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Agrivoltaic Pretrial

Experiment Report

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Abstract

In the agrivoltaics pretrial in Wädenswil, lamb's lettuce was grown in three cultivation rounds (winter, early and late spring) under and behind ground-based solar modules to study their effects on crop growth. Leaf chlorophyll content was measured indirectly by means of the SPAD-502Plus Konica Minolta® chlorophyll meter. At harvest, specific leaf area (SLA) was collected from leaf punches and leaf length and width of single leaves and fresh weight of individuals were measured.

The results include significant differences in plant traits (chlorophyll content, leaf length, width, SLA) and harvestable fresh weight. Chlorophyll contents of lamb's lettuce leaves were significantly higher when grown under solar modules compared to the control and behind modules. Leaves were significantly longer and wider and had a higher SLA under solar modules ($p < 0.05$). Across all cultivation rounds, fresh weight under and behind modules increased by 17% and decreased by 8%, respectively, compared to the control. However, the influence of treatments strongly varied with season. Lamb's lettuces grown under solar modules had the highest fresh weight in cultivation round 1 and 3. Lamb's lettuces behind the solar modules had the lowest fresh weight in round 1 and 2. In cultivation round 2, fresh weight was identical for lamb's lettuce under the modules and in the control and slightly smaller in the zone behind the modules (-17%). In cultivation round 3, fresh weight increased by 67% and 16% under and behind the modules, respectively, compared to the control.

Our findings suggest that beneficial effects of agrivoltaics on crop growth are possible and – among other factors of influence – depend on the season. In the case of lamb's lettuce, a preferential microclimate under solar modules can be assumed during winter months while its growing season may be potentially prolonged in late spring. Adverse effects were only observed in the area behind the modules with the lowest fresh weights in the first and second cultivation round.

Contents

Introduction

The purpose of the agrophotovoltaics pretrial was to gather first experiences with an agrivoltaic system within our research group and on our campus. It included the planning and installation of nine transparent THEIA solar modules with optical micro-tracking technology from Insolight® and the cultivation and growth analysis of lamb's lettuce (*Valerianella locusta* L.) in three rounds.

Since land is a scarce commodity, the approach of dual land use for energy production and arable farming or livestock breeding has recently been gaining increasing socio-political interest. Concurrently, the combination of arable farming and energy production requires comprehensive know-how in technical and agronomic issues in order to find an ideal design for the respective location and the specific use with the different requirements.

Lamb's lettuce (also known as corn salad) is a common winter salad in Switzerland. It can be sown directly or planted as a seedling. The duration of its growth until harvest strongly depends on the season and can vary between 4 and 13 weeks. Lamb's lettuce was chosen for cultivation due to its temporal flexibility of growth, the possibility to compare multiple rounds of cultivation in different seasons, the large number of individuals per area, the potential benefit from shade and its low height, which suits the experimental design with ground-based solar modules. This final report presents the results of all three cultivation rounds.

Materials and Methods

Experimental site and design

Nine THEIA-cSi (Translucency & High-Efficiency In Agrivoltaics crystalline Silicon) photovoltaic modules from Insolight® were installed on 8 November 2021 on the campus of the ZHAW. The solar modules were mounted between 0.60 and 1.60 m above the ground in a 3 x 3 arrangement (covering an area of 3.50 x 1.50 m). A detailed installation scheme can be found in the appendix. The modules were put into operation on 10 November 2021 by Sven Strebel (Renewable Energies Research Group). The MLT-mode (Maximum Light Transmission), in which according to the manufacturer up to 70% of the incident light are transmitted, was chosen for all modules during the first cultivation round due to the shortened daytime in winter. In cultivation round 2 and 3 the E-mode (Maximum Electricity Generation mode) with 15% light transmission was set for midday (12 to 2 pm) to enhance electricity production at a time of abundant light and a potentially beneficial shade effect for lamb's lettuce.

As the area was previously a meadow, approximately 30 cm of the grassy soil was removed and filled with mixed substrate of extensive rooftop garden soil and peat-free potting soil (one part each). 1788 individuals of organic lamb's lettuce seedlings (*Valerianella locusta* L. 'Festival' in the first round and 'Princess' for the second and third round) were planted on two areas of approximately 3.50 x 3.00 m within a perforated foil with a 10 x 12 cm spacing, 2 m apart from each other (Fig. 1). The planting dates for the three rounds were 8 November 2021, 16 March 2022 and 10 May 2022. Lamb's lettuce was harvested 8 February (after 92 days), 21 April (after 36 days) and 2 June (after 23 days). The solar modules covered an area of 2.00 x 3.50 m (treatment "under modules", "M") and the area North of the modules (treatment "behind modules", “Mb”), which is shaded but not covered by the modules, were divided into three subplots (West, Central, East) each. The two control zones (“C1”, “C2”) were initially also divided in a West, central and East subplot. However, for cultivation round 2 and 3 only the West subplots were taken. Received solar radiation was modelled with the softwares “SektchUp 2021” and the extension “Watt” from “De Luminae Light Extentions (11.0.5)” by Manuel Hunziker (Renewable Energies Research Group). An example is given for the early spring period (Fig. 2). More examples can be found in the appendix.

The planted lamb’s lettuce plants were well watered in both treatments and the control. Subsequently, no additional irrigation was applied. Air temperature, dew point and air humidity were measured in the third cultivation round with EL-USB-2+ Data Loggers (see SI Tab. 1 in the Appendix). Soil temperature was measured with PlantControl sensors installed by Jean Petit Matile Luzius (Geology Research Group) in cultivation round 2 and 3 (see SI Tab. 2).

