BOTH Research and Extension

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TITLE: Investigating the Impact of Various Solar Installation Construction Methods on Wild Blueberry Growth and Development

OBJECTIVE(S)

Identify whether use of distinct construction and solar installation methods can minimize the impact of construction on existing wild blueberry fields.

LOCATION(S): Rockport, ME

PROJECT TIMEFRAME: August 2020 – August 2022

INTRODUCTION

Agrivoltaics (co-locating solar and agricultural operations on the same land) is a growing industry, which has successful installations on cranberry bogs in Massachusetts (Mupambi 2020). The solar and agriculture industries in Maine have increasing interest in developing similar projects on wild blueberry fields. Like cranberry, wild blueberry is grown low to the ground, tolerant of shade and moderate physical disturbance. Solar development firms are interested in installing on agricultural land because these lands have low tax rates and are already cleared. Wild blueberry farmers are interested in responsibly stewarding their farmland and in diversifying revenue streams. To our knowledge, farmers have been offered approximately $2,500/acre within solar contracts, which usually last 15-20 years. On average, a wild blueberry farmer in Maine produces 3,000 lbs/acre at $0.40 cents/lb for an income of $1,200/acre (Personal Communications and NASS 2020). A solar installation is thus attractive financially, especially as growers continue to face financial challenges with late frosts (50% of the crop lost in 2019) and drought conditions (45% of the crop lost in 2020) (Schattman et al. 2021), which will continue to occur as climate change progresses.

Maine lacks regulatory and/or financial incentives to encourage development of such dual-use solar projects. Massachusetts has these incentives and the accompanying rapid growth of these projects. Developing agrivoltaics is more expensive because the array's design must be angled and elevated 8-10 feet off the ground to allow sunlight to reach the plants and for growers to maneuver underneath. This project, situated in Rockport, is a case study for Maine to understand how such incentives could be established. Studying this installation will also identify whether using deliberate construction methods mitigates damage to wild blueberry and what management changes and costs growers can expect when transitioning to agrivoltaics. This solar array utilizes two different types of solar panels: monofacial and bifacial. Monofacial panels are standard panels that have solar receptors only on the sun-facing side of the panel and generate energy just from that side. Bifacial panels are a newer technology with solar receptors on both sides of the panel that can generate energy from both sides. Bifacial panels allow more sunlight through the panel and generate energy from solar energy reflected off the surface underneath the panels. This was the first year of several tracking the wild blueberry to determine how much damage the plants suffered and how quickly they recovered. Data collection in future years will improve our understanding of wild blueberry production under this array and sunlight penetration to wild blueberry plants in shade, partial-shade, and full sun.

(Information on how farmers can start discussing options for solar development on their land can be found under the “Current Recommendations” header.)

METHODS

Panel installation (completed by construction contractors)

A south-facing 12-acre portion of the 40-acre installation was allocated for this study and divided into three categories: Standard, Mindful, and Careful construction methods. Rows of panels are separated by a drive-row which is wide enough for a vehicle to pass, if needed.

- In Standard (rows 27-31): construction and installation methods were unaltered from industry and company standards; equipment could drive and operate anywhere, was not restricted from turning or rotating, and foot traffic was not limited.
- In Mindful (rows 14-18): equipment could only enter and exit the site along one path; equipment could only rotate 90°; and foot traffic was limited to as few paths as possible.
- In Careful (rows 2-6): poly mats (see Figure 1, below) were placed on top of the blueberry plants to work and drive equipment on; poly mats could remain in place for only 4 weeks at a time in spring and as summer progressed the mats could only be in place one workday at a time; equipment could only turn 90° if the equipment was situated fully on plywood (otherwise, equipment could only drive straight in and straight out); and foot traffic was allowed only along one path.

Figure 1 Dr. Lily Calderwood discusses impacts on blueberry plants with members of the construction and panel installation team. All are standing on the poly mats used to minimize disruption to existing blueberry plants in the Careful treatment. These mats were driven on by construction and installation equipment and served as pathways for workers. Photo credit: Brogan Tooley.

Detailed construction methods and restrictions were designed by the planning team, which included Dr. Calderwood, members of BlueWave Solar, Solar Agricultural Services, and CS Energy. CS Energy, the construction firm, took it upon themselves to write down the protocol and train their workers in the field on how to implement the three construction methods. Employees took a blueberry protection training prior to entering the site.

