

Title: Calibration for an Ensemble of Grapevine Phenology Models under Different Optimization Algorithms

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Authors: Chenyao Yang, Christoph Menz, Samuel Reis, Nelson Machado, João A. Santos and Jairo Arturo Torres-Matallana

Corresponding Author: Chenyao Yang

Affiliation of corresponding author: Centre for the Research and Technology of Agro-Environmental and Biological Sciences (CITAB)/ Inov4Agro (Institute for Innovation, Capacity Building and Sustainability of Agri-Food Production), University of Trás-os-Montes and Alto Douro (UTAD), 5000-801, Vila Real, Portugal.
College of Agronomy, Sichuan Agricultural University, Chengdu 611130, China
Telephone: +351 259 350 475

Email: cyang@utad.pt; chenyao_yang@outlook.com

Supplementary Material

Table S1. Selected parameters of phenology models for calibration. Specified initial lower and upper boundary of parameter distribution corresponds to the expanded baseline setting of each parameter range (Table 2) by 100%. The “×” symbol indicates the parameter intended for the calibration of a given model. All model simulations are driven by the daily mean temperature from the first day of the year (t_0).

Parameter abbreviation	Description	Unit	Initial lower bound	Initial upper bound	Model name				
					Growing Degree Day (GDD)*	Richardson	Sigmoid	Triangular	Wang
F^*	Critical state of thermal temperature	degree.days ⁻¹ * or temperature ratios*	0* or 900*	120* or 1500*	×	×	×	×	×
T_b	Minimum development temperature (base temperature)	°C	−5	10		×		×	×
T_{opt}	Optimum development temperature	°C	19	28				×	×
T_{max}	Maximum development temperature	°C	26	44		×		×	×
d	Fitted parameter of sharpness of response curve	/	−30	15			×		
e	Fitted parameter of mid-response temperature	°C	0	30			×		

GDD and Richardson compute the F^ with the degree.days⁻¹ while the other models compute F^* (explained in equation 1) with temperature ratios (between 0 and 1). Accordingly, the initial F^* search boundary is defined as 900–1500 degree.days⁻¹ for GDD and Richardson, and 0–120 for other models. For the GDD model, the base temperature (T_b) is constantly set at 0°C.

Table S2. The optimized parameter values of applied phenology models under different algorithms given the observed flowering data for the variety of Touriga Franca (TF) and Touriga Nacional (TN). These are obtained with the expanded lower and upper boundary of parameter distribution by 100%, relative to the baseline settings. The parameters units and explanations are in Table 2.

Algorithm	GDD	Richardson			Sigmoid			Triangular				Wang				Variety
	F^*	F^*	T_b	T_{max}	F^*	d	e	F^*	T_b	T_{opt}	T_{max}	F^*	T_b	T_{opt}	T_{max}	
MLE	1456.7	905.5	4.3	36.1	41.6	-0.3	14.4	30.0	6.7	27.2	35.8	28.9	4.1	27.7	37.9	Touriga Franca (TF)
SA	1456.7	905.6	4.2	35.6	24.9	-0.1	26.4	31.2	6.9	25.9	25.9	28.5	2.4	26.5	34.9	
SCE-UA	1456.7	907.5	4.3	33.5	37.5	-0.6	13.9	35.6	6.7	23.9	35.5	33.5	4.5	25.8	35.4	
MLE	1417.0	905.6	3.9	43.4	35.3	-15.9	13.3	16.5	9.7	27.5	33.0	25.1	5.4	24.4	31.6	Touriga Nacional (TN)
SA	1414.9	905.0	3.9	42.8	7.7	-0.2	25.9	24.7	9.3	22.4	39.9	34.3	-4.6	22.5	27.8	
SCE-UA	1415.8	905.0	4.0	39.1	35.9	-28.3	13.2	21.9	9.7	23.1	34.3	24.4	5.6	25.1	32.8	

