Optimization of parameters of the 'Virtual Fruit' model to design peach genotype for sustainable production systems

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Designing sustainable production systems that are respectful of the environment and produce safe food of quality is a challenge for the future. A critical step is to find the best combinations of genetic resources and cultural practices adapted to target environments. The objective of this work is to illustrate how an ecophysiological process-based simulation model could be possibly used to design genotypes and to propose innovative production systems, by applying a methodology of optimization.

As example, we studied the peach-brown rot system and used the 'Virtual Fruit', a process-based model that has been extensively tested, to perform virtual experiments. The peach-brown rot couple is a complex system under the triple influence of the genotype (fungus and host), the environment and cultural practices. Studying this system could lead to a reduction of fungicide use and thus to ecological, economical and health benefits.

The challenge was to optimize the trade-off between antagonistic criteria of major importance for both fruit quality (increasing fruit mass and sweetness) and sensitivity to brown rot (decreasing skin density of cracks) in four different cultural scenarios. A multiobjective evolutionary algorithm, namely NSGA-II, was applied to solve this optimization problem based on the 'Virtual Fruit'. The optimized variables were six parameters of the 'Virtual Fruit', selected on the basis of a sensitivity analysis.

The algorithm proved to be well adapted to solve a multiobjective problem with highly contradictory criteria. The optimized solutions represented a real improvement in comparison to non-optimized solutions. Indeed some solutions located in non-crowded zones constitute some original alternatives for the final decision-maker. However, further development of the method is still needed to reduce computational time and improve the successive phases of the optimization procedure.

The optimization step provided a large diversity of solutions among which the decision-maker can choose the best suited trade-off between criteria according to a particular objective. The results confirmed the strong antagonism between the criteria considered. Large fruits had a weak sweetness and high crack density and for a given mass, those with improved sweetness had higher crack density. In a current breeding scheme, fruit mass would be the only criteria considered but alternative schemes could be considered for future, favoring organoleptic quality or environment friendly practices. In those cases, some interesting optimized solutions were identified.

Simulations by the 'Virtual Fruit' of the optimized solutions with contrasting cultural scenarios emphasize the impact of conditions of growth on the phenotypes. This suggested that one might adapt his goal to a type of cultural practices and a target environment. The methodology proposed here may help reasoning such choices.

This study provides a general framework for further works which would highly benefit from the integration of genetic knowledge. Work has to be done now to take into account more complex genetic models and to evaluate their predictive capacity against empirical data. Besides, the approach may be extended to the consideration of contrasted climatic conditions. Similarly, the optimization procedure could be applied to the optimization of the cultural practices. All together, these forthcoming works would contribute to the design of sustainable production systems combining genotypes and specific practices adapted to a targeted environment.

This study represents a proof of concept of the approach linking process-based models and optimization methods. It will hopefully give rise to more complete studies that may confirm highly valuable implications of the methodology for breeders, agronomists and decision makers.

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