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Wheat Production under Western North Coast Conditions Using A Simulation Model

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Abstract
This study was carried out at Marsa Matruh governorate - western north coast Egypt (31° 15′ 35″ N, 27° 9′ 43″ E) in the 2014/2015 growing season. The experiment was conducted to assess and validate the AquaCrop model under various factors [sowing dates, tillage operation and different Supplementary irrigation strategies] on biomass and grain yield production for winter wheat. Thus; the factor of sowing date comprise into three treatments (1st Nov, 15th Nov and 30th Nov). Second factor is tillage with two treatments (no tillage and tillage 20cm) and the third factor is Supplementary irrigation with three treatments (0, 75 and 112.5mm). The AquaCrop model adequately simulated the biomass yield (BY), and grain yield (GY) for winter wheat under different treatments. The simulated (BY) agreed well with the measured (BY) across different treatments where (R^2= 0.82 & E = 0.82 & RMSE = 6.7%) for winter wheat under different treatments of (sowing dates and supplementary irrigation strategies) with tillage process. measured and simulated (GY) were also closely related. The AquaCrop model calibrated the GY with the prediction statistics error by (R^2= 0.69 & E = 0.7 & RMSE = 2.8%) with tillage process. Moreover; the (1 Ton.Fed^{-1}) for (BY) needs for (635.9, 588.3 and 510.6) heat units (AGDD) as an average under different sowing dates (1st Nov, 15th Nov and 30th Nov.) respectively. Further; the (1 Ton.Fed^{-1}) from grain yield needs for (1779.05) heat units if sowing on the (1st Nov.), for (1641.85) heat units on (15th Nov.) and for (1468.7) heat units on (30th Nov.). Notable; that the highest value for heat uses efficiency (HUE) observed with (112.5mm) and tillage operation under sowing date 30th Nov by (2.2 & 0.72 Kg. fed $^{-1}$ C^{-1}day^{-1}) for both (BY) and (GY) respectively. Consequently; these results suggest that the AquaCrop model could be used to predict BY and GY of winter wheat with a high degree of reliability at western north coast conditions.
Keywords: AquaCrop model; sowing date; Tillage; Supplementary irrigation and winter wheat production.

1. INTRODUCTION

Scarcity of water and limitation water resource leads to reduction in water available for irrigation crops. In addition; Agriculture is the principal user of all water resources, such as, rainfall, water in rivers, lakes and aquifers. Thus; Rainfall is one of the most important climatic variables because of its two sided effects - as a deficient resource, such as droughts and as a catastrophic agent, such as floods. It is the primary source of water for agricultural production. For instance; Winter wheat is a vital food crop for the majority of all development country especially in Egypt. The rainfall in Egypt is 156mm as an average especially at western north coast where plantation a winter wheat may be a useful for maximizing water use from rainfall.

Otherwise; Temperature is second critical parameter for climate which the potential productivity level for winter crops (Kalra et al., 2008). For most plants phonological development from seeding to maturity is related to temperature and daily accumulation of heat units. The amount of heat units required to move the plant to next development stage remains constant from year to year, however; the actual amount of time (days) can vary considerably from year to year because the change of weather conditions. For instance; winter wheat minimum daily temperature for measurable growth is about 5 C°. Mean daily temperature for optimum growth and tillering is between 15 and 20 C° (Doorenbos & Kassam, 1979).Generally; wheat production needs to promote all agricultural system parameters as (climate and water resource management) to get a highest value.

On the other hand; several studies have described several such irrigation strategies for use by farmers (Geerts et al., 2009). Since the mid-1960s, the relationship between water and crop yield has been described with both empirical and mechanistic models (Penning et al., 1989). Furthermore; a simulation of the soil-plant-climate continuum remains an important part of such research, especially with regard to expansion of the application range of resulting models to a wider array of cropping systems (Xiu-liang et al., 2014).

Therefore, the Food and Agricultural Organization (FAO) developed the AquaCrop model in an effort to meet this need in 2009. This model was originated from the ‘‘yield response to water’’ data (Doorenbos & Kassam, 1979)., and evolved to a normalized crop water productivity (NCWP) concept (Steduto et al.,2009). Compared with other models, AquaCrop is relatively simple to operate by those with little or no research experience, and allows for simulation of crop performance in multiple scenarios. Moreover; to a high level of accuracy, this robust model requires a limited set of input parameters, most of which are relatively easy to acquire (Hsiao et al., 2009). The AquaCrop model is also capable of predicting crop productivity, water requirements, and water use efficiency under water-limiting conditions (Raes et al ., 2009). So; the aims of this study to validate the AquaCrop model under various sowing dates, tillage process and different water applied strategies on biomass and grain yield production for winter wheat. The relation between different growing degree-days (GDD) and yield production.

