WHEAT VARIETIES PRODUCTION UNDER DIFFERENT IRRIGATION LEVELS UTILIZING AQUACROP MODEL IN SEMIARID CONDITION OF DUHOK –IRAQI KURDISTAN

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ABSTRACT

This experiment was conducted at the research farm of the College of Agriculture, University of Duhok, Iraq Kurdistan Region season of 2015-2016. Irrigation treatments include (Rainfed, 50% and 100% of field capacity). with three broad wheat varieties (IPA-95, Abu-Graib and Sham-4) cultivated by application the (AquaCrop) model. Wheat varieties of IPA-95 and Abu-Graib-3 consistently resulted in higher yields than Sham-4 variety, the highest grain yield of 3.872 t. ha^{-1} was recorded by IPA-95 variety. Highest grain yield of 3.78 t.ha^{-1} was obtained from Total Field Capacity. The biomass varied from 12.162, 12.214 and 13.056, 11.591 and 11.211 to 11.866 t.ha^{-1} for measured and simulated values. Also the results indicated that the highest crop water productivity of grain yield was obtained by Abu-Graib-3 in both measured and simulated water productivity kg.m^{-3} which were (5.404 and5.767 kg.m^{3}).

Keywords: Aqua Crop model, Irrigation levels, crop water productivity.

أنتاجية اصناف من الحنطة تحت مستويات ري مختلفة باستعمال موديل (AquaCrop) في الظروف شبه الجافة لمحافظة دهوك في اقليم كوردستان العراق.

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المستخلص

طبقت تجربة في حقل ابحاث كلية الزراعة، جامعة دهوك، في أقليم كوردستان العراق للموسم الزراعي 2015-2016 حيث شملت التجربة ثلاث معاملات للري وهي (الري المطري- الري 50% و100% من السعة الحقلية)،وكذلك استخدم ثلاث اصناف من الحنطة الناعمة (اباء-95، أبو غريب-3 و شام-4) اعطيا الصنفان اباء-95 و ابو غريب-3 استمرارية في زيادة الانتاج مقارنة مع صنف شام-4 و سجل الصنف اباء-95 اعلى حاصل للحبوب بلغ 3.872 طن هكتار$^{-1}$، وعندالمستوى الماء 100% من السعة الحقلية اعلى حاصل للحبوب بلغ (3.78 طن هكتار$^{-1}$). نتائج المحاكات من خلال تطبيق موديل (AquaCrop) لقيم الانتاج البايولوجي بينت اختلافا عن القيم المقاسة من 12.162، 12.214 الى 13.056 و 11.591، 11.211 الى 11.866 طن.هكتار$^{-1}$ للقيم المقاسة والمثلة بالترتيب. وكذلك أظهرت النتائج اعلى انتاجيه للمياه(كغم.م$^{-3}$) لحاصل الحبوب كانت عند زراعة صنف ابو غريب-3 في كلا الحالتين المقاسة والمقدرة والتي كانت (5.404، 5.767كغم.م$^{-3}$).

كلمات مفاتيحة: موديل Aqua Crop، مستويات الري، انتاجيه المياه للمحاصيل

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INTRODUCTION

Water has been always the main factor limiting crop production, the most of the world when the rainfall is not ample with recent increases in demand of agricultural commodities and ensuing food crisis in poor development countries, the need to improve the efficiency water use in crop production is never more apparent (16). 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. AquaCrop, a crop water productivity model developed by the Land and Water Division of FAO and released for use during 2009, Stedutoet al.(15)using to simulateyield response to water of several herbaceous crops. Mkhabela and Bullock,(10) evaluated AquaCrop for wheat crop grown in five different experimental sites in Canadian Prairies, they reported that the difference between observed and simulated grain yield was only 3% and the difference between observed and simulated total soil water content was 2%. They concluded that the AquaCrop can be a valuable tool for simulating both grain yield of wheat and soil water content on the Canadian Prairies, particularly considering the fact that the model requires a relatively small number of explicit and mostly intuitive input data, which can be readily available or easily collected. Salemi et al. (12) 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 under deficitirrigation condition. Xiangxiang et al. (17) evaluated AquaCrop model for simulating the impact of irrigationregimes on the biomass and grain yield of wheat and Singh et al.(13)calibratedand validated FAO AquaCrop model for 10wheat grown cultivars in West Bengal and reportedthat the model performed well with minimalinput data in prediction of wheat yield.

