



Full Report

APV Phase Two

— January 2023 - December 2024 —

Prepared By

Juli Burden

Tyler Jones

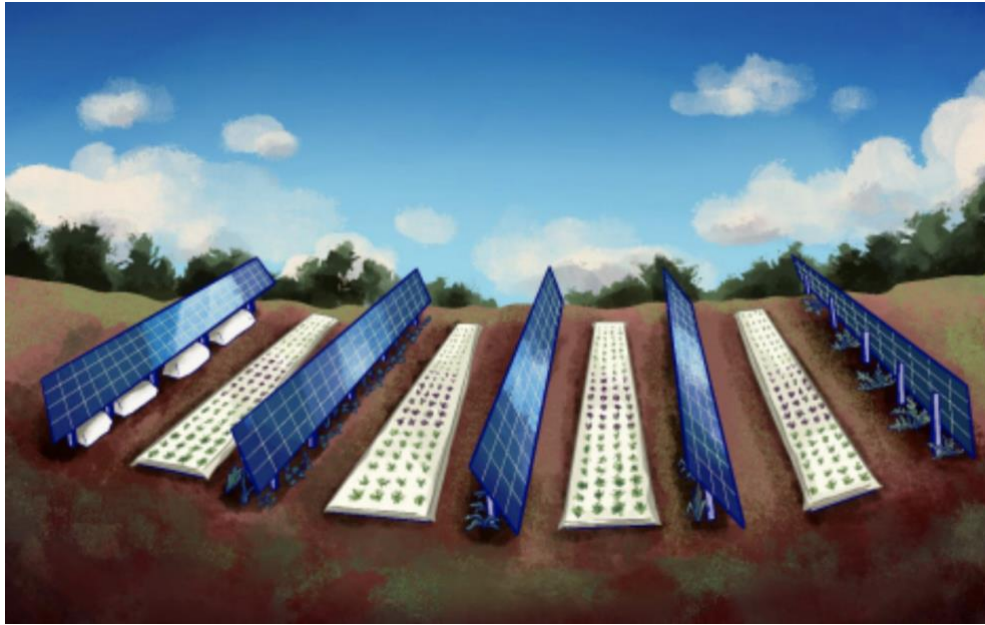


Hawai'i Agriculture Research Center

P.O. Box 100, Kunia, HI 96759

Ph: 808-621-1350/ Fax: 808-621-1399

www.harc-hspa.com



Executive Summary

Lanikuhana Demonstration Site

- Tested consecutive hydroponic lettuce trials with additional crops such as basil and watercress.
- Tried over 43 varieties of crops, including high-value crops and trellis crops.
- Testing plant nursery production under the panels using high-value crops and native species.
- Conducted a log mushroom trial with four strains of mushrooms and eight species of trees.
- Installed three active beehives at site and one at Mililani 1

Mililani 1 Agrivoltaic System

- Converted utility-scale PV land into agrivoltaic plots with soil rehabilitation techniques.
- Constructed an 8x8 ft hydroponic trough for comparisons between the two sites.
- Completed 10 diverse crop analyses, highlighting which crops have the highest APV potential for marketable quality.
- Control plots consistently outperformed APV plots in total yield except in herbs and leafy greens.

Public Engagement

- Hosted weekly tours over two years, engaging stakeholders from high schools, policy groups, and federal agencies.
- Held tours with local and federal government policymakers, Blue Planet Alliance, and local educators to promote agrivoltaic adoption.
- Generated interest through public outreach and media features.

Hydroponic Production at the Agrivoltaic Site

Hydroponic lettuce production under solar panels at the agrivoltaic site continued to show consistent growth in yield trends throughout 2023, reinforcing its viability in this dual-use system. However, in the spring of 2024, a significant challenge arose when several hydroponic troughs experienced outbreaks of *Pythium* root rot. This fungal-like pathogen caused substantial losses, killing off multiple lettuce troughs and prompting a transition to exploring alternative crops.

To mitigate the stress caused by *Pythium* outbreaks, improving water circulation and oxygenation in the hydroponic system is critical. Recirculating water within the troughs and maintaining sufficient dissolved oxygen levels would not only reduce the risk of pathogen growth but also support healthier crop development. Plans to restart the hydroponic system are underway, and a fully operational micro-solar grid is essential for powering an inline water sterilizer and a continuous 24-hour water pump. These upgrades will provide a reliable, renewable energy source to sustain water quality and reduce disease pressures.