2. MATERIAL AND METHOD

Study site

field experiment were conducted in the 2014/2015growing season at western north coast experimental site (31° 15′ 35″ N, 27° 9′ 43″ E), Marsa Matruh governorate, Egypt. The site of experiment falls into an arid area with a Mediterranean climate. The site is about 92 m above sea level with an annual rainfall of 157 mm/year, temperatures of 19.2 °C, relative humidity of 66.97%, and wind speed of 3.7 m/s. The total annual evapo-transpiration (ETo) is 1570 mm/year (table 1).

Table 1: Climatic characteristics at the experiment site.

Month	Prc.	Tem. max	Tem min.	Hum.	Sun shine	Wind (2m)	ETo
	mm/m	°C	°C	%	%	m/s	mm/d
Jan	37	17.2	9.4	67.9	63.8	4.6	2.6
Feb	21	17.7	9.5	64.9	67.0	4.2	3.0
Mar	12	19.7	10.6	63.9	67.7	4.3	3.8
Apr	5	22.6	12.4	63.3	69.7	4.1	4.6
may	3	25.4	14.9	66.7	75.2	3.8	5.2
Jun	3	28.3	18.4	67.5	83.4	3.4	5.9
Jul	0	29.1	20.6	71.2	86.6	3.6	6.0
Aug	1	29.6	21.0	70.5	87.8	3.7	5.8
Sep	3	28.6	19.6	67.9	83.9	3.3	5.1
Oct	21	26.4	16.9	67.3	77.1	3.1	4.0
Nov	19	22.5	13.7	66.7	72.6	3.2	3.0
Dec	31	18.9	10.6	65.9	62.9	3.4	2.5

(*Prc.* = Precipitation; *Tmp. min/max* = minimum/maximum temperature; *hum.* = relative humidity; *Sun shine* = Sun shine as percentage of day length; *Wind (2m)* = wind speed at 2m; *ETo* = Reference evapotranspiration) (FAO AQUASTAT 2015).

Soil data analysis:

The soil at the experimental site represents the major soil type (loamy sand). Analyses of soil and some physical and chemical characteristics were carried out according to (Klute, 1986). These analyses are presented in tables [(2) and (3)]. The maximum field capacity for soil was (16.2% at 0.0– 0.2 m and 19% at 0.2–0.4 m).The physical soil characteristics were measured and used for input into AquaCrop.

Table 2. Some physical characteristic and mechanical analysis for experimental site.

Soil dept (cm)	Bulk density (Mg/cm	Very coarse sand %	Coars sand %	Mediun sand %	Fin sanc %	Very fine sand %	Silt +cla %	Soil Field capacit %	Textur
0-20	1.62	0.82	2.69	34.94	29.4	29.3	2.67	16.2	L S*
20-4	1.64	0.90	2.82	31.38	26.7	34.6	3.53	19	L S*

*L.S= Loamy sand

Table 3. Some chemical characteristic for the experimental site

Soil depth (cm)	O.M %	N	P	K	Ca CO_3
0-20	0.18	6.	12	0.2	4.63
20-40	0.48	4.	10	0.3	6.74

For assessment an AquaCrop simulation model the experiment built depending on, spilt spilt plot design, three factors: first factor is sowing date which divided into three treatments (Nov. 1st, Nov. 15th and Nov. 30th) for winter wheat. Second factor is tillage with two treatments (no tillage and tillage 20cm) and the third factor is Supplementary irrigation with three treatments (0 , 75 and 112.5mm) this done by adding (75mm) on mid of February plus adding (37.5mm) on the first week of March]. Further; Using machine with 180 cm working width Consist of seven shanks with chisel blade arranged in two rows and forward speed of tractor was 4.5 km h^{-1} for implement the tillage processes. Memorable; that the harvest was accomplish on mid of April.

Clarification AquaCrop Model

The AquaCrop model was proposed by the FAO in 2009, with a detailed description presented in (Steduto et al., 2009) and (Raes et al.,2009a). The model computes a daily water balance, and separates evapotranspiration into evaporation and transpiration components. The crop's stomata conductance, canopy senescence, leaf growth, and yield response to water stress are modelled using four stress coefficients (stomata closure, leaf expansion, canopy senescence, and change in harvest index (Hi). The model subsequently estimates yield from the daily crop transpiration values. (fig.1)

