatic conditions on mycorrhizal relationships.

Methods

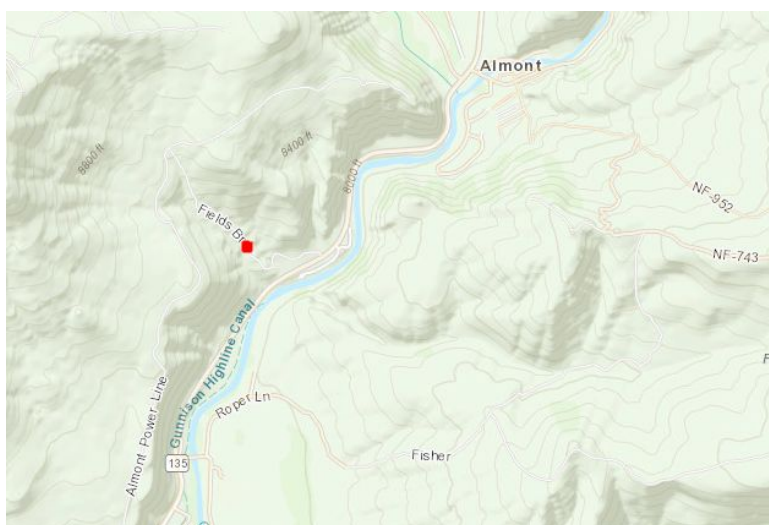
In July of 2020, I selected three sites along an elevational gradient near Gothic, Colorado USA. The high elevation site was situated at Cinnamon mountain (38.99,-107.06). The mid-elevation site was located near Judd falls (38.97,-106.99). The low elevation site was located in the Almont triangle (38.65,-106.86). The three sites had elevations of 3460m, 2943m, and 2480m respectively. Sites are displayed in figure 1.



a



b



c

Figure 1 maps of study site locations. 1a is the judd falls site, figure 1b is the cinnamon site, figure 1c is the almont site.

I selected three plots to sample within each site randomly by spinning around a few times with my eyes closed before tossing an identifiable object to mark the center of the quadrant. Each plot was 0.5 m² as determined by a quadrant. The quadrant was divided into twenty five sections to better enable a visual estimate of ground cover. I estimated ground cover by species so that variation in root structure could be compared to variation in species composition. Any unknown species was identified by herbarium specialist Dr. C. F. Rick Williams. All living ground cover biomass was collected for drying.

After biomass collection four soil samples were taken from each plot using a soil core. Cores were 10 cm deep as determined by perpendicular measure to the ground except in cases where extraneous factors prevented a depth of 10 cm from being reached. The four soil samples were then combined into one sample per plot. Soil samples were then sifted through for roots using a 2mm pore sieve and forceps. Only live roots were selected with the dead roots being determined by a lack of elasticity. Roots were divided into either coarse roots or fine roots. Coarse roots were any roots with a diameter equal to or greater than 1mm while fine roots were any roots under 1mm in diameter. Any fine roots connected to coarse roots were cut so that roots could be better divided into the proper diameter category. Root diameter was measured using calipers. All roots were rinsed with DI water to remove excess soil.

Ten of the root pieces of each fine root sample were randomly selected and scanned using a flatbed scanner for image analysis. These images were used to analyse the branching pattern of the roots. Coarse roots were not included because of the manipulation to remove connected fine roots. The images were analysed using image J.

The roots were then dried with scanned fine roots separated from those not scanned so the branching pattern could be compared to weight. Roots were dried in a drying oven at 60°C for 120 hrs before weighing. All living ground cover biomass was dried at 60°C in a drying oven for 72 hours before weighing. Samples were weighed in small batches and given five minutes to ensure all samples equally absorbed atmospheric moisture.

Results

I compared the biomass of fine root across all the elevation sites. Fine root biomass increases with elevation (P value 0.2353). Coarse root biomass also increases with elevation (P-value = 0.18527). When comparing the fine to coarse root ratio across elevations, low elevation has the greatest fine to coarse root ratio. High elevation has the lowest fine to coarse root ratio. And the ratio for mid elevation is between that of low and high (P-value = 0.13479).

I then did correlation/regression to look for any effects of ground cover on root biomass. There is a loose association between forb ground cover and coarse root biomass. Woody shrub groundcover is positively correlated with coarse root biomass. Woody shrub

groundcover is more strongly positively correlated with fine root biomass. Coarse root biomass is negatively correlated to graminoid groundcover.