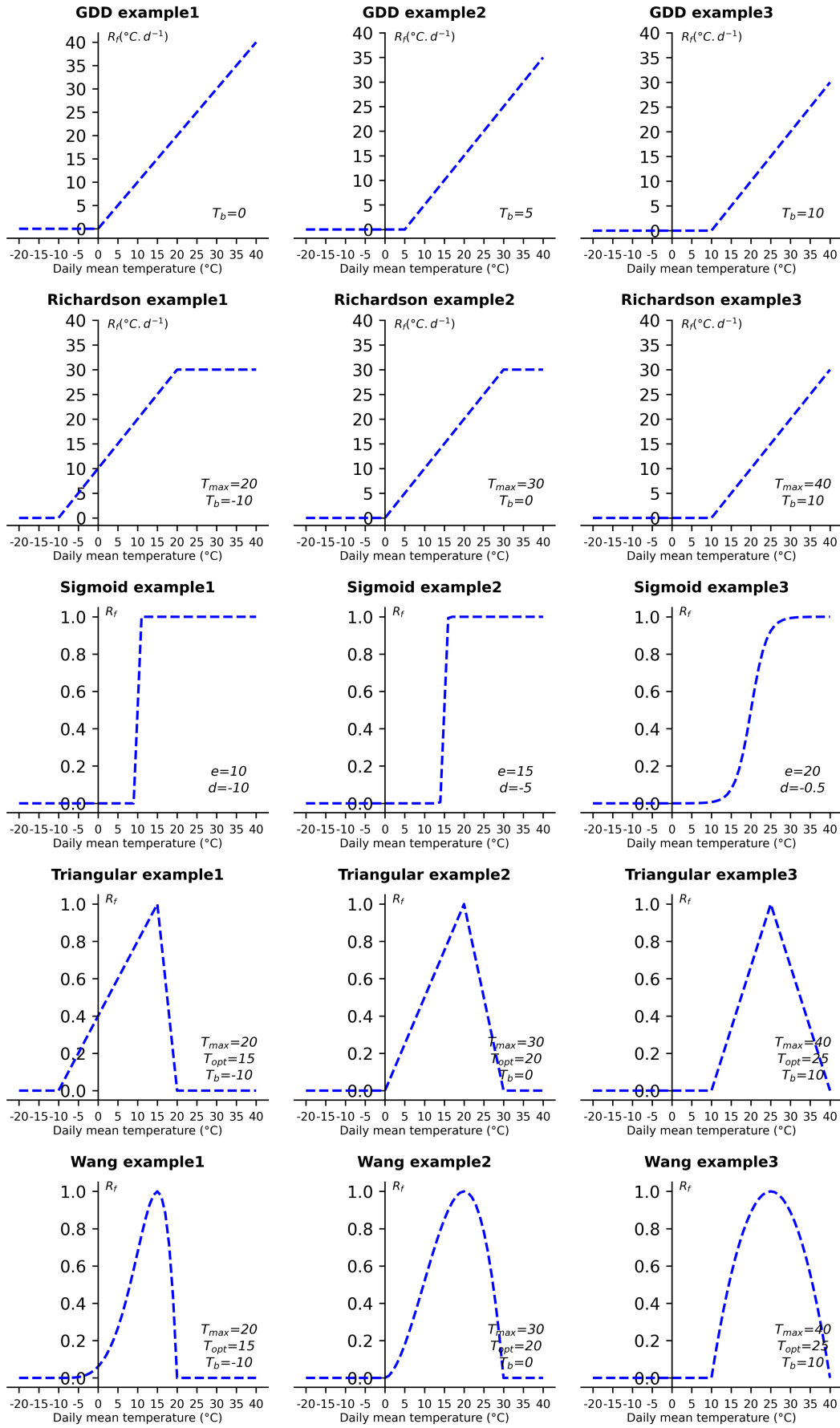


Fig.S1 Graphic representation of examples of different parameter sets provided for each studied phenology model.

