Effect of Light Conditions on Abundance of Fungi Growth

Brian A., Mariam A., Jennifer D., Ellah M.

Abstract

Fungi play a vital role in the decomposition of organic matter and the transformation of key nutrients (Starke, 2020). Although fungi have a crucial place in ecosystem dynamics, factors which influence species distribution patterns are poorly understood (Tedersoo, 2014). This study aims to better understand how light affects fungi growth in coastal temperate forests. In this study, fungi growth was observed at the Botanical Garden at the University of British Columbia (UBC). Data was collected and used to calculate the mean number of fungi and average light intensity at four different locations (North, South, East, West) from the center of Wharton Glade. It was found that the highest mean number of fungi were in the southern quadrant, which had medium light intensity (2100-6300 lux). This finding is contradictory to contemporary research on this topic which identifies that fungi typically grow optimally under low light conditions (Idnurm, 2005; Simon, 2013). A potential source of error was generalizing a variation of fungi species as “fungi”. Moreover, fungi species were counted one month prior to the measurement of light intensity. Future research on this topic should consider the effect of other abiotic factors on fungal growth such as soil pH, moisture, temperature, and season.

Introduction

Fungi play a vital role in the decomposition of organic matter and the transformation of key nutrients (Starke, 2020). Fungi are “essential to the recycling of nutrients in all terrestrial

habitats because they are the dominant decomposers of the complex components of plant debris, such as cellulose and lignin" (Kendrick, 2011). Moreover, many fungi have established mutualistic symbioses with a wide range of organisms and can affect human health. Despite this, factors which influence fungi species distribution patterns are poorly understood (Tedersoo, 2014). Therefore, this study aims to better understand fungal distribution patterns, investigating light as a causal factor. In this study, fungi abundance (mean number) and light intensity (average lux) patterns at UBC Botanical Gardens were used to determine how light affects fungi growth in coastal temperate forests. Light availability is known to vary in forests due to sun angle, precipitation and vegetation geometry (Théry, 2001). Less light reaches the forest floor during the winter, when precipitation is high and when there is a dense amount of canopy tree coverage overhead (Canham, 1994). Unlike plants, mushrooms do not require photosynthesis for growth. Therefore, many fungi species are cultivated in dark and cool environments, without intense exposure to sources of ultraviolet light (Simon, 2013). As such, the fall in British Columbia (B.C) is a common growth season for many types of fungi (Thiessen, 2018). The sun angle and precipitation at this time of year generates cool, moist, and dark environments in many areas which are optimal for fungi growth (Kurjata, 2019). However, even during the fall season there are areas in B. C's forests exposed to relatively high light intensities - due to minimal canopy coverage - which can lead to suboptimal fungi growth environments (Carlile, 1965; Furlan, 1997; Simon, 2013). It was hypothesized that, if fungi grow optimally in low light conditions, then there will be a higher mean number of fungi species in quadrants with low light average light intensity (lux).

Methods

The goal of the experiment was to identify the variations in fungal growth and light in the Botanical Garden at UBC. The center of the garden, Wharton Glade, was found using the map available at the entrance. From the center of Wharton Glade, four different routes in the North, East, South, and West direction were utilized to observe fungal growth and light intensity patterns. The portion of garden in each direction was broken up into four sections, roughly five meters apart. In each section, we collected four samples of data. Using a ruler, we measured out a square (30 cm x 30 cm) and counted the number of fungi in each square. Additional observations, pertaining to the size of fungi and canopy coverage were recorded, and photos were taken of each fungi sample. Light intensity (lux) was measured using *Light Lux Meter Pro* and average light intensities were calculated for each location (North, South, East, and West). After the data collection was complete, photos from each location were uploaded to *iNaturalist* and the species names were recorded (see Appendix A).

Common light levels outdoors are roughly 107 lux (very dark day), 1075 lux (overcast day), and 10,752 lux (full daylight) (Engineering ToolBox). The measurements of the light intensity at each location were collected on the same day, at noon. Therefore, sun angle and precipitation were held constant. Therefore, the amount of canopy coverage determined the variations in light intensity at each location. Low, medium, and high light condition ranges were created using a combination of common light levels and data relating to canopy coverage at each location (see Appendix A). The light conditions developed for further analysis of fungal distribution patterns included: low light (0-2100 lux), medium light (2100-6300 lux), and high

light (≥ 6300 lux). The low light condition was defined qualitatively as “little to no sunlight reaching the ground” and this was used as the control group.

We performed an ANOVA analysis to determine if the differences between light levels were statistically significant (see Appendix B). We compared the mean number of fungi found in three light conditions (low light, medium light, high light). To perform an ANOVA analysis, the data for each light condition must be normally distributed with equal variances, independent, and sampled randomly. The data were independent because each within-group data point and between-group data point did not influence any other data point. Each data point was collected by a different person in a different location, ensuring random sampling. To test for normality, we performed a Shapiro-Wilk test.

Figure 1. Map of UBC Botanical Garden with pin showing location of Wharton Glade indicated by red marker.

