Comparison of DSSAT wheat models performances with different regions and cultivars

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Introduction

Process-based crop models can integrate the complex interactions of soil properties, climatic conditions, management practices, and crop genetic characteristics. They differ in the way they simulate soil-plant-atmosphere processes, in detail of describing crop growth, water use and soil water balances, also in the number of parameters and inputs required (Rötter et al., 2012). The prediction uncertainty of crop models not only differs from one model to the other but also through different environmental conditions (Ramirez-Villegas et al., 2017). In fact, crop models response differently and nonlinearly to different environmental conditions. In addition to the model structure, the number of environments using for the model calibration also impact on the model response to the different environmental condition (Kassie et al., 2016). This paper aims to compare the response of DSSAT v.4.7 wheat models (CERES-Wheat, CROPSIM-Wheat and N-Wheat) with different climates using different cultivars.

Materials and Methods

Experimental data include 26 locations that categorized into four different climates in Iran. Concerning yield level and season length, we classified the locations from as high yielding and long seasons in the northwest of Iran, and short seasons as low yielding in south of Iran. Cultivars were Shahriyar, Pishtaz, Tajan, and Chamran cultivated in cold, temperate, humid and tropical regions of Iran, respectively. Planting time varied from October (in the northwest) to December (in the south), depending on the planting window for each experimental site. A limited measured data including planting, anthesis and maturity dates, and yield was used to calibrate and validate the models. Applying a local sensitivity analysis, we selected the most sensitive parameters for first the phenology, then growth and yield. All the models are executed for potential and attainable conditions.

Results and Discussion

All three models were very robust in simulating the critical phenological growth stages (anthesis and maturity) of the wheat cultivars (Table 1). RMSE for grain yield varied from 341 kg ha-1 to 933 kg ha-1 (Table 1). Nwheat underestimated grain yield of Chamran cultivar for low-yielding locations. The response of the crop models to heat stress varied significantly in the simulation of grain filling duration, biomass production, and grain yield. Biomass simulated by Nwheat model were more sensitive to heat stress effects than CERES-Wheat and CROPSIM-Wheat. CERES-Wheat simulated the higher biological yield than other models. In the Nwheat model, the specific heat stress function accelerated leaf senescence with Tmax>34 °C, explains heat stress effects during grain filling on grain yield in cultivars (Liu et al., 2016). Because the cultivars differ regarding resistance to the end season heat stress, crop models need to consider cultivar-specific tolerance to heat stress for better simulation of temperature effects on wheat cropping systems.

In the CROPSIM-Wheat model, the proportion between grain number and weight was better and the grain weight was more accurate than the other two models, but totally grain weight was not very accurate. In the Nwheat model, the grain number was highly dependent on plant population, and the model seems to be sensitive to plant density. So that in low plant population, the model cannot compensate for the tiller number and grain number.

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Table 1.
Statistical indices of evaluating comparative performance of CERES-Wheat, CROPSIM-Wheat and Nwheat models for predicting anthesis and maturity days and grain yield for four wheat cultivars.

Variable	Models Performance index	Shahriyar			Pishtaz			Tajan			Chamran		
		CSCER	CSCRP	WHAPS	CSCER	CSCRP	WHAPS	CSCER	CSCRP	WHAPS	CSCER	CSCRP	WHAPS
Anthesis day	RMSE	2.43	2.30	3.15	2.41	2.52	1.78	2.57	2.48	2.33	3.86	2.97	3.51
	CV (%)	1.14	1.08	1.48	1.36	1.42	1.00	1.75	1.69	1.59	3.55	2.73	3.23
	d	1.00	1.00	0.99	0.99	0.99	0.99	1.00	1.00	1.00	0.99	1.00	0.99
	ME	0.98	0.98	0.97	0.95	0.95	0.98	0.99	0.99	0.99	0.97	0.98	0.98
	R2	0.98	0.98	0.98	0.99	0.99	0.98	0.99	0.99	0.99	0.98	0.99	0.98
Maturity day	RMSE	2.46	3.01	2.38	2.97	3.43	2.73	2.36	2.68	2.25	3.48	3.42	3.26
	CV (%)	0.96	1.17	0.92	1.33	1.54	1.23	1.25	1.42	1.19	2.29	2.25	2.15
	d	1.00	0.99	1.00	0.98	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
	ME	0.98	0.98	0.99	0.93	0.91	0.94	0.99	0.98	0.99	0.98	0.98	0.98
	R2	0.98	0.98	0.99	0.94	0.96	0.95	0.99	0.99	0.99	0.99	0.99	0.98
Grain yield	RMSE	619	711	702	609	546	627	341	515	568	716	591	933
	CV (%)	10.8	12.4	12.2	10.8	9.7	11.2	7.8	11.8	13.0	14.4	11.9	18.7
	d	0.89	0.87	0.83	0.86	0.90	0.84	0.93	0.80	0.85	0.84	0.91	0.83
	ME	0.61	0.48	0.50	0.47	0.63	0.51	0.76	0.46	0.34	0.48	0.65	0.12
	R2	0.65	0.59	0.51	0.56	0.65	0.53	0.78	0.47	0.59	0.50	0.68	0.56

Keywords: Multi-Model ensemble, CERES-Wheat, CROPSIM-Wheat, Nwheat, Uncertainty.

References:

1. Kassie, B.T., Asseng, S., Porter, C.H., Royce, F.S., 2016. Performance of DSSAT-Nwheat across a wide range of current and future growing conditions. Eur. J. Agron. 81, 27–36. https://doi.org/10.1016/j.eja.2016.08.012
2. Liu, B., Asseng, S., Liu, L., Tang, L., Cao, W., Zhu, Y., 2016. Testing the responses of four wheat crop models to heat stress at anthesis and grain filling. Glob. Chang. Biol. 22, 1890–1903. https://doi.org/10.1111/gcb.13212
3. Ramirez-Villegas, J., Koehler, A.K., Challinor, A.J., 2017. Assessing uncertainty and complexity in regional-scale crop model simulations. Eur. J. Agron. 88, 84–95. https://doi.org/10.1016/j.eja.2015.11.021
4. Rötter, R.P., Carter, T.R., Olesen, J.E., Porter, J.R., 2011. Crop–climate models need an overhaul. Nat. Clim. Chang. 1, 175.