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Eddy covariance measurements in screenhouses: turbulence characteristics and flux gradients

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Shading banana and other orchard crops with screens is popular in arid and semi-arid regions for decreasing water use and increasing fruit quality. However, crop water use within this unique environment is much less studied than for canopies in the open. Previous studies of our research group have established the use of the Eddy Covariance (EC) technique for reliable evapotranspiration and sensible heat flux measurements within screenhouses. These studies focused on operating conditions of the system. The present paper is a comprehensive study which examined the performance of the EC system in different types of screenhouses (shading and insect-proof), different crops (banana and pepper) at different development stages (small and large plants) and different climatic regions in Israel. The main goal was to establish guidelines for optimal application of the EC technique in screenhouses. The research consisted of 6 field campaigns: in 3 campaigns two EC systems were simultaneously deployed either vertically or horizontally, and in 3 other campaigns a single EC system was deployed at one measurement height. EC systems were deployed at different normalized system heights, Zs, which define the relative measurement heights within the air gap between the canopy top and the horizontal screened roof. System performance was examined using quality tests like energy balance closure, flux variance similarity, friction velocity, footprint modeling, energy spectrum, turbulence intensity and vertical and horizontal flux gradient analyses. Resulting energy balance closure slopes averaged 0.81 ± 0.08 and 0.91 ± 0.08 for the smaller and larger plants, respectively. Turbulent flows were found to be marginally developed within the air gap between the top of the plants and the horizontal screened roof. Turbulence intensity, flux variance similarity test, energy spectrum decay rate and friction velocity were essentially independent of the measurement height and were within the common range for flows in the open. Insect proof screenhouses were found to inhibit turbulence development. Considering common dimensions of commercial screenhouses, a footprint model, originally derived for canopies in the open, suggested that the normalized EC system height for which 90% of the measurements are within the available fetch is within the range $0.04 < Zs < 0.29$. Vertical gradients of water vapor, sensible heat and CO_2 fluxes were within the range of expected deviations (up to 26% difference between two vertically deployed EC systems) and were not correlated with advection effects. Hence, it is suggested that these gradients originated either due to non perfect energy balance closure or limitations of raw data corrections. We conclude that there is a constant flux layer in the screenhouse environment. The horizontal gradient of the vertical latent heat flux, measured in one campaign, was very small, suggesting that measurements were done in a position where the surface layer was already in equilibrium with the vegetation below.