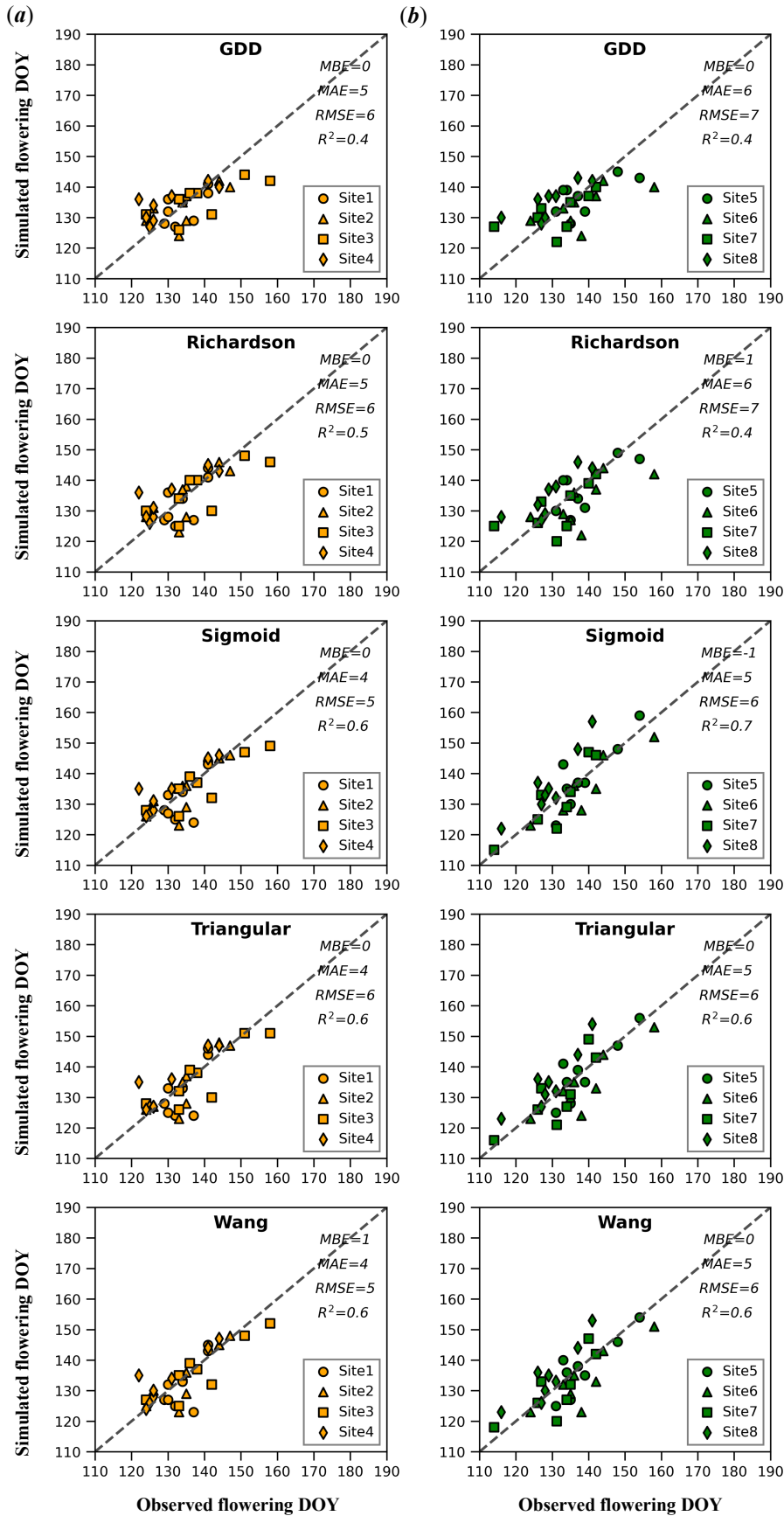


Fig.S2 Comparison between observed and simulated flowering DOY (day of year) by individual phenology model simulations with optimized parameter values from the Maximum Likelihood Estimation (MLE) for (a) Touriga Franca (TF) and (b) Touriga Nacional (TN). Conventional statistics such as Mean Bias Error (MBE), Mean Absolute Error (MAE), Root Mean Squared Error (RMSE) and the coefficient of determination (R^2) are calculated.

