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PREDICTION OF GROWTH AND YIELD OF DIFFERENT WHEAT VARIETIES UNDER RAINFALL CONDITION BY AQUACROP PROGRAM

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Abstract

The experiment was conducted at the research farms of the college of Agriculture, University of Duhok, Iraqi Kurdistan Region during the growing season 2015-16, consisting of three wheat varieties (Abu-Graib, Al-Rashid and Sham-6) cultivated under rainfed (RF) condition. The AquaCrop model was calibrated with experiment generated data sets of 2015-16. The results revealed that the maximum measured and model simulated production parameters were obtained from Sham-6 wheat variety; 4.540, 4.923, 10.735, 9.569 and 15.275, 14.492 ton/ha for the production parameters of grain yield, dry matter and biomass of the wheat varieties respectively. On the other hand, the minimum values of same parameters were obtained from Abu-Graib variety of wheat which were (3.418, 3.566), (6.982, 7.795) and (10.400, 11.361) ton/ha for both measured and simulated values excluding the simulated dry matter which was found by AL-Rashid wheat variety. It was also observed that the model predicted grain yield, dry matter, and biomass yield by AquaCrop model was with prediction error of 4.33%, 21.3% and 8.43%; for grain yield and dry matter of 11.64%, 17.47% and 10.86% for Abu-Griab, Al-Rashid and Sham-6 wheat varieties respectively. At the same time the model predicted error of biomass and it was noticed that the maximum percentage was obtained from Abu-Graib wheat variety which was 9.24% while the minimum value of error percentage found in Sham-6 variety was 5.10%.

Moreover, relationships between the model simulated and observed grain yield, dry matter and biomass yield was observed that the R^2 (coefficient of determination) for grain yield was 0.844, whereas R^2 for dry matter and biomass were 0.561and 0.864 respectively. Water productivity of wheat varieties was observed that the highest crop water productivity for grain yield, dry matter and biomass was found by Sham-6 variety and for both measured and model simulated values, while the lowest values were obtained by Abu-Graib and Al-Rashid varieties. It was demonstrated that highest value of Harvest Index (HI) was found in Sham-6 wheat variety for both measured and simulated values which were 0.297 and 0.340 respectively, whereas the lowest (HI) value was obtained from Abu-Graib variety and for both measured and model simulated during the wheat crop growth of 2015-16.

Key words: AquaCrop model, Rainfed farming, Crop water productivity, Wheat variety.

Introduction

Field crop production is the main source of livelihood for many rural families in the Kurdistan Region of Iraq (IKR), each of wheat and barley serving as the two main crops under cultivation. Wheat fields in the Kurdistan Region occupy approximately 570,000 hectares and produce in the average an estimated 500,000 tons each year. Wheat production is mainly rain-fed, but rain dependent (Mazid, 2015). Cultivation is heavily influenced by rainfall (quantity and distributions). As a result, both wheat cultivation areas and yields have large variation. The yield ranged between 400 and1300 kg/ha and this is very low and there is potential opportunity to improve it significantly. The Region is expected to play a key role in achieving high self-sufficiency of food, though there are many technologies to be disseminated. For example, extensive agriculture is common in the rain-fed cultivation areas covering majority of land in Kurdistan Region of Iraq. It is considered that introduction of suitable wheat varieties and improved cultivation techniques such as fertilizing, pest control and harvesting are necessary to improve the yield. Furthermore, supplemental irrigation techniques need to be introduced so that the limited water resources could be utilized to maximize crop productivity (Mazid, 2015).

Many sophisticated crop-growth models, based on physiological processes, have been developed and applied in water management projects with varying degrees of success. Many of these models however, have not yet been tested under DI in arid conditions of GRB. Some widely acceptable cereal models are hybrid models, such as CERES (Gabele, 2002), and DSSAT that simulate the growth of crops under water-limited conditions (Setiyono, 2007); but due to improper simulations of evapotranspiration, the crop yield reductions estimated by this model should be taken with caution (Cavero *et al.*, 2000). Nearly, all these models are complicated, demanding advanced skills for their calibration and operation and need large number of parameters (Heng *et al.*, 2009). To address these concerns and in trying to achieve an optimum balance between accuracy, simplicity and robustness, a new crop simulation model named AquaCrop has been developed by FAO (Steduto *et al.*, 2009; Raes *et al.*, 2009).

