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Comparison and Hybridization of Two Approaches for Maize Simulation

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Two approaches dominate simulation modeling of maize growth: (1) a generic approach, represented by the family of crop models developed by Dutch scientists at the Wageningen University, e.g. SUCROS (Spitters et al, 1989), WOFOST (Diepen at al, 1989) and INTERCOM (Kropff and van Laar, 1993), and (2) a maize-specific approach, represented by CERES-Maize (Jones and Kiniry, 1986) and its derivatives such as the maize module in DSSAT, and the MSB model developed by Muchow et al. (Muchow et al, 1990). These two approaches differ in three aspects. First, maize development in generic models is driven primarily by availability of assimilate from photosynthesis, while temperature is the primary driving force in the maize-specific models. Second, growth respiration and maintenance respiration are explicitly accounted for in the generic models to determine net dry matter production, while the maize-specific approach derives net dry matter production directly from intercepted solar radiation by means of a fixed value of radiation use efficiency (RUE) that implicitly accounts for respiration costs. Third, the generic approach requires phenology specification of growing degree days (GDD) to anthesis and does not consider hybrid differences in traits such as sensitivity to daytime length, potential number of kernels and potential grain filling rate, while the maize-specific approach requires specification or estimation of several phonological events and hybrid-specific parameters.

A generic model (INTERCOM) and a maize-specific model (CERES-Maize, standard version) were evaluated with regard to their requirements for input parameters and their accuracy in predicting maize dry matter accumulation, leaf area expansion, and final grain and stover yields. Detailed field measurements from a 3-year study in which maize was grown with minimal possible stress were used for validation. Results suggest that CERES-Maize, in which temperature determines the potential leaf and stem growth, performed better than INTERCOM in which availability of assimilate is the primary driving force. In contrast, the separate routines for photosynthesis and respiration in INTERCOM provided greater sensitivity for crop response to temperature than CERES-Maize, which mostly relies on a fixed value of RUE for determining dry matter accumulation. Whereas INTERCOM requires specification of (GDD) to anthesis as an input parameter, CERES-Maize predicts anthesis from the GDD interval from emergence to end of the juvenile phase, and this 'juvenile-phase' parameter is not readily available for most hybrids.

Both models consistently underestimated maize yields under near-optimal growth conditions: grain yield was underestimated by 6% (±3%) and stover yield by 20% (±3%). Such underprediction would result in reduced estimates of C sequestration, especially in high-yield environments where the potential for C sequestration may be large. They would also underpredict nutrient requirements for fertilizer recommendations based on yield potential.

A new maize simulation model, Hybrid-Maize, was developed by combining the strengths of the two modeling approaches and modification of several other growth functions. It features temperature-driven maize phenological development, vertical canopy integration of photosynthesis, organ-specific growth respiration, and temperature-sensitive maintenance respiration. It also requires fewer hybrid-specific parameters without sacrificing the prediction accuracy. For example, the close linear relationship between GDD to anthesis and GDD to maturity was used to improve prediction of anthesis because information about GDD to maturity is available for most commercial hybrids. Hybrid-Maize simulated maize dry matter accumulation, final grain and stover yields more accurately and more consistently than INTERCOM and CERES-Maize in the high-yielding environments in which they were evaluated. In addition, the program has a Windows-based user interface, and comprehensive graphic presentation of simulation results, climate data, and cross-year comparisons for time-series simulations. Efforts are currently in progress to develop and validate water and nitrogen balance components so that maize can be simulated in suboptimal environments with these limitations.

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