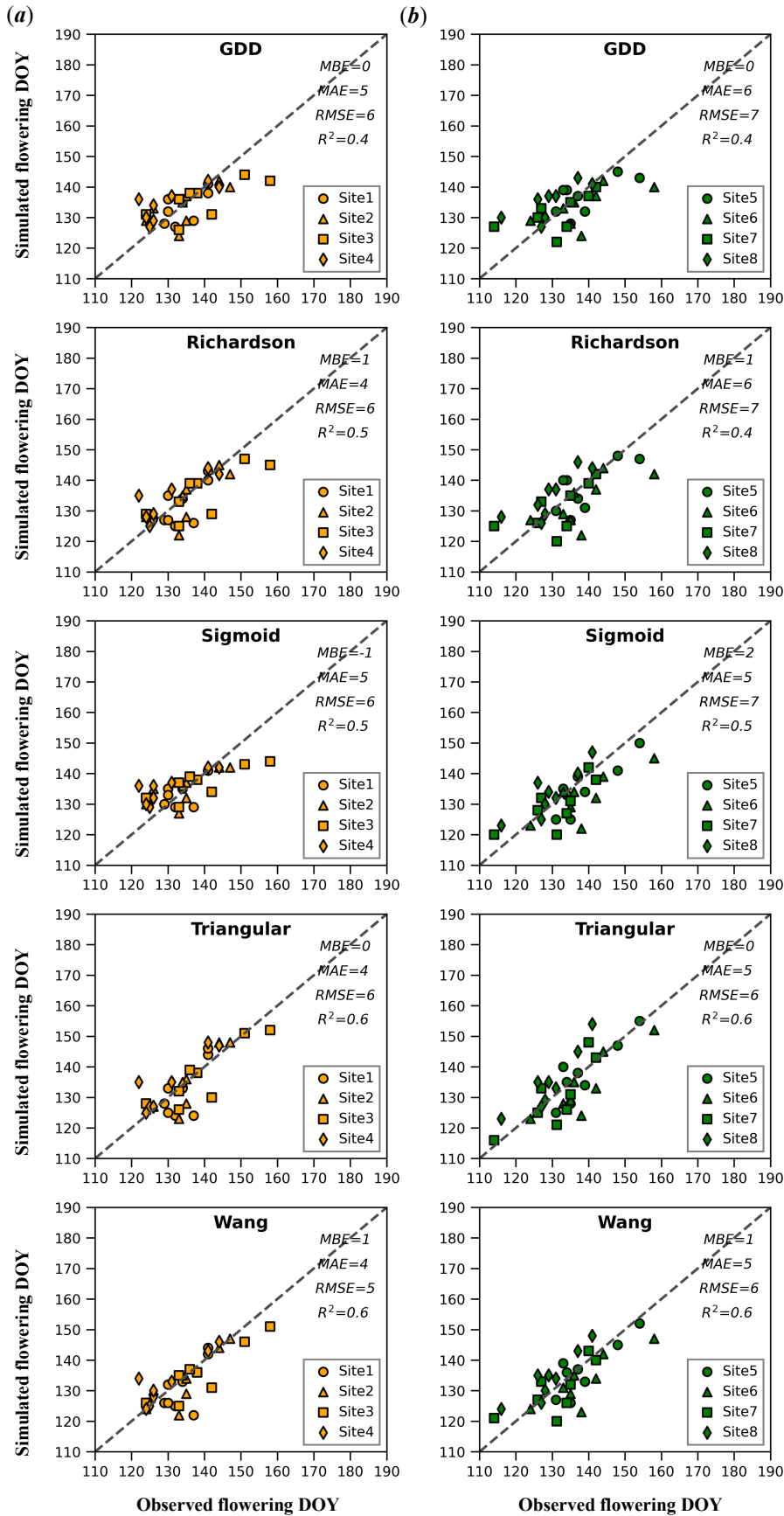


Fig.S3 Comparison between observed and simulated flowering DOY (day of year) by individual phenology model simulations with optimized parameter values from the Simulated Annealing (SA) for (a) Touriga Franca (TF) and (b) Touriga Nacional (TN). Conventional statistics such as Mean Bias Error (MBE), Mean Absolute Error (MAE), Root Mean Squared Error (RMSE) and the coefficient of determination (R^2) are calculated.

