From field phenotyping to GWAS: a multi-scale, multi-environment study to decipher the physiological and genetic determinants of apple tree responses to drought

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From field phenotyping to GWAS: a multi-scale, multi-environment study to decipher the physiological and genetic determinants of apple tree responses to drought.

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To cope with increasing water scarcity, breeding programs targeting for more efficient crop water use are crucial. This requires comprehensive knowledge of plant responses to drought, including the regulation of water status (by stomatal closure) and water-use efficiency (the ratio of carbon gain to water use). These questions have been scarcely studied in fruit trees, yet are of major economic importance. A main limitation results from the lack of high throughput techniques to characterize the physiological responses of hundreds of trees in the field as required to perform genetic analyses. We screened the diversity of European apple tree responses to drought, by unique combination of high throughput and in planta measurements applied on two core-collections in Montpellier (France) and Bologna (Italy), respectively. A progressive soil water deficit was ensured and continuously monitored in both orchards, through summer irrigation withholding. In the whole collections (>250 varieties), a semi-empirical index (IPL index), computed from chlorophyll fluorescence measurements, was used as an indicator of leaf photosynthesis, whereas the variability of stomatal regulation and canopy structure was characterized by airborne imagery. The validity of high-throughput indices was assessed through fine measurements of water potential, stomatal conductance and photosynthesis on 6 varieties common to both collections. A large variability of IPL index was observed, with highly significant effects of the genotype and watering scenario (well-watered vs water stress). A genome wide association study (GWAS) was undertaken to identify the genomic regions controlling the variations detected. In parallel, the effect of interaction between Genotype and Environment (GxE) was dissected to highlight contrasted strategies of water use under drought across the varieties studied.

Keywords:
Malus × domestica, core-collection, water deficit, photosynthesis, fluorimetry, water-use efficiency, GWAS