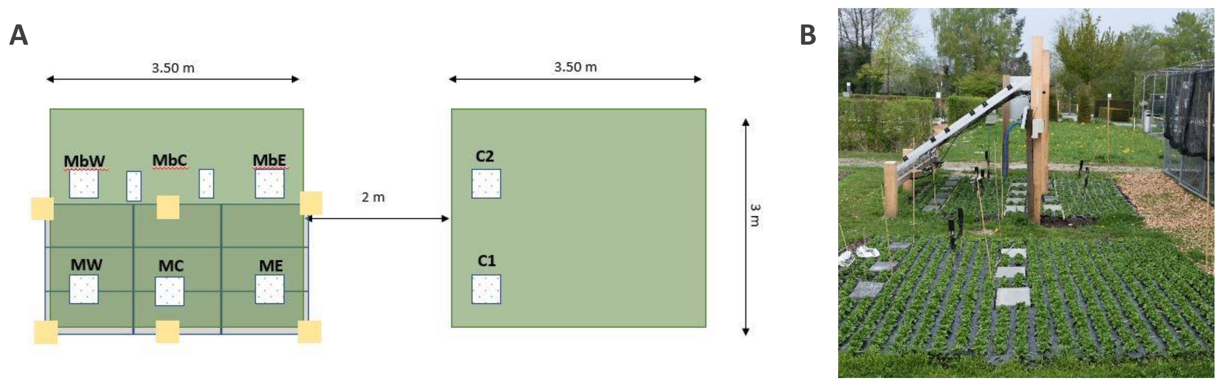

Fig. 1: (A) Schematic representation of the experimental design at the Grüental pretrial site with an NW-SE orientation. The green areas represent the area planted with lamb’s lettuce where at the left bottom side the solar modules were mounted. The white dotted areas represent subplots where measurements were taken. The yellow squares are the wooden construction poles for mounting the modules. (B) Lateral view of the ground-based modules with the control area in the front part of the picture. Photo credit: Christina Vaccaro

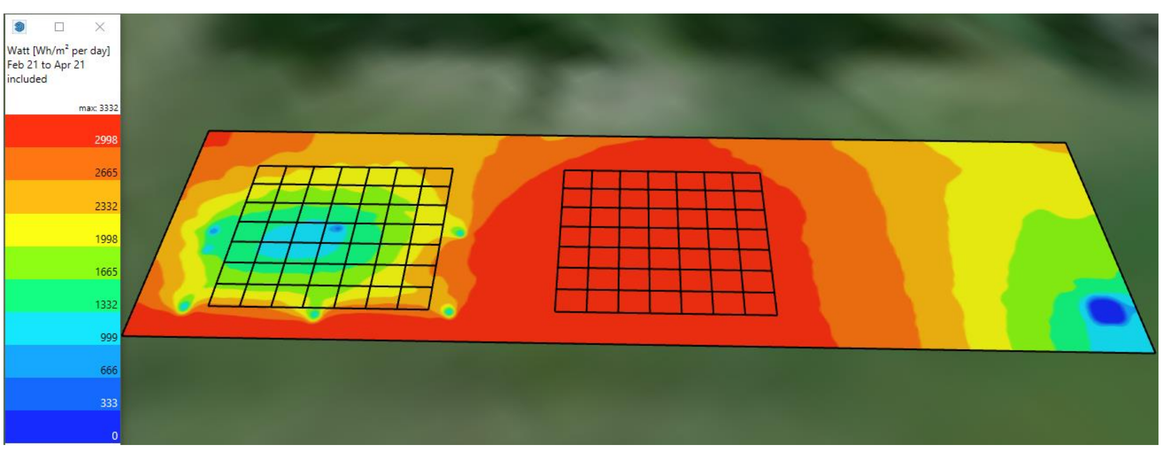

Fig. 2: Modelled daily mean of solar radiation (Wh m^{-2} per day) from 21 February to 21 April). The two chequered areas in NW-SE direction represent the 3.5 x 3.5 m wide planting areas with the solar modules on the left (front half under modules, back half behind the modules) and the control on the right. Red: approx. 3000 Wh m^{-2} per day, green: approx. 1700 Wh m^{-2} per day. Modelling performed by Manuel Hunziker

Leaf chlorophyll content

Leaf chlorophyll content was assessed with a chlorophyll meter (SPAD-502Plus Konica Minolta®, Fig. 3). The measurement device determines the relative amount of chlorophyll by measuring the absorbance in two wavelength regions where one wavelength corresponds to an absorbance peak of chlorophyll. A numerical SPAD value is then calculated from the difference in absorbance and is proportional to the amount of present leaf chlorophyll. Measurements were taken on the youngest fully developed leaf, taking care to place the measuring head in the same way each time. Sample number and procedure varied slightly between cultivation rounds: In the first round, one measurement of 30 individuals per subplot was taken in a defined order on 7 January 2022 to test leaf chlorophyll content along the NW-SE-transect of the area. As the position along the NW-SE-transect was not significant, the approach was not pursued further in the second and third round. Instead, SPAD measurements were conducted on three leaves per individual on 10 individuals per subplot in the second round (15 April). Since it was observed that a repetition per individual was not necessary, the repetition was dispensed within the third round where one SPAD measurement was taken per individual on 10 individuals (24 May).

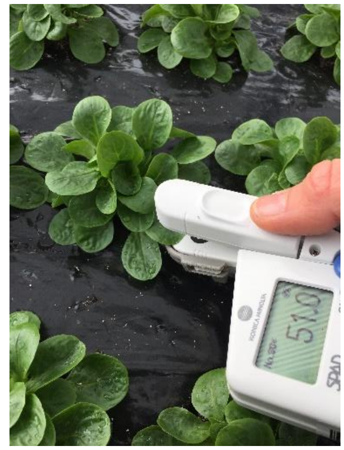

Fig. 3: SPAD measurements with the SPAD-502Plus Konica Minolta chlorophyll meter.

Leaf length and width

In each subplot, one fully developed leaf per individual was chosen of in total 4 (round three) to 6 (round one and two) individual lamb's lettuces per subplot. Leaf length and width were measured with a calliper at harvest.

