EVALUATION OF THE PERFORMANCE OF THE AQUACROP MODEL UNDER DIFFRENT IRRIGATION AND CULTIVATION METHODS AND THAIR EFFECT ON WATER CONSUMPTION.

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ABSTRACT

This study was aimed to evaluate the Aqua program in calibration and validity and its use in simulation to study the productive and water characteristics of maize crop.. The experiment was conducted in two irrigation methods, sprinkler irrigation and surface irrigation, and two cultivation methods are borders (lines) and furrows (lines and then furrows) and for two cultivars of maize, a hybrid (unlocal) and a local variety. The results that sprinkler irrigation reduced water consumption compared to surface irrigation, as it reached (558.38) mm for sprinkler irrigation, and (668.79) mm for surface irrigation. While the method of furrows after borders outperformed the borders only in improving growth characteristics and increasing productivity, and the hybrid (unlocal) cultivar outperformed the local cultivar. The various experimental parameters were also calibrated using Aquacrop program, and it was found that the program gave a good convergence between the simulated and field values, as it gave R^2 values that ranged between (0.71-0.92) and RMSE between (0.12-23.76) for all studied traits.

Key words: sprinkler irrigation ; surface irrigation; simulation ; furrow irrigation
*** Part of Ph.D. dissertation of the 1st author.**

تقييم اداء برنامج AquaCrop تحت طرائق ري وزراعة مختلفة وتاثيرها في الاستهلاك المائي

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المستخلص

الهدف من هذه الدراسة هو تقييم برنامج اكوا في المعايرة والصلاحية واستخدامة في المحاكاة لدراسة الصفات الانتاجية والمائية لمحصول الذرة اجريت التجربة بطريقتي ري هما الري بالرش والري السيحي وطريقتي زراعة هما الواح (خطوط) ومروز (خطوط ثم تمرز) ولصنفين من محصول الذرة الصفراء هما صنف هجين وصنف محلي. اظهرت النتائج تفوق طريقة الري بالرش على الري السيحي في تقليل الاستهلاك المائي اذ بلغ (558.38)مم للري بالرش وبلغ (668.79)مم للري السيحي, بينما تفوقت طريقة التمريز بعد الخطوط على الخطوط في تحسين صفات الانبات وزيادة الانتاجية كما تفوق الصنف الهجين على الصنف المحلي. كما تمت معايرة معاملات التجربة المختلفة باستخدام برنامج Aquacrop وقد وجد ان البرنامج اعطى تقارب جيد بين القيم المحاكاة والحقلية فقد اعطى قيم R^2 تراوحت بين (0.71-0.92) و RMSE بين (0.12-23.76) لجميع الصفات المدروسة.

الكلمات المفتاحية : الري بالرش، الري السيحي، محاكاة، زراعة المروز
*البحث مستل من اطروحة دكتوراه للباحث الاول