Figure 2. Aerial view of the solar array under installation. Photo credit: BlueWave Solar, CS Energy.

<u>Data collection (completed by University of Maine Team)</u>

Pre-construction baseline data was collected on November 20, 2020 and included quadrat data taken along 4 randomly selected field transects. Within each of 4 quadrats per transect, 6 stems were selected for stem heights and bud counts. Stem density and soil compaction were also collected in each quadrat and a single soil sample was taken across the whole field.

After construction and panel installation was complete, multiple data were collected in each of the construction categories and at a control site situated outside the solar array, which was not impacted by construction or installation (referred to as “external control”). Measures quantifying the immediate impacts of installation included soil compaction and blueberry cover. Long-term impacts may include increased weed pressure, and changes in soil moisture, organic matter, and nutrient availability due to soil disturbance and compaction. The direct impacts of reduced light availability were quantified through observations of phenological growth and development, leaf chlorophyll content and soil moisture. 2021 data collection is described below. Fruit yield and berry quality will be collected in 2022.

Multiple Photosynthetically Active Radiation (PAR) sensors with data loggers (ZL6 from METER group, Pullman, WA) were installed on July 9, 2021 to measure, in 15-minute intervals, the amount of sunlight penetrating through the solar panel array. This sun was assumed to be available to the wild blueberry plants below and was measured in the following locations: directly under panels, called “under-panel”, partial shade (in drive rows behind panels, called “drive-row-shade"), and full sunlight conditions (in drive rows between solar arrays, called “drive-row-sun"). There were 4 sensors (full shade, partial shade, full sun, and a localized control, called “array control”) installed in each construction category (Standard, Mindful, Careful), for a total of 12 PAR sensors. No PAR sensors were installed in the control plots situated outside of the array perimeter (called “external control”) for pest and plant data collection. PAR sensors in full sunlight provided the localized control value, or “light quantities,” for comparison with the partial and full shade conditions.

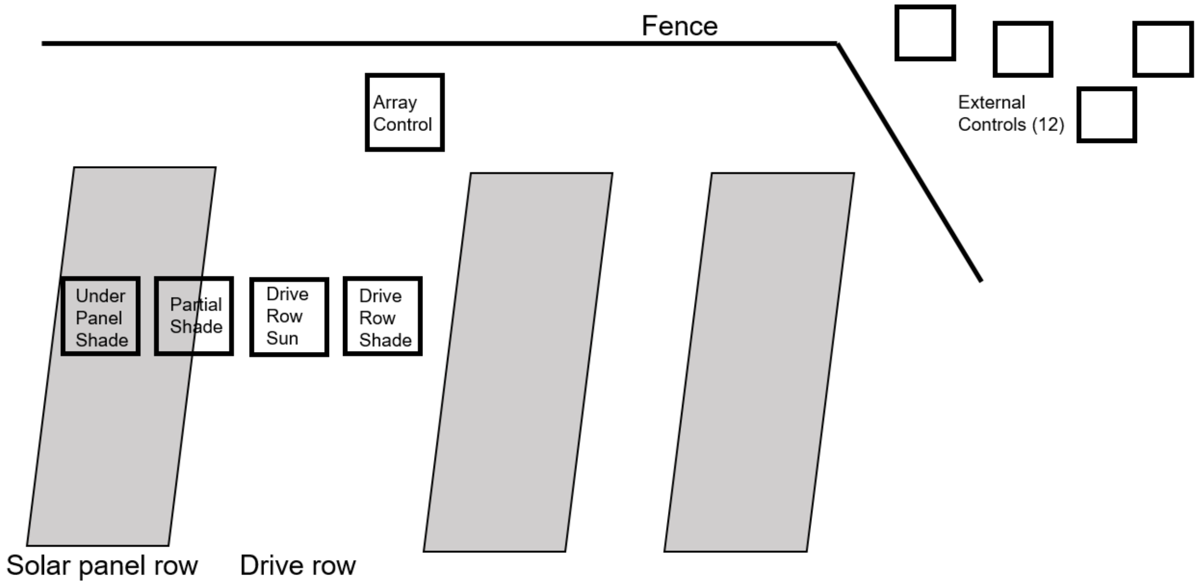

Figure 3. Example of one replication plot layout in the field where black squares represent quadrats where data collection occurred.

