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Clean Energy Extension

Broccoli Production Under Agrivoltaic Solar Array in Hadley, MA

Information Sheet: First Year Preliminary Results
March 2024

Agrivoltaics is the simultaneous production of both solar energy and crops on the same land. This entails trade-offs that are poorly understood and require optimization between two objectives for which there is little research-based guidance. The presence of solar panels above the crops can modify the microclimate variables such as light intensity, photoperiod, and temperatures. To study the dynamics of agrivoltaic systems on crop production, late-season broccoli was chosen for the experiment under an on-farm solar array in Hadley, MA in 2023. Broccoli is a staple vegetable with high nutrition and commercial values that is adapted to various environmental conditions. Changes in the sun's angle, panel height and orientation, tracking system, and spacing between panels create distinct microclimate environments for crops underneath panels. Therefore, we evaluated microclimate variables such as photosynthetically active radiation, relative humidity, air temperature, and soil temperature at different transect positions throughout the crop growing seasons along with crop growth and yield of late-season broccoli.


Joe Czajkowski Farm, Hyperion Systems

Materials and Methods

The field contains fine sandy loam soils and has historically been used for rotational vegetable crops. The array is a north-south single-axis tracker system (azimuth 69.8 degrees) meaning the modules track the sun east to west throughout the day for greater energy capture compared to a fixed tilt south-facing system. The array has a capacity of 0.445 MW DC on 2.2 acres and was completed in July 2023. The modules are installed at a height of 10' to module horizontal. At a maximum tilt angle, the modules will be 7.75' to the ground, but during the 2023 trial year, they were not connected to the grid and remained in a horizontal position. The modules are 7.48' in length and 3.72' in width. The spacing of the modules is 18.1' panel edge to panel edge. The shading tool used by the Massachusetts Department of Energy Resources to evaluate dual-use applications calculated that this configuration should result in an average of 28% shade with a maximum of 38% shade compared to baseline conditions between March and October. The tool predicts that 34 percent of the array will experience shading between 30%-38%, while the remainder has less than 30%.

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Broccoli was transplanted on August 18, 2023, with a spacing of 30 cm between plants and 90 cm between rows. Microclimate sensor stands were placed only in three beds: 1) leading panels, 2) between two panels, and 3) near the back panel in three replications as depicted in Figure 1. Microclimate sensors were installed on August 22, and in control sites on August 22 and September 3, 2023. The sensors were mounted in the stand as in Figure 2 at a height of 20 inches above the soil. All sensors were removed from the field on Dec 6, 2023, and stored for the next season.

Figure 1. Broccoli planted in three different bed positions under the solar array.

The chlorophyll index (CI) was measured non-destructively with the portable SPAD 502 Chlorophyll Meter (Minolta Co., Ltd.) weekly from Sep 11 to Oct 31, 2023. Readings were taken from three leaves per plant with 6 plants per bed in control and 4 plants per bed in the array i.e., 18 plants in control and 36 plants in the array.

An independent sample t-test was conducted to compare the control group with each bed position within the array. To compare the effects of bed positions within the array without control, one-way analysis of variance (ANOVA) was done. Mean separation for statistically significant effects was performed using Tukey's HSD test.

Figure 2. Mounting unit assembly with sensors.

Preliminary Results

- Mean PAR was lowest in bed positioned under the leading panel (BP 1) in comparison to control. However, BP 2 (positioned between two panels) and BP 3 (positioned under the back panel) received a similar light quantity (PAR) as in the control.
- There were similar air temperatures, relative humidity, and soil temperatures under array and control probably due to the design of the panel which is fixed at 90° and consistent airflow between control and array.
- The chlorophyll index of broccoli leaves showed a weak negative correlation with mean PAR.