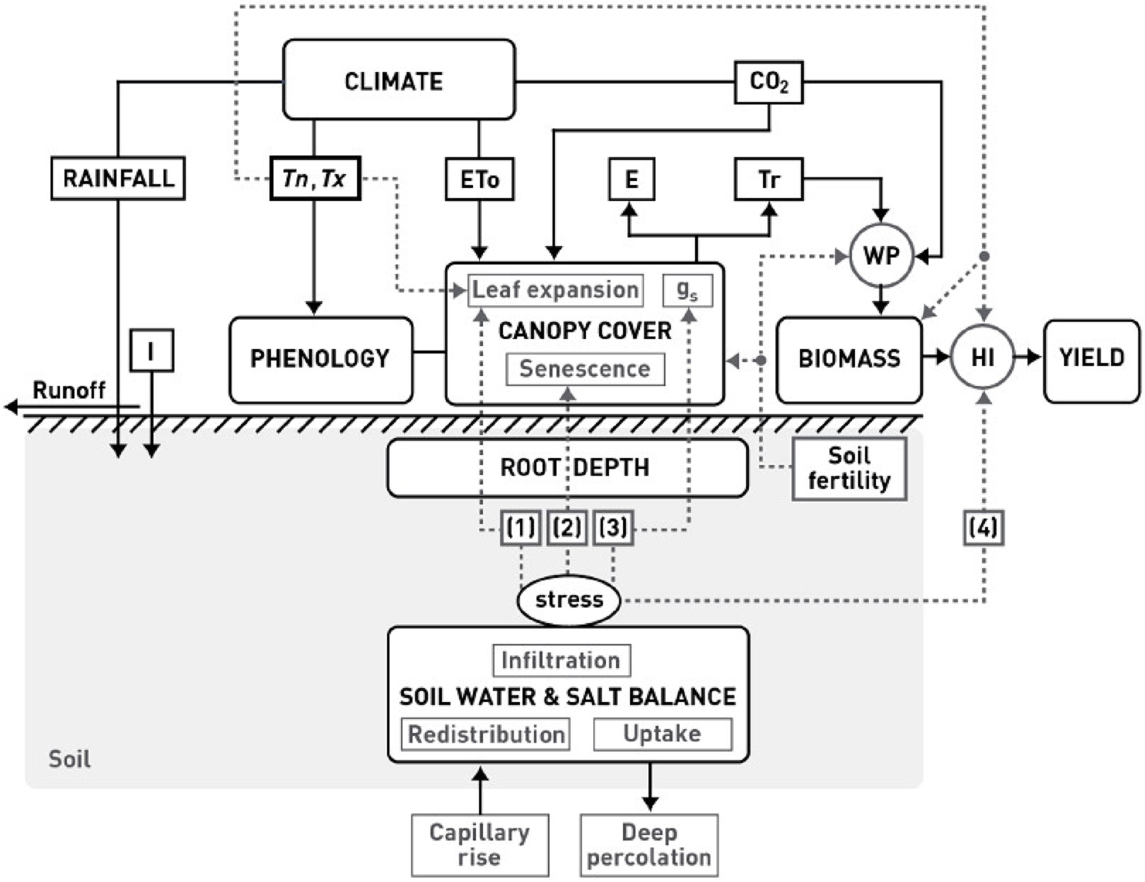


Figure 1. Flowchart of AquaCrop indicating the main components of soil-plant-atmosphere

Moreover; Some of the advantages of AquaCrop are: a) it is widely applicable with acceptable accuracy; b) it requires only commonly available input (i.e. climate, soil, crop and field data); all these input data were used in the model to predict the yield, water productivity, biomass and harvest index of a given crop c) it allows easy verification of simulation results with simple field observations. In general, the crop water productivity (CWP) is considered constant for a given climate condition and crop (For crops not nutrient-limited, the model provides categories ranging from slight to severe deficiencies corresponding to lower water productivity (WP)). So; the CWP remained at 15 g m^{-2} for the winter wheat. Moreover; the crop's daily aboveground biomass is calculated using CWP from the AquaCrop model (Hsiao et al., 2009)

Biomass yield (BY) is calculated by multiplying CWP by the ratio of crop transpiration (T), and evapotranspiration (ETo), following calculation of BY (its harvestable portion), and the grain yield (GY) is determined via harvest index (Hi).

$$BY = \sum \left(\frac{T}{ET_o}\right) x\ CWP \qquad (1)$$

$$GY = BY\ x\ Hi \qquad (2)$$

Where:

BY	=	Biomass Yield (Kg. Fed^{-1}),and
T	=	Crop transpiration (mm), and
ET_o	=	Reference evapotranspiration (mm),and
CWP	=	Crop water productivity (g m^{-2}).
GY	=	Grain yield (Kg. Fed^{-1})
Hi	=	harvest index.

The coefficient of determination (R^2), root mean square error (RMSE), and model efficiency (E) were used as the error statistics to evaluate both calibration and validation results. These statistical indices were used to compare measured and simulated values. Model performance was assessed using E (Nash and Sutcliffe, 1970) as follows:

$$E = 1 - \frac{\sum_{i=1}^{n}(S_i - O_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O}_i)^2} \quad (3)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(S_i - O_i)^2}{n}} \quad (4)$$

Where:

Si = Predicted data,and
Oi = Observed data, and
Ōi = Mean value of Oi, and
N = Number of observation.

When E and R^2 approaching one, and a RMSE near zero this indicate that the model performance were improved.

