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ASSESSMENT OF AQUACROP MODEL IN PREDICTION MAIZE HYBIRDS YILD BY SIMULATION PRODUCTION UNDER DEFICIT IRRIGATION

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ABSTRACT

The study was carried out at the field of Agriculture College, Duhok University, during spring season 2015, using drip irrigation system., the irrigation levels (100%, 75% and 50% of field capacity) arranged in main plots and maize hybrids namely Symiami, IK58*HS and Ddhi9445*HS in the sub plots within split plot design in Randomize Complete Block Design.The data were recorded on, grain yield, above ground biomass, and harvest index. The results showed that the Actual evapotranspiration (ET_a) was linear relationship with water applied and water use.

The production parameters were significantly affected by increasing irrigation levels. The level 100% of field capacity showed higher amounts of grain yield, above ground biomass and grain yield plant^{-1} compared with 75% and 50% of field capacity. The maize hybrids exhibited a significant effect on grain yield and above ground biomass and the hybrid IK58*HS was superior in grain yield plant^{-1} and above ground biomass.AquaCrop model was found to be accurate and fit to simulate grain yield, above ground biomass.According to this study, which was revealed that the productivity parameters of maize hybrids were more affected by deficit irrigation. The 100% of field capacity and the hybrid IK58*HS gave a significant increase in most of production parameters. AquaCrop model can be used as a helpful tool in the evaluation and comparison of crops productivity and irrigation strategies.

KEYWORDS: AquaCrop model, ,Defecit Irrigation, Grain Yield ,maize genotype.

INTRODUCTION

Water has been the main limiting factor for plant production in most places of the world. Rainfall is not adequate to meet water crop needs (Farahani *et al*., 2009).

As a result, many researchers have resorted to add some improved materials to the soil in order to increase the ability of soil to retain water and improve the storage of it. However, it is better to resort the use of other irrigation systems, for example, the use of drip irrigation, and this leads to increase productivity secure water and food. Deficit irrigation (DI) has been widely investigated as an option and a valuable strategy that might improve WUE for dry regions, where water is the limiting factor in crop production (Fereres and Soriano, 2007; Geerts and Raes, 2009; Farahani *et al*., 2009).

Maize is considered as one of the most important crops in the world (Panda *et al*. 2004). Grain is used as feed, food and a resource for many unique industrial and commercial products (Kuscu and Demir, 2013). It is grown in almost all parts of Iraq with various soil and climatic conditions. According to Central Statistical Organization of Iraq, in 2014 there was about 299500ha sowing with maize crop with an average production of 4167.5kg/ha, while in Kurdistan region the cultivated area with maize was 1824ha with average production of about 5139kg/ha (Central statistical organization of Iraq, 2014).

However, recently the water scarcity in arid and semi-arid region particularly has been considered as one of the major constrains limiting maize production (Geerts and Raes, 2009). In addition, it was shown that maize hybrids respond differently to the application of irrigation levels.

Simulation models that clarify the effects of water and crop genotype on grain yield and final above ground biomass of crop are useful tools for improving farm level water management and obtaining high production. The software AquaCrop has been developed by FAO to help

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project managers, consultants and farm managers with the formulation of guidelines to increase the crop water productivity for both rain-fed and irrigated production system. AquaCrop has a roughly limited number of input parameters for ease of use and greater appeal to agricultural extension, consultants, and practitioners (Farahani *et al*., 2009).

However, few studies have tested of the AquaCrop model were undertaken in Iraq, particularly in Kurdistan region, where crop yields are often limited by moisture deficit. In order to achieve the aims of the study, the following objectives of the study were addressed:

1-To assess AquaCrop model in prediction of soil water dynamics.

2-To determine the responsive ability of three hybrids of maize which are H_1 (Symiami), H_2 (IK58*HS) and H_3(Ddhi944*HS) to DI and to investigate the influence of DI on the yield.

3-To determine the crop coefficient (K_c) of maize under study conditions**.**

MATERIALS AND METHODS

1. Site description

A field experiment was carried out at research field of Agriculture College, Duhok University, during spring season 2015. The site is situated at the Agricultural College, 15 Km west of Duhok city, Kurdistan Region – Iraq, at national grid reference (36° 51′ N, 52° 02′ E) with altitude of 473m above the sea level (Fig.1).

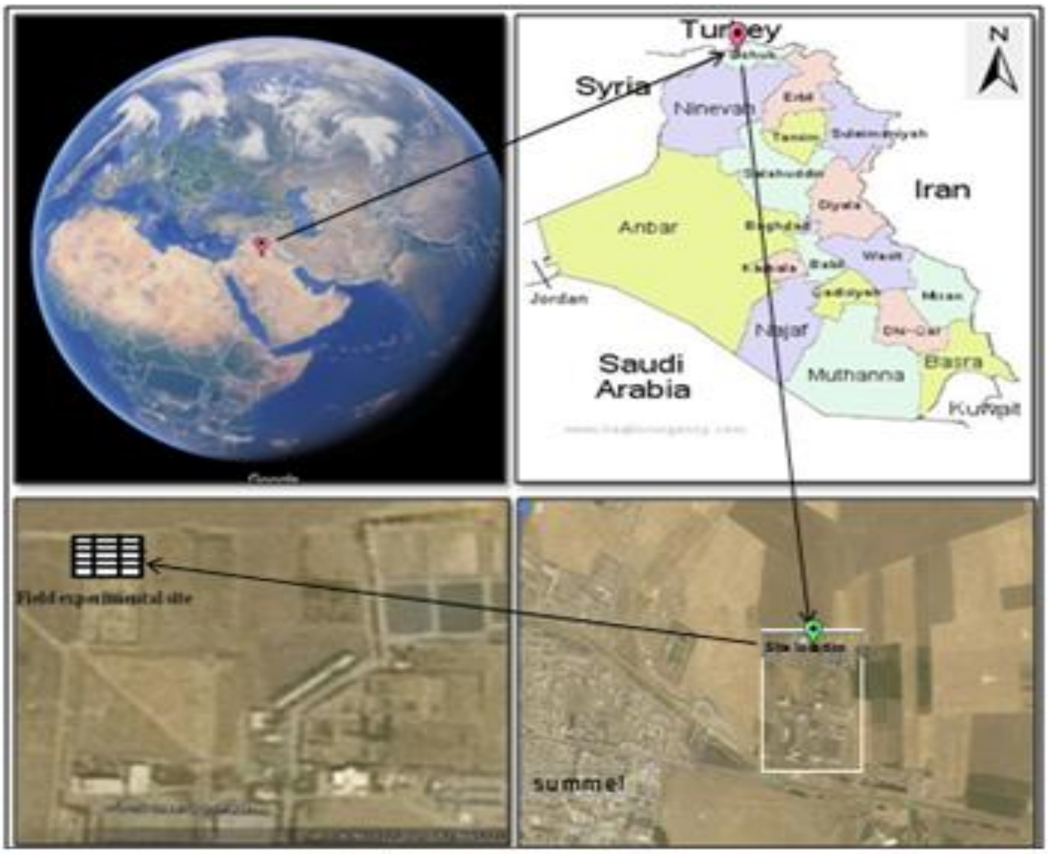

Fig. (1): Map of Iraq with satellite image showing field experimental site.

