# DETERMINATION OF CULTIVAR COEFFICIENTS OF CROP MODELS USING A GENETIC ALGORITHM: A CONCEPTUAL FRAMEWORK

J. P. Pabico, G. Hoogenboom, R. W. McClendon

**ABSTRACT.** *Most crop simulation models include parameters and coefficients that define responses and interactions with environmental and management conditions. This article presents a conceptual framework for using a genetic algorithm to determine cultivar coefficients of crop simulation models. The model's multi-dimensional outputs were transformed into a scaled and dimensionless fitness evaluation function based on the $L_1$-metric measure of vector distances between the simulated and observed output. The cultivar coefficients were linearly mapped and encoded into genetic algorithm chromosomes. Empirical evidence comparing the performance of the cultivar coefficients calculated by the genetic algorithm to the existing cultivar coefficients that was calculated by other methods was used to evaluate the performance of this approach. The evidence suggests that the genetic algorithm may be as good as or better than the traditional cultivar coefficient calculation method.*

***Keywords.*** *Crop models, Cultivar coefficients, Genetic algorithms, Genotype.*

Genetic Algorithms (GAs) are probabilistic search techniques suited for solving large, complex, multidimensional, multimodal, discontinuous, and/or noisy search, and optimization problems. Applied to such problems, GAs outperformed several tested search and optimization procedures such as the gradient techniques and some various forms of random search (Beaty, 1993; Davis, 1987, 1991; Goldberg, 1989; Grefenstette and Baker, 1989; Holland, 1992). Generally, GAs manipulate a population of strings of characters that are defined over some alphabet, e.g., a set of encoding symbols. These strings are analogous to chromosomes in molecular biology. The alphabet encodes possible solutions to the problem being solved. These solutions that are processed implicitly in parallel, i.e., the simultaneous searching of the space, evolve over a number of generations (Grefenstette and Baker, 1989). In each generation, the best (or fittest) solutions, as determined by a fitness evaluation function, are allowed to reproduce using genetic operators (Goldberg, 1989). The genetic operators are also analogous to molecular biology's DNA recombination (crossover) and gene mutation. These operators give the algorithm the ability to search for the global optima of large and difficult optimization tasks.

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The authors are **Jaderick P. Pabico,** Graduate Research Assistant, Department of Biological and Agricultural Engineering, The University of Georgia, Athens, **Gerrit Hoogenboom,** ***ASAE Member Engineer,*** Associate Professor, Department of Biological and Agricultural Engineering, The University of Georgia, Griffin, and **Ronald W. McClendon,** ***ASAE Member Engineer,*** Professor, Department of Biological and Agricultural Engineering, The University of Georgia, Athens, Georgia. **Corresponding author:** Gerrit Hoogenboom, The University of Georgia, Department of Biological and Agricultural Engineering, 1109 Experiment St., Griffin, GA 30223; voice: (770) 229-3438; fax: (770) 228-7218; e-mail: gerrit@bae.uga.edu.

An example of such a difficult optimization task is the calculation of cultivar coefficients of crop models. These coefficients are inputs that account for cultivar differences of a certain crop. They allow the models to simulate the growth and development of a crop under different environmental conditions, taking into account the genotype by environment interaction of a crop (Hoogenboom et al., 1992). In the current Decision Support System for Agrotechnology Transfer (DSSAT) crop models (Tsuji et al., 1994), the calculation of the cultivar coefficients is either by trial and error, using a heuristic search technique, or with the Genotype Coefficient Calculator or GENCALC program, using a gradient search technique. The trial and error of calculating the cultivar coefficients favors the exploration, i.e., locating unexplored areas, of the search space. The implementation of such a technique, however, is tedious and products uncertain search results. GENCALC, on the other hand, estimates the coefficients via iterations of deterministic processes. These deterministic processes adjust the coefficients by varying their values within the crop's realistic physiological ranges, i.e., flowering date, physiological maturity date, critical daylength, seed size, etc. (Hunt et al., 1993). The deterministic nature of GENCALC allows the process to concentrate on exploiting a promising area, i.e., making productive use of already known points, of the search space. However, it can only sample a small area of the search space and thus the search result, which depends on the starting point, may not be the global optimum. There are other optimization techniques that can be used, such as the least-squares, the non-linear least-squares, and the simplex methods. Each of these techniques has its own limitations; one of the most common limitation is that the search becomes trapped in a local optimum when applied to complex optimization and search problems (Cong and Li, 1994).

In spite of the problems inherent to the techniques described above, the strength of each can not be set aside. The search for a global optimum, or optima for

  