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# EFFECTS OF DIFFERENT SHADE CONDITIONS ON THE HEIGHT OF WISCONSIN FAST PLANTS

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## ABSTRACT

The Wisconsin fast plant, or *Brassica rapa*, is an herbaceous full-sun plant. Like other plants, it has a shade avoidance response that results in increased height. This increase in height was studied under varying shade conditions over the course of a month, which was long enough for *B. rapa* to go from seed to flower. Plants in shadier conditions grew taller earlier in the study period, but they matured slower and were overall less healthy than plants grown in full sun.


*Key words: shade avoidance,* Brassica rapa*, Wisconsin Fast Plant, growth rate, maturity rate, shoot elongation*

## INTRODUCTION

All plants need access to light to grow and reproduce. However, light can be blocked by various factors such as tall plants, geographic features, geological features, and human structures. Plants have evolved several different methods for getting around this conundrum. Many species of plants such as ferns have evolved to be shade tolerant (cite), some trees have evolved to tower over sources of shade, and some still thrive in full sun. From one of these full sun plants, a botanical lab rat was derived: the Wisconsin fast plant, or *Brassica rapa*. *B. rapa* was created in a lab in Wisconsin, and it is meant to be grown under a grow light. It is particularly useful to study, as its seeds, when purchased, come with an instruction manual. The manual outlines ideal growth conditions for the plant, along with a timeline of when certain milestones, such as flowering, should occur (Wisconsin Fast Plants® Team, 2023). This gives a good basis of comparison for study outside of those set parameters.

Any plant that thrives in full sun will try its best to be in full sun. This is called a shade avoidance response. Shade avoidance responses in plants most often take the form of extended growth in the direction of a light source, usually straight up towards the sun, but sometimes off to the side just out of the shade. This growth is regulated by the hormone auxin (cite). To see how *B. rapa's* shade response affected its height and body size, an experiment was conducted as outlined below.

## MATERIAL AND METHODS

Twenty *Brassica rapa* seeds were planted in their own small plastic pots with one seed per pot. They were planted in pre-wetted potting soil mixed with sand. Immediately after planting, they were placed in the same greenhouse under different four different shade conditions with five plants in each group. The shade conditions are defined below:

Full sun: Plants placed where they could have the most possible access to full sun

Partial plant shade: Plants placed underneath sparse cover by other greenhouse plants

Full plant shade: Plants placed in the closest possible approximation of full shade from other greenhouse plants

Full inanimate object shade: Plants placed under a pot

Every three days, we tended to the plants and recorded data. Each plant was watered with an eighth cup of water unless it was thoroughly wet. Each plant's growth was measured in centimeters with a small ruler and recorded in a data table. If the plant was drooping, it was held up against the ruler to determine how tall it would be if it were not drooping. The status of each plant -- either alive, dead, sickly, or wilted – was recorded along with the compass direction each plant was facing, if any, whether they had flowered, and any additional notes.

We performed a one-way ANOVA test using Excel on the April 7th data and the April 24th data to determine if the mean height of *B. rapa* in each shade condition differed at the beginning and end of the study period. The null hypothesis states that the means of each shade condition are equal and the alternative hypothesis states that the means of each shade condition are not equal.

## RESULTS

Anova: Single Factor

4/7/23

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Full sun | 5 | 1.7 | 0.34 | 0.038 |
| Partial plant | 5 | 5.5 | 1.1 | 0.015 |
| Full plant | 5 | 2.5 | 0.5 | 0.235 |
| Full inanimate | 5 | 9.9 | 1.98 | 0.282 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 8.272 | 3 | 2.757333 | 19.34971 | 1.43E-05 | 3.238872 |
| Within Groups | 2.28 | 16 | 0.1425 | | | |
| | | | | | | |
| Total | 10.552 | 19 | | | | |

Fig. 1: The ANOVA test results from April 7th, 2023.

Anova: Single Factor

4/24/23

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Full Sun | 5 | 49.7 | 9.94 | 31.883 |
| Partial plant | 5 | 46 | 9.2 | 3.825 |

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| | | | | |
|---|---|---|---|---|
| Full plant | 5 | 22.4 | 4.48 | 17.627 |
| Full inanimate | 5 | 0 | 0 | 0 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 320.1895 | 3 | 106.7298 | 8.004487 | 0.001751 | 3.238872 |
| Within Groups | 213.34 | 16 | 13.33375 | | | |
| Total | 533.5295 | 19 | | | | |

Fig. 2: The ANOVA test results from April 24th, 2023.