Leaf punches (dry weights and SLA)

The same leaves which were collected for measuring leaf length and width were punched with a metal puncher (diameter: 12 mm) at the same leaf position. The punches were put in paper bags and dried for 48 hours at 80°C in an oven to obtain their dry weight. As the area of the leaf punches was known, specific leaf area (SLA) was calculated by dividing the area by the dry weight. In the first round, additional measurements were taken beforehand: Directly after punching the fresh weight of each was measured. Each leaf was then put in a plastic bag with soaked cotton overnight (for 20 hours) and thereafter its saturated weight was measured before it was dried (as described above) to compare ratios of leaf dry mass and fresh weight or saturated weight, respectively. As the results from the saturated weights showed no differences, the approach was not further pursued.

Fresh Weight

The upper part of 8 (first round) or 10 (second and third round) individuals in the central part of each subplot was harvested with the aid of a knife. In the first round, the dry weight was obtained additionally (they were put into separate paper bags and dried for 48 hours at 80°C). As this approach did not show significant differences between treatments, dry weight measurements were not pursued further.

Energy production

Energy production was measured by the module's internal measurement system and was logged into Insolight's proprietary web application.

Statistical analysis

Statistical analyses were carried out with R (first round: version 3.6.1, second and third round: version 4.1.2). The data was tested for normality and homogeneity of variance by the Shapiro–Wilk test and a visual inspection of residuals. Differences in group means among groups was analysed by a multifactorial ANOVA (type I, sequential sum of squares). Significances of each factor were assessed by means of the F-test. Statistical modelling was performed with several linear mixed-effects models, following the pattern of response variable ~ cultivation round * treatment + (1|Plot) with the lmer()-function from the R lme4 package (Bates et al. 2015) where "treatment" comprised the three treatments "under module", "behind module" and "control". The post-hoc Tukey test was used to compare the means of treatment groups with the emmeans()-function within the R agricolae package (Russell V. Lenth et al. 2022) with a significance threshold of α = 0.05.

Results

Chlorophyll content

The results of SPAD-measurements are summarized in Tab. 1. In the general model, leaf chlorophyll content was significantly higher in lamb's lettuces grown under the modules. There were no differences between the control and the lamb's lettuces grown behind the modules. Analysing each round separately, differences in SPAD were only significant in the third round which had in total lower values (Fig. 4).

Tab. 1: Mean leaf chlorophyll contents and their standard deviation in all three cultivation rounds. Small letters indicate significant differences (p < 0.05).

	Leaf Chlorophyll Content [SPAD]			
Treatment	Round 1	Round 2	Round 3	Round 1-3
under module	50.5 ± 1.1a	47.6 ± 0.6a	38.5 ± 0.5a	45.5 ± 4.0a
behind module	47.2 ± 0.8b	46.1 ± 0.6a	33.9 ± 0.5b	42.4 ± 4.0b
control	48.1 ± 0.8b	47.6 ± 0.6a	36.0 ± 0.7b	43.2 ± 4.0b

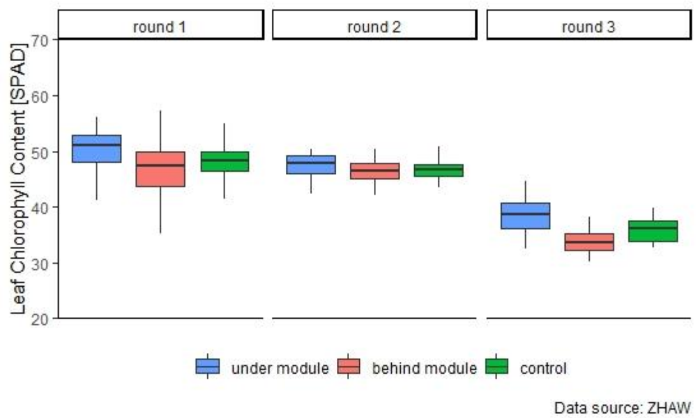

Fig. 4: Comparison of leaf chlorophyll contents between treatments (under module, behind module and control) and cultivation rounds. The boxplots range from the first quartile (25%) to the third (75%) with a line representing the median. The whiskers are drawn within the 1.5 times distance between the upper and lower quartiles.

Leaf length and width

Leaves were significantly longer and wider under the modules compared to the control and lamb's lettuce grown behind the modules in cultivation round 1 and 3 and in the general model for all three cultivation rounds (Tab. 2). In cultivation round 2 the difference was not significant (Fig. 5).

Tab. 2: Mean leaf lengths and widths of lamb's lettuce and their standard deviation in all three cultivation rounds at harvest. Small letters indicate significant differences (p < 0.05).

	Leaf Length [cm]				**Leaf Width [cm]**			
Treatment	Round 1	Round 2	Round 3	Round 1-3	Round 1	Round 2	Round 3	Round 1-3
under module	6.3 ± 0.2a	6.3 ± 0.4a	6.1 ± 0.2a	6.3 ± 0.2a	3.0 ± 0.1a	3.2 ± 0.2a	2.7 ± 0.1a	3.0 ± 0.2a
behind module	5.2 ± 0.2b	5.5 ± 0.4a	4.6 ± 0.2b	5.1 ± 0.2b	2.6 ± 0.1ab	3.0 ± 0.2a	2.1 ± 0.1b	2.6 ± 0.2b
control	4.9 ± 0.2b	5.8 ± 0.7a	4.3 ± 0.3b	5.1 ± 0.3b	2.5 ± 0.1b	3.0 ± 0.3a	2.7 ± 0.1b	2.5 ± 0.2b

