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

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Introduction

One challenge of FSPM 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.

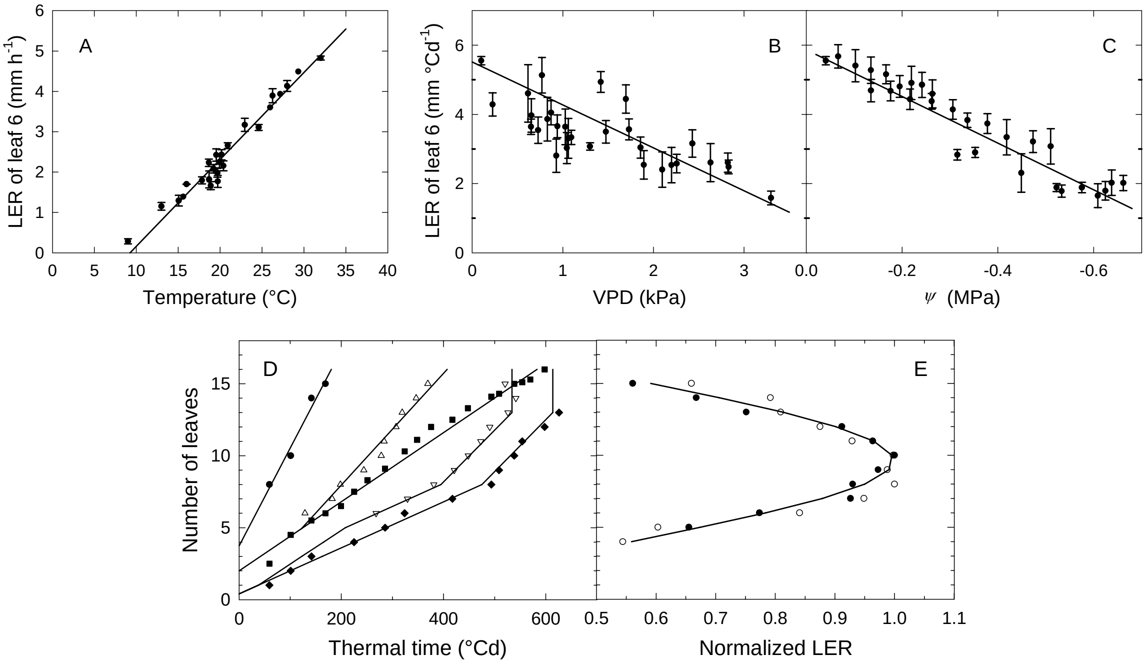

Fig. 1. Models used for predicting individual leaf extension and their responses to water deficit in soil and air. (A-E) Responses of leaf elongation rate (LER) of leaf 6 to temperature, vapour pressure difference between meristem and air (VPD), and predawn leaf water potential (ψ). (D) Timing of leaf development expressed in thermal time for individual leaves (●, leaf initiation; △, beginning of linear expansion; ■, tip appearance; ▽, end of linear expansion). (E) Normalized leaf extension rate as a function of leaf position. Data from greenhouse and growth chamber experiments (A-C) and one field experiment (D-E).

The model

The model of leaf growth and development combined (i) the model of leaf extension proposed by Reymond *et al.* (2003) to predict effects of QTLs on leaf expansion rate under short-term environmental variations (Fig. 1 A-C) with (ii) a model coordinating the development of the individual leaves of a plant (Fig. 1 D-E). The latter was based on results of three experiments where all leaves were measured every second day from their initiation. The resulting whole-plant model was incorporated as a replacement module for canopy development in the APSIM platform (Wang *et al*., 2002; Keating *et al*., 2003). In addition, a new micrometeorological module was added to APSIM to provide environmental inputs at an hourly time-step to the leaf extension module.

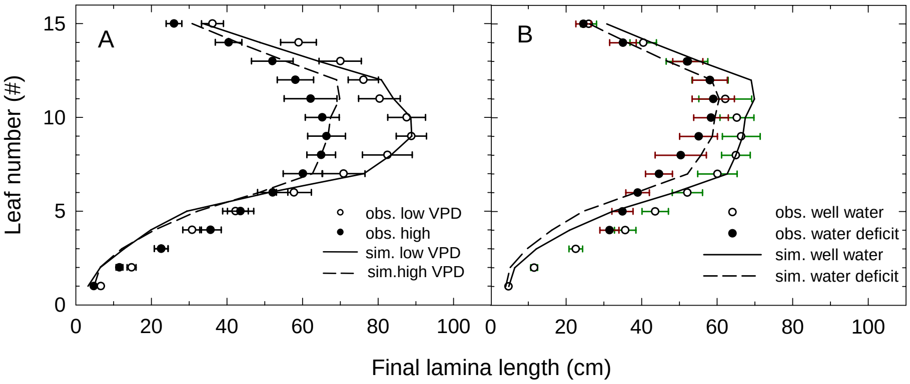

Fig. 2. Observed and simulated length of fully expanded leaves, for plant grown in field with contrasting vapour pressure deficits (A) and soil water status (B).

Results

Twelve field situations with contrasting temperatures, evaporative demands and soil water status were used to test the model. The model showed strong effects of high evaporative demand and water deficit in reduced leaf area at the whole-plant level (Fig. 2). Short water deficits affected only leaves developing during the stress, either visible or still hidden in the whorl, independently of other leaves. The model adequately simulated whole-plant profiles of leaf area with a single set of parameters which applied to the same genotype in all experiments. It was also suitable to predict biomass accumulation and yield of a similar hybrid in different field conditions.

Conclusion

This model extends existing physiological knowledge of leaf elongation responses to environmental conditions. It can be applied to determine how the genetic controls of these responses translate into yield differences for large ranges of climatic scenarios.

References

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