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# Investigation of the Effects of Water Stress on *Vigna radiata* and *Brassica rapus*

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# Investigation of the Effects of Water Stress on *Vigna radiata* and *Brassica rapus*

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## 1. Introduction

Water is crucial to photosynthesis because it provides electrons for the light-dependent reactions. Additionally, plants decrease transpiration rate during drought in an effort to minimize water loss, resulting in changes in $CO_2$ uptake and photosynthetic rate (Vico, 2008; Özenc, 2008; Galmés et al.,2007). Water use efficiency (WUE), the ability of a plant to maintain photosynthesis despite water loss, is an essential component of determining plant performance in drought conditions. Previous studies have shown an association between water stress and increased WUE (Zhang et al., 2010). Therefore, we hypothesize that the photosynthetic rates in both the *Vigna radiata* (mung beans) and *Brassica rapus* (rutabagas) will decrease after withholding water until exhibition of water stress symptoms, and the WUE of water-stressed plants will be higher than watered counterparts.

## Methods and Materials

The LICOR6400 was used to measure the photosynthetic rate, conductance, and transpiration of each plant. After a baseline reading, three plants of each species were watered regularly, while the other three plants were not watered. After two days treatment, the rutabaga plants exhibited water stress symptoms, and treatment data were collected for all plants. However, it took seven days in total for the mung bean plants to begin to wilt, so treatment data was collected a second time for mung beans after seven days of water stress.

The water percentage of leaves was found by cutting a leaf off off at the stem, weighing it, and setting it out to dry. Once leaves were completely dried, they were weighed again to determine the amount of water lost and, therefore, percent water content.

## Sources of Error

1) Inconsistent times waiting for level-off in logging data points with LiCor
2) Dry plants may have been watered by greenhouse crew
3) Needed to use hand-written estimates of data points for wilted data rather than precise computer-logged LiCor data
4) Inconsistent soil media among plants could have different water retention
5) Did not account for time-of-day changes in stomatal limitation (transpiration) and photosynthetic rate (Zhang et al., 2010)

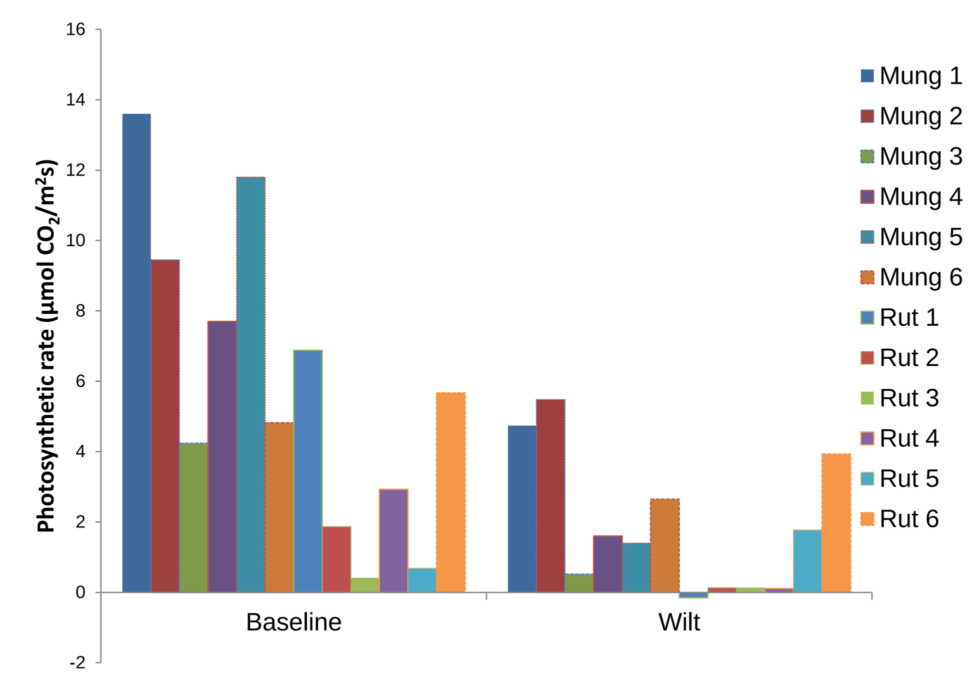


Figure 1 Photosynthetic rate of baseline and wilted plants after exhibiting water stress symptoms (2 days treatment in rutabagas, 7 days treatment in mung beans) (n = 3 plants in each treatment set)