Growing degree-days (heat units) (GDD)

Growing degree days (GDD) or heat units was calculated using the single sine curve method (Baskerville & Emin, 1969) during growing season of wheat crop. This simple linear method requires only daily minimum and maximum air temperatures, which recorded by the local meteorological weather station in site of experiment, equation (5) give explanation for calculating growing degree days:

$$GDD = [(T_{max} + T_{min}) / 2] - T_{base} \quad (5)$$

Where:

T_{max} = Daily maximum temperature (C°)
T_{min} = Daily minimum temperature (C°), and
T_{base} = Base temperature (C°).

Heat use efficiency (HUE) is the ration of yield to accumulated growing degree days according to (Kingra & Prabhjyot-Kaur, 2012) equation (6).

$$HUE = Yield(Ygi) / (AGDD). \quad (6)$$

Where:

HUE = Heat use efficiency (kg fed^{-1} $C°^{-1}$ day^{-1})
Y_{gi} = The economic yield (kg/fed).
GDD = Accumulated growing degree days (C° day).

Heat units are often used to predict the rate of phonological development of plant species. Developmental rates increase approximately linearly as a function of air temperature (Snyder et al., 1999), therefore the higher or lower temperature will be affected on crop by reducing the plant growth and total yield. So; the lower temperature (T_{base}), was set as 5 C° (Ash & Raddatz, 1993; Bishnoi, et al , 1995).

Finally; The data were analyzed using the three way ANOVA as spilt split plot with Duncan's HSD test at $p<0.05$ using the COSTAT 3.03 System software.

3. RESULT AND DISCUSSION

a) Calibration and validation of AquaCrop:-

Biomass and Grain yield

As shown at (fig.2). The data indicated that there is a strong relationship between a simulated and measured Biomass Yield (BY) (R^2= 0.82 & E = 0.82 & RMSE = 6.7%) for winter wheat under different treatments of (sowing dates and supplementary irrigation strategies) with tillage process. Moreover; under No tillage treatment data represented that the relationship between a simulated and measured are still have a good performance for (R^2, E and RMSE) by 0.889 and 0.9 and 6.3% respectively to Biomass Yield under different treatments (fig.3). Obviously; from (fig.4) under tillage and no tillage treatments there are an intense relationship between a simulated and measured Grain Yield (GY) by (R^2= 0.69 & E = 0.7 & RMSE = 2.8%)

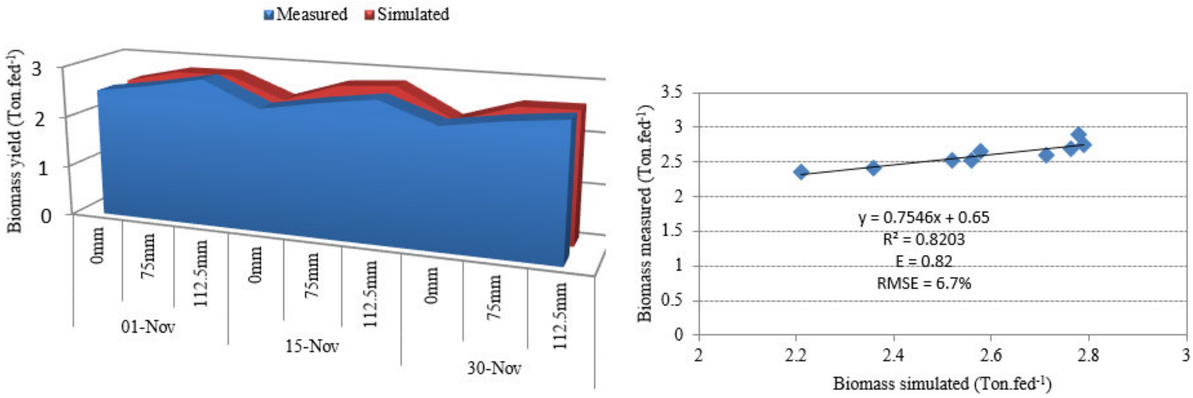


Figure 2. Relationship between measured and simulated Biomass Yield (BY) for winter wheat under tillage processes and different treatments

