Physiological failures in *Zea mays* during water-stress: opportunities for improvement

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Objectives:

To identify central physiological responses limiting net assimilation and biomass production in maize under water stress by:

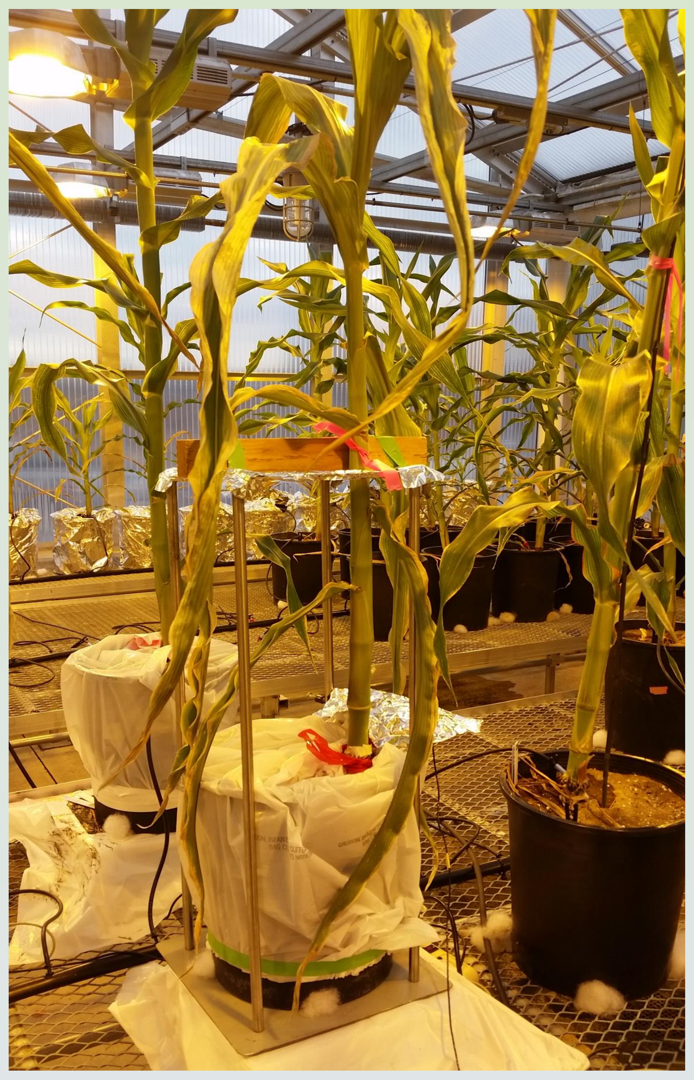
1) How much is whole-plant hydraulic conductance reduced (K_{plant})during dry down and [how] are these reductions aligned with increasing leaf water stress (ψ_{leaf})?
2) Do these reductions in K_{plant} manifest from increased resistance in the xylem (roots, stems, leaf) or elsewhere?
3) How well is photosynthetic functioning aligned with increasing water stress?
4) Are observed declines in xylem , stomatal, and photochemical functioning associated with meaningful reductions in net CO_2 assimilation (A_{net})?
5) How quickly does maize recover from severe water stress?

Discussion:

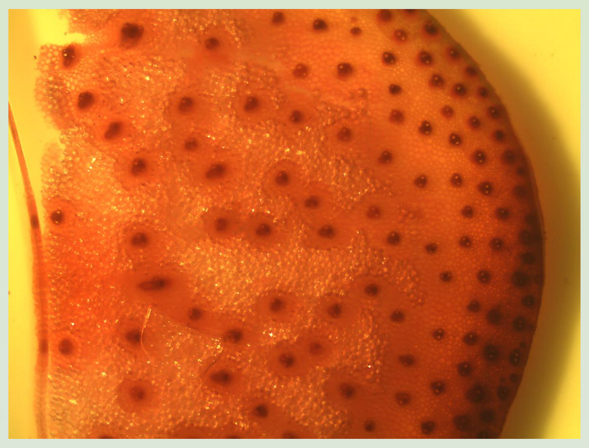
- Producing productive as well as drought resistant plants is a difficult task – linked physiological systems must all operate at low water potential.
- Research on the linkage of these physiological systems has been missing. We show here close coordination and proportional down-scaling among light harvesting, Calvin cycle reactions, and hydraulic functioning in response to water stress.
- The strategies to improve the species will depend on whether plants are subjected to continuous water stress (e.g., deficit irrigation) or short and severe dry spells.
- Careful consideration should given to the whole-plant perspective because improvements in one trait will likely result in failure of other “linked” system component rather than leading to improved growth.