Results

The calculated mean number of fungi and standard deviation was 8.000 ± 9.033 in low light condition (n = 6), 79.33 ± 50.39 in medium light condition (n = 6), and 4.571 ± 2.878 in high light condition (n = 7) (Figure 2).

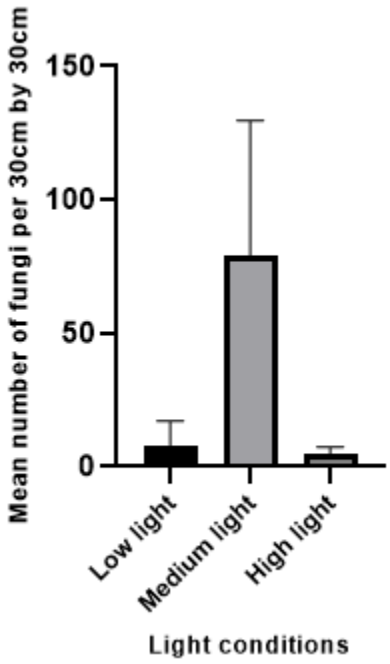

Figure 2. Mean number of fungi in low light condition (n = 6, p-value = 0.0064), in medium light condition (n = 6, p-value = 0.8356), and in high light condition (n = 7, p-value = 0.9303). Low light (0 - 2100 lux), medium light (2100 - 6300 lux), High light (≥ 6300 lux). Error bars represent standard deviation.

Performing a Shapiro-Wilk test, our low light condition data set did not pass the normality test while the medium and high light groups passed the normality test (see Appendix D).

For the ANOVA test, our null hypothesis states that the mean number of fungi is the same for all three groups of light conditions. Our alternative hypothesis states that at least one of the

three groups is different from the others. The ANOVA analysis returned an F-value of 13.40 and a p-value ≤ 0.05, denoting statistical significance. Since our results from the ANOVA were statistically significant, we performed a Tukey-Kramer's test (see Appendix C).

Our null hypotheses for the Tukey-Kramer test are that the mean number of fungi between any two of the three groups are equal. The difference between the low and high light condition has a p-value > 0.05, denoting statistical insignificance while the other two comparisons have a p-value ≤ 0.05, denoting statistical significance (see Appendix C).

Discussion

The results from this study suggest that moderate light conditions yield a higher mean number of fungi. The data in the low light condition were not normally distributed (see Appendix D). Despite this, all data from the low light condition were used in the ANOVA test, due to small sample sizes and lack of outliers. Based on the ANOVA result ($p \leq 0.05$), we rejected the null hypothesis, determining there were significant differences between the mean number of fungi between light conditions. Given the statistically significant ANOVA results, we performed a Tukey-Kramer's test. Since the low and high light conditions have p-value > 0.05, we fail to reject the null hypothesis. Therefore, the mean number of fungi in the low and high light groups are equal. This contradicts our hypothesis that a greater mean number of fungi will be found in low light conditions. However, the comparison between the low and medium light group and the medium and high light group had a p-value ≤ 0.05. Therefore, we reject the null hypothesis, and these results suggest that light conditions do affect fungi growth. Since a greater mean number of species were found in medium light conditions, the results of this experiment do not support the hypothesis. The hypothesis was based on previous research on this topic which indicates that low

light conditions are typically optimal for fungi growth (Carlile, 1965; Furlan, 1997; Simon, 2013). As such, the results yielded from this experiment were unexpected. An interesting finding from this study is that the low and high light conditions both had low mean numbers of fungi, relative to the medium light condition. These findings imply that fungi growth is supported when light intensity is moderate and not extremely low or high. Many of the fungi in this experiment were mushrooms (see Appendix A). One explanation for these findings, derived from previous studies, is that high light conditions negatively affect the mushroom head formation, while moderately light are adequate for mushroom heads growth (Furlan, 1997). Since mushroom head formation is an essential stage of mushroom maturation, mushroom growth could have been inhibited in high light conditions. However, this same line of reasoning cannot explain the lack of fungi abundance in the low light conditions.

There are many possible sources of error which may have led to fungal distribution patterns observed in this study. Firstly, there were many different fungi species identified in the data collection processes (see Appendix A). For simplicity, species were not separated into different groups before the data were analyzed. Past research identified that fungi grow optimally in low light conditions. One reason for this is that mushrooms do not contain chlorophyll, therefore do not use photosynthesis to produce carbohydrates (Simon, 2013). Therefore, in this study, we assumed that high light conditions are suboptimal fungi growth. However, recent studies reveal that certain types of fungi grow more optimally in moderate to high light conditions (Starke, 2020). Therefore, grouping a wide variety of fungi species together could have affected the results. Secondly, our group wrote down fungi observations found only on man-made paths or areas easily accessible by foot (no shrubs/complicated terrain to cover). Since

shrubs and dense brush affect light intensity, this could have resulted in missing data, especially in low light conditions. Moreover, the more easily accessible locations were continuously disturbed by people stepping on the paths which likely affected fungi growth in these locations.

