Selfish or Sharing: Fungal Nutrients in the Intemperate Rainforest

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10,000 Meter View

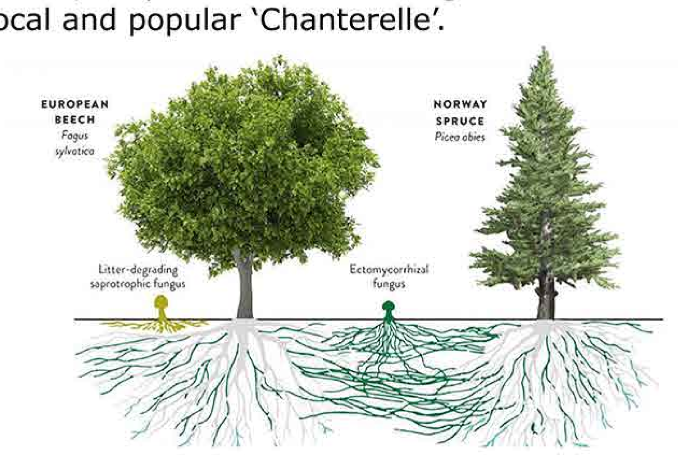
Many studies ask how host plants react in the absence of their symbiotic fungal associates, but few ask what happens when fungi are in absence of a host. Here we investigate the differences in nutrients between two distinct but evolutionarily linked fungal guilds. Ectomycorrhizal fungi, which form an intimate and near obligate symbiosis with host plants, and Saprotrophic fungi, which are 'free-living', and do not form symbiosis with plants. Both utilize thread like growth called 'mycelium' to unlock basic materials for physiological function. For our purposes we focus on calcium, magnesium and potassium. Described in more detail below, both guilds require these cations to function, however, ectomycorrhizal fungi share some of these cations via their symbiosis with their host tree. When investigating the nutrient contents of both guilds we expect to see evidence of this nutrient constraint.

Saprotrophic Fungi

'Saprobes' occupy a vast range of habitats and are important decomposers in our forests. These fungi specialize in enzymatic degradation of dead (and sometimes living) materials. They do not form symbiosis and thus keep all the nutrients from what they degrade for their own metabolism and growth. The 'selfish' saprobes thus need to collect all of what they need through their mycelium, both nutrients and carbon, while the ectomycorrhizal guild described below uses a symbiotic relationship to access unlimited carbon! Familiar examples of these saprotrophic fungi are the common button or oyster mushrooms you find in every supermarket.

Ectomycorrihzal Fungi

'ECM' fungi similarly occupy an incredible range of habitats, however, they are limited by the presence of appropriate hosts, as ECM are unable to freely live for long without forming a symbiotic relationship with a willing plant partner. These fungi's mycelium grows in-between plant root cells where they exchange essential nutrients they scavenge, like calcium, magnesium, and potassium, for what trees produce from photosynthesis: carbon. On one hand, the 'sharing' ECM may give up some of their nutrients, but on the other hand, they don't need to forage their own carbon. Familiar examples of these mushrooms are the local and popular 'Chanterelle'.



Objectives and Hypotheses

The objective was to build upon previous work from Dr. Kranabetter and Dr. Hawkins, which showed phosphorus and nitrogen nutrient constraints in ectomycorrhizal fungi compared with that of saprotrophic fungi[1]. We investigated a similar relationship with other important nutrient cations, calcium (Ca), magnesium (Mg) and potassium (K). Additionally, we sought to investigate possible host effects on saprotrophic fungi between Red Cedar (no ECM present) and Sitka Spruce (ECM present).

Hypotheses

- Ectomycorrhizal sporocarps in pure *Picea sitchensis* (Sitka spruce) and/or *Pseudotsuga menziesii* (Douglas-fir) plots will have lower cation content (Ca, Mg, K) than that of saprotrophic sporocarps in the same plots.
- There is a difference in saprotrophic sporocarp nutrient content between pure *Picea sitchensis* (Sitka spruce) and pure *Thuja plicata* (Western red cedar) plots.

Methods

Fungal fruiting bodies (mushrooms) were collected from an experimental forestry plot near Port Renfrew on Vancouver Island's west coast. The plots were either pure *P. sitchensis* (N=3) or pure *T. plicata* (N=3). The mushrooms were identified either visually or via sanger sequencing, sorted into the appropriate guild, then analysed for cation content (%).

Previously collected fungal, soil and foliar cation data from this plot and others was included and analysed as a complete set. Relevant data was compared using linear modelling and was statistically compared using t-tests or regressions. Soil cation data was converted to kg per hectare, all other data was analysed as percentage of tissue mass.