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2. Meteorological Data and Evapotranspiration Calculation

The climate of the area is semi-arid (similar to Mediterranean - type climate) with mean annual maximum and minimum temperatures are 26 and 14°C, respectively. In addition, rainfall, temperature, relative humidity, solar radiation, sunshine duration and wind speed at 2m height from 1997 to 2015 were obtained from Duhok central meteorological station. The obtained weather data were used **to** calculate the daily ET_o (mm day^{-1}) for the local area using Penman-Montieth 56, Blaney-criddle and Hargreaves-Symanni methods. ET_c was calculated by using the general ET_c equation as follows:

$ET_c = k_c * ET_o$.. [eq.1] ,

Where:

ET_c = Crop evapotranspiration (mm day^{-1}).

K_c = Crop coefficient (dimensionless).

ET_o = Reference evapotranspiration (mm day^{-1}).

3. Study elements

3.1. Irrigation treatments

The IS that was used in this study for the purpose of applying water for all treatments which brings the soil moisture co

Three irrigation levels were used in this experiment named D_1, D_2 and D_3 with 100%, 75% and 50%, respectively of

Over the growing period, the moisture content variation was regularly monitored using Tensiometers.

3.2. Actual maize evapotranspiration

ET_a was calculated by soil water budget method as described by Farahani *et al*. (2009). This can be applied by meas

$ET_a = P + I - D - R \pm \Delta S$... [eq.2]

Where:

P= Amount of precipitation (mm).

I= Irrigation (mm).

D= Deep percolation below root zone (mm).

R= Runoff (mm).

ΔS= Change in stored water content (mm) of the soil profile.

Maize was drip irrigated using plastic (polyethylene) pipes with gage meter for measuring the required quantity of applied irrigation. The drip lines were installed before sowing and placed on soil surface with 0.75m apart and emitters spaced 0.20m on the laterals. The discharge of emitters was 1.6L/hr, with uniformity distribution of 95% for the system, which was estimated according to Vermeiren and Jobling (1980).

3.3. Yield response factor

Yield response factor (K_y), which can be used to determine the effect ofwater stress on crop yield, was calculated by relating the relative yield decrease to the relative ET deficit through a K_y as shown in the following equation (Doorenbos and Kassam, 1979):

$K_y = [1 - Y_a/Y_m] / [1 - ET_a/ET_m]$.. (eq.3)

Where:

Y_a = Actual crop yield (kg/ha).

Y_m = Maximum crop yield (kg/ha).

$(1 - Y_a/Y_m)$ = Relative yield decline (dimensionless).

$(1 - ET_a/ET_m)$= Relative evapotranspiration deficit (unit less).

K_y = Yield response factor to water stress (dimensionless).

3.4. Soil sampling and analysis

3.4.1. Soil sampling and preparation

The representative samples of soil were collected from the fi

sieve thoroughly .The soil physical and chemical properties determined in the present study are illustrated in (Tables 1 and 2).

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Table (1): Physical properties of the studied soil:

Soil property	Measuring units	Soil depths (cm)			
		(0-30)	(30-60)	(60-90)	(90-120)
Particle size distribution	Sand%	4.48	5.23	4.49	3.78
	Silt%	54.22	46.81	49.69	53.47
	Clay%	41.3	47.96	45.82	42.75
Soil texture	....	Silty clay	Silty clay	Silty clay	Silty clay
Bulk density	gm cm^{-3}	1.365	1.381	1.43	1.58
ϴm at (F.C) is equal -33kPa	kPa	31.61	30.08	28.31	28.88
ϴm at (W.P) is equal -1500kPa		19.82	20.00	18.14	19.00

Table (2): Chemical properties of the studied soil:

Soil property		Measuring units	Soil depths (cm)			
			(0-30)	(30-60)	(60-90)	(90-120)
pH at 25°C in (1:2) extract		....	7.95	7.99	7.99	7.96
ECe at 25°C		dS. m^{-1}	0.51	0.368	0.351	0.304
Available N		mg. Kg^{-1}	105.95	106.25	106.38	106.33
Available P		mg. Kg^{-1}	4.88	4.85	4.88	4.86
soluble cations	K^+	mmolcL^{-1}	0.2	0.16	0.18	0.18
	Ca^{2+}		1.66	1.65	1.67	1.68
	Mg^{2+}		1.03	1.05	1.07	1.07
	Na^+		0.62	0.6	0.61	0.62
soluble anions	Cl^-	mmolcL^{-1}	0.5	0.55	0.58	0.59
	HCO_3^-		2.33	2.3	2.34	2.35
	$CO_3^=$		Trace	Trace	Trace	Trace
$CaCO_3$		g Kg^{-1}	217.6	216.9	217.7	217.8
Active $CaCO_3$		g Kg^{-1}	109.9	111.2	110.8	110.8
OM		g Kg^{-1}	1.772	1.654	1.543	1.435
CEC		Cmolc kg^{-1}	33.35	32.43	31.65	31.46

3.4.2. Soil analysis methods

3.4.2.1. Physical analysis of soil

The physical analysis of soil is shown in Table (1). The Bouyoucos hydrometer method was used for determining th

3.4.2.2. Chemical analysis of soil

The chemical analysis of soil is shown in Table (2), soil electrical conductivity was measured using EC–meter (mo described by Al-Sulaivani (1993). Cation exchange capacity was determined after the soil samples were extracted with 1M ammonium acetate (pH 7.0), and cation was measured using flame photometer (Estefan *et al*., 2013). Available nitrogen was determined by kjeldahl method (Bashour and Sayegh, 2007).

3.5. Filed experiment

3.5.1. Cultural practices

Prior delineating the experiment layout, the field was plough whenever is necessary.