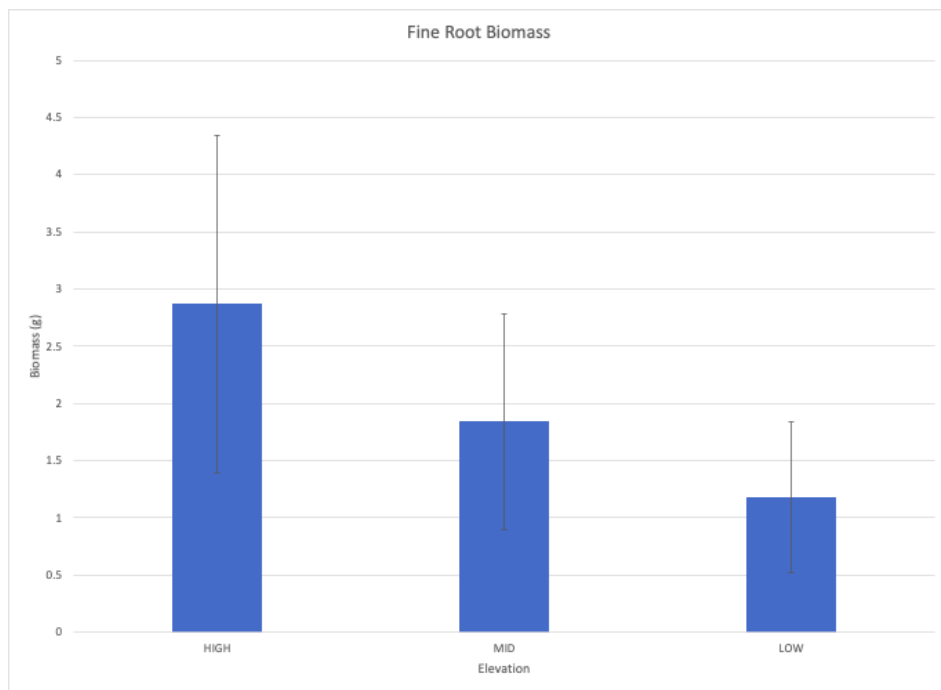


Figure 2: Fine root biomass tends to increase with elevation.
P value 0.2353

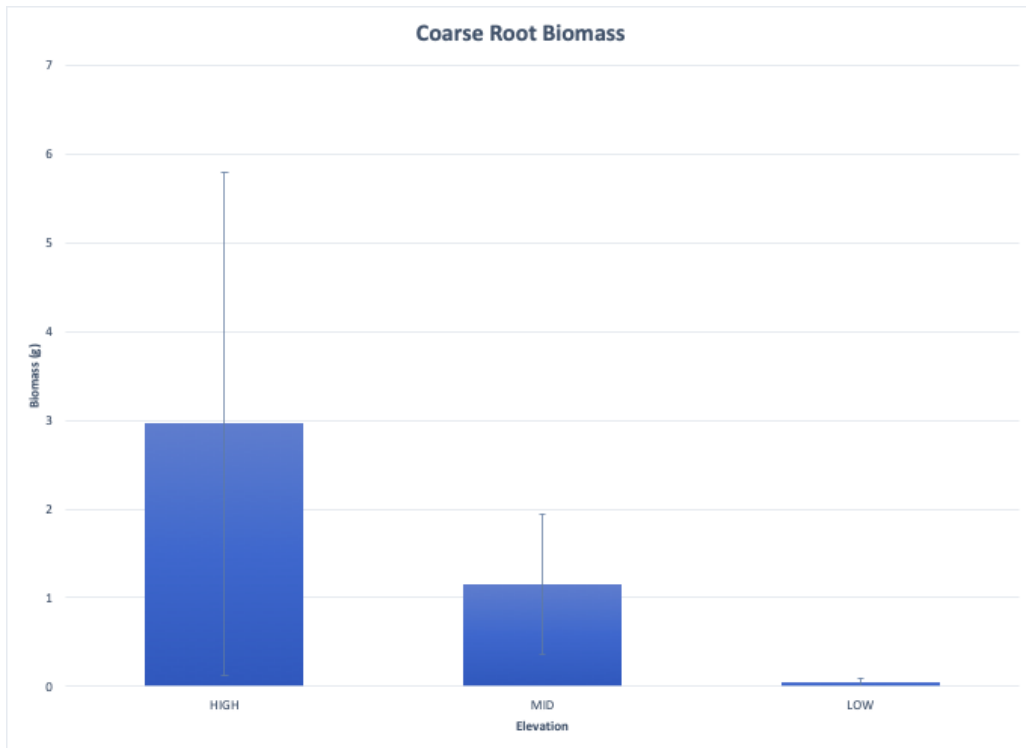


Figure 3: Coarse root biomass tends to increase with elevation. P-value = 0.18527