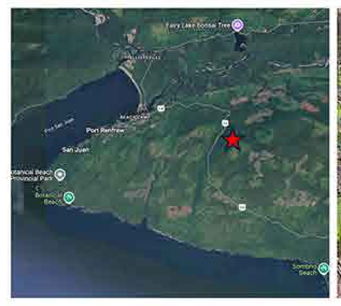
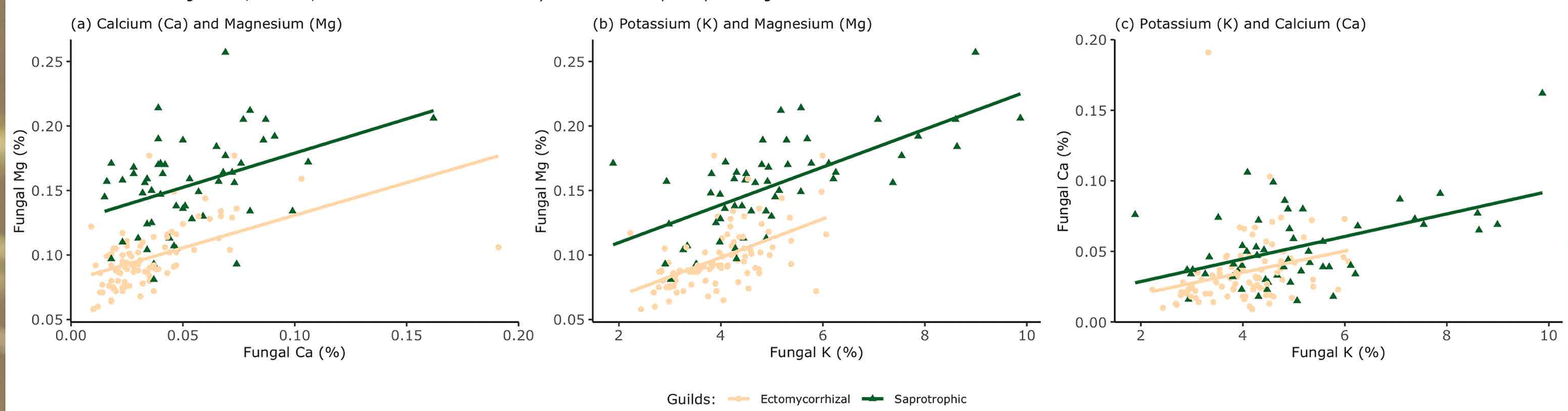


Figure 1.

Cation Constraints of Magnesium, Calcium, and Potassium Between Ectomycorrhizal and Saprotrophic Fungal Guilds



Note. Fungal cations (% by tissue mass) grouped by guild—ectomycorrhizal (E) and saprotrophic (S)—and fitted with linear regressions in experimental plots of *Pseudotsuga menziesii* ($N = 14$) on Vancouver Island. Sample sizes per guild: ectomycorrhizal ($n = 91$), saprotrophic ($n = 57$). Mean (± SE) % concentrations: Ca (E) = 0.03 ± 0.003, Ca (S) = 0.05 ± 0.004, Mg (E) = 0.10 ± 0.002, Mg (S) = 0.15 ± 0.005, K (E) = 3.99 ± 0.09, K (S) = 5.03 ± 0.22. (a) Magnesium and calcium, (b) magnesium and potassium, (c) calcium and potassium.