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3.5.2. Plot dimension and plant population

A split-plot design of 2 factors with Randomized Complete Block Design with 3 replications was used. The main pl each plot with 2.50 m in length and 0.75 m apart. The graphical layout of the experimental design for this study is illustrated in Fig. (2). The sowing date was performed in 15th April 2015 by sowing seeds in row at rate of 3 seeds per a pit at (5-6cm) depth a total number of plant populations of 40 plants per plot in order to obtain theoretically optimum plant population of 66667 plants/ha.

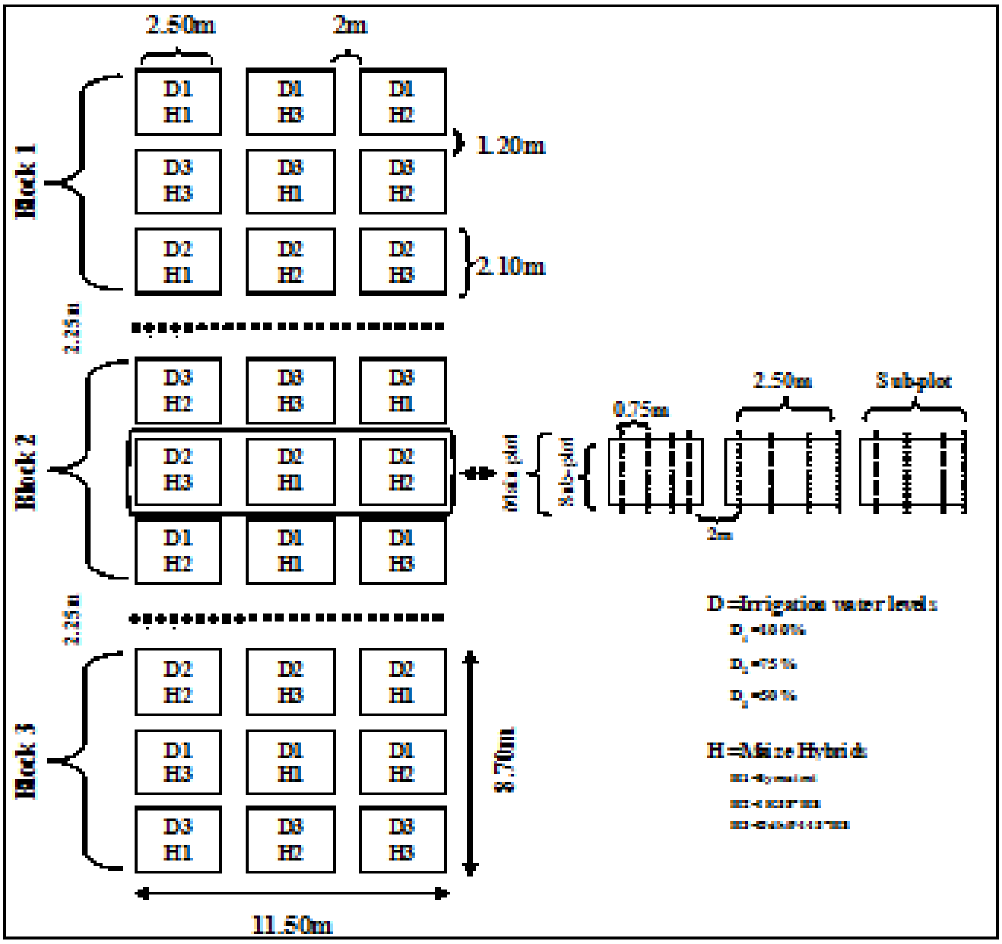

Fig. (2): The layout diagram of the field experiment.

3.6. Crop studied parameter

Yield parameters

Six plants for each plot were hand-harvested on 11th August 2015 ... portioned ... constant weight and their masses were recorded. The ear samples were oven-dried at 70°C to a constant weight and grains were shelled by hand, weighed and the moisture content converted to 15.5% by using the (Eq.4) formula Kenneth and Hellevang (1995) determine, average GY and AGB per plant were calculated for each plot and expressed in t/ha

$$\text{dry wt.} = [\frac{100\% - \theta m\%}{100\% - 15.5\%} * \text{wt. of wet grains} \ldots\ldots (\text{eq. } 4)$$

Where :

Θ_m= Means grain moisture content, then the grains weight converted from gram to t/ha.

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3.7. AquaCrop model

3.7.1. Description of AquaCrop model

AquaCrop is a CWP model developed by the Land and Water Division of FAO. It is a companion tool for a wide a adjustments to stresses, and therefore final yield. The growth engine of AquaCrop is water-driven, in that transpiration is calculated first and translated into biomass using a conservative, crop-specific parameter, the biomass water productivity, normalized for atmospheric evaporative demand and air CO_2 concentration. The normalization is to make AquaCrop applicable to diverse locations and seasons. The model uses canopy ground cover instead of LAI (Leaf Aera Index) as the basis to calculate transpiration and to separate soil evaporation from transpiration. Although grounded on basic and complex biophysical processes. AquaCrop uses a small number of explicit parameters and largely-intuitive input variables (Smith, 2000).

3.7.2. Soil and weather data

The weather and soil data of the growth season in the study site are presented in Table (3 and 4). They were collected using AquaCrop model.

Table (3): Growing season (15th April-31th July) 2015 weather summary for research location:

Station	Growing Season	Ave. Daily max.airTemp. (°C)	Ave. Daily min.airTemp. (°C)	Rainfall (mm/month)	Ave.Daily RH(%)	Ave. Solar Radiation (w/m^2)	wind speed (m/s) at 2m high
Collage of Agriculture	April	22.70	11.60	0.20	59.00	215.90	2.62
	May	33.07	14.90	11.40	37.30	262.71	3.25
	June	38.16	19.10	1.80	26.40	279.50	3.63
	July	43.49	22.90	0.00	21.40	264.19	2.90
	August	42.38	21.60	0.00	25.20	225.16	3.09

The dominant soil series at the site is silty clay with slope of 1%. The soil was well drained, in general, with a deep water table. The soil data for the experimental site is presented in Table (4).

