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# Increased Light Exposure Decreases Lichen Abundance on Linden Trees in the Prairie Grassland Biome of West Central Minnesota

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## INTRODUCTION

Lichen is composed of a symbiotic relationship between a fungus and an alga. Algae are photosynthetic organisms that rely on light in order to carry out light-dependent reactions. Thus, one might expect that the abundance of lichen on the surface it is growing might vary with the level of sunlight it receives, which differs based on the cardinal direction the surface is facing.

One might assume that since lichens are photosynthetic organisms, lichen abundance would increase with increased sunlight exposure due to increased rates of photosynthesis. However, the existing literature on this topic indicates mixed results about the effect of sunlight on lichen.

For example, Vitt et al. (2019) found that forests that had more canopy openings also had more abundant populations of reindeer lichen. Meanwhile, Cung et al. (2021) concluded that there was no relationship between sun exposure and lichen abundance on each face of the rocks they studied. However, they also noted that other microenvironmental factors like slope may also influence lichen communities and that more research is needed on the topic. Lauriault et al. (2020) report that slopes that face north receive less direct sunlight than south slopes, which results in a reduced rate of water evaporation, ultimately making north slopes better lichen habitat. Their data supported this hypothesis and indicated that boreal felt lichen occurred more on north slopes.

Sales et al. (2016) indicated that some species of lichen prefer shaded environments. However, they also say that on shaded sides of trees, moss grows faster and may hinder the growth of lichen. Kubiak & Osyczka (2020) indicated that it is challenging to draw conclusions about the effect of sunlight on lichen due to all of the other factors that influence lichen growth, such as humidity and wind speed. They still note that light is an important factor for lichen growth, however.

Taken altogether, these mixed results indicate that more research is needed on the subject in order to draw firm conclusions about the relationship between lichen abundance and the amount of sunlight it receives relative to the cardinal direction it faces. Additionally, we suspect that results will vary based on environmental conditions of each study site. Our question is: does sunlight exposure affect lichen abundance in the prairie grassland biome of West-Central Minnesota? We hypothesized that the cardinal faces of a tree that receive higher amounts of sun exposure will support fewer lichens due to increased rates of evapotranspiration in the prairie grassland biome of West-Central Minnesota.

## METHODS

When collecting our data, we followed the instructions given in the Ecological Research as Education Network Lichens in Diverse Landscapes module (Ecological Research as Education

Network, n.d.). We printed out the provided lichen sampling grids and traced them onto plastic bags with permanent markers. The grids were 20x20 cm and had 100 evenly-spaced circles which allowed us to directly correlate the number of lichens in the grid to percent lichen abundance. We identified trees of the genus *Tilia* (*Tilia americana* and *Tilia cordata*) and used a diameter at breast height (DBH) tape to ensure that each tree met our minimum DBH of 35 cm. This minimum was set so that there was adequate room for the sampling grid on each side of the trees. We sampled trees around the University of Minnesota, Morris campus and also took note of whether the tree was in a "solitary" or "interior" location. We treated trees whose canopies touched the canopies of other trees as interior and trees whose canopies did not touch other canopies as solitary. The reason we recorded this is due to the possibility of overlapping canopies decreasing sunlight exposure to the bark of the tree. We estimated the canopy cover for each tree and used a compass app in order to find the cardinal faces. Then we placed the sampling grids at breast height (approximately 4.5 ft/1.3 m) on each side and took photographs of the grids. We counted percent lichen cover by counting the number of circles on the sampling grid where lichen was visible. There were 100 circles on each grid, so the number of circles correlated directly with percent lichen cover. We entered our data into a Google spreadsheet and then did a two-way ANOVA test to analyze the data. In order to determine which of the cardinal directions had significantly different mean percent lichen cover, we also carried out a Tukey HSD test.

## RESULTS

The north side of the trees had the greatest mean lichen percent cover (Figure 1). Cardinal direction had a significant effect ($p = 0.0006$), but solitary vs. interior was not significant ($p = 0.6993$). We can conclude that there is no difference in the percent lichen cover between interior and solitary trees, so we are unable to reject the null hypothesis. The north and south sides were significantly different (Tukey HSD, $p < 0.05$). Thus, we can reject the null hypothesis that there is no difference between the percent lichen coverage between the north and south faces and accept the alternative hypothesis that there is a difference in the lichen percent coverage between the north and south faces. However, we are unable to reject the null hypothesis for the other faces of the trees.