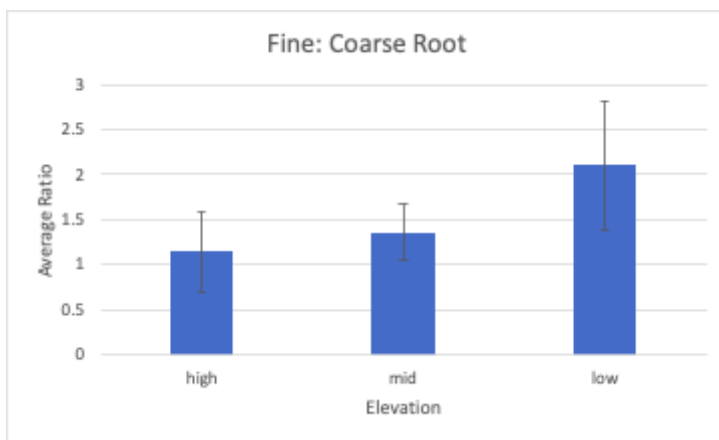


Figure 4: Fine to coarse root ratio across elevations. P-value = 0.13479

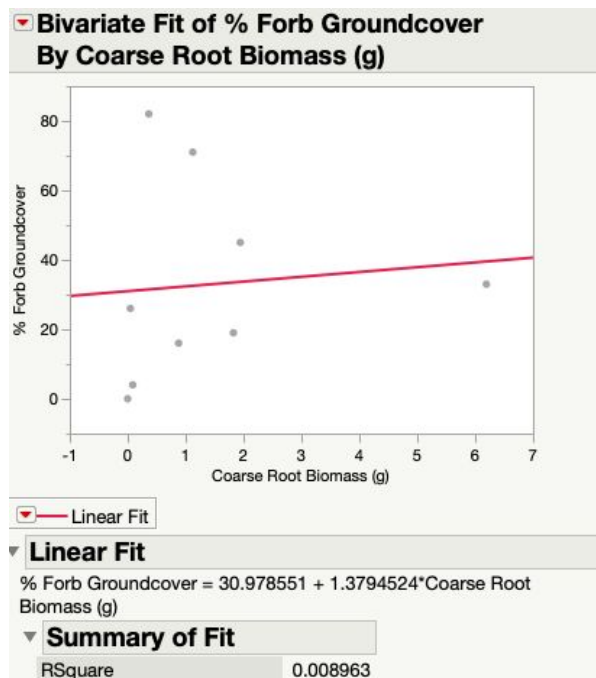


Figure 5 : Linear correlation between coarse root biomass and forb ground cover.

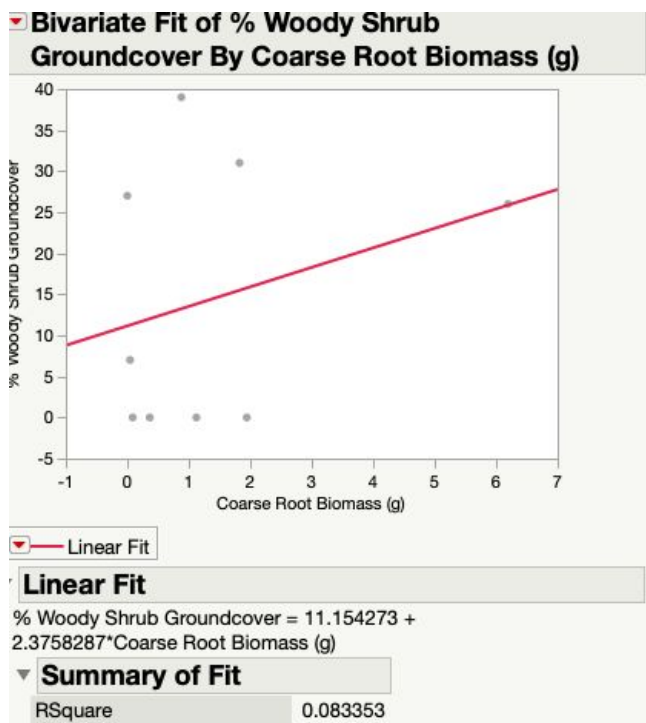


Figure 6: Linear correlation between coarse root biomass and woody shrub groundcover. Woody shrub groundcover is positively correlated with coarse root biomass.