Table (4): Hydraulic properties for the soil of the studied Location:

Depths (cm)	Soil texture	Saturation water content cm^3/cm^3	Field capacity cm^3/cm^3	Permanent wilting point cm^3/cm^3	Saturation hydraulic conductivity mm/d
0-30	Silty Clay	51.60	31.61	19.82	90.00
30-60		52.60	30.08	20.00	72.72
60-90		52.20	28.31	18.14	75.84
90-120		51.50	28.88	19.00	79.20

The determined parameters, of soil analysis, were: soil texture, hydraulic properties, field capacity, permanent wilting point and soil water content was measured gravimetrically in each 0.3m layers down to 1.2m. Volumetric water and bulk density.

The study area climate is of semi-arid type, which is mild in winter and dry and hot in summer. The average annual rainfall for 20 years is 485mm. Average annual potential evaporation at this location is 2084mm.

3.7.3. Maize hybrid management

Journal of University of Duhok., Vol. 22, No.1 (Agri. and Vet. Sciences), Pp 7-23, 2019
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The planting date was 15th April 2015 with an average of 6.7 plants per m^2 for H_1, H_2 and H_3 (Table 5). Weeds were controlled using herbicides. No pests or disease infestations were observed during the growing seasons. It was fertilized with 881.8 kg/ha of compound fertilizer NPK

Table (5): Agronomic information of three maize hybrids:

Station	Growing Season Period	Crop Genotype	Planting Date	Harvesting Date
College of Agriculture	April-August	H_1	15/04/2015	11/08/2015
		H_2		
		H_3		

3.8. User-specific parameters

The heading of user-specific input parameters were: grouped site, management, and crop-specific parameters such as soil water characteristics, maximum rooting depth, plant density, sowing date, irrigations, and phenology (Hsiao *et al.*, 2009), as shown in fig. (3).

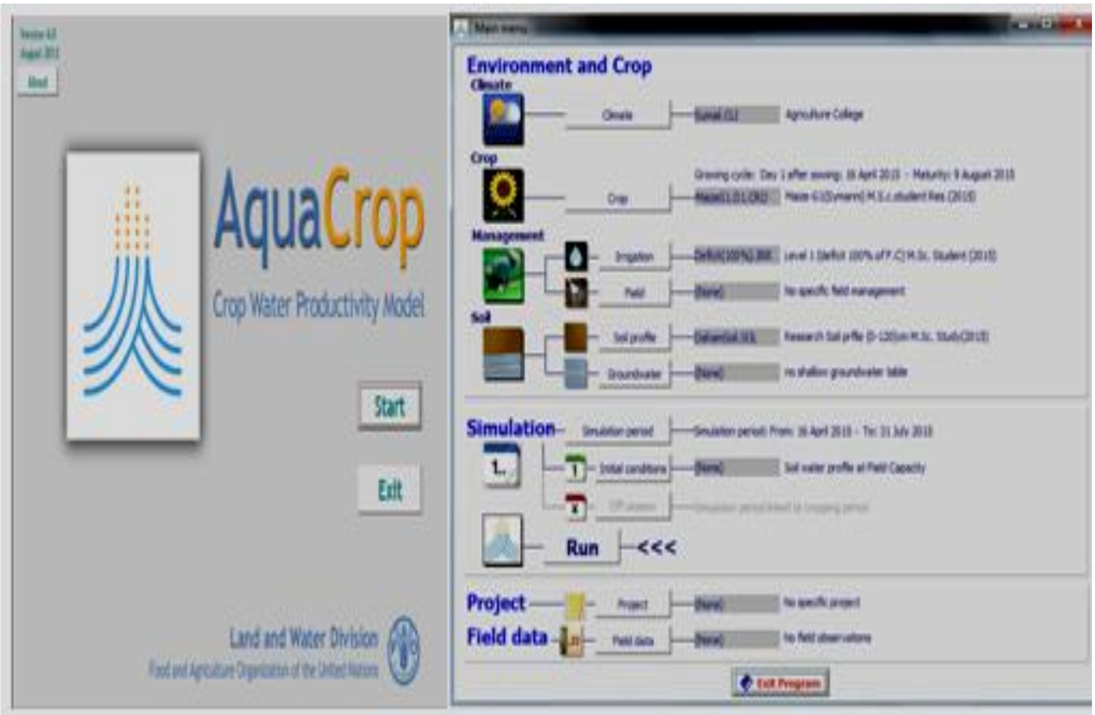

Fig. (3): AquaCrop user-specific input parameters.

3.9. Statistical analysis

The results were statistically analyzed by using Excel Software and Stat Graphics Software Release plus 4.0.Least Si

4. RESULTS AND DISCUSSION

4.1. Irrigation and water use

The DI levels were worked at 22 days after sowing (DAS) and finished on 96 DAS depending on the changes in the soil profile moisture content that corresponds to DI levels. The depleted water is replenished as illustrated in Fig. (4a), and final soil moisture depth values were 751.48, 633.61 and 470.74mm/90cm (Fig.4a.).

