WHICH PARAMETER ESTIMATION PROCEDURE HAS TO BE CONDUCTED TO ADAPT THE STICS MODEL TO DURUM WHEAT CULTIVARS?

S. Guillaume, J.E. Bergez, E. Justes
INRA, UMR INRA-ENSAT 1248 AGIR, BP 52627, 31326 Castanet-Tolosan Cedex, France

Introduction

One of the major characteristics of interest for industrial transformers and producers in durum wheat production is grain protein content. Irrigation and nitrogen fertilization management are means to increase nitrogen and water availability in order to achieve high grain protein content but if these operations are not conducted at a proper time and rate, they can lead to grain quality degradation and negative environmental impacts.

Simulation crop models are useful tools to understand and evaluate the effect of soil, climate and management options on grain yield and grain protein content formation. Generic models like STICS treat crop-specificity through crop-specific parameters value and differences between cultivar responses are taken into account through cultivar-specific parameters. Despite the large number of crop models, only a few of them was adapted to durum wheat species (Bassu et al, 2009) and to our knowledge, none of them was adapted for several durum wheat cultivars. Adaptation of a generic crop model to durum wheat species requires the estimation of crop-specific and cultivar-specific parameters.

Difficulties of parameter estimation for complex crop models reside in the fact that the number of parameters included in a crop model often exceeds the number of observed data and that model response to crop parameter value is not always linear. Local minimum can be reached before the algorithm reaches global minimum, which leads to different estimated parameter values (Makowski et al, 2006). Compensatory effects between parameters can occur during optimization if many parameters are estimated simultaneously using few indirect response variables (Jeuffroy et al, 2006).

Our work concerns the adaptation of the STICS generic crop model to various durum wheat cultivars using the OPTIMISTICS parameter estimation tool (Wallach et al, submitted). The objectives of the paper is (i) to test different procedures of parameter estimation using the OPTIMISTICS tool, (ii) to provided a set of parameters for the STICS model for different durum wheat cultivars and (iii) to evaluate STICS performances for durum wheat over different growing conditions.

Material and methods

Three types of procedure combined with different datasets were conducted to estimate parameter values of the STICS model. The first procedure consists of estimating parameters relevant of physiological process step by step (Table 1). In that procedure (named OE), we aimed at keeping parameter biophysical significance as far as possible. Our hypothesis was that improving simulation of intermediate process leads to a better simulation of final process. Our hypothesis was that it is necessary, for a better simulation of final process such grain yield and grain protein content, to take into account simulation of intermediate processes and so intermediate variables which are dependent on water and mineral nutrition conditions. The second procedure consists of estimating all intermediate parameters for grain yield and grain protein elaboration in one step and then to focus on parameter relative to grain yield and grain protein elaboration. This procedure is called OG_3e.The third procedure consists of simultaneously estimating intermediate and grain yield parameters and then to focus on parameter relative to grain protein elaboration. This procedure is called OG_2e. In the two last approaches, we assumed compensatory effects of simultaneous parameters' estimation and the lack of biophysical significance of the estimated parameters. All of these three procedures include the estimation of crop-specific and cultivar-specific parameters.

Procedure	dataset	Number of optimization steps	Number of estimated crop-specific parameters	Number of estimated cultivar-specific parameters
OE	complete	12	20	6*n
OG_3^{e}	complete	3	6	3*n
OGV_3^{e}	cultivar	3	0	9*n
OG_2	complete	2	6	3*n
OGV_2e	cultivar	2	0	9*n

***Table 1** : Characteristics of the estimation procedures. n is the number of cultivar datasets. In our case n=7.*

Experimental data were collected from experimental trials conducted in different locations by INRA and Arvalis-institut du végétal. Criteria for data collection were (i) sufficient information regarding permanent soil characteristics and nitrogen and water soil status at simulation starting date to allow model initialisation and (ii) measurements of dynamic and final response variables simulated by the model. It encompasses seven durum wheat cultivars. This dataset was split into two subsets: one subset for parameter estimation : "the optimization dataset", and one subset for independent model performance evaluation : "the evaluation

dataset”. The optimization dataset was further split into cultivar optimization datasets corresponding to data relative to a specific cultivar. The two last procedures were conducted with the complete optimization dataset and with each of the cultivar dataset.
Parameter estimation was based on the minimisation of the sum of squares between estimated and observed response variables using the OPTIMISTICS tool.
Final parameter set was selected based on statistical criteria calculated between observed and simulated values for grain yield and grain protein content (Wallach D., 2006). Criteria were calculated separately for the two subsets. Model evaluation was conducted by looking at model responses compared to observed responses for different N treatments.

