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USING AQUACROP MODEL TO EVALUATE THE EFFECT OF PULSE DRIP IRRIGATION TECHNIQUES AND WATER STRESS ON MAIZE WATER PRODUCTIVITY

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Abstract

The objectives of this research were to evaluate by AquaCrop model the effect of pulse drip irrigation technique were: a) 6 lph and b) 10 lph, and different water stress amounts treatments from evapotranspiration (ETo): 80 %, 65 %, 50 % on maize (*Zea mays* L., HF-10 variety) vegetative growth, grain and biomass yield. Observed and simulated grain yield, and biomass yield. The experiments design was split in randomized complete block with three replicates. To carry out items mentioned above a field experiment for one growing season (2018) was conducted in sandy soil at the agricultural research field of national research center, El-Nubaria, Egypt. Pulse drip irrigation water was added in order to compensate for etc of maize and salt leaching requirement. Data on hand could be summarized as follow: the effect of different discharges of pulse drip irrigation on pulse drip irrigation system efficiencies, overall pulse drip irrigation efficiencies, and effective pulse drip irrigation efficiencies, data could be ranked in the following descending orders: 6 lph > 10 lph and based on these results, with decreasing of pulse drippers discharge will be increasing and give the greater all efficiencies. Observed and simulated Grain and biomass yield could be ranked in following descending orders: 10 lph > 6 lph and 50 > 65 > 80. in respect to pulse drip irrigation and ETo %, while water productivity (WP) could be ranked in following descending orders: 6 lph > 10 lph and 80 > 65 > 50. The effect on observed and simulated maize water productivity (WP), grain and biomass yield, one can notice significant difference at the 5 % level between all means values of pulse drip irrigation and et %. according to the interaction effect of the investigated factors, the highest and lowest values of maize biomass yield recorded under interactions of 6 lph x 80 and 10 lph x 50. The treatments of 80 % ET and 65 % ET were covered water requirements and also recorded convergent results in values which means that the amount of water added, which is the difference between the 80 - 50% = 30% ET, it amounts in excess of the plant required under the current conditions of the experiment. So it can be recommend to using 50% for saving 30% from water requirements under pulse drip irrigation system using 6 lph treatment.

Introduction

Maize (*Zea mays* L.) is cultivated in areas lying between 56 ° north latitude and 40 ° south latitude from sea level up to an altitude of 3,6 00 meters. It is a crop which is irrigated worldwide. The main maize producing country being the USA. (Musick *et al.*, 1990 and Filintas, 2003). Most research projects on this particular subject refer to the effect of drip irrigation on maize yield using sprinkler drip irrigation or furrow drip irrigation. In contrast, only a few studies have been made on maize cultivation under drip irrigation (Filintas *et al.*, 2006; Filintas *et al.*, 2007 and Dioudis *et al.*, 2006, agreed with (Tayel *et al.*, 2012 a,d, Mansour 2015, Mansour *et al.*, 2015 a,b,c; Mansour *et al.*, 2016a, b, c; Mansour 2006, 2012, 2015 and Mansour and Goyal, 2015); Goyal and Mansour 2015, El-Hagarey *et al.*, 2015; Mansour *et al.*, 2019 a,b, Mansour *et al.*, 2015 a,d, and Mansour *et al.*, 2016a,c, Ibrahim *et al.*, 2016 and Mansour and Aljughaiman 2012, 2015, Mansour and El-Melhem 2012, 2015; Attia *et al.*, 2019, (Tayel *et al.* (2012 a,b), (2015 a-e), (2016), (2016), (2019), Mansour (2015) and Mansour *et al.* (2014) Consequently, the water application rate is one key factor determining the soil water content around the emitter Mansour *et al.* (2013), Mansour *et al.* (2014), Mansour *et al.* (2015 a-f), (2019 a,b) and (2016 a-c); Goyal and Mansour (2015) and El-Hagarey *et al.* (2015), Abd-Elmabod *et al.* (2019). These few studies used the evaporation pan method to calculate the amount of water needed for drip irrigation. This method was used in England, in 2001, for drip irrigation scheduling in up to 45 % of the irrigated areas of the country in outdoor cultivation, (Weatherhead and Danert, 2002). Also, an additional advantage of drip drip irrigation is that, there are many tools available for soil moisture measurement Cary and Fisher, 196 3; Filintas, 2005, electronic programmers and electro hydraulic elements which give the possibility of complete automation of drip irrigation networks (Charlesworth, 2000; Filintas, 2005).

The repeatable and reoccurring real systems can be validated independently making it possible to the develop models and continue to build on them year after year, (Loomis *et al.*, 1979). The development of crop growth models began in the 1960s and have advanced and become more refined since, (El-Sharkawy, 2011). Crop models can be useful for the agronomic research tools that predict of the growth, the development and crop yield in the response to the surrounding environment (Steduto *et al.*, 2009). There are many existing crop models that are used around the world. All of the models have different structures, methods, inputs and algorithms for simulating crop growth (Todorovic *et al.*, 2009). The next section will provide the review of AquaCrop model used in this study.

The AquaCrop model is defined by Steduto *et al.* (2009) as "canopy-level and the engineering type of the model, mainly focusing on simulating an attainable crop biomass and the harvestable yield in the response to water available. The model was developed for purpose to using the fewer parameters in the balance of the simplicity, accuracy, and robustness. Water is used as main driver in AquaCrop for simulating yield production. Water is very important for crop production and was proven early on to be one of major limiting factors in crop growth (De Wit and Van Keulen, 1987).

The application of fertilizers is usually by hand with low efficiency, resulting in higher costs and environmental problems, (Aboukheira, 2009). He stated that maize (*Zea mays* L.) is one of the most important cereals, both for peoples and animals consumption, in Egypt and is grown for both grain and forage. The questions often arise, “What is the minimum drip irrigation capacity for irrigated transgenic maize? And what is the suitable drip irrigation system for irrigating transgenic maize?” These are very hard questions to answer because they greatly depend on the weather, yield goal, soil type, area conditions and the economic conditions necessary for profitability.