A 0.37 m^2 quadrat was used at each PAR sensor location for four panel rows; this totaled 16 quadrat samples per construction method for a total of 48 quadrats within the array. In addition, there were 12 external control quadrat plots, for a total of 60 quadrat plots across the entire project. All 60 quadrats were flagged for repeated measurements in the same locations throughout the season.

Wild blueberry health was evaluated within each quadrat by ranking overall blueberry cover using the Daubenmire Cover Scale of 0-6, where 0 = not present, 1 = ≤1-5% coverage, 2 = 6-25% coverage, 3 = 26-50% coverage, 4 = 51-75% coverage, 5 = 76-95% coverage and 6 = 96-100% coverage (Daubenmire 1959). Weed pressure was evaluated using the Daubenmire rank, totaling the number of weeds present, and listing the top three weed species present. Disease pressure was evaluated by counting the number of blueberry stems showing signs of disease, listing the top three diseases present, and ranking the severity of the disease observed. These blueberry coverage, weed pressure, and disease pressure measurements were all taken three times in 2021, on August 6, August 13, and September 27. In addition, blueberry stem heights and stem number per quadrat were recorded on August 13, 2021.

Wild blueberry plant health was further evaluated by gathering SPAD and TDR data. SPAD (Soil Plant Analysis Development) is a measure of how much chlorophyll is present in the leaves of the plant and was measured using a handheld chlorophyll meter (SPAD 502; Minolta Corp., Osaka, Japan). The higher the value calculated by the meter, the healthier the plant. SPAD values were taken in pairs on the same stem, reading the value on a lower and upper leaf. These pairs were taken on 4 randomly selected stems within each quadrat. TDR (Time Domain Reflectometry) is a measure of soil moisture content and temperature and was measured using a FieldScout TDR 150 Soil Moisture Meter (Spectrum Technologies, Inc., Aurora, IL, USA) to measure soil conditions to a depth of 12 cm. TDR samples were taken twice in each quadrat. SPAD and TDR samples were gathered thrice in the 2021 season, on August 13, August 27, and September 27.

Soil compaction was measured in each quadrat using an AgraTronix penetrometer (AgraTronix; Streetsboro, OH, USA) thrice in each quadrat. This compaction data was collected on August 6, 2021.

A soil sample in each of the three construction categories was collected on August 6, 2021 and analyzed at the University of Maine Soil Analysis Lab, Orono, ME, USA. This sample provided information about the nutrient profiles and organic matter present at each location. The Soil Analysis Lab also analyzed dried leaf samples to determine leaf nutrient content. These leaf samples were gathered on August 13 and 27, 2021.

Data analysis

Due to locational changes of the PAR sensors in the first month of the trial, the quadrat data collected around the PAR sensors was removed from analysis. All quadrat related data presented below (soil compaction and moisture, leaf chlorophyll, blueberry stem density and height) are from the 36 plots within the array and the 12 ‘external’ control plots outside of the array. The 12 external control plots were randomly assigned to a section (careful, mindful, standard) to maintain equal sample size in statistical comparison. Computations were carried out using JMP Version 15.2 (SAS, Carry, NC) statistical software. PAR data and pest pressure data did not meet statistical assumptions of a normal distribution and statistics were not performed but will be revisited with more data in 2022. When data met statistical assumptions (i.e soil compaction, soil moisture, plant chlorophyll, stem density and height), evaluations were completed using a one-way ANOVA and a Tukey’s Pairwise comparison.

RESULTS

Environment

The greatest levels of soil compaction occurred under-panel (relative to the control) and in the Standard and Mindful construction methods where greater disturbance likely occurred (Figure 4). Here, the Standard drive-row-shade and the Mindful under-panel had significantly more compacted soils than the external control. The Mindful under-panel also had significantly more compacted soils than the Careful drive-row-sun, suggesting the more careful construction methods may have mitigated disturbance.