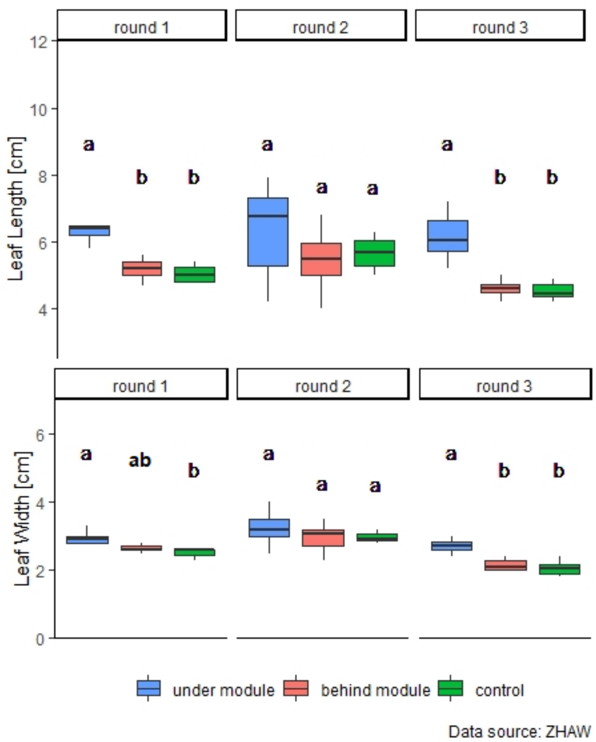

Fig. 5: Comparison of leaf lengths and widths between treatments (under module, behind module and control) and cultivation rounds of lamb's lettuce. The boxplots range from the first quartile (25%) to the third (75%) with a line representing the median. The whiskers are drawn within the 1.5 times distance between the upper and lower quartiles.

Leaf punches (dry weights and SLA)

Treatment had a significant effect on fresh and dry weight and thus SLA of leaf punches ($p < 0.001$). SLA of leaf punches was highest under and behind the modules and significantly lower in both controls (Tab. 3). The punches of the control had the highest dry weight and thus the lowest calculated SLA. Conversely, the punches of lamb's lettuce under the modules had the lowest dry weight and highest SLA. (Fig. 6).

Tab. 3: Mean leaf punch dry weights and specific leaf area (SLA), respectively, and their standard deviation in all three cultivation rounds at harvest. Small letters indicate significant differences ($p < 0.05$).

	Leaf Punch Dry Weight [mg]				**Leaf Punch SLA [$mm^2\ mg^{-1}$]**			
Treatment	Round 1	Round 2	Round 3	Round 1-3	Round 1	Round 2	Round 3	Round 1-3
under module	3.8 ± 0.1b	5.1 ± 0.3b	4.6 ± 0.5b	4.6 ± 0.5b	30 ± 1a	24 ± 1a	25 ± 1a	26 ± 2a
behind module	4.0 ± 0.1b	5.5 ± 0.2b	4.8 ± 0.5b	4.8 ± 0.5b	29 ± 1a	22 ± 1ab	22 ± 1a	24 ± 2a
control	4.4 ± 0.1a	6.2 ± 0.3a	5.4 ± 0.5a	5.4 ± 0.5a	26 ± 0.4b	19 ± 1b	18 ± 1b	21 ± 2b

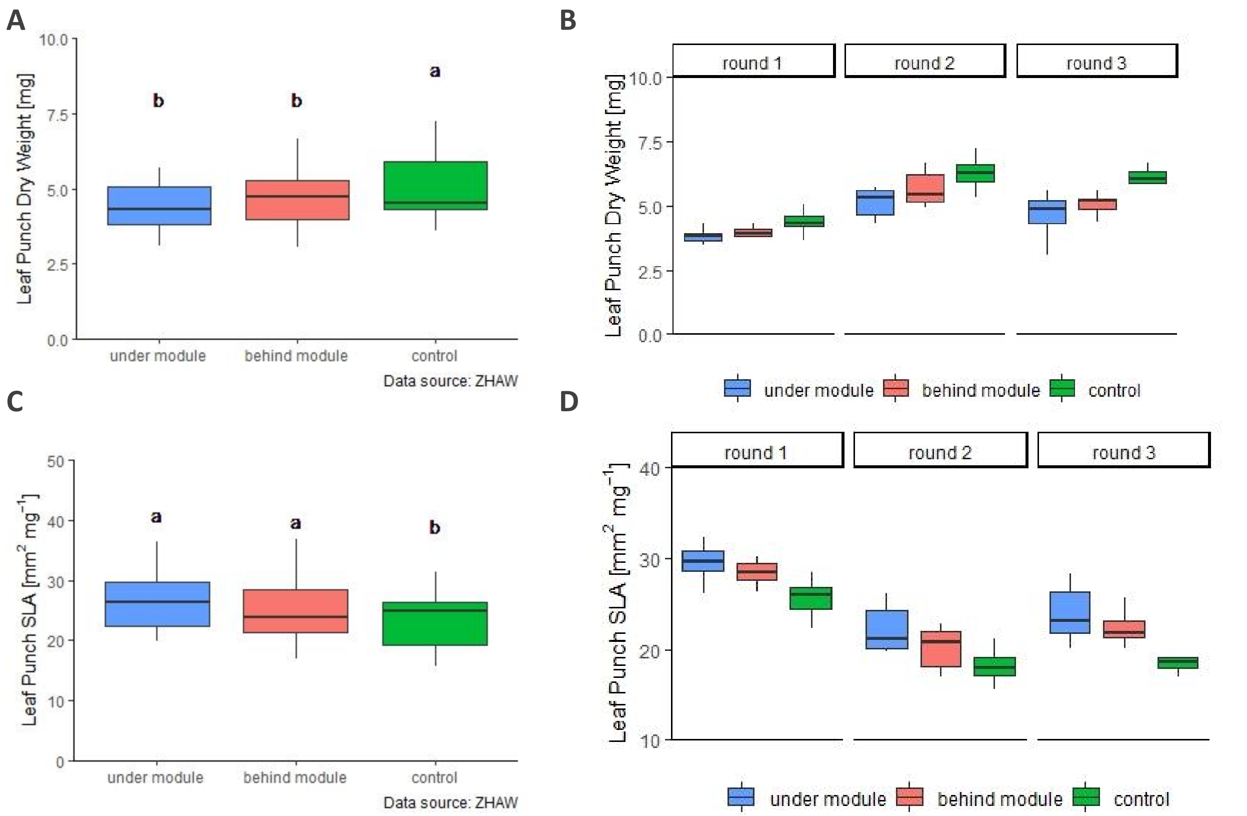

Fig. 6: Comparison of leaf punch dry weights between treatments (under module, behind module and control) (A) averaged over all three cultivation rounds and (B) within each round and of leaf punch specific leaf area (SLA) (C and D, respectively). Small letters indicate significant differences ($p < 0.05$). The boxplots range from the first quartile (25%) to the third (75%) with a line representing the median. The whiskers are drawn within the 1.5 times distance between the upper and lower quartiles.

