Investigating the Effects of Photosynthetically Active Radiation on Chlorophyll Content in Butternut Squash

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Background

Agrovoltaics refers to the synergistic co-location of agriculture and photovoltaic solar panels on the same land. Although dual-use systems tend to yield lower individual crop outputs (lbs/acre) or electricity (kWh/acre), their collective benefits often surpass those of singular use. This strategy not only diversifies the income sources for farmers but, for certain crop species, can provide better shading, preserve soil moisture, and foster conditions that promote enhanced germination and crop yields.

The goal of this project was to investigate the impact of varying PAR levels on the chlorophyll content in butternut squash, C*ucurbita moschata.* In the absence of solar panels, the plants were expected to exhibit greater levels of chlorophyll content than those within the array beds. The study was conducted in Grafton, MA.

Project Experimental Design

Data Collection Timeline:
Span: 3 distinct weeks during summer spaced bi-weekly.
Week 1: 7/17-7/20
Week 2: 7/31-8/03
Week 3: 8/14-8/17

PAR (Photosynthetically Active Radiation):
- Daylight recorded from 9:30am to 8:30pm.
- Four days of data recorded per week.
- Each bed was equipped with one PAR sensor for a total of four sensors per bay.

Chlorophyll:
- Samples recorded on the same day every week.
- Data collected from each bed position across three replications (bays) for both the control and array sections.

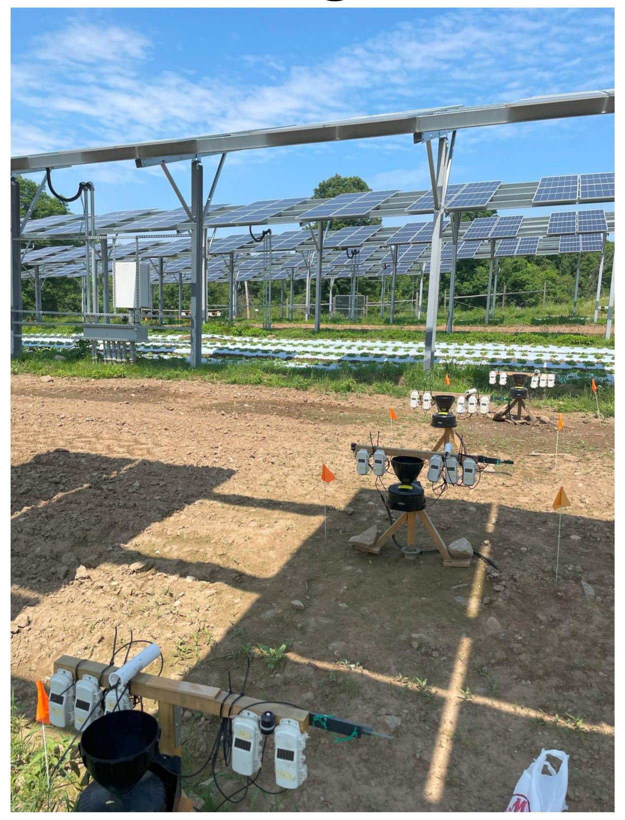

Photo 1: *Array bed positions 1-4 in a bay of solar panels (6/16/23).*

Figure 1: *Supplemental Satellite view of the research site. Satellite image retrieved from Google on 9/1/23.*

Photo 2: *Both replications of control section (6/16/23).*

Specific Aims

__Objective__: To characterize the relationship between solar panel shading and chlorophyll content in butternut squash at varying field positions in an agrovoltaic setup.

Investigative Goals:
- *Variation Assessment:* Evaluate differences in PAR levels between the solar panel array section and the control.
- *Positional Impact:* Understand how shading from solar panels affects chlorophyll content based on field position, particularly within the array section.
- *Correlation Exploration:* Analyze the direct correlation between PAR values and chlorophyll content across the various field positions.

__**Hypothesis:**__ Given the essential role PAR plays in plant growth, we predicted that plants in the unshaded control section will have a higher chlorophyll content, reflecting optimal PAR exposure.