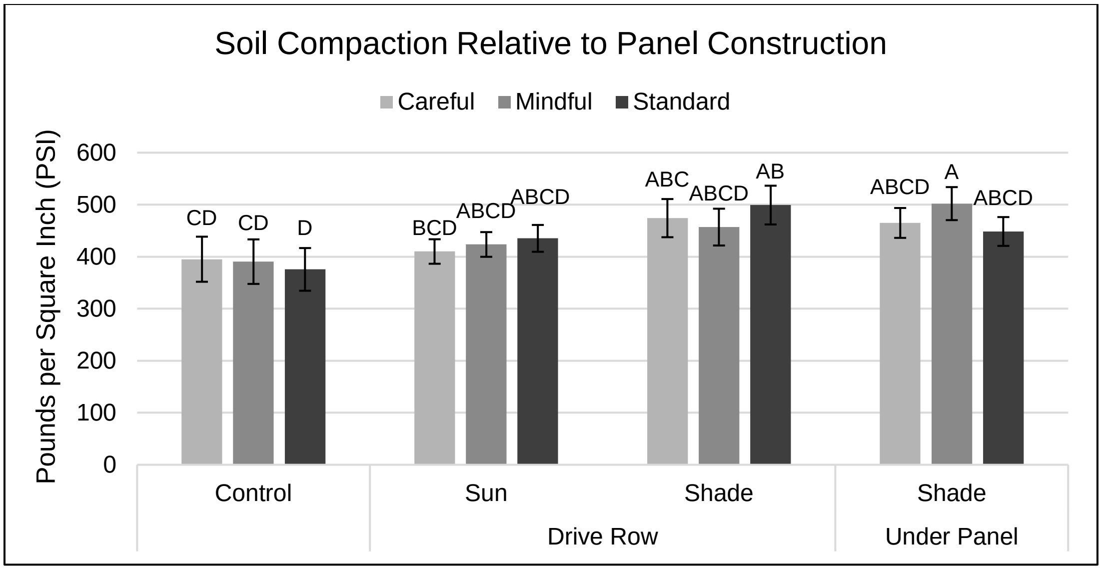

Figure 4. Soil compaction relative to construction mode and amount of shading from solar panels measured on August 6, 2021. Letters indicate significance at the 0.05 level of significance. Error bars indicate the standard error of the mean.

All under-panel locations across all construction methods had significantly higher soil moisture relative to the external control with the exception of the Mindful drive-row-sun and Mindful under-panel (Figure 5). Of the treatments exhibiting significant differences, the volumetric water content of the external control soil ranged from 23-25% while the under-panel soil moisture ranged from 32-38%. The under-panel soil moisture measures were 35-54% greater than the external control soil moisture measures.

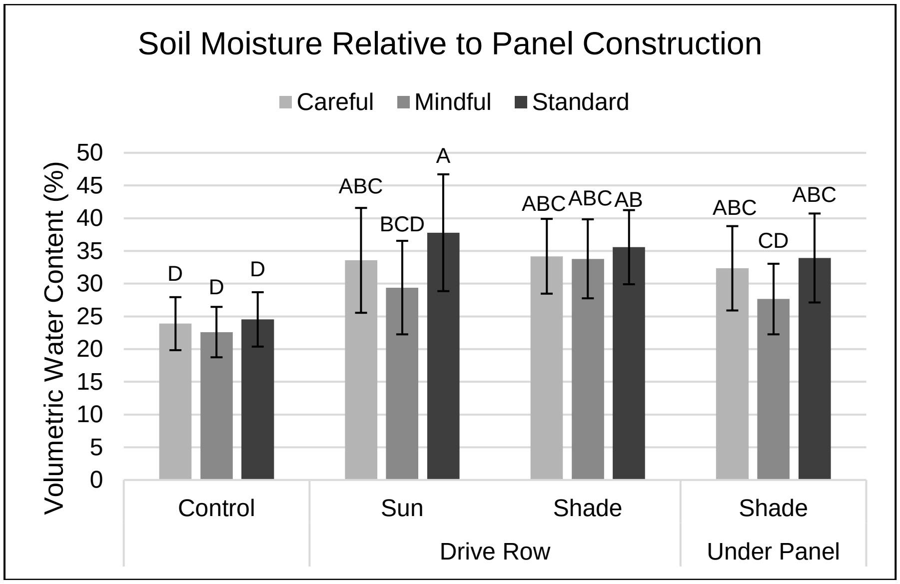

Figure 5. Soil moisture (% VWC) relative to the mode of construction and amount of shading from solar panels, measured August 13, 2021. Letters indicate significance at the 0.05 level of significance. Error bars indicate the standard error of the mean.

A clear difference existed in PAR measures between the panels (drive-row-sun and array control) and underneath the panels (drive-row-shade and under-panel) (Figure 6). Although not yet statistically analyzed due to the failure of the data to meet parametric assumptions, the drive-row-sun plots received on average 18% less PAR than the full sun array control. The drive-row-shade and under-panel locations received as much as 83% and 88% less PAR (sunlight) than the control, respectively.

