Investigation of Metabolic Activity and Relative Water Content of Crop Leaves Using Chlorophyll Content and Leaf-to-Soil Temperature Ratio

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SAFS 3530H 2025WI

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Word Count: 1000

February 11th, 2025

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Abstract

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1 Introduction

1.1 Background

Relative water content (RWC) is the measurement of crop hydration relative to saturated (aka turgid, hydrated) conditions, and is a standard indicator of plant water usage and drought stress (Arjenaki et al. 2012). RWC is calculated as follows:

$$\text{RWC} = \frac{m_{\text{fresh}} - m_{\text{dry}}}{m_{\text{turgid}} - m_{\text{dry}}} \times 100\%$$

Drought stress is a major concern, as it can significantly impact crop yield and food quality. Without sufficient hydration, plants are susceptible to overheating and reduced photosynthetic rate, leading to wilting and eventual crop loss.

1.2 Focus

This study focuses on the physiology and metabolic activity of crop leaves across differing levels of drought stress. Leaves are the most sensitive to dehydration, as leaf tissue adapts more quickly to stress. Furthermore, the leaves are the primary site of photosynthetic activity, and are as-such responsible for the majority of a plant's metabolic activity.

1.3 Objectives

The primary objective of this study is to investigate the existence of relationships between leaf relative water content and both leaf chlorophyll content and the ratio between leaf temperature and soil temperature, as these are both good indicators of metabolic activity.

1.4 Hypotheses & Predictions

It is hypothesized that RWC will differ strongly between droughted and well-hydrated plants. It is also predicted that chlorophyll content will be higher in well-hydrated plants, and that the leaf:soil temperature ratio will be higher in well-hydrated plants due to increased metabolic activity.

2 Methods

2.1 Sampling

A collection of crop plants have been cultivated under greenhouse conditions, with half of the plants receiving droughted treatment and the other half as a control group. Drought treatment pots were watered one week prior to harvest to ensure that plants did not wilt or start to desiccate. Leaves from 4 plants (2 drought, 2 hydrated) were harvested by 15 groups of participants, producing 15 samples. Further ambient and soil measurements were also taken using standard means.

2.2 Data Collection

1. At-pot measurements are recorded, including: Soil moisture, electroconductivity, temperature; light intensity; and relative humidity and leaf temperature.
2. Plants are harvested and each is labelled with the pot number.
3. One complete leaf is sampled and the **fresh mass** (m_{fresh}) is taken.
4. A photo is taken of the sample with its label and a ruler for scale.
5. Chlorophyll content readings are taken.
6. Leaf samples are packaged inside a hydrated paper towel and, after resting for 24 hours, **turgid mass** (m_{turgid}) is taken.
7. All soil is removed from the root system, and roots and shoots are separated and placed into a drying oven for one week, after which **dry mass** (m_{dry}) is taken.
8. Data from all samples are digitized and compiled into a single spreadsheet for analysis.

2.3 Analysis

Both chlorophyll content and leaf:soil temperature ratio are plotted against RWC to determine if relationships exist. A linear regression is performed to determine the strength of each relationship.

3 Results

3.1 Raw Bulk Data

Table 1: Raw study data. Note: # indicates pot number, H indicates hydrated, D indicates droughted.

#	Trt.	Fresh (g)	Turgid (g)	Dry (g)	RWC	Soil °C	CCI	Leaf °C	L °C / S °C
1	H	0.93	1.21	0.02	76.5%	18.5	38.2	19.6	1.06
1	H	3.68	4.04	0.45	90.0%	18.3	32.5	19.8	1.08
1	H	5.70	7.85	1.02	68.5%	18.7	22.6	18.7	1.00
1	H	4.13	4.58	0.39	89.3%	18.3	2.50	18.6	1.02
2	H	4.91	5.46	0.27	89.4%	18.4	16.0	19.0	1.03
2	H	5.19	5.66	0.27	91.3%	18.7	14.3	18.7	1.00
2	H	5.55	6.32	0.34	87.1%	15.0	16.7	19.5	1.00
3	D	1.49	1.65	0.16	89.3%	19.4	18.3	20.0	1.03
3	D	1.65	1.97	0.22	81.7%	19.3	14.9	17.7	0.92
3	D	3.82	4.09	0.18	93.1%	19.0	16.8	21.5	1.13
4	D	12.07	13.77	1.19	86.5%	20.3	14.6	21.1	1.04
4	D	11.23	11.99	1.19	93.0%	19.8	11.5	20.3	1.03
4	D	9.60	10.25	0.66	93.2%	20.2	6.9	21.4	1.06
4	D	9.34	10.82	1.12	84.7%	19.9	30.4	20.5	1.03
4	D	7.03	7.65	0.58	91.2%	18.7	29.50	20.6	1.10

Results continue on next page.