Fresh Weight

Mean lamb's lettuce fresh weight of all cultivation rounds was significantly higher under solar modules compared to the control and the area behind modules ($p < 0.05$) (Fig. 7A). Analysing the cultivation rounds separately, lamb's lettuces under modules had the highest fresh weight in the first and third cultivation round and the same weight as in the control in the second cultivation round (Fig. 7B, Tab. 4). Lamb's lettuces behind the modules had the lowest fresh weights in the first and second cultivation round. Differences in fresh weights were significant in the first and third cultivation round ($p < 0.05$).

Tab. 4: Mean lamb's lettuce fresh weights and standard deviation at harvest in all three cultivation rounds. Small letters indicate significant differences ($p < 0.05$).

	Lamb's lettuce Fresh Weight [g]			
Treatment	Round 1	Round 2	Round 3	Round 1-3
under module	10.9 ± 0.4a	13.9 ± 0.8a	9.2 ± 0.3a	11.4 ± 1.6a
behind module	8.9 ± 0.4b	11.5 ± 0.9b	6.4 ± 0.3b	8.9 ± 1.6b
control	9.4 ± 0.3b	13.9 ± 1.2a	5.5 ± 0.5b	9.7 ± 1.6b

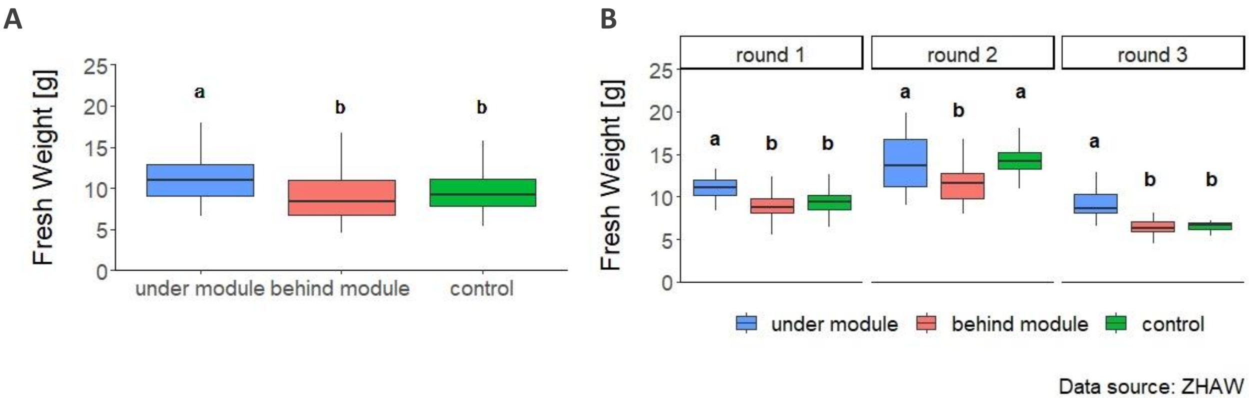

Fig. 7: Comparison of lamb's lettuce fresh weights between treatments (under module, behind module and control) (A) averaged over all three cultivation rounds and (B) within each round at harvest. Small letters indicate significant differences (p < 0.05). The boxplots range from the first quartile (25%) to the third (75%) with a line representing the median. The whiskers are drawn within the 1.5 times distance between the upper and lower quartiles.

Across all cultivation rounds, fresh weight under and behind modules increased by 17% and decreased by 8%, respectively, compared to the control. However, the influence of treatments strongly varied with season. Lamb's lettuces grown under solar modules had the highest fresh weight in cultivation round 1 and 3. Lamb's lettuces behind the solar modules had the lowest fresh weight in round 1 and 2. In cultivation round 2, fresh weight was identical for lamb's lettuce under the modules and in the control and slightly smaller in the zone behind the modules (-17%). In cultivation round 3, fresh weight increased by 67% and 16% under and behind the modules, respectively, compared to the control.

Energy production

Total produced energy from 11 November 2021 to 2 June 2022 (200 days) amounted to 143.130 kWh in total (with a daily mean of 716 ± 708 Wh). It should be noted that the solar modules were set to the MLT-mode for most of the time, i.e. entirely for cultivation round 1 and 22 out of 24 hours for cultivation round 2 and 3. Thus, the produced energy does not represent the full potential of energy production of the panels.

Tab. 5: Total energy production and daily means during the three lamb's lettuce cultivation periods and from the beginning of the installation until the harvest of the last cultivation round. The energy was produced by 9 modules covering an area of 3.50 x 1.50 m. The modules were set to the maximum light transmission mode for cultivation round 1. For cultivation round 2 and 3 the E-mode was chosen between 12 and 2 pm.

Time Period	Total Energy Production [kWh]	Daily Mean ± Standard Deviation [Wh]
11.11.2021 – 8.02.2022 (90 days)	20.96	233 ± 180
16.03.2022 – 21.04.2022 (37 days)	48.57	1,313 ± 712
10.05.2022 – 2.06.2022 (24 days)	35.02	1,459 ± 701
11.11.2021-2.06.2022 (200 days)	143.13	716 ± 708

Discussion

The results from this small agrivoltaics experiment provide first insights in possible agronomic and plant physiological responses that might occur in the combined use of agricultural and energy production.

