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Predicting growth and yield of wheat using plants growth simulation model

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Key words: Wheat, simulation, phonological stages, harvest index, AquaCrop model.

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Abstract

This research was carried out in order to simulation of wheat growth under regimes of water different using AquaCrop model in Sistan region at 2012-13. In this research were studied parameters of phonological stages, yield and harvest index of wheat. The simulation results showed that model simulates all parameters measured well only for treatments of optimum irrigation and moderate stress. So that $RMSE_n$ for parameters simulated and measured in these two treatments was achieved less than 10%. But this model hasn't enough accuracy for simulating parameters measured in treatments of severe stress and very severe stress.

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Introduction

Wheat (*Triticum* aestivum) is a cereal grain, originally from the Levant region of the Near East and Ethiopian Highlands, but now cultivated worldwide (Belderok *et al.*, 2000). This grain is grown on more land area than any other commercial food. World trade in wheat is greater than for all other crops combined. Globally, wheat is the leading source of vegetable protein in human food, having a higher protein content than other major cereals, maize (corn) or rice (Cauvain *et al.*, 2003).

Since the first aim in wheat production is to gain higher yields, scientists are doing researches in this matter. One of these researches is crops growth simulation using models. One of these models is AquaCrop. AquaCrop is a crop water productivity model developed by the Land and Water Division of FAO. It simulates yield response to water of herbaceous crops, and is particularly suited to address conditions where water is a key limiting factor in crop production (Steduto *et al.*, 2009).

AquaCrop attempts to balance accuracy, simplicity, and robustness. It uses a relatively small number of explicit and mostly-intuitive parameters and input variables requiring simple methods for their determination (Raes *et al.*, 2009).

AquaCrop is mainly intended for practitioners such as those working for extension services, governmental agencies, NGOs, and various kinds of farmers associations. It is also of interest to scientists and for teaching purposes, as a training and education tool related to the role of water in determining crop productivity. AquaCrop includes the following sub-model components: the soil, with its water balance; the crop, with its development, growth and yield; the atmosphere, with its thermal regime, rainfall, evaporative demand and CO_2 concentration; and the management, with its major agronomic practice such as irrigation and fertilization (Steduto *et al.*, 2009; Raes *et al.*, 2009).

Since crops growth simulation is one advantage method for studies in matters of crops growth and yield, the present study was carried out with the main objective calibration and performance of the AquaCrop model under varying water regimes on wheat in Zabol region.

Materials and methods

AquaCrop Modeling

AquaCrop was parameterized and tested using data from a study during 2012-13 that was conducted at Zabol (61°20´ N, 31°2´ E, and 487 m above mean sea level), in Iran earth. The experimental site is characterized by a warm dry climate; mean precipitation is 50 $mm.yr^{-1}$ with no rainfall during the summer. It has mean minimum, mean maximum and average air temperatures of 16, 30 and 29°C, respectively.

The field experiments had the objective of analyzing the effect of different water regime on wheat yield and water use efficiency. The experimental design was a randomized complete block with four levels of irrigation included: optimum irrigation (field capacity (FC)) moderated stress (80% FC), severe stress (60% FC) and very severe stress (50% FC). The version of AquaCrop (v. 3) used in this study. AquaCrop was parameterized using data from the 2012-13 cropping season that provided the most extensive in-season plant measurements. The performance of the parameterized model was tested by simulating wheat yield and water use efficiency in the 2012-13 season. AquaCrop requires the input data files for climate, crop, soil, irrigation, and initial soil water (SWini) conditions (Raes *et al.*, 2009), which were assembled using the field data described below.

Management Practices

The wheat cultivar of Hamoon was sown by hand during the 1 October, in 25 cm rows, at a density of 400 seeds m^{-2} in 2012-13. The plots were 2 m wide by 4 m long and managed. The first irrigation occurred a few days after seeding, with observed emergence about 6 d later. Field was monitored for pests and weeds, and pesticides were applied as needed. Chemical fertilizer (N, P and K) as urea, super phosphate triple and sulfate potassium were used according to conventional consumption of region. Wheat was harvested by hand in date 10 May 2013.

