Using plant phenotypic plasticity to improve crop performance and stability regarding climatic uncertainty: a computational study on sunflower

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Using plant phenotypic plasticity to improve crop performance and stability regarding climatic uncertainty: a computational study on sunflower.

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Abstract

A crop can be represented as a biotechnical system in which components are either chosen (cultivar, management) or given (soil, climate) and whose combination generates highly variable stress patterns and yield responses.
In this study, we used modeling and simulation to predict the crop phenotypic plasticity resulting from the interaction of plant traits, climatic variability and management actions [1].
We relied on numerical experiment to explore how virtual plant material, designed by recombining 8 plant traits within bounds observed in cultivated genetic diversity, performed in a large target population of cropping environments. We used optimization methods to search for trait combinations that matched desired crop specifications, in this case increasing the crop yield expectation and avoiding low yield (third quantile).
Results showed a trade-off between crop performance and stability, with different optimal trait combinations among the best solutions. There was little variability in the value of three plant traits (late maturity, low leaf area distribution, conservative stomatal conductance regulation) among the optimal solutions, indicating that these traits had a major value in the tested population of environments. On the other hand, the five other traits displayed variability in optimal values, which was identified as the basis of the performance/stability trade-off. Four plant types, corresponding to different strategies of resource use were identified in the optimal solutions. These plant types ranged from a conservative resource management strategy (early flowering, low light extinction coefficient) to a more productive one. Results suggested that key traits were responsible the cultivar global adaptation capacity whereas secondary traits allowed distinctive resource use strategies that were more adapted to specific conditions.
We argue that process-based modeling and simulation could be integrated in trait-based breeding approaches as a way to screen plant phenotypic plasticity in large population of environments before proceeding to phenotyping approach in field conditions.

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