In addition to lettuce, several other crops were trialed in the hydroponic system, including basil (*Ocimum basilicum*), edible flowers, and watercress (*Nasturtium officinale*). These crops demonstrated relative success, with healthy growth and yields unaffected by *Pythium*. The trials highlighted the potential for diversifying hydroponic production under solar panels, expanding beyond lettuce to include high-value specialty crops.

Looking ahead, the team is eager to resume hydroponic operations with enhanced infrastructure and to explore additional crop options. By integrating renewable energy into water management systems and diversifying crop production, the agrivoltaic site continues to push the boundaries of sustainable agriculture and renewable energy integration. Based on our nearly two years of lettuce production in agrivoltaic systems we believe this would be an ideal synergistic match. Future trials will focus on optimizing hydroponic conditions and further assessing crop performance under agrivoltaic conditions.

Screened Crops at Demonstration Site

At our agrivoltaic demonstration site, a wide variety of crops were screened for their productivity and adaptability under agrivoltaic (APV) conditions. Leafy greens, such as kale, chard, and mizuna, demonstrated vigorous growth and were selected for comparison trials due to their high productivity and quality. Root vegetables like carrots and radishes showed strong performance, with varieties such as Bolero carrots and Bravo radishes excelling. Crops like broccoli, cauliflower, and basil exhibited notable yields, with basil standing out for its delayed flowering and aromatic leaves.

Conversely, some crops, including full-sun varieties like asparagus and certain beans, showed lower productivity under the panels, indicating they may not be suitable for APV systems. Mamaki and vanilla showed promise as potential candidates for commercial production, with consistent growth observed under the panels.

This comprehensive evaluation (Table 1) informs future trials and highlights the potential of leafy greens, herbs, and select root crops as good candidates for future comparison trials and potential for integration into APV systems in Hawai'i.

Table 1. List of crops grown at the demonstration site from March 23' - November 24'.

Crop	Variety	~Sq. Ft	Yield/Performance	OutLook
Asparagus	Purple Passion	45	Sho wed the least vigorous growth but the minimal stalks produced were vivid purple and had a mild sweet taste.	Not an option for high production production.
	Jersey Giant	45	Sho wed the most vigorous growth of all four varieties planted. Stalks were tender and sweet.	Not an option for high production production.
	Jersey Knight	45	Sho wed the most vigorous growth of all four varieties planted. Stalks were tender and sweet.	Not an option for high production production.
	Millennium	45	Sho wed the some of the least vigorous growth but the minimal stalks produced were vivid purple and had a mild sweet taste.	Not an option for high production production.
Basil	Prospera	30	Highly productive, delayed flowering, large tender and aromatic leaves.	selected for comparison trial
Beans	Dragon Tongue	15	Susceptible to rust, not very productive	not included in comparison trials
	Tri-Color	15	Susceptible to rust, not very productive	not included in comparison trials
	Provider	15	Highly productive with large sweet fruits	selected for comparison trial
Beets	Bouldor	30	productive with a mild earthiness and sweet	selected for comparison trial
	Green Magic F1	20	Vigorous growth and large healthy crowns.	selected for comparison trial
Broccoli	Purple Magic F1	15	In progress	in progress
	Purple	30	little to no productivity	selected for comparison trial
Bok Choy	Little Shanghai	15	Vigorous growth and sweet healthy stalks	selected for comparison trial
Cabbage	Rubicon	30	Vigorous growth and sweet healthy heads	selected for comparison trial
	Merlot	30	Little to no productivity	not included in comparison trials
	Flash	30	Vigorous growth and sweet healthy heads	selected for comparison trial
Carrots	Boiero	180	best producer tested, some susceptibility to nematodes	selected for comparison trial
	Kyoto Red	40	good producer but difficult to harvest without the proper equipment	not included in comparison trials
	Mokum	30	decent production but less productive than boiero	not included in comparison trials
Cauliflower	Purple Moon	30	Vigorous growth and large healthy crowns.	selected for comparison trial
	Clementine	30	decent sized crowns but inconsistent crowning	not included in comparison trials
	Amazing	30	Vigorous growth and large healthy crowns.	selected for comparison trial
Chard	Bright Lights	30	Vigorous growth and large healthy, sweet and tender leaves	selected for comparison trial
Celery	Tango	15	Vigorous growth and sweet healthy stalks	selected for comparison trial
	Pink	30	Vigorous growth and sweet healthy stalks	selected for comparison trial
Eggplant	Express	25	Nice fruits and healthy growth.	selected for comparison trial
	Annina	15	Nice fruits and healthy growth.	selected for comparison trial
Fennel	Dragon F1	90	Vigorous growth and sweet healthy stalks.	selected for comparison trial
Kale	Starbor	20	Vigorous growth and large healthy, sweet and tender leaves	selected for comparison trial
Maile	n/a	5	Slow growing but growth is consistent and healthy, still in progress	result to date are very promising as a potential candidate for commercial production on trellis
Mamaki	n/a	100	Very well adapted for planting directly under the panels so long as farmers can keep up with the pruning and harvesting	result to date are very promising as a potential candidate for commercial production on trellis
Mizuna	Mizuna	25	Vigorous growth and large healthy, sweet and tender leaves	selected for comparison trial
Onion	Nabe	15	In progress	in progress
	Madalyn F1	15	In progress	in progress
Radish	Red Meat	20	Vigorous growth and large adn sweet bulbs	selected for comparison trial
	Bravo	180	Vigorous growth and large adn sweet bulbs	selected for comparison trial
	Purple Heart	20	Vigorous growth and large adn sweet bulbs	selected for comparison trial
Peppers	Brown Jalapenos	20	large healthy fruits and vigorous growth without a lot of melon fly pressure	selected for comparison trial
	Shishito	20	In progress	in progress
Shiso	Britton	20	Vigorous growth and large healthy, sweet and tender leaves	selected for comparison trial
	Green Shiso	20	Vigorous growth and large healthy, sweet and tender leaves	selected for comparison trial
	Red Shiso	20	Vigorous growth and large healthy, sweet and tender leaves	selected for comparison trial
Strawberry	Quinhault		Vigorous growth with aromatic, acidic, and sweet fruits	selected for comparison trial
Vanilla	Tahitian	10	Slow growing but growth is consistent and healthy, still in progress	result to date are very promising as a potential candidate for commercial production on trellis