The aims of this work were to evaluate by AquaCrop model the effect of discharges of pulse drip irrigation technique treatments: a) 6 LPH and b) 12 LPH, and different water amounts treatments from evapotranspiration (ET): 80 %, 65 %, 50 % on maize (*Zea mays* L.) vegetative growth, grain and Biomass yield.

Material and Methods

The experiment for one growing season (2018) was conducted in sandy soil at the Agricultural Research Field of National Research Center, El-Nubaria, Egypt. The aim of study to evaluate by AquaCrop model the effect of pulse drip irrigation technique treatments: a) 6 LPH and b) 12 LPH, and different water amounts treatments from evapotranspiration (ET): 80 %, 65 %, 50 % on maize (*Zea mays*-L, HF-10 Varity) vegetative growth, grain and Biomass yield. Vegetative growth and yield included: Leaf area, Leaf length, leaf number plant-1, Plant height, grain yield, and Biomass yield. Texture of experimental field after (Gee and Bauder, 1966) and Moisture retention after (Klute, 1966). Whereas soil chemical characteristics of soil paste saturation extract and drip irrigation water analysis are shown in Tables (1, 2; 3) Rebecca, (2004).

The experiments design was split in randomized complete block with three replicates. To carry out items mentioned above a field experiment for one growing season (2018) was conducted in Sandy soil at the Agricultural Research Field of National Research Center, El-Nobaria, Egypt. Source of drip irrigation water was from ground water. The total experimental area was one feddan (one Fed = 0.42 ha). After seeding preparation maize grains (*Zea mays* L.), Varity (Giza-155) were seeded on May 3, 2013 (30000 plant fed^{-1}). Plants were irrigated every 3-4 days using PI. Drip irrigation water was added in order to compensate for ETc of maize and salt leaching requirement. Data on hand could be summarized as follow: Details of the pressure and water supply control have been described by (Safi *et al.*, 2007).

Drip irrigation networks include the following components are: 1.Control head: It was located at the water source supply. It consists of centrifugal pump 3`` /3``, driven by electric engine (pump discharge of 60 m^3/h and 40 m lift), sand media filter 46 ``(two tanks), screen filter 2`` (120 mesh), back flow prevention device, pressure regulator, pressure gauges, flow-meter, control valves and chemical injection, 2. Main line: PVC pipes of 65mm in (ID) Ø to convey the water from the source to the main control points in the field, 3. Sub-main lines: PVC pipes of 65mm in (ID) Ø were connected to with the main line through a control unit consists of a 2`` ball valve and pressure gauges, 4. Manifold lines: PVC pipes of 50mm in (ID) Ø were connected to the sub main line through control valves 1.5``, 5. Lateral lines: PE tubes of 16 mm in (ID) Ø were connected to the manifolds through beginnings stalled on manifolds lines, 6. Emitters: These pulse emitters built on PE tubes 16 mm in (ID) Ø, emitter discharge of 6 and 12 lh^{-1} at 1 atm. nominal operating pressure and30 cm spacing in-between. The components pulse drip irrigation system include, supply lines, control valves, supply and return manifolds, lateral lines, pulse emitters, check valves and air relief valves/vacuum breakers.

Pulse drip irrigation system efficiency:

Yoder and Eisenhauer, 2010 stated that the term of the drip irrigation system efficiency, in this study pulse efficiency (PE) is used to be defining the effectiveness of the pulse drip irrigation system in delivering all the water beneficially used to produce the crop. Pulse drip irrigation efficiency is defined as the ratio of the volume of water that is beneficially used to the volume of drip irrigation water applied. It is expressed as:

$$PE = (Vb / Vf) \times 6\ 0 \qquad ...(1)$$

Where:

PE = pulse drip irrigation Efficiency
Vb = volume of water beneficially used (fed-cm)
Vf = volume of water delivered to the field (fed-cm)

Overall pulse drip irrigation efficiency (PIE):

It is calculated by multiplying the efficiencies of water conveyance and water application:

$$PIE = (Ec \times Ea) \times 6\ 0 \qquad ...(2)$$

Where:

PIE = overall pulse drip irrigation efficiency (%)
Ec = water conveyance efficiency (decimal)
Ea = water application efficiency (decimal)
Effective pulse drip irrigation efficiency (PE)

It is the overall pulse drip irrigation efficiency corrected for runoff and deep percolation water that is recovered and reused or restored to the water source without reduction in water quality. It is expressed as:

$$PIE = [\ Eob + (FR) \times (1.0 - PE)\ ] \times 80 \qquad ...(3)$$

Where:

FR = fraction of surface runoff, seepage, and /or deep percolation that is recovered.

Table 1 : Some physical properties of the soil.*

Particle Size distribution, %				Texture class	θS % on weight basis			HC (cmh^{-1})	BD (g/cm^3)	P (cm^3 voids /cm^3 soil)
C. Sand	F. Sand	Silt	Clay		F.C.	W.P.	AW			
6 .6	76.7	6 .6	5.9	Sandy	14.0	6.0	6 .0	6.17	1.67	0.37

* Particle Size Distribution after (Gee and Bauder, 196 6) and Moisture retention after (Klute, 1966)
F.C.: Field Capacity, W.P.: Wilting Point, AW: Available Water, HC: Hydraulic conductivity(cmh^{-1}), BD: Bulk density (g/cm^3) and P: Porosity (cm^3 voids/cm^3 soil).