The collection of the same parameters during three subsequent cultivation methods allowed the comparison of possible effects on lamb's lettuce at different times of the year. While in cultivation round 2 hardly any significant differences between the treatments and the control were observed, cultivation rounds 1 and 3 showed significant differences in chlorophyll content, leaf mass and size, and fresh weight to harvest between the salads under the modules and the other treatment and control. It is interesting to note that cultivation round 2 corresponds to the peak lamb's lettuce season. Cultivation round 1 was relatively late in terms of planting date for open field production and cultivation round 3 lay outside the usual growing season.

Higher leaf chlorophyll content under the modules and higher specific leaf area (SLA) under and behind the modules in cultivation round 1 and 3 reveal a physiological and morphological adaption to the reduction of light. Leaf length and width were highest under the modules throughout all growing periods. Leaf length was lowest in the control in round 1 and 3, leaf width in round 1. Leaf length and width were lowest in the zone behind the modules in round 2 (length) and 3 (width), respectively.

At harvest, lamb's lettuces under the solar modules had the highest fresh weight. Lamb's lettuces behind the solar modules were lowest but the difference to the control was not significant. Fresh weight was lowest in the zone behind the modules except for cultivation round 3 (late spring) where the salads in the control had the lowest fresh weight. In cultivation round 3, fresh weight increased by 67% under the modules compared to the control. With the restriction that at this time of year no lamb's lettuce cultivation takes place without protective covers, this could still be interpreted as a potential prolonging of the lamb's lettuce by growing season by provision of shade for this common winter crop.

In total, the crops under the solar modules benefited from the environment created by the modules. This advantage could have occurred due to the retention of ground radiation or the clearance from snow cover. It can be theorized that these possible beneficial effects on the microenvironment were not present in the zone behind the modules. Hence, assumably in the lack of positive environmental influences the adverse reduction in light availability reduced lamb's lettuce yield. In cultivation round 3, air temperature data showed distinctly reduced maxima which can be expected to be beneficial for lamb's lettuce in its late season (see SI Tab. 1).

When grown under shade, plants across habitats of varying light availability show increasing chlorophyll contents with decreasing light availability (Franklin 2008, Niinemets 2010). The small area of the nine solar modules created a small area of direct shading which, furthermore, was subjected to pronounced daily shifts of shade due to the winter sun's low angle (see appendix). Yet, higher chlorophyll contents were observed in lamb's lettuce grown under solar modules for the first and third cultivation round. Equally, the leaf punch dry weights and SLA was lowest and highest in lamb's lettuce grown under the modules, respectively, suggesting a common reaction to shade with a thinner leaf morphology (e.g. Taiz and Zeiger 2010, Gommers et al. 2013). However, there is a difference in SLA calculated for whole plants or for single leaves, the latter varying with leaf position and with leaf age, the former with plant age (Gunn et al. 1999). As care was taken to choose leaves of the same age, our results should still be a good estimate of SLA. The measurements of leaf length and width underline significant changes in leaf morphology towards longer and wider leaves, i.e. a higher leaf area in lamb's lettuce grown under modules. It appears that the lamb's lettuces grown under shade showed shade-induced reactions by developing larger but thinner leaves. Generally, leafy vegetables can be considered as relatively shade tolerant (Laub et al. 2022).

The harvestable fresh weight is an important parameter for agronomists. In our pretrial, it was significantly higher in lamb's lettuces under the solar modules except for cultivation round 2. This result could well have been expected, as lettuce generally prefers moderate shading in midsummer conditions. From an agronomic point of view, sensory properties would have to be clarified in addition to yield values. For example, whether thinner leaves are more pleasant to eat or whether there is a change in taste-forming substances.

The inhomogeneity of the control area is to be criticised. The significantly different measurements between the front and back control ("C1" and "C2" in cultivation round 1, results not presented) give evidence for a non-homogenous environment within the control which can probably be attributed to varying light availability caused by another nearby solar panel installation and additional emitted radiation from the nearby hen houses.

Conclusion

Agrivoltaics systems face several challenges to optimize energy and plant production. Our pretrial focused solely on the agronomic aspect and showed that solar modules could exert a positive influence on crop growth through a beneficial microenvironment, in particular outside of the common growing season. Our findings suggest that beneficial effects of agrivoltaics on crop growth are possible and – among other factors of influence – depend on the season. In the case of lamb's lettuce, a preferential microclimate under solar modules can be assumed during winter months while its growing season may be potentially prolonged in late spring.

Acknowledgements

We thank Sven Strebel and Manuel Hunziker (Renewable Energies Research Group), Jean Petit Matile Luzius (Geology Research Group) and Gaël Nardin (R&D Manager at Insolight) for their contribution to the success of the project.