Nursery Production Under Solar Panels

Nursery production under solar panels has proven highly effective for cultivating native species, coffee, and vegetable crops. The partial shade reduces water stress and mimics natural growing conditions, resulting in strong plant performance. Additionally, the shaded environment is ideal for vermicast production, leveraging moderated temperatures to recycle organic waste into nutrient-rich compost, enhancing soil fertility.

Throughout the life of Phase 2 of this project, we trialed commercial and native plants that included:

- Mamaki (*Pipturus albidus*)
- Ilima (*Sida fallax*)
- Milo (*Thespesia populnea*)
- Pohinahina (*Vitex rotundifolia*)
- Hibiscus (*Hibiscus spp.*) – includes various species like *Hibiscus rosa-sinensis* (ornamental hibiscus) and *Hibiscus brackenridgei* (Hawaiian native yellow hibiscus).
- Poha Berries (*Physalis peruviana*)
- Maile (*Alyxia stellata*)
- Alahe'e (*Psydrax odorata*)
- A'ali'i (*Dodonaea viscosa*)
- Ma'o (*Gossypium tomentosum*)
- Ma'o Hau Hele (*Hibiscus brackenridgei*)
- Maiapilo (*Capparis sandwichiana*)
- Nanea (*Vigna marina*)
- Coffee (*Coffea arabica*)

Successful implementation requires reliable water access and infrastructure, such as raised nursery tables, efficient irrigation systems, and vermiculture bins. This approach supports dual-use agrivoltaic systems, integrating renewable energy with sustainable agriculture to promote productivity and ecological benefits.

Log Mushroom Production Under Solar Panels

A trial was conducted to evaluate the feasibility of producing mushrooms on logs from invasive softwood tree species under solar panels. Four heat-tolerant mushroom strains were tested, including three shiitake strains (*Lentinula edodes*)—Halo, Night Velvet, and Native Harvest—and a heat-tolerant oyster mushroom strain (*Pleurotus ostreatus*) called PoHu. Logs from seven tree species were inoculated: octopus tree (*Schefflera actinophylla*), gunpowder tree (*Trema orientalis*), African tulip (*Spathodea campanulata*), albizia (*Falcataria moluccana*), java plum (*Syzygium cumini*), koa (*Acacia koa*, non-invasive), and silk oak (*Grevillea robusta*).

The tree logs were sourced from the HARC Maunawili substation, and five logs of each species were inoculated with all four mushroom strains. Among the species, the octopus tree demonstrated the best overall performance, with the PoHu oyster mushroom yielding the highest productivity on its logs. Koa logs also performed well, particularly with the Halo shiitake strain, suggesting that this non-invasive native species could serve as a suitable substrate for shiitake production under agrivoltaic systems. As more koa

is grown for commercial timber, HARC anticipates an increased supply of small-diameter koa logs such as those used in the trial, as a waste product from precommercial thinnings.