The way forward:

- Maize functioning under continuous water-stress would benefit from reduced stomatal conductance and selection for increased photosynthetic capacity.
- Breeding strategies may benefit from genotypes:
    1) exhibiting robust xylem
    2) xylem functioning at water potentials down to -4.0MPa
- Success of future genotypes will likely be:
    1) trial-and-error
    2) developed to maintain stomatal conductance during moderate water stress



“B73” maize genotype under water-stress.



Cross section of maize stem in fully-watered treatment.

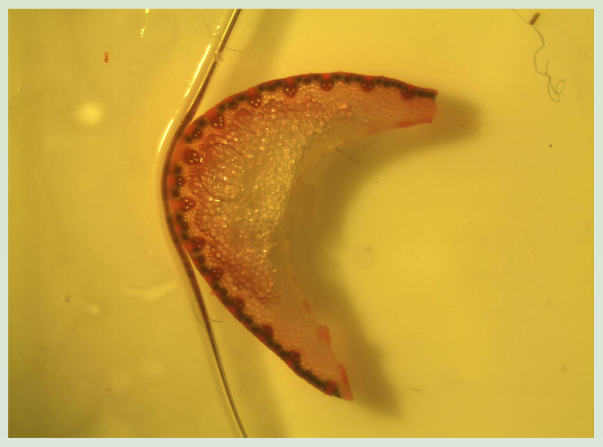
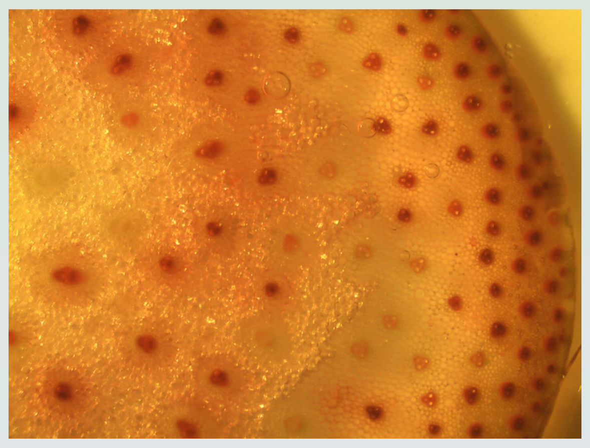
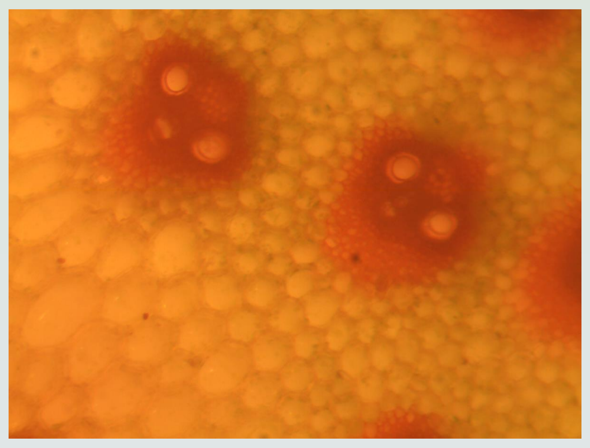


Image showing vascular bundles along maize leaf midrib.