Received:22/7/2021, Accepted:13/10/2021

INTRODUCTION

The Water is the main determinant of the cultivation process, as the growth and yield of plants is closely related to the percentage of available and ready moisture in the root zone of the plant, which meets its needs for the processes of evaporation, transpiration, tissue building and the transport of nutrients (5). Thus, in areas that depend on rain, plants obtain sufficient moisture for their growth from precipitation, so agriculture in these areas is called rain fed agriculture. As for the dry and semi-arid regions, which suffer from a lack of precipitation with fluctuations in the falling quantities, agriculture is exposed to the risks of drought. Therefore, plants must obtain their need of moisture by delivering water to the root zone in sufficient quantity and at the appropriate time through various methods and means, and this process is called irrigation (16 ,19 , 22 , 35) Evans. The effects of different irrigation levels using sprinkler irrigation system on crop yield, yield components, water and water use (WUE) and irrigation water use efficiency (IWUE) for maize (*Zea mays L.*) in Vojvodina (Northern Serbia), on Chernozem soils in temperate environment for 3 years were investigated. Consecutive years (2006-2008). The amount of water in it reached (557, 417 and 566) mm for the years, respectively (15 , 29) also conducted a study in estimating corn water use and water productivity in the Four Corners area of New Mexico. Maize was grown under full irrigation during the 2011, 2012, 2013, 2014 and 2017 seasons at the Agricultural Science Center in Farmington (New Mexico). The seasonal quantities of irrigation ranged from 576.6 to 1051.6 mm, with an average of 837.7 mm, and the total water supply ranged from 693.4 to 1140.5 mm. In a study conducted in Aleppo, Syria, to show the water consumption of maize crop for three irrigation methods (sprinkler, surface irrigation, drip) and for four years in comparison to the simulation of the AquaCrop program. It was found that the water consumption was between (497-597)mm for the four years (7). In a study by (24) for five different regions in the Aero Valley in Spain to grow maize using the sprinkler irrigation method, it was found that water consumption differed between the mentioned sites due to the different conditions of each site, whether environmental or related to the soil, and the water consumption amounted to (684, 559, 789, 717, 755)mm. Crop growth simulation programs and models have been advanced along with computer technical advances since the late 1960s with the aim of supporting simulations of plant physiological processes and describing crop growth and development. This development coincided with the efforts made to model crop growth by changing the objectives, user group, or agricultural policy outcomes, starting from explanatory models with a precise scientific vision at the paper level to those that focus on scientific applications and the impact of management practices on a single crop or a complex agricultural system (2, 41). This progress has dictated different modeling systems with regard to levels of complexity, processes to be processed, their functions, algorithm selection, metrics for typical growth units, and the type of inputs required (12,20,17,43) showed that all crop simulation models agree that they are mathematical representations of plant growth processes that are affected by interactions between genetic structure and factors surrounding the crop, and that the use of crop simulation models can be an effective complement to experimental research. It is used to understand the response of crops to potential changes in crop characteristics, traditional management processes and climate variables. (44) showed that in the nucleus of any crop growth model, there is a set of equations that estimate the rate of biomass production from at least one of the resources that constitute the main engine of the plant for the production of living mass, namely: either carbon dioxide gas, solar radiation, or water. .A study was conducted to show the possibility of AquaCrop model in the incomplete irrigation practices of wheat crop in Isfahan province. The results were (2.31 - 5.63) for the RMSE standard, (0.97 - 1) for the d standard, (93 - 99) for the E standard, and finally (0.15 - 0.016) for the CRM standard. The model in this study provided an excellent simulation of vegetation cover, grain yield and water productivity (39).This study aims to show the possibility of AquaCrop model in the irrigation and cultivation methods practices for two variety of maize crop in Babylon province and effect in water consumption and for each stage growth and make simulation by using Aquacrop model for some growth properties. The Aquacrop model is being worked on and used for calibration, validity and simulation, and it has multiple benefits, especially in the field of studying climatic conditions and their relationship to crop water productivity. Thus, evaluation of the procedure for adapting to climate change, where the model simulates crop growth, for several characteristics and for several years, was developed by FAO. The program takes into consideration the factors of field management, irrigation and the interrelationships between soil and plants. The program also takes the relationship with the atmosphere through the upper limits of the mass studied. For example, ETo, CO2 and energy required for plant growth are calculated as well as the contribution of the groundwater table by capillary action. (40) found that the measured dry yield values ranged between (13.96 - 11.98) and (13.07 - 6.72) and the simulation values (14.04 - 11.36) and (12.72 - 8.21) tons ha-1 for the 2011 and 2012 seasons, respectively. The measured values of water productivity were (2.33 - 2.81) and (2.64 - 1.66) and simulated values (3.02 - 2.32) and (2.56 - 1.92) kg m-3 for the 2011 and 2012 seasons, respectively. The values of the differences measures (R2, RMSE, EF) were (0.84, 0.36 and 0.81) and (0.72, 0.83 and 0.66) for the dry yield and the water productivity values were (0.10, 0.32 and -4.51) and (0.30, 0.25 and 0.0) for the two seasons 2011 and 2012, respectively. These results are in agreement with (33 , 48). Several tests have also been conducted using AquaCrop in the field of irrigation simulation and crop yield response to various water stress applications across large areas of the world (31). (3) used AquaCrop program for testing crop water in East Africa and simulated crop growth and soil water content under total and deficit irrigation administrations in southern Iran. As for (20), they evaluated irrigation management strategies to improve agricultural water use in southern Taiwan. (36) used AquaCrop to improve water productivity for various irrigation strategies in India. The ability of the AquaCrop model to simulate yield in response to water has been demonstrated by several researchers (1 , 9 , 10 , 22 , 35). The use of these models can help evaluate and reduce costly and time-intensive field tests (1986) FAO has worked on developing this model to address the problem of food security as well as the problem of future climate changes. The program's calculations were built on the basis of complex biophysical processes to ensure accurate simulation of the plant's response within the plant-soil system. The practical applications of this program can be summarized as (understanding the response of the crop to environmental changes, comparing crop yields in ideal conditions with actual yields, determining the factors that limit crop production and limiting water productivity, developing strategies in conditions of water shortage, and studying the effect of climatic variations on crop production) using historical climate conditions data and future expected climate conditions data. Biomass, crop yield, harvest index and water yield are calculated.