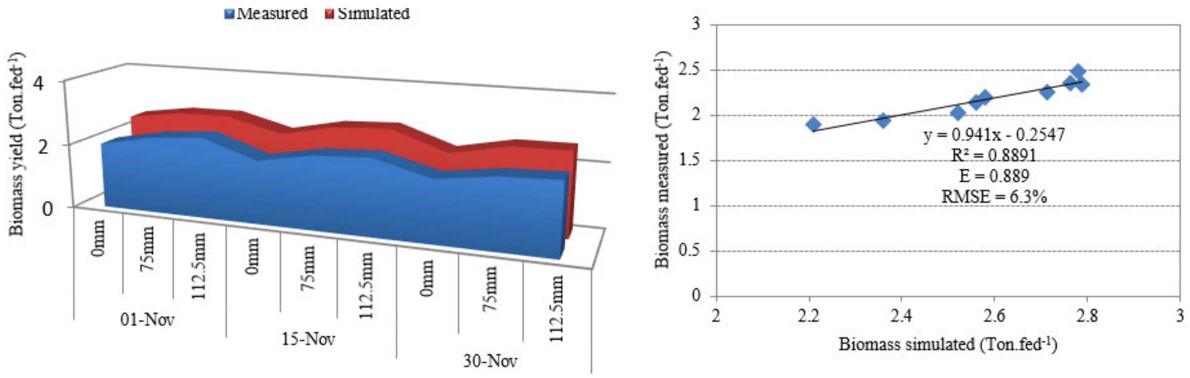


Figure 3. Relationship between measured and simulated Biomass Yield (BY) for winter wheat under no tillage and different treatments

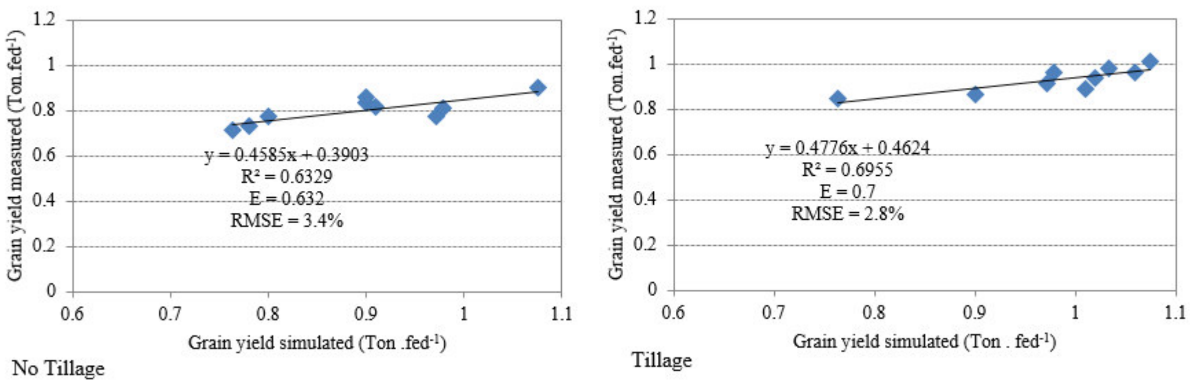


Figure 4. Relationship between measured and simulated Grain Yield (GY) for winter wheat under different treatments

With tillage process and (R^2= 0.63 & E = 0.632 & RMSE = 3.4%) with no tillage for winter wheat under different treatments of (sowing dates and supplementary irrigation strategies).

Noticeable; that the higher R^2 and E values and the lower RMSE values indicated a good model performance. However, the best values for R2, E and RMSE obtained with tillage treatment under other different treatments comparing with no tillage process. Further; the average for both a measured and simulated (Hi) are 0.368 and 0.347 respectively. Consequently; these results suggest that the AquaCrop model is useful for simulating winter wheat for BY and GY under different planting dates, and irrigation strategies.

Accumulated growing degree days (AGDD):

Table (4) illustrate the mean 10 day monthly, real and adjusted temperature, growing degree days (GDD) and accumulated growing degree days (AGDD) during wheat growing season; clearly, the total amount of heat units required for wheat to develop from one point to another in its life cycle was 1699, 1522 and 1333.6 C °/ season, for sowing date 1st Nov, 15th Nov and 30th Nov. respectively. As shown at fig (5); with no tillage treatment the biomass yield for wheat has no significant different value for both (75mm and 112.5mm) under different AGDD

1336.6, 1522 and 1699 c° day. However; the biomass values under (0 mm) recorded a lowest value comparing with other water treatment by (2.016, 1.931 and 1.896 ton.fed^{-1}) under (1699, 1522 and 1333.6 c° / season) respectively. Meaning that the (1 Ton.fed^{-1}) Biomass Yield from winter wheat needs for (744.19, 700.1 and 641.6) heat units as an average under different sowing dates (1st Nov, 15th Nov and 30th Nov.) respectively with different treatments. Clearly; under no tillage the biomass increases liner with increasing the AGDD. This relation can be summarizing by (Eq.7).

$$BY_{nt} = 0.0005\ (AGDD) + 1.328 \qquad (7)$$

Where: -

BY_{nt} = The Biomass yield for wheat under No tillage (Ton. fed^{-1}).