Iqbalet al. (7)simulated the soil moisture, grain yield and biomassof winter wheat in the Northern China Plain regionand indicated that the model can be used with reliable degree of accuracy, and Kumaret al. (9) compared AquaCrop and SWAP model for prediction ofgrain yield of wheatcultivars to salt-tolerant and non salt-tolerant in the semi-arid region of India and suggesteduse of AquaCrop model which requires less input dataas comparetoSWAPmodel.Sarangi1et al.(13) were observed yield that the AquaCrop model can be used to simulate the grain yield and biomass of wheat crop with acceptable accuracy under different irrigation regimes in a semi-arid region. The FAO AquaCrop model predicts crop productivity, water requirement, and water use efficiency under water limiting conditions. This model has been tested for maize, (5;6 and 15), under different environmental conditions. Bitrietal. (4)have illustrated that the model could accurately simulate the crop biomass and yield as well as soil water dynamics under full irrigation. Bread wheat (*Triticum aestivumL.*) is the most important cereal crops in Kurdistan region Iraq. There is 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% ofthe farm area is allocated to wheat) as well as the household income (wheat accounts for morethan 55% of the average household income)(2).

Theobjectives include:

1- Determining water application 2-Rates suitable for study region Identifyingwheatvarietiesresponse to supplemental irrigation practices

3- To evaluate this model under supplemental irrigation (rainfed, deficit and full irrigation) on three varieties of bread in a semi-arid region of Duhok Iraqi Kurdistan.

MATERIALS AND METHODS

Site description

The experiment was conducted at the 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. The test area had a relatively constant south facing slope of about 1%, which provides assured irrigation during the crop growth period. Water available for irrigation in the farm was of salinity less than 1 dsm^{-1}, hence the salinity stress was also not considered in the AquaCrop model to simulate the growth and yield of wheat. Climate data during the experiment period for AquaCrop model was acquired from the Agriculture College weather station located within the college farm. The rainfall, maximum and minimum temperature and relative humidity variations as observed during the experiment period for 2015-2016 is shown in Table 1.

Field layout and experiment details

The data on growth and yield parameters of wheat crop varieties, soil and irrigation scheduling, 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 experiment was designed as factorial experiment of tow factor in Randomize Completely Block design (RCBD) with the three replications. The first factor include three regimes of irrigation (W1 Rainfed, W2 50% field capacity and W3 full irrigation), and second factor was three varieties of bread wheat (IPA-95, Abu Graib-3, and Sham-4). Wheat varieties were sown in row with spacing 20cm in plot 6*3.5m, the plot to plot spacing was main-tained at 2m and replications were separated by 2.75m in the entire of experiment. The physical and chemical properties of soil experiment are presented in Table 2.Moreover reference evapotran-spiration (ET_o) was estimated using ET0 Calculator, version,3.2 September, 2012, FAO(Food and Agriculture Organization Land and Water Division, Italy Rome andused in AquaCrop as one of the input climatic parameter.The data oninitial condition, soil, climate and crop growth obtainedfrom field were used in AquaCrop model to generate crop yield, biomass and water productivity(WP).Measured quantity of irrigation water based on soilmoisture content was directly applied to the furrowsusing HDPE pipes to eliminate conveyance loss ofwater. The harvesting was done during the maturitystage on 29/5/2016 with grain moisture content of about13-1

Table 1. Growing season (29/11/2015–29/5/2016) weather summary for location study (Sumail).