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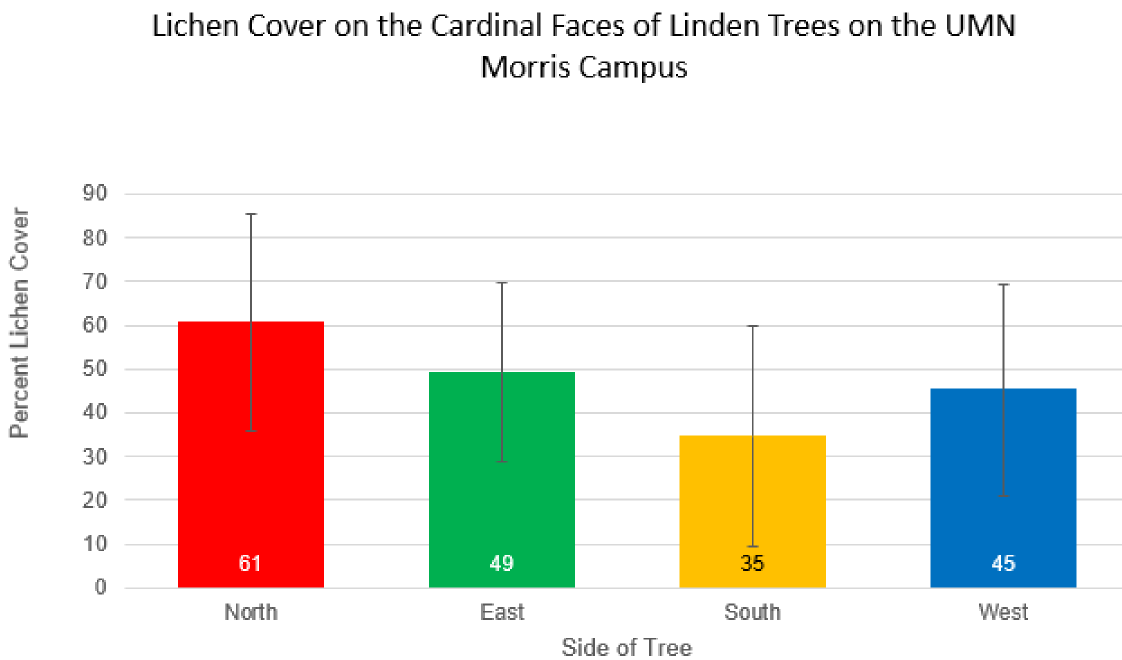


**Figure 1:** Percent lichen cover vs. cardinal direction. Mean lichen percentage is plotted in a bar graph with standard deviation error bars. Data was collected using a lichen sampling grid.

## DISCUSSION

This could be due to the fact that we collected data on the UMM campus, which does not have any densely forested areas, so there was not a biologically significant difference between interior and solitary trees to begin with. The amount of sunlight reaching the tree bark probably did not vary a lot between interior and solitary trees due to the fact there was very little overlap between the canopies in both cases.

One potential explanation for these results is that the north faces of trees receive less sunlight than the south faces in the northern hemisphere due to the tilt of the Earth's axis (Lauriault et al., 2020). The east and west sides receive intermediate amounts of sunlight compared to the north and south sides. Although sunlight is an important resource for the photosynthetic algae in lichens, increased sunlight also increases the rate of evapotranspiration. There may be a tradeoff for lichens to grow on a side of the tree that receives enough sunlight to support the light-dependent photosynthetic reactions, but not so much sunlight that evapotranspiration causes unsustainable water loss for the organism. The south sides of the trees were effectively limited in water, whereas the north sides of the trees were limited in sun exposure. Given that the north sides of the trees had the highest average percent lichen cover despite limited sun exposure, we can conclude that sun exposure is not the limiting factor for lichen growth in our study. Additionally, the fact that the south sides of the trees had the lowest average percent lichen cover supports the conclusion that sun exposure is inversely correlated with lichen percent cover. This suggests that moisture is a limiting factor to lichen growth in our study; increased sun exposure on the south sides of the trees results in higher rates of moisture loss by evapotranspiration.

