Phenotyping of sorghum photoperiod responses using heuristics

Michael Dingkuhn[a], Mamatou Kouressy[b], Michel Vaksmann[ab], Benoît Clerget[a c], Jacques Chantereau[a]

[a]*CIRAD, TA A-59/01 Av. Agropolis, 34398 Montpellier Cedex 5, France*
[b]*IER, Laboratoire Sol Eau Plante de Sotuba, P.O. Box 262 Bamako, Mali*
[c] *ICRISAT Samanko Research Station, BP 320, Bamako, Mali*

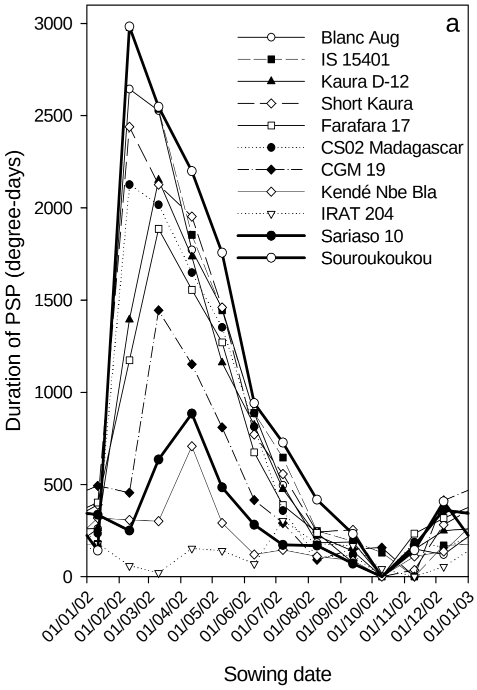
Problematic. Effects of photoperiod (PP) on panicle initiation (PI) of West African sorghums are essential for agro-ecological adaptation. Conventional models based on fixed (genetic) PP thresholds (qualitative response) or signal accumulation (quantitative response), are able to predict flowering for only a limited range of conditions. Accurate phenotyping requires a model having broader validity.

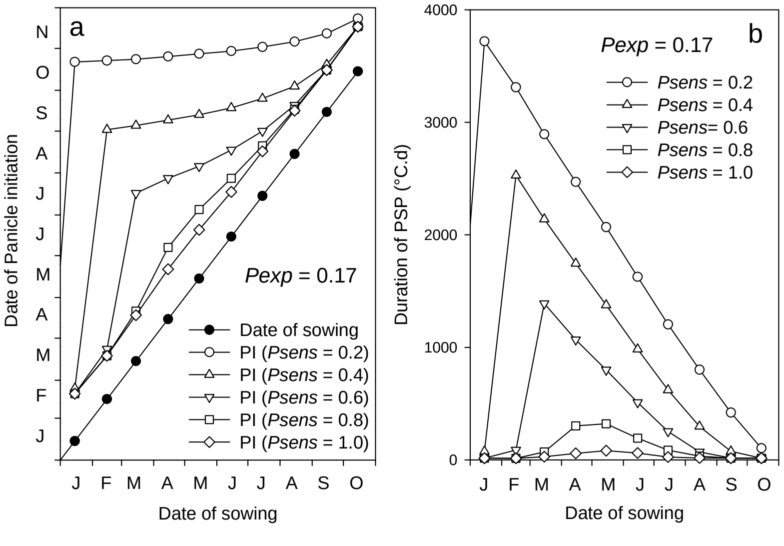
Approach. An alternative model is proposed in which PP thresholds that vary with plant age. The generic algorithm was called "*Impatience*" because it implements decreasing day length requirements during prolonged wait states, or appetence, during the photoperiod sensitive phase (PSP). The model was applied to field data obtained from sowing date experiments in Mali, in order to validate it and evaluate the range of genotypic responses that can be explained. On this basis, a heuristic model-assisted phenotyping approach was developed for field conditions using 3 sowing dates and fitting of 3 parameters (P_{exp}, P_{sens} and BVP). Phenotyping for the 3 parameters requires data on flowering or flag leaf ligulation dates for the 3 dates and daily min/max temperature.

Genetic materials. The model was tested with extensive data sets for 20 very diverse genotypes including traditional and improved *caudatum*, *guinea*, *guinea margaritiferum*, *durra-kafir* and *durra-caudatum* materials. The phenotyping methodology was evaluated for a subset of 5 genotypes (E35-1, *caudatum*; Kendé, *guinea margaritiferum*; Wassoulou, *guinea*; Souroukoukou, *caudatum;* CSM 388, *guinea*).

Results. Genotypes having diverse sensitivity to PP showed a common pattern of variability of PSP *vs.* sowing date (Fig. 1). PSP was shortest for October sowings and consistently longer for earlier sowings, unless the crop was sown before a critical, genotype specific date associated (break point).

Fig. 1. Duration of the photoperiod sensitive phase (PSP) observed for 12 monthly sowing dates in 2002/3 at Samanko near Bamako, for 11 contrasting sorghum genotypes. →





↑ **Fig. 2.** Sensitivity of the *Impatience* model to variation of the *Psens* parameter for the Bamako site. a: variation of date of PI; b: variation of PSP.