Determine the feasibility of compatibility

To evaluate the performance of the Aquacrop model in predicting the productivity of maize in the two previous seasons Table (1), the appropriateness of the measured and expected values was calculated according to the measures of variation that determine the quality of the source of error for those values according to Willmot (47) methodology.

MATERIALS AND METHODS

Experiment site and soil characteristics before cultivation: A field experiment was carried out to grow Maize crop *Zea mays L* during the fall cultivation season 2019. The site is a mixture soil in one of the fields of the Medhatiya Agriculture Division, Babylon Governorate. The site is located at latitude 44°36'32.N north and longitude 32°28'22.E to the east and at an altitude of 28m above sea level. The soil of the field was classified as sedimentary, classified to the level of Typic Torrifluvent according to the classification of (42).

Treatment of experiment and statistical design

1. Irrigation methods:
a. Surface Irrigation Method S1
b. Sprinkler Irrigation Method S2
2. Methods of cultivation:

a. Treatment of cultivation lines in Border B
b. Treatment of cultivation furrows in border F.
3. Classification of the crop:
a. Local variety Fajr VP1
b. Hybrid(unlocal) Drakma V2
The experiment was designed according to the RCBD randomized complete block design with three replicates, and the treatments were distributed on the experimental panels .Fig 1.

Surface irrigation

Rep 1	**B V1**	**B V2**	**5M**	**F V1**	**F V2F**
					1m
Rep 2	**F V2**	**F V1**		**B V2**	**BV1**
Rep 3	**B V1**	**B V2**		**F V1**	**F V2**

Sprinkler irrigation

Rep 1	**F V2**	**F V1**	**B V2**	**B V1**
Rep 2	**B V1**	**B V2**	**F V1**	**FV2**
Rep 3	**F V2**	**F V1**	**B V2**	**B V1**

Figure 1. show treatment of the experimental study

Preparation of the soil for cultivation

The experiment was carried out with borders of dimensions 7.5 m x 9 m. The experiment site was plowed by means of a perpendicular plow, perpendicular to a depth of 0.30 m. Then, laser adjustment and leveling operations were carried out, and the distance between one and the other was marked 0.75 m after the plant reached about 20 cm. The field was divided into three main sectors, and the sectors were divided into experimental units and three replications. A separation distance of 5 m was left between the two irrigation methods, a distance of 4 m between varieties, 1 m between the experimental units, and 2 m between sectors for surface irrigation, and it was less than that for sprinkler irrigation for the purpose of controlling irrigation and laying pipes.

Agriculture and service operations

The seeds were sown on 25/7/2019 .local cultivar Fajr and hybrid (unlocal) Drakma cultivar, The milling process was also carried out at this stage for some treatments to ensure that the aerial roots were covered. Urea fertilizer containing 46% nitrogen at a level of 176 kg.ha-1 was added in two batches, the first after 14 days of cultivation, i.e. after thinning and the seedlings entered the rapid growth phase (logarithmic) and the second batch after 30 days of cultivation (4).

Irrigation scheduling

Irrigation for germination was given after cultivation on 25/07/2019. Irrigation was carried out after germination based on the measurement of moisture content. Irrigation scheduling was done according to the depletion of soil moisture content at different soil depths. When 50% of the available water was depleted, irrigation is done. Net depth irrigation was calculated according to the following equation (37):

$$d = (\theta_{fc} - \theta_w)D.......(1)$$

Where:
d = depth of water applied (mm)
θ_{fc} =Volumetric water content at field capacity (cm^3 cm^{-3})
θ_w = Volumetric water content before irrigation (cm^3 cm^{-3})
D = Soil depth to be wetted at irrigation CM.

Water consumptive use (evaporation) of the crop was measured using the following water balance equation (6):

$$(I + P + C) - (ET_a + D + R) = \mp\Delta s \ldots\ldots(2)$$

I=irrigation (mm) ; P=precipitation (mm) ; C= capillaries (mm) ; ET_a= actual evapotranspiration (mm) ; D= deep percolation (mm) ; R=rune off (mm) ; ΔS= changes in the water soil.

R=0 (plain soil), C=0 (limited contribution, water table depth= 3m) and D=0 (because irrigation is limited to depletion at field capacity) Equation (2) becomes:

$$I + P - ET_a = \pm\Delta s \ldots\ldots..(3)$$

Statistical Comparison

In this study, five Statistical parameters were applied to test the performance of the model and compare the simulated and measured results:

1- Root mean square error (RMSE) (**25**):

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Si - Mi)^2} \qquad (4)$$

Where: Si and Mi are simulated and measured values, respectively, and n is the number of observations.