Array Section Positional Average Results

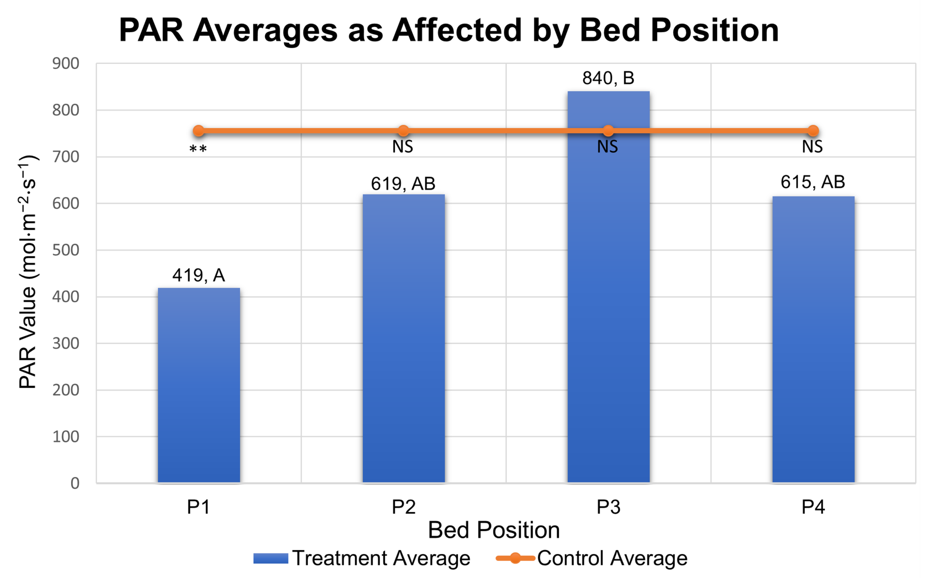

Figure 2: *An unpaired t-test compared bed positions within the array to the control. **Indicates a significant difference from the control at $p \leq 0.01$. NS means no significant difference, $p > 0.05$. Within the array, Tukey's Honest Significant Different test assessed differences between bed positions; control was excluded. A, AB, B from Tukey's denote which groups are statistically similar: "A" differs from "B", but "AB" overlaps with both.*

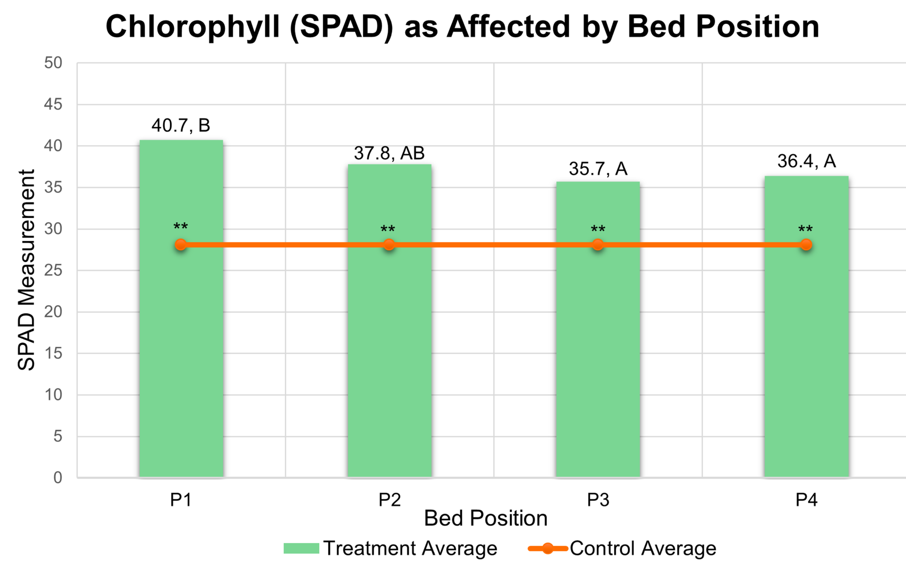

Figure 3: *Chlorophyll (SPAD) variations by bed position. An unpaired t-test compared bed positions within the array to the control; all positions were strongly significantly different** ($p \leq 0.01$). Tukey's Honest Significant Difference test was calculated between array bed positions only, excluding the control. As in Figure 2, "A", "B", and "AB" illustrate which groups are statistically similar/different.*