Limitations of this study were time and scope. This study was conducted over a short time span (six weeks) with a team of four researchers. More time and a greater number of researchers could have led to a more exhaustive data set and a more in-depth analysis of fungal distribution patterns at UBC Botanical Gardens. Future research studies could develop a more comprehensive understanding of fungal distribution patterns in the coastal temperate forest, by considering other abiotic or biotic factors including soil pH, moisture, temperature, and season.

Conclusion

Overall, the results of this experiment showcased the highest fungi growth in medium light conditions. Our results do not support our hypothesis that a greater mean number of fungi would be found in low-light conditions. However, these findings contradict contemporary research on this topic. Given the important role of fungi in ecosystem dynamics, more research is needed to understand the fungal distribution patterns and causal factors.

Acknowledgements

Thank you to the University of British Columbia for offering Biology 342 to allow students to gain research skills and learn from Dr. Celeste Leander and her teaching assistants. Thank you to the UBC Botanical Garden for allowing us to conduct our study and we recognize that we gathered on the traditional, ancestral, and unceded territory of the Musqueam people.

Literatures Cited

Carlile, M. 1965. The Photobiology of Fungi. *Annual Review of Plant Physiology, 16, 175-202*. https://doi-org.ezproxy.library.ubc.ca/10.1146/annurev.pp.16.060165.001135**.**

Canham, C., Finzi, A., Pacala, S. et al. 1994. Causes and consequences of resource heterogeneity in forests: interspecific variation in light transmission by canopy trees. *Canadian Journal of Forest Research, 24*. https://doi-org.ezproxy.library.ubc.ca/10.1139/x94-046.

Idnurm, A., Heitman, J. 2005. Light Controls Growth and Development via Conserved Pathway in the Fungal Kingdom. *Plos Biology* 3(4).

Kendrick, B. 2011. Fungi: Ecological Importance and Impacts on Humans. https://doi.org/10.1002/9780470015902.a0000369.pub2.

Kurjata, A. 2019. It's been the 'mushroom season of the century' in northern B.C. *CBC News*. https://www.cbc.ca/news/canada/british-columbia/fungi-mushrooms-prince-george-2019-1.5280111.

Øyvind Rustan (Compositae AS, H. (n.d.). UBC Botanical Garden. Retrieved November 28, 2020, from https://collections.botanicalgarden.ubc.ca/.

Simon, R., Borzelleca, J., DeLuca, H. Weaver, C. 2013. Safety Assessment of the post-harvest treatment of button mushrooms (*Agaricus Bisporus*) using ultraviolet light. *Food and Chemicals Toxicology 56*, 278-289. https://doi.org/10.1016/j.fct.2013.02.009

Recommended Light Levels.

https://www.noao.edu/education/QLTkit/ACTIVITY_Documents/Safety/LightLevels_outdoor+indoor.pdf

Starke, R. Capek, P. Morais, D., et al. 2020. The Total Microbiome Functions in Bacteria and Fungi. *Journal of Proteomics, 213*(20). https://doi.org/10.1016/j.jprot.2019.103623.

Tedersoo, L., Bahram, M., Polme, S., et al. 2014. Global Diversity and Geography of Soil Fungi. *Science, 346*(6213). 10.1126/science.1256688.

Théry, M. 2001. Forest light and its influence on habitat selection. *Plant Ecology 153*, 251-261.

Thiessen, C. 2018. Foraging for Fungi. *British Columbia Magazine*. https://www.bcmag.ca/foraging-for-fungi/.

Appendix A. Species identification and canopy coverage at each location (North, South, East and West) from Wharton's Glade at UBC Botanical Gardens.

Location	Species Name(s)	Canopy Coverage
North	Mica-cap (*Coprinellus micaceus*) Honey Mushroom (*Armillaria solidipes*) Oyster Mushroom (*Pleurotus ostreatus*)	Dense canopy coverage In grass field, no canopy coverage Dense canopy coverage
South	*Armillaria sinapina* Umber-brown puffball (*Lycoperdon umbrinum)* Red edge brittlestem (*Psathyrella longipes*)	Minimal canopy, lots of shade
East	Lilac Bonnet (*Mycena pura)*, Nitrous Bonnet (*Mycena leptocephala*)	Dense canopy coverage in all quadrants
West	Bonnets (*Mycena*)	Dense canopy coverage in all quadrants

Appendix B. ANOVA test results.

	Sum of Squares	Degrees of Freedom	Mean Square	F- Value	P-Value
Treatment (between columns)	22023	2	11011	F(2, 16) = 1	P=0.0004
Residual (within columns)	13151	16	821.9		
Total	35174	18			

Appendix C. Tukey-Kramer's test results.

	Mean difference	95.00% CI of difference	Below Threshold?	Summary	Adjusted P-value
Low light vs. Medium light	-71.33	-114.0 to -28.62	Yes	**	0.0015
Low light vs. High light	3.429	-37.73 to 44.59	No	ns	0.9749
Medium light vs. High light	74.76	33.61 to 115.9	Yes	**	0.0007

Appendix D. Shapiro-Wilk test results.

	Low light	Medium light	High light
W	0.7014	0.9621	0.9747
P value	0.0064	0.8356	0.9303
Passed normality test (alpha = 0.05)?	No	Yes	Yes
P value summary	**	ns	ns