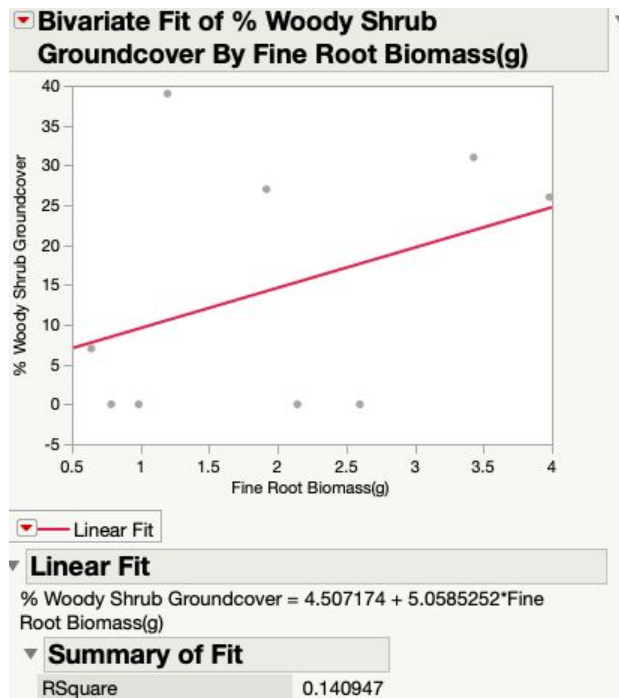


Figure 7: Linear correlation between fine root biomass and woody shrub groundcover. Woody shrub groundcover is positively correlated with fine root biomass.

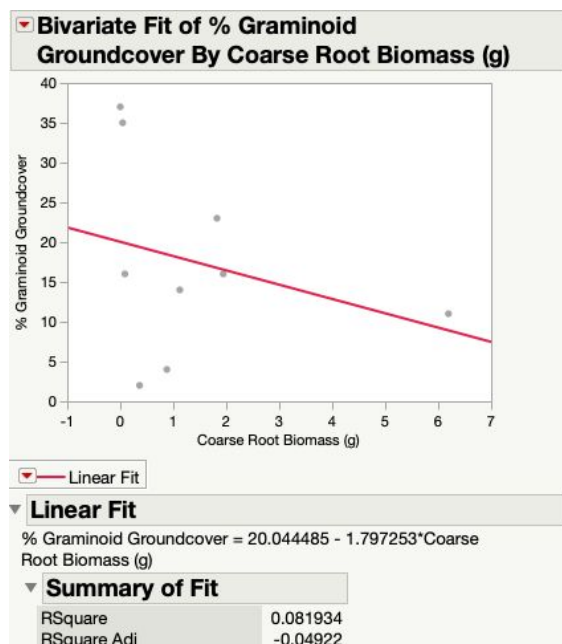


Figure 8: Linear regression of coarse root biomass by graminoid groundcover

Discussion

I set out to explore how plants -- above- and below-ground -- responded to shifts in elevation. I hypothesised that fine and coarse root biomass would change to reflect differing soil biome conditions across elevations. Overall, my data indicated that the fine to coarse root ratio decreased with increasing elevation. The low elevation site had the highest fine to

coarse root ratio. High elevation has the lowest fine to coarse root ratio. This pattern follows my hypothesis. The High elevation plants appear to be producing fewer fine roots in relation to coarse roots. This decrease in fine root production is expected if plants are reducing energy expenditure by not producing unnecessary roots. DSE could be providing these high elevation plants with increased access to nutrients enabling fine roots to be reduced without negatively impacting the overall health of the organism.

DSE is more prominent in the high elevation while AMF is more prominent at low elevation. The greater reduction of fine roots at high elevation could indicate that DSE provides greater resource allocation benefits to its symbiotic plant partner than AMF. This would also explain why DSE replaces AMF in the harsher environment of high elevation.

The ratio of coarse to fine root at mid elevation is between the ratios found at high and low elevation. The ratio is closer to high elevation however, suggesting that Mid and high elevation soil biomes are more similar than mid and low. This is interesting as mid elevation has milder conditions and thus there is less selective pressure for symbiotic interactions. More study into the soil biomes of moderate elevation could help explain this.

I also found some influence of groundcover and root biomass. Increased woody shrub groundcover is correlated to increased coarse root biomass. This is expected since woody plants often live multiple years and invest in a long term substantial network of coarse roots to provide structure. Interestingly, woody shrub biomass is more strongly correlated with fine root biomass. Over fourteen percent of variation in woody biomass is related to fine root biomass. This influence is unexpected. Graminoid groundcover and coarse root biomass are negatively correlated. Graminoids produce root systems dominated by fine roots and graminoids can compete with other species that may produce more coarse roots.

The small sample size of this study makes the statistical significance of these results low. However, this experiment did uncover some interesting patterns that warrant further study. It points to DSE having more influence on root structure than AMF. The role of DSE in symbiotic relationships is not well understood but this study points to an increase in the efficiency of fine roots. Overall this study shows the influence of underground biomes on the physiology of plants and showcases the diversity of these biomes across elevation. Elevational gradient studies can be used to predict ecosystem wide effects of climate change. Changing elevational gradient and thus changing climate has an effect on soil community and thus has an effect on plant physiology which can have ecosystem wide impacts.

References

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