Year 2015-2016	station	Ave. Daily Max. temp C°	Ave. Daily Mini. temp C°	Seasonal relative humidity RH (%)	Seasonal Rainfalls mm	Ave. Solar radiation MJ^{-2} day^{-1}	Wind speed $m.s^{-1}$	Et_o mm
DEC	Agic.	13.52	1.27	74.00	87.0	7.67	1.697	1.00
JAN	College	10.6	1.40	78.40	90.5	6.20	2.606	0.97
FEB	DuhokUnv.	16.83	4.50	74.80	39.0	10.07	2.503	1.88
MAR		18.81	6.57	70.40	88.0	13.04	2.532	2.55
APR		25.69	4.08	56.70	40.6	20.16	2.633	4.62
MAY		31.56	14.9	41.40	2.8	22.61	2.955	6.70

Table 2. Some physicochemical soil properties of study location

Depth of soil (cm)	Soil texture class	g kg^{-1} soil			Bulk density Mg m^{-3}	cm^3 cm^{-3}		
		sand	silt	clay		F.C	W.P	A.W
0-30	SIC	488.0	515.2	440.0	1.29	41.1	26.1	0.15
30-60	SIC	523.0	468.1	479.6	1.27	49.9	27.7	0.14
60-90	SIC	449.0	496.2	458.9	1.28	41.4	26.6	0.15
90-120	SIC	375.0	535.0	427.5	1.30	40.6	25.0	0.16

Crop growth parameters viz. above ground biomass(AGB), grain yield (GY), mass of dry matter, harvest index(HI).Crop water productivity (CWP) and irrigation crop water productivity(ICWP) were mea-sured for observed and simulated treatments. Irrigation scheduling in the experiment all experimental plots was irrigated using surface method of irrigation. Irrigation water depth indicated by the soil moisture deficit (d) in each trea-tment was calculated using soil moisture content before irrigation, root zone depth of plant and bulk density of soil using the Equation (1) :

$d = (\theta_{Fc}-\theta_{IT}) \times D$ ……….(1), Where, d: soil moisture deficit (mm), θFc: volumetric soil water content at field capacity (%), θi:

volumetric soil water content before irrigation (%), D: root zone depth (mm), viz.f(RF)=(Rainfed), f(HFC) = 0.50 and f(TFC) = (total irrigation up to FC without any deficit) were used for different treatments to estimate the quantity of irrigation water.

Estimation of Crop Evapotran-spiration

Soil water budget method was used to estimate actual crop evapo-transpiration (ETa). The compon-ents of water balance equation within the soil profile up to root zone depth were measured using Equation (2):

[I+P+C]–[Eta +D +R]=Δs…. (2)

Eta=I + p+Δs………..………(3)

Eta is crop evapo-transpiration (mm), P is precipitation(mm), I is total irrigation depth (mm), C is capillary contribution from ground water table to the crop root zone (mm), D is deep percolation losses (mm),R is runoff (mm) and ΔW is the change in soil water content (mm). The basins in the exper-imental plots were closed by bunds and the water table depth was 4m below the ground surface. Ther-efore, the surface runoff and the vertical upward seepage or the capillary flow to the root zone was assumed negligible in the calcu-lation of ET using Equation 2. Besides this, the drainage below root zone, after a number of soil-water content measurements, was considered to be negligible. Input data for the AquaCrop model: Operation of AquaCrop model requires input data consi-sting 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 temp-erature, reference crop evapotran-spiration (ETo), and mean annual carbon dioxide concentration (CO2). ETo was estimated by ETo calculator using the daily maxim-um and minimum temperature, wind speed at 2m above ground surface and hours of bright sunshine.

Crop data

In AquaCrop, 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 (3).

Soil parameters

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

Irrigation and field management parameters

Irrigation and field manag-ement during the experiment are three important components consi-dered in the AquaCrop model. In Rainfed treatment no water appli-cated in full irrigation treatment, water was applied up to field capacity level when soil moisture in the root zone approached 50% of total field capacity (TFC). The details of agronomic practices during the crop growing season have been listed in Table (4).

Table 3. Conservative crop production parameters of wheat varieties.