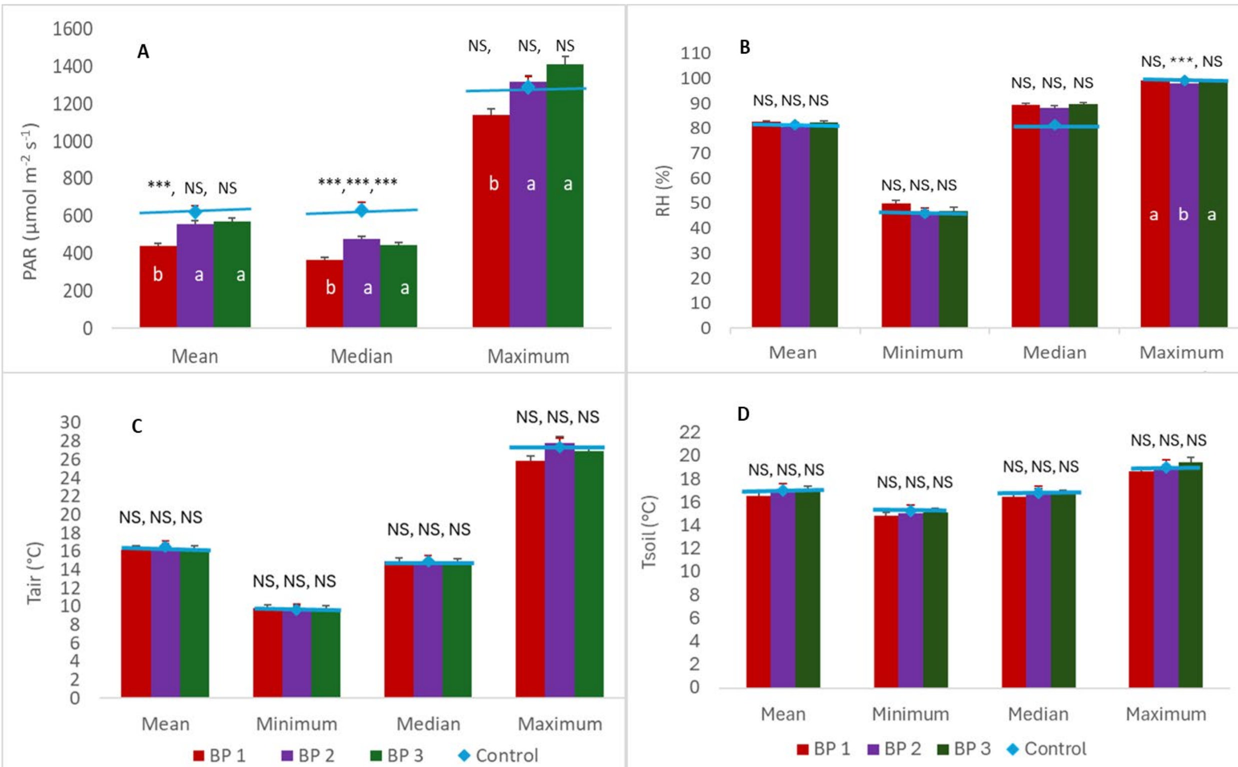

Figure 3. Variables measured under solar and control in broccoli crop. Treatments with the same letter are not significantly different from each other.

A) Photosynthetically active radiation (PAR)
B) Relative humidity (RH)
C) Air temperature (Tair)
D) Soil Temperature (Tsoil)

Photo credit: Sam Glaze-Corcoran

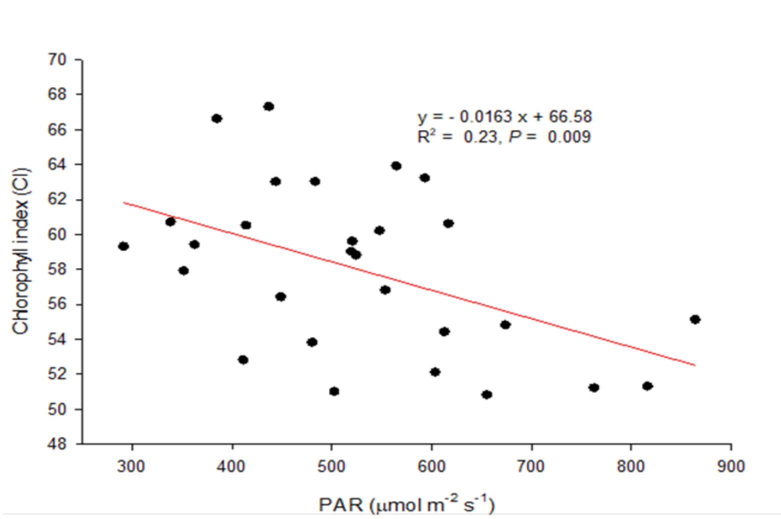

Figure 4. Relationship between CI of broccoli leaves and PAR in control and three different bed positions under array.

The current results gave us a snapshot of how the presence of solar panels modifies the microclimate variables at the crop canopy level while averaging data from the whole crop season. However, to explore more about the effects of solar panels on microclimate variables in detail, a time series analysis will be done. The comparative analysis between control and array on different timescales: daily, weekly, and monthly allows for a comprehensive understanding of the impacts of microclimate variables on broccoli growth and development. Lessons learned in 2023 will be applied during the 2024 season.

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