

Predicting plant phenotypes in the context of global change

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In plant breeding, the primary goal is to develop new crop varieties that meet the diverse needs of farmers, processors, and consumers. This endeavour is critical in an era of global change, where agriculture must adapt to reduced inputs and a changing climate. The varieties identified must, for example, be highly adapted or resilient to the specific environmental conditions in which they will be cultivated.

Crop varieties comprise thousands of interacting genes, and their growth and development are influenced by hundreds of environmental factors. As a result, developing a new variety can be a highly complex task. Predictive approaches—integrating knowledge of a variety’s DNA and environmental factors—are essential tools for navigating this complexity. These methods enable breeders to forecast how a given variety will perform in a new environment, even if the variety has never been observed in the field. This capability considerably enhances the speed and screening capacity of plant breeders.

However, the predictive ability of these models remains limited, primarily due to their inability to fully capture the underlying biological processes. In our study (Ali et al. 2025), we introduced novel methods for modelling gene interactions and regulatory mechanisms using gene expression and protein abundance data. By integrating variabilities at the DNA, gene and protein levels, we achieved a 50% improvement in predictive ability compared to the reference model under certain conditions.

Using state-of-the-art statistical models, we also demonstrated that integrating these datasets allowed us to identify far more genetic regions than conventional approaches. Notably, we revealed the substantial contribution of regulatory regions to phenotypic traits and showed that these regions are far more predictive than other regions of the genome.

This work paves the way for the practical application of systems genetics in plant breeding, leading to more accurate predictions and a deeper understanding of the complex biological processes that shape traits of interest. These findings hold significant importance for both fundamental, and applied research in particular in the field of plant breeding in the context of global change. They also have practical implications for guiding varietal recommendations to farmers, taking into account local pedoclimatic conditions.

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