Correlation Analysis

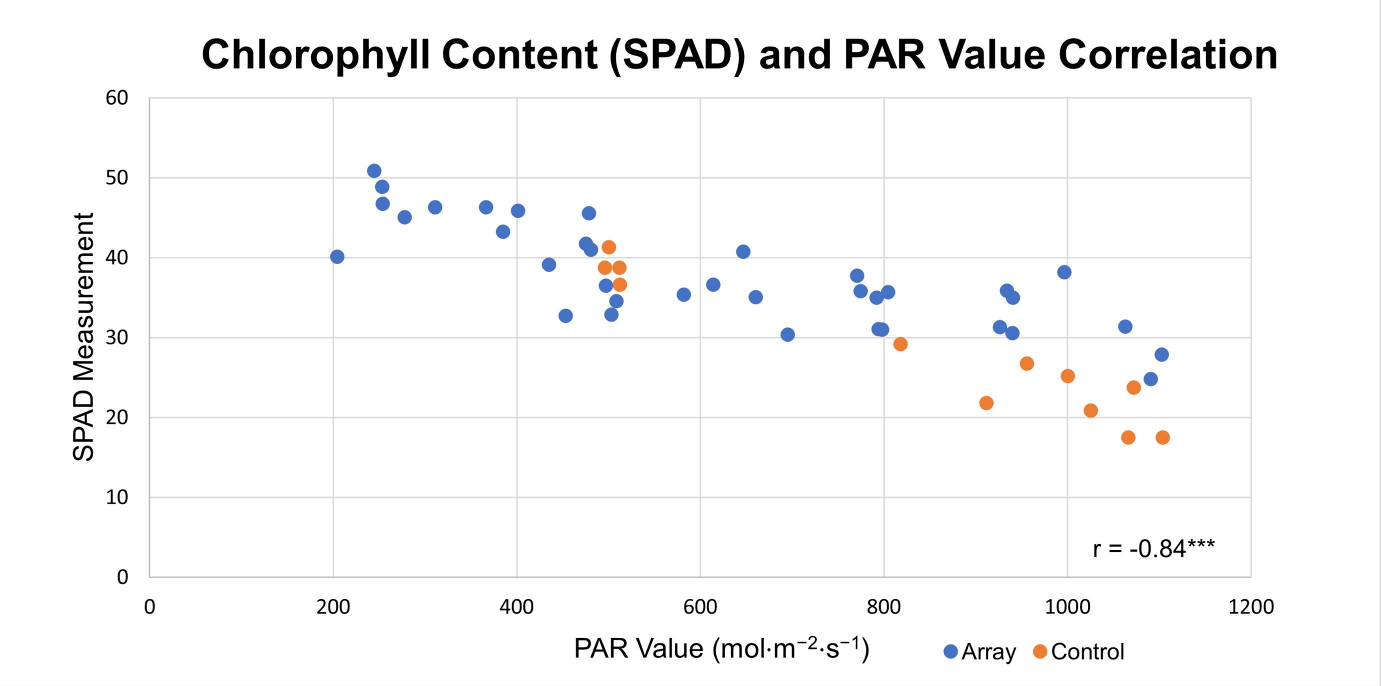

Figure 4: *Scatter plot pairs each weekly positional SPAD measurement with the averaged positional PAR value for both the control and array groups. Orange dots represent averaged weekly data from 12 array positions over 3 weeks for a total of 36 calculated values. Blue dots signify averaged weekly data from 4 control positions over 3 weeks for 12 total readings. __There is a strong (negative) correlation*** that is very significant ($p \leq 0.001$).__*