Crop growth simulation models of varying complexity have been developed for predicting the effects of soil, water and nutrients on grain and biomass yields and water productivity of different crops. Aqua Crop, a crop water productivity model developed by the Land and Water Division of FAO and released during 2009 (Steduto *et al.*, 2009), and used to simulate yield response to water of several herbaceous crops. Mkhabela & Bullock (2012) evaluated AquaCrop for wheat crop grown at five different experimental sites; they concluded that the AquaCrop can be a valuable tool for simulating both wheat grain yield and soil water content on the Canadian Prairies. Salemi *et al*., (2011) used the AquaCrop model for simulating the grain yield and water productivity of winter wheat grown in the Gavk-huni River Basin (GRB), central Iran. Bread wheat (*Triticum aestivum* L.) is the most important cereal crops in Kurdistan region as well as in Iraq. There is an urgent need to improve and stabilize the production of this strategic commodity. Wheat is an important crop for farmers in IKR in terms of the area allocated (on average 51% of the farm area is allocated to wheat) as well as the household income (wheat accounts for more than 55% of the average income) (Mazid, 2015).

The main objectives include:

1. Identifying the available wheat varieties with better parameters in terms of crop production (grain yield, dry matter, biomass, and crop water productivity and harvest index).
2. To evaluate this model under Rainfed farming of three varieties of wheat production (Abu-Graib, Al-Rashid and Sham-6) in a semi-arid region of Duhok, Iraqi Kurdistan.

Materials and Methods

Site description: The experiment was undertaken in the experimental farm of Agriculture College at Sumail, 13 km west of Duhok city (36°51'N,52°02'E) and at an altitude of 473.0 m above sea level (Omer *et al*., 2016). The test area had a relatively constant south facing slope of about 1%., which provides assured irrigation during the crop growth period. Climate data during the experiment period for AquaCrop model was acquired from the Agriculture College Weather Station. The rainfall, maximum and minimum temperature and relative humidity variations as observed during the experiment period for 2015-16 is shown in Table 1.Weather parameters of minimum and maximum temperature, Evapotranspiration (ET), and rainfalls during the wheat varieties crop growth period in have been depicted in Figs. 1, 2 and 3, respectively.

Field layout and experiment details: The data on growth and yield parameters of wheat crop varieties, soil, soil moisture and other input parameters required for model application were obtained from the field experiments conducted in the research farm of Agriculture College during the winter season during year 2015-2016. The field experiment comprised of sowing three varieties of wheat including (Abu-Graib, Al-Rashid and Sham-6 under semiarid condition of Duhok Iraqi-Kurdistan; arranged in RCBD design with four replications. The region under study was received in the current season total amount of annual rainfalls of 481.5 mm. Wheat varieties were sown with row spacing of 20cm in the plot of 6 × 3.5 m size. Plot to plot spacing was maintained at 2m and replications were separated by 2.75m in the entire experiment. The physical properties of soil for the experiment are presented in Table 2.

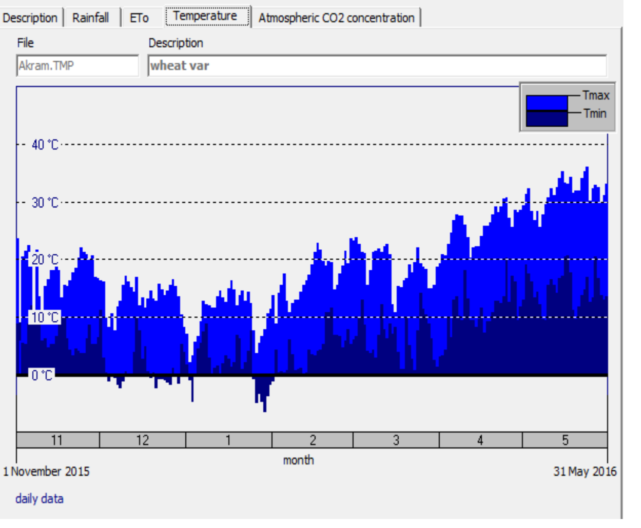

Fig. 1. Weather parameter of minimum and maximum temperature during the wheat varieties crop growth period in 2015-16.

