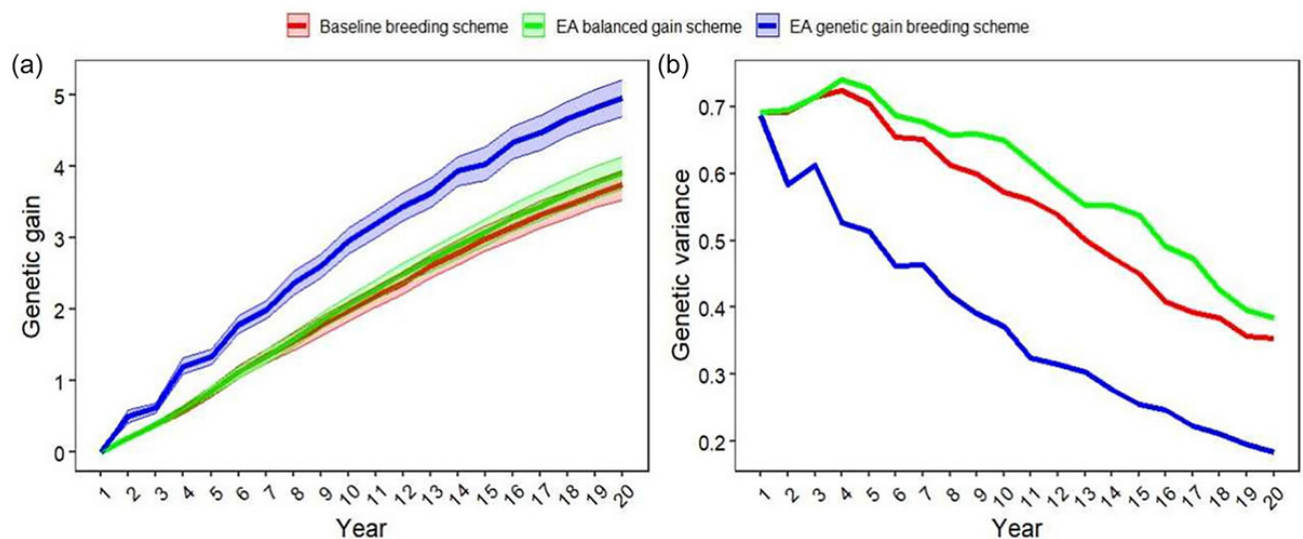




Optimizing breeding programs through simulation and evolutionary algorithms

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Genetic gains (a) and genetic variance (b) trends for a simulated wheat line breeding program (with 100 independent simulations). The red line represents the baseline breeding scheme, the blue line represents the evolutionary algorithm (EA) genetic gain breeding scheme, and the green line represents the EA balanced gain breeding scheme (a breeding scheme which aimed to maintain a balance between genetic gains and genetic diversity). Figure courtesy of Torsten Pook.

Plant breeders face a constant challenge: improving crop performance while working within limited budgets. Decisions about how many crosses to make, how many lines to test, and where to invest resources are tightly connected. Improving one part of a breeding program can affect performance throughout the entire pipeline, making it difficult to identify the best overall strategy.

To address this, researchers developed an optimization framework that combines breeding program simulations with an evolutionary algorithm. The approach evaluates thousands of possible breeding program designs and identifies those that use resources most efficiently. The framework was tested in both wheat line and hybrid wheat breeding programs.

The optimization process revealed that breeding programs can often be redesigned in unexpected ways to achieve better outcomes. Many highest-performing designs differed markedly from current breeding practices, suggesting that traditional resource allocation may not always be optimal. Across both line and hybrid wheat breeding programs, optimized designs delivered greater genetic improvement and/or maintained more genetic diversity.

These results show that breeding efficiency can be improved substantially without increasing costs. By treating breeding program design as a single optimization problem, breeders can allocate resources more strategically, accelerate genetic progress, and better balance short-term gains with long-term sustainability.

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Hassanpour, A., Rohde, A., Simianer, H., & Pook, T. (2026). Optimization of wheat breeding programs using an evolutionary algorithm achieves enhanced genetic gain through strategic resource allocation. *Crop Science*, 66, e70294.

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