Array vs. Control PAR Results

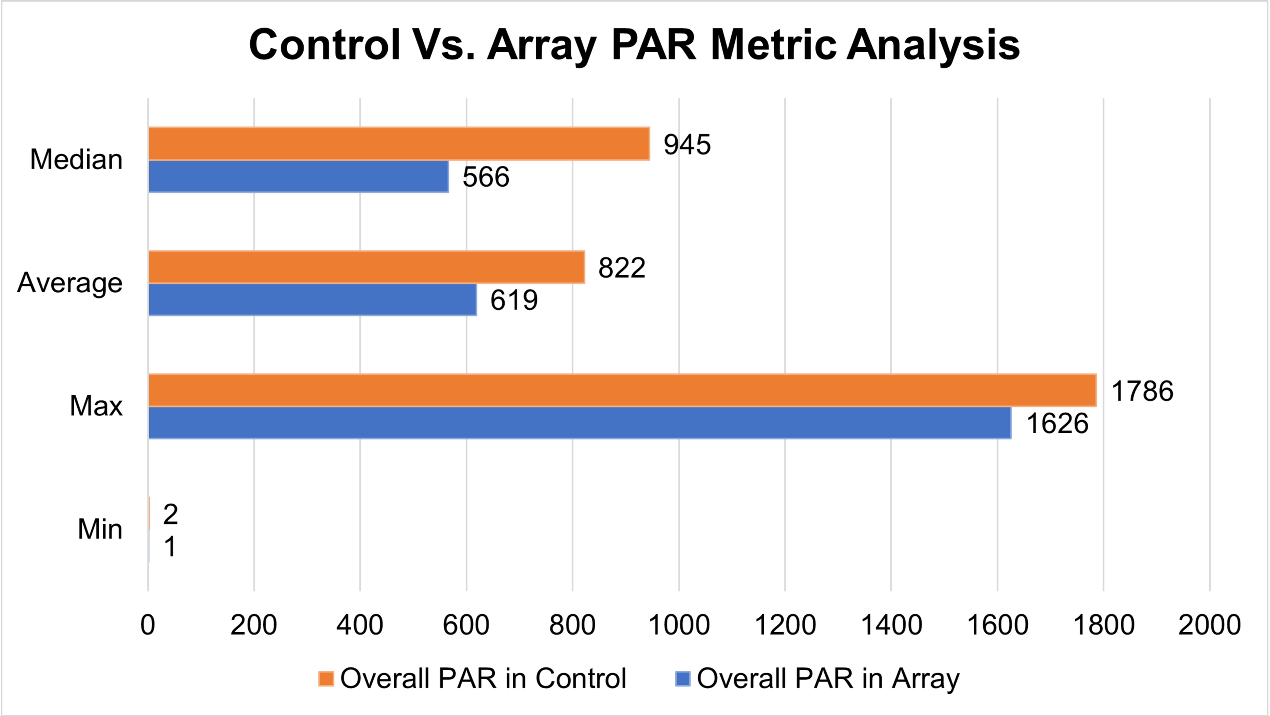

Figure 5: *Bar graph showcases variations in PAR between the array and control groups. Data was collected in 5-minute intervals during daylight recorded hours (9:30am-8:30pm) for a total of 12 days across 3 weeks. Readings were segmented into hourly metrics and averaged to get an overall value for the control and array group positions.*

Over 30,000 PAR data readings were analyzed to generate these insights!

Discussion

Unexpected Chlorophyll Levels:
- Higher SPAD values in array section despite less sunlight

Adaptive Plant Response:
- Plants may increase chlorophyll to enhance photosynthesis when light is scarce.

Site-Specific Factors:
- Potential variability in fertilizer application affected by control's fence proximity

Photo 3: *A butternut squash plant from the __control__ group, subjected to chlorophyll sampling (8/3/23).*

Photo 4: *A butternut squash plant from the __array__ group, subjected to chlorophyll sampling. (8/3/23).*

Future Work

Temperature & Moisture Analysis:
- Study differences in temperature and moisture between control and array.
- Assess if arrays reduce evaporation and influence moisture due to cooler conditions.

Nitrogen Uptake Study:
- Explore nitrogen uptake in butternut squash under different light conditions to corroborate the findings of this research.

References and Disclaimers

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