Other tree species showed lower productivity in this trial, although the potential for improved performance with optimized conditions is significant. Factors such as log size, moisture retention, and environmental conditions under the solar panels may have influenced the results. While the trial demonstrated the feasibility of using invasive species for mushroom production, focusing future efforts on the best-performing species, such as octopus tree and koa, may yield more consistent and scalable outcomes.

This study highlights the potential of integrating log mushroom production under solar panels using locally available invasive tree species. Converting invasive biomass into valuable mushroom crops offers a sustainable dual-use strategy for agrivoltaic systems, contributing to renewable energy, food production, and invasive species management. Future research could focus on refining substrate selection and inoculation protocols to maximize yields under agrivoltaic conditions.

Integrating Pollinators into APV Systems

We installed three beehives at the demonstration site and one at Mililani 1. After the first year, the hives produced a successful harvest of 20 pounds of honey, which we now use as gifts for visitors during tours and as a natural sweetener in the mamaki tea we brew for guests. Hive health has been steady overall, though the bees have shown occasional signs of stress during periods of high heat and limited food availability when wildflower foraging resources are low. We are exploring additional planting strategies to support the hives in providing consistent forage and improving hive resilience, further integrating sustainable practices into our APV systems.

Mililani I

Lettuce Comparison

To evaluate the feasibility of lettuce production under a higher-density panel system compared to Lanikuhana, a small trough was constructed at Mililani 1 as a representative block of the larger hydroponic troughs. The 8 ft x 8 ft trough was built using plywood, 2x4 planks, wood screws, and the same Pliner food-grade plastic cover used in the hydroponic systems at Lanikuhana. The smaller trough holds 288 plants, whereas the larger troughs at Lanikuhana hold 1,800 plants.

A mix of lettuce seed grown at Kunia Country Farms was germinated in June 2023 and harvested six weeks later. Two additional sequential plantings of lettuce. The summer months of August and September negatively affected plant health at both sites eliminating much of the lettuce before maturity.

Despite these challenges, trends in lettuce growth revealed no adverse impacts from the tighter row spacing at Mililani. Notably, several benefits were observed, including higher marketable yield (with no additional shade required), zero plant loss during transplanting from the nursery to the trough, and no delay in days to maturity compared to Lanikuhana.

Open Field Control Plot Establishment at Lanikuhana

The open field control plot was established at the Lanikuhana site due to available space at the back of the demonstration area and its proximity to both the nursery and water access. The ground, similar to the rest of the site, was compacted and required significant remediation for vegetable crop production. A 50 ft x 100 ft section was flagged, ripped, and tilled using a tractor equipped with ripping and disking implements, and subcontracted through the Operations Manager at Mililani Ag Park.

Approximately seven cubic yards of compost were added to the plot, covering the soil surface with a ½-inch layer, which was incorporated through a final disking. The control plot was oriented north to south, aligning with the agrivoltaic experimental plots to ensure consistent sunlight exposure and isolate the variable being tested: the presence or absence of solar panels. To suppress weed pressure and improve labor efficiency, landscape fabric was manually installed in the walkways between beds. The design included 15 permanent beds approximately 3 ft x 45 ft, enabling simultaneous crop testing and the rotation of cover crops to implement best practices for soil health management.

Agrivoltaic Plot Establishment at Mililani 1

Two alley spaces between the solar panels were ripped and tilled using the same protocols as the control plot. This process required additional planning and time due to the panels being operational. To maximize efficiency, the operator scheduled work in the morning and evening when the panels were at a more favorable tilt. A more effective approach would involve having a technician from the energy company orient the panels to their maximum tilt during soil preparation and then reset them to auto-tracking afterward.

At the Mililani 1 site, the panels are spaced at 21-foot centers, with 8 ft between panels at horizontal orientation. Three-foot-wide beds were prepared and covered with landscape fabric, with three beds established in a single alley. The layout includes one bed positioned in the east, one in the west, and one in the center, aligning with our experimental design requirements (Diagram 1).

The two full alley spaces were ripped and tilled, resulting in:

- Three rows of 3 ft x 80 ft
- Three rows of 3 ft x 250 ft
- Total space of planting beds = 990 sq ft; Total space including panels = 6,930 sq ft
- 14.2% of the total land footprint was converted to planting beds.

These long rows provide flexibility to test multiple crops or varieties simultaneously while maintaining the same spacing as the control plot.

Diagram 1. Plot layout of plots at APV site running south to north.



