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Possible decoupling between needle temperature and transpiration in a semi-arid pine forest during summer drought

Jonathan D. Müller (1), Yakir Preisler (1,2), Eyal Rotenberg (1), and Dan Yakir (1)

(1) Weizmann Institute of Science, Rehovot 7610001, Israel (jonathan.muller@weizmann.ac.il), (2) Faculty of Agriculture, Food and Environment, The Hebrew University, Rehovot 7610001, Israel

Due to their wide global distribution (~18% of land area), semi-arid regions play an important role in the climate system. Forests in this zone are characterized by high radiation exposure, low albedo, and limited evaporative cooling, all of which can greatly affect canopy temperature. This, in turn, can negatively influence biological processes such as photosynthesis and plant water stress through increased transpiration. Therefore, under these conditions, control over leaf temperature and any cooling processes must rely on the sensible heat flux (ultimately resulting in a canopy convector effect; Rotenberg & Yakir, 2010). In this project, we assess the effect of summer drought on needle temperature in a water-limited semi-arid pine forest in control and summer-irrigated plots in our semi-arid research site in southern Israel. We employed a specially built system using a high-resolution infrared camera combined with a reference surface for high accuracy, continuous leaf-scale measurements of temperature and background thermal radiation, along with simultaneous air temperature measurements. This setup was deployed consecutively in the control and irrigated plots during the seasonal summer drought period using a portable mast within the canopy.

First results from our newly developed system indicated that correcting for background thermal radiation reduced the discrepancy between infrared and thermocouple-based leaf temperature from ~2°C to ~0.5°C. Based on this novel approach we found that at night, pine needles cool down to near air temperature. During the dry midday, when evapotranspiration was minimal, leaf temperature remained within 1-2°C of air temperature, which was >30°C. This is surprising in light of observations of leaf temperature 2-3°C higher than air temperature in fully irrigated, high transpiration broad-leaf trees in similar climatic conditions (Cohen et al. 1997). Furthermore, comparing needle temperature in the control and irrigated plots in our forest showed that when exposed to sunlight leaf temperature was similar (within 1°C) in both plots in spite of a x10 higher transpiration rate in the irrigated plot. When shaded, needle temperature in the irrigated plot adjusted to air temperature within ~1h while needles in the control (drought) plot remained ~1-2°C above it.

These results suggest an effective coupling between leaf and air in our semi-arid pine forest, which prevents overheating and may explain the observed resistance of these trees to the harsh conditions. Furthermore, the results suggest some decoupling between needle temperature and transpiration in our ecosystem. This, in turn, may be inconsistent with the prediction of a large increase in leaf temperature associated with higher future atmospheric CO_2 levels that would lead to stomatal closure and reduced transpiration.

Cohen, Shabtai, Samuel Moreshet, Loic Le Guillou, Jean-Christophe Simon, and Moises Cohen. 1997. 'Response of Citrus Trees to Modified Radiation Regime in Semi-Arid Conditions'. Journal of Experimental Botany

Rotenberg, Eyal, and Dan Yakir. 2010. 'Contribution of Semi-Arid Forests to the Climate System'. Science