2- Determination Coefficient (R^2) (34):

$$R^2 = \frac{\sum Si\,Mi - \sum Si + \sum Mi}{\sqrt{\sum Si^2 - (\sum Si)^2 x}\sqrt{\sum Mi^2 - (\sum Mi)^2}} \qquad (5)$$

3- Mean Absolute error (MAE) (25):

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}|mi - si| \qquad (6)$$

4- Index of agreement (d) of (47): $d = 1 - \frac{\sum_{i=1}^{n}(Si-Mi)^2}{\sum_{i=1}^{n}(Si-\bar{M}\,| + Mi-\bar{M}\,|)^2}$ (7)

Where: $\bar{M}$ is the mean of the n measured values. The value of d range from-∞ to 1.0.======= 5- Coefficient of Efficiency (E) (21):

$$E = 1 - \frac{\sum_{i=1}^{n}(Si - Mi)^2}{\sum_{i=1}^{n}(Mi - \bar{M})^2} \qquad (8)$$

Table 1. AquaCrop calibrated values for main parameters used in maize simulation

Values	Calibrated
Canopy cover per seedling (cm^2 $plant^{-1}$)	6.7
Maximum rooting depth (m)	0.60
Crop coefficient for transpiration (Kcb)	1.30
Canopy expansion stress coefficient (Pupper)	0.13
Canopy expansion stress coefficient (Plower)	0.68
Canopy expansion curve shape	2.5
Stomatal conductance threshold (Pupper)	0.33
Stomatal closure shape factor	5
Canopy senescence stress coefficient (Pupper)	0.41
Canopy senescence shape factor	2.5
Aeration stress coefficient (% vol saturation)	4
Canopy decline coefficient (% GDD^{-1})	0.69
Reference harvest index (%)	52
Crop growth stages (GDD)	1800
Time from sowing to emergence	90
Time from sowing to max canopy cover	760
Time from sowing to senescence	1720
Time from sowing to maturity	1835
Time from sowing to flowering	910
Length of flowering stage	193

RESULT AND DISCUSSION

Total water consumption

The results in Table (2-a,b,c,d) show the factors of the water balance equation for the different irrigation and sprinkler irrigation treatments and their interaction with the cultivation methods of border and (lines and then furrow). As the values of ETa varied according to the different irrigation and cultivation treatments, and the highest water consumption was when dealing with surface irrigation and the method of cultivation panels in Babylon Governorate, as it reached 668.79 mm by 13 irrigation. The lowest water consumption was when treated with sprinkler irrigation and the method of cultivation the panels, which amounted to 558.38 mm, which received 17 irrigation, which indicates that the ETa has decreased by (19.7)%. Tables (2-b) and (2-d) indicate the percentage of decrease in the two treatments of surface irrigation, the method of cultivation lines then furrow and sprinkler irrigation, and the method of cultivation lines and then furrow, which amounted to 623.33 and 587.16 mm, by 14 and 18 irrigation, with a decrease in percentages that amounted to 623.33 and 587.16 mm. 7.2 and 13.9% about the treatment of surface irrigation and the method of cultivation with border. The reasons for the decrease in water consumption in the sprinkler irrigation method compared to the surface irrigation method are due to the difference in the amount of water added, as it was greater in each irrigation for the treatment of surface irrigation compared to sprinkler irrigation. Direct contact of water with the plant by spraying water on the plant directly, which reduces the amount of water absorbed by the soil, moistening the plant and reducing evaporation from the stomata. This is consistent with what was found by (14, 24, 28, 32, 46). As for the method of cultivation, it differed in increasing and decreasing water consumption, as it was less consuming in the furrows than in the method of cultivation the plots during the surface irrigation and the opposite of that with the sprinkler irrigation method, as the furrows were more consuming compared to the panels. This is due to the fact that in the irrigation method in the furrows, a part of the area of the plots is reduced because it does not get wet. In the sprinkler irrigation method, the principle of irrigation is adopted in a diagonal manner without reducing the area, and high amounts of water do not accumulate inside the furrows, which maintain the presence of water quantities for longer periods. These results were consistent with What reached (38). It was shown that the irrigation of the furrows saved water from the amount of added irrigation water, due to what was reduced from the plots on the basis of the irrigation of the furrows (8)

Table (2-a) Factors of the water balance equation for the treatment of surface irrigation and of border cultivation

