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Evidence for efficient non-evaporative leaf cooling mechanism in a pine forest under drought conditions

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The reduced availability of evaporative cooling resulting from a hotter and drier climate can lead to high leaf temperatures resulting in overheating. This can affect a variety of biophysical and biochemical processes that could enhance mortality. Plant resilience to these increasingly stressful conditions could rely on non-evaporative cooling. However, to what extent this plays a role is poorly known at present.

In order to assess heat dissipation under the long summer drought conditions, we measured leaf-to-air temperature differences $\Delta T_{leaf\text{-}air}$ of pine needles in semi-arid conditions in a drought-exposed and in an experimentally irrigated plot. For this purpose, we developed a novel, high accuracy system based on an infrared camera capable of continuous measurements of leaf temperature under field conditions. Both drought-exposed and irrigated trees, which had a 10x higher transpiration rate, exhibited a similar $\Delta T_{leaf\text{-}air}$ that remained mostly below 3.5°C. Variations in mean wind speed did not strongly affect $\Delta T_{leaf\text{-}air}$, but it depended highly on within-canopy turbulence. This suggests a non-evaporative cooling mechanism that relies on the low leaf resistance to heat transfer, thus generating a large sensible heat flux. The ~30% reduction in resistance between leaves of drought-exposed and irrigated trees in the same species must be a result of changes in leaf characteristics and differences in canopy structure influencing wind penetration into the canopy. This reduction in resistance is required to generate the sufficiently larger sensible heat flux of nearly 100 W m^{-2} observed between both treatments under high radiation.

Non-evaporative cooling was demonstrated to be an effective leaf- and leaf-branch-scale cooling mechanism in trees with small leaves, which can be a critical factor in forest resistance to drying climates. The generation of a leaf-scale sensible heat flux is considered as a possible mechanism leading to the development of the previously identified canopy-scale 'convector effect'.