We can conclude that in drier areas, more sunlight would likely decrease lichen growth due to water being a limiting factor, and in moist areas, more sunlight would increase lichen growth because moisture would not be limiting. Thus, if both adequate amounts of sunlight and water are present, we hypothesize that there would be greater lichen abundance.

As discussed earlier, some of the literature supports our findings, while other studies drew different conclusions. For example, Vitt et al.'s (2019) findings that more open canopies were associated with increased lichen abundance contradicted our results. However, Lauriault et al. (2020) found that the north-facing sides of objects were more ideal lichen habitats due to the decreased amount of direct sunlight. Still other studies, like Kubiak & Osyczka (2020), indicate that drawing any firm conclusions about sunlight and lichen is difficult due to the many factors that influence lichen growth. Nonetheless, every study conducted on the subject is a further contribution to the scientific discussion on the subject.

If conducting this experiment again in the future, it would be valuable to record more data at sites that are more densely forested to further investigate how canopy cover and tree density can play into sunlight exposure and lichen abundance. In a forested area, we might find that the overall lichen abundance would be reduced due to less sunlight exposure if other environmental factors are not affecting it. Additionally, there might be less of a difference between lichen percent cover on different sides of trees, as all sides would receive similar amounts of sunlight.


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# APPENDIX

Datasheet 1: Data from first collection session (10/14/2022)

| Date: Oct 14 | Tree species: Linden | DBH: >35 | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Tree No. | % Canopy Cover (<10%, 10-50%, >50%) | %Lichen-North | %Lichen-East | %Lichen-South | %Lichen-West | Interior or solitary location? | Comments |
| 1 | 10-50 | 76 | 64 | 90 | 94 | solitary | |
| 2 | >50 | 71 | 74 | 35 | 68 | solitary | |
| 3 | <10 | 25 | 68 | 64 | 63 | solitary | |
| 4 | >50 | 81 | 52 | 24 | 47 | solitary | |
| 5 | 10-50 | 58 | 48 | 32 | 52 | solitary | |
| 6 | <10 | 46 | 11 | 21 | 67 | solitary | |
| 7 | 10-50 | 98 | 44 | 12 | 52 | solitary | |
| 8 | 10-50 | 80 | 44 | 33 | 54 | solitary | |
| 9 | 10-50 | 53 | 7 | 17 | 69 | solitary | |
| 10 | <10 | 62 | 72 | 25 | 53 | solitary | |
| 11 | >50 | 50 | 79 | 39 | 87 | solitary | |
| 12 | >50 | 12 | 54 | 3 | 20 | solitary | |
| 13 | 10-50 | 91 | 42 | 4 | 38 | solitary | |
| 14 | 10-50 | 54 | 17 | 19 | 14 | solitary | |
| 15 | >50 | 17 | 29 | 1 | 6 | solitary | |

Datasheet 2: Data collection session 2 (10/21/2022)

| Date: Oct 21 | Tree species: Linden | DBH: >35 | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Tree No. | % Canopy Cover (<10%, 10-50%, >50%) | %Lichen-North | %Lichen-East | %Lichen-South | %Lichen-West | Interior or solitary location? | Comments |
| 1 | >50 | 89 | 51 | 9 | 25 | interior | |
| 2 | 10-50 | 84 | 45 | 38 | 58 | Interior | |
| 3 | >50 | 88 | 58 | 38 | 21 | Interior | |
| 4 | >50 | 35 | 83 | 0 | 77 | interior | north side has some damage, south side weird |
| 5 | >50 | 85 | 67 | 53 | 64 | solitary | |
| 6 | >50 | 48 | 37 | 78 | 60 | Interior | |
| 7 | >50 | 77 | 70 | 51 | 7 | interior | |
| 8 | >50 | 37 | 15 | 70 | 20 | interior. | |
| 9 | <10 | 59 | 46 | 25 | 27 | Interior | |
| 10 | <10 | 80 | 27 | 20 | 21 | Solitary | |
| 11 | <10 | 20 | 55 | 6 | 7 | interior | |
| 12 | <10 | 31 | 45 | 67 | 34 | Interior | |
| 13 | <10 | 48 | 70 | 80 | 48 | Interior | |
| 14 | <10 | 88 | 64 | 44 | 47 | solitary | |
| 15 | >50 | 77 | 35 | 40 | 56 | solitary | |