NO. Irr	Date of Irr	No. of Days	water content before irr	Root depth zone Cm	Net Depth Irr mm	depth irr / effecenicy	water storge mm	rain mm	ETa mm
1	7/25/2019	0	0.16	20	36	52.94	26.17	0	79.11
2	7/28/2019	3	0.249	20	18.2	26.76	-1.76	0	25
3	8/1/2019	4	0.243	20	19.4	28.52	-13.82	0	14.7
4	8/6/2019	5	0.244	30	28.8	42.35	0.88	0	43.23
5	8/12/2019	6	0.246	30	28.2	41.47	-2.2	0	39.26
6	8/19/2019	7	0.241	30	29.7	43.67	-14.55	0	29.11
7	8/27/2019	8	0.241	40	39.6	58.23	2.94	0	61.17
8	9/4/2019	8	0.246	40	37.6	55.29	-0.58	0	54.7
9	9/13/2019	9	0.245	40	38	55.88	-12.5	0	43.38
10	9/22/2019	9	0.247	50	46.5	68.38	-3.67	0	64.7
11	10/2/2019	10	0.242	50	49	72.05	-12.64	3.4	62.81
12	10/12/2019	10	0.244	60	57.6	84.7	-2.64	1.4	83.45
13	10/23/2019	11	0.241	60	59.4	87.35	-22.94	3.7	68.11
Sum		90				717.64	-57.35	8.5	668.79

Table (2-b) Factors of the water balance equation for the treatment of surface irrigation and furrow cultivation

NO. Irr	Date of Irr	No. of Days	water content before irr	Root depth zone Cm	Net Depth Irr mm	depth irr / effecenicy	water storge mm	rain mm	ETa mm
1	7/25/2019	0	0.16	20	3.6	52.94	26.17	0	79.11
2	7/28/2019	3	0.249	20	1.82	26.76	-1.76	0	25
3	8/1/2019	4	0.243	20	1.94	28.52	0.29	0	28.82
4	8/6/2019	5	0.244	20	1.92	28.23	-8.56	0	19.67
5	8/11/2019	5	0.248	30	2.76	36.8	0	0	36.8
6	8/17/2019	6	0.248	30	2.76	36.8	-0.4	0	36.4
7	8/24/2019	7	0.247	30	2.79	37.2	-11.33	0	25.86
8	8/31/2019	7	0.249	40	3.64	48.53	-1.6	0	46.93
9	9/7/2019	7	0.246	40	3.76	50.13	1.06	0	51.2
10	9/15/2019	8	0.248	40	3.68	49.06	-12.26	0	36.8
11	9/24/2019	9	0.248	50	4.6	61.33	-0.66	3.4	64.06
12	10/4/2019	10	0.247	50	4.65	62	-12.4	1.4	51
13	13/10/2019	9	0.247	60	5.58	74.4	-2.4	0	72
14	2019/10/23	10	0.244	60	5.76	76.8	-30.84	3.7	49.65
Sum		90				669.53	-54.7	8.5	623.33

Table (2-c) Factors of the water balance equation for the treatment of sprinkler irrigation and the method of border cultivation

NO. Irr	Date of Irr	No. of Days	water content before irr	Root depth zone Cm	Net Depth Irr mm	depth irr / effecenicy	water storge mm	rain mm	ETa mm
1	7/25/2019	0	0.16	20	36	41.86	20.46	0	62.32
2	7/28/2019	3	0.248	20	18.4	21.39	-0.69	0	20.69
3	7/31/2019	3	0.245	20	19	22.09	-0.46	0	21.62
4	8/3/2019	3	0.243	20	19.4	22.55	0.69	0	23.25
5	8/6/2019	3	0.246	20	18.8	21.86	0.46	0	22.32
6	8/9/2019	3	0.248	20	18.4	21.39	-12.79	0	8.6
7	8/13/2019	4	0.242	30	29.4	34.18	2.09	0	36.27
8	8/18/2019	5	0.248	30	27.6	32.09	0	0	32.09
9	8/23/2019	5	0.248	30	27.6	32.09	0	0	32.09
10	8/29/2019	6	0.248	30	27.6	32.09	-11.16	0	20.93
11	9/5/2019	7	0.247	40	37.2	43.25	0.93	0	44.18
12	9/12/2019	7	0.249	40	36.4	42.32	-1.86	0	40.46
13	9/19/2019	7	0.245	40	38	44.18	1.86	0	46.04
14	9/27/2019	8	0.249	40	36.4	42.32	-10.58	3.4	35.14
15	10/6/2019	9	0.249	50	45.5	52.9	-1.74	1.4	52.56
16	15/10/2019	8	0.246	50	47	54.65	2.9	0	57.55
17	2019/10/23	9	0.251	50	44.5	51.74	-53.25	3.7	2.18
Sum		90			527.2	613.02	-63.13	8.5	558.38

Table (2-b) Factors of the water balance equation for the treatment of sprinkler irrigation and the method of furrow cultivation

