Drought tolerance: which mechanisms, traits and alleles for which drought scenarios?

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Plants are subjected every day to rapid variation of evaporative demand and soil water availability, resulting in rapid changes in stomatal conductance, expansive growth and metabolism over minutes. Because yield involves several months, the connection between physiological mechanisms and response of yield to drought scenarios faces a massive problem of time scales. Furthermore, yield results from optimization between traits and alleles that lead to either minimize the risk of crop failure or to increase crop production. Evolution has tended to favour conservative processes (short crop cycle, low transpiration and leaf area, large root systems) which are favourable under severe stresses, whereas yield in milder water deficits is associated with the opposite traits. Hence, one aims at identifying which traits and alleles are favourable in which drought scenarios, rather than at a generic 'drought tolerance'. We deal with these methodological difficulties by combining phenomics, modelling, genetic analysis and genomic prediction. A first strategy explores the genetic variability of key processes, which are translated into parameters of a crop model. This requires detailed analyses in phenotyping platforms with a capacity of thousands of plants, with the relevant time scales. These parameters are analysed by GWAS and simulated via genomic prediction. The model can then simulate yield in hundreds of fields for hundreds of genotypes, from genetic parameters of each genotype and environmental conditions in each field. A second strategy directly explores the responses of yield to environmental conditions in contrasting environmental scenarios, e.g. in 40 fields. This results in a mixed model whose parameters are analysed genetically and can be estimated by genomic prediction, thereby allowing one to predict yields in new genotypes and fields. As a whole, the combination of field and platform data allows identification of combination of traits and alleles associated with tolerance in specific scenarios of heat and drought.

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