First steps of calibrating SoySim model for soybean maturity group between 4.0 - 8.0

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ABSTRACT: The objective of this study was to test and calibrate the SoySim model for soybean maturity group (MG) of 4.0 to 8.0. This model was initially developed and calibrated in State of Nebraska, USA, with soybean cultivars of MG ≤ 4.0. Initial testing of this model in Rio Grande do Sul State, Brazil, with cultivars ranging MG between 4.8 and 8.2, resulted poor agreement with observed data. The first step was to fit the crop plant phenology, especially the reproductive stages which is critical to simulation of crop growth and yield. Along with revisions of model functions, model parameters were calibrated against phenology data observed in a field experiments in Santa Maria County, Rio Grande do Sul, Brazil, that was conducted on 2010 to 2014 growing seasons. This paper will report the results of model revision and calibration for the phenological stages R1, R3, R3.5, R4, R5, R6, R7 e R8.
KEY WORDS: *Glycine max* (L.) Merr, crop modeling.

Primeiro passo de calibração do modelo SoySim para cultivares de soja com grupo de maturação entre 4.0 - 8.0

RESUMO: O objetivo deste estudo foi testar e calibrar o modelo SoySim para grupos de maturação de soja (GM) de 4.0 a 8.0. Este modelo foi inicialmente desenvolvido e calibrado no Estado de Nebraska, EUA, com cultivares de soja de grupos de maturação (GM) ≤ 4.0. Testes iniciais do modelo no Estado do Rio Grande do Sul, Brasil, com cultivares variando o GM entre 4.8 e 8.2, resultaram em pobre concordância com os dados observados. O primeiro passo foi ajustar a fenologia da cultura da soja, especialmente os estágios reprodutivos que são críticos para a simulação do crescimento e rendimento. Junto com as revisões das funções do modelo, os parâmetros do modelo foram calibrados com dados observados de fenologia de experimentos de campo no município de Santa Maria, Rio Grande do Sul, Brasil, que foi conduzido nos anos agrícola de 2010 a 2014. Este trabalho irá relatar os resultados da revisão e calibração do modelo para os estágios fenológicos R1, R3, R3.5, R4, R5, R6, R7 e R8.
PALAVRAS-CHAVE: *Glycine max* (L.) Merr, modelagem agrícola.

INTRODUCTION

Crop modeling has become an important tool in scientific research for many crops. In Brazil soybean is the crop with the largest harvest area today, with around 94.5 million ton for the 2014/2015 growing season (USDA, 2015). There are several models that simulate the growth, development and yield for soybean (Ruíz-Nogueira et al., 2001; Setiyono et al., 2010, 2008, 2007; Sinclair, 1986). The Sinclair-Soybean model (Sinclair, 1986) is simpler and require fewer cultivar specific inputs, and is empirical and sensitive to environment (Muchow and Sinclair, 1986). The WOFOST model (Brisson et al, 1998) is a mechanistic but generic crop model, mechanistic, but difficult to be adapted to specific cultivars. The CROPGRO-Soybean (Boote et al, 1998a, Jones et al., 2003) is a soybean specific model but needs extensive genotype-specific inputs calibration for new cultivars. The SoySim model (Setiyono et al., 2010) takes a more balanced approach in terms of requirements for genetic coefficients and calibration for new cultivars.

As crop modeling is being used more widely in Brazil, it is very important have a good model to preview the next growing season, predict impact of climate change, and guide crop management, e.g., defensive applications of insecticides or fungicides. The objective of this study is to how to calibrate the SoySim for soybean maturity group greater than 4.0.

MATERIAL AND METHODS

The data were obtained from irrigated field experiments and a cultivar x sowing date (2010-2014) conducted at the University Federal of Santa Maria, in Santa Maria, Rio Grande do Sul, Brazil (29°43’S, 53°43’W, 95 m above sea level) (Figure 1). The experiment field has is a loam soil under conventional tillage.

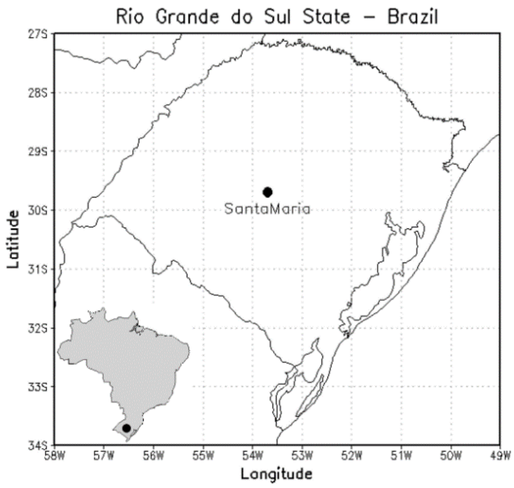

Figure 1. Location of the experiments field and meteorological station of INMET (National Meteorological Institute) at UFSM (University Federal of Santa Maria). The two locations 20 meters apart.