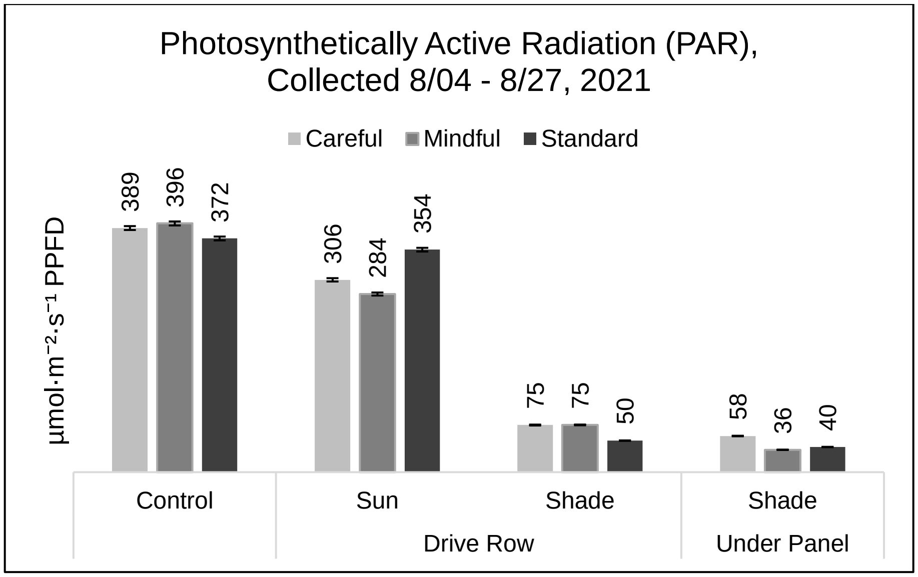

Figure 6. PAR relative to the mode of construction and amount of shading from solar panels, measured August 4 - 27, 2021. Significant differences were not tested due to non-normality in the data. Error bars indicate the standard error of the mean.

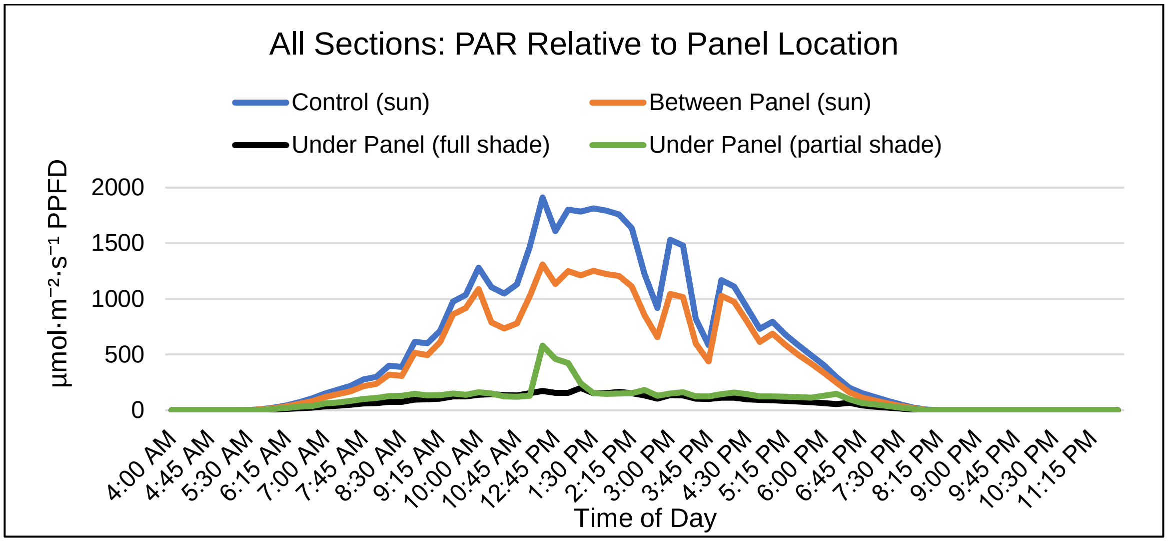

Figure 7. Hourly PAR for a sunny day (August 8, 2021) relative to panel location.