Datasheet 3: Combined data collection sessions

| | % Canopy Cover (<10%, 10-50%, >50%) | %Lichen- North | %Lichen- East | %Lichen- South | %Lichen- West | Interior or solitar | Comments |
|---|---|---|---|---|---|---|---|
| DAY 2 | >50 | 89 | 51 | 9 | 25 | interior | |
| DAY 2 | 10-50 | 84 | 45 | 38 | 58 | Interior | |
| DAY 2 | >50 | 88 | 58 | 38 | 21 | Interior | |
| DAY 2 | >50 | 35 | 83 | 0 | 77 | interior | north side has some damage, south side weird |
| DAY 2 | >50 | 48 | 37 | 78 | 60 | Interior | |
| DAY 2 | >50 | 77 | 70 | 51 | 7 | interior | |
| DAY 2 | <10 | 59 | 46 | 25 | 27 | Interior | |
| DAY 2 | <10 | 20 | 55 | 6 | 7 | interior | |
| DAY 2 | <10 | 31 | 45 | 67 | 34 | Interior | |
| DAY 2 | <10 | 48 | 70 | 80 | 48 | Interior | |
| DAY 2 | >50 | 37 | 15 | 70 | 20 | interior | |
| DAY 1 | 10-50 | 76 | 64 | 90 | 94 | solitary | |
| DAY 1 | >50 | 71 | 74 | 35 | 68 | solitary | |
| DAY 1 | <10 | 25 | 68 | 64 | 63 | solitary | |
| DAY 1 | >50 | 81 | 52 | 24 | 47 | solitary | |
| DAY 1 | 10-50 | 80 | 44 | 33 | 54 | solitary | |
| DAY 1 | <10 | 62 | 72 | 25 | 53 | solitary | |
| DAY 2 | >50 | 85 | 67 | 53 | 64 | solitary | |
| DAY 2 | <10 | 80 | 27 | 20 | 21 | Solitary | |
| DAY 2 | <10 | 88 | 64 | 44 | 47 | solitary | |
| DAY 2 | >50 | 77 | 35 | 40 | 56 | solitary | |
| DAY 1 | 10-50 | 58 | 48 | 32 | 52 | solitary | |
| DAY 1 | <10 | 46 | 11 | 21 | 67 | solitary | |
| DAY 1 | 10-50 | 98 | 44 | 12 | 52 | solitary | |
| DAY 1 | 10-50 | 53 | 7 | 17 | 69 | solitary | |
| DAY 1 | >50 | 50 | 79 | 39 | 87 | solitary | |
| DAY 1 | >50 | 12 | 54 | 3 | 20 | solitary | |
| DAY 1 | 10-50 | 91 | 42 | 4 | 38 | solitary | |
| DAY 1 | 10-50 | 54 | 17 | 19 | 14 | solitary | |
| DAY 1 | >50 | 17 | 29 | 1 | 6 | solitary | |
| AVERAGE | | 60.7 | 49.1 | 34.6 | 45.2 | | |

Datasheet 4: Two-way ANOVA column and row assignments

| | |
|---|---|
| | Column 1= North |
| Interior = row 1 | Column 2= East |
| solitary = row 2 | Column 3=South |
| | Column 3=West |

Datasheet 5: ANOVA test results

| Source | SS | df | MS | F | P |
|---|---|---|---|---|---|
| Rows | 83.49 | 1 | 83.49 | 0.15 | 0.6993 |
| Columns | 10427.23 | 3 | 3475.74 | 6.28 | 0.0006 |
| r x c | 3260.04 | 3 | 1086.68 | 1.96 | 0.1241 |
| Error | 61993.83 | 112 | 553.52 | | |
| Total | 75764.59 | 119 | | | |

Datasheet 6: Tukey-HSD critical values

| | **HSD[.05]** | **HSD[.01]** |
|---|---|---|
| **Rows** [2] | 8.83 | 11.69 |
| **Columns** [4] | 15.88 | 19.38 |
| **Cells** [8] | 27.64 | 32.36 |
| | | |


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