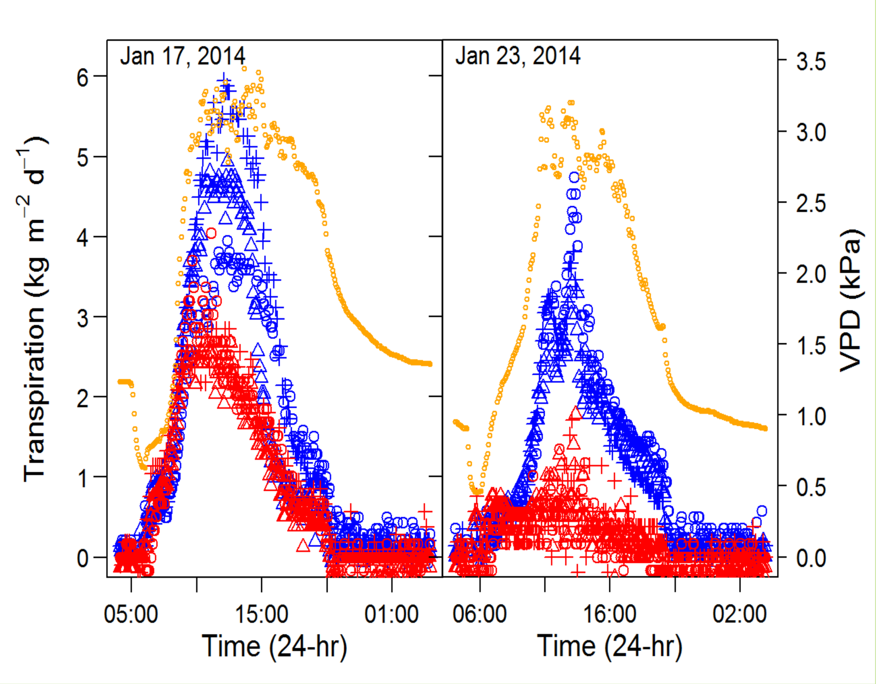


Cross section of maize stem in water-stressed treatment.

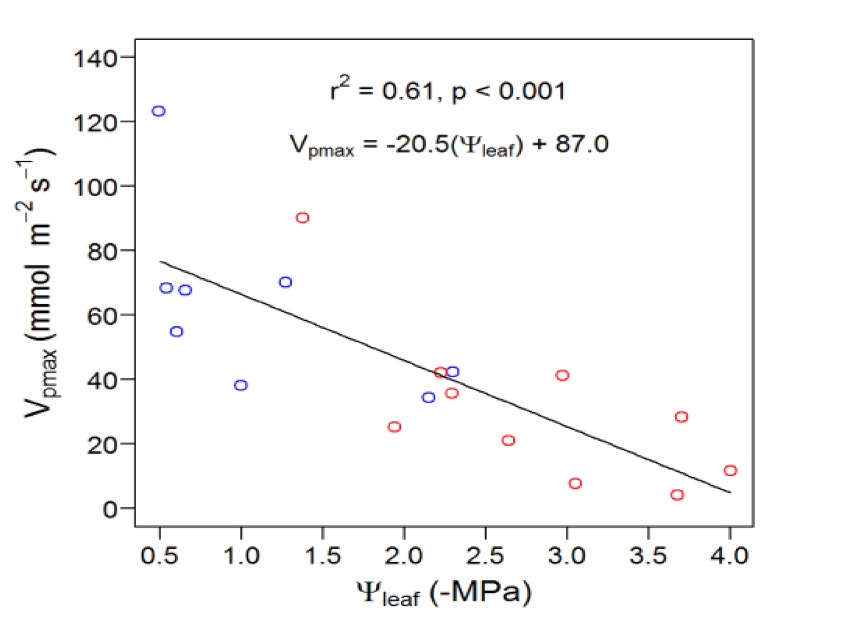


Magnified image showing fully functional vascular bundles.

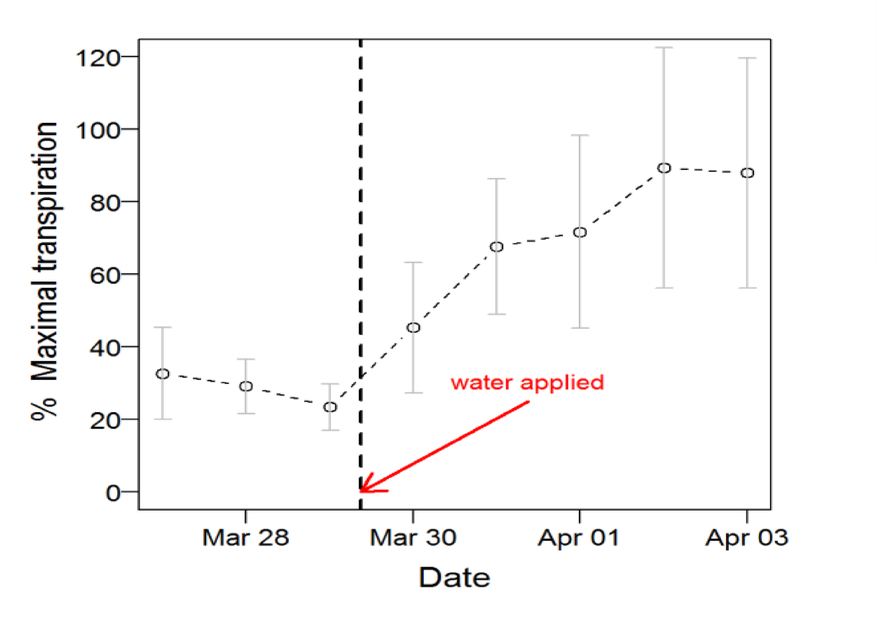
Results:



