How are driving forces of root water uptake altered in maize under water deficit?

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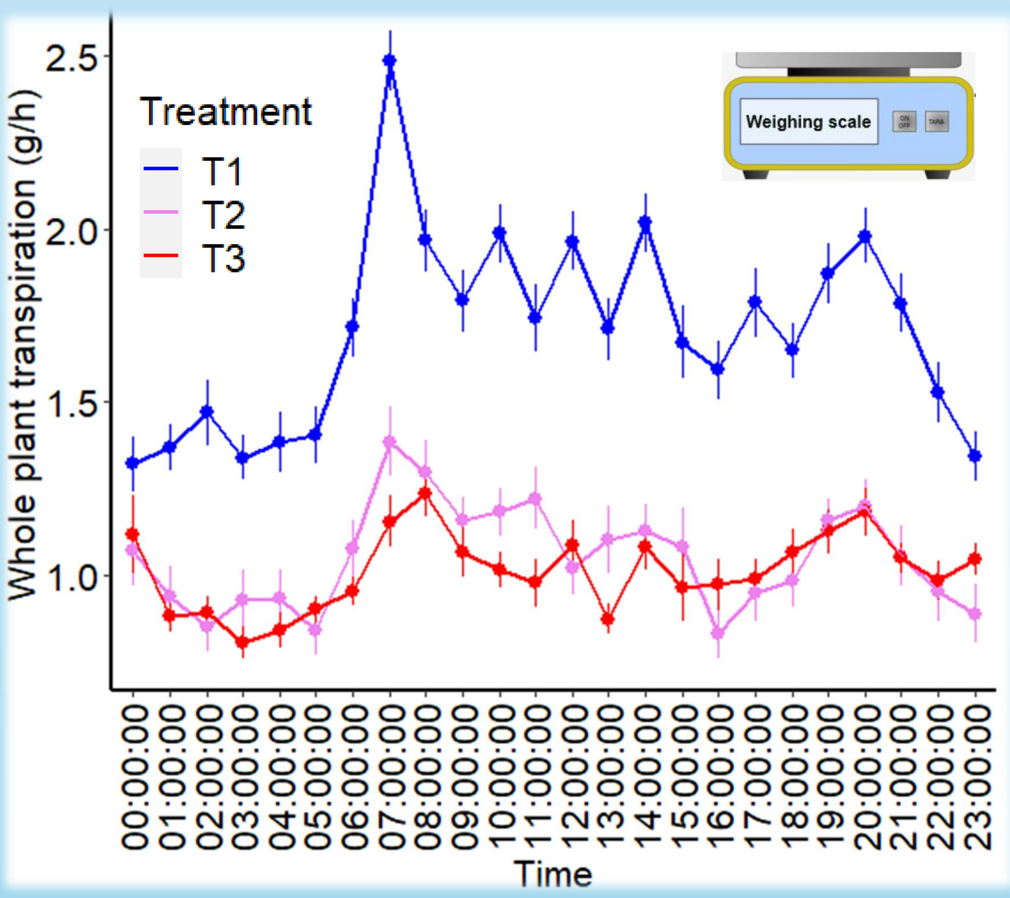
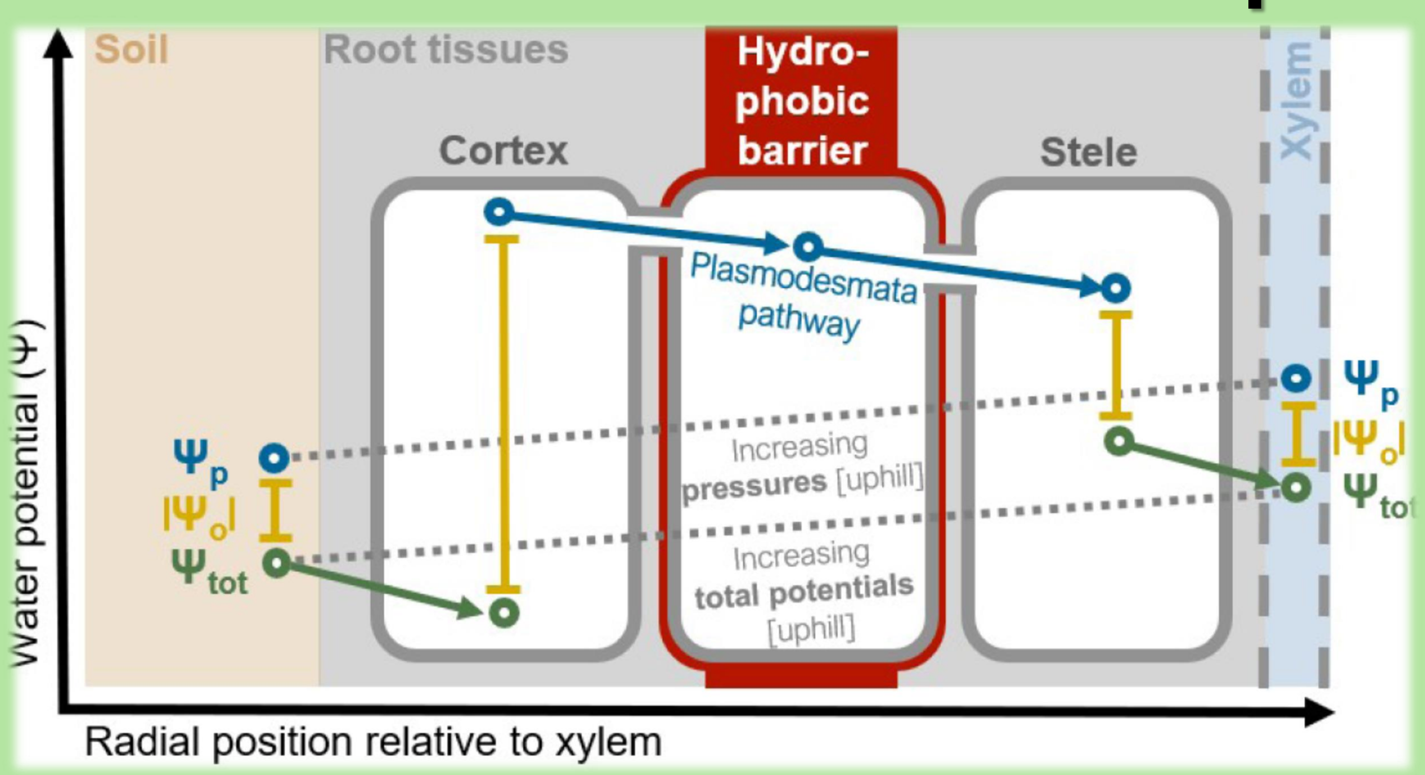
- In vascular plants, water flows along decreasing gradients of pressure (Ψ_p) or total water potential (Ψ_{tot}).
- It was occasionally observed that water flowed along increasing gradients of water potential across roots (Miller, 1985; Enns et al., 2000; Rowan et al., 2000; Bai et al., 2007).
- By combining micro-hydrology modeling with cell solutes mapping data, it was suggested that osmotic potential (Ψ_o) gradients across living cells may generate a complementary driving-force that is missing in the current paradigm of water flow across roots (Couvreur et al., 2021). This gradient may act as an active water pump.

