Scaling up to whole-plant and crop levels short-term responses of leaf growth to water deficit

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1 *Context*

One challenge of plant models in ecophysiology is to bridge the gap between physiological and genetic studies that focus on short-term mechanisms, and whole-plant models designed to predict biomass accumulation, transpiration and yield in field conditions. We developed here a model of leaf growth and development in maize and interfaced it with the crop model APSIM for simulation at canopy level.

2 *Stable patterns provide the experimental base of a development model*

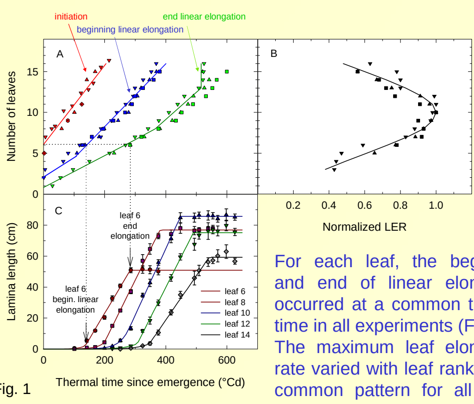


Fig. 1

For each leaf, the beginning and end of linear elongation occurred at a common thermal time in all experiments (Fig.1A). The maximum leaf elongation rate varied with leaf rank with a common pattern for all experiments (Fig. 1B).

3 *Model*

The model was calibrated with data taken from field, growth chamber and greenhouse experiments (Fig. 2, first row). It combines (i) the estimation of key developmental stages (Fig. 2A) that set the period during which leaves grow, and (ii) environmental responses of leaf elongation rate (Fig. 2B-D) that are applied to every leaf using an hourly time-step (Fig. 2E). Each leaf thus expands during a fixed period at a rate determined by the interactions of environmental factors (Fig. 2G). Leaf area per plant increases with the sum of expansion of all leaves every day.

This model of leaf growth and development was interfaced with the crop model APSIM which provided the hourly leaf environmental variables as inputs to the single-leaf model and accepted the leaf model outputs to estimate canopy area and simulated biomass and grain growth on a daily time step for the duration of a crop.

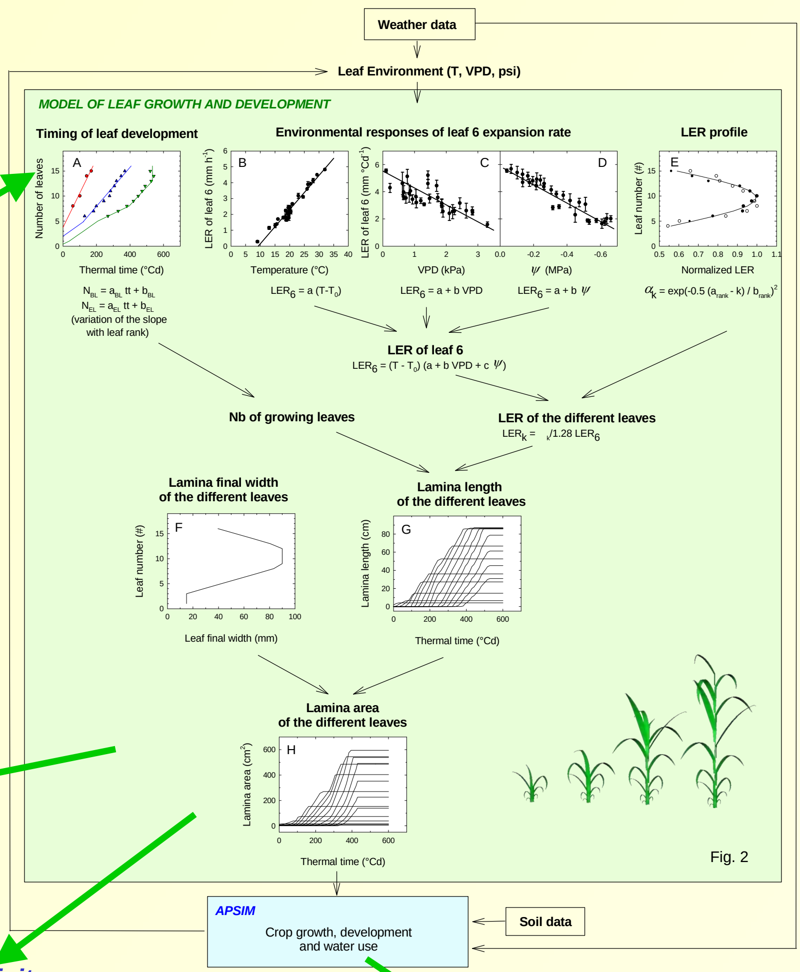
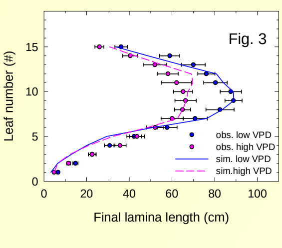


Fig. 2

4 *Observed and simulated effect of evaporative demand, at whole-plant level*



5 *Observed and simulated effect of water deficit, at whole-plant level*

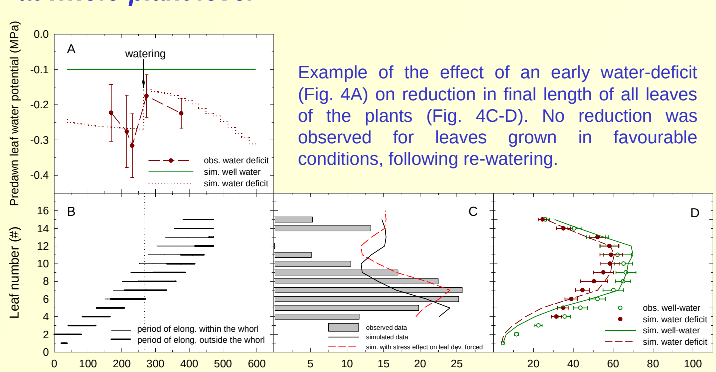
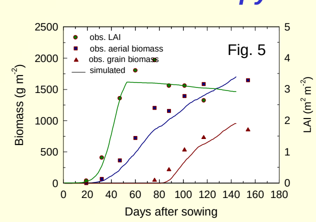


Fig. 4

Example of the effect of an early water-deficit (Fig. 4A) on reduction in final length of all leaves of the plants (Fig. 4C-D). No reduction was observed for leaves grown in favourable conditions, following re-watering.

6 *Simulation at canopy level*



7 *Conclusion*

This model extends existing physiological knowledge of leaf elongation responses to environmental conditions at the canopy level. The leaf-scale approach developed here is a first step to develop and integrate 3D virtual plants within the crop model APSIM. The resulting model would allow a better estimation of light interception over development and stress impact on yield.