AGDD = Accumulative of growing degree-days (c° day)

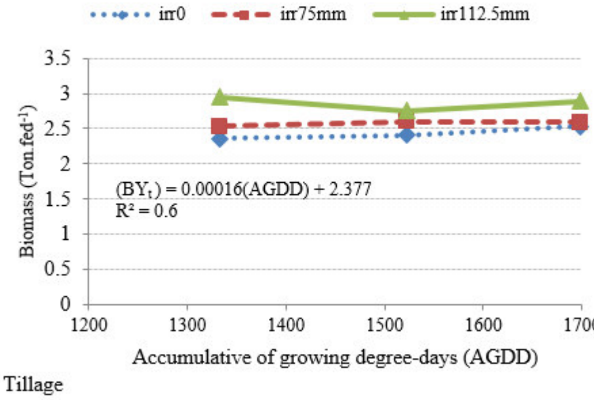
On the other hand; under tillage the biomass values have different demeanour; where, that with high amount of Supplementary irrigation (112.5mm) there is not an influence of AGDD on Biomass. In addition; the value recorded (2.894 ton.fed^{-1}) with (1699 c° / season) and (2.947 ton.fed^{-1}) with (1333.6 c° / season). Further; with (75 mm) biomass's value did not recorded a significant impact comparing with (0 mm). Notable; that the (1 Ton.Fed^{-1}) biomass yield needs for (635.9, 588.3 and 510.6) heat units as an average under different sowing dates (1st Nov, 15th Nov and 30th Nov.) respectively. The flowing equation (Eq.8) represented the relation between (AGDD) and (Bi) with tillage under such conditions.

$$BY_{t} = 0.00016\ (AGDD) + 2.377 \qquad (8)$$

Where: -

BY_t = The Biomass yield for wheat under tillage (Ton. fed^{-1}).

AGDD = Accumulative of growing degree-days (c° day)



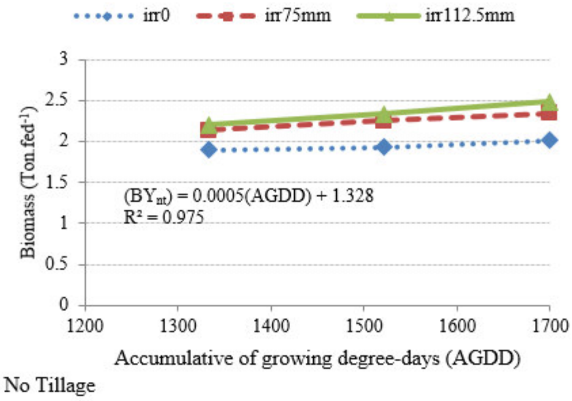
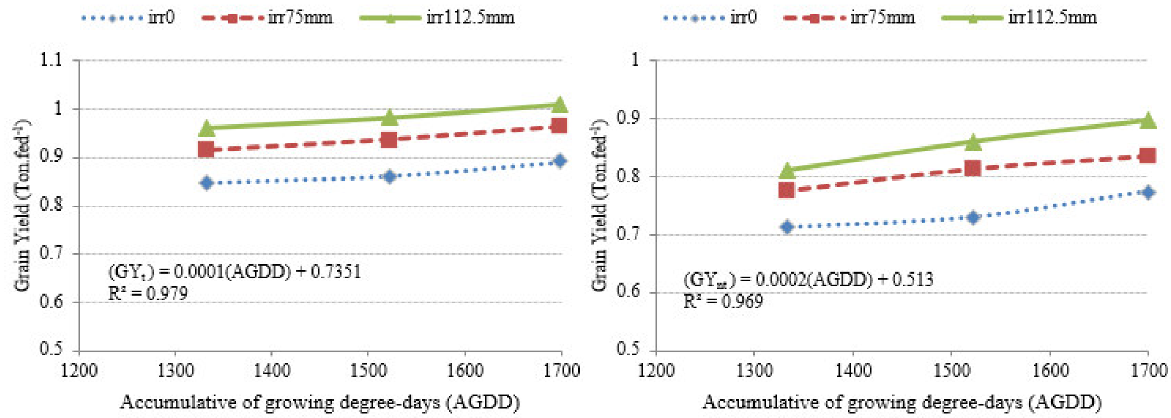


Figure 5. Relationship between Biomass Yield (BY) for winter wheat and Accumulative of growing degree-days under different treatments.

Table 4. Mean 10day monthly, temperature, growing degree days (GDD) and accumulated growing degree days (AGDD) during wheat growing season.