NO. Irr	Date of Irr	No. of Days	water content before irr	Root depth zone Cm	Net Depth Irr mm	depth irr / effecenicy	water storge mm	rain mm	ETa mm
1	7/25/2019	0	0.16	20	36	41.86	20.46	0	62.32
2	7/28/2019	3	0.248	20	18.4	21.39	-0.69	0	20.69
3	7/31/2019	3	0.245	20	19	22.09	-0.46	0	21.62
4	8/3/2019	3	0.243	20	19.4	22.55	0.69	0	23.25
5	8/6/2019	3	0.246	20	18.8	21.86	0.46	0	22.32
6	8/9/2019	3	0.248	20	18.4	21.39	-0.46	0	20.93
7	8/13/2019	4	0.246	20	18.8	21.86	-12.32	0	9.53
8	8/17/2019	4	0.242	30	29.4	34.18	2.09	0	36.27
9	8/22/2019	5	0.248	30	27.6	32.09	-0.69	0	31.39
10	8/27/2019	5	0.246	30	28.2	32.79	0.69	0	33.48
11	9/1/2019	5	0.248	30	27.6	32.09	-0.34	0	31.74
12	9/7/2019	6	0.247	30	27.9	32.44	-12.67	0	19.76
13	9/13/2019	6	0.243	40	38.8	45.11	2.32	0	47.44
14	9/20/2019	7	0.248	40	36.8	42.79	-0.46	3.4	45.72
15	9/28/2019	8	0.247	40	37.2	43.25	-9.65	1.4	35
16	10/6/2019	8	0.249	50	45.5	52.9	-2.32	0	50.58
17	2019/10/14	8	0.244	50	47	54.65	4.06	0	58.72
18	2019/10/23	9	0.245	50	47.5	55.23	-54.17	3.7	16.75
Sum		90			542.3	630.58	-63.48	8.5	587.13

Water consumption according to plant growth stages: Tables 3 shows the depth of water added for each stage of maize growth germination, vegetative growth, flowering and maturation, the duration of each stage, the number of irrigations and the percentage of depth of water added as well as the average depth of one irrigation for the different study parameters of irrigation methods, cultivation methods, and two types of maize. As we note the values of the depth of water added when treating surface irrigation and the method of borders cultivation for the province of Babylon amounted to 140.44, 239.6, 197.86 and 90.89 and 154.85, 254.26, 203.3 and 56.38 mm with the number of irrigations 4, 6, 1, 2 and 1 and 5 , 5, 2 and 1 irrigation for the local variety and the hybrid, respectively, with percentages of 21, 35.8, 29.5 and 13.7% and 23.1, 38, 30.4 and 8.5% of the total water consumption. The values of the depth of water added when treating the surface irrigation and the method of cultivation the furrows were 144.73, 225.49, 181.62, 71.49 mm and 152.6, 240.39, 185.73, 44.61 mm with the number of irrigations 4, 6, 3, 1 and 5, 6, 2, 1 irrigation for the local variety and the hybrid, respectively, at rates of 21, 35.8, 29.5, 13.7% and 23.1, 38, 30.4, 8.5% of the total water consumption. As for the treatment of sprinkler irrigation and border cultivation, the amount of water consumed in all stages of growth decreased, as the values reached 150.23, 220.4, 166.36, 21.37 mm and 154.53, 244.88, 143.98, 14.97 mm with the number of irrigations 6, 7, 3, 1 and 6, 8, 2, 1 irrigation for the local variety and the hybrid, respectively, with percentages of 27, 39.4, 29.8, 3.8% and 27.6, 43.8, 25.8, 2.6 percent of the total water consumption. The values of the depth of water added when treating with sprinkler irrigation and the method of furrow cultivation for each stage were 150.2, 230.54, 170.42, 36 mm and 160.66, 248.45, 163.04, 15.01 mm with the number of irrigations 6, 7, 4, 1 and 6. 8, 3, 1 irrigation for the local variety and the hybrid, respectively, at rates of 25.6, 39.2, 29, 6.2% and 27.4, 42.4, 27.7, 2.5% of the total water consumption, respectively. It is noted that the highest value of the actual water consumption at the stage of vegetative growth, as it reached the highest percentage of water consumption, which is 46.1% for the site of Babylon from the total water consumption. The vegetation and the increase in evaporation from the soil surface due to the high temperatures in August and September, as well as the length of vegetation stage and the increase in the number of irrigations, which led to an increase in the actual water consumption (11 , 27). Then ETa decreased in the stage of Flowering due to the completion of the plant size and the increase in the area of the leaves, so the area of the vegetative cover increased for the surface of the soil, so evaporation from the surface decreased, so the plant’s need for water decreased, in addition to the short duration of this stage and the few irrigations compared to the stage of vegetative growth, so the actual water consumption decreased. In the vegetative growth stage, the depth of the roots was doubled from 0.20 - 0.60 m in order to provide the water requirements of the plant and this is consistent with what was found by (26 , 45).The decrease in ETa continued at the harvest stage due to the lack of plant growth and the drying of some of its parts, as well as the decrease in temperature, which led to a decrease in the values of ETa (29, 30).

