Water Status, Irrigation Requirements and Fruit Growth of Apple Trees Grown under Photovoltaic Panels

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1. Introduction

According to the current scenarios of global warming, increase in mean air temperature about 1.5 °C are expected between 2010 and 2052 in most parts of the World as well as more frequent extreme weather events such as heat waves that can devastate crop yields [1]. Agrivoltaic systems seem to be an appropriate protection solution for extreme weather conditions. This concept consists of the association, on a same land area, of agricultural and electrical productions by means of solar photovoltaic panels (PV) located above the crop [2]. However, nowadays it is not well understood if all existing crops are compatible with such systems due to the significant decrease in the amount of transmitted light. The behaviour of apple trees for example is unknown, and the potential benefits in the reduction of air temperature and increase in air humidity must be evaluated in balance of the reduction in light. With this problem in mind, a three-year study (2019-2022) is being developed to understand the effect of shading below solar panels in apple production. In this study, results related with the tree water status, irrigation requirements and fruit growth during the first experimental year are presented to provide valuable information about the suitability of apple trees in agrivoltaic systems.

2. Material & methods

2.1. Experimental location and plant material

An agrivoltaic system was installed in February 2019 in a ten-year-old 'Golden Delicious' apple orchard located in the experimental station of La Pugère (Mallemort, France: 43.74 °N; 5.125 °E). The system covered a total area of 730 m² next to a control plot (Not under PV structure) of 300 m². The PV modules rotate following a 'Solar Tracking' approach to maximise their radiation interception (mean interception: 50-55 %) and consequently the production of electricity. The irrigation was scheduled to maintain midday Stem Water Potential (mSWP), that is considered a reliable water status indicator in apple, above -1.0 MPa [3]. The scheduled hours of irrigation were registered, and the amount of water applied was calculated considering the duration of each irrigation and the irrigation system delivery capacity (35 liters per hour). Selected experimental trees had similar flowers loads to avoid an effect of tree variability in water status and fruit growth.

2.2. Midday stem water potential, irrigation applied, and fruit growth

mSWP was measured with a pressure chamber (NP 50, DG-MECA) twelve times between May 15th and September 19th on three experimental trees per plot (three mature leaves at a height of approximatively 1.50 m). Measurements were conducted on non-transpiring leaves that had been enclosed within bags on the tree at least one hour prior to excision and measurement at solar noon. Regarding fruit growth, eight fruits in ten experimental trees were tagged on May 7 (80 fruits per plot) to determine their diameter on a weekly basis until harvest (September 13) by using a numeric caliper. mSWP and fruit growth was evaluated by analysis of variance. Wilcoxon Test (non-parametric statistical test) was used to separate mean values that were significantly different.

3. Results and Discussion

Fruit growing season is separated in 4 periods: Period 1 (May 7-June 26), Period 2 (June 26-July 11), Period 3 (July 11-August 22) and Period 4 (August 22-September 13). During the experiment, trees grown under PV received less irrigation in period 3 and 4 and had always better water status than control trees (Figure 1). Although control trees were around the threshold value of water potential that limits fruit growth [4], there were no significant difference in fruit growth rate, except in period 2, when fruit from control trees had lower values than those from under solar panels (Figure 2). Consequently, any potential negative effect of reduction of light availability on fruit growth was compensated by a better water status under the solar panels leading to a similar fruit growth. However, despite similar tree floridity, apple trees grown under solar panels had much lower crop loads compared to controls indicating a potential negative effect on fruit setting.

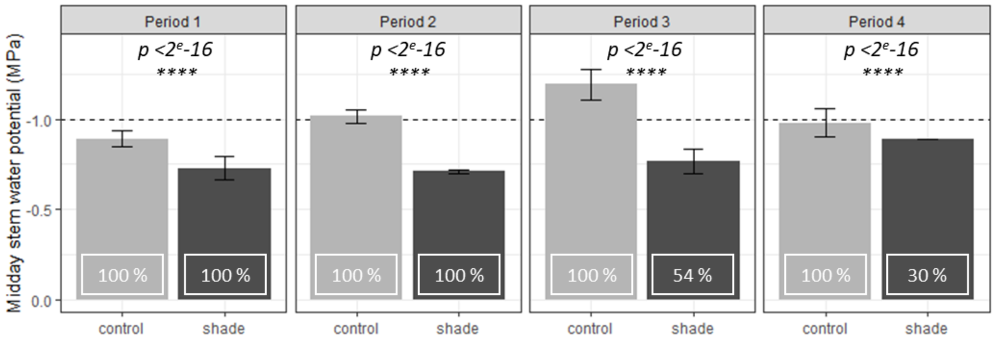

Figure 1: Midday stem water potential during different growth periods in 2019. Dashed horizontal line at –1 MPa represents the water stress threshold for irrigation scheduling. More negative values of water potential indicate a water deficit [4]. Percentages indicate the amount of water applied for each period relative to the control plot. Each bar and its standard error line represent the mean value of three trees. **** significant differences between treatments.

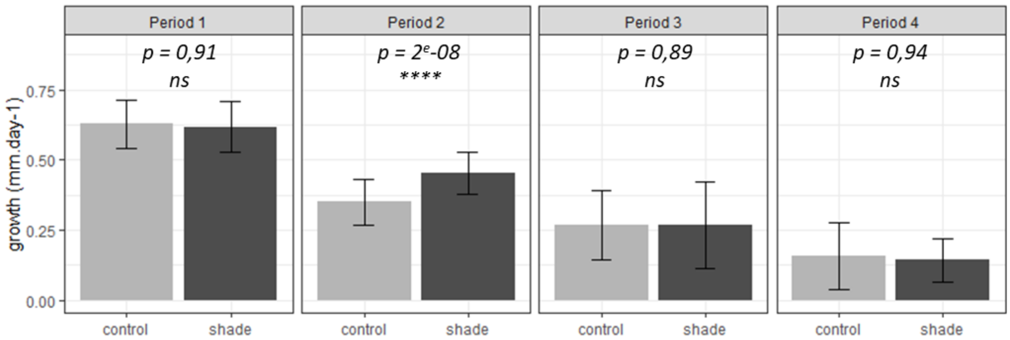

Figure 2: Fruit growth (mm.day^{-1}) during different growth periods in 2019. Each bar and its standard error line represent the mean value of 80 fruits. **** significant differences between treatments, and *ns* indicates no significant difference between treatments.

4. Conclusion

The presence of solar panels on top of apple trees improved their water status with less water applied in the period before harvest (reduction about 30%) without any negative effect in the rates of fruit growth in comparison with trees grown without panels. These results encourage the implementation of PV in apple trees but raise questions about fruit set and fruit abscission considering the lower crop loads under shade. Furthermore, these results need to be complemented with physiological information, vegetative growth, yield, fruit quality, return bloom and fruit set during the three years of the project to determine the sustainability of agrivoltaic systems in apple orchards. Preliminary results of all the previous traits will be discussed to have a wider overview of the effect of intermittent shading in apple.

Acknowledgement

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