Months	sowing date 1th Nov.					sowing date 15th Nov.					sowing date 30th Nov.				
	Date	T_{max}	T_{min}	GDD	AGDD	Date	T_{max}	T_{min}	GDD	AGDD	Date	T_{max}	T_{min}	GDD	AGDD
2014-2015	D	C°	C°	C°	C° day	D	C°	C°	C°	C° day	D	C°	C°	C°	C° day
Nov	1-10	24	15.1	145.5	145.5	*	*	*	*	*	*	*	*	*	*
	11-20	22.6	13.5	130.5	276	15-24	22	13.8	129	129	*	*	*	*	*
	21-30	21.7	12.6	121.5	397.5	25-4	20.6	12.1	113.5	242.5	*	*	*	*	*
Dec	1-10	19.9	11.6	107.5	505	5-14	19.5	11	102.5	345	30-9	20	11.5	107.5	107.5
	11-20	19	10.6	98	603	15-24	18.6	10.8	97	442	10-19	19	10.7	98.5	206
	21-30	18	10	90	693	25-3	18	10	90	532	20-29	18.9	10	94.5	300.5
Jan	31-9	17.8	10	89	782	4-13	17.6	10	88	620	30-8	17.9	10	89.5	390
	10-19	17	9.6	83	865	14-23	17	9.8	84	704	9-18	17	9.7	83.5	473.5
	20-29	17	9	80	945	24-2	17	9	80	784	19-28	17	9	80	553.5
Feb	30-8	17.8	9	84	1029	3-12	17.4	9	82	866	29-7	17.9	9	84.5	638
	9-18	18	9.6	88	1117	13-22	18	9.8	89	955	8-17	18	9.7	88.5	726.5
	19-28	18	10	90	1207	23-4	18.7	10	93.5	1048.5	18-27	18	10	90	816.5
Mar.	1-10	18.9	10	94.5	1301.5	5-14	19	10.9	99.5	1148.5	28-9	18.8	10	94	910.5
	11-20	19.5	10.3	99	1400.5	15-24	20	11	105	1253	10-19	19.6	10.4	100	1010.5
	21-30	20.7	11.8	112.5	1513	25-3	21.7	11.6	116.5	1369.5	20-29	20.6	11	108	1118.5
April	31-9	22.7	12	123.5	1636.5	4-13	22.7	12.6	126.5	1496	30-8	22.9	12	124.5	1243
	10-15	23	12	62.5	**1699**	14-15	23	13	26	**1522**	9-15	23	12.9	90.6	**1333.65**



Tillage No Tillage

Figure 6. Relationship between Grain Yield (GY) for winter wheat and Accumulative of growing degree-days under different treatments

Moreover; data represented at (fig.6). There is a power response between Grain yield and and accumulative growing degree-days with an average R^2 = 0.97 at both two tillage application treatments (Eqs. 9 & 10) .

$$GY_{nt} = 0.0002\ (AGDD) + 0.513 \qquad (9)$$

Where: -

GY_{nt} = The Biomass yield for wheat under No tillage (Ton. fed^{-1}).

AGDD = Accumulative of growing degree-days (c° day)

$$GY_{t} = 0.00016\ (AGDD) + 2.377 \qquad (10)$$

Where: -

GY_t = The Biomass yield for wheat under tillage (Ton. fed^{-1}).

AGDD = Accumulative of growing degree-days (c° day)

The strong liner relationship between Grain yield and AGDD with average bower (R^2) = 0.97 for both treatment tillage and no tillage. Nevertheless; the highest value recorded with tillage treatment where the value of grain yield was (1.01 $Ton.Fed^{-1}$) under (1699 c° / season) with (112.5mm) treatment. Generally; with No tillage the (1 $Ton.Fed^{-1}$) grain yield needs for (2081.4, 1897.7 and 1738.7) heat units under different sowing dates (1st Nov, 15th Nov and 30th Nov.) respectively with different water treatments. However; under Tillage application (1 $Ton.Fed^{-1}$) from grain yield needs for (1779.05) heat units if sowing on the (1st Nov.) and for (1641.85) heat units if sowing on (15th Nov.) but with sowing date (30th Nov.) the (1 $Ton.Fed^{-1}$) from grain yield needs for (1468.7) heat units under such conditions.

Furthermore; data of heat uses efficiency (HUE) were obtained as shown on table (5) under different treatments. The highest value observed with (112.5mm) and tillage operation under sowing date 30th Nov by (2.2 & 0.72 Kg. fed^{-1} $C^{-1}day^{-1}$) for both Biomass and grain yield respectively. Because , the efficiency of utilization of heat in terms of dry matter accumulation, depends on crop type, genetic factors and sowing time and has great practical application (Rao et al , 1999). In addition; under no tillage operation the same result was recorded with amount of water (112.5mm) and sowing date (30th Nov) by (1.65 Kg. fed^{-1} $C^{-1}day^{-1}$) for biomass and by (0.6 Kg. fed^{-1} $C^{-1}day^{-1}$) for grain. However; the lowest value for HUE observed under sowing date (1st Nov.) under both treatments no tillage and tillage operation by (1.18 and 1.48 Kg. fed^{-1} $C^{-1}day^{-1}$) for biomass and by (0.45 and 0.52 Kg. fed^{-1} $C^{-1}day^{-1}$) respectively under (0 mm). Ultimately; the best interlaced impact for treatments is using tillage operation with sowing date 30th Nov with adding (112.5mm) as a Supplementary irrigation under rainfall (40mm) before sowing date. Because; that the tillage operation gave an opportunity to collecting more water on surface soil which helping crop at first stage. a purport; Good soil water management in rain fed agriculture can also be achieved through minimum tillage and rainwater harvesting techniques /structures (Walter et al, 2006). Further; the heat units at the end of November may more effective on plantation and phonology for wheat comparing with other sowing date.