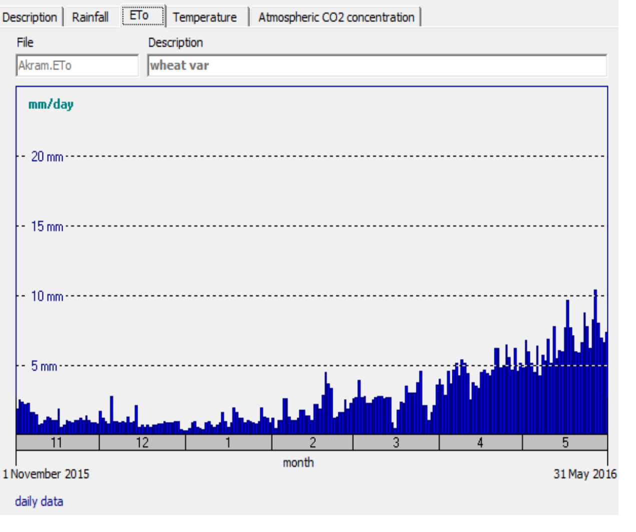

Fig. 2. Weather parameter of evapotranspiration (Eto) during the wheat varieties crop growth period in 2015-16.

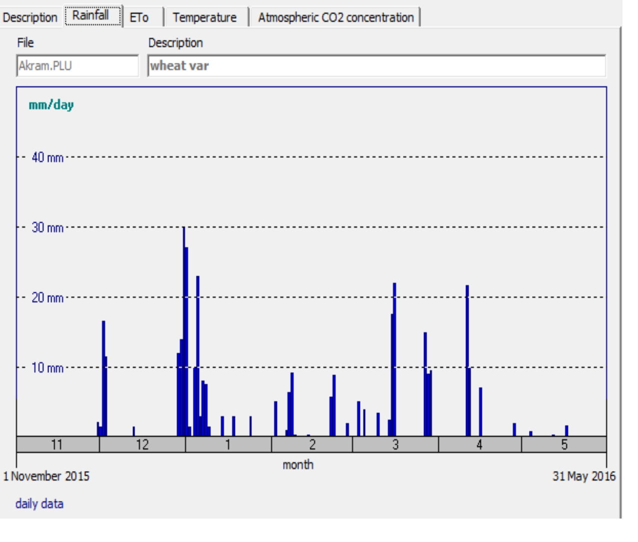

Fig. 3. Weather parameter of rainfall during the wheat varieties crop growth period in 2015-16.

Table 1. Growing season (23/11/2015–26/5/2016)weather summary for location study, Sumail – Duhok.

Year	Station	Ave. Daily Max Tem. ℃	Ave. Daily Min. Tem ℃	Seasonal relative humidity, RH (%)	Seasonal rainfalls (mm)	Ave. Solar radiation (w/m²)	Wind speed (m/s)	ET (mm)
2015-2016								
December	Agric. College, Duhok Uni.	13.32	1.24	74.00	87.00	88.58	1.697	0.90
January		13.94	2.55	76.84	171.8	93.03	0.574	0.85
February		16.45	3.01	57.86	7.6	149.6	0.753	1.94
March		19.95	7.87	69.39	151.4	163.64	0.748	2.32
April		26.48	10.78	52.23	18.7	228.97	0.826	4.34
May		33.34	10.16	36.77	6.4	256.1	0.916	6.36

Table 2. Some physical soil properties of study location*.

