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IMPROVING YIELD FOR SUBOPTIMAL CONDITIONS: MAKING USE OF ALLELES FOR ADAPTIVE TRAITS

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Yield results from the integration of processes over months, whereas the physiological mechanisms involved in drought or heat responses operate over minutes to hours, following the diurnal fluctuations of environmental conditions. The resilience of leaves and reproductive organs to rapidly fluctuating environmental conditions ('stress tolerance') therefore relies on traits that differ from those maximizing yield. Indeed, trade-offs are most often observed between carbon accumulation and physiological mechanisms that minimize the risk of deleterious plant water status. A given physiological adaptive trait may therefore have negative or positive consequences on yield in favorable vs unfavorable environmental conditions.

An analysis of the genetic progress over the last 60 years revealed that maize breeders successfully selected for high yield across environments, including dry or hot environments (about +100 kg ha^{-1} year^{-1} in all tested environmental scenarios). In doing so, breeders essentially selected for constitutive traits for which the genetic progress was similar in favorable and unfavorable conditions, such as plant architecture, number of reproductive organs and duration of phenological phases. In contrast, physiological traits involved in drought acclimation (e.g. growth sensitivity, water use efficiency or stomatal conductance) showed no trend with genetic progress. The allelic diversity that governs them was left largely unexploited because they can have positive or negative effects on yield depending on environmental scenarios.

In order to facilitate the use of alleles for physiological adaptive processes in breeding programs, we proposed a probabilistic approach where the benefits and risks of alleles combinations are estimated for the most likely environmental scenarios in each region, under current or future

climates. The responses of yield or traits to temperature, water deficit and light were established by combining phenomics and modelling, and the sensitivity of these responses were predicted based on genotypic information. Yield was then predicted based on a model. This allowed yield prediction of 100s of genotypes in 10s of environments, including new genotypes and new fields. This strategy may allow exploiting new alleles for yield in future climates by explicitly taking into account those alleles that optimize physiological adaptive processes.