Plant transpiration rate



T1, control; T2, mild drought; T3, severe drought

The Plant Water Pump



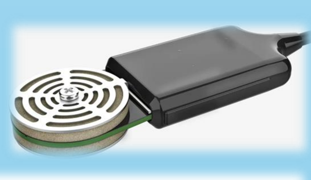
From the microscale, water flows across plasmodesmata “downhill” of **Ψ_p gradients**, so that more turgid cells with a more negative Ψ_o may pump water into xylem, “uphill” of macroscale Ψ_p & Ψ_{tot} gradients (xylem vs soil).

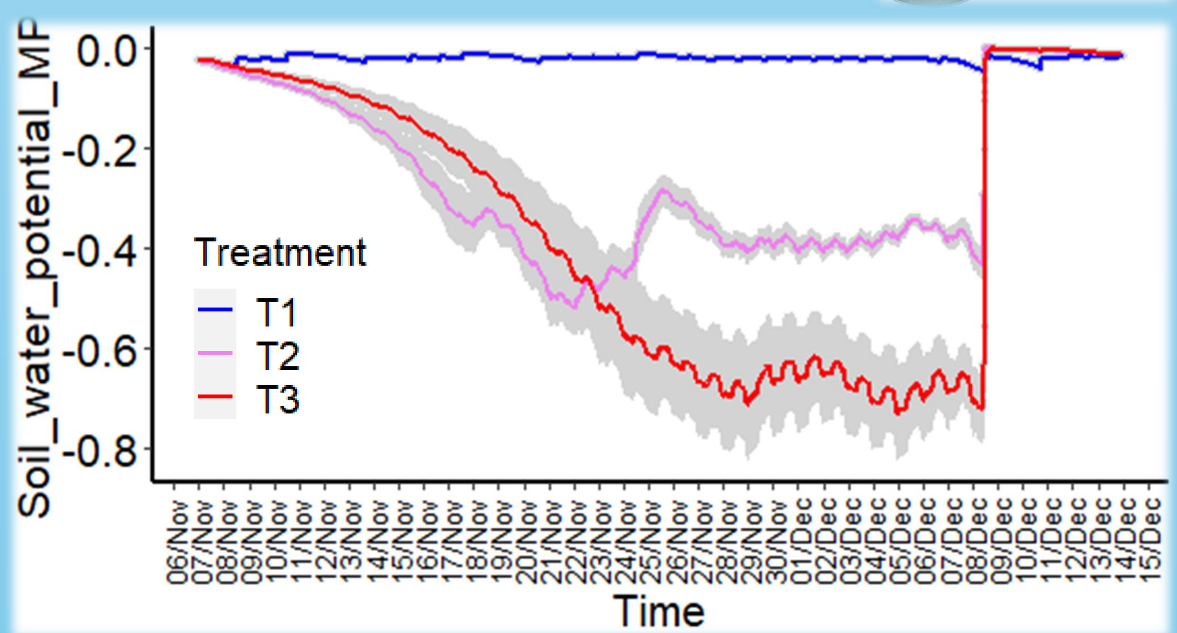
