The genetic basis of plant water use efficiency

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To date, only slight improvements for crop WUE have been achieved. However, the evidence that natural genetic variation for WUE is more strongly correlated with decreased transpiration than increased assimilation implicates transpiration and, more generally, stomatal development and physiology, as potential targets for improving WUE. The optimization of stomatal conductance to maximize carbon assimilation and minimize water loss has been discussed for some time, but the underlying mechanisms that control these mechanisms are poorly understood. We have identified several processes that allow for reduced water loss without a concomitant loss in carbon assimilation and therefore, biomass accumulation and/or yield. Recently, AtGTL1, one of the AtGT-2 family transcription factors that encodes a putative Ca2+/CaM binding transcriptional activator, was identified as a negative regulator of stomatal development. gtl1 T-DNA insertional mutations (gtl1-1, gtl1-2 and gtl1-3) substantially enhance the capacity of plants to survive in response to severe water deficit stress by which maintain leaf relative water content during dehydration through reduced transpiration. Furthermore, gtl1 mutations increase WUE, indicating that AtGTL1 is a transcriptional regulator of drought adaptation and WUE. The resulting phenotype is an approximately 20% reduction in water loss without any loss in carbon assimilation or biomass accumulation. In many cases, greatly reduced stomatal conductance during the day results in a yield penalty because CO2 assimilation is reduced. In most plants studied to date, nighttime water loss can be as much as 5 – 30% of diurnal water loss. Selecting for genotypes or engineering crops that lose less water at night should be an effective means to increase overall WUE. However, it is still not clear if there is a physiological or ecological role of nighttime water loss. We are using several model species to try to understand the genetic variability and potential roles stomatal traits in WUE: Arabidopsis thaliana, Thellungiella halophila (a stress tolerant relative of Arabidopsis), and several species of poplar (a woody species). The potential for manipulation of stomatal traits (and consequently WUE) through crop breeding and management will be discussed.