Table 2 : Some chemical properties of the soil*.

pH 1:2.5	EC dS/m	Soluble Cations, meq/L				Soluble Anions, meq/L			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{-}
6 .3	0.34	0.56	0.41	1.05	0.23	0	0.12	0.6 1	1.23

*Chemical properties after Rebecca, (2004)

Table 3 : Some chemical properties of drip irrigation water used.

pH	EC dS/m	Soluble cations, meq/L				Soluble anions, meq/l				SAR
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{-}	
7.3	0.37	0.76	0.24	2.6	0.13	0	0.9	0.32	2.51	4.61

The flow rate through the pipe put depends on pipe surface roughness and air layer resistance. The change of hydraulic friction coefficient values, depending on variations in Re number values. Hydraulic losses at plastic pipes might be calculated as losses at hydraulically smooth pipes, multiplied by correction coefficients that assess losses at pipe joints and air resistance.

Drip irrigation scheduling: Intervals of drip irrigation (I) in day were calculated using the following equations:

$$I = d / ETc \quad ...(4)$$

Where:

d = net water depth applied per each drip irrigation (mm), and ETc = crop evapotranspiration (mm/day).

$$d = AMD . ASW . Rd . P \quad ...(5)$$

Where:

AMD = allowable soil moisture depletion (%), ASW = available soil water, (mm water/m depth), Rd = effective root zone depth (m), or drip irrigation depth (m), and p = percentage of soil area wetted (%).

$$AW(v/v \%) = ASW(w/w \%) . B.D \quad ...(6)$$

Where:

B.D. = Soil bulk density (gm cm^{-3}).

Drip irrigation Intervals used was 4 days under both closed circuits and traditional drip irrigation systems.

Measuring the Seasonal evapotranspiration (ETc):

The (ETc) was computed using the Class Pan evaporation method for estimating (ETo) on daily basis was taken from nearest meteorological station as showing in Table (4).

The modified pan evaporation equation to be used:

$$ETo= KpEp \quad ...(7)$$

where:

ETo = reference evapotranspiration [mm day^{-1}],

Kp= pan coefficient of 0.76 for Class A pan placed in short green cropped and medium wind area. Ep= daily pan evaporation (mm day-1), Seasonal average is [7.5 mm day-1].(Allen *et al.*, 1996).

The reference evapotranspiration (ETo) is then multiplied by a crop coefficient Kc at particular growth stage to determine crop consumptive use at that particular stage of maize growth.

$$ETc= EToKc \quad ...(6)$$

The reduction factor (Kr) was calculated using Eq. 6.

$$Kr = GC + ½ (1 - GC) \quad ...(9)$$

Where: GC = ground cover percentage.

Drip irrigation efficiency (Ea) calculated by

$$Ea =Ks\ Eu \quad ...(10)$$

Where:

Ea = Drip irrigation efficiency, Eu = emission uniformity (%) and Ks = reduction factor of soil wetted.

The distance between rows was 0.7 m and 0.25 m between plants in the row. Each row was irrigated by a single straight lateral line in the closed circuits and traditional drip drip irrigation plots. The total experimental area was 4200 m^2. This area divided to tow pars for each of the dripper discharge of pulse drip irrigation system, plot areas of pulse drippers discharges were 26 0 m^2, the plot area 26 0 m^2 divided to three sub-plots each water amount treatments from (ET) 6 0, 65 and 50% = 700 m^2. Drip irrigation season of maize was ended 15 days before harvest. Maize yield was harvested on September 15. Plants densities were 40000 plants per fed according to Ministry of agricultural in Egypt. Fertilization program had been done according to the recommended doses throughout the growing season (2012) for maize crop under the investigated drip irrigation systems using fertigation technique. These amounts of fertilizers NPK (20-20-10), were 6 0 kg/fed of (20 % N) and 40 kg/fed of (20 % K_2O). While 65 kg/fed of (10 % P_2O_5). For all plots, weed and pest control applications followed recommendations of transgenic maize yield in El-Nobaria, Egypt.

Measurements of maize plant growth and yield:

Components of yield or measured include plant height (cm), leaf length (cm), leaf area (cm^2), number of leaves plant-1, total grain weight Kg/fed and biomass yield (Kg/fed). Plant measurements and observations were started 21 days after planting, and were terminated on the harvest date. All plant samples were dried at 65^o C until constant weight was achieved. Grain yield was determined by hand harvesting the 6 m sections of three adjacent center rows in each plot on 2013 and was adjusted to 15.5% water content. In all treatments plots, the grain yields of individual rows were determined in order to evaluate the yield uniformity among the rows.

Canopy cover was estimated based on the method used by Geerts *et al.* (2009) and Farahani *et al.* (2009):

$$CC = 1 \exp (-0.65LAI) \quad ...(1)$$

Where CC is canopy cover as shown in Fig (1) and LAI is the leaf area index. LAI was calculated as LAP×NPM2, LAP being the leaf area per plant (m^2), and NPM2 the number of plants per m^2 (Royo *et al.*, 2004). The nil biomass and grain yield were obtained from all plots after maturity from an area of 6 m^2 in all cropping seasons.