Crop Comparison Trial Results

Bright Lights Rainbow Chard

In this chard comparison analysis, it was observed that location within the APV plot (e.g., east block, center, west block) did not significantly impact yield, as similar results were recorded across rows. However, a notable difference emerged when comparing the total weights of marketable yields between the Control and APV plots. The Control plot produced approximately 20 kg of marketable chard, while the APV plot produced approximately 40 kg. The APV plot outperformed the Control plot in terms of total yield and marketable yield, highlighting the potential of agrivoltaic systems to support leafy green production and their total productivity demonstrates promise for integrating renewable energy systems with crop cultivation.

Skyway F1 Tomatoes

In this tomato trial, the Control plot significantly outperformed the APV site in total yield, with the Control plot producing a combined total of 62.8 kg compared to the APV site's 17.5 kg. Within the Control plot, the west row showed the highest productivity, followed by the east and center rows, indicating some shade effect. Within the APV plot, the area with the highest yield was the center row, which produced 11.6 kg, surpassing the other rows within the same site. These findings suggest that while the Control plot outshines the APV site in overall yield, the APV's central area could be further tested with other varieties or systems for further optimization in future studies. Given these results, beefsteak tomato does not look like an economically viable crop for APV systems in Hawai'i. Given that only a single tomato variety was tested in this trial, future efforts could explore identifying or breeding low UV-tolerant genetic lines better suited for agrivoltaic systems.

Purple Moon Cauliflower and Green Magic Broccoli

In this trial, the center row of the Control plot outperformed the center row of the APV plot in total yields for both broccoli and cauliflower. For broccoli, the Control plot produced 7.5 kg, which was approximately 1 kg higher than the APV plot's center row yield of 6.5 kg. Similarly, for cauliflower, the Control plot produced 7.5 kg, surpassing the APV plot's center row yield of 5.8 kg by 1.7 kg. These results highlight the overall higher productivity of the Control plot compared to the APV plot for these crops.

Despite the lower yields in the APV plot, the center row within the APV system emerged as the most productive location for both broccoli and cauliflower, outperforming other rows (east and west). This indicates that microclimatic conditions in the center row of the APV system may be more favorable for crop growth compared to other areas within the same system. These findings suggest that while the Control plot remains more productive, the center row of the APV plot shows potential for optimization and targeted management to improve yields further.

88-11 Pumpkin

A local variety of pumpkin ("88-1") was included as we were eager to test the performance of a low-growing fruiting crop under agrivoltaic (APV) conditions compared to a traditional control plot. Despite pumpkins being well-suited for low-growing environments, the APV plot experienced significantly delayed flowering, resulting in low fruit production. The control plot far outperformed the APV plot, producing 98 fruits compared to just 1 fruit in the APV plot. This stark difference in yield could be attributed to either the delayed flowering observed in the APV system or to genetic factors unique to the 88-11 pumpkin variety. Further testing is required to determine whether this outcome is an isolated circumstance or a broader trend for pumpkins in agrivoltaic systems. Future trials should include additional pumpkin varieties and environmental conditions to better understand the interaction between genetics, flowering behavior, and the impact of solar panel shading on fruit production.

Provider Green Bean (Bush Bean)

In the green bean trial, the Control plot significantly outperformed the APV plot in total yield, producing 43.3 kg compared to the APV plot's 16.8 kg. Within the APV plot, the west row had the highest yield, producing 6.2 kg, followed closely by the center row with 5.5 kg. The difference in yield between the west and center rows was relatively minor, just 0.7 kg, indicating comparable production levels between these two locations. These results highlight the overall better performance of the Control plot. Future studies could look at different varieties of bush beans and concentrate efforts on the 8 ft area with the most sun.

Prospera Basil

In this trial, the Prospera variety of basil was evaluated for performance under agrivoltaic (APV) conditions compared to a traditional Control plot. The APV plot demonstrated larger leaf growth, with an average leaf length of 14.3 cm and width of 6.6 cm, compared to the Control plot's 10.5 cm and 4.1 cm, respectively. However, the APV plot had significantly lower total yields, producing 16.84 kg compared to the Control plot's 21.46 kg, resulting in a difference of 4.2 kg (21.5% reduction) in favor of the Control plot. On a per-plant basis, the APV plot averaged 0.24 kg per plant, compared to 0.30 kg per plant in the Control plot. This suggests that while the APV system enhances vegetative growth, it may not yet be optimized for maximum yield.

A key advantage observed in the APV plot was delayed flowering, with only half (51%) of plants flowering on average, compared to most (81%) in the Control plot. Basil leaf from non-flowering plants is highly preferred due to its superior flavor profile. The west row of the APV plot exhibited the least flowering at 33%, while the center row of the APV plot had the highest flowering at 64%. In terms of yield, the center row performed the best within the APV plot, producing 8.6 kg, followed closely by the east row with 8.1 kg, and the west row with 6.2 kg.

