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# A modeling approach to simulate the whole-plant leaf expansion responses to light in three annual dicotyledonous species

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**Highlights:** A generic leaf area growth model based on the simulation of leaf growth dynamics in response to light microclimate was built, calibrated and validated for three dicotyledonous species.

**Keywords:** leaf area, temperature, radiation, relative elongation rate, development.

Plant leaf area plasticity is a key adaptive process to fluctuating environmental resources. Modeling and simulating leaf area is necessary to analyze and explore plant agronomic performances under various environments. The purpose of this work was to propose a generic plant model simulating leaf area dynamics. The model simulates plant leaf area dynamics according to temperature and light conditions. Three dicot species with different patterns of vegetative growth were selected: *Arabidopsis thaliana* L., *Helianthus annuus* L. and *Lactuca sativa* L. First, the model simulates organ and plant development on the basis of an organogenetic body plan, driven by intrinsic organ growth and production rhythms. These rhythms are modeled according to temperature through thermal time. This organogenetic body plan allows estimating for each leaf its potential time of (i) initiation, of (ii) end of exponential growth and of (iii) end of expansion (Fig. 1A). Response curves between development rate and the amount of intercepted radiation are used to simulate the impact of light conditions on these developmental timings (Chenu et al. 2005). The model computes the potential relative elongation rates (RER) of each leaf according to its insertion rank and according to its age (Fig. 1B). Each day, the RER during the exponential phase of leaf expansion is computed as the product of potential relative elongation rates and of a stress coefficient calculated according to the amount of absorbed radiation by the plant. Lastly, individual leaf area is computed and whole plant leaf area is obtained by summing the area of individual leaves. This growth model is coupled with a phylloclimate model estimating on a daily basis the amount of absorbed radiation by leaves using 3D reconstructions of plants and a radiative balance. Model parameterization was derived from experiments conducted for the three species in field, greenhouse and growth chambers. For each species, an independent data set was used to validate the model under different light conditions. According to the quality of the simulations (Fig. 1C), the model appears to be promising to simulate the dynamics of leaf area in response to light and temperature for the three different species. Sensitivity analyses were performed to analyze the relative contributions to plant leaf area of plant development rate, duration of the exponential expansion phase and sensitivity to light conditions. Lastly, for the parameters related to these processes, a sensitivity analysis was carried out to identify optimal target parameter values that maximize whole plant leaf area development under different light regimes.

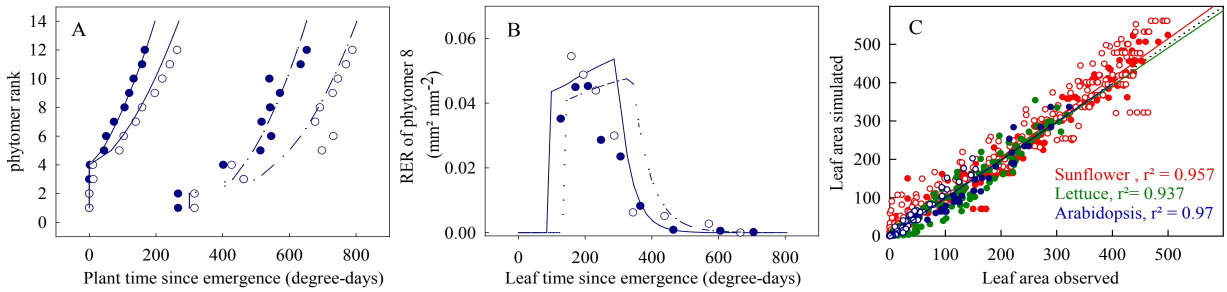


Fig. 1 Results of model simulations for two light regimes (9.3 mol $m^{-2}$ $day^{-1}$,color symbols and 3.7 mol $m^{-2}$ $day^{-1}$ empty symbols). Times of leaf initiation and end of leaf expansion for all phytomers of *Arabidopsis thaliana* plants (A), time-course of RER for phytomer 8 (B) and observed and simulated individual leaf area for sunflower (cm²), lettuce (cm²) and Arabidopsis Thaliana (mm²) (C). Lines represent simulation results. Color symbols refer to high light conditions and empty symbols refer to low light conditions.

**Chenu K, Franck N, Dauzat J, Barczi JF, Rey H, Lecoeur J. 2005.** Integrated responses of rosette organogenesis, morphogenesis and architecture to reduced incident light in *Arabidopsis thaliana* results in higher efficiency of light interception. *Functional plant Biology* **32:** 1123-1134.