Genetic analysis of the morphological and ecophysiological responses to water deficit in an apple tree core-collection through a combination of high-throughput and physiological approaches

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Context and objectives

In the face of increasing water scarcity, adapting breeding programs to target crops for more efficient water use is crucial. This requires a comprehensive knowledge of the plant physiological responses to drought, including the regulation of water status in plant tissues (by stomatal closure) and the determinants of water-use efficiency (the ratio of carbon gain to water use). These challenging questions have been scarcely studied in perennial crops such as apple tree, yet of major economic importance.

Here, we aim at screening the European diversity of apple trees responses to drought to decipher their genetic and physiological bases.

Methods and first results

1. We imposed two watering scenarios to the core-collections by irrigation withholding.

   The soil water status was monitored on 12 trees (6 for each scenario) equipped with tensiometers and capacitive sensors. The water deficit was gradually established during the month of July, and \( \Psi_{\text{sat}} \) reach up to \(-120\) kPa at the end of this period (Fig 1).

2. In both sites, we characterized a subset of 10 varieties for their responses all along the season.

   Leaf water potential at predawn (\( \Psi_{\text{p}} \)), stem and leaf water potential at midday (\( \Psi_{\text{m,stem}} \) and \( \Psi_{\text{m,leaf}} \)), stomatal conductance (\( g_s \)) and net photosynthesis (\( A_n \)) were measured at 4 dates (Fig 1). Marked contrasts were observed among the subset for their behaviours in WW and WS conditions.

3. We used high-throughput tools to measure the whole core-collection: airborne imaging (thermal, Fig 2; and multispectral), fluorimetry (\( F_{\text{PL}} \), Fig 3), terrestrial scanner LIDAR (Fig 4), and we assessed the robustness of correlations with the corresponding, fine in planta variables measured on the 10 varieties (respectively \( g_s \), Fig 2; \( A_n \), Fig 3; and an example for leaf area in Fig 4).

A wide range of variability was found for all traits, with a highly significant effect of the genotype. Mixed-models including watering scenario and spatial effects were used to calculate BLUPs. \( H^2 \) were medium to high (0.40 < \( H^2 \) < 0.85).

4. GWAS was undertaken on the high-throughput variables, with 275K SNPs issuing from a 400K array (LMM with per-chromosome Kinship (Rincent et al., 2014)) QTLs were detected for all traits (as exemplified for estimated leaf area in Fig 5). The analysis of QTLs colocations together with correlations between BLUPs is being performed to decipher the common bases to the responses to water deficit.

References

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