Salad yields under Agrivoltaics: a field test

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1. Introduction

An exchange of solar energy between photovoltaic (PV) and crops is the ultimate goal of Agrivoltaics. Theoretically, optimality is achieved when both renewable energy and crop yield are satisfactory. This paper briefly reports on an investigation made in an agrivoltaic plant in Italy. The trial that was made with escarole (*Cichorium endivia* var. *latifolium*) was originally proposed by a farmer specialized in ready-to-eat salad production. His professional curiosity was translated into a scientific question: is it possible to successfully close a fourth summer production cycle of escarole under agrivoltaics? Indeed, the experience of the farmer was suggesting that such a fourth cycle was nearly impossible under the typical early summer climate of the Po-plain in northern Italy. From June 2022 onwards, excessive radiation and high temperature loads in open fields are in fact leading to photoinhibitory effects and water stress conditions that cannot be further counterbalanced by irrigation.

2. Materials & Methods

The experiment was made in the Agrovoltaico® plant of Borgo Virgilio (Mantova, I, 45°05’40’’N - 10°47’30’’E) which has been built by REM Tec srl and is in operation since 27.04.2011. The system occupies an area of approx. 15 ha of agricultural land, it has a nominal power of 2,150.4 kWp being made of 768 trackers and 7680 PV modules (Figure 1). The overall PV module area is 1.49 ha so the Ground Coverage Ratio (GCR) is 13%. Escarole seedlings at trifoliate stage were transplanted mechanically in the field on 10.06.2022 with 0.3 x 0.3 m row spacing. Three replicates were planted under “standard” agrivoltaic trackers and three replicates under “extended” agrivoltaics with a GCR of 41% (Figure 1). One large plot of 150 m^2 was also planted at a side of the agrivoltaics to be then used as “full sun” reference. The plots were fully watered by drip irrigation until 20.06.2022 when the irrigation was halved in half of the plot areas. Plants in each plot (both fully and partly irrigated) were sampled four times during the growing season on 29.06, 12.07, 28.07 and on 25.08.2022 when the crop was harvested. Five plants were randomly collected at each sampling date and the fresh mass determined immediately by weighing individual plants. Maximum / minimum diameter and the total number of leaves in each clump were also determined soon after the harvest. Dry weight of individual clumps was determined after a drying period of 48 hrs in an oven at 65°C. At final harvest, the size/weight of a larger number of plants was also determined by annotating their relative spatial position in the plot space.

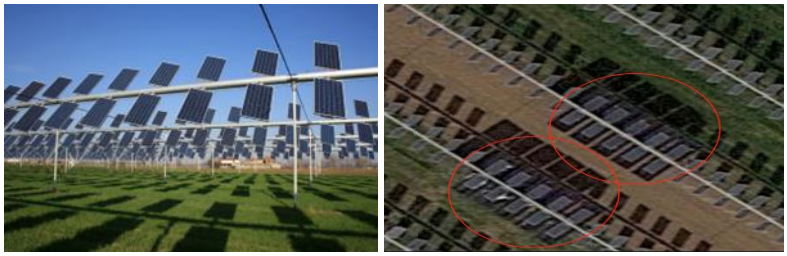

Figure 1 – A view of the Agrovoltaico® plant in Borgo Virgilio (left) and an airborne image of standard and extended PV area (highlighted in red) that was used in this experiment

3. Results and Discussion

Escarole plants established well in all the replicated plots and at the first sampling date, 18 days after transplanting, differences in fresh and dry weight as well in dimensions were negligible among the different treatments. Those differences rapidly increased and became appreciable at 28 days after transplanting, when the plots were sampled before irrigation levels were modified. On 12.07 the mean fresh weight of the plants grown under the standard and extended agrivoltaics were 37.8% larger compared to that of plants grown under full sun (Figure 2). Clump dimensions (diameter and height) were well correlated to the fresh weight, while the number of leaves per clump was comparable.

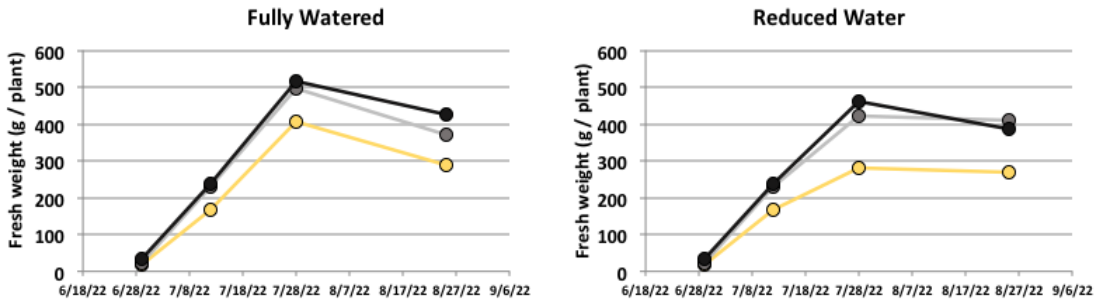

Figure 2 – The time course of the mean fresh weight of escarole under fully (left) and partly irrigated (right) regimes. Black and grey dots&lines refer to the extended and standard PVs while the yellow dots&line refer to the full sun plots

The dry weight of plants grown under the sun or under the agrivoltaics was instead very similar (data not shown). The modification of the irrigation regime (50% on half of the plots) had a very limited effect on the fresh weight of plants growing under the agrivoltaics, irrespective of the "standard" and "extended" dimension of the PV panels. The effect on plants growing in the full sun was instead very large. On 28.07, the fresh weight of lettuce grown under "standard" PV was reduced by 8% compared to "extended PV", while the fresh weight of plants grown in full sun was 38% lower. The difference in clump dimensions over space that was observed on 25.08, clearly showed that the plants grown in PV-shaded areas were definitely larger and no major deviations could be noticed between plants grown next to the agrivoltaic tracking lines. (Figure 3).

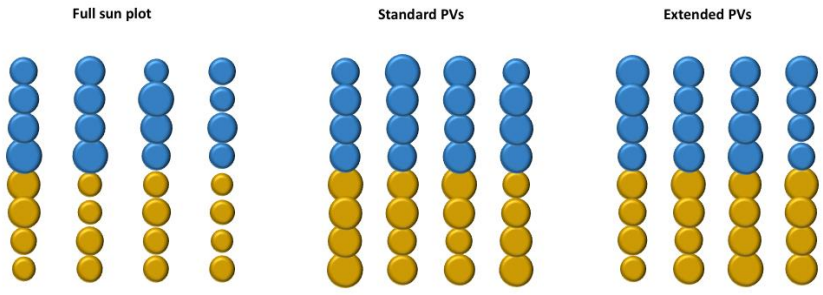

Figure 3 – A graphical representation of the three treatments in the lettuce trials. Each dot in the figure is the mean of the fresh weight of 5 lettuce clumps collected over squares of 1 x 1 m inside the area of the plots. The size of each dot is proportional to the fresh weight observed at harvest

Overall, the experiment clearly indicated that a fourth cycle of lettuce is possible under the PVs of agrivoltaics. Both fresh weight and size of the salad bowls were significantly increased by the shade provided by the PVs. Lettuce appeared to be very tolerant to the shade and commercial yields were boosted, compared to full sun treatments, even under extended shade conditions. Such an effect can be likely explained by an overall amelioration of the water status in shaded plots.