Figure 2 shows the sensitivity of the *Impatience* model to the parameter *Psens*. Variation of *Psens* explained much of the genetic diversity of patterns observed in Fig. 1. Specifically, the model predicted accurately that (1) PI does not occur at any genotype specific day length, but instead, on increasingly long days as the PSP is extended; (2) PI occurs predominantly when day length decreases, or after summer solstice; (3) PSP increases linearly (but not always proportionally) when crops are sown earlier in the year; (4), a genotype specific sowing date exists in winter (cool season) or spring (hot dry season) after which PSP suddenly increases by up to 160 days ("break point"); and (5), the largest variance of PSP occurs near the break point. However, the model tended to underestimate the duration of PSP when it fell into the cool season, which might be explained by specific thermal effects or a specific inhibitory effect of increasing day length on PI in some genotypes.

The ability of the model to discriminate among genotypes was used to devise a simple, model assisted phenotyping methodology. Genotypic parameters were determined by measuring one model parameter (BVP) and by fitting two others (*Psens* and *Pexp*) to measured dates of flag leaf ligule appearance for three sowing dates. Thus parameterized, the model predicted accurately the phenological patterns of contrasting materials observed in different experiments and years (Fig.3).

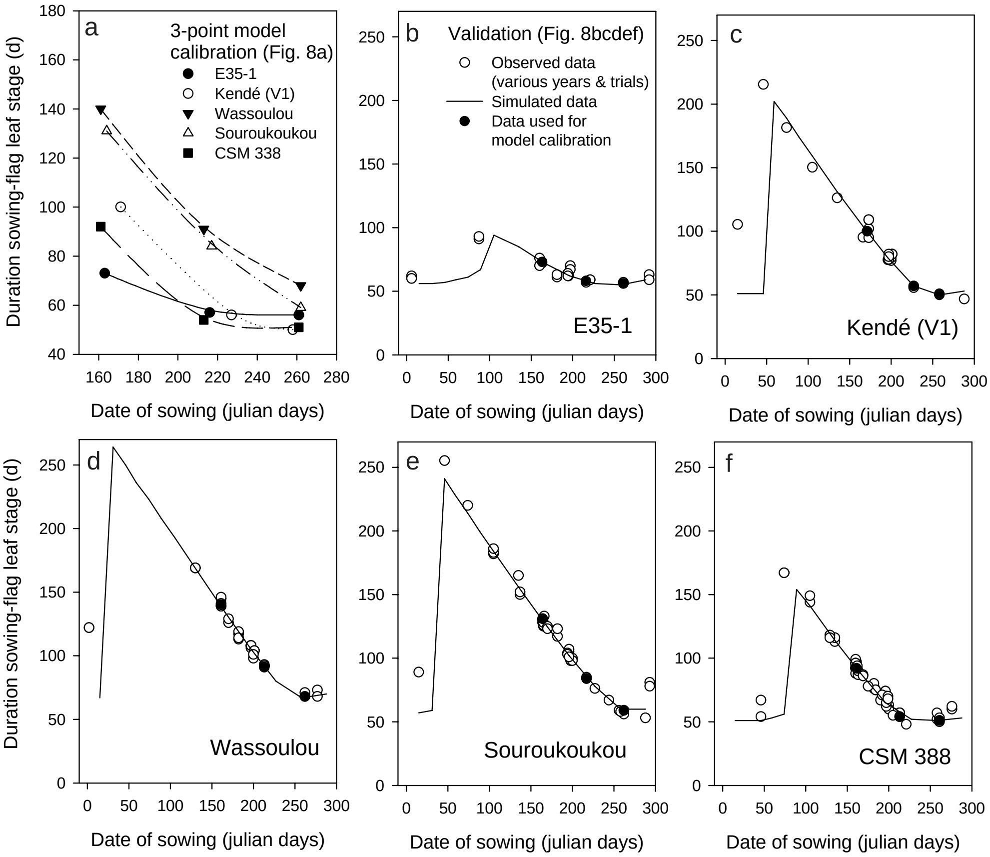


Fig. 3. Model assisted phenotyping of 5 sorghum genotypes having contrasting phenology: Calibration of the *Impatience* model based on observed date of flag leaf ligulation for 3 sowing dates (Fig. 6a) and validation of model for a larger range of sowing dates (Fig. 6bcdef).

Conclusion. By varying a single model parameter, the essential genotypic differences in PP response could be simulated (including "quantitative" and "qualitative" response), but 3 model parameters had to be parameterized to achieve fit to all observed patterns. In an environment comparable to that of Bamako, 3 sowings (June, August, and September) and simple observations of flowering or flag leaf ligulation date are sufficient to phenotype sorghum accessions with the help of the *Impatience* model. Further research will show whether and how genotypic variation of model parameters correlates with genetic information in the context of QTL or association studies. Further studies are also planned to explore the validity of the model for a broader range of latitudes and climatic conditions.

Articles reporting these results:

Dingkuhn, M., Kouressy, M., Vaksmann, M., Clerget, B., Chantereau, J. 2007. Applying to sorghum photoperiodism the concept of threshold-lowering during prolonged appetence. *European Journal of Agronomy* **(in press).**

Kouressy M., M. Dingkuhn, M. Vaksmann, A. Clément-Vidal and J. Chantereau. 2007. Potential contribution of dwarf and leaf longevity traits to yield improvement in photoperiod sensitive sorghum. *European Journal of Agronomy* **(in press).**

Kouressy M, Dingkuhn M, Vaksmann M, Heinemann AB. 2007. Adaptation to diverse semi-arid environments of sorghum genotypes having different plant type and sensitivity to photoperiod. *Agricultural and Forest Meteorology* **(in press).**