Table 5. Heat use efficiency (HUE) for winter wheat under different treatments

water treatments (mm)	No Tillage					
	1st Nov.		15th Nov.		30th Nov.	
	Biomass	Grain	Biomass	Grain	Biomass	Grain
	(Kg. fed $^{-1}$ C^{-1}day^{-1})					
0	1.18	0.45	1.26	0.48	1.42	0.53
75	1.38	0.49	1.48	0.53	1.6	0.58
112.5	1.46	0.52	1.53	0.56	1.65	0.6
water treatments (mm)	Tillage					
	1st Nov.		15th Nov.		30th Nov.	
	Biomass	Grain	Biomass	Grain	Biomass	Grain
	(Kg. fed $^{-1}$ C^{-1}day^{-1})					
0	1.48	0.52	1.58	0.56	1.76	0.63
75	1.52	0.56	1.7	0.61	1.89	0.68
112.5	1.7	0.59	1.8	0.64	2.2	0.72

Finally; after made a statistical analysis for recording data of biomass yield to winter wheat under different factors (Table. 6). Analysis data represented that there are a significant influence for all treatments on biomass yield. The highest value recorded with tillage operation, sowing date 1st Nov and supplementary irrigation (112.5mm) by 2.5, 2.48 and 2.53(Ton.Fed^{-1}) respectively. Further; the same result was observed with Grain yield where there are significant impacts between all treatments on Grain Yield. However; under sowing date there are not significant influences between (1st Nov and 15th Nov), (15th Nov and 30th Nov). In addition; the best values observed with treatment (112.2mm, sowing date 1st Nov. and tillage) by (0.925, 0.897 and .932 Ton.Fed^{-1}) respectively. These results obtained because the winter wheat needs to some soil managements to enhance soil ability to harvest rain water which reflected on yield production. This agree with (Hatfield et al, 2001) who suggested that it was possible to increase crop by 25- 40% through soil management. On the other hand; that the winter wheat needs to irrigate by limitation Supplementary irrigation to increase both biomass and Grain (Zhang et al., 2002 a, b) pointed out; that the maximum yield of wheat does not necessary mean the highest consumption of water. Under some condition, more consumption of water by wheat could decrease yield.

Table 6. Statistical analysis for all treatments on Biomass and Grain yield for winter wheat

Irrigation			Date			Tillage operation	
0mm	75mm	112.5mm	1st Nov	15th Nov	30th Nov	Tillage	No tillage
Biomass Yield (Ton.Fed^{-1})							
2.16c	2.42b	2.53a	2.48a	2.37b	2.26c	2.5a	2.16b
LSD .05 = 0.075			LSD .05 = 0.097			LSD .05 = 0.083	
Grain Yield (Ton.Fed^{-1})							
0.803c	0.873b	0.925a	0.897a	0.865ab	0.84b	0.932a	0.802b
LSD .05 = 0.027			LSD .05 = 0.050			LSD .05 = 0.042	

4. CONCLUSION

This paper elucidate that the AquaCrop model adequately simulated the biomass yield(BY), and grain yield(GY) of winter wheat under different sowing dates, irrigation strategies and tillage operation. The simulated (BY) agreed well with the measured (BY) across different treatments. (R^2= 0.82 & E = 0.82 & RMSE = 6.7%) for winter wheat under different treatments of (sowing dates and supplementary irrigation strategies) with tillage process. The measured and simulated (GY) were also closely related. The AquaCrop model calibrated the GY with the prediction error statistics of by (R^2= 0.69 & E = 0.7 & RMSE = 2.8%) with tillage process. Moreover; the (1 Ton.Fed^{-1}) (BY) needs for (635.9, 588.3 and 510.6) heat units (AGDD) as an average under different sowing dates (1st Nov, 15th Nov and 30th Nov.) respectively. Further; the (1 Ton.Fed^{-1}) from grain yield needs for (1779.05) heat units if sowing on the (1st Nov.) and for (1641.85) heat units if sowing on (15th Nov.) but with sowing date (30th Nov.) the (1 Ton.Fed^{-1}) from grain yield needs for (1468.7) heat units under such conditions. Notable; that the highest value for heat uses efficiency (HUE) observed with (112.5mm) and tillage operation under sowing date 30th Nov by (2.2 & 0.72 Kg. fed $^{-1}$ C^{-1}day^{-1}) for both (BY) and (GY) respectively. Consequently; these results suggest that the AquaCrop model could be used to predict BY and GY of winter wheat with a high degree of reliability at western north coast conditions. Further; that there is not a deterioration on yield production whatever delay the sowing date under such conditions.

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