Calendar	(*Triticum aestivum* L.) varieties		
	IPA-95	Abu-Graib-3	Sham-4
From day one after sowing 30/November/2015		Day	
Emergence	14-Dec	14-Dec	14-Dec
Max. canopy cover	2-Mar	5-Mar	5-Mar
Max. root depth	25-Mar	22-Mar	30-Mar
Flowering	22-Mar	21-Mar	24-Mar
Start canopy senescence	26-Apr	25-Apr	26-Apr
Maturity	23-May	27-May	18-May

Table 4. Agronomic information for three varieties of wheat (*Triticum aestivum* L.) across 2015 and 2016.

year	Station	Crop genotype	Planting date	Growth season day	Harvesting date
2015-2016	Agric. College	IPA-95	29/11/2015	175	29/11/2015
		Abu-Graib-3		179	
		Sham-4		170	
Total water			Rain fed	HFC	TFC
used in, mm			No irrigation	63.8	99.7
Irrigation supplies			0	2	2

RESULTS AND DISCUSSION

The statistical analysis of the data showed significant difference (0.05) in grain yield due to different varieties of wheat and a highly significant difference (0.01) under different irrigation levels, while the interaction between wheat varieties and irrigation level appear same later effect as shown in Table5. IPA-95 variety and Abu-Graib-3 consistently showed higher grain yield than Sham-4 variety, the highest grain yield of 3.872 Ton ha^{-1} register by IPA-95 variety while the lowers grainyield of 3.162 Ton ha^{-1} was register by Sham-4 variety. Also grain yield affected a highly significant by irrigation levels. The highest grain yield of 3.78 Ton ha^{-1} was obtained from at level Total Available Water (TAW) while the lowest grain yield of 3.12 Ton ha^{-1}was obtained at Rainfed treatment, these results in agreement with results reported by Adary et al.,(1) who indicated that in the growing season of 1997/98 (annual rainfall 236 mm), rain-fed wheat yield increased 2.16 Ton ha^{-1} to 4.61 Ton ha^{-1} by applying only 68 mm of irrigation water in the spring. Applying 100 to 150 mm of SI in April and May achieved the maximum results. And these findings are in agreement with results found by Oweis and Hachum, (11).

AquaCrop model

The results of output of AquaCrop model was accomplished by using the observed values from the field experiment during 2015-2016 as model input parameters and then operating the model to obtain the simulated output in terms of grain yield, biomass and water productivity. The calibrated model is presented in Table 6. The model predicted outputs were compared with the observed grain yield and biomassunder different irrigation levels and differentwheat varieties.Observed and model simulatedgrain yield biomass

Table 5. Grain yield (Ton ha^{-1}) as affected by irrigation level and wheat variety

Wheat variety		Irrigation levels			Mean	LSD for IL	
		RF	HFC	TFC		0.05	0.01
IPA-95		3.153	3.810	4.653	3.872	0.689	ns
Abu-Graib-3		2.883	3.660	3.643	3.395		
Sham-4		3.317	3.130	3.040	3.162		
Mean		3.118	3.533	3.779			
LSD for WV	0.05	0.173					
	0.01	0.237					
LSD for IL*WV	0.05	0.300					
	0.01	0.411					

yield under different irrigation levels is presented in Table 6. It was observed from Table 6 that the grain yield varied from 3.118,3.535 and 3.779 to 3.562,4.404 and 3.806 Ton ha^{-1} for measured and simulated values respectively, and the model output for biomass values it noticed from same table the biomass varied from 12.162,12.214 and 13.056 to 11.591,11.211 and 11.866 Ton ha^{-1}for measured and simulated values respectively and from Table 7 the AquaCrop model under different varieties of wheat it was showed that The model the grain yield varied from 3.872,3.396 and 3.162 to

4.251,3.623 and 3.898 Ton ha^{-1} for measured and simulated values respectively and the model output for biomass values it noticed from same table the biomass varied from 12.166,12.588 and 12.731 to 12.128,11.159 and 11.380 Ton $ha^{-1}$for measured and simulated values respectively. These results in agreement with the findings of several other researches (10; 17).Moreover, the model simulated and observed grain yield under different varieties and under irrigation levels is shown in Figs (1) and (2), respectively. It was observed that the R2 for grain yield was 1.0for both cases of cultivating different wheat varieties and under irrigation regimes levels. These results in agreement with results conducted by other researcher (13; 10 and 3). Also the AquaCrop model was accomplished by using the observed values from the field experiment during 2015-2016 as model input parameters and then operating the model to obtain the simulated output in terms of water productivity. The model predicted outputs which were compared with the observed grain yield, water productivity and biomass under different irrigation levels produc- tivity. The model predicted outputs which were compared with the observed grain yield, water productivity and biomass.