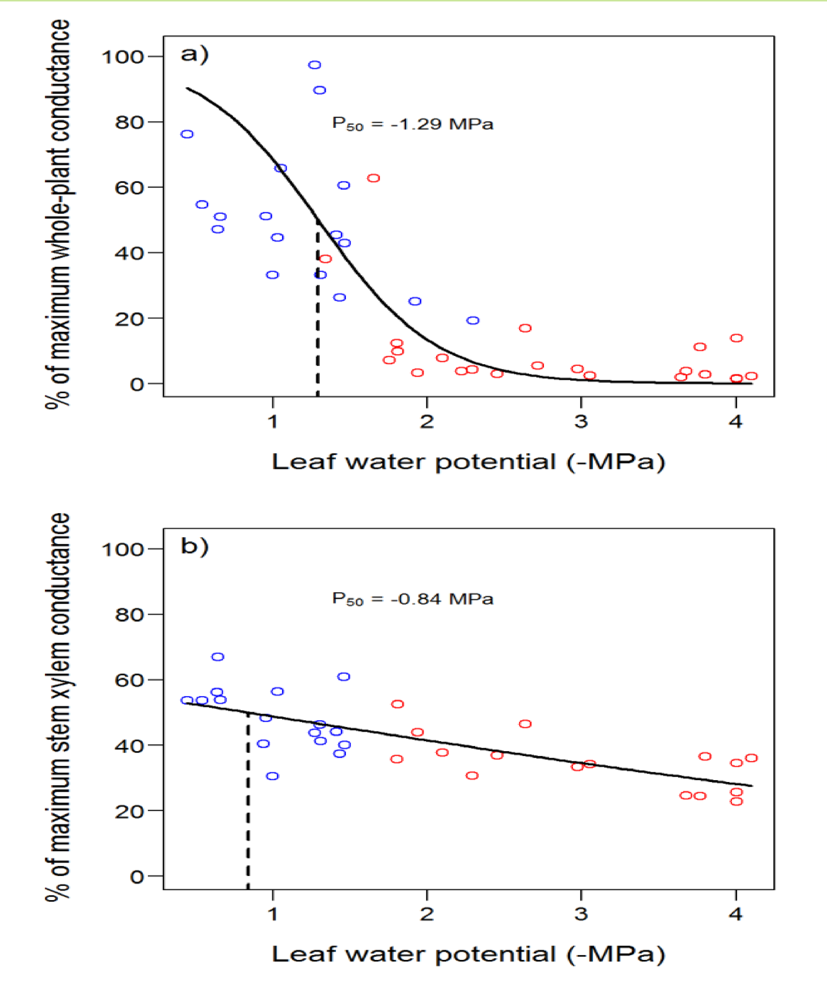
Diurnal responses of whole-plant transpiration (expressed per unit leaf area) at 12 days into the dry-down (January 17) and towards the end of dry-down (January 23). Red symbols denote three water-stressed plants. Blue symbols denote three fully-watered plants. Open orange circles denote the vapor pressure deficit of the air. Each red and blue symbol represent a single-plant measurement every 15 min.



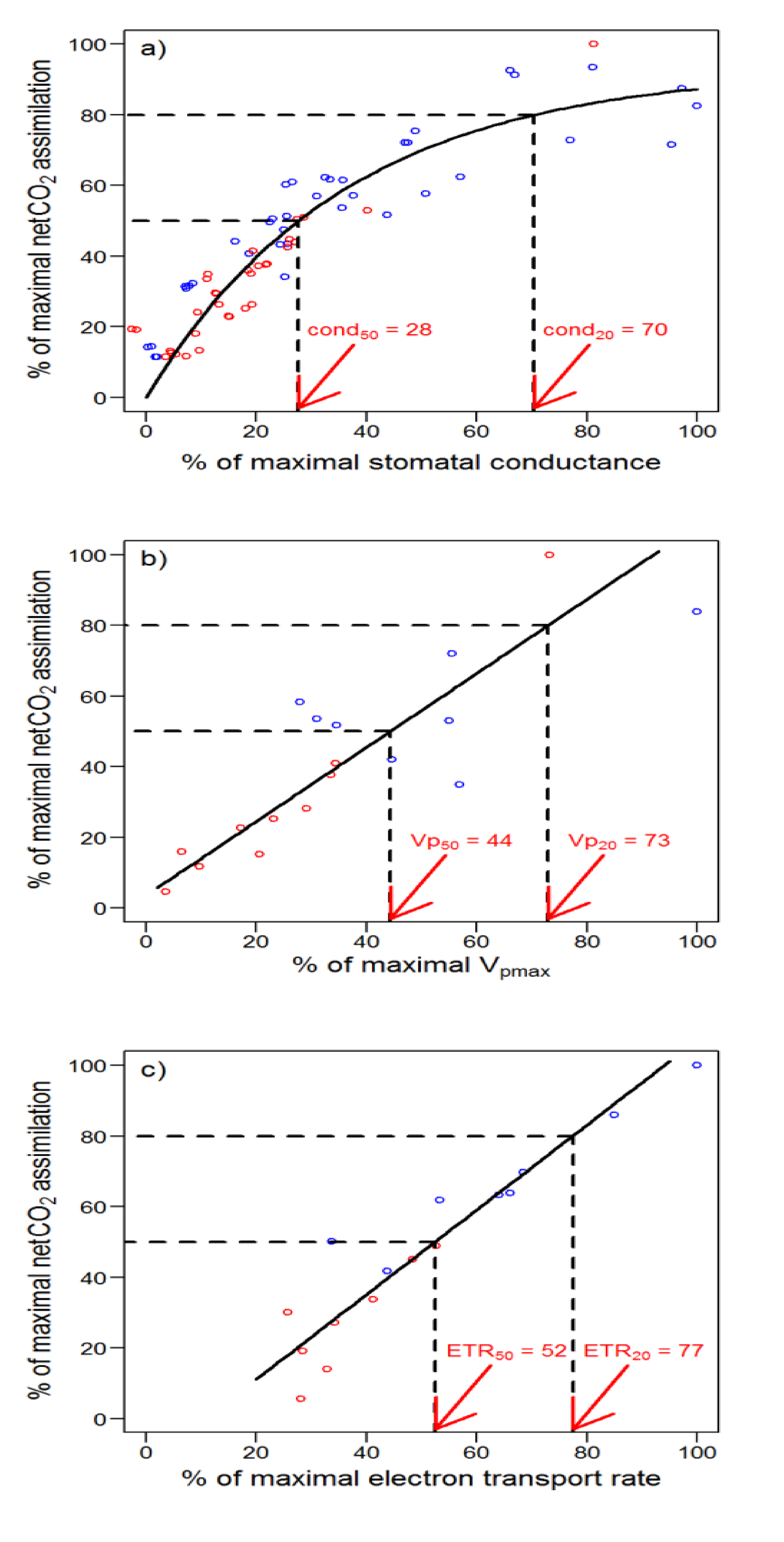
The maximal activity of PEPc (V_{pmax}) under increasing water stress (estimated by Ψ_{leaf}). Open red and blue circles denote individual plants in fully watered and water-stressed treatments, respectively. V_{pmax} activity was modeled from $A \sim C_m$ curves after von Caemmerer (2000).



Recovery trajectory of whole-plant transpiration from extreme water stress (Ψ_{leaf} values between -3.4 and -4.0 MPa). Broken line indicates when water-stressed plants were watered back up to 100% of field capacity. Maximal transpiration was calculated each day from well-watered plants not subjected to stress. Each open circle represents the mean response of three water-stressed plants. Error bars represent +/- 1SD.



Losses of whole-plant conductance (expressed per unit leaf area) (a) and stem xylem conductance (b) as a function of leaf water potential. Leaf water potentials at which 50% of conductance is lost are identified with a broken line.



Relationships between maximal net CO_2 assimilation and stomatal conductance (a), maximal PEPc activity (V_{pmax}) (b), and electron transport through photosystem II (c). Rates of electron transport (ETR) estimated from leaf chlorophyll fluorescence. Dashed lines indicate reductions in stomatal conductance, V_{pmax}, and ETR associated with 20 and 50% reductions in net CO_2 assimilation.

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