Results and conclusion

All optimization procedures reduce the bias of grain yield simulation and OG_2e leads to the smallest one for grain yield and grain nitrogen content (Table 2). The procedure OG_2e leads to the most effective decrease of RRMSE for both grain yield and grain nitrogen content. Grain yield model efficiency becomes positive and close to the one with OG_2e parameter set. OG_2e is the only procedure that leads to a positive model efficiency for grain nitrogen content but the efficiency is still negative if the evaluation dataset is considered.

Procedures	Initial	OE	OG_3e	OGV_3e	OG_2e	OGV_2e
Biais						
Grain yield	**1.59**;*1.95*	**0.37**;*0.61*	**0.22**;*0.87*	**1.08**;*1.77*	**0.06**;*0.5*	**0.28**;*0.8*
Grain nitrogen content	**-0.1**;*-0.07*	**-0.01**;*0.03*	**0.32**;*0.19*	**0.02**;*-0.18*	**-0.01**;*-0.04*	**-0.10**;*-0.34*
RRMSE (% of the mean)						
Grain yield	**37**; *42*	21;*24*	**19**;*24*	**29**;*38*	**14**;*19*	**23**;*31*
Grain nitrogen content	**19**;*16*	**19**;*20*	**27**;*19*	**15**;*20*	**12**;*15*	**32**;*49*
EF(-)						
Grain yield	**-1.56**;*-0.68*	**0.18**;*0.44*	**0.35**;*0.46*	**-0.63**;*-0.43*	**0.65**;*0.65*	**-0.02**;*-0.07*
Grain nitrogen content	**-0.5**;*-0.66*	**-0.4**9;*-1.66*	**-2.06**;*-1.5*	**-0.05**;*-1.73*	**0.39**;*-0.6*	**-3.38**;*-15*

Table 2 *: Statistical criteria obtained from the different procedures. Bold numbers refer to criteria computed on the complete optimization dataset and italic numbers refer to criteria computed on the evaluation dataset.*

Whereas an increase of N-split with a delay of late application leads to a decrease of grain yield and an increase of grain N content variations in model responses are inexistent (Figure 1).
This demonstrates that STICS does not take into account the timing and the N_splitting effect on grain N content and grain yield and egg on for the introduction of formalisms that reproduce the plant N absorption and transfer into the grain.

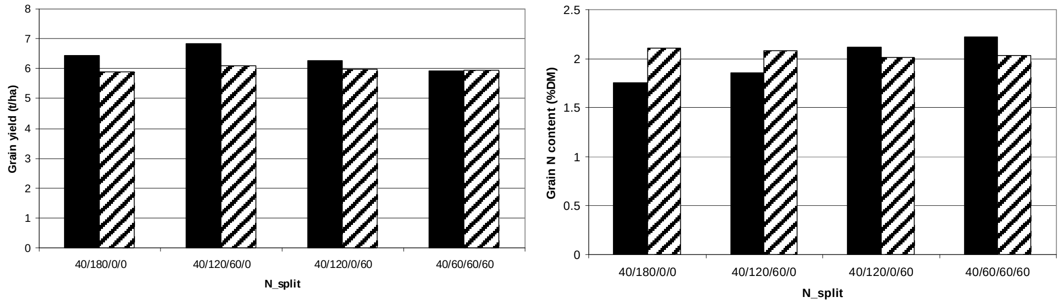

Figure 1 *: Simulation and observation response of grain yield (left) and grain N content (right) to N split (Ntillering/N1cm-ear/Nlast leaf/Nflowering) for cultivar Lloyd with OG_2e parameter set. Full bars represent observed values and streaked bars represent simulated values*

References

Bassu S., Asseng S., Motzo R., and Giunta F. (2009). Optimising sowing date of durum wheat in a variable Mediterranean environment. *Field Crops Research*,111:109-118.
Jeuffroy M.-H., Barbottin A., Jones J.W., and Lecoeur J. (2006). Crop models with genotype parameters. in Working with dynamic crop models,281-307.
Makowski D., Hillier D., Wallach D., Andrieu B., and Jeuffroy M.-H. (2006). Parameter estimation for crop models. in Working with dynamic crop models,101-149.
Wallach D. (2006). Evaluating crop models. in Working with dynamic crop models,Elsevier:11-53.
Wallach D., Buis S., Lecharpentier P., Bourges J., Clastre P., Launay M., Bergez J.-E., Guerif M., Soudais J., and Justes E (2009). A package of parameter estimation methods and implementation for the STICS crop-soil model. Submitted in European Journal of Agronomy.