Table 6. Measured and simulated grain yield (Tonha^{-1}) and biomass (Ton ha^{-1}) of wheat under irrigation regime levels

Irrigation Levels	Wheat Production (2015-2016)			
	Yield Grain (Ton ha^{-1})		Biomass(Ton ha^{-1})	
	Measured	Simulated	Measured	Simulated
Rainfed	**3.118**	**3.562**	**12.168**	**11.591**
HFC	**3.533**	**4.404**	**12.214**	**11.211**
TFC	**3.779**	**3.806**	**13.056**	**11.866**

Table 7. Measured and simulated grain yield (Ton ha^{-1}) and biomass (Ton ha^{-1}) for bread wheat varieties.

Wheat Varieties	Wheat Production (2015-2016)			
	Yield Grain (Ton ha^{-1})		Biomass(Ton ha^{-1})	
	Measured	Simulated	Measured	Simulated
IPA-95	**3.872**	**4.251**	**12.166**	**12.128**
Abu-Graib-3	**3.396**	**3.625**	**12.558**	**11.159**
Sham-4	**3.162**	**3.898**	**12.731**	**11.380**

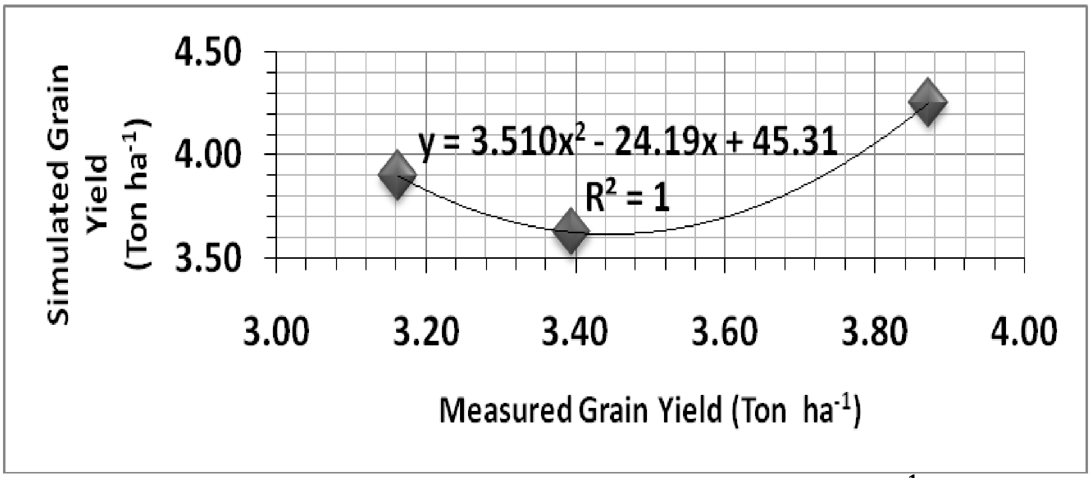

Fig 1. Relationship between measured and simulated grain yield (Ton ha^{-1}) for three varieties of wheat.