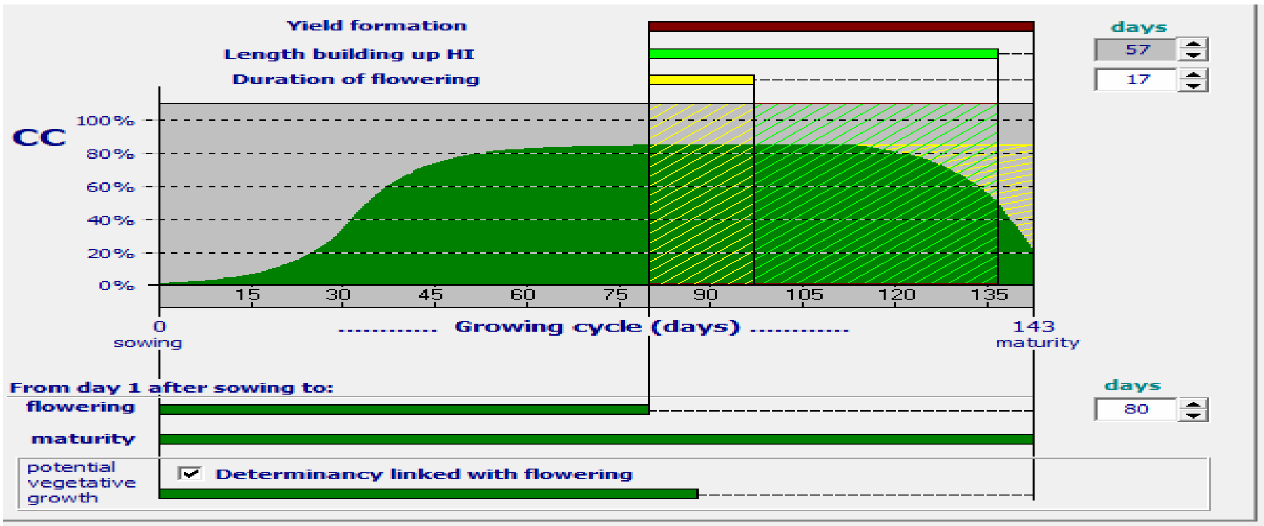

Fig. 1 : Canopy cover, flowering and yield formation of maize by AquaCrop model.

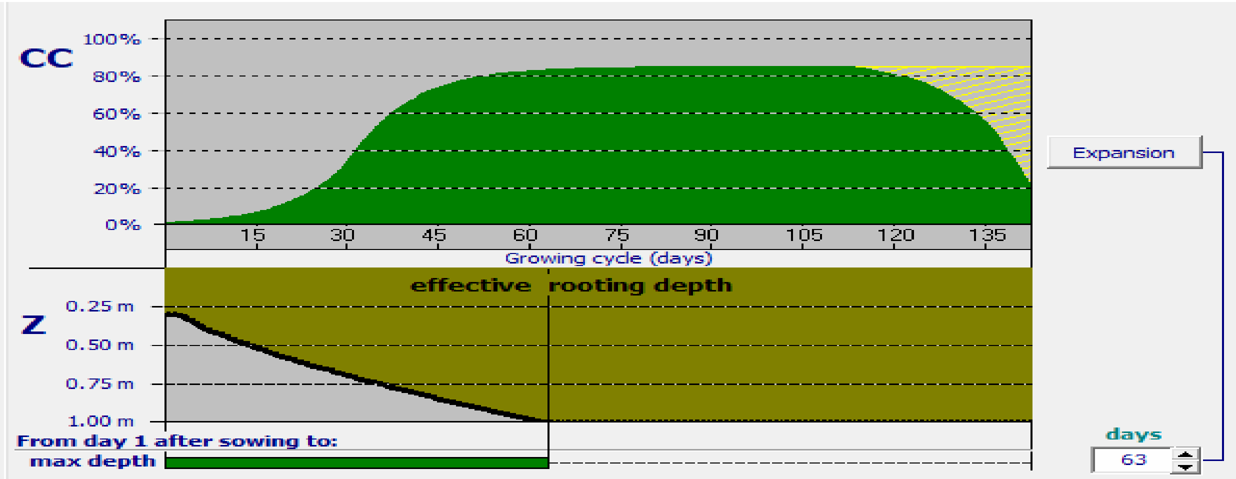

Fig. 2 : Effective root depth of maize varieties by AquaCrop model.

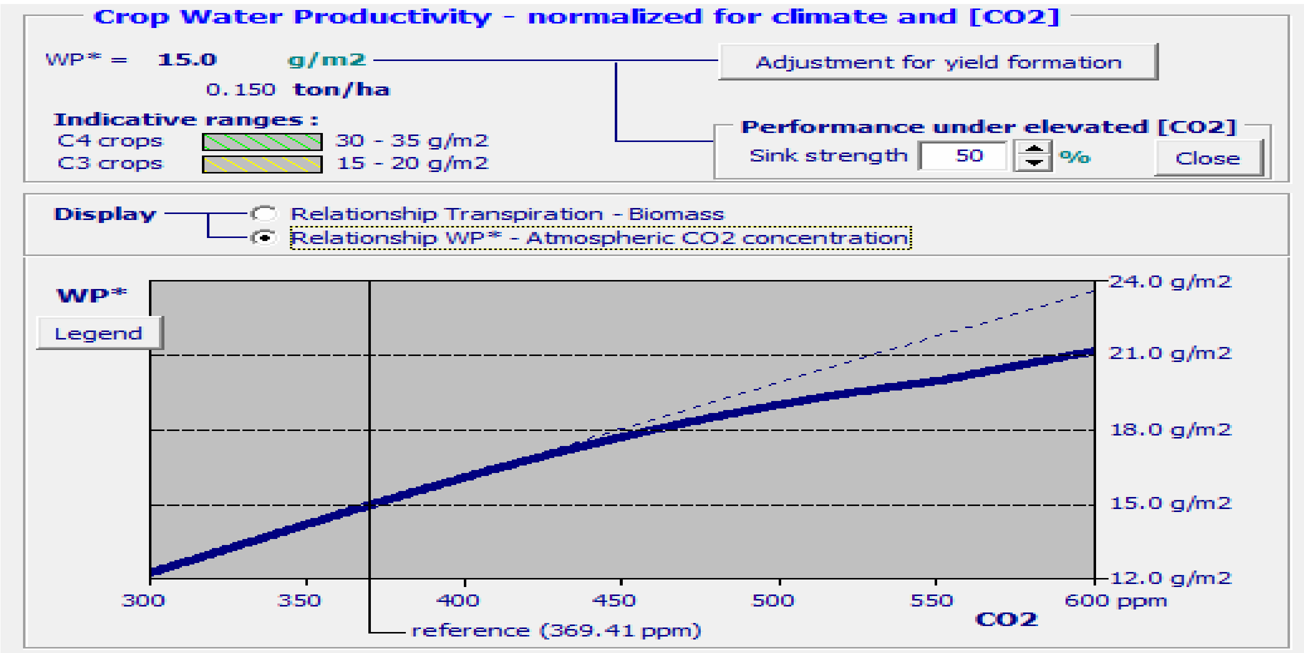

Fig. 3 : The relationship between maize water productivity and CO_2.