Model Parameters and Input Data

Weather Data

The weather data required by AquaCrop are the daily values of minimum and maximum air temperature, ETo, rainfall and solar radiation (Raes *et al*., 2009, Steduto *et al*., 2009). The standard procedure is to calculate daily reference evapotranspiration (ETo) following the FAO Penman–Monteith equation (Allen *et al*., 1998).

Soil Data

The required input soil parameters for AquaCrop are the saturated hydraulic conductivity (Ksat), volumetric water content at saturation (θsat), field capacity (θFC), and permanent wilting point (θPWP).These parameters were derived from field measurements.

Wheat Growth Measurements

During the 2012 season, canopy development was monitored in terms of growth stages and aboveground biomass. Before cutting the plants at the ground level, growth stage was recorded.

AquaCrop requires identifying generic growth stages of time to emergence, maximum canopy cover, start of senescence, and maturity. For the purpose of AquaCrop simulation, time to emergence, maximum canopy cover, and start of senescence were based on field observations.

Model Evaluation

Several statistics methods were used to compare the simulated and observed results. In this paper evaluated model performance using the root means square error normalized (RMSEn) (Rinaldy *et al*., 2003).

$$RMSE_n = 100 \left(\sum_{i=1}^{n} (P_i - O_i)^2 / n\right)^{0.5} / O_{mean}$$

Where Pi is the simulated value, Oi is the measured value and n is the number of measurements. RMSE was stated as percentage of simulated amounts than observed amounts. So according to above descriptions, RMSE <10% is excellent, 10% < RMSE < 20% is well, 20% < RMSE < 30% is moderate, RMSE > 30% is weak (Rinaldy *et al*., 2003).

Results and discussion

Simulation of phonological growth stages

Simulation of phonological growth stages showed that model in treatments of optimum irrigation and moderate stress simulate stages of flowering, seed milky and ripening well. So that RMSEn for flowering obtained 1.49% and 2.25%, for seed milky obtained 2.04% and 2.11% and for ripening obtained 1.09% and 2.54% in treatments of optimum irrigation and moderate stress respectively. But this model hasn't enough accuracy for simulating these growth stages in treatments of severe stress and very severe stress. So that RMSEn for flowering obtained 10.02% and 12.36%, for seed milky obtained 9.98% and 10.44% and for ripening obtained 10.31% and 19.77% in treatments of severe stress and very severe stress respectively (Table 2, 3 and 4). Alizadeh *et al*, (2010) showed that AquaCrop model simulate wheat phonological growth stages with high accuracy in optimum irrigation treatments than low-water treatments.

Table 1. Simulated and measured flowering stage in wheat (DAP†).

treatment	flowering		RMSEn (%)
	measured	simulated	
field capacity (FC)	193	195	1.49
moderated stress (80% FC)	187	191	2.25
severe stress (60% FC)	179	170	10.02
very severe stress (50% FC)	172	164	12.36

† Days after planting

Table 2. Simulated and measured seed milky stage in wheat (DAP†).

treatment	seed milky		RMSEn (%)
	measured	simulated	
field capacity (FC)	206	209	2.04
moderated stress (80% FC)	205	209	2.11
severe stress (60% FC)	198	191	9.98
very severe stress (50% FC)	189	180	10.44

Simulation of seed yield

Table 5 show results of model simulation for seed yield. According to tale was seen that simulated seed yield in treatments of optimum and moderate irrigation has coincidence well with observed seed yield. So that model simulation was excellent (RMSEn obtained 5.87% and 8.44% in treatments of optimum irrigation and moderate stress respectively) (Table 5). The results similar to this research were reported by García-Vila and *et al.*, (2009).