While the quality of the basil, including aromatic profiles and flavor, was not directly evaluated in this study, the combination of delayed flowering and larger and more tender leaves observed in the APV plot suggests the potential for a trade-off: lower overall yields but higher quality basil leaves. Larger leaves and reduced flowering could enhance the aromatic intensity and market value of the basil, but additional data would need to be collected in future studies to confirm these benefits. Further research could evaluate the impact of APV conditions on basil quality. Additional research could also seek to take advantage of the differences seen in flowering rates and attempt to extend the growing length to overcome the decreased yields observed.

Brown Jalapeno Peppers

The Control plots of Brown Jalapeno peppers significantly outperformed the APV plot in total yield. The Control plot produced 41.0 kg, compared to 12.0 kg in the APV plot. Within the APV plot, the center row was the best-performing location, yielding the highest weight and count of peppers, followed by the east and west rows, which demonstrated much lower productivity.

In the size distribution data that was also gathered, the APV plot produced a relatively balanced mix of large, medium, and small peppers, with large peppers contributing the most to total weight. However, the overall size trends suggest that the APV system may favor larger pepper growth under certain conditions, even with reduced total yields compared to the Control plot.

In a direct comparison between the center row of the control plot and the center row of the APV plot, the control plot produced 12.0 kg, nearly double the yield of the APV plot, which produced 5.2 kg. Based on this data, peppers do not appear to be a suitable crop for APV systems in Hawai'i.

Future research could identify varieties better adapted to low UV conditions inherent in agrivoltaic systems. Focusing on the center row for production comparisons, while excluding the east and west rows, could allow for more precise data collection and analysis to understand better the potential of optimized agrivoltaic systems for jalapeño production. This approach would provide more actionable insights for improving yields and quality under these conditions.

Rubicon (Napa) Cabbage

In the ongoing trial evaluating Rubicon cabbage production under agrivoltaic (APV) panels and in a Control plot, preliminary data indicates a similar trend to the broccoli and cauliflower trial. The Control plot is currently outperforming the APV plot in total yields, suggesting that traditional growing conditions may be more favorable for overall cabbage production. However, within the APV plot, the center row is emerging as the most productive location, consistently yielding higher results compared to the east and west rows. This mirrors findings from previous trials, where microclimatic conditions in the center row, such as moderated shading or temperature, appear to create a more favorable environment for crop growth. As data collection continues, further analysis will help clarify whether these trends persist and how agrivoltaic conditions

influence Rubicon cabbage growth and productivity. It would also be beneficial to repeat a comparison in the summer months.

Comprehensive Summary of Crop Comparison Research and Trends

In the trials conducted, the agrivoltaic (APV) system demonstrated unique benefits, such as delayed flowering, larger leaf size in certain crops, and potential for climate adaptation, but consistently underperformed in overall yield compared to traditional Control plots (Table 2). For crops like tomatoes, broccoli, cauliflower, chard, and peppers, the Control plot yielded significantly more, except for specific rows. Within the APV plot, the center row often showed the best performance in terms of yield and quality. Basil in the APV plot produced larger leaves and exhibited delayed flowering, indicating potential for higher-quality aromatic profiles, but lower yields compared to the Control plot. Trends in pepper size showed that the APV plot produced a balanced mix of sizes, favoring larger peppers under certain conditions. These findings suggest APV systems may require further optimization to enhance crop yields while maintaining their inherent advantages.

To refine these results, future trials could focus on testing different crop varieties, particularly those adapted to Hawaii's unique microclimates and the low UV conditions of APV systems. Collaborating directly with farmers and leveraging the expertise of the University of Hawaii could provide access to local knowledge, resources, and genetics better suited for these systems. Crops like carrots, lettuce, or other leafy greens, which may benefit from shading, or tropical crops like taro or sweet potatoes, could be promising candidates for further exploration.

Additionally, the outer rows of APV plots, which consistently underperformed in yield for larger crops, could be better utilized for leafy greens or herbs. These crops often thrive under reduced light and space requirements, providing farmers with an opportunity to maximize production in these areas while focusing larger crop trials on the more productive center rows. Such an approach could balance research goals with practical production needs, offering farmers a pathway to integrate agrivoltaic systems without compromising profitability.

Repeating trials with Hawaii-adapted varieties or varieties specifically bred for low light and UV conditions would provide clearer insights into crop adaptability. Expanding farmer partnerships could facilitate on-farm testing, offering real-world conditions and feedback to improve agrivoltaic integration across the state. These collaborative efforts could better define the balance between sustainable energy production and agricultural productivity, paving the way for successful agrivoltaic adoption in Hawaii.