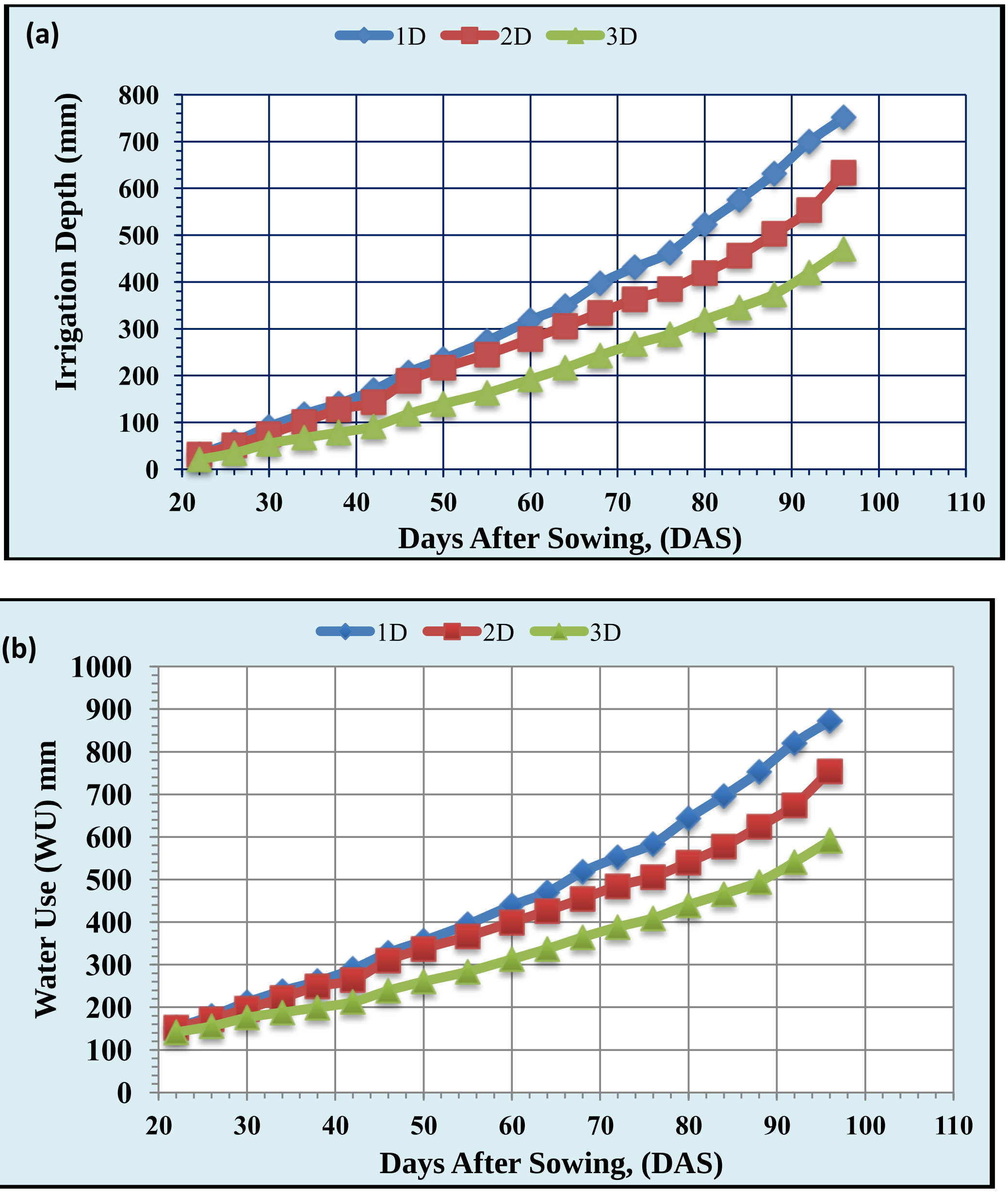

Fig. (4): Cumulative depth of (a) irrigation and (b) water use, for different treatments of irrigation levels (D_1, D_2 and D_3).

4.2. Crop evapotranspiration

4.2.1. Actual crop evapotranspiration (ET_a)

Daily and cumulative ET_m (ET_m=ET_a for no water stress) from the emergence stage and lasted until the stage of physiological maturity was practically measured and founded to be as 691.45mm for level D_1, that was obtained with 96 DAS, and the highest ET_m during growing season was equal to 18.35 mm day^{-1} that was obtained at 40 DAS.

4.2.2. Calculated crop evapotranspiration (ET_c)

ET_a was determined by using water balance method then comparing the results among the periods for ET_c and ET_a. It was concluded that water requirement for these periods especially the second to the fourth periods from 1^{st} May to 31^{st} July 2015 can be estimated (Table 6). The ET_o season grown (118 days) was calculated by using each Penman-Monteith 56, Blaney-criddle and Hargreaves equations for year 2015. Tables (6 and 7), ET_a was also determined by using water

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balance method for same season and the same years.

The average values of K_c were calculated and found to be 0.75 for year 2015 (Table 7) and showing that-both averages are approximately the same and

Table (6): References evapotranspiration (ET_o) mm day^{-1}, calculated evapotranspiration (ET_c) mm day^{-1} and K_c for Duhok 2015:

Periods	Days	k_c	Water Balance equation ET_m daily	2015						
				Penman-Montieth		Blaney-Criddle		Hargreaves		Average
				ET_o	ET_c	ET_o	ET_c	ET_o	ET_c	ET_c
15-30 Apr.	16	0.40	2.92	5.18	2.07	3.39	1.36	4.54	1.82	1.75
1-31 May.	31	0.73	5.33	6.38	4.47	5.88	4.12	6.72	4.70	4.43
1-30 Jun.	30	1.10	8.02	7.69	8.46	7.78	8.56	8.02	8.82	8.61
1-31 Jul.	31	0.83	6.06	7.48	5.98	9.56	7.65	8.88	7.10	6.91
1-10 Aug.	10	0.70	5.11	7.42	5.19	8.50	5.95	8.04	5.63	5.59

Table (7): Accumulative actual evapotranspiration (ETa), average references evapotranspiration (ETo) mm day-1, average Kc and Ks for the growing season at different irrigation levels (D1, D2 and D3) for Duhok growing season(2015).

Irrigation levels	Accumulative ET_a	2015										
		Penman-Montieth			Blaney-Criddle			Hargreaves			Average	
		ET_o	k_c k_s	k_s	ET_o	k_c k_s	k_s	ET_o	k_c k_s	k_s	k_c	k_s
D_1	691.45	817.17	0.85	1.00	851.32	0.81	1.00	877.00	0.79	1.00	0.75	1.00
D_2	565.02	817.17	0.69	0.82	851.32	0.66	0.82	877.00	0.64	0.82	0.75	0.82
D_3	395.94	817.17	0.48	0.70	851.32	0.47	0.70	877.00	0.45	0.70	0.75	0.70

agreed with those found by Tawfeek (2006).Depending on Bandyopadhyay and Mallick (2003), K_s is equal one in the case of no water stress, as exposed for D_1, and then K_s calculated less than one for these treatments D_2 and D_3. From these information, the averages values were 0.82 and 0.70 for year 2015, respectively as shown in Table (7), revealing that $K_s= ET_a/ET_m$, which indicates the degree of water stress. The nearer K_s value to 0.5, the most likelihood of plant wilting, or the growth and yield (mechanism) components will be greatly affected. The results were in agreement with the findings of Aoda and Fattah (2011).

4.2.3. Relationships between irrigation, water use and ET_a

Table (8) present the 3 levels of DI, the total number of irrigation, amounts of irrigation water applied, irrigation water saving, ET_a and ET_a/ET_m ratios. ET_a was linearly increased with irrigation water applied (Figs. 4-a and 4-b). These results are in agreement with results of other researches (Payero *et al.*, 2006a; Payero *et al.*, 2008; Oktem, 2008; Aoda and Fattah, 2011). Payero *et al.* (2008) and Aoda and Fattah (2011) reported that ET_a increased with the amounts of irrigation water applied up to a certain point where irrigation became excessive then no increase in ET_a was observed or (ET_a was stoppied).

