Parameterization of maize phenology, canopy development and dry matter partitioning in cool versus warm climate

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Introduction

Perceptions of a warming climate and recent experience of warmer weather has increased the agronomic interest for maize in North Europe. Experiences from warm regions can help to better understand the dynamics of maize growth in cool/temperate regions. Crop models are especially useful for that purpose because they provide an explicit illustration of the fundamental processes such as crop development, photosynthesis and dry matter partitioning as driven by climate. The objective of the present study was to calibrate the DAISY crop growth model to capture actual maize development and growth under two different climatic conditions.

Methods

DAISY is a process-based simulation model with an embedded detailed description of crop phenology, growth, soil water transport and N transformations in the agro-ecosystem. Within the crop module, the crop phenology (development stages, DS) is simulated with daily development rates from emergence (DS=0) to flowering (DS=1), and to maturity (DS=2), whereas assimilate, a net result of photosynthesis, respiration (growth and maintenance) and root-shoot ratio, is partitioned between leaf, stem and grain as function of DS. Further details on the model equations and assumptions may be provided by Hansen (2002). Maize field measurements were performed in the North China Plain (warm climate) and Denmark (cool climate) for multiple of years in order to capture the climate variation. The maize was sampled three to four times during the growth seasons and at harvest. The measurements included, among others, leaf area index (LAI) and above-ground dry matter (DM) concentration and yield. The field data were used to calibrate the default settings of the maize module in DAISY. Parameters governing phenology, LAI and partitioning of DM were directly adjusted to the measurements. Other parameters were calibrated based on sensitivity analysis and expert knowledge of the processes and the model.

Results and Discussion

Calibration of crop phenology is of foremost importance in the model because many other parameters are functions of the plant development. Under both warm and cool climate, maize germination was simulated to start 18 (±5) days after sowing, while flowering was always induced in the beginning of August. The most uncertain simulation was the duration of the reproductive period under cool climate due to intra-seasonal climate variability. The DAISY result cannot be linked to measurable (e.g. BBCH) units, but a DS value of 1.8 simulated at harvest of maize for silage under cool climate should approximate the reality. The simulation of maize DS at harvest under warm climate is more straight-forward because the maize always reaches physiological maturity (DS value of 2.0). The calibration of maize canopy development and assimilate partitioning is presented in Fig. 1. Higher air temperatures throughout the maize season steadily accelerate the rate of LAI development, which makes it possible to describe the canopy development under warm climate with a single function in the model, regardless of year (Fig. 1A). Under cool climate, however, LAI varied significantly between years and treatments (coefficient of variation of 60%). Thus, large range in the parameter values describing LAI (LeafAIMod) has occurred. The efficiency of assimilate carbon use during crop growth (E) is a physiological parameter with values ranging between 68-87% (Vries, 1989). Compared to a warm climate, E of leaf and stem under cool climate conditions

were higher (Fig. 1B) but corresponded to reduced assimilate partitioning to these organs (Fig. 1C). Similarly to LeafAIMod, wide calibration range of E was necessary to describe the growth of maize between the years. The variation of the maize specific leaf weight (SpLAI) on Fig. 1B was measured.

Table 1. Main parameters in DAISY model for maize phenology under warm and cool climates

Parameters*	EmrTSum	DSRate1	DSRate2
Warm climate (NCP)	200	0.024	0.020
Cool climate (Denmark)	180	0.022	0.021

* EmrTSum=Soil temperature sum at emergence (°C day); DSRate1=development rate in vegetative period (DS day^{-1}); DSRate2=development rate in reproductive period (DS day^{-1}); NCP=North China Plain.

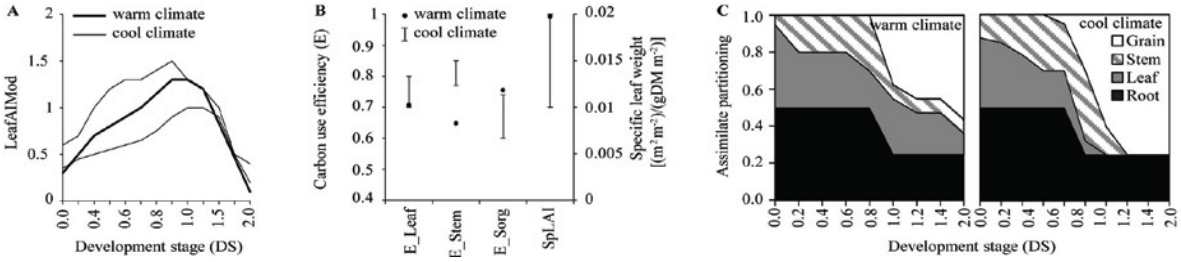

Figure 1. Maize parameters in the DAISY model under warm and cool climate. (A) LAI modifier, (B) Carbon use efficiency, and (C) assimilate partitioning between crop organs. The lower and upper curves of LeafAIMod correspond to lower and upper limit of the calibration range under cool climate.

The panels below in Fig. 2 display the patterns and magnitudes of the modeled and measured maize growth under warm and cool climates. Although simulated LAI was slightly lower than the measured one (Fig. 2A), the calibrated maize could simulate the actual fluctuations of measured leaf, stem and grain (Fig. 2B).

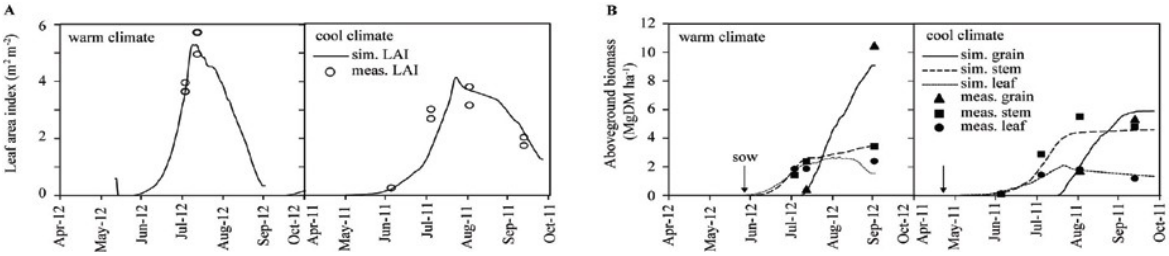

Figure 2. DAISY-simulated leaf area index (A) and aboveground biomass (B) of maize under warm (North China Plain) and cool (Denmark) climate.

Conclusions

The maize growth under warm climate could be simulated using single parameter values in DAISY whereas a relatively wide calibration ranges were found to describe the maize growth under cool climate conditions. The results of this study can be used to further refine the model performance to capture the measured maize dynamics in other regions of North Europe. Also, some limitations exist because of uncertainties from e.g. root growth or photoperiod effect on maize growth, which are influential but were not considered in this study.

References

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