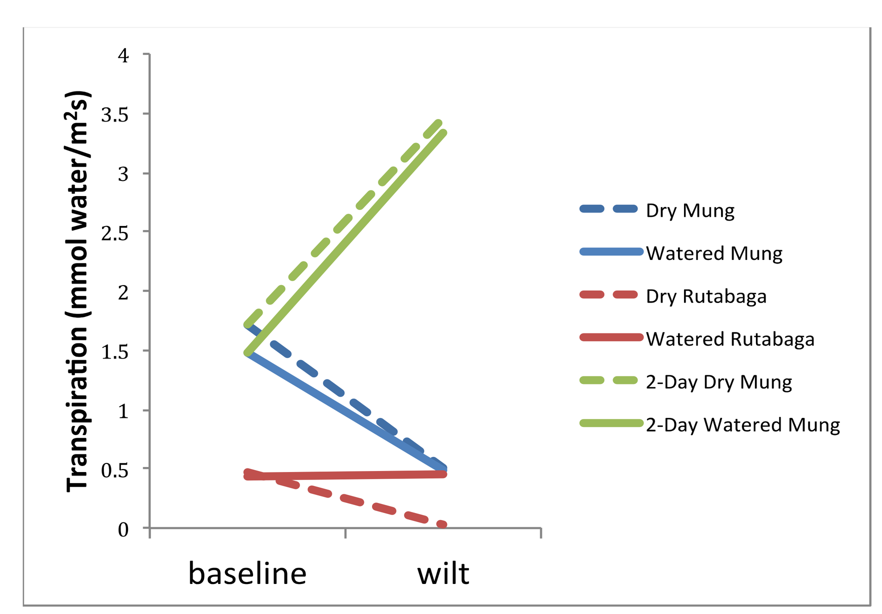


Figure 2 Changes in transpiration rate in dry and watered mung beans and rutabagas after exhibiting water stress symptoms (n = 3 plants in each treatment set)

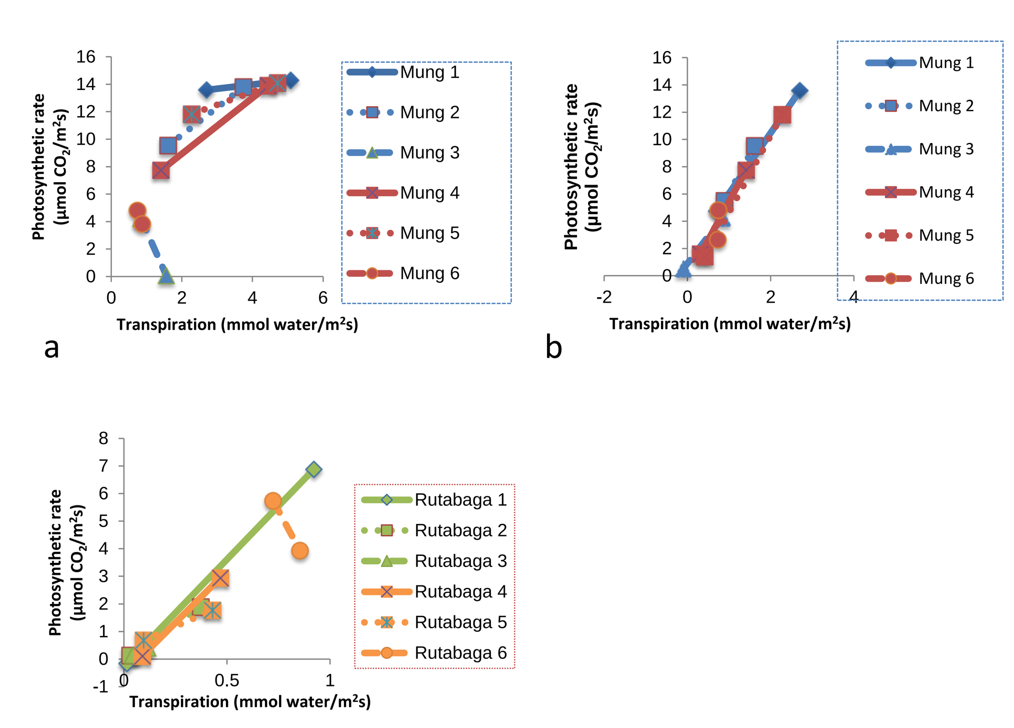


Figure 3 Photosynthetic rate as a function of transpiration rate in water-stressed and watered plants (a) 2-day treatment Mung beans (b) 7-day treatment Mung beans (c) 2-day treatment rutabagas