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Table (8): The total number of irrigation amounts applied, irrigation water saving, ET_a, ET_a/ET_m ratios of maize for the three levels of DI:

Irr. Levels	No. of Irr.	WS initial (mm)	WS last (mm)	∆ S (mm)	Irr. Cumul. (mm)	WU (mm)	Irr.W saving (%)	ET_a (mm)	ET_a/ET_m
D1	20	120.90	60.87	60.04	751.48	872.38	0.00	691.45	1.00
D2	20	120.90	52.31	68.60	633.61	754.51	15.69	565.02	0.82
D3	20	120.90	46.11	74.80	470.74	591.64	37.36	395.94	0.70

4.3. Maize studied parameters

4.3.1. Production parameters

4.3.2.1. Grain yield

4.3.2.1.1. Measured grain yield

The results of present study indicated that there was a highly significant difference in grain yield (GY) means amongst different irrigation levels (Table 9). D_1 gave the highest GY compared to D_2 and D_3. GY was also found to be highly significantly amongst MH. The highest GY was found in H2. Moreover, the interaction effect between irrigation levels and MH on GY was found to be high significant effects on grain yield (GY).

Table (9): Grain yield (t/ha) affected by irrigation levels, MH and their interaction:

Irrigation Levels		Maize Hybrids H1	H2	H3	Mean	LSD for D 0.05	LSD for D 0.01
D_1		11.13	15.57	14.37	13.69	2.41	4.00
D_2		9.88	10.84	9.99	10.23		
D_3		7.43	8.70	8.80	8.31		
Mean		9.48	11.70	11.05			
LSD for H	0.05	1.08					
	0.01	1.51					
LSD for D*H	0.05	2.37					
	0.01	3.94					

4.3.2.1.2. Relationships between measured and simulated grain yield.

AquaCrop model was simulated using experiment data during spring season 2015 to predict GY under different water levels and MH in the experiment. The simulated GY under different irrigation levels and MH were highly correlated (R^2 = 1.0 and 1.0) with measured GY as illustrated in Figs.(5 a,b).

It was observed that the AquaCrop model simulation results for the GY under full irrigation (up to FC without any d

The results showed the simulated and measured GY of the 3 hybrids under the effect of water stress are nearer in all levels and MH, except in D_1 in both evaluations of the measured and simulated for MH in H2 reached its maximum level. The simulation results showed affected match between measured and simulated values by the model. It is well known that the final objective behind any crop experiment is to obtain higher productivity in the case of no water deficit problems. While, in this region like any other arid and semi-arid region, the purpose will change to obtain higher productivity by using less amount of water (Aoda and Fattah, 2011). However, a study by Payero *et al.* (2009) found that full irrigation maximized maize yield in July while decreased in September. Therefore, they stated that the amount of irrigation cannot be a fixed factor for all times (Payero *et al.*, 2009).

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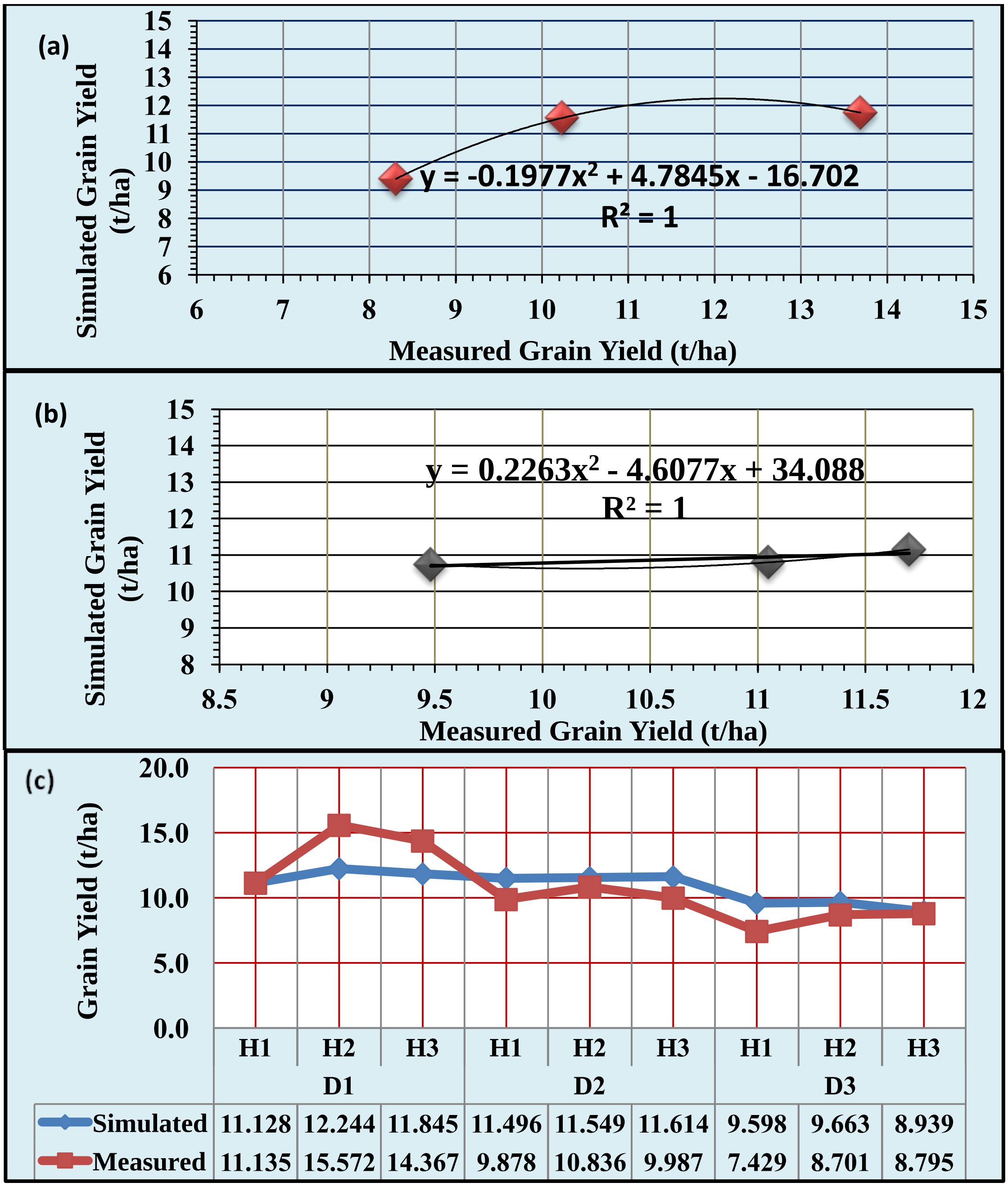

Fig. (5): Relationships between measured and simulated grain yield affected by (a) DI levels, (b) MH and (c) interaction between DI and MH.