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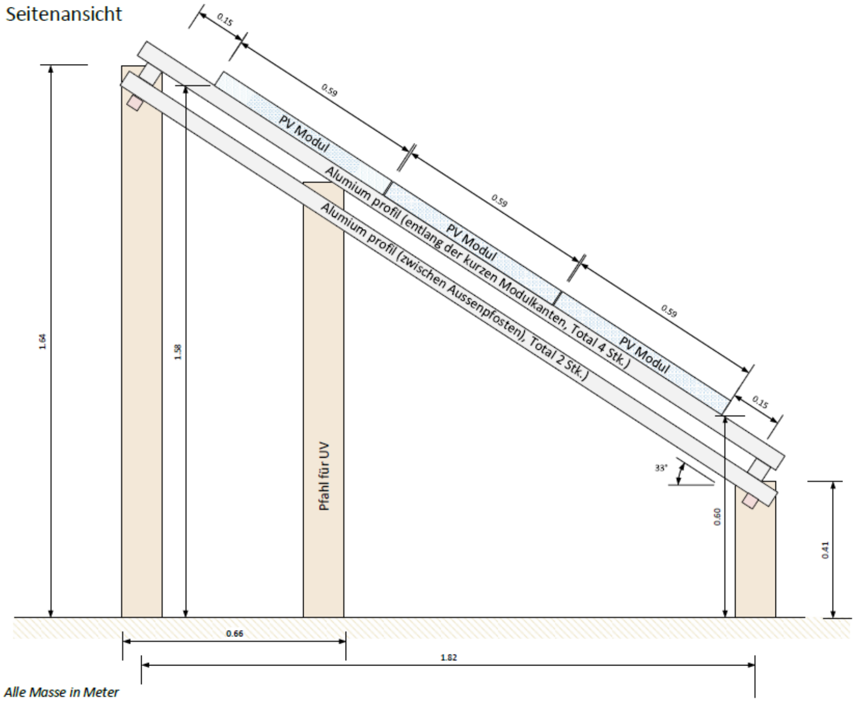
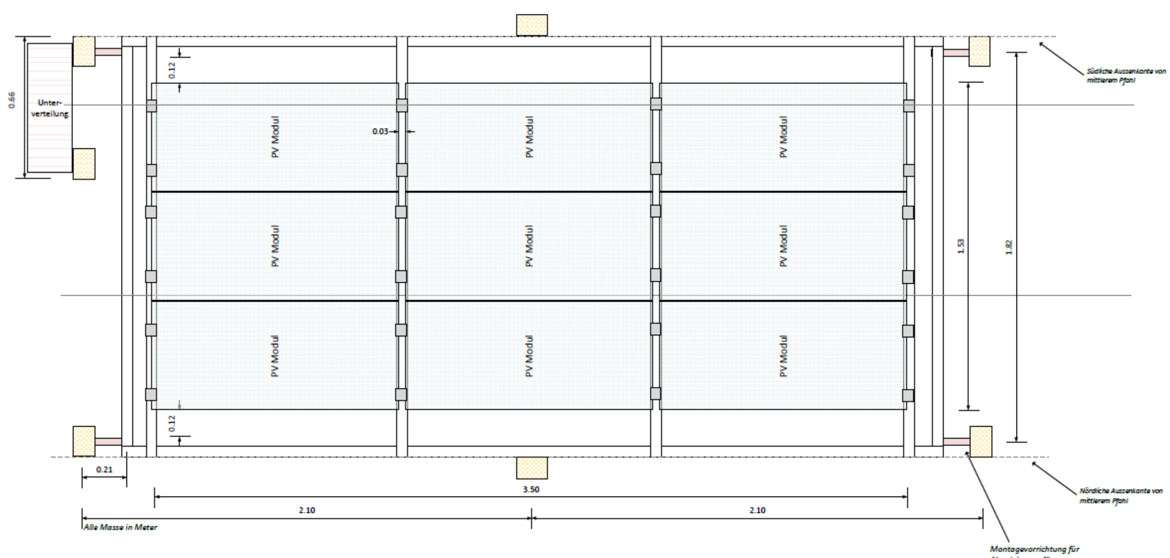
Appendix

Detailled installation scheme by Sven Strebel (Renewable Energies Research Group)