AquaCrop has four sub-model components: (i) the soil (water balance); (ii) the crop (development, growth and yield); (iii) the atmosphere (temperature, rainfall, evapotranspiration (ET) and carbon dioxide (CO_2) concentration); and (iv) the management (major agronomy practices such as planting dates, fertilizer application and irrigation if any). Fig. (4) showing the relationship between Maize biomass water productivity and transpiration/ETo and

Fig (4) showing the relationship between Maize water productivity and CO_2 draw by AquaCrop model.

AquaCrop calculates a daily water balance that includes ail the incoming and outgoing water fluxes (infiltration, runoff, deep percolation, evaporation and transpiration) and changes in soil water content. There are five weather input variables required to run AquaCrop including daily maximum and minimum air temperatures (T), daily rainfall, daily reference evapotranspiration (ETo) and the mean annual CO_2 concentration in the bulk atmosphere. The advantage with AquaCrop is that it requires only a minimum of input data, which are readily available or can easily be collected. AquaCrop has default values for several crop parameters that it uses for simulating different crops including maize, however, some of these parameters are not universal and thus have to be adjusted for local conditions, cultivars and management practices.

$$\text{Deviation \%} = 100- ((Oi.100)/Si) \quad ...(2)$$

where Oi: Measured values and Si: Simulated values.

The AquaCrop model uses the yield response to water equation (Eq. 3) as a starting point for the model. Doorenbos and Kassam (1979) developed this equation, which has been widely used to estimate yield response to water by planners, economists and engineers (Vaux and Pruitt, 1983; Howell *et al.*, 1990). AquaCrop evolves from this approach (Eq. 3) by separating the evapotranspiration into crop transpiration and soil evaporation to develop a final yield as a function of the final biomass of the crop (Eq. 4). This separation allows for distinguishing the effects on the non-productive consumptive use of water, soil evaporation, to better simulate crop growth. The water productivity (WP, biomass produced per unit of cumulative transpiration) is a conservative parameter, which is considered to be constant for given climatic conditions (Steduto *et al.*, 2009).

$$(Yx - Ya)Yx = ((ETx - ETa) \quad ...(3)$$

where Yx and Ya are maximum and actual yield, ETx and ETa are maximum and actual evapotranspiration and Ky is the proportionality factor between relative yield loss and relative reduction in evapotranspiration.

$$B = WP^* \sum Tr \quad ...(4)$$

where B is the final biomass, WP is the water productivity (biomass per unit of cumulative transpiration), and Tr is the crop transpiration.

The WP parameter is based on the atmospheric evaporative demand and the atmospheric CO_2 concentration for the purpose of being applicable to diverse locations and simulating future climate scenarios. Equation 5 shows the procedure for calculating the normalized WP based on adjustments to annual CO_2 concentrations. This approach has a tendency to over-simulate future crop yields caused by CO_2 fertilization when compared to free air CO_2 enrichment (FACE) experiments (Vanuytrecht *et al.*, 2011). This lead to the introduction of a crop sink strength parameter to address the response of WP, resulting in higher yields (Vanuytrecht *et al.*, 2011), but there are still many uncertainties and more research is needed for a better understanding of crop behavior with increased CO_2 concentrations.

$$WP = (B \sum \ (TrET_0)\ CO2 \quad ...(5)$$

where CO_2 is the mean annual CO_2 concentration and ETo is the atmospheric evaporative demand. The CO_2 outside the bracket is the normalization concentration for a given year. Once the final biomass is calculated at harvest, the final yield output is the function of the final biomass (B) and the Harvest Index (HI). HI is the ratio between the harvested product and the total above ground biomass (Unkovich *et al.*, 2010). AquaCrop simulates the build-up of HI starting from the flowering stage to reach the reference HI, a crop parameter set by the user. The build-up of HI increases linearly with time, but adjustments of HI are made depending on crop stresses during simulations, resulting in lower yields or even zero yields under conditions of pollination failure caused by severe stress (Steduto *et al.*, 2009).

Vanuytrecht *et al.* (2014a) performed a global sensitivity analysis of AquaCrop in an attempt to create guidelines for model simplification and efficient calibration. The parameters that were determined to be a priority for AquaCrop are parameters describing the crop phenology, a crop response to extreme temperatures, water productivity, root development, and soil water characteristics. These parameters require the most attention for model calibration for accurately simulating final yields.

AquaCrop is effective for modelling yields under a limited number of site locations. The current version of AquaCrop (6.0), This issue has been assessed by the creation of two external utility programs called AquaData and AquaGIS (Lorite *et al.*, 2013). The flow chart (Fig. 4) describes the process of using AquaCrop with the two utility programs AquaData and AquaGIS. This allows a spatial visualization of crop yields over a greater area enabling the capability to perform a spatial analysis (Lorite *et al.*, 2013). AquaData acts as a database that contains all data necessary for creating input files used in AquaCrop. FAO have developed an AquaCrop plug-in program that will run AquaCrop without a user interface, which allows an application like AquaData to automatically run multiple crop simulations much more efficiently (Raes *et al.*, 2013). The AquaCrop plug-in program can be used for iterative runs for calibration purposes or for inputting into a Geographical Information System (GIS) for subsequent spatial analysis. Using similar methods, AquaCrop can be used for calibrating and analyzing long-term climate change impacts on crop yields in southern Alberta.

