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Simulation of Water Stress and Climate Change Impacts on Canola Yield, Seed Quality and Water Productivity at North Delta, Egypt

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ABSTRACT

A field trial was conducted at Sakha Experimental Research Station, Kafr El-Sheikh Governorate, Egypt during the two successive winter seasons of 2018/2019 and 2019/2020 to calibrate and validate the AquaCrop model (Version 5). Two cultivars of canola (Serw4 and Serw6) were sown to study the influence of two irrigation regimes (50 and 70% of soil moisture depletion SMD). Then, AquaCrop model was calibrated using the dataset of 1st season and validated using the 2nd season dataset by different statistical indicators *i.e.* coefficient of determination (R^2) and degree of agreement (d). Also, the simulation of climate change impact on canola yields was done. Results show that mostly, irrigation at 50% depletion from soil moisture gives higher values of seed and biomass yields (Mg ha^{-1}) and canola water productivity compared to 70% depletion from soil moisture. This trend is found with both canola cultivars but the Serw4 records values better than Serw6. Also, results show that AquaCrop model (Version 5) is able to simulate well seed and biomass yield of canola cultivars as well as canola water productivity under different irrigation treatments at the studied region, where, values of R^2 and d record a robust agreement among predicted and observed values. As for the simulation of climate change influence, the findings indicate that increasing temperature leads to increasing the reduction percentage of seed yield of different canola cultivars, and the reduction percentage with Serw6 was more than Serw4.

***Keywords**:* AquaCrop model, calibration, canola, validation, climate change, water productivity.

INTRODUCTION

Climate change and agriculture are interrelated processes. Climate change is a natural phenomenon, which takes place on a global scale and affects agriculture through changes in timing and quantity of rainfall, temperature, CO_2, and solar radiation. Agriculture can both alleviate or worsen global warming. In the atmosphere, some of the increase in CO_2 is due to the decomposition of soil organic matter, and emission of much of the methane into the atmosphere. Also, global warming leads to changes in pests and diseases, ground-level ozone concentrations, the nutritional quality of some foods and sea level (Muñoz-Rojas *et al.*2017).

Canola (*Brassica napus L.*) is one of the fundamental oil crops in many countries particularly in the European Union, the USA, Canada and Australia. In Egypt, cultivation of canola may give a chance to conquer some of the local deficit of vegetable edible oil production (Megawer and Mahfouz, 2010). In the course of the most recent decades, canola has become a crop of high worldwide agro-economic importance, using for feed, food and fuel purposes (Kheir and Kamara, 2019).

Egypt faces trouble in resources of irrigation water due to its water budget is fixed, so saving irrigation water is the major step of the Egyptian government strategy as well as raising agricultural productivity from the unit area with the minimum quantity of irrigation water. Generally, there is a pressing need to increase crop water productivity (WP), because of continuing population increment and the acute declining in water resources allocated to purposes of agriculture (El-Hamdi *et al.* 2011). To increase the territory of irrigated land and thus increasing overall crop creation in Egypt utilizing the same quantity of available water, options that save water and enhance water productivity (WP) require to be developed. Deficit irrigation (DI) is some of these options. Thusly, the need to create crop simulation models was emerged to utilize the current knowledge of yield responses to irrigation water supply and evaluate that in term of yield losses. For this purpose, several models have been developed to simulate the future and current scenarios for the management of the water resources. AquaCrop is among such models that reliably simulate achievable yields of main crops as a function of water consumption under a deficit, supplemental, rainfed and full irrigation circumstances, with comparatively less data demand (Saad *et al.* 2014). In Egypt, Khier, (2013) indicated that AquaCrop model can simulate well maize water productivity under various irrigation treatments, N-fertilization levels and mulching application at North Delta. Maize was the 1st crop chosen to define and test the new FAO AquaCrop model (Hsiao *et al.* 2009). While, Farahani *et al.* (2009) used it for growth stimulation of cotton. Also, it was used for growth stimulation of sunflower (Steduto *et al.* 2009) and barley (Araya *et al.* 2010b), under various water treatments. Mainuddine *et al.* (2010) investigated using AquaCrop to assess the climate change influence on crops productivity under the climate-

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change scenarios A2 and B2 (IPPC, 2007) and for the period 2010-2050. This model was used to simulate rice and maize in fourteen agro-climatic areas, distributed among Laos, Thailand, Cambodia and Vietnam. They reported that AquaCrop was very reasonable for their examination and the performance was exceptionally acceptable. The results of these trials found that the AquaCrop model can be used to enhance the water productivity and explore management options. Therefore, the objectives of this investigation are:-

1- To evaluate the effect of different irrigation regimes on yield and quality of two different cultivars of canola plants (Serw4 and Serw6).