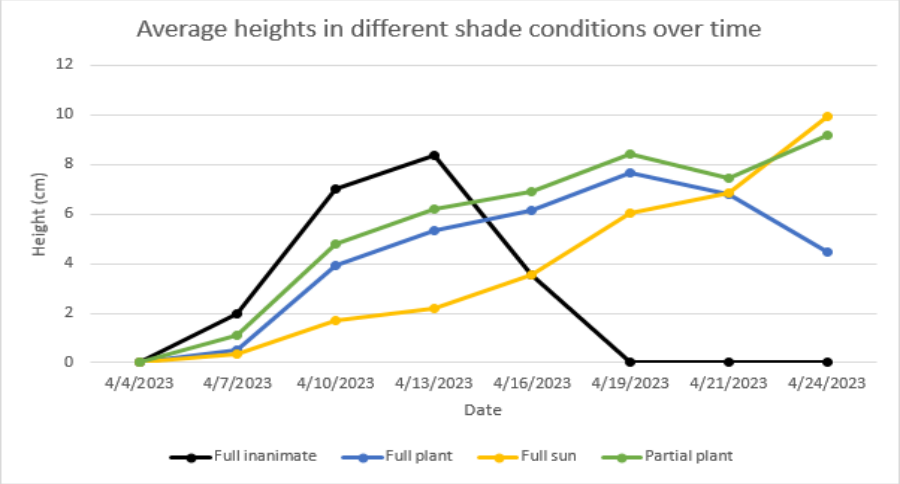


Fig. 3: A graph showing the average height of each shade response group over time.

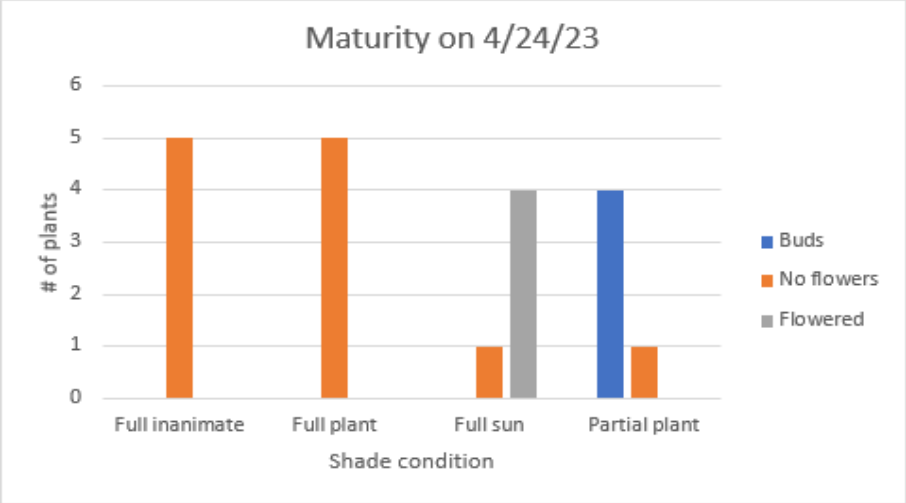


Fig. 4: A chart showing how many plants have flowered or budded in each shade condition on April 24th.

| 4/24/23<br>Shade Condition | Alive | Dead | Sickly | Wilted |
|---|---|---|---|---|
| Full inanimate | | 5 | | |
| Full plant | | 2 | 3 | |
| Full sun | 5 | | | |
| Partial plant | 1 | | 1 | 3 |

Fig. 5: A table with the number of alive, dead, sickly, and wilted plants in each shade condition.

## DISCUSSION

On April 7th, $p < 0.0001$, so there was a significant difference between the average height of *B. rapa* in each shade condition (see fig. 1). On April 24th, $p = 0.002$, so there was a significant difference between the average height of *B. rapa* in each shade condition (see fig. 2). The alpha level of both tests is 0.05.

As shown in figure 3, the average height of *B. rapa* in each shade condition changed over time. The plants in full inanimate object shade grew the fastest in the beginning, but by April 19th, all the plants in inanimate object shade were dead. In partial plant shade and full plants shade, *B. rapa* grew faster than the plants in full sun. However, by April 24th, two full plant shade plants were dead, and the growth rate of both conditions appeared to be decreasing. The *B. rapa* in full sun grew the slowest, but none of the plants died off, and they were, on average, the tallest plants by the end of the study period.

*B. rapa* grows best under a twenty-four hour grow light (Carolina® Team, 2023), and our closest equivalent was the full sun plants. but it does attempt to acclimate to shadier conditions by growing tall quickly. However, the trade-off is that it does not mature as fast. When stressed, *B. rapa* tends to delay life cycle stages (Steinbrenner et. al., 2012). The plants in partial plant shade grew tall faster than the plants in full sun (see fig. 3), but they only had buds when most of the full sun plants had flowers (see fig. 4). The *B. rapa* in shade conditions (full inanimate, full plant, and partial plant) was also more likely to die; about 47% of the plants in shade conditions died, and an additional 47% were either wilted or sickly by April 24th (see fig. 5).

There were a few confounding variables in this study. The most prevalent issue was that of water. The experimental design was such that each plant would receive 1/8th cup of water once every three days, but the pots had no drainage, and there were times that, for one reason or another, they would be flooded, and so would not be watered that day. This was due to the communal nature of the greenhouse, and the fact that we, the researchers, were not solely responsible for watering all plants in said greenhouse.

Though some results may have been influenced by overwatering, the shoot elongation of the *B. rapa* in shadier conditions is more consistent with a shade response (Ruberti et. al., 2012). The shade response of the *B. rapa* allows it to survive in inadequate conditions, but it comes with the tradeoff of slower reproductive maturity. Plants' shade responses are an investment of resources that does not always get a return. Some of our plants died before they had a chance to reproduce. The best way to avoid shade may be through evolution rather than acclimation. For future study, it would be useful to grow *B. rapa* outside in natural conditions to see plants under naturalized plants have a different response to shade, or a different maturity rate.

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