Table 2. Summary of Crops Grown in Crop Comparison Trials during Phase 2

Crop	Variety	Total Sq. Ft	Yield/Performance	Outlook
Broccoli	<i>Green Magic F1</i>	240	<i>Overall control plot produced higher than the APV plot with the center APV row producing the highest within the APV plot.</i>	<i>Low UV tolerant varieties could be tested</i>
Bush Beans	<i>Provider</i>	480	<i>Control plot produced much more than APV plot, best producing location within APV plot is the west side and center rows</i>	<i>Low UV tolerant varieties could be tested</i>
Basil	<i>Prospera</i>	480	<i>In overall yield control outperformed APV plot while the APV plot expressed delayed flowering and larger leaves, implying a higher market quality. All rows performed similarly in weight in APV plot, but East and West rows flowered last.</i>	<i>APV Compatible</i>
Cabbage	<i>Rubicon</i>	480	<i>Final Data in Progress</i>	<i>N/A</i>
Cauliflower	<i>Purple Moon</i>	240	<i>Overall control plot produced higher than the APV plot with the center APV row producing the highest within the APV plot.</i>	<i>Low UV tolerant varieties could be tested</i>
Chard	<i>Bright Lights</i>	480	<i>APV Plot outperformed control plot by over double and position within APV plot made no difference in overall marketable yield.</i>	<i>APV Compatible</i>
Cilantro	<i>Calypso</i>	480	<i>Cilantro saw delayed bolting in APV plots with the center row bolting first. Similar yields observed in both APV and control plot.</i>	<i>APV Compatible</i>
Tomatoes	<i>Skyway F1</i>	480	<i>Control Plot outperformed APV plot by over double but the center row of the APV plot performed best and had higher marketable yield.</i>	<i>Low UV tolerant varieties could be tested</i>
Peppers	<i>Brown Jalapeños</i>	480	<i>Lower overall production in the APV plot with the highest row being the center row.</i>	<i>Low UV tolerant varieties could be tested</i>
Pumpkin	<i>88-11</i>	480	<i>Pumpkin control plot outperformed the APV plot significantly with the control plot producing 98 fruits and 1 in the APV plot.</i>	<i>Low UV tolerant varieties could be tested</i>

Planning for Agricultural Farms in PV Systems

Converting land previously used for utility-scale photovoltaic (PV) systems into agrivoltaic (APV) systems requires careful land preparation to optimize crop growth while maintaining efficient energy production. APV systems, which integrate agricultural production with solar energy generation, offer a unique opportunity to enhance both food production and renewable energy. However, transitioning from a solar site to a productive agricultural system presents challenges, especially in areas like Central Oahu, where soil compaction, debris, and degraded soil health are common.

Effective land preparation begins with soil rehabilitation, including mechanical processes like deep ripping and tilling to alleviate compaction, conducting soil nutrient analyses, and incorporating high-quality compost to improve soil structure and fertility. Soil compaction, a significant challenge in PV-dedicated land, restricts root growth, water infiltration, and nutrient mobility. Deep ripping breaks compacted layers, while tilling aerates the soil and incorporates organic matter to improve water retention and root development.

A thorough soil nutrient analysis is essential to address nutrient deficiencies due to prior land-use practices. Recommendations for nitrogen, phosphorus, potassium, and pH adjustments should be based on the results, and manganese content should be assessed to avoid crop toxicity. Compost additions further enhance soil health by increasing organic matter, improving water-holding capacity, and promoting beneficial microbial activity. Uniform compost integration during tilling ensures better nutrient cycling and fertility.

Selecting appropriately sized tractors and implements is crucial for efficient land preparation in APV systems. Compact tractors with subsoilers, rotary tillers, and spreaders allow effective operation within solar panel spacing. Timing land preparation with auto-tracking solar panels in a vertical position ensures thorough tilling while avoiding damage to infrastructure. Additionally, debris removal, such as mulching plastic, drip tape, and general trash, is essential for a successful transition to agrivoltaic farming.

By addressing soil compaction, improving fertility with compost and amendments, and carefully managing equipment and debris, PV-dedicated land can be transformed into productive agrivoltaic systems. These best practices ensure soil health and enable farmers to maximize crop growth while supporting renewable energy goals.

Equipment Needed and Subcontracting Costs for Preparing an Agrivoltaic Site

Effective soil preparation and management in agrivoltaic (APV) systems require versatile equipment capable of operating within the confined spaces between solar panel support structures. At present, Mililani Ag Park has been instrumental in supporting the project by preparing the soil using their tractors and attachments. However, this comes at a significant cost of \$135 per hour for the operator's time, with total costs for site preparation ranging between \$1,000 and \$2,000 per half acre, depending on the complexity of the site and the required preparation. These costs do not include the costs of compost and other required amendments. The relatively high costs highlight the importance of careful budgeting and planning for larger scale agrivoltaic projects in the future.