The main concepts of connecting the soil-crop-atmosphere continuum in AquaCrop are illustrated in Fig. (4). The soil component of the continuum is focused on the water balance within the soil, the plant represents the growth, development and yield processes, and the atmosphere represented by air temperature, rainfall, evaporative demand, carbon dioxide concentrations and irrigation (Steduto *et al.*, 2009). Figure 2-3 shows the interaction of different variables that AquaCrop combines for simulating yield output. The model uses separate input components of climate data, crop parameters, management (irrigation and field), soil (soil characteristics and groundwater) and simulation period for simulating crop yield.

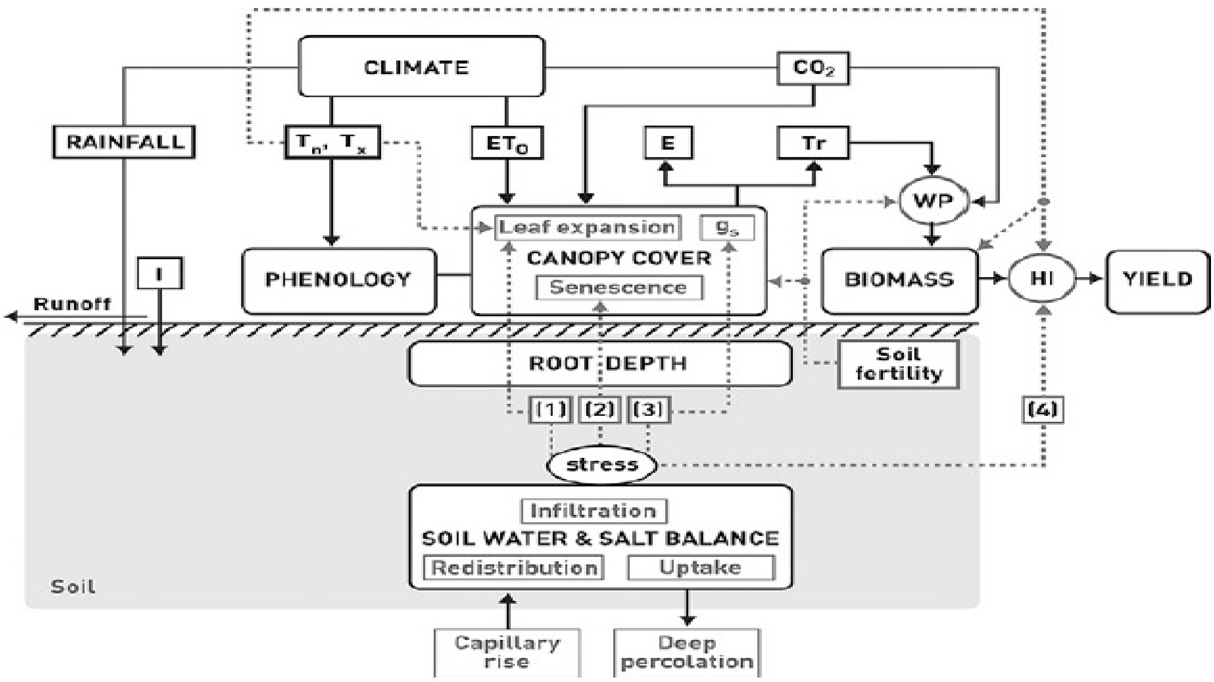

Fig. 4 : Chart of AquaCrop indicating the main components of the soil–plant–atmosphere continuum and the parameters driving phenology, canopy cover, transpiration, biomass production, and final yield [I, irrigation; Tn, minimum air temperature; Tx, Max air temperature; ETo, reference evapotranspiration; E, soil evaporation; Tr, canopy transpiration; gs, stomatal conductance; WP, water productivity; HI, harvest index (Steduto *et al.*, 2009).

The drip irrigation system consists of the following components, as following:

Control head: It is located at the water inlet and consists of:- Pump: centrifugal electric pump (0.75HP), n ≈ 2900 rpm and discharge 3 m^3/h., Filter: screen filter 1.5" (one unit), 155 mesh, Max. Flow 7.2m^3/ h and maximum pressure 150 (PSI)., Injection unit: venturei PE of 1", rang of suction capacity 34-279 l/h., Measurement units: spring brass non return valve 2", Pressure gauges, control valves and flow meter.

Main line: PVC pipe of 63 mm diameter - 6 bar, connects the control unit to convey the water to sub main line: PVC 32 mm diameter line, delivered from the main line to feed the group of the laterals which represent treatments.

Laterals: It is 16 mm diameter PE tubes, with 30 cm apart, built in drippers of 4 lph discharge at 1bar operating pressure. Distance between laterals was 0.9 m. Irrigation system design according to Mansour and Aljughaiman (2012) and Tayel *et al.*, (2012 a; b), Mansour *et al.*, (2015 a, b, c; d), Tayel *et al.* (2016), Pibars and Mansour, (2015) Pibars and Mansour (2016) and Mansour *et al.* (2014).

Table 1 : Conservative and non-conservative crop parameters for maize obtained from various sources.