2- Calibrating and validation Aquacrop model using a dataset of two successive winters growing seasons.

3- To explore the predicted influence of climate change on canola seed yield under current circumstances.

MATERIALS AND METHODS

A field experiments were carried out in a loamy clay soil at Sakha Experimental Research Station, Kafr El-Sheikh Governorate, Egypt (31° 33 40.4 Latitude and 31° 19 52.5 longitudes with 2.5 m elevations above sea level), during the two successive winter seasons of 2018/2019 and 2019/2020, to investigate the effect of two irrigation regimes (50 and 70% of soil moisture depletion SMD) with two cultivars of canola (Serw4 and Serw6) on seed and biomass yield of canola plants (*Brassica napus* L.) as well as oil and protein percentages in canola seeds.

Before sowing canola seeds, soil samples were taken from the experimental site at different depths for different determinations of soil physical properties according to Buurman *et al.* (1996), Table 1 shows some characteristics of the investigated soil.

Average monthly climatic data including solar radiation, maximum and minimum temperature and rainfall through the canola growing seasons were obtained from the closet automated weather station which belongs to the Central Laboratory of Agricultural Climate (CLAC), Figures 1 and 2.

Table 1. Initial soil analysis before sowing

Depth (cm)	Sand	Silt	Clay	Texture	өs	LL	DUL	OC	ρb	K_s
		%					%		(g cm-3)	(cm h^{-1})
0-20	23.5	46.5	30.0	LC	55	17.0	36.0	0.30	1.33	0.70
20-40	20.5	45.8	33.7	LC	56	17.5	36.5	0.28	1.35	0.65
40-60	18.5	48.0	33.5	LC	55	18.0	37.2	0.27	1.35	0.60
60-80	17.0	48.5	34.5	LC	58	18.5	37.5	0.18	1.37	0.55

LC: Loamy clay, өs: saturation percentage (%), LL: wilting point (%), DUL: field capacity (%), OC: organic carbon (%), ρb: bulk density and Ks: saturated hydraulic conductivity.

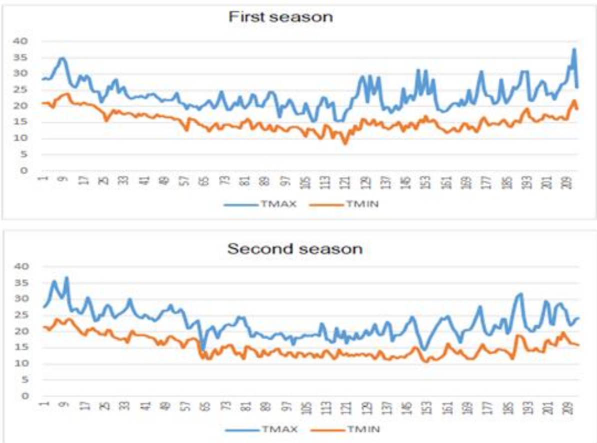

Fig 1. Daily maximum temperature and minimum temperature during canola growing seasons.

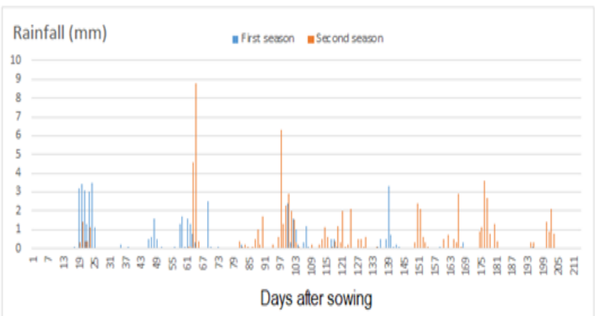

Fig .2. Daily rainfall during growing seasons of canola

The experimental design was a split plot design with two levels of depletion from soil available water (50 and 70% of soil moisture depletion SMD) and two canola cultivars (Serw4 and Serw6). Canola cultivars represented the main plots while the irrigation regimes were allocated in the sub-plots. Each treatment was replicated three times. The grains of canola were sown at rate of 3 kg fed^{-1} on 16^{th} October in both growing seasons and harvested after 6 months on 12^{th} April in both investigated seasons. The preceding crops were maize and sunflower in the 1^{st} and 2^{nd} seasons, respectively. With soil tillage, phosphorus fertilizer in the form of super phosphate (15.5 % P_2O_5) was applied at rate of 100 kg P_2O_5 h^{-1}. Before the 1^{st} irrigation, potassium fertilizer in the form of potassium sulphate (48% K_2O) was applied as one dose directly at rate of 60 kg K_2O h^{-1}. Also, nitrogen fertilizer in the form of urea (46.5 % N) was applied directly before the1^{st} and 2^{nd} irrigations at two equal doses with a rate of 110 kg N ha^{-1}.