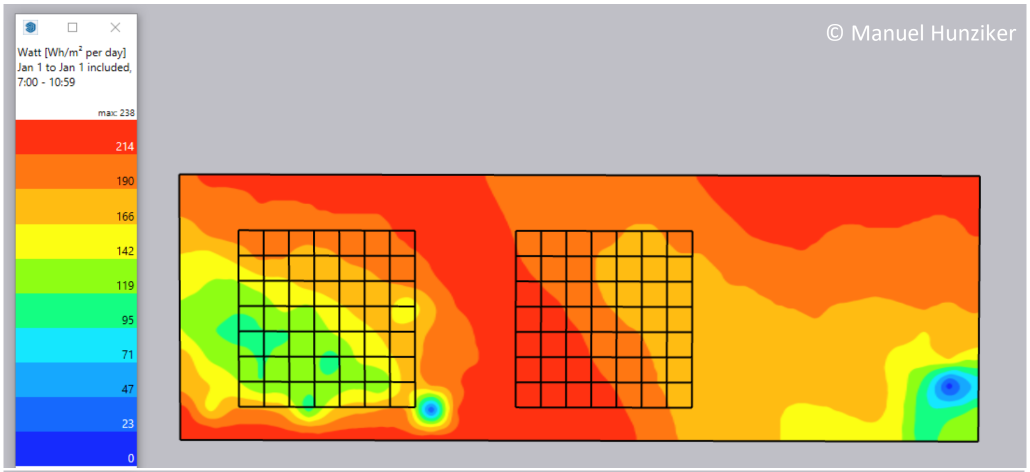
Seitenansicht

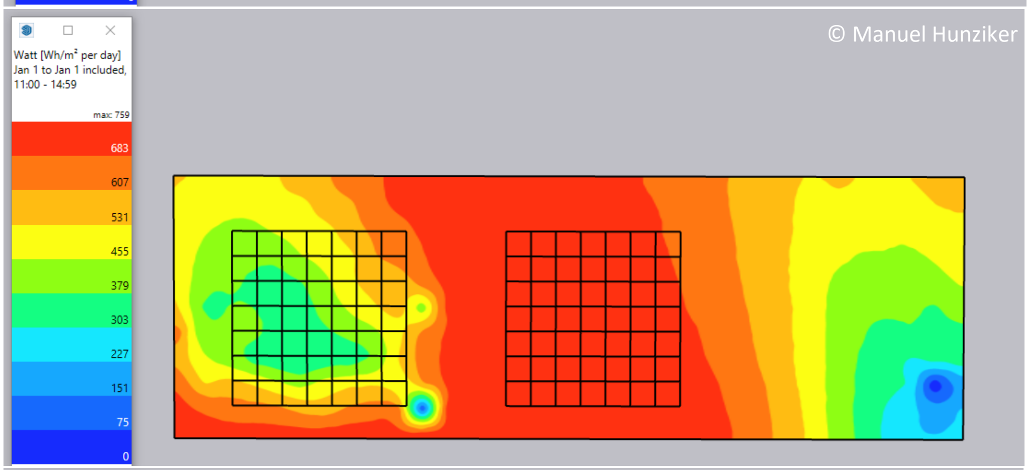


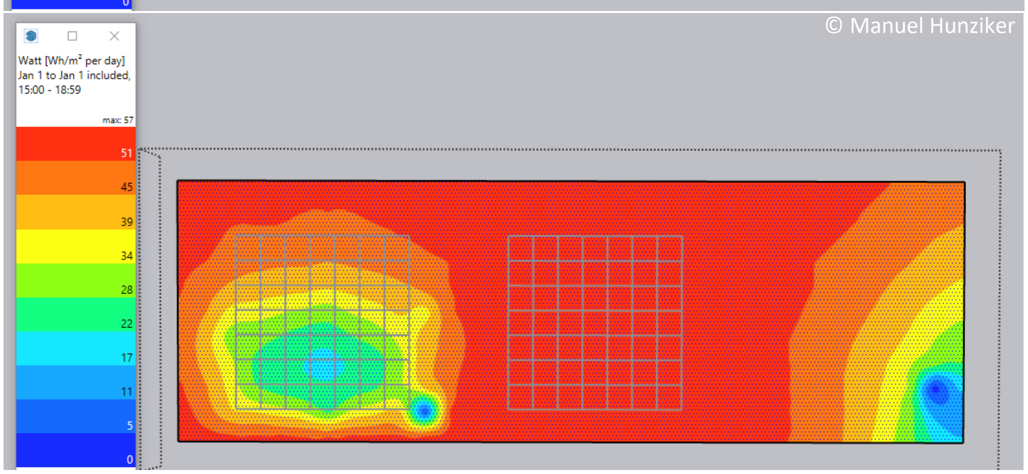
Aufsicht

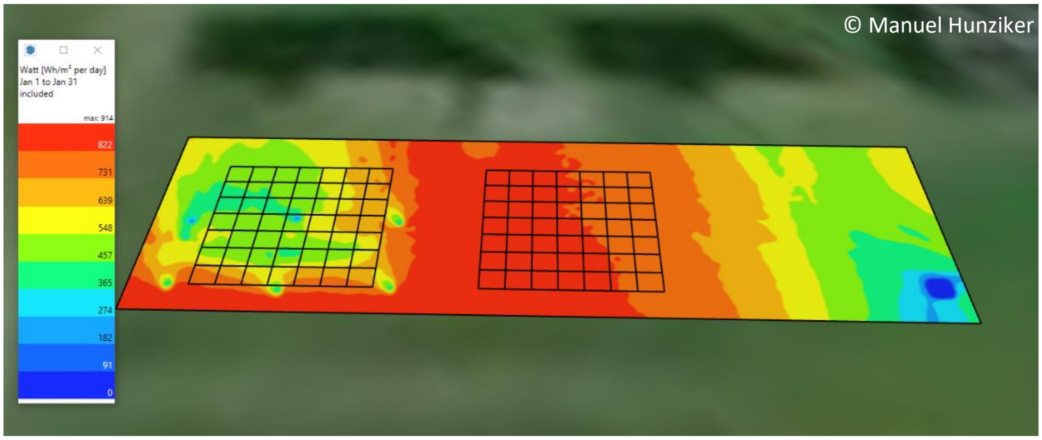


Below four graphs modelling direct solar radiation (Wh m^{-2}) are presented. The time duration (7 to 10:59 am, 11 am to 2:59 pm and 3 to 7 pm) is readable at the left side in the top white box (first three graphs). The last graph shows the daily mean for January.









Four pictures give visual impressions of the pretrial. Photo credits: Christina Vaccaro

*SI Tab. 1: Summary of data from EL-USB-2+ Data Loggers with air temperature [°C], dew point [°C] and humidity [% relative humidity] from cultivation round 3 (10 May – 2 June 2022). * This value is in doubt. It could have been caused by the sensor temporarily falling over and direct exposure to the sun.*

position	air temperature [°C]		dew point [°C]		humidity [(%rh]	
	min-max	mean ± sd	min-max	mean ± sd	min-max	mean ± sd
module – sensor 1	6.5-34.0	18.7 ± 5.6	5.0-27.9	14.0 ± 3.6	34.0-97.0	75.6 ± 13.7
module – sensor 2	6.5-35.0	18.9 ± 5.5	4.4-25.5	13.4 ± 3.3	36-98.5	72.6 ± 15.6
behind module – sensor 1	6.5-49.0*	19.3 ± 6.8	4.2-23.3	13.2 ± 3.5	22-96.5	70.7 ± 17.5
behind module – sensor 2	6.0-42.0	18.9 ± 6.5	4.1-28.1	13.6 ± 3.8	37-97.5	73.6 ± 16.4
control – sensor 1	5.5-41.5	20.0 ± 7.5	3.9-32.2	13.8 ± 3.8	29-98.5	71.2 ± 19.7
control – sensor 2	5.0-39.5	19.9 ± 7.1	4.0-23.9	13.8 ± 3.6	28.5-99.5	71.2 ± 19.2

SI Tab. 2: Summary of data from PlantControl sensors with soil temperature [°C] for cultivation round 2 and 3.

	soil temperature [°C]			
position	cultivation round 2 (data from 21 March – 21 April)		cultivation round 3 (data from 13 May – 28 May)	
	min-max	mean ± sd	min-max	mean ± sd
module – sensor 1	7.5-15.3	11.5 ± 1.7	17.1-36.7	19.3 ± 1.2
module – sensor 2	7.5-15.3	11.8 ± 1.7	16.7-36.7	19.1 ± 1.3
module – sensor 3	7.5-15.3	12.8 ± 1.7	17.1-36.7	19.5 ± 1.2
behind module – sensor 1	7.5-15.3	11.1 ± 1.7	17.4-36.7	20.3 ± 1.7
behind module – sensor 2	7.5-15.3	11.5 ± 1.7	17.2-36.7	20.2 ± 1.8
control – sensor 1	7.5-15.3	12.3 ± 1.7	17.6-36.7	20.6 ± 1.5
control – sensor 2	7.5-15.3	12.6 ± 1.7	17.8-36.7	20.5 ± 1.4