IXIM: A New Maize Simulation Model For DSSAT v4.5

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The Decision Support System for Agrotechnology Transfer (DSSAT) is a suite of crop simulation models and associated tools for simulating growth, development, and yield of 25 crops. The maize simulation model in DSSAT is CSM-CERES, the modular version of CERES-Maize, which was first published in 1986. The newest release of DSSAT, version 4.5, provides users with the opportunity to run an alternative maize simulation model. IXIM (eeh-sheem), the Mayan language for maize, is a new, more mechanistic, maize simulation model fully compatible with DSSAT. The purpose of this work is to compare seasonal simulations of maize growth and N uptake using CSM-CERES and IXIM.

Methodology

IXIM was modified from CSM-CERES and includes a number of improvements and new modules. Leaf area expansion and senescence are simulated using sigmoidal functions to describe expansion, longevity, and senescence of individual leaves (Lizaso et al., 2003). Leaf rolling per-leaf is calculated as a function of time of the day, atmospheric transmission of radiation, and water stress intensity. Instantaneous assimilation of each green leaf is calculated as a function of hourly-absorbed photosynthetic photon flux density, leaf age, and air temperature (Lizaso et al., 2005). Canopy gross assimilation is calculated by integrating the contributions of successive vertical leaf classes. Canopy respiration accounts for maintenance respiration and growth respiration for tissue synthesis (Lizaso et al., 2005). Specific leaf area determines potential allocation of biomass to individual leaves. Specific leaf area of each leaf is a function of light intensity, temperature, and leaf position within the canopy. Partitioning of assimilates among organs was completely modified. Ear growth occurs within a thermal time window of 250 degree-days before silking, until 100 degree-days after silking. Kernel number per plant is calculated as a curvilinear function of the daily shoot growth rate averaged over the same thermal time window around flowering used for ear growth. Maximum daily nitrogen uptake is limited by a curvilinear function of daily growth rate. This constraint recognizes the energy cost for N uptake, reduction, and assimilation. IXIM requires two additional genetic inputs relative to CSM-CERES: 1) Surface area of the largest leaf (cm^2), and 2) Longevity of the most long-lived leaf (degree-day). Model parameters are included in a new maize species file and are accessible to the user. Data distributed with DSSAT (UFGA8201, Irrigated and non-irrigated during the vegetative phase treatments) were simulated and compared. Willmott's d index (Willmott, 1982) was used to evaluate model accuracy. Index d has values within the range 0-1 with higher values indicating more accurate simulations.

Results

Both models produced better results when simulating non-stress conditions as compared to the water stress treatment (Figure 1). CSM-CERES consistently overestimated leaf area in the irrigated treatment. However, it was able to accurately simulate biomass accumulation and grain yield (d values of 0.991 and

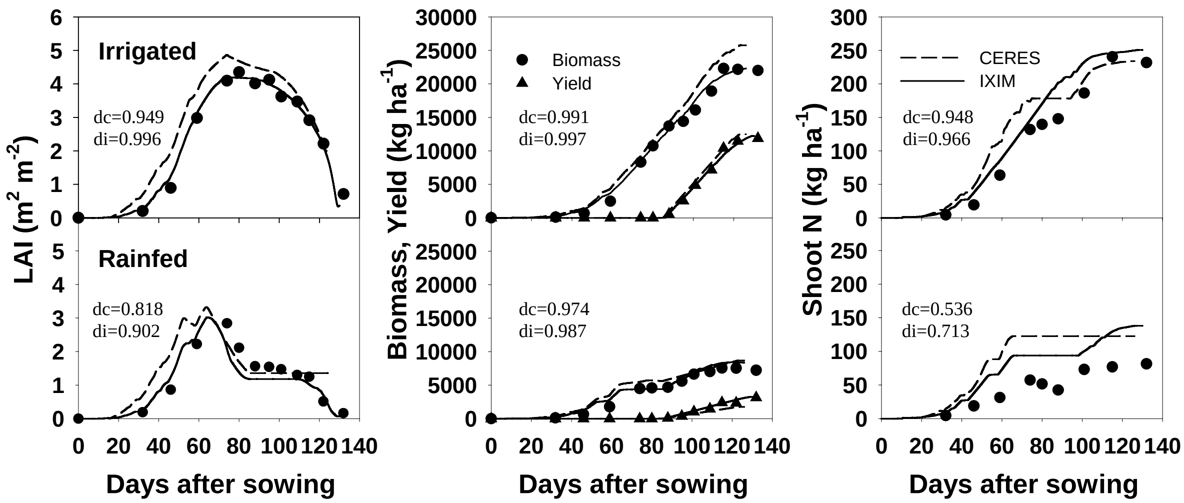

Figure 1: Leaf area index, biomass accumulation, grain yield, and shoot N uptake in maize irrigated and water stressed during the vegetative phase (Rainfed), simulated with CSM-CERES (dashed lines) and with IXIM (continuous lines) compared to observed (symbols). Index of agreement (Willmott, 1982) calculated with CERES simulations (dc) and with IXIM simulations (di).

0.973). It also calculated faster than observed shoot N uptake especially immediately after applying fertilizer.

CSM-CERES overestimated leaf senescence in response to soil water shortages during the vegetative phase. However, simulations of biomass and grain yield were adequate with d values of 0.974 and 0.977 respectively. The model simulated, at flowering, more than two-fold greater than measured N uptake.

On the other hand, IXIM improved consistently the estimations of growth and N uptake. Willmott's d index (Willmott, 1982) improved 5 and 10% when simulating leaf area of irrigated and vegetative water stress treatments. Simulations of biomass and yield showed minor differences between models, but N uptake simulations improved 2 and 33% for irrigated and rainfed treatments. Partition of dry mass between leaves and stems was also simulated closer to measured by IXIM as compared to CSM-CERES (not shown).

In summary, IXIM outperformed CSM-CERES when simulating growth and N uptake of non-stressed and water stress treatments. Values of d index fluctuated between 0.966 and 0.997 under irrigation, and between 0.713 and 0.987 for water stress conditions. Corresponding ranges for CSM-CERES were 0.948 and 0.991for irrigated and 0.536 and 0.977 for rainfed conditions. Simulation of N uptake, especially under stress conditions needs further attention.

References

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