In this study, it appears that the GY was severely reduced when drought occurred during the reproductive stage. These results are in agreement with the experimental results reported in other studies which attributed poor production of GY to water stress (Khalil *et al.*, 2002; Aoda and Fattah, 2011; Yihun *et al.*, 2011; and Ahmed *et al.*, 2015). The reason for this is due to prolong irrigation intervals which puts the plant under water stress, and accordingly causes low growth rates and reducing of leaf area and increasing the possibility of stomata resistance for CO_2 exchange and its seclusion, therefore low carbon synthesis process and lower metabolism take place, this process leads to reduction in GY. Furthermore, It has been claimed that the water stress before and during silking causes failure in ear development and silk drying; water stress after

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pollination causes limitation of kernel numbers, thus results in maximum reduction of kernel numbers and subsequently reduces the final yield (Classen and Shaw, 1970; Doorenbos and Kassam, 1979; Fischer and Palmer, 1984; Shrestha, 2014).

GY was also significantly affected by MH. The highest GY was recorded by H2 and H3, while the lower GY was re

4.3.2.3. Above ground biomass

4.3.2.3.1. Measured above ground biomass:

The effect of irrigation levels and MH on above ground biomass (AGB) is illustrated in Table (10) . AGB was found to be highly significantly varied due to different irrigation levels ($P < 0.01$)

and MH ($P < 0.05$). AGB was also found to be significantly higher for **H2** and H3 compared to H1. On the other hand, highly significant effect on AGB was found interaction between irrigation levels and MH.

Table (10): Above ground biomass (t/ha) affected by irrigation levels, MH and their interaction .

Irrigation Levels		Maize Hybrids			Mean	LSD for D	
		H1	H2	H3		0.05	0.01
D_1		27.29	34.13	30.09	30.50	3.45	5.72
D_2		25.02	26.41	26.79	26.07		
D_3		20.72	23.18	23.12	22.34		
Mean		24.34	27.91	26.67			
LSD for H	0.05	1.82					
	0.01	N.S.					
LSD for D*H	0.05	4.03					
	0.01	6.68					

4.3.2.3.2. Relationships between measured and simulated above ground biomass

The relationships between simulated and measured AGB was determined. There were strong relationships between them with irrigation levels (R^2=0.8255) as well as with MH (R^2=1) as shown in Fig. (6 a,b). Additionally, the relationships between simulated and measured AGB were determined (Fig.6c). It was found that the measured AGB was higher than simulated.

AGB, referring to all living biomass of plants above soil, was found to be highly and significantly varied due to different irrigation levels and MH. It was observed that AGB was significantly enhanced by increasing levels of water applied. D_1 showed the highest AGB, while the lowest values were observed with D_2 and D_3.

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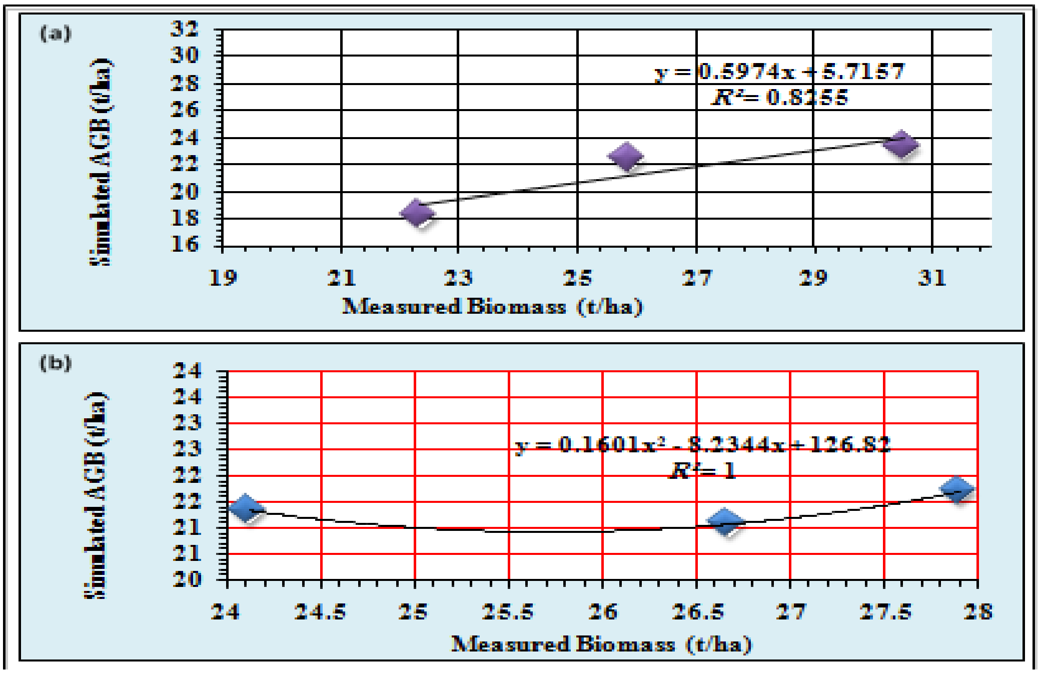

Fig. (6): Relationships between measured and simulated of above-ground biomass affected by; (a) DI levels, (b) MH and (c) interaction between DI and MH.

Finding of current study confirmed with other studies that found reduction in AGB of plant with water stress (Howell *et al.*, 1998; Dagdelen *et al.*, 2006; Khalili *et al.*, 2008 and Payero *et al.*, 2008). Therefore, management practices that would increase during the growth stages of maize would lead to an increase in the AGB of maize and vice versa.

The findings of this study agreed with the previous research that found the irrigation levels had a considerable effe Yemane *et al.*, 2015).

4.4. Harvest Index (HI):

The effects of irrigation level, MH and their sinteractions on HI are presented in Fig.7. A significant effect ($p < 0.05$) of irrigation levels was observed on HI. There was no significant effect of MH on HI. The interaction between irrigation levels and MH was also significant ($P < 0.05$) for HI.

HI shows the physiological efficiency of plants to convert the fraction of photo assimilates to GY (Mahesh, *et al.*, 2016). So as to explore the high potential that maize plants produce GY, it is necessary to understand how the HI is influenced by the different environmental factors and management practices.