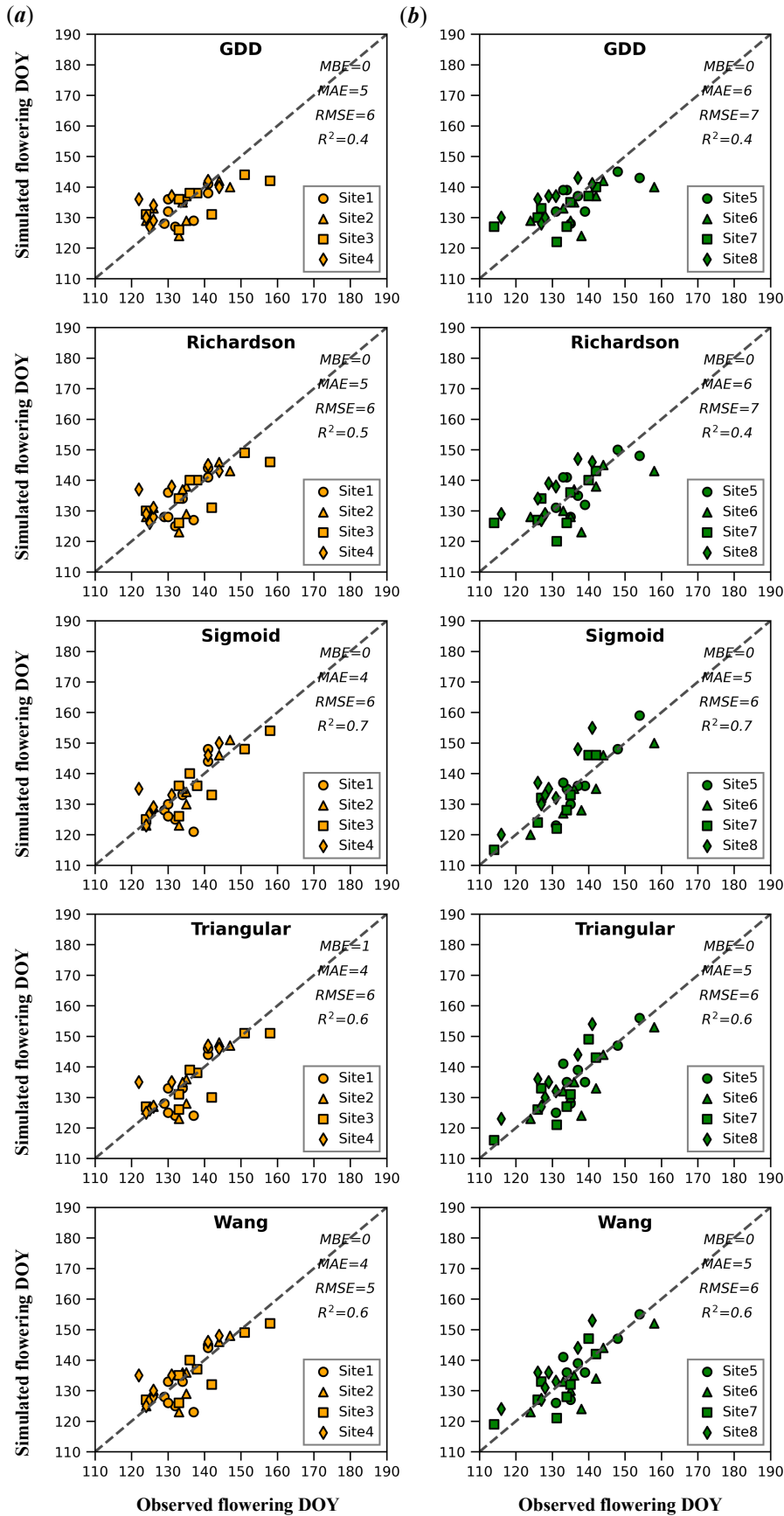


Fig.S4 Comparison between observed and simulated flowering DOY (day of year) by individual phenology model simulations with optimized parameter values from the Shuffled Complex Evolution-University of Arizona (SCE-UA) for **(a)** Touriga Franca (TF) and **(b)** Touriga Nacional (TN). Conventional statistics such as Mean Bias Error (MBE), Mean Absolute Error (MAE), Root Mean Squared Error (RMSE) and the coefficient of determination (R^2) are calculated.