A review on model-based development of drought-tolerant cereal ideotypes

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Climate models are predicting a spiraling trend in global mean temperatures and altered precipitation patterns. Consequently, production levels of staple foods are alarmingly dropping due to increased climate variations and recurring weather extremes such as heatwaves and drought spells.

To increase climate resilience of cereal production, it is crucial to understand the most affected processes in crop production and develop respective adaptation strategies. Crop modeling is a tool that allows investigating the genotype * environment * management interactions by simulating the plant-soil-atmosphere system. Crop models can simulate crop growth under future climatic conditions by performing *in silico* experiments. Climate change adaptation options can be investigated, including the design of novel genotypes better adapted to future climate, i.e., crop ideotypes.

An ideotype is a model plant defined on a set of crop and cultivar-specific parameters that control crop development and growth in different environments. These parameters describe morphological, physiological, and phenological traits; for an ideotype, they are combined to optimize crop performance in a particular biophysical environment and crop management situation for a specific end-use. Phenotyping and genotyping results constitute the base providing guidance to identify and optimize parameters of desirable ideotypes.

Phenotypic data is a result of screenings for physiological, morphological, and phenological traits contributing to drought tolerance and recovery. These results are used as an input to design a model build ideotype. Phenotypic experiments provide a base to define growth and yield parameters of ideotypes and plausible/optimal range of values.

Breeders use genomics to define the genetic composition, point out meaningful mutations, describe their functions in the expression of qualitative and quantitative traits, and clarify the links and interactions between target genotypes (G*G) and interactions between genotypes * environment. Genotyping creates a roadmap for future phenotyping and ideotyping.

To create genotypes adapted to future climates, we need to place emphasis on the variations caused by the interactions between genotypes and environments. The accurate representation of the target environments is crucial to have reliable results. That is reached by collaborations of breeders, agricultural engineers, and crop modelers, combining phenotyping, genotyping, and crop modeling tools.

In the present study, we highlight and discuss the basic operations required for designing and developing drought-tolerant cereals. We review recent scientific advancements and related challenges. We further explore the required linkages between these three operations and how they can be utilized to shape the crops of the future.