



Dissecting reverse sap flow in desert shrubs: effects of event timing, rainfall thresholds and species

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In arid regions, precipitation is scarce and predominantly occurs as pulsed rainfall events. These events alter both atmospheric and soil moisture conditions, thereby obscuring the dominant controls on plant water transport and making their role in replenishing vegetation water use unclear. We isolated the direct atmospheric pathway by excluding infiltration beneath canopies and quantified organ-level sap flow responses of *Haloxylon ammodendron* and *Tamarix ramosissima* to controlled rainfall applied in the morning, afternoon and at night (2, 6 and 10 mm) in the Ulan Buh Desert (June–August). Sap flow of primary branches, main trunks and root system was measured with heat-balance sensors and analysed against meteorological drivers using partial correlations and random-forest models. Responses were strongly time dependent: nighttime rainfall events most readily induced reverse flow, with larger magnitudes in *H. ammodendron* (e.g. $-29.7 \text{ g}\cdot\text{h}^{-1}$ in stems; $-5.2 \text{ g}\cdot\text{h}^{-1}$ in roots). Optimum rainfall amount differed by species: by day, reversals required $\approx 6 \text{ mm}$ in *H. ammodendron* but $\approx 10 \text{ mm}$ in *T. ramosissima*; at night, $\approx 2 \text{ mm}$ versus $\approx 6 \text{ mm}$, respectively. Aboveground organs of *T. ramosissima* responded sooner (trunk 19 min; branch 21 min) than those of *H. ammodendron* ($\approx 23 \text{ min}$), whereas root system of *H. ammodendron* responded earlier (38 min vs. 43 min). Photosynthetically active radiation was the dominant meteorological driver of sap flow in both species and exerted a stronger overall effect in *T. ramosissima*. Our results demonstrate that small, well-timed nighttime pulses can transiently reverse xylem flow via the atmospheric pathway, with species-specific optimum rainfall amount. This insight carries practical implications for the scheduling of restoration efforts in desert oases, particularly when incorporating considerations of water resource carrying capacity and planting density.