Table 1 Changes in photosynthetic rate from baseline to appearance of water stress symptoms in mung beans and rutabagas

Table 1.

| | | Baseline (µmol water/ m-2/s-1) | Wilt (µmol water/m-2/s-1) | Change in Rate | Average Change | p-value |
|---|---|---|---|---|---|---|
| Dry | Mung 1 | 13.6 | 4.74 | -8.86 | | |
| | Mung 2 | 9.45 | 5.48 | -3.97 | | |
| | Mung 3 | 4.24 | 0.517 | -3.723 | -5.52 | 0.152 |
| | Rut 1 | 6.88 | -0.154 | -7.034 | | |
| | Rut 2 | 1.87 | 0.134 | -1.736 | | |
| | Rut 3 | 0.413 | 0.138 | -0.275 | -3.02 | 0.199 |
| Watered | Mung 4 | 7.7 | 2.93 | -4.77 | | |
| | Mung 5 | 11.8 | 0.681 | -11.119 | | |
| | Mung 6 | 4.82 | 5.67 | 0.85 | -5.01 | 0.114 |
| | Rut 4 | 1.6 | 0.11 | -1.49 | | |
| | Rut 5 | 1.4 | 1.77 | 0.37 | | |
| | Rut 6 | 2.65 | 3.93 | 1.28 | 0.050 | 0.966 |

Table 2 Leaf water content of mung beans and rutabagas before undergoing water stress treatment

| | Leaf Weight Healthy (g) | Leaf Weight Dry (g) | Total Water (g) | Percent | Average |
|---|---|---|---|---|---|
| Mung 1 | 0.355 | 0.0483 | 0.3067 | 0.136056338 | |
| Mung 2 | 0.192 | 0.033 | 0.159 | 0.171875 | |
| Mung 3 | 0.5071 | 0.1044 | 0.4027 | 0.205876553 | 0.171269 |
| Mung 4 | 0.2612 | 0.0396 | 0.2216 | 0.151607963 | |
| Mung 5 | 0.2937 | 0.0388 | 0.2549 | 0.132107593 | |
| Mung 6 | 0.3476 | 0.0733 | 0.2743 | 0.210874569 | 0.164863 |

| | Leaf Weight Healthy (g) | Leaf Weight Dry (g) | Total Water (g) | Percent | Average |
|---|---|---|---|---|---|
| Rut 1 | 0.938 | 0.2074 | 0.7306 | 0.221108742 | |
| Rut 2 | 0.437 | 0.0668 | 0.3702 | 0.152860412 | |
| Rut 3 | 0.4791 | 0.0977 | 0.3814 | 0.203924024 | 0.192631 |
| Rut 4 | 0.3882 | 0.0369 | 0.3513 | 0.095054096 | |
| Rut 5 | 0.4323 | 0.0962 | 0.3361 | 0.22253065 | |
| Rut 6 | 0.6469 | 0.1126 | 0.5343 | 0.174060906 | 0.163882 |

Table 3 Average changes in transpiration in sets of 3 watered or dry plants of each species after 7 days of water stress in mung beans and 2 days of water stress in rutabagas (transpiration units: mmol water/$m^2$s)

| | Baseline transpiration | Wilted transpiration | Average change in transpiration | p-value (dry vs. watered) |
|---|---|---|---|---|
| 7-Day Dry Mung beans | 1.72±0.9 | 1.48±0.8 | -1.22±0.7 | |
| 7-Day Watered Mung beans | 0.503±0.5 | 0.489±0.2 | -0.988±0.9 | 0.750 |
| Dry Rutabaga | 0.470±0.4 | 0.029±0.01 | -0.441±0.4 | |
| Watered Rutabaga | 0.029±0.01 | 0.458±0.38 | 0.029±0.4 | 0.220 |
| 2-Day Dry Mung beans | 1.72±0.9 | 3.46±1.8 | 1.74±0.9 | |
| 2-Day Watered Mung beans | 1.48±0.8 | 3.34±2.1 | 1.86±1.5 | 0.944 |

