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Modelling the genetic diversity of perennial grass phenology in contrasted temperate climates

Simon Rouet[1], Jean-Louis Durand[1], Didier Combes[1], Abraham Escobar Gutiérrez[1], Romain Barillot[1]

[1]*INRAE UR P3F, Lusignan, France*

For correspondence: simon.rouet@inrae.fr

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Introduction

In perennial grasses, flowering is a periodical event that deeply affects plant morphogenesis and has consequences on biomass production, quality and tiller demography. Despite the importance of perennial grasses in continental ecosystems, we still lack accurate models predicting perennial grass flowering and its consequences on plant development. The available models often directly use the heading date (HD) as an input parameter or poorly account for the floral induction process in response to climate. In addition, the vegetative and reproductive developments are usually represented as two independent phases instead of a continuous process. In the present work, we developed an original Functional-Structural Plant Model (FSPM) of grasses, named L-grassF representing the floral development of individual tillers in interaction with the vegetative stages and considering the dynamic effect of environmental conditions on floral induction. Our objective was to simulate the genetic diversity of the response of floral induction and growth of individual tillers to environmental variations.

Materials and Methods

L-grassF describes the canopy as a set of individual plants, each being composed of one or more tillers. The dynamics of leaf growth and tillering are determined by self-regulation rules as described in the original version of the L-grass model (Verdenal et al. 2008). We added a phenological module integrating the effects of temperature and photoperiod on the functioning of each apex of the plant, assuming a dual induction requirement as established for *Lolium perenne* (Heide 1994). The model predicts the HD of tillers from the emergent process of heading which results from the simulation of floral transition (FT), final leaf number and 3D expansion of leaves, internodes and spikes. Parameters of vegetative growth and floral induction were calibrated on an experiment describing organ appearance and growth in three *Lolium perenne* cultivars grown under four inductive conditions in growth chambers. Three conditions consisted in a period of primary induction followed by an exposition to long days after 0, 3 or 6 weeks of short days. In the fourth condition, plants were not exposed to the conditions necessary for the primary induction. Finally, the model was evaluated against phenological records of the same cultivars grown in seven French field sites for several years.

Results and Discussion

The model was run in two contrasted environments for tillers initiated arbitrarily at four different dates in order to represent different cohorts, from main stems emerged after sowing in October, to tillers initiated in April (Figure 1). Simulations were performed at two locations (Fig.1a, c) with similar photoperiod but different thermic regimes. In particular, winter temperatures in Theix (Fig.1c) were significantly colder than in Ploudaniel (Fig.1a). The environmental conditions modified the proportion of flowering tillers (Fig.1b, d). Under a climate with a relatively warm winter (Fig.1a), young tillers (initiated on Feb. 1st and Apr. 1st) do not accumulate enough low temperatures to reach primary induction (blue arrows). As the secondary induction by photoperiod (green arrows) is constrained by the achievement of the primary induction, these tillers remained vegetative and produced leaves indefinitely. Lower temperatures in winter (Fig.1c) reduced the duration required for primary induction and allowed the flowering of one more tiller. The final leaf number of heading tillers globally increased with

higher winter temperatures (Fig.1b). It was also dependent on primary and secondary induction dates. The HD (red arrows) occurred at different time after the last leaf appearance depending on the spike morphology (spikelet number) and the temperature conditions during its growth. Nevertheless, whatever the climate context, the model simulates close HD in comparison with the repartition of the tiller initiation dates. Changing the values of the induction model parameters allowed the simulation of the genetic diversity of the HD in *Lolium perenne* in interaction with the environment (results not shown).

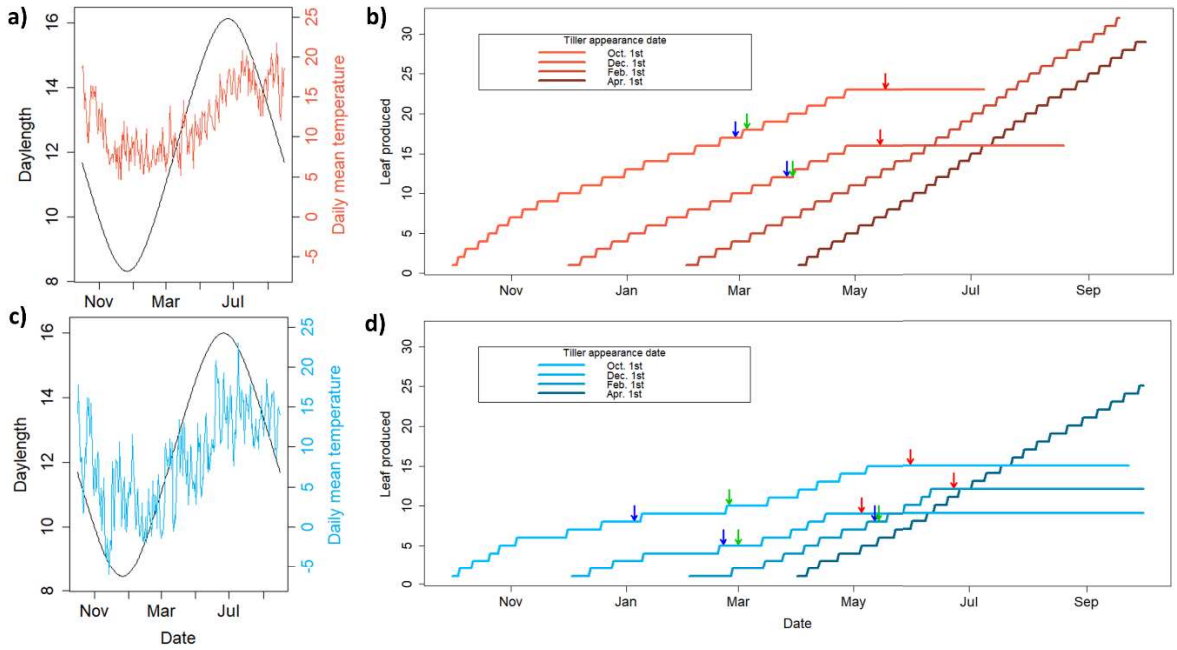

Figure: Cumulated number of leaves produced by tillers set on four different dates (Oct.1st, Dec.1st, Feb.1st and Apr.1st) in two French contrasted climates. Climates and simulations of the phenology: (a, b) in Ploudaniel (oceanic) and (c, d) in Theix (continental). Blue arrows: end of primary induction, green arrows: secondary induction, red arrows: HD

Conclusion

The present model is the first individual-based model of perennial grasses accounting for plant morphogenesis and FT in response to environmental factors. In the context of climate change, the model can allow the identification of perennial grass ideotypes for meadows adapted to future climate conditions and therefore help the breeding of new cultivars.

References

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