Results

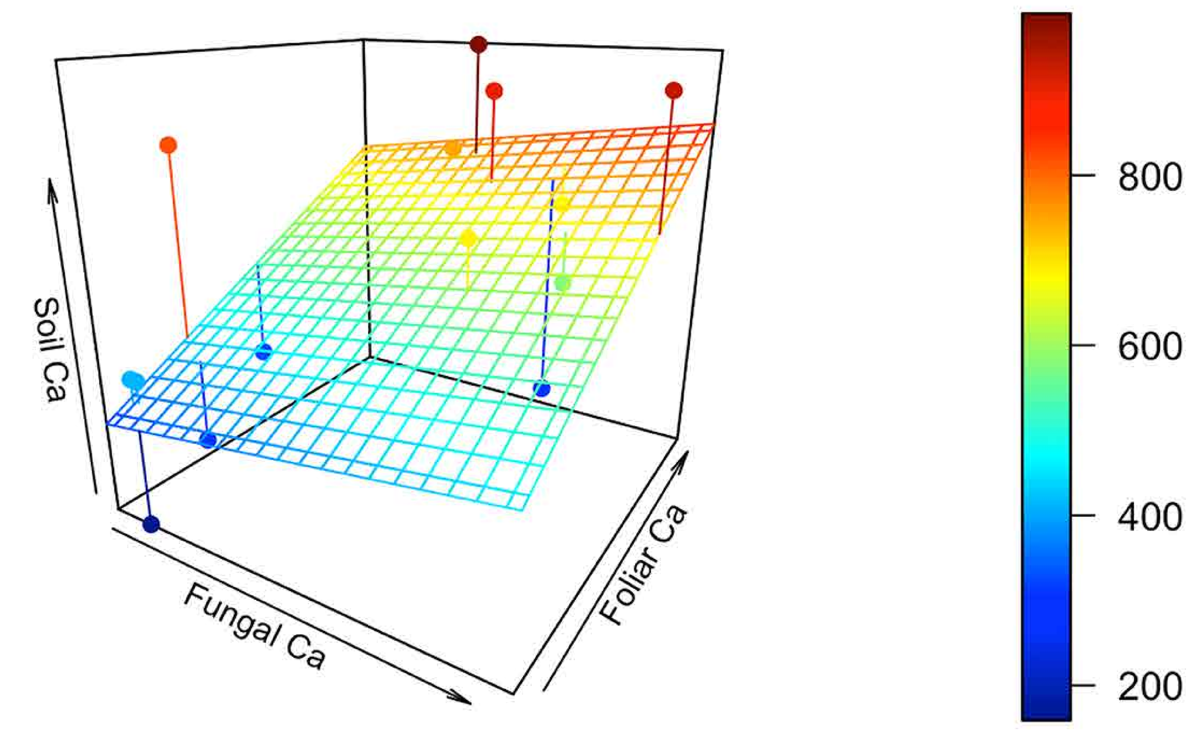
Calcium, magnesium and potassium were all significantly higher in saprotrophic fungi than in ectomycorrhizal fungi. Calcium in saprotrophic compared to ectomycorrhizal, $t(146) = -3.105$, $p = .002$, magnesium between both guilds, $t(146) = -9.992$, $p < .001$, and finally potassium in saprotrophic fungi compared to ectomycorrhizal fungi, $t(146) = -3.959$, $p < .001$.

Saprotrophic fungal calcium levels did not differ significantly between cedar and spruce plots, $t(30) = -0.92$, $p = .365$. Neither did magnesium, $t(30) = 0.86$, $p = .399$, or potassium, $t(30) = 1.43$, $p = .164$.

Only fungal calcium showed a significant relationship with *P. menziesii* foliage calcium averaged across all sites, n=14; $p = .019$, $R^2 = 0.38$; figure 2. While magnesium, $p = .17$, $R^2 = 0.15$, and potassium, $p = .18$, $R^2 = 0.14$, showed moderate correlation without significance.

Figure 2.

Calcium in plot soil, Douglas-fir foliage and fungal tissue across 14 plots



Note. Trends in ECM fungal calcium (%), foliar calcium (%), and kg per hectare soil concentrations over 14 experimental plots of *Pseudotsuga menziesii* on Vancouver Island. The legend represents soil calcium in kg per hectare. The graph is fitted with a linear regression model represented by the grid. Details in results section

Conclusion

We found clear constraints in Mg, K and Ca between fungal guilds. As expected, the saprotrophic fungi consistently contained higher percentages of all three cations while ectomycorrhizal fungi contained less. It is unclear if the ectomycorrhizal fungi hold on to a minimum cation content for their own function or hold on to excess while giving a minimum to the host tree. Additionally, there appears to be a rather large species effect, represented in the data scatter. It is unclear if this cation enrichment in certain fungi is an innate quality at the species/genus level or an artifact from soil microsite conditions.

We found no host effect. Saprotrophic fungi in pure red cedar had no greater/less cation content than those on Sitka spruce.

Finally, the previously collected foliar data coupled with soil and fungal cation data showed some correlation in Ca but little in Mg and K, with only Ca being significant. However, in more limiting nutrients like nitrogen and phosphorous these fit a near 1:1 model[1] (fungal N/P : foliar N/P). Thus, this may be an interesting but unconventional proxy that tell us about how limited, or not limited, the host trees are in Ca, Mg and K.

Future Considerations

Constraints in mycorrhizal fungi are likely shared with the host plants; quantifying community wide constraints can help us understand that community more thoroughly. modelling relationships between host foliage, fungi and soil nutrients may be a novel proxy for quantifying nutrient limitations in forests.

The high heterogeneity in our forests mean data collected in forestry sciences must be robust and further collection is required to normalise species effects. Teasing out smaller differences in data. Investigating on a guild level means that noise is inherit as many species are captured in each dataset.

Acknowledgments

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References

1. Kranabetter, J. M., Harman-Denhoed, R., & Hawkins, B. J. (2019). Saprotrophic and ectomycorrhizal fungal sporocarp stoichiometry (C: N: P) across temperate rainforests as evidence of shared nutrient constraints among symbionts. *The New Phytologist*, 221(1), 482–492. https://doi.org/10.1111/nph.15380