Table 3. Actual evapotranspiration (ETa), reference evapotranspiration (ET0), yield coefficient (Kc), depth of water added during maize growth stages and for two different cultivars for irrigation treatments and different cultivation methods for the province of Babylon of water quality and tillage systems on penetration resistance

maize variety	irrigation methods	cultivation methods		Germination	vegetation	Flowering	Maturity	Sum
				growth stage				
Local	Surface	border ((line	no. irr	4	6	2	1	
			no. days	15	42	30	25	112
			ETa	140.44	239.6	197.86	90.89	668.79
			ETo	192.1	264.9	132.4	98	687.4
			Kc	0.73	0.9	1.49	0.92	4.05
			water % consumption use	21	35.8	29.5	13.7	
		Furrow	no. irr	4	6	3	1	
			no. days	15	42	30	25	112
			ETa	144.73	225.49	181.62	71.49	623.33
			ETo	192.1	264.9	132.4	98	687.4
			Kc	0.75	0.85	1.37	0.72	3.7
			water % consumption use	23.2	36.1	29.1	11.6	
	Sprinkler	border ((line	no. irr	6	7	3	1	
			no. days	15	42	30	25	112
			ETa	150.23	220.4	166.36	21.37	558.38
			ETo	192.1	264.9	132.4	98	687.4
			Kc	0.78	0.83	1.25	0.21	3.08
			water % consumption use	27	39.4	29.8	3.8	
		furrow	no. irr	6	7	4	1	
			no. days	15	42	30	25	112
			ETa	150.2	230.54	170.42	36	587.16
			ETo	192.1	264.9	132.4	98	687.4
			Kc	0.78	0.87	1.28	0.36	3.3
			water % consumption use	25.6	39.2	29	6.2	
Unlocal	Surface	border ((line	no. irr	5	5	2	1	
			no. days	17	45	31	26	119
			Eta	154.85	254.26	203.3	56.38	668.79
			ETo	198.5	305.6	128	73.2	705.3
			Kc	0.78	0.83	1.2	0.66	3.48
			water % consumption use	23.1	38	30.4	8.5	
		Furrow	no. irr	5	6	2	1	
			no. days	17	45	31	26	119
			ETa	152.6	240.39	185.73	44.61	623.33
			ETo	198.5	305.6	128	73.2	705.3
			Kc	0.76	0.78	1.45	0.6	3.61
			water % consumption use	29.5	38.5	29.8	7.2	
	Sprinkler	border ((line	no. irr	6	8	2	1	
			no. days	17	45	31	26	119
			ETa	154.53	244.88	143.98	14.97	558.3837
			ETo	198.5	305.6	128	73.2	705.3
			Kc	0.77	0.8	1.12	0.2	2.909357
			water % consumption use	27.6	43.8	25.8	2.8	
		furrow	no. irr	6	8	3	1	
			no. days	17	45	31	26	119
			ETa	160.66	248.45	163.04	15.01	587.16
			ETo	198.5	305.6	128	73.2	705.3
			Kc	0.8	0.81	1.27	0.2	3.1
			water % consumption use	27.4	42.4	27.7	2.5	