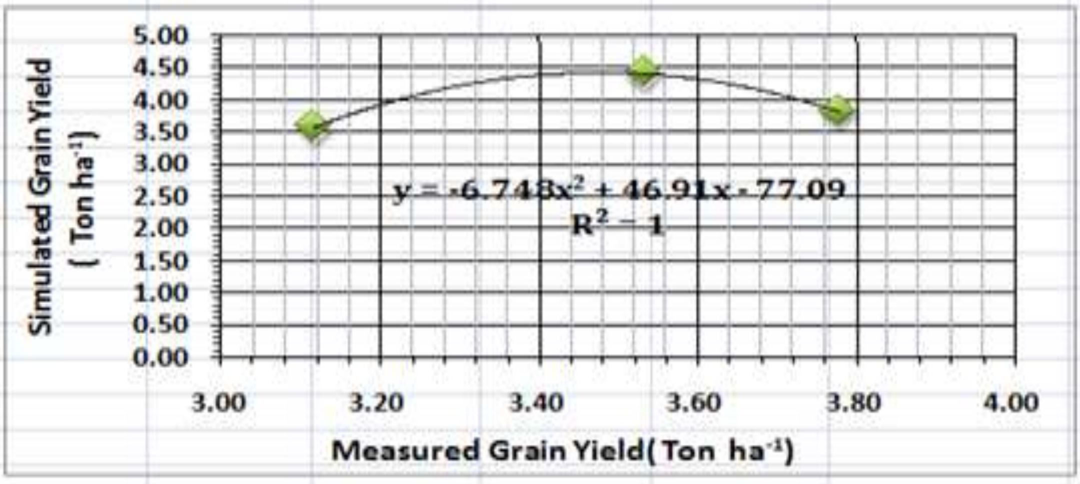

Fig 2. Relationship between measured and simulated grain yield (Ton ha^{-1}) of three varieties of bread wheat under different irrigation levels.

Table 8.showed that the measured and simulated water productivity Kg.m^{-3} of wheat varieties grain yield of (IPA-95, Abu-Graib-3 and Sham-4) varied from (1.237,5.404 and4.363 kg.m^{-3} for measured (observed) values to (1.398,5.767 and 5.378 kg.m^{-3} for simulated model values and for same varieties of wheat while the crop water productivity of grain yield of wheat production under irrigation levels ranged from3.401,3.709and 3.841 kg.m^{-3} for measured values to 3.799,4.748 and 3.995 kg.m-3for simulated model and for irrigation level of Rainfed, Halve Field Capacity and Total Field Capacity. Also we could illustrate the effect of wheat varieties and irrigation levels on the crop water productivity of wheat biomass Table 9. Illustrate the Crop Water productivity of wheat biomass of Abu-Graib-3 variety which gave the highest biomass during the both values of measured and model simulated were19.988and 17.761kg.m^{-3} respectively while the minimum biomass found by IPA-95 variety Table 9. And also shows that under different irrigation levels the crop water productivity of wheat biomass the maximum production of wheat biomass was produced under total available water and for both measured and model simulated values which were 14.791 and 12.657 kg.m^{-3} respectively, while the minimum biomass found under Rainfedcultivating and for both measured and model simulated which were 13.488 and 12.657 kg.m^{3} respectively. However, the model performed well in grain yield especially during cultivating different wheat varieties treatments when com- pared with irrigated treatments, the reason for poor prediction of water productivity by AquaCrop model can be attributed to the difference in the estimation procedure of water productivity used in the model simulation process and as estimated using the experiment data.

Table 8.Crop water productivity (kg.m^{-3}) of bread wheat Grain Yield and Biomass for three varieties.

Wheat Varieties	Crop Water Productivity (kg.m^{-3})			
	Yield Grain		Biomass	
	Measured	Simulated	Measured	Simulated
IPA-95	1.273	1.398	4.001	3.988
Abu-Graib-3	5.404	5.767	19.988	17.761
Sham-4	4.363	5.378	17.564	15.700

Table 9. Crop water productivity (kg.m^{-3}) of bread wheat Grain Yield and Biomass under three levels of irrigation.

Irrigation Levels	Crop Water Productivity (kg.m^{-3})			
	Yield Grain		Biomass	
	Measured	Simulated	Measured	Simulated
RF	3.401	3.799	13.448	12.440
HFC	3.799	4.748	13.314	12.353
TFC	3.841	3.995	14.791	12.657

Similar results were also reported by Iqbalet al.,(7);Kumar et al., (9) and Kumar et al.,(8) in which the model performed well in prediction of grain yield and biomass yield as compared to the water productivity biomass compared to other irrigation levels treatments. It was observed that the Aqua-Crop model could simulate the grain yield, biomass yield and water productivity of wheat under three irrigation levels and during cultivating different wheat variet-ies. Experiment generated data of 2015-16 and AquaCrop model simulated results revealed that wheat grain yield and above ground biomass were significantly affected under irrigation levels. However, the AquaCrop model prediction for grain yield of wheat was better during cultivating different wheat varieties than under irrigation levels. Similarly, for biomass yield, and water productivity the model performed well. 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 and biomass yield with acceptable accuracy under variable irrigation levels in a semi-arid environment as that of the experiment region.

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