Depth (cm)	Soil texture class	PSD (%)			Bulk density Mg/m^3	F.C VOL %	P.W.P VOL %	AW cm/m
		sand	silt	Clay				
0-30	SIC	4.48	51.52	44.00	1.29	41.1	26.1	0.15
30-60	SIC	5.23	46.81	47.96	1.27	49.9	27.7	0.14
60-90	SIC	4.49	49.62	45.89	1.28	41.4	26.6	0.15
90-120	SIC	3.75	53.50	42.75	1.30	40.6	25	0.16

*PSD; Particle size distribution, FC; Field capacity, PWP; Permanent wilting point, AW; Available water

Table 3. Agronomic information for the three varieties of wheat crop (*Triticum aestivum* L.).

Year	Station	Crop genotype	Planting date	Length of growing day	Harvesting date
2015-2016	Agric. College	Abu-Graib	23/11/2015	183	26/5/2016
		Al-Rashid		190	
		Sham-6		188	

Table 4. Conservative crop production parameters of wheat varieties.

Calendar	(*Triticum aestivum* L.) varieties		
	Abu-Graib	Al-Rashid	Sham-6
From day one after sowing 23/November/2015		**Day**	
Emergence	15-Dec	15-Dec	15-Dec
Max. canopy cover	11-Apr	17-Apr	14-Apr
Max. root depth	4-Apr	19-Apr	18-Apr
Flowering	1-Apr	8-Apr	5-Apr
Start canopy senescence	18-Apr	24-Apr	24-Apr
Maturity	24-May	31-May	29-May
Length of growing (day)	183	190	188

Moreover, Reference evapotranspiration (ET) was estimated using ET Calculator, version, 3.2 September, 2012, FAO (Food and Agriculture Organization) Land and Water Division, Italy Rome and used in AquaCrop as one of the input climatic parameter. The data on initial condition, soil, climate and crop growth obtained from field were used in AquaCrop model to generate crop yield, biomass and water productivity (WP) of the three varieties of wheat crop treatments including Abu-Graib, Al-Rashid, andSham-6 and which their agronomic information is presented in Tables (3 and 4).

The harvesting was done during the maturity stage on 26/5/2016 with grain moisture content of about 13-15%.Crop growth parameters *viz.* above ground biomass (AGB), grain yield (GY),mass of dry matter, harvest index (HI), crop water productivity (CWP) were measured for the observed and simulated treatments.

Input data for the AquaCrop Model: Operation of AquaCrop model requires input data consisting of climatic parameters, crop, soil and field and irrigation management data.

Climate data: The climate data required for AquaCrop model are daily rainfall, minimum and maximum air temperature, reference crop evapotranspiration (ET), and mean annual carbon dioxide concentration (CO_2). ET was estimated by ET calculator using the daily maximum and minimum temperature, wind speed at 2 m above ground surface and hours of bright sunshine.

Crop data: In AquaCrop program, the crop file contained phenological crop growth stages with canopy and root development, evapotranspiration, water, fertility, and temperature stress parameters. The list of crop parameters with unit and their value used in this experiment is presented in Table (4).

Soil parameters: Soil parameters of experiment site required for AquaCrop model as input data are number of soil horizons, soil texture, field capacity (FC), permanent wilting point (PWP), saturated hydraulic conductivity (Ksat), volumetric water content at saturation (sat) and initial soil moisture content and its salinity.

Table 5. Grain yield, Dry matter and Biomass of wheat varieties express in (ton/ha) during wheat crop growth in 2015-16.

Wheat Var.	Production parameter of wheat varieties (ton/ha).			
		Grain yield	Dry matter	Biomass
Abu-Graib	Measured	3.418	6.982	10.400
	Simulated	3.566	7.795	11.361
Al-Rashid	Measured	3.295	9.155	12.450
	Simulated	3.997	7.556	11.553
Sham-6	Measured	4.450	10.735	15.275
	Simulated	4.923	9.569	14.492

Table 6. Prediction error of grain yield (GY), dry matter (DM) and biomass of wheat during application the AquaCrop model.

Wheat Var.	Production parameter of wheat varieties (ton/ha)		
	GY Pe (± %)	DM Pe (± %)	Biomass Pe (± %)
Abu-Graib	4.33%	11.64%	9.24%
Al-Rashid	21.30%	17.47%	7.20%
Sham-6	8.43%	10.86%	5.10%

Results and Discussion

Application of the AquaCrop model was accomplished by using the observed values from the field experiment during 2015-16 as model input parameters and then the model was operated to obtain the simulated output in terms of grain yield, biomass and water productivity.

