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Estimating sensible heat exchange between screen-covered canopies and the atmosphere using the surface renewal technique

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Screenhouses and screen-covers are widely used in arid and semi-arid agriculture to protect crops from direct solar radiation and high wind speed, and to increase water use efficiency. However, accurate estimation of crop water use under screens is still a challenge. The most reliable method that directly measures evapotranspiration, the Eddy Covariance (EC), is both expensive and complex in data collection and processing. This renders it unfeasible for day to day use by farmers. A simpler alternative is the Surface Renewal (SR) technique which utilizes high frequency temperature readings of low-cost fine-wire thermocouples, to estimate the sensible heat flux. Assuming energy conservation and employing relatively cheap complementary measurements, the evapotranspiration can be estimated. The SR technique uses a structure function mathematical analysis that filters out noise and involves a time lag parameter to provide amplitude and time period of a ramp-like temperature signal. This behavior arises from the detachment of air parcels that have been heated or cooled near the surface and sequentially renewed by air parcels from above. While the SR technique is relatively simple to employ, it requires calibration against direct measurements. The aim of this research is to investigate the applicability of the SR technique in two different types of commonly used screenhouses in Israel.

Two field campaigns were carried out: In the first campaign we studied a banana plantation grown in a shading screenhouse located in the coastal plain of northern Israel. The second campaign was located in the Jordan Valley region of eastern Israel, where a pepper plantation cultivated in an insect-proof screenhouse, with a much denser screen, was examined. In the two campaigns, SR sensible heat flux estimates were calibrated against simultaneous eddy covariance measurements. To optimize the SR operation, in each campaign fine-wire (50–76 μm) exposed T-type thermocouples were placed at several heights. Thermocouple output was continuously recorded at 10 Hz and data analysis was performed at 10, 5, 2 and 1 Hz to examine the validity of low frequency data acquisition.

Results for daytime hours revealed temperature ramp amplitudes of up to 2ºC, with ramp periods spanning from several to tens of seconds. Best linear regressions between EC and SR sensible heat fluxes during validation were obtained for the thermocouples located above the screen, 0.1 m above the shading screen and 0.45 m above the insect-proof screen. The coefficients of determination were generally higher for the shading than the insect-proof screenhouses. This was due to the effect of the insect-proof screen which induces a higher resistance to airflow than the more porous shading screen that covers the banana plantation. At both campaigns, results were better for unstable than for stable boundary layers. At unstable conditions and above the canopy, low frequency data analysis produced reasonable results, such that 2 Hz analysis performed as good as 10 Hz. Parameters like turbulence intensity, two-point correlation and quadrant analysis illustrate the effect of the two different screenhouses on turbulence characteristics of the flow.