Non-conservative parameters	**Maize**
Base temperature (°C) below which crop development does not progress	0.0
Upper temperature (°C) above which crop development no longer increases with an increase in temperature	35.0
Number of plants per hectare	90000
Maximum effective rooting depth (m)	1.3
Harvest Index (HIo) (%)	33
Conservative parameters	
Water Productivity normalized for ETo and CO_2 (WP*) (gram/m^2)	15.0
Water Productivity normalized for ETo and CO_2 during yield formation (as % WP*)	100
Maximum air temperature above which pollination starts to fail (heat stress) (°C)	35.0
Minimum air temperature below which pollination starts to fail (cold stress) (°C)	5.0
Excess of potential fruits (%)	100
Canopy growth coefficient (CGC): Increase in canopy cover (fraction soil cover per day)	0.1241
Maximum canopy cover (CCx) in fraction soil cover	0.8
Canopy decline coefficient (CDC): Decrease in canopy cover (in fraction per day)	0.07697
Soil surface covered by an individual seedling at 90 % emergence (cm^2)	1.5
Crop coefficient when canopy is complete but prior to senescence (Kcb, x)	1.10
Maximum root water extraction (m^3 water/m^3 soil.day) in top quarter of root zone	0.019
Maximum root water extraction (m^3 water/m^3 soil.day) in bottom quarter of root zone	0.006
Effect of canopy cover in reducing soil evaporation in late season stage	50
Soil water depletion factor for pollination (p - pol) - Upper threshold	0.55
Shape factor for water stress coefficient for canopy expansion (0.0 = straight line)	3.0

Source: Zeleke *et al.* 2011, Mkhabela and Bullock (2012) and Robertson *et al.* (2013)

Treatments mean were compared using the technique of analysis of variance (ANOVA) and the least significant difference (L.S.D) between systems at 1 %, (Steel and Torrie, 1980).

Results and Discussion

Table (4) illustrate the effect of two different discharges on field pulse drip irrigation efficiencies, the effect of different discharges of pulse drip irrigation on pulse drip irrigation system efficiencies, overall pulse drip irrigation efficiencies, effective pulse drip irrigation efficiencies, Data could be ranked in the following descending orders: 6 lph > 10 lph and based on these results, with decreasing of pulse drippers discharge will be increasing and give the greater all efficiencies and vice versa. This is due to the ability to control the drip irrigation process by pulse drip irrigation system and the lack of drip irrigation losses realized in the case of the little pulse dripper discharges.

Table 4 : Pulse drip irrigation efficiencies by using different two field discharges.

Pulse Drip Irrigation	Pulse drip irrigation system efficiencies (%)	Overall pulse drip irrigation efficiencies (%)	Effective pulse drip irrigation efficiencies (%)
Equations used	EP = (Vb / Vf) x 80	EP = (Ec x Ea) x 80	PIE = [Eob + (FR) x (1.0 – Eob)] x 80
6 LPH	94.6.28	96.58	46.53
10 LPH	93.36	95.32	45.46

Table (4) showed the main one of pulse drip irrigation dripper discharge pulse drip irrigation and sub-main one of the evapotranspiration percentage (ET %) on some vegetative growth and yield parameters of maize. Measured parameters were: leaf area (cm^2), plant height (cm), leaf length (cm), number of leaves, grain yield (ton/fed) and biomass yield (ton/fed).

Grain yield (GY):

Data in **Table (5)** indicate the effect of pulse drip irrigation and et% on maize grain yield (kg/fed), both of them could be ranked in the following ascending orders: 6 lph > 12 lph and 60 > 65 > 50, respectively. in respect to the main effect of pulse drip irrigation on grain yield, one can notice that, the differences in grain yield were significant among pulse drip irrigation treatments at the 5 % level. the highest and lowest grain yield were obtained in 6 lph and tdis, respectively. according to grain yield, the effect of (ET %) treatments on grain yield, there is significant differences at the 5% level between 60, 65; 50, whenever highest and lowest values were achieved under 60 and 50, respectively.

Table 5 : Effect of discharge of pulse drip irrigation system and water amount a on maize grain and Biomass yield .

Pulse Drip Irrigation	ET (%)	Water amount (m^3)	Observed			Simulated by AquaCrop		
			Grain yield (Kg/fed)	Biomass (Kg/fed)	WP (Kg/m^3)	Grain yield (Kg/fed)	Biomass (Kg/fed)	WP (Kg/m^3)
6 LPH	80		5656	4576	5.89	6787	5491	7.07
	65		5789	4456	7.42	6947	5347	8.91
	50		5143	4354	8.57	6177	5225	10.29
12 LPH	80		5524	4565	5.75	6629	5478	6.91
	65		4676	4423	5.99	5611	5308	7.19
	50		4345	4364	7.24	5214	5237	8.69
(1) X (2)	LSD 0.05		23	32	0.23	34	42	0.14
(1) Means	6 LPH		5376	4646	7.3	6635	5354	8.75
	10 LPH		46 61	426 1	6.3	5818	5341	7.6
	LSD 0.05		56	106	0.08	45	43	0.11
(2) Means	80		5505	4690	5.82	6708	5485	6.99
	65		5096	4594	6.71	6279	5327	8.05
	50		4653	4110	7.91	5693	5231	9.49
	LSD 0.05		66	56	0.05	23	40	0.12

Pulse drip irrigation: discharges in liter per hour (lph), 6 LPH: Pulse dripper discharge=10 LPH : Pulse dripper discharge =12 lph, (ET %): evapotranspiration treatments, (LSD0.05):less significant differences at 5 % level.

Biomass yield (BY):

Table (5) indicated the effect of both pulse drip irrigation and (ET %) on maize biomass yield (kg/fed). We can notice that the change in maize biomass yield took the same trend of vegetative growth parameters and thus took the trend of grain yield too. Concerning the positive effect of pulse drip irrigation and ET % on maize biomass yield, they could be ranked in following descending orders: 6 LPH > 10 LPH and 60 > 65 > 50. In respect to pulse drip irrigation and ET % effect on maize biomass yield, one can notice significant difference at the 1% level between all means values of pulse drip irrigation and ET%. According to the interaction effect of the investigated factors, the highest and lowest values of maize biomass yield recorded under interactions of 6 LPH X 60 and 10 LPH X 50.

