Optimized cultivar deployment improves the efficiency and stability of sunflower crop production at national scale

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Casadebaig Pierre[1] (pierre.casadebaig@inra.fr), Gauffreteau Arnaud[2], Langlade Nicolas[3], Mestries Emmanuelle[4], Sarron Julien[5], Trépos Ronan[6], Debaeke Philippe[1]

[1] *UMR AGIR, INRA, Castanet-Tolosan, France*; [2] *UMR Agronomie, INRA, Thiverval-Grignon, France*; [3] *UMR LIPM, INRA, Castanet-Tolosan, France*; [4] *Terres Inovia, Castanet-Tolosan, France*; [5] *UMR HortSys, CIRAD, Montpellier, France*; [6] *UR MIAT, INRA, Castanet-Tolosan, France*

Plant breeding programs design new crop varieties which, while adapted to distinct population of environments, are nevertheless grown over large areas during their commercial life.
Over this global farming area, the crop is exposed to highly diverse stress patterns caused by climatic uncertainty and various management options, that can often lead to decreased crop performance regarding to the expected level (yield gap).
Phenotypic plasticity is defined as the range of phenotypes a single genotype can express as a function of its environment (Nicotra et al., 2010). At the population level, this process underlies the relative variation in performance of varieties across environments. It is commonly referred as genotype x environment interactions in plant breeding and agronomy and can explain up to 20% of total yield variance observed in multi-environment trials.

In this study, our aim is to assess how a finer spatial management of genetic resources could reduce the genotype-phenotype mismatch in farming environments and ultimately improve the efficiency and stability of crop production. We used modeling and simulation to predict the crop performance resulting from the interaction between cultivar growth and development, climate and soil conditions, and management actions (Casadebaig et al., 2016). We designed a computational experiment that evaluated the performance of a collection of commercial sunflower cultivars in a realistic population of farming environments in France, built from agricultural surveys (Sarron et al., 2017). Distinct farming locations that shared similar simulated abiotic stress patterns were clustered together (Chenu et al., 2013) to specify environment types (figure 1). Optimization methods were then used to search for cultivars x environments combinations that lead to increased yield expectations.

Results showed that a single cultivar choice adapted to the most frequent cropping environments is a robust strategy. However, the relevance of cultivar recommendations to specific locations was gradually increasing with the knowledge of pedo-climatic conditions. At the national scale, tuning the choice of cultivar impacted crop performance the same magnitude as the effect of yearly genetic progress made by breeding.

We argue that this approach, while being operational on current genetic material could act synergistically with plant breeding as more diverse material could allow access to cultivars with distinctive traits that are more adapted to specific conditions.

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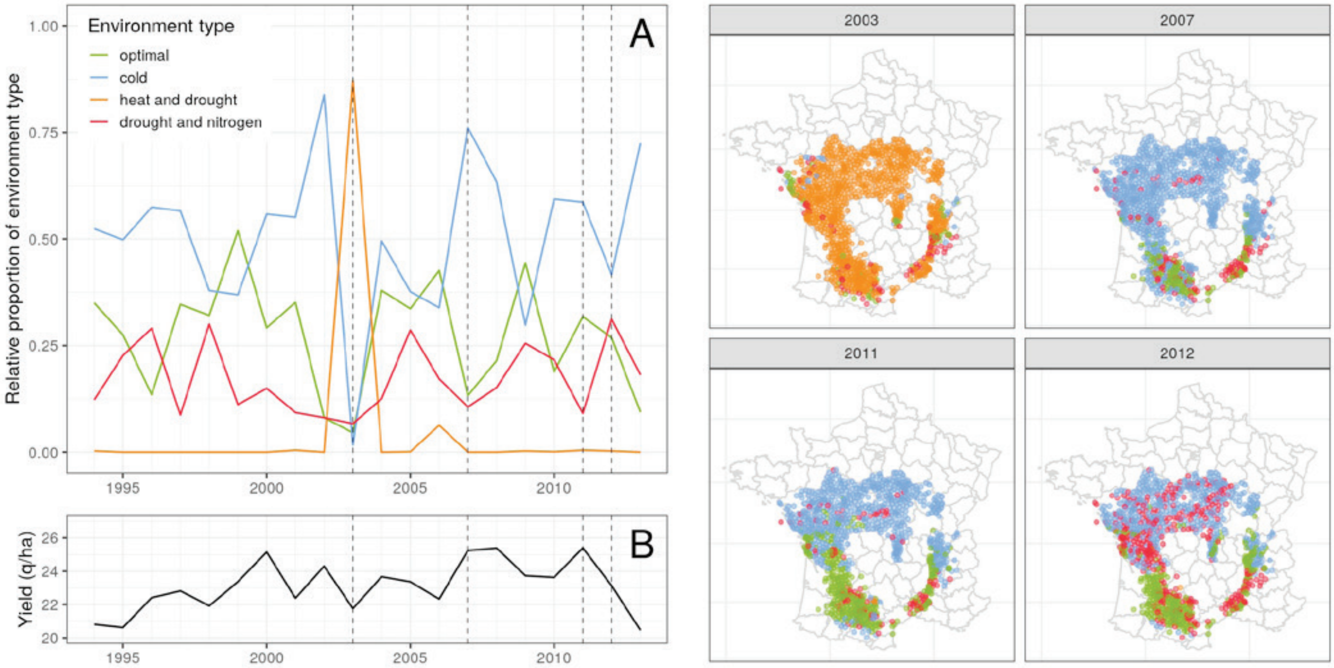

Figure 1. Temporal and spatial distribution of environment types. The panel A displays the evolution of the relative proportion of environment types over 20 years. For reference, panel B is the national sunflower yield. The right panels display the spatial distribution of environment types (colors) for each individual farming condition (dots) of the sampled cropping area, for a subset of four contrasted years.

Keywords: crop management, phenotypic plasticity, modeling, genotype-by-environment interactions, sunflower crop.

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