Performance AquaCrop model

The performance of the AquaCrop model was evaluated using the statistical parameters, which are Root Main Square Error RMSE, Main Absolute Error, MAE Correlation Coefficient R^2, Model E, and Index of Agreement. The results were presented for each of the biomass, dry matter, harvest index, water productivity, grain yield and actual evaporation, and their results are shown in Tables (4-a,b). To evaluate the efficiency of the model ability in simulating biomass, which is shown in Table (4-a). It was found that the Aquacrop model was able to excellently simulate the biomass, as the value of the coefficient of determination was R^2 0.90 for the two sites, while the values of the RMSE approached 0.56, and the agreement was high between the real values and the predicted values, according to (18), as it reached 0.96, while the MAE amounted to 0.46, while the efficiency of using the model was 0.87. The results were similar to the simulation of Aquacrop biomass of maize, confirming that the program performance was good in the simulation for the difference in the environment, irrigation method and agriculture (40, 13). Calibration results showed that the simulated maize crop biomass values ranged between (18,419 - 23.53) tons hectares for Babylon Governorate, while the simulated values reached between (19.38 - 23.42) which is an ideal match under the different conditions of the experimental fields. From other studied factors such as dry weight, harvest index, water productivity grain yield and actual evapotranspiration, a good agreement can be made between the measured and simulated values. It was found that the coefficient of determination R^2 was (0.82,0.95,0.82,0.71,0.97) for each of the dry matter, harvest index, water productivity, grain yield and actual evaporation transpiration, respectively. The RMSE values were (0.32,0.60,0.85,0.12,23.7) for each of the dry weight, harvest index, water yield, grain yield and actual evapotranspiration, respectively, while the values of (MAE) were 0.27, 0.50, 0.09, 0.76, 23) for each of the dry weight, harvest index, water yield, grain yield and actual transpiration evaporation, respectively, the concordance index values between the measured and simulated values were d (93, 97, 94, 80, 94%) for each of the dry weight, harvest index, water yield, grain yield and actual evapotranspiration, respectively. As for the dry weight, measured values ranged between (10.39-12.53) tons ha^{-1}, while the simulated values were between (10.63-12.53) tons ha-1. As for the harvest index, its measured value reached between (44.58-49.17)%, while the simulated values reached between (45-50)%. As for the water productivity, its measured values ranged between (1.22 - 1.99) Kg m^{-3}, while the simulated values ranged between (1.27 - 2.2) Kg m^{-3}. As for the grain yield, its measured values ranged between (8.22-11.49) tons.ha^{-1}, while the simulated values were between (8.63-12.71)ton.ha-1. The actual values of evaporation meter measured between (558.38 - 668.79) mm, while the simulated values were between (541.1 - 688.5) mm. AquaCrop model predictions for grain, biomass and water productivity were consistent with the corroborative observed data with E and R^2 values close to one. The graph of the evaluated model and the observed values for all treatments related to grain yield, biomass and water productivity are shown in Figure 4.13. It was found from the above that the best treatment for estimating the value of each of the biomass, dry weight, harvest index, water productivity, grain yield and actual evapotranspiration of maize crop when treated with L1S2FV. The use of sprinkler irrigation S2 with the sprinkler irrigation treatment resulted in values of the estimated parameters as a result of providing irrigation water at the effective root depth of the plant. The addition of covering the aerial roots with irrigation water helped in the preparation and provision of nutrients near the root system, giving the best values of biomass, dry weight, harvest index and water productivity for the two sites.

Table 4-a. Effect of the irrigation and cultivation methods, maize cultivars on the measured and simulated some Biomass , dry weight and HI

Treatment	Biomass tons.ha^{-1}		dry weight tons.ha^{-1}		Harvest index %	
	Measured	Simulated	Measured	simulated	Measured	Simulated
L1S1BV1	18.44	19.38	11.22	11.44	44.58	45
L1S1FV1	20.73	19.89	11.44	11.84	44.8	46
L1S2BV1	19.85	20.52	10.81	11.22	45.54	46
L1S2FV1	22.63	22.69	12.53	12.5	44.62	45
L1S1BV2	19.18	19.76	10.44	10.63	45.59	46
L1S1FV2	21.03	21.22	11.32	11.28	46.19	46
L1S2BV2	20.43	20.73	10.39	10.73	49.17	50
L1S2FV2	23.53	23.42	12.04	11.47	48.84	49
R2	0.9		0.82		0.95	
RMSE	0.56		0.32		0.6	
MAE	0.46		0.27		0.5	
D	0.96		0.93		0.97	
NSE	0.87		0.78		0.87	

***S1: SURFACE IRRIGATION S2: SPRINKLER IRRIGATION B: BORDER F: FURROW V1:LOCAL V2:HYRBID**

Table 4-b. Effect of the irrigation and cultivation methods, maize cultivars on the measured and simulated some WP , Grain yield and Eta

Treatment	WP Kg m^{-3}		Grain yield tons.ha^{-1}		ETa mm	
	measured	simulated	Measured	Simulated	Measured	Simulated
L1S1BV1	1.22	1.29	8.22	9.68	668.8	697
L1S1FV1	1.49	1.27	9.29	8.63	623.3	654.4
L1S2BV1	1.62	1.62	9	9.16	558.4	545.6
L1S2FV1	1.75	1.71	10.1	9.51	587.1	562.9
L1S1BV2	1.3	1.46	8.74	9.7	668.8	688.5
L1S1FV2	1.56	1.53	9.71	9.26	623.3	647.7
L1S2BV2	1.8	1.85	10.05	9.46	558.4	541.1
L1S2FV2	1.99	2.2	11.49	12.71	587.1	560.2
R2	0.82		0.71		0.974	
RMSE	0.12		0.859		23.76	
MAE	0.09		0.761		23.07	
D	0.94		0.806		0.946	
NSE	0.72		0.451		0.853	

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