The experiment was conducted in four growing seasons with sowing dates shown below (in bold are the recommended sowing dates in Rio Grande do Sul):

- 2010/2011: **Dec/10/2010** and Jan/08/2011.
- 2011/2012: Sep/24/2011, **Nov/19/2011** and Jan/28/2012.
- 2012/2013: Sep/22/2012, **Nov/03/2012**, **Dec/02/2012** and Feb/06/2013.
- 2013/2014: Sep/27/2013, **Nov/15/2013** and Feb/19/2014.
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The cultivars used in this experiments are listed in Table 1. Note that cultivars TMG 7161 RR Inox and TEC 5936 Ipro were introduced recently in the growing season of 2013/2014. For all experiments, observations of leaf number, R-stages (R1, R3, R3.5, R4, R5, R6, R7 and R8) were based on Fehr and Caviness (1977) scale. The first step is to present the adjustment of the phenological data, because it drives calibration of other parameters.

Table 1. Name, maturity group, and stem termination of thirteen cultivars used in the experiments in Santa Maria, Brazil.

Cultivar	**Maturity Group**	**Stem termination**
NS 4823 RR	4.8	Indeterminate
TMG 7161 RR Inox	5.4	Indeterminate
TEC 5936 Ipro	5.5	Indeterminate
BMX Energia RR	5.5	Indeterminate
BMX Turbo RR	6.0	Indeterminate
NA 5909 RG	6.3	Indeterminate
IAS 5	6.4	Determinate
Igra RA 518 RR	6.6	Semi-determinate
BMX Potência RR	6.7	Indeterminate
Fepagro 36 RR	7.2	Determinate
BRS 246 RR	7.2	Determinate
Bragg	7.3	Determinate
CD 219 RR	8.2	Determinate

The calibration of SoySim model was done for all years, but with the sowing dates on the recommended period (that are in bold above). The validation was done using data of other sowing dates.

The modifications were centered around the cardinal temperatures, including minimum temperature (Tmin) optimal temperature (Topt) and maximum temperature (Tmax) for development, and the maximum development rates (Rmax) for vegetative and reproductive stage. Moreover, a final effect of temperature and photoperiod was changed from multiplication of the two to the most limiting one between the two.

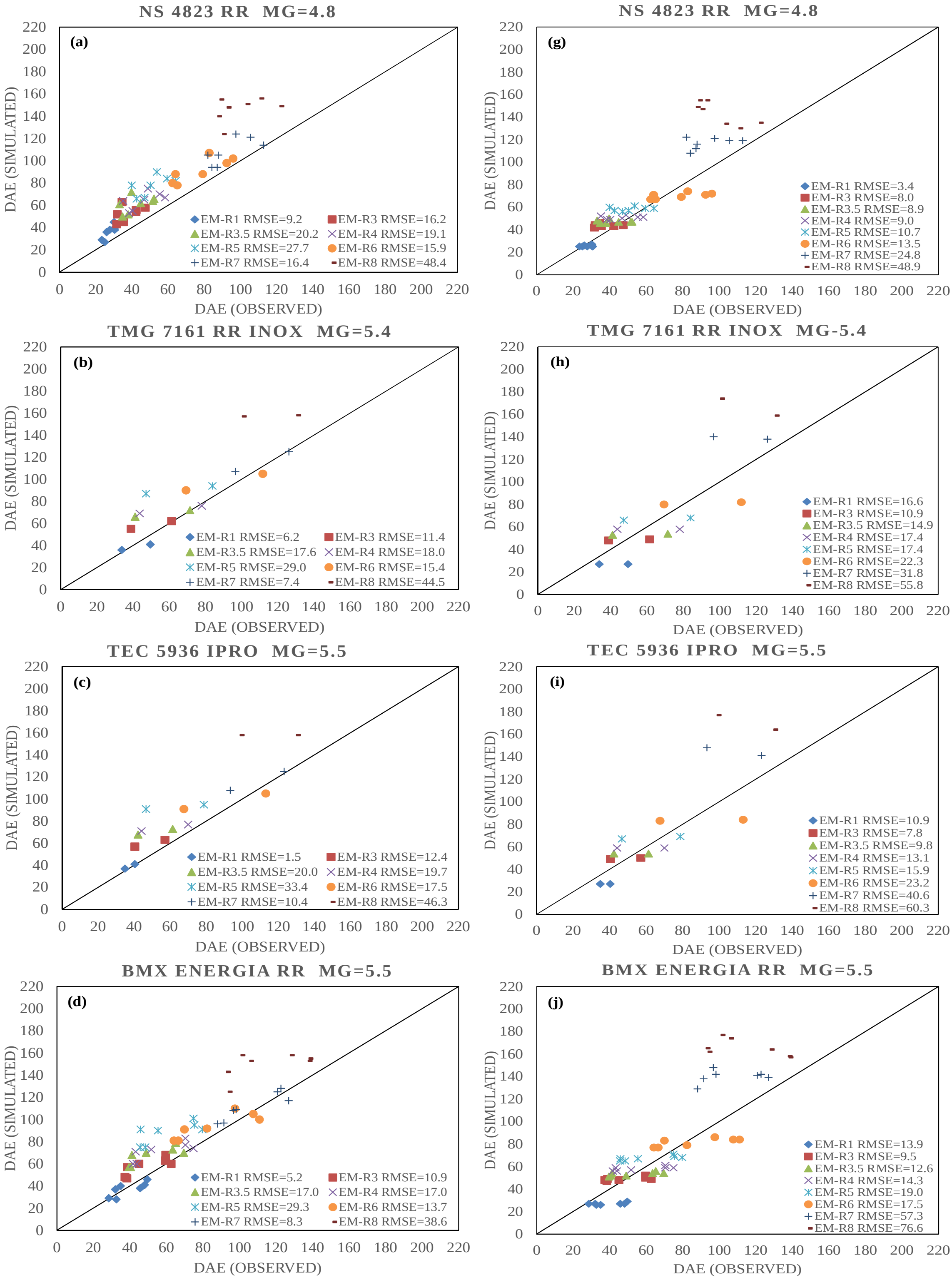
The root mean square error (RMSE) is used to evaluate the model performance and is calculated as:

$$RMSE = \left[\frac{\sum(S_i - O_i)^2}{n}\right]^{0.5} \qquad (1)$$

where ‘s’ is the simulated value, ‘o’ is the observed value, and ‘n’ is the number of observations i.

RESULTS AND DISCUSSION

Based on the results until now, the phenology on the second version (right side in Figure 2) is different. On the first version (left side in Figure 2) the model seems overestimated the R-stages, and on the second version the phenology is less sensitive to different sowing dates so that different sowing dates resulted in the similar R-stage. At the same time, RMSE on the second version is lower, mainly for the R-stages R3, R3.5, R4 and R5. For R7 and R8, the RMSE increased from the first version, and the period between R6 to R7 is too large, it is also a point to be improved, because the total cycle is too long (Figure 2), around 200 days for the MG 6.0, where the observed data is nearby 140 days (Figure 2 e,k).


NS 4823 RR MG=4.8
(a)
EM-R1 RMSE=9.2
EM-R3 RMSE=16.2
EM-R3.5 RMSE=20.2
EM-R4 RMSE=19.1
EM-R5 RMSE=27.7
EM-R6 RMSE=15.9
EM-R7 RMSE=16.4
EM-R8 RMSE=48.4
NS 4823 RR MG=4.8
(g)
EM-R1 RMSE=3.4
EM-R3 RMSE=8.0
EM-R3.5 RMSE=8.9
EM-R4 RMSE=9.0
EM-R5 RMSE=10.7
EM-R6 RMSE=13.5
EM-R7 RMSE=24.8
EM-R8 RMSE=48.9
TMG 7161 RR INOX MG=5.4
(b)
EM-R1 RMSE=6.2
EM-R3 RMSE=11.4
EM-R3.5 RMSE=17.6
EM-R4 RMSE=18.0
EM-R5 RMSE=29.0
EM-R6 RMSE=15.4
EM-R7 RMSE=7.4
EM-R8 RMSE=44.5
TMG 7161 RR INOX MG-5.4
(h)
EM-R1 RMSE=16.6
EM-R3 RMSE=10.9
EM-R3.5 RMSE=14.9
EM-R4 RMSE=17.4
EM-R5 RMSE=17.4
EM-R6 RMSE=22.3
EM-R7 RMSE=31.8
EM-R8 RMSE=55.8
TEC 5936 IPRO MG=5.5
(c)
EM-R1 RMSE=1.5
EM-R3 RMSE=12.4
EM-R3.5 RMSE=20.0
EM-R4 RMSE=19.7
EM-R5 RMSE=33.4
EM-R6 RMSE=17.5
EM-R7 RMSE=10.4
EM-R8 RMSE=46.3
TEC 5936 IPRO MG=5.5
(i)
EM-R1 RMSE=10.9
EM-R3 RMSE=7.8
EM-R3.5 RMSE=9.8
EM-R4 RMSE=13.1
EM-R5 RMSE=15.9
EM-R6 RMSE=23.2
EM-R7 RMSE=40.6
EM-R8 RMSE=60.3
BMX ENERGIA RR MG=5.5
(d)
EM-R1 RMSE=5.2
EM-R3 RMSE=10.9
EM-R3.5 RMSE=17.0
EM-R4 RMSE=17.0
EM-R5 RMSE=29.3
EM-R6 RMSE=13.7
EM-R7 RMSE=8.3
EM-R8 RMSE=38.6
BMX ENERGIA RR MG=5.5
(j)
EM-R1 RMSE=13.9
EM-R3 RMSE=9.5
EM-R3.5 RMSE=12.6
EM-R4 RMSE=14.3
EM-R5 RMSE=19.0
EM-R6 RMSE=17.5
EM-R7 RMSE=57.3
EM-R8 RMSE=76.6
DAE (SIMULATED)
DAE (OBSERVED)