Soil

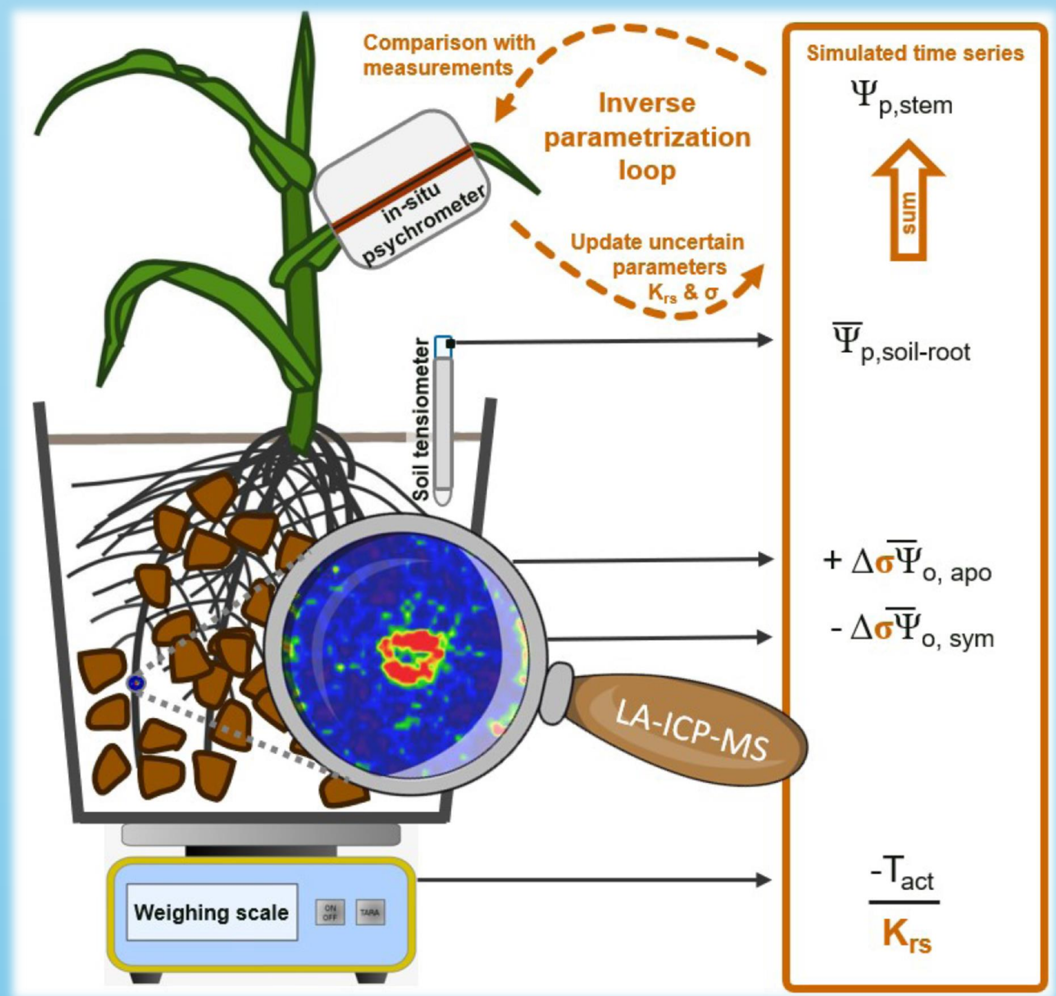
Xylem

Soil water potential Ψ_p

Measured continuously by TEROS 21



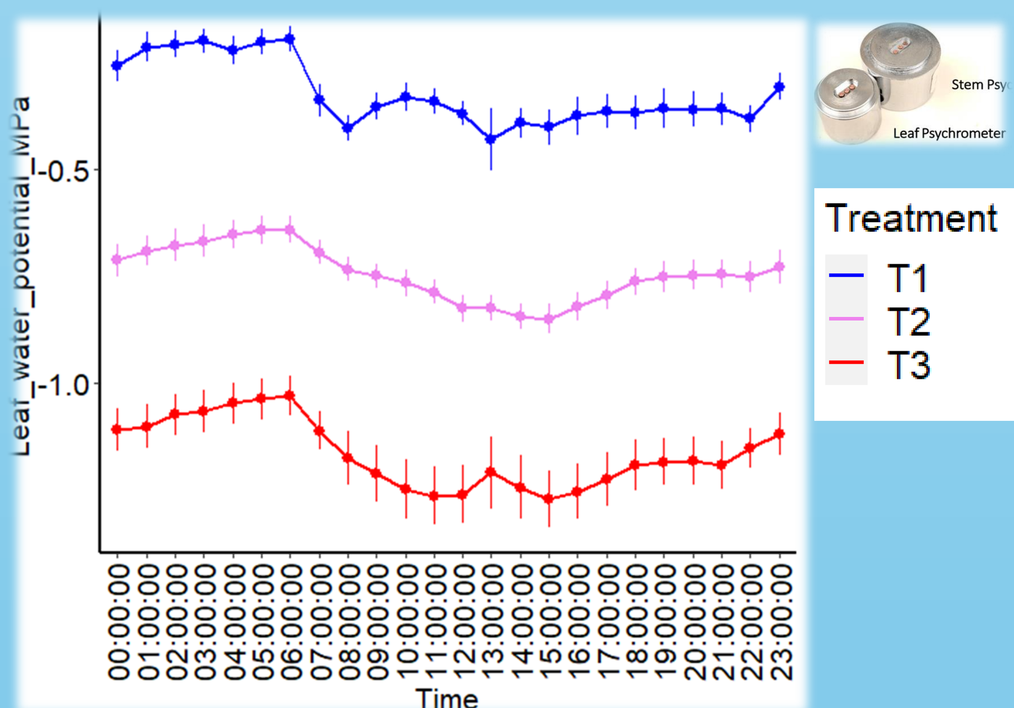




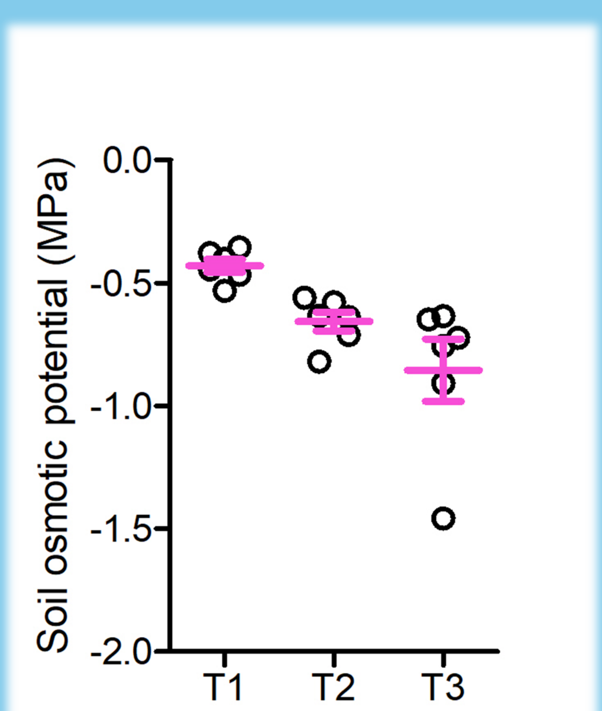
T_{act}, transpiration; K_{rs}, hydraulic conductance; σ, reflection coefficient; Ψ_o, osmotic potential; Ψ_p, pressure potential; LA-ICP-MS, Laser Ablation - inductively Coupled Plasma - Mass Spectroscopy