We can notice that maize grain and biomass yield took the same trend of other vegetative growth parameters, and this finding could be attributed to the close correlation between vegetative growth from side and grain and biomass yield from the other one and also due to positive relations between increasing of growth parameters and increasing maize grain and biomass yield.

Water productivity (WP):

Table (5) and Fig. (5) indicated the effect of both pulse drip irrigation treatments and water amounts on observed and simulated water productivity (WP) of maize yield (kg/m3). We can notice that the change in maize observed WP took the same trend of simulated WP and thus took the trend of biomass and grain yield too. Concerning the positive effect of pulse drip irrigation and ET% on WP, they could be ranked in following descending orders: 6 LPH > 10 LPH and 80 > 65 > 50. In respect to pulse drip irrigation and ET% effect on maize WP, one can notice significant difference at the 1% level between all means values of pulse drip irrigation and ET%. According to the interaction effect of the investigated factors, the highest and lowest values of maize biomass yield recorded under interactions of 6 LPH X 60 and 10 LPH X 50.

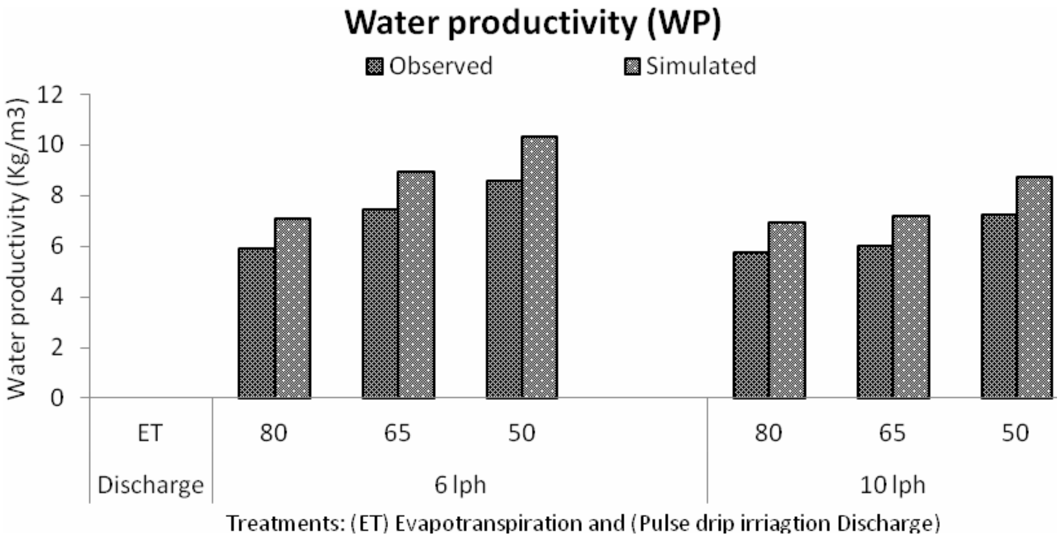

Fig. 6 : Effect of Pulse drip irrigation discharges and ET on observed and simulated maize water productivity.

Discussion

Concerning the effect of pulse drip irrigation x Et % on grain yield, there were significant differences at the 5 % level, except at the following interaction: 6 lph x 60, 6 lph x 65. the maximum and minimum values of grain yield were obtained in 6 lph x 60 and 10 lph x 50, respectively. lamm, 2004 found that a range of seasonal drip irrigations applied relative to meeting the full drip irrigation requirement. grain yield vs. seasonal drip irrigation were grouped for years having average or greater rainfall (1996, 1999, 2004) or significant drought (2000-2003) for simulated low-pressure precision applicators and drip irrigation, where yield and seasonal drip irrigations were averaged for each group of years. For average to wet years, grain yield with drip irrigation was slightly greater than simulated low-pressure precision applicators, but vice versa for drought years. in average to wet years, differences in grain yields were primarily due to kernel weight, but in drought years, this was due to the number of kernels per ear (see lamm, 2004 for actual yield component data).

The drip irrigation water requirements of maize oscillate from 500 until 600 m^3 for achievement of maximum production by a variety of medium maturity of seed (Doorenbos and Kassam, 1966). On a coarse texture soil, maize production increased with a combination of deep tillage and the incorporation of hay deposits in mulch, together with a general increase in crop drip irrigation (Gill *et al.*, 1996). Other research scientists Filintas *et al.* (2006, 2007) and Dioudis *et al.* (2006) have made an extensive drip irrigation study in the cultivation of maize, found that the same conclusion i.e. that drip irrigation is of the utmost importance, from the appearance of the first silk strands until the milky stage in the maturation of the kernels on the cob. Once the milky stage has occurred, the appearance of black layer development on 50 % of the maize kernels is a sign that the crop has fully ripened. The aforementioned criteria were used in the experimental plot for the total drip irrigation process.

Conclusion

It could be concluding to simulate maize water productivity by AquaCrop model under water stress in Egyptian desert conditions; conclusion could be summarized as following that:

The effect of different discharges of pulse drip irrigation on pulse drip irrigation system efficiencies, overall pulse drip irrigation efficiencies, and effective pulse drip irrigation efficiencies, Data could be ranked in the following descending orders: 6 lph > 12 lph and based on these results, with decreasing of pulse drippers discharge will be increasing and give the greater all efficiencies.

Observed and simulated water productivity (WP), maize grain and biomass yield took the same trend, and this finding could be attributed to the close correlation between vegetative growth from side and grain and biomass yield from the other one and also due to positive relations between increasing of growth parameters and increasing maize grain and biomass yield.

These results due to the treatments of 80 % ET and 65 % ET were covered water requirements and also recorded convergent results in values which means that the amount of water added, which is the difference between the 80 - 65% = 25% ET, it amounts in excess of the plant required under the current conditions of the experiment. So it can be recommend to using 65% for saving 15% from water requirements under pulse drip irrigation system using 6 LPH treatment.

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