Table 4 Water use efficiency of mung beans and rutabagas after 7 or 2 days, respectively, of water stress

| Label | Equation | Water Use Efficiency (slope) |
|---|---|---|
| Dry Mung | | |
| Mung 1 | y = 4.4387x + 1.6107 | 4.4387 |
| Mung 2 | y = 5.6431x + 0.4238 | 5.6431 |
| Mung 3 | y = 4.0004x + 0.8882 | 4.0004 |
| **Average** | | **4.69±0.850** |
| Watered Mung | | |
| Mung 4 | y = 5.6219x - 0.1765 | 5.6219 |
| Mung 5 | y = 5.6112x - 0.9567 | 5.6112 |
| Mung 6 | y = 138.14x - 98.193 | 138.14 |
| **Average** | | **49.79±76.5** |
| Dry Rutabaga | | |
| Rutabaga 1 | y = 7.7589x - 0.2681 | 7.7589 |
| Rutabaga 2 | y = 5.1149x - 0.0205 | 5.1149 |
| Rutabaga 3 | y = 3.7469x - 0.0201 | 3.7469 |
| **Average** | | **5.54±2.04** |
| Watered Rutabaga | | |
| Rutabaga 4 | y = 7.5065x - 0.5648 | 7.5065 |
| Rutabaga 5 | y = 3.2539x + 0.3708 | 3.2539 |
| Rutabaga 6 | y = -13.739x + 15.677 | -13.739 |
| **Average** | | **-0.993±11.24** |
| 2-Day Dry Mung | | |
| Mung 1 | y = 0.3004x + 12.774 | 0.3004 |
| Mung 2 | y = 1.997x + 6.311 | 1.997 |
| Mung 3 | y = -5.7883x + 9.1127 | -5.7883 |
| **Average** | | **-1.16±4** |
| Mung 4 | y = 2.0318x + 4.8787 | 2.0318 |
| Mung 5 | y = 0.9356x + 9.6935 | 0.9356 |
| Mung 6 | y = -7.4396x + 10.352 | -7.4396 |
| **Average** | | **-1.49±5** |

Table 5 Statistical significance of differences in water use efficiency between plant sets (3 of each plant per set)

| **Comparison** | **P-value** |
|---|---|
| *Dry plants* | |
| 7-Day Mung vs. Rutabaga | 0.543 |
| 2-Day Mung vs. Rutabaga | 0.064 |
| 7-Day Mung vs. 2-Day Mung | 0.072 |
| *Watered plants* | |
| 7-Day Mung vs. Rutabaga | 0.319 |
| 2-Day Mung vs. Rutabaga | 0.948 |
| 7-Day Mung vs. 2-Day Mung | 0.311 |
| *Dry vs. Watered* | |
| 7-Day Mung | 0.365 |
| Rutabaga | 0.378 |
| 2-Day Mung | 0.936 |

## Results

- Decrease photosynthetic rates from baseline to wilt ($p > 0.05$ in all sets) (Figure 1, Table 1)
- No significant differences in water content between sets ($p > 0.05$) (Table 2)
- Similar changes in transpiration rate between dry and watered plants($p > 0.05$) (Figure 2, Table 3)
- Increase in WUE after water stress; only significant difference in WUE found between 7-Day and 2-Day dry mung beans (Figure 3, Table 4, Table 5)

## Discussion

**Decreased Photosynthetic Rate**

- Mild water stress → decrease stomatal $CO_2$ (decrease transpiration) → decrease photosynthetic rate (Vico & Porporato, 2008)
- Mesophyll conductance to transport $CO_2$ within leaf decreases with water stress → decrease photosynthesis (Galmés et al., 2007)
  - Expected more significant changes in photosynthetic rate and transpiration, but general negative trends in both are consistent with hypothesis
  - Similar effects among all treatment groups → can draw correlational but not causal relationship

**Decreased Transpiration**

- Transpiration trade-off of losing water while taking up $CO_2$ becomes more important under water stress → close stomata → decrease transpiration after water stress to reduce water loss (Özenc, 2008)
  - Consistent with hypothesis but unexpected insignificant difference in transpiration changes between dry and watered plants

**Decreased WUE**

- Unexpectedly lower WUE in watered plants than dry plants in all but 7-Day mung beans. Contrary to increased WUE in water-stressed lilies (Zhang et al., 2010)
  - Insignificant differences → results inconclusive
- Mung beans took longer to exhibit water stress symptoms and had significantly different water use efficiency from rutabagas after the same duration of water stress. After exhibiting symptoms, had similar water use efficiency to wilted rutabagas.
  - Suggests increased drought tolerance in mung beans compared to rutabagas. May be due to mung bean origins in warm, dry climate of India rather than rutabaga origin in cool, wet climate of Sweden.

## Conclusions

1. No statistically significant differences in measurement renders results inconclusive
2. Water stress is associated with decreases in photosynthetic rate, but cannot draw conclusive or causal relationship from this data
3. Transpiration rate decreases with water stress
4. Mung beans exhibit higher water use efficiency and generally higher drought tolerance than rutabagas given same duration of water stress