The model parameters are presented in Table (5). The model predicted outputs were compared with the observed grain yield, dry matter, biomass under cultivating different varieties of wheat crop. Observed and model simulated grain yield, dry matter and biomass of wheat varieties revealed that the maximum measured and model simulated production parameters found from Sham-6 variety, were (4.540 and 4.923) and (10.735 and 9.569) and (15.275 and14.492) ton/ha for the production parameters of grain yield, dry matter and biomass of the Abu-Griab, Al-Rashid and Sham-6 respectively. While the minimum values of same parameters obtained from Abu-Graib variety, were (3.418 and 3.566) and (6.982and 7.795) and (10.400 and11.361) ton/ha for both measured and simulated values, with the exceptionof simulated dry matter which was found by AL-Rashid variety.

It was observed from Table 5 that the grain varied from 3.418, 3.295 and to 4.540 ton/ha during the model calibration and 3.82 to 4.75 ton/ha during the validation of the AquaCrop model under different irrigationregimes. The model prediction error was estimated and presented in Table (6). It was observed that the grain yield prediction during2013-14 data set resulted in absolute prediction error of 4.33 %, 21.30 % and 8.43% for each of Abu-Griab, Al-Rashid and Sham-6 wheat varieties respectively.

It was also observed that the model predicted grain yield, dry matter and biomass yield by AquaCrop model was with the prediction error of 4.33%, 21.3% and 8.43% for grain yield and for dry matter of 11.64%, 17.47% and 10.86% for (Abu-Griab, Al-Rashid and Sham-6) wheat varieties respectively (Table 6). At the same time the model predicted error of biomass and it was noticed that the maximum percentage was obtained from Abu-Graib wheat variety which was(9.24%) while the minimum value of error percentage (5.1%) was found in Sham-6 wheat variety.

Moreover, the relationships between simulated model and observed grain yield, dry matter and biomass yield for application process are shown in Figs 4, 5 and 6, respectively. It was observed that the R^2 for grain yield was 0.844 (Fig. 4), whereas for dry matter the R^2 was 0.561(Fig. 5) and for the biomass yield the R^2 was 0.864 (Fig. 6).

Rainfall water productivity of wheat varieties is shown in Fig. 7. It was observed that the highest crop water productivity for grain yield, dry matter and biomass was found by Sham-6 wheat variety and for both measured and model simulated values, while the lowest values were obtained by Abu-Graib and Al-Rashid varieties.

Harvest Index (HI) of Sham-6 wheat variety was for both measured and simulated values which were (0.297 and 0.340) respectively (Fig. 8), whereas the lowest (HI) value was obtained from Abu-Graib variety and for both measured and model simulated during the wheat crop growth of 2015-16.

However, the model performed very well in predicting dry matter and biomass for varieties of Sham-6 and Abu-Graib varieties while the model performed very well in predicting grain yield more than the two others varieties. Similar results were also reported by Singh *et al*., (2013), Iqbal *et al.*, (2014), Kumar *et al*., (2014) and Kumar *et al*., (2015) in which the model performed better for prediction of grain and biomass yield as compared to the water productivity. These results are in agreement with the findings of (Sarangi1 *et al*., *(*2016), Mkhabela Bullock, (2012) and Andarzian *et al.*, 2011).

Nonetheless, it was observed that the model performed perfectly for the prediction of grain, dry matter and biomass yield. Also, it predicted the water productivity and Harvest Index (HI) for all wheat varieties when compared with the observed data generated from the field experiment.

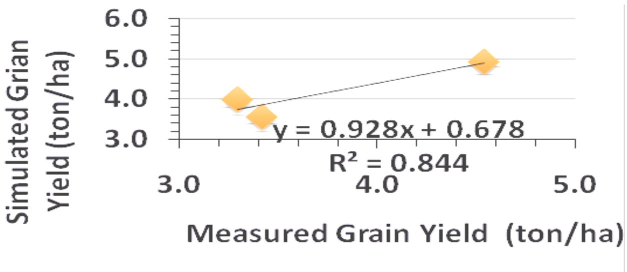

Fig. 4. Model application results for grain yield under cultivating different wheat varieties during 2015-16.