Leaf xylem water potential Ψ_{tot}

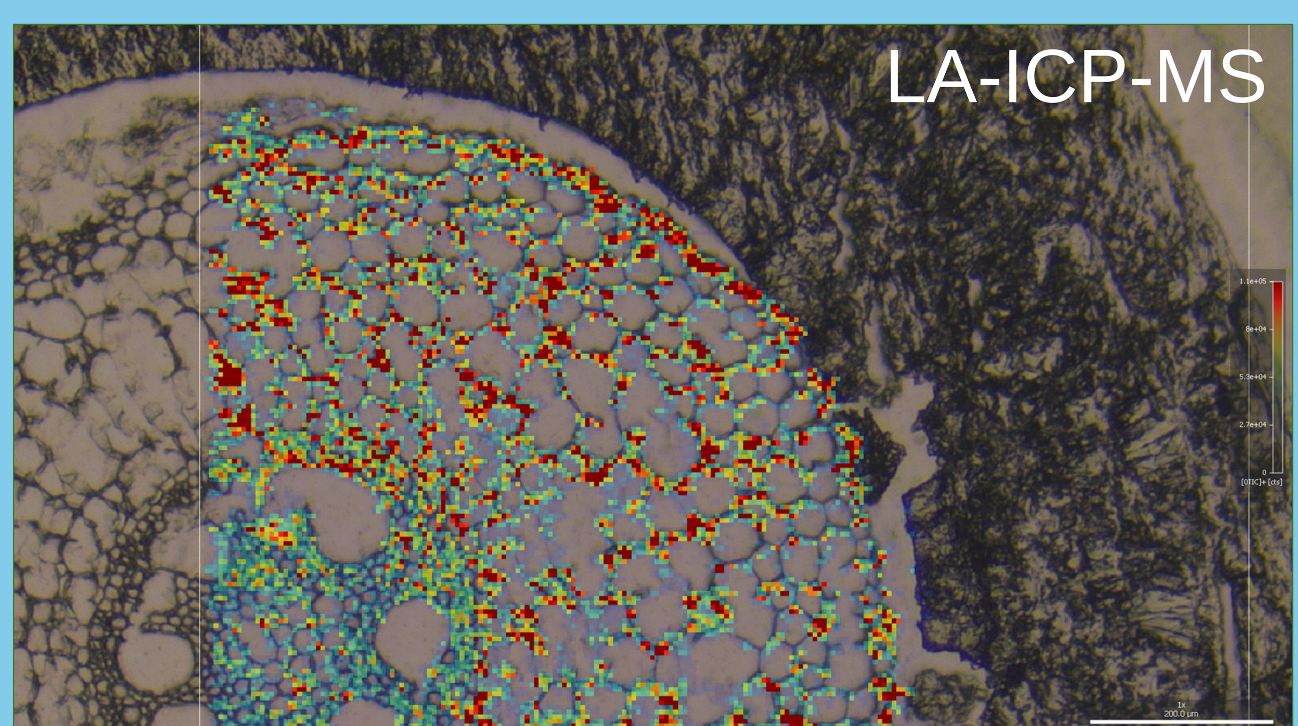
Measured continuously by in situ psychrometers