Plant Health

In response to reduced PAR within the array, leaf chlorophyll concentrations (as measured with SPAD) in drive-row-sun and under-panel were significantly higher than the external full sun control except for Standard drive-row-sun and Careful and Standard drive-row-shade (Figure 8). The leaf chlorophyll content of external control ranged from 23.4 to 27.2, while the under-panel had the highest leaf chlorophyll ranging from 38.3 to 40.2. Overall, the leaf chlorophyll content of the plants within the array (under-panel and drive-row-shade) were 10-51% higher than the external control plants.

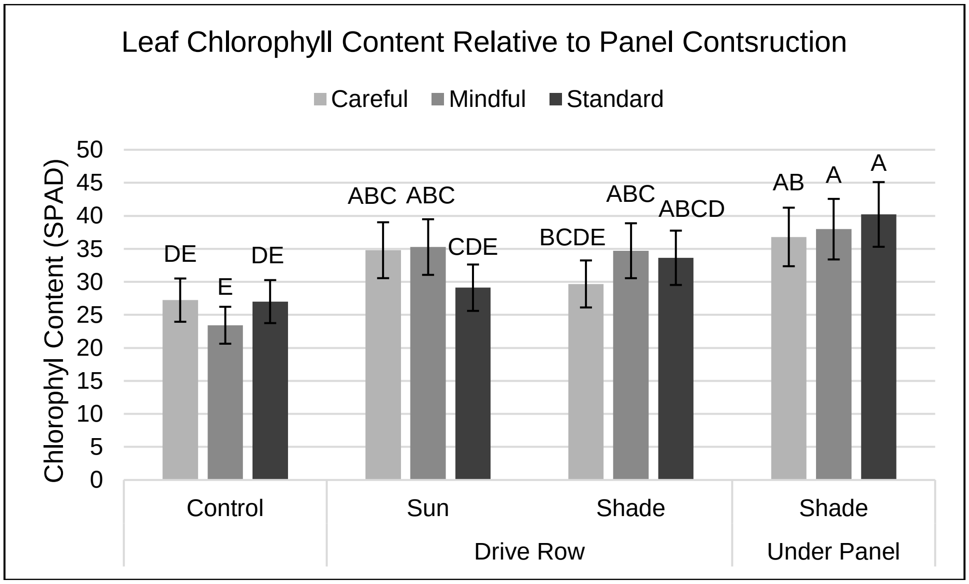

Figure 8. Leaf chlorophyll content (SPAD) relative to the mode of construction and amount of shading from solar panels, measured August 13, 2021. Letters indicate significance at the 0.05 level of significance. Error bars indicate the standard error of the mean.

Lowbush blueberry stem density and stem height did not present statistically significant differences between treatments, but still exhibited some interesting trends (Figure 9). Stem density appeared to reduce with the mode of construction such that Careful maintained the highest stem counts (even in drive-row) compared to Mindful, Standard, and the external control (Figure 9a); Mindful and Standard saw reduced stem numbers within their drive-rows as well. Blueberry stem height reflected greater differences in sample locations within the panels (i.e., drive-row vs. under-panel) rather than with mode of construction (Figure 9b). The external control had the tallest stems followed by Mindful under-panel. Careful drive-row had the tallest stems, followed by Mindful and Standard.