3.2 Chlorophyll Content Index

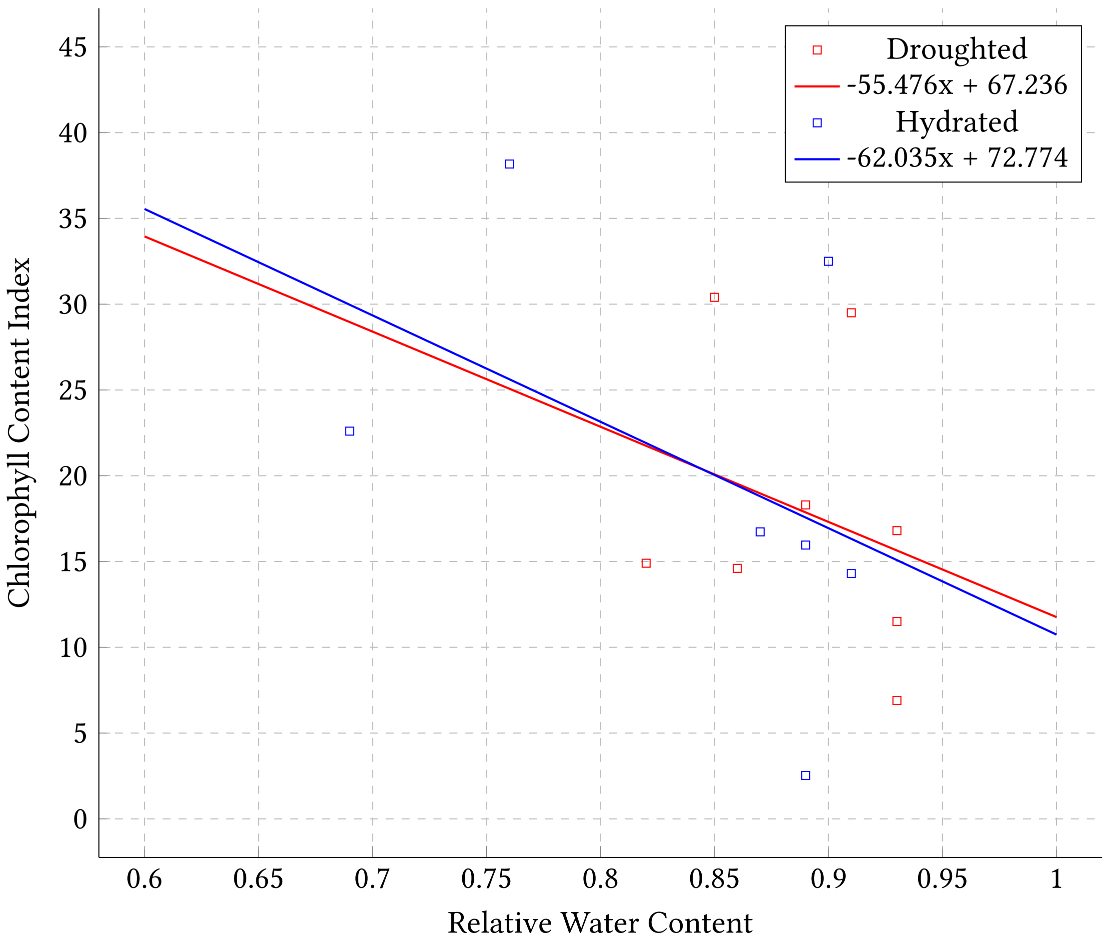

Figure 1: Chlorophyll Content Index (CCI) vs. Relative Water Content (RWC) in droughted (Pots #1 & #2) and hydrated (Pots #3 & #4) samples.

Droughted $R^2 = 0.0819$, Hydrated $R^2 = 0.1939$

Results continue on next page.