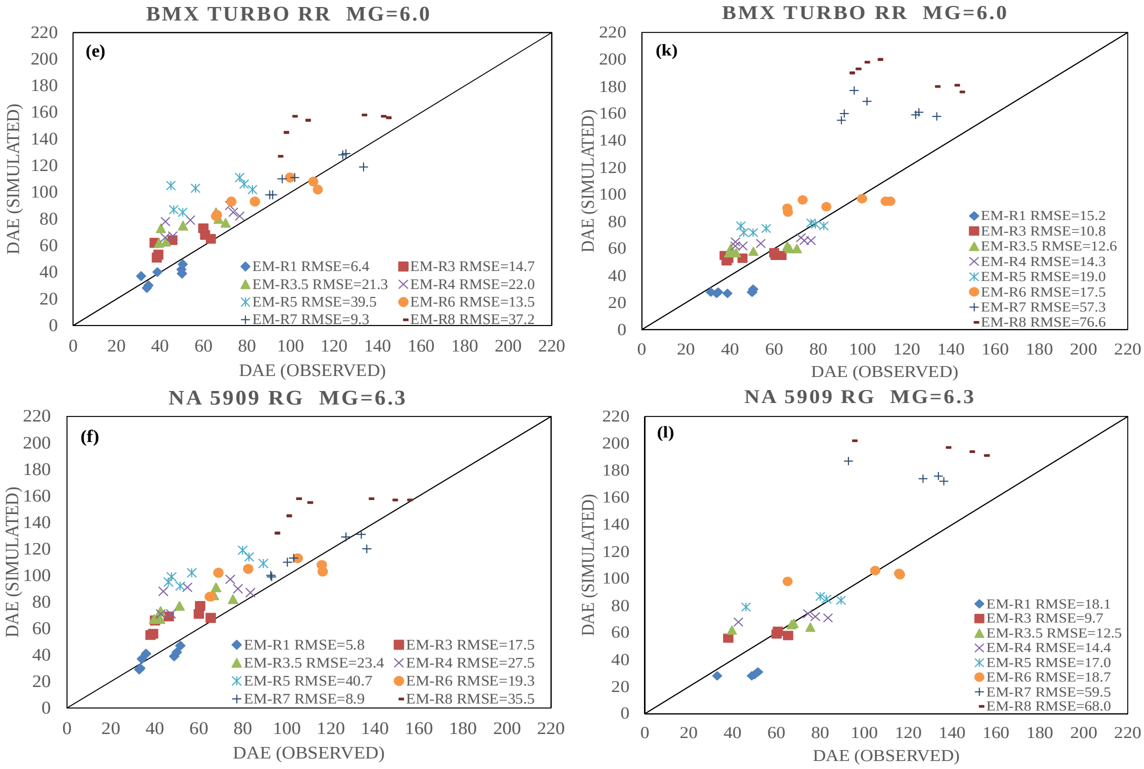


Figure 2. Comparison of two versions of SoySim on duration from emergence (EM) to different R stages. Plots on the left side (a,b,c,d,e,f) are from the original version, while those on the right side (g,h,i,j,k,l) are from the modified version. Cultivar names and maturity group (MG) are shown on top of each plot. All cultivars are indeterminate type.

We are currently still working on the model calibration and modification to improve its performance for phenology prediction, as well as yield simulation.

CONCLUSIONS

The current modification of SoySim has improved simulations on phenology but the RSME for this cultivars is less satisfactory, especially for the R7 and R8 reproductive stages and its less sensitivity to the different planting dates.

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