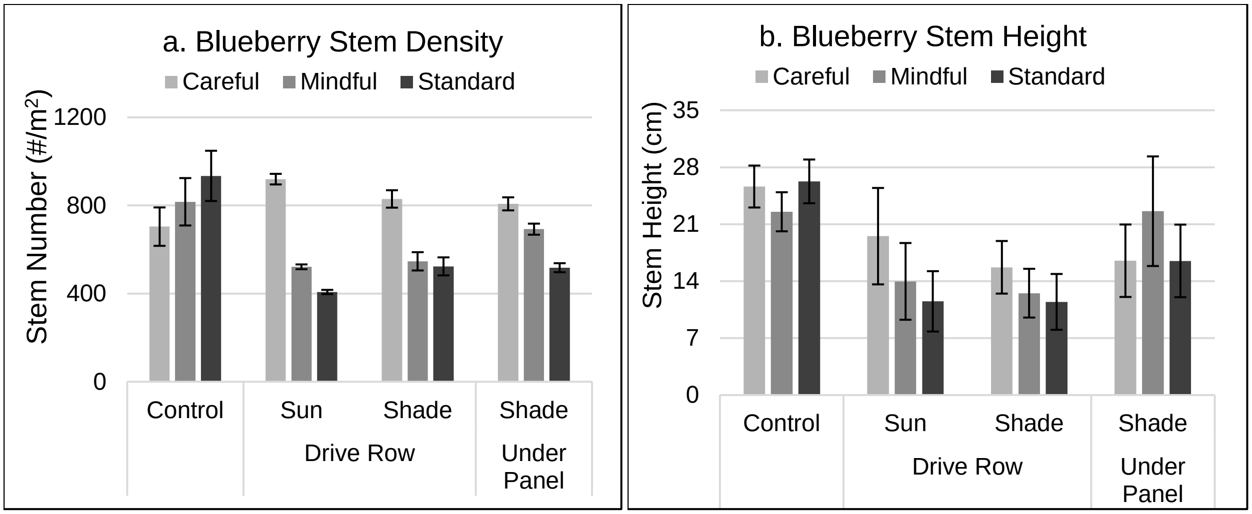

Figure 9. Lowbush blueberry stem density (9a) and stem height (9b) relative to the mode of construction and amount of shading from solar panels. Differences in blueberry stem number and stem heights were non-significant at the 0.05 level of significance. Error bars indicate the standard error of the mean.

Pest Pressure

Weed, insect and disease pressures in the blueberry were non-significant between treatments (within the array vs. outside the array; data not shown). Observationally, insect and weed pressures were variable in this initial year. Disease presented a visual trend, where shaded plots within the array exhibited less disease than the external control, likely due to the higher soil moisture and reduced heat stress. However, higher disease presence and early leaf drop was observed within the array in the fall where rain hit panels and fell to the ground at breaks between the panels.

DISCUSSION

Observationally, the wild blueberry crop is recovering faster than expected from construction disruptions, with darker than usual, healthy-looking leaves in the shaded areas (under-panel and drive-row-shade). Parts of this field were in prune and crop cycles in 2021 and are in the process of being transitioned to one unified cycle across the whole area. Wild blueberry plants in the crop year bloomed during construction and produced some fruit under the solar panels after construction finished yet harvest did not take place in this first year.

The soil was most compacted directly underneath the panels for all construction methods, and particularly under Standard and Mindful methods where more disturbance occurred compared to the Careful section.

Preliminarily, shaded locations within the array exhibited higher soil moisture content than what was measured in the external full sun control. Under-panel soil moisture levels were 35-54% greater than those in the external control. This indicates that the solar panels improve soil moisture retention, perhaps by preventing the evapotranspiration of moisture from the soil and plants. Drought conditions have caused crop loss in wild blueberry with

45% of the crop lost in 2020 (Schattman et al., 2021) making these findings important if the crop can maintain berry production under the shade produced from solar panels. Even more intriguing is the trend towards higher soil moisture in the partial shade (drive-row-shade) and partial sun (drive-row-sun) in the drive row where it will be much easier to continue farming. Wild blueberries require 1 inch of rain per week between April and October to sustain plant demand (Trevett, 1967; Hunt et al., 2008). The probability of reaching this rainfall requirement is estimated to be less than 50% during most of the growing season and less than 20% during the critical fruiting period (July – August) based on rainfall histories since 1959 (Dalton and Yarborough, 2004). Recent research by UMaine colleague, Yongjiang Zhang, suggests that volumetric water content of 10% or higher is adequate for wild blueberry production but should not drop to 5% or lower. All soil moisture readings during this first year of study were 20% or higher. Continued observation and measurement will indicate whether or not these solar panels serve to shield soils from drying out as quickly as uncovered soils do.

Mindful plots consistently saw lower soil moisture and higher compaction levels, indicating these measures could be correlated and indicative of preconstruction landscape conditions. The entire solar array is mostly situated atop rocky outcroppings with exposed patches of bedrock with the most exposed bedrock in the Mindful section. This area therefore has less soil and is more vulnerable to compaction and reduced soil moisture levels.

Though PAR data did not meet parametric assumptions, comparing PAR measures directly shows a stark difference in the levels of PAR reaching the plants under each sunlight condition. Intuitively, control plots received more sunlight and therefore measured the greatest amount of PAR. Compared to the control, the drive-row-sun plots measured 18% less PAR, the drive-row-shade plots measured 83% less PAR, and the under-panel-shade plots measured 88% less PAR. Wild blueberry are tolerant of shade, but a near-total reduction in received PAR will likely prove more limiting for the wild blueberry than the plant can handle. Further study in future growing seasons will increase our understanding of how the wild blueberry handles reductions in PAR availability.