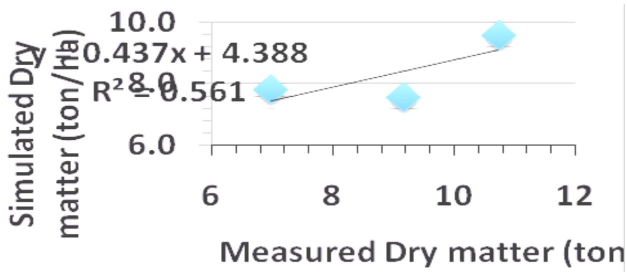

Fig. 5. Model application results for dry matter under cultivating different wheat varieties during 2015-16.

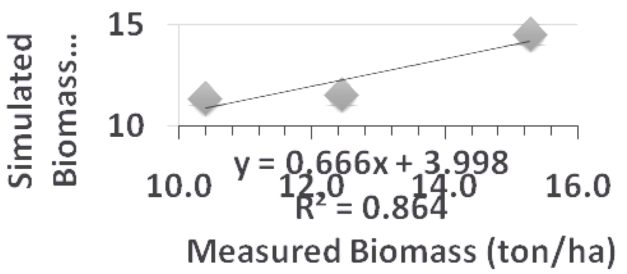

Fig. 6, Model application results for biomass under cultivating different wheat varieties during 2015-16.

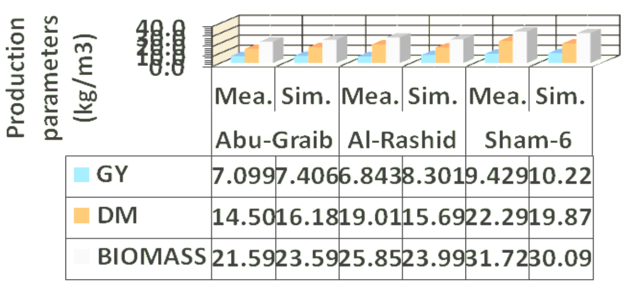

Fig. 7. Illustrate the Rainfall crop water productivity (kg/m^3) for the parameters production for wheat varieties during growth season of 2015-16.

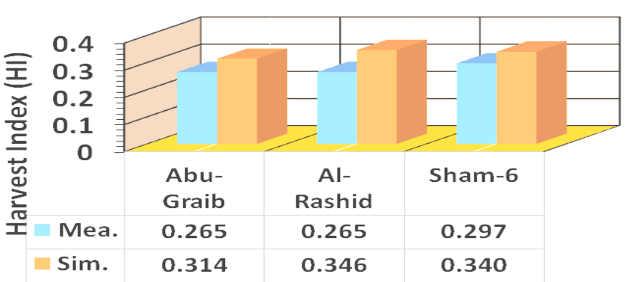

Fig. 8. Illustrate the Harvest Index (HI) for wheat varieties during growth season of 2015-16.

Conclusions

It can be concluded from the current study the following points:

1. It was observed that the model performed well for prediction of grain, dry matter, biomass yield, more than water productivity and harvest Index (HI).
2. It was also observed that the AquaCrop model could simulate the production parameters for all studied wheat varieties with acceptable accuracy under variable varieties.
3. Under conditions of the study investigation with annual rainfall of 381.5 Mm, the wheat variety of Sham-6 gave the highest values in term of production parameters of (grain yield, dry matter, biomass, water productivity and harvest index).

Recommendations

It can be recommended from this study that the AquaCrop model, which requires less model input data in comparison to other crop models can be used for prediction of wheat grain, dry matter, biomass yield, crop water productivity with acceptable accuracy under cultivating variable varieties of wheat crop, and sometimes encouraging cultivate Sham-6 variety of wheat in a semi-arid environment as that of the experiment region.

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