3.3 Leaf:Soil Temperature Ratio

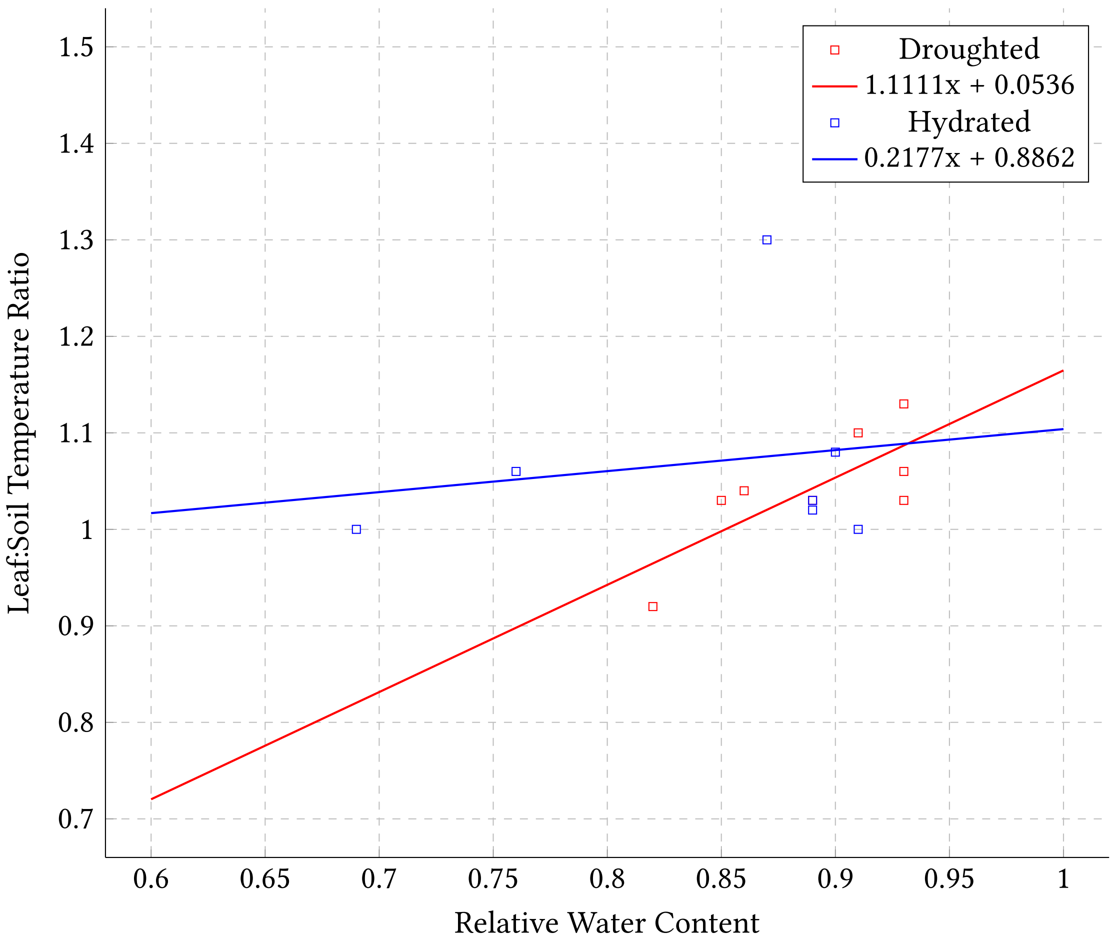

Figure 2: Leaf:Soil Temperature Ratio vs. Relative Water Content (RWC) in droughted (Pots #1 & #2) and hydrated (Pots #3 & #4) samples.

Droughted $R^2 = 0.5815$, Hydrated $R^2 = 0.0306$

4 Discussion

4.1 Relative Water Content

Drought treatment pots were watered one week prior to harvest to ensure that plants did not wilt or start to desiccate - this may have impacted the variance of RWC between droughted and hydrated samples: there was very little difference in mean RWC between the two groups (Droughted Mean RWC = 89.1%, Hydrated Mean RWC = 84.6%).

4.2 Chlorophyll Content Index

Chlorophyll content is a good indicator of photosynthetic activity, and as such was expected to be higher in well-hydrated plants. The relationship between RWC and CCI is weak, with R^2 values of 0.0819 and 0.1939 for droughted and hydrated samples, respectively. This suggests that RWC has little impact on chlorophyll content, and that other factors may be more influential.

4.3 Leaf:Soil Temperature Ratio

More than one plant per pot may have introduced crowding in the canopy, causing leaf:soil temperature to be consistently high and weakening the strength of correlation between RWC and leaf:soil temperature ratio.

4.4 Limitations

Leaf relative water content might influence chlorophyll content more under hydrated conditions, but the relationship remains weak overall

Leaf relative water content significantly influences leaf-to-soil temperature ratio under drought conditions but has little impact when plants are well-hydrated.

References

Arjenaki, F. G., Jabbari, R., & Morshedi, A. (2012). Evaluation of drought stress on relative water content, chlorophyll content and mineral elements of wheat (*Triticum aestivum L.*) varieties. *International Journal of Agriculture and Crop Sciences*, *4*(11), 726–729.