Canola plants were exposed to depletion of 50 and 70 % from soil moisture (Israelson and Hansen, 1962) by cutthroat flume (20 × 90 cm) according to (Early, 1975), using the following equations:

For the free flow: $\mathbf{Q = C\times (H\alpha)}$

Where: Q=Discharge in (m^3/sec), C= Flow discharge coefficient (0.74), n= constant (1.84), Hα= water head at upper stream gauge.

For the submerged flow: $\mathbf{Q = C\ (H_a\text{-}H_b)^n/\text{-}\ (Log_{10}S)}$

Where: C= 0.413; H_b =Water head at downstream gauge; n=1.482; S = Actual submergence fraction (H_b/H_a).

The flow is free if (H_b/H_a) = <65%; and if (H_b/H_a) = >65% the flow is submergence. The source of irrigation was pumped from the main canal near the experimental field. (EC = 0.75 dSm^{-1}).

Plant Measurements: At canola maturity, the middle row was harvested randomly from each plot to determine:

- Seed yield (Mg ha^{-1}) by weighting two ridges after air-dried, then canola seeds were weighted at 15 % moisture and converted to Mg ha^{-1}.
- Biomass yield (Mg ha^{-1}).
- Oil content (percentage) was determined according to (AOAC. 2007).
- Protein content (%) was calculated by multiplying the total nitrogen in canola grains by 5.75.

Water Productivity (WP): WP was calculated according to the following equation according to Davis *et al.* (2017).

$$\mathbf{Wp\ kgm^{-3}} = \frac{\textit{Yield kg Fed}^{-1}}{\textit{Total water applied } m^3 \quad \textit{Fed}^{-1}}$$

Statistical Analysis: The data were statistically analyzed using analysis of variance (ANOVA) technique according to (Steel and Torrie, 1980).

Description of AquaCrop Model.

AquaCrop has many features that did not exist in any other model in this field of study. Where, AquaCrop utilizes a relatively modest number of explicit and mostly intuitive boundaries and attempts to balance accuracy, simplicity and robustness. Assessment of model performance is imperative to provide a quantitative gauge of the model ability to reproduce an observed variable, to assess the effect of calibrating model parameters and compare model outcomes with past reports (Krause *et al.* 2005). Many statistical indicators are available to assess the model performance (Loague and Green, 1991). Each has its own weaknesses and strengths, which means that the usage of an ensemble of various indicators is necessary to sufficiently evaluate the model performance (Willmott, 1984; Legates and McCabe, 1999).

Coefficient of determination (R^2) was measured according to Moriasi *et al.* (2007).While; Root Mean Square Error (RMSE) was measured according to Jacovides and Kontoyiannis, 1995). Wilmot's index of agreement (d) was measured according to (Willmott, 1982 and Willmott, 1984).

Climate change leads to decreasing main crop production. In the future (at the year of 2050), for summer crops, climate change will increase water requirements by up to 16% but these requirements will decrease by up to 2% for winter crops (Khier, (2013). Thus, to test the response of two different canola cultivars to climate change, we used a crop growth simulation AquaCrop model (Version 5).

RESULTS AND DISCUSSION

Effect of Different Irrigation Regimes on Growth, Yield and Quality of Different Canola Varieties.

- **Seed and biomass yield (**Mg ha^{-1}**).**

Data of Table 2 show the effects of different levels of irrigation water (50 and 70% of Soil Moisture Depletion SMD) with two cultivars of canola (Serw4 and Serw6) on seed and biomass yield of canola plants during both seasons of the experimentation.

Illustrated data in Table 2 reveal that irrigation regimes and canola cultivars differently affected seed and biomass yield (Mg ha^{-1}) of canola plants during both seasons of the experimentation, where the effect of irrigation regimes was significant, while the effect of canola cultivars was significant only for biomass yield (Mg ha^{-1}) in the first season and non-significant for other aforementioned traits. Also, concerning the interaction influence between the treatments under investigation, data show that there are non-significant differences between all of the interactions as shown in Table 2.

Table 2. Seed and biomass yield (Mg ha^{-1}) of different canola varieties subjected to different irrigation regimes during seasons of 2017/2018 and 2018/2019.

Cultivars (C)	Irrigation (I)	Seed yield (Mg ha^{-1}) 1st season	Seed yield (Mg ha^{-1}) 2nd season	Biomass yield (Mg ha^{-1}) 1st season	Biomