TreeD


Transpiration efficiency using 3D canopy structure

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Context — The EU seeks to achieve the target of 20% of its primary energy needs provided by renewable sources of energy. The on-going climate change is predicted to result in a higher frequency of dry and warm summers even for temperate regions, increasing thereby the risk of water supply shortage for tree plantations as well as natural populations, with an increased risk of wood production reduction. Therefore, the optimization of water use for the production of biomass is an important research aim in poplars variety improvement. Appropriate answers to these climatic risks might be found in the selection of genotypes able either to find larger amounts of water from the soil, or to use the transpired water more efficiently, i.e. increasing the biomass production per unit of transpired water. Whole plant water use efficiency (WUE), called here transpiration efficiency (TE) is generally estimated by lysimetric methods to determine daily water loss and biomass allometrics or destructive harvesting for biomass accumulation. For long term studies on planted trees it is necessary to use models, as well for water use as for biomass accumulation. The MAESTRA model could be used to predict whole tree transpiration.

Objectives — The principal objective of the project is to determine the transpiration efficiency at different scales: at leaf level and at the tree scale using measurements and a modelling approach that will be parametrized at the leaf level.

Approach — Two poplar genotypes (*Populus deltoides* × *P. nigra,* Carpaccio and I214) have been selected according to their tolerance to drought. The two chosen poplar genotypes were planted in 2014 in the nursery at INRA Champenoux. Half of the trees have been subjected to a reduced water input by a partial rain exclusion set-up, whereas the other half have been irrigated when necessary. We performed gas exchange measurements for stomatal dynamics, ^{13}C analyses (proxy of WUE). We measured every week growth of all trees (monitoring height and diameter). We measured the transpiration at the whole plant level with sap flow sensors and the above ground biomass on one half of the trees after cutting them. We performed 3D processing on 48 poplars for tree morphology and the position and the angle of individual leaves. The volume of each slice was computed making it possible to assess the vertical distribution of the crown volume, and, cumulatively, the total crown volume.

Key results —

- Stomatal dynamics were linked with whole-plant transpiration

- Despite a reduction of soil water content and whole-plant transpiration, growth was stimulated in the rainfall exclusion plot, likely as a result of an increased nitrogen assimilation. Genotype ranking remained fairly constant for transpiration, carbon isotopic discrimination (Δ) and TE.
- WUE measured as Δ or TE was not associated with lower biomass production. Relatively good agreement was found between Δ and TE in the field.
- Parametrization of model Maestra is on-going.

Main conclusions including key points of *discussion* — Our results were compared with a similar experiment in glasshouses with the same genotype. These results suggest that Δ may be a good proxy for TE, and could be used, both as a breeding target for genotype selection in glasshouses without impacting biomass production when planted in the field. However, reduced water availability modified the genotype ranking, suggesting a diversity of poplar response to drought that should be considered in breeding strategies.

Future perspectives — Our results were compared with a similar experiment in glasshouses with the same genotype. Even though the environmental conditions and age of the poplars in the glasshouse and the field experiment were largely different, the absolute values of transpiration efficiency were similar, and the genotype ranking was fairly maintained. There was good agreement between TE and Δ in the field, suggesting that leaf processes are the main drivers of whole-plant TE. Thus, measurements of Δ could be used to estimate WUE instead of the more laborious measurement of TE. Moreover, while TE was driven by water used in the glasshouse experiment and biomass production in the field, both results suggest that genotypes could be selected for both higher biomass production and lower water use. More research is needed, for example in other poplar genotypes, to investigate the effect of the environment during growth on WUE in poplars so that a consensus can be reached. Other factors may play a major role. For example differences of stomatal dynamics along the day has been found to impact whole-plant transpiration in poplar genotypes, partly linked to variation in stomatal density and sizes (Durand et al., 2019). Under field and glasshouse conditions, stomatal density, size and speed and their relation to transpiration and WUE may be different. The higher wind speed in the field than in the glasshouse may lead to widely different boundary layer conductance of the leaf, changing the relation between variations of environmental conditions and leaf transpiration. This highlights the need for future studies to investigate the drivers behind these contrasting patterns so that the opportunity to breed plants for improved water use does not remain beyond our reach forever.

Valorisation —

DURAND M, BRENDEL O, BURE C, COURTOIS P, LILY JB, GRANIER A, LE THIEC D. 2020. Impacts of a partial rainfall exclusion in the field on growth and transpiration: consequences for leaf-level and whole-plant water-use efficiency compared to controlled conditions. *Agricultural and Forest Meteorology* in press

DURAND M, BRENDEL O, BURE C, LE THIEC D.. Distinct stomatal dynamics induced by changes in irradiance and vapour-pressure deficit under drought between glasshouse and field-grown poplars. *New Phytologist* submitted

DURAND M, BRENDEL O, BURE C, LE THIEC D. 2018. Contrasting dynamics of water use efficiency under drought on four poplar genotypes: leaf level causes and whole plant consequences”. Seventh International poplar Symposium, New bioeconomies: exploring the potential role of Salicaceae. October 28 - November 4, Buenos Aires, Argentina. Présentation orale.