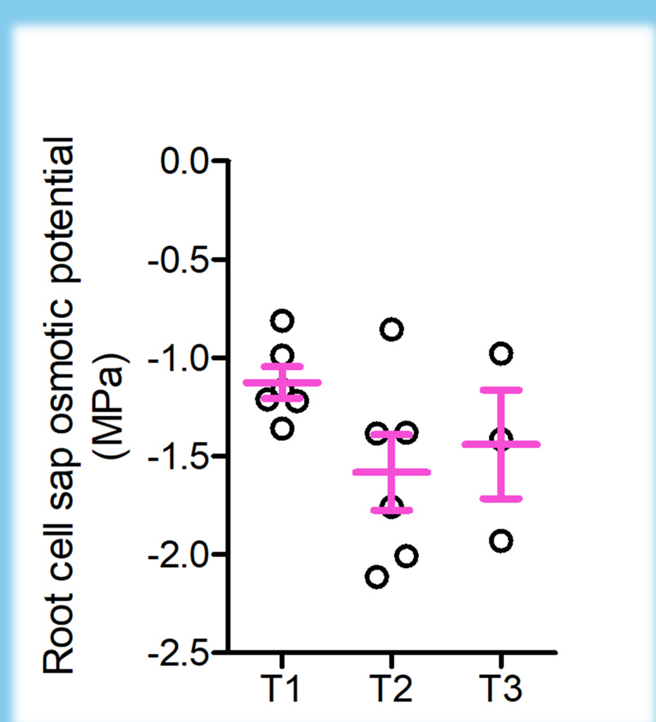


Ψ_o in soil

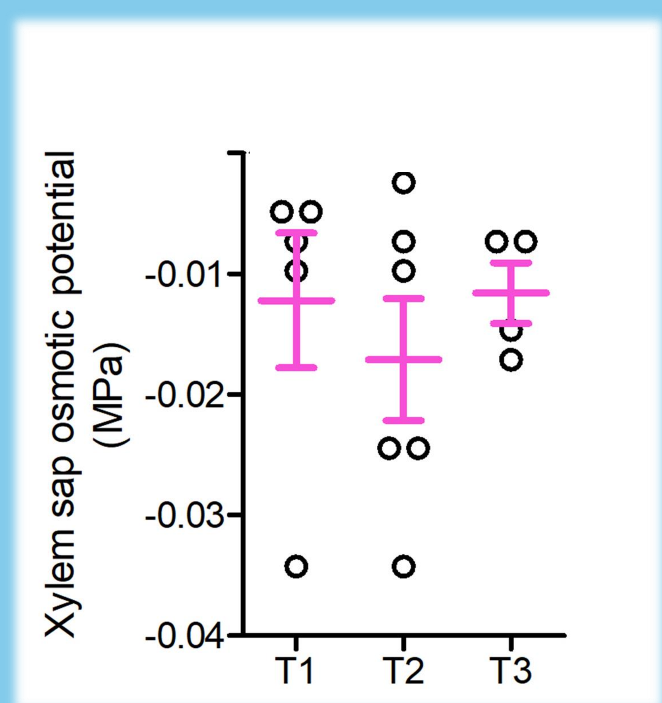


Ψ_o in roots





Ψ_o in xylem sap



Take messages

Under severe drought, (i) root bulk Ψ_o decreased rather than xylem Ψ_o; (ii) lower xylem Ψ_{tot} (-1.3 MPa) was not enough to explain what allows the inflow of water from the soil (Ψ_{tot} <-1.5 MPa)

Bai X-F, Zhu J-J, Zhang P, Wang Y-H, Yang L-Q, Zhang L (2007) Na+ and Water Uptake in Relation to the Radial Reflection Coefficient of Root in Arrowleaf Saltbush Under Salt Stress. Journal of Integrative Plant Biology 49: 1334-1340.

Couvreur V, Heymans A, Lobet G, Draye X (2021) Evidence for a multicellular symplasmic water pumping mechanism across vascular plant roots. bioRxiv: 2021.2004.2019.439789.

Enns LC, Canny MJ, McCully ME (2000) An investigation of the role of solutes in the xylem sap and in the xylem parenchyma as the source of root pressure. Protoplasma 211: 183-197.

Miller DM (1985) Studies of Root Function in Zea mays. III. Xylem Sap Composition at Maximum Root Pressure Provides Evidence of Active Transport into the Xylem and a Measurement of the Reflection Coefficient of the Root 77: 162-167.

Rowan A, McCully ME, Canny MJ (2000) The origin of the exudate from cut maize roots. Plant Physiology and Biochemistry 38: 957-967.