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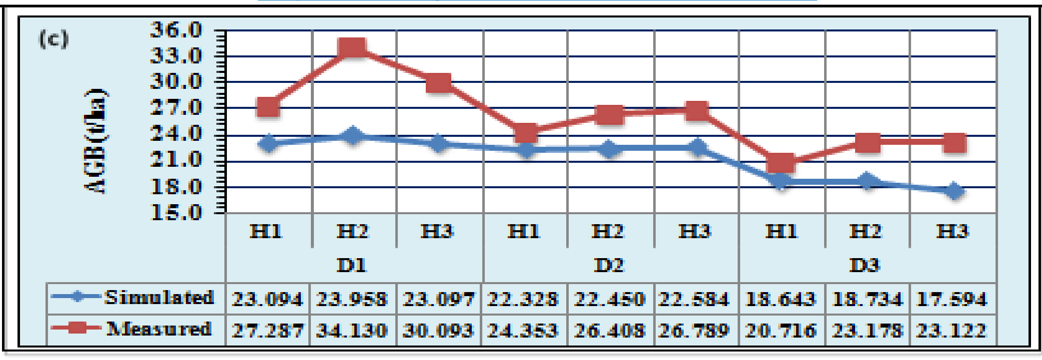

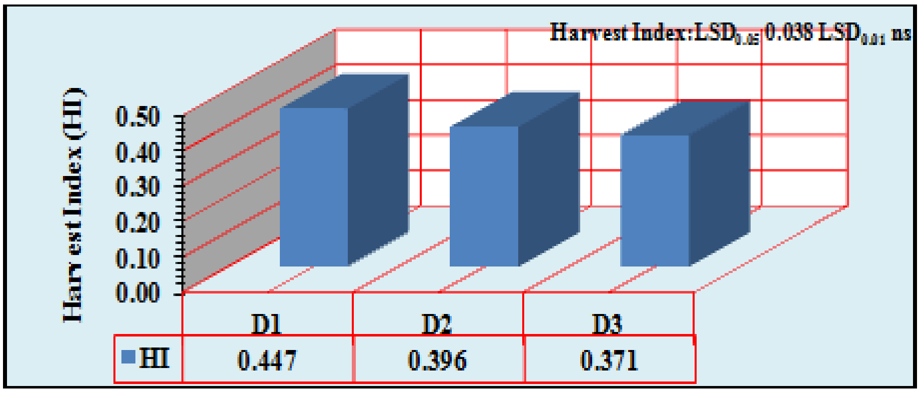

Fig. (7): The effect of irrigation levels on HI.

However, it was found that the HI of maize in the current study was significantly improved as a result of increasing the amount of irrigation levels. It is also assumed that beyond 75% of full irrigation treatments the additional transpiration contributed more to biomass production than to GY (Djaman, *et al.*, 2013). Farré and Faci (2009) reported a significant effect of limited irrigation on HI, which ranged from 0.31 to 0.55, indicating that HI is very sensitive to the irrigation quantity. Therefore, the present study results of HI were consistent with Farré and Faci (2009) results. The effect of irrigation level on HI in the present study ranged from 0.37 to 0.44.

4.5. Grain yield response to ET_a/ET_m

In all treatments GY tended to increase with increasing ET_a up to point where ET_a became ET_m, except for stressed irrigation with H1, which was at the lowest increase amongst all MH and DI (Table.11).

Table (11): The percentage of yield increase at different ranges of ET_a/ET_m ratio for different hybrids of maize:

Maize Genotypes	ET_a/ET_m		
	0.70- 0.82	0.82- 1.0	0.70 - 1.0
H1	24.80	11.28	33.28
H2	19.71	30.41	44.13
H3	11.94	30.49	38.78

To display the impact of the ET_a/ET_m ratios on yield increasing percentage, the data shown in Table (11). It is clear from thisTable that the yield percentage generally increased with ET_a/ET_m ratios for all treatments, except for H1 with stressed irrigation which was the lowest increase. The highest yields were 24.80, 30.49 and 44.13% when ET_a / ET_m ratios increased from 0.70 to 0.82, 0.82 to 1.0 and 0.70 to 1.0 for H1, H3 and H2, respectively, whereas the lowest ones were 11.28 (0.82 to 1.0), 19.71 and 11.94 (0.70 to 0.82) for H1, H2 and H3, respectively. The current study's results are consistent with previous findings of Hanson *et al.* (1999), Aoda and Fattah (2011) who found that the maize yield was increasing when ET_a/ET_m increased.

4.6. Crop response factor (K_y)

K_y to DI was calculated by stewart *et al.* (1977) model. Average K_y to different irrigation levels and MH are presented in Table (12).

Table (12): Crop response factor for different irrigation levels and MH:

Maize Genotypes	Average k_y	
	D_1 - D_2	D_1 - D_3
H1	0.617	0.779
H2	1.663	1.032
H3	1.667	0.907

K_y is defined as decrease in yield per unit decrease in ET (Aoda and Fattah, 2011). The findings of this study were in line with Aoda and Fattah (2011) who found that Average values of K_y were 0.909, 1.018; 0.662, 0.877; 0.634, 0.845 and 0.670, 0.876 for 75% and 50% in combination with 100%; and the present studies results were 0.617, 0.779; 1.663, 1.032; and 1.667, 0.907 for D_1 with D_2 and D_1 with D_3 for H1, H2 and H3, respectively.

CONCLUSIONS

According to the present study, the following points were concluded:

1. The productivity parameters of maize hybrids were influenced by deficit irrigation, and Irrigation Level (100%) caused a significant increase of all plant parts .

2. The AquaCrop model was an effective strategy for estimating the actual parameters measured in the field in shorter time.

3. By predicting crop production based on a simulated soil water balance, AquaCrop model is used as a decision support tool to assist in improving crop productivity in resource limited environments, where the need for increased agricultural production is highest.

Recommendations

From the present study's findings, the following points are recommended:

1. Relying on k_y and ET_a/ET_m under water deficit irrigation condition.

2. AquaCrop Model is recommended for applications under different climatic conditions, deficit irrigation levels and irrigation systems.

3. Using AquaCrop model in the simulation for the production parameters, soil and water dynamics and water - yield relations for the hybrids that are suitable with Iraqi-Kurdistan region conditions.

4. Further research is needed to study the effect of different levels of deficit irrigation with water qualities.

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