Table 3. Simulated and measured seed ripening stage in wheat (DAP).

treatment	seed ripening		RMSEn (%)
	measured	simulated	
field capacity (FC)	216	217	1.09
moderated stress (80% FC)	209	212	2.54
severe stress (60% FC)	200	195	10.31
very severe stress (50% FC)	199	190	19.77

Table 4. Simulated and measured seed yield in wheat.

Treatment	seed yield		RMSEn (%)
	measured	simulated	
field capacity (FC)	3640	3708	5.87
moderated stress (80% FC)	2480	2695	8.44
severe stress (60% FC)	977	956	13.71
very severe stress (50% FC)	547	505	14.99

Simulation of harvest index

According to phonological growth stages and seed yield, simulation of harvest index showed that model in treatments of optimum irrigation and moderate stress simulate harvest index well. So that RMSEn for harvest index was achieved 3.12% and 7.55% in treatments of optimum irrigation and moderate stress respectively. But this model hasn't enough accuracy for simulating harvest index in treatments of severe stress and very severe stress. So that RMSEn for harvest index obtained 15.8% and **20.04% in treatments of severe stress and very severe stress respectively (Table 6).

Table 5. Simulated and measured harvest index in wheat.

treatment	harvest index		RMSEn (%)
	measured	simulated	
field capacity(FC)	39.6	40.4	3.12
moderated stress (80% FC)	35.3	37.5	7.55
severe stress (60% FC)	32.3	30.1	15.8
very severe stress (50% FC)	30.0	26.4	20.04

Table 6. Simulated and measured harvest index in wheat

treatment	harvest index		RMSEn (%)
	measured	simulated	
field capacity (FC)	39.6	40.4	3.12
moderated stress (80% FC)	35.3	37.5	7.55
severe stress (60% FC)	32.3	30.1	15.8
very severe stress (50% FC)	30.0	26.4	20.04

García-Vila and *et al.*, (2009) reported that performance of AquaCrop model for simulation of harvest index in optimum irrigation treatment is higher than low-water treatments.

Conclusion

In this research parameterized AquaCrop for wheat under different irrigation regimes and tested its performance under a hot and dry climate in Iran earth region. Model simulate phonological growth stages, yield and harvest index across four levels of irrigation regimes with high accuracy particularly in treatments of optimum irrigation and moderate stress.

References

Alizade HA, Nazari B, Parsinejad M, Ramazani Etedali H, Janbaz HR. 2010. Evaluation of AquaCrop model in low irrigation management of wheat in Karaj region. Iranian Journal of Irrigation and Drainage **2(4),** 273-283. (In Persian with English Summery).

Allen RG, Pereira LS, Raes D, Smith M. 1998. Crop evapotranspiration. Guidelines for computing crop water requirements. Irrigation and Drainage, paper no. 56. FAO, Rome.

García-Vila M, Fereres E, Mateos L, Orgaz F, Steduto P. 2009. Deficit irrigation optimization of cotton with AquaCrop. Agronomy Journal **101,** 477–487.
http://dx.doi.org/10.2134/agronj2008.0179s

Belderok RB, Hans M, Dingena DA. 2000. Bread-Making Quality of Wheat, Springer, 3 p.

Cauvain SP, Cauvain PC. 2003. Bread Making. CRC Press. 540 p.

Raes D, Steduto P, Hsiao TC, Fereres E. 2009. AquaCrop-The FAO crop model for predicting yield response to water: II. Main algorithms and software description. Agronomy Journal **101,** 438–447.
http://dx.doi.org/10.2134/agronj2008.0140s

Rinaldy M, Losavio N, Flagella Z. 2003. Evaluation of OILCROP-SUN model for sunflower in southern Italy. Agricultural Systems **78,** 17-30.

Steduto P, Hsiao TC, Raes D, Fereres E. 2009. AquaCrop-The FAO crop model to simulate yield response to water: I. Concepts and underlying principles. Agronomy Journal **101,** 426–437.
http://dx.doi.org/10.2134/agronj2008.0139s