Variations in PAR availability for the plants also impacted the level of leaf chlorophyll concentrations, as measured by SPAD. Drive-row-sun (less the Standard plot) and under-panel plots were significantly higher than the control. This is the plant’s response to shade allowing them to absorb more light. With less PAR reaching the plant, it is advantageous for the plant to produce more chlorophyll to better utilize what limited PAR does reach the plant. Under-panel leaves were visually observed as being consistently darker green than those with higher light quantity.

Lowbush blueberry stem density and height did not exhibit statistically significant differences between treatments, although they did display some other interesting trends. Careful saw the greatest stem density in all plots (even the drive-rows) compared with the other construction methods and the external control, which aligns with the knowledge that blueberry plants respond well to slight disturbance. Meanwhile, blueberry stem heights were more varied based on their location (drive-row vs. under-panel) instead of construction method. Generally, stem heights were shorter in drive-row than under-panel. Taken in combination, the stem density and height information indicate that blueberry plants were either successfully protected by the Careful precautions taken or the plants responded to disturbance by producing more stems which has been seen in other cases (Libby 2011).

While weed, insect and disease pressures in the wild blueberry were nonsignificant between treatments and varied in their occurrence and cover. Plots within the array displayed less disease than the external control, likely due to the increased shading and soil moisture which reduced drought or heat stress to the plant. The greatest disease pressure was measured in Standard drive-row-shade, which aligns with knowledge that leaf spot can spread through physical disturbance. In general plant diseases will increase where more moisture is present, this was visually apparent along the drip edge of the panels. The lack of treatment differences for weed, insect and disease pressure may have been due to late season sampling, due to late construction completion in July 2021. Measuring the vernal emergence of pests and their impact on wild blueberry plants during the 2022 season will be more indicative of the long-term impacts of construction methods and a solar array on pest presence.

CURRENT RECOMMENDATIONS

- When considering a solar array decide if it the main goal is farming or energy production.

NEXT STEPS

- Continue data collection (dependent on funding)
- During and after the 2022 growing season, quantify costs associated with managing fields that now host solar arrays and identify costs and management changes needed to transition to hosting solar while continuing to harvest wild blueberry commercially
- Form group of wild blueberry farmers with interest in agrivoltaics to advise research, education, and adoption efforts
- Present results and recommendations at UMaine Wild Blueberry Conference, summer blueberry field meetings, and UMaine Blueberry Hill Field Day

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REFERENCES

Daubenmire, R.F. 1959. Canopy coverage method of vegetation analysis. *Northwest Science 33:*43-64.

Fernandez, I., S. Birkel, C. Schmitt, J. Simonson, B. Lyon, A. Pershing, E. Stancioff, G. Jacobson, and P. Mayewski. 2020. Maine's Climate Future 2020 Update. Orono, ME. climatechange.umaine.edu/climate-matters/ maines-climate-future/

Hunt, J.F., C. W. Honeycutt, G. Starr, and D. Yarborough. 2008. Evapotranspiration rates and crop coefficients for wild blueberry (Vaccinium angustifolium). International Journal of Fruit Science 8(4): 282-298. doi:10.1080/15538360802597549.

Libby, B. 2011. University of Maine Master's Thesis. Propagation, nursery container production, and rhizome growth studies of *Vacciumium angustifolium* Ait and *Vaccinium vitis-idaea* L. subsp. Minus (Lodd.) Hulten. University of Maine Master of Science Thesis.

Mupambi, G. (2020). 2020 update MTG: Cranberry Production and Solar. ScholarWorks@UMass Amherst. Retrieved October 21, 2021, from https://scholarworks.umass.edu/cranberry_extension/301/

Trevett, M. F. 1967. Irrigating lowbush blueberries the burn year. Maine Farm Research, 15(2).

USDA NASS (National Agricultural Statistics Service). 2021. Noncitrus Fruits and Nuts: 2020 Summary. Retrieved January 3, 2022 from https://downloads.usda.library.cornell.edu/usda-esmis/files/zs25x846c/sf269213r/6t054c23t/ncit0521.pdf

Schattman, R. E., Goossen, C., and Calderwood, L. 2021. The 2020 Maine Drought and Agriculture Report. University of Maine, Orono. 1-30. DOI: 10.6084/m9.figshare.14474055