For future APV expansions, it will be crucial to evaluate equipment availability and access. Questions such as whether a centralized operator or dedicated service will be available for agrivoltaic projects and how costs can be managed or shared among farmers will play a key role in planning. Exploring alternatives, such as investing in compact, multi-functional tractors designed specifically for tight spaces or establishing partnerships with local agricultural service providers, could help reduce operational costs while maintaining efficient land preparation. Additionally, offering training programs for local farmers to operate and maintain this equipment independently may further lower costs and foster community-driven sustainability for agrivoltaic systems.

Commercial Equipment Examples:

- John Deere 5E Series (60 HP) or similar models for larger-scale ripping and tillage and ground cover mowing
- Kubota L Series (40 HP) for compact disking and intermediate preparation.
- Honda FRC800 Walk-Behind Tiller and Honda FG110 Mini Tiller for precision tilling in narrow or hard-to-access areas.

This combination of equipment allows for scalable and targeted soil management while accommodating the spatial limitations of agrivoltaic systems, ensuring optimal preparation for crop production under solar panels.

Public Outreach

Public outreach and stakeholder engagement have been critical components of our agrivoltaic project's success. Over the past two years, we have welcomed a diverse array of visitors, ranging from high school students and educators to international climate advocates, policymakers, and federal agencies. This outreach has fostered enthusiasm and built a broad network of supporters for the project, demonstrating its potential as a model for sustainable farming and energy production.

We successfully connected with key stakeholders, including international groups like the Blue Planet Alliance, local policymakers from the Public Utilities Commission (PUC), Ways and Means (WAM) committee, and the Environmental Protection Agency (EPA), as well as state and federal agencies such as the Hawai'i Department of Agriculture (DOA), Farm Service Agency (FSA), USDA, and US Senators from the Appropriations Committee. Educators and students from the University of Hawai'i, Punahou School, and Waipahu High School also visited to learn firsthand about agrivoltaic farming. Local high school students from HARC's Seeds for Tomorrow program attended a workday to participate in harvesting activities and gain hands-on experience. This program is designed to inspire the next generation of agricultural leaders by immersing them in sustainable farming practices. Additionally, we hosted eight CSP Army interns, which offering military members the chance to transition to civilian careers through immersive learning experiences in sectors like agriculture. Hosting them at the project site provided a valuable introduction to agrivoltaic farming and reinforced the importance of integrating renewable energy with agriculture.

Our tours, ranging in size from intimate groups of two to larger gatherings of up to 50, averaged approximately one per week over the past two years, generating unprecedented interest in the project. These tours not only educated but also transformed perspectives. Community members, educators, and policymakers who were initially skeptical about the feasibility or relevance of agrivoltaic systems left eager to see the project succeed. For policymakers, in-person visits to the site provided a tangible understanding of the project's impact, from the productive integration of crops and renewable energy to the visible opportunities for economic and environmental benefits. Seeing the site in operation has been instrumental in turning skeptics into advocates and building a foundation of support for further development.

The enthusiasm and interest generated through these tours underscore the importance of creating accessible spaces where the public, educators, and decision-makers can directly engage with innovative projects. Continued outreach and collaboration will ensure that agrivoltaic farming becomes a central part of the conversation about Hawai'i's sustainable future, inspiring local and global efforts to address food security, renewable energy, and climate resilience.

Published and Event Based Public Outreach

Agrisolar Clearinghouse Case Study

On October 9th, a [case study](#) detailing the Hawai`i Agrivoltaic Research and Demonstration Center was published by the National Center for Appropriate Technology's (NCAT) *AgriSolar Clearinghouse*. This platform serves as an information-sharing, relationship-building, and public communications hub for all things agrisolar.

EAT THINK DRINK - *Solar + Ag: Cultivating a Sunny Future*

The EAT THINK DRINK event, organized by the Hawaii Agricultural Foundation on October 11th, was a great success! The panel discussions reflected a shared vision for clean energy and sustainable agriculture in Hawaii. We would like to extend our gratitude to everyone who contributed to making this event a success.

Hawai`i Public Radio

The project was featured in HPR's October 17th piece titled '*Mililani project hopes to show possibilities in combining solar panels and agriculture.*' The [article](#) emphasizes the collaborative approach of the project and its goal to support long-term viability for farmers and increase local food production.