Protection net and the canopy layer decouple gas exchanges, affecting carbon and water net fluxes: the case of a kiwi orchard in a Mediterranean environment

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Introduction

State of the Art

Multifunctional nets are used to protect tree crops from extreme meteorological events.

Their use on kiwifruit (*Actinidia chinensis*) has the main objective to protect from hailing and reduce the excess of radiation, but may reduce the coupling between plant microclimate and the atmosphere. This in turn may induce positive and negative secondary effects, such as a reduction in evapotranspiration demand, increases in the recycling of carbon dioxide and water vapor, but also increasing the leaf wetness and the related physiopatological issues.

Thus, it is desirable to optimize the benefits of this systems, while minimizing unwanted secondary effects.

Objectives

Characterizing how a protection net and the pergola training system impact the drivers of evapotranspiration and the main gas exchanges (carbon dioxide and water vapor) between the orchard and the environment.

Materials and Methods

Study area:

- An kiwifruit (*cv Hayward*) orchard (140 m x 90 m; 1.3 ha; vines spaced 2.0 m x 4.5m) trained as pergola, irrigated with ca. 6-8mm/day in summer 2021.
- The field is located in southern Italy (municipality of Bernalda, Basilicata region) an area with high VPD and low rainfalls.
- An horizontal hail protection net, installed at about 4.15 m height, covers the whole plot.
- Canopies and the net split the envitroment above the ground in three horizontal layers.

Fig.1: Kiwi orchard trained as pergola, covered by a homogeneous hail protection net.

Fig.2: Three aligned eddy covariance systems (sonic anemometers, net radiometers and thermoigrometers) on a vertical mast: above the net, between net and canopies, and below the canopies.

Methods:

Meteorological data:

A 6m high vertical mast is installed to host meteorological instruments at three levels: 1) below the canopies, 2) between canopies and the net, 3) above the net.

At each level we monitored:

- Short and long wave, downward and upward radiation
- Air temperature and humidity
- Three dimensional wind speed and direction
- CO2 and H2O concentrations

- Anemometers are oriented to record the main winds
- Coupling high frequency (10Hz) measurements of wind and gas concentrations allows to infer vertical gas exchanges across layers

Results and Discussion

In a summer day at different hours:

- all variables are heavily impacted by the canopy layer, while the net has a major impact only on some of them.

Radiation

Reductions mostly impact the downward short wave: -24% (+-19%) across the net and - 79% (+-36%) across the canopy.

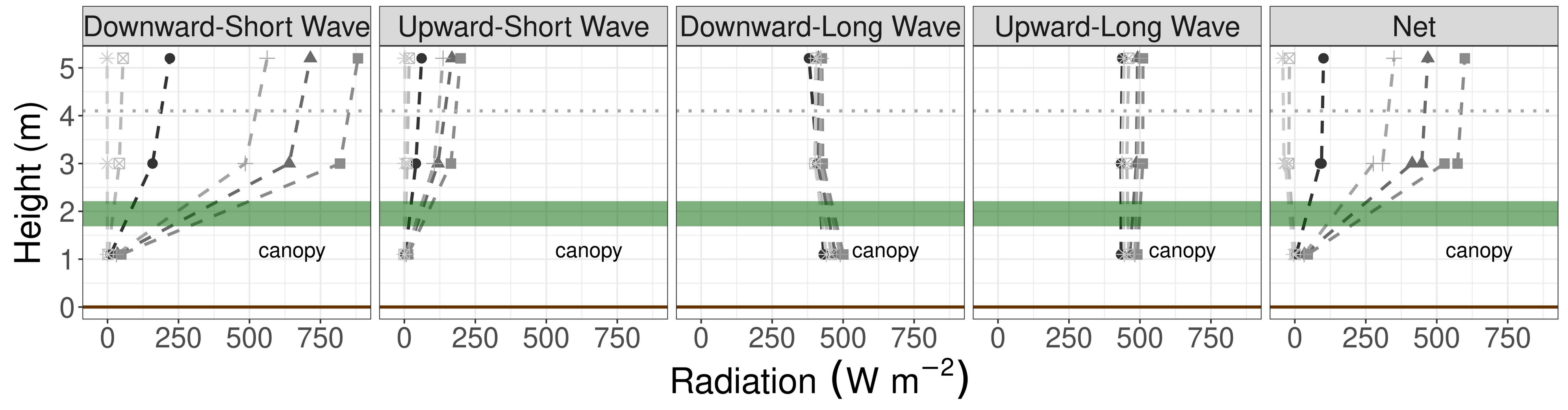

***Fig.3:** Radiation components measured below the canopy, between canopy and the net and above the net, during a summer day during (averages during a period of 1 hour).*

Other Meteorological variables

The net and the canopy induced respectively:

- an increase of 1.8 (2.1) % and 6.9 (2.3) % in air humidity, of 2.1 (2.5) % and 5.9 (4.7) % in vapor pressure, and a reduction of 59 (16) % and 27 (57) % in wind speed;
- a reduction of 0.051 (+- 0.701) °C and 0.89 (0.57) °C in air temperature, and of 12 (20)% and 35 (19)% in vapor pressure deficit.

The reduction in wind speed below the net is associate to a reduction in CO2 concentration by 1.5 (0.4) % during the day, and its increase in late hours (at 9pm, +0.7%).

Similarly, CO2 accumulates under the canopy, especially from late afternoon to the early morning (+12% at 9 pm; + 3.6% at 6 am), likely thanks to soil respiration, and then decreases, likely recycled by the canopy during daytime.

High correlation of wind speed across the net → strong coupling of the processes for most of the time.

This is occasionally true across the canopy.

Layer — Across net — Across canopy

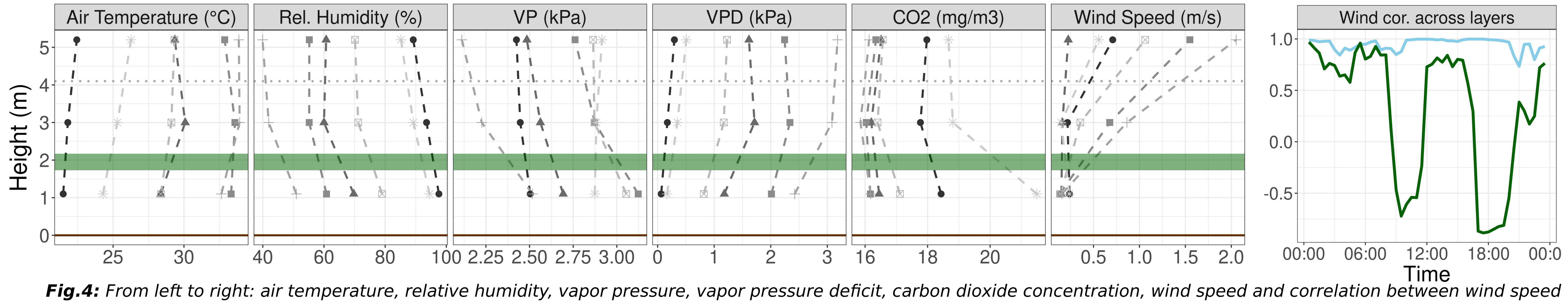

***Fig.4:** From left to right: air temperature, relative humidity, vapor pressure, vapor pressure deficit, carbon dioxide concentration, wind speed and correlation between wind speed across the net and the canopy, during a summer day (averages during a period of 1 hour).*

Fluxes

Carbon fluxes are driven by tree canopy assimilation, which is highest in morning hours (-1.01+- 0.11 mg m^{-2} s^{-1}). Conversely, respiration is driving the flux in the understory (0.084+-0.031 mg m^{-2} s^{-1}).

The energy used for water evapotranspiration (LE) is in minimally absorbed by the soil and grass (2.4 +- 2.9 W m^{-2} below the canopy), while is absorbed by the tree canopy, modestly early and late during the day (12 +- 12 W m^{-2}), and substantially during the central part of tha day (between 9 and 15 hour: 303 +- 52 W m^{-2}).

The sensible heat (Hs) exiting the understory level is one order of magnitude lower than LE (0.32 +- 1.87 W m^{-2}). Conversely Hs exiting the canopy increases up to about 24% of LE during the morning hours (74 +- 26 W m^{-2} at 9 and 12am).

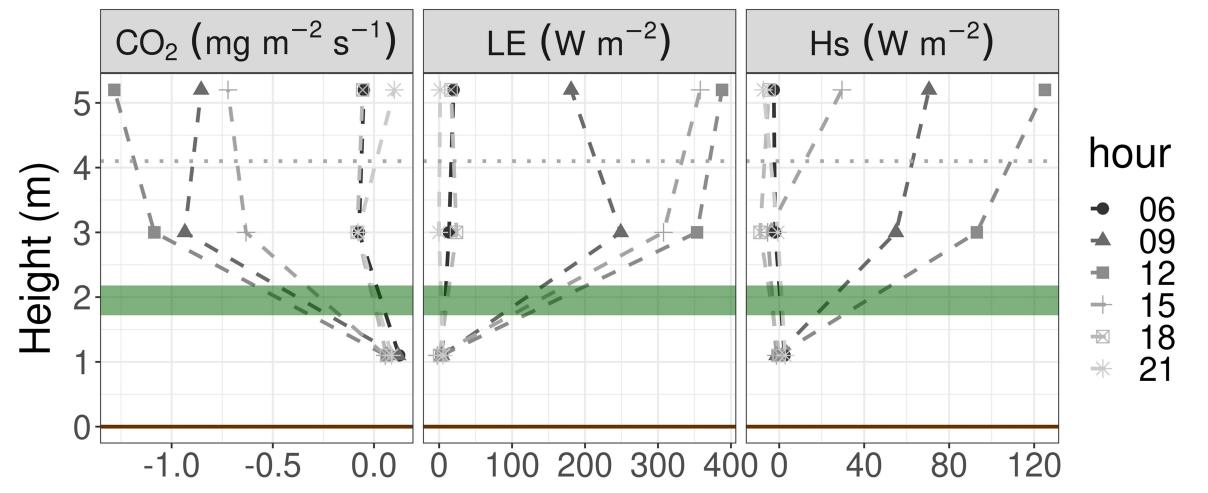

***Fig.5:** From left to right: fluxes of carbon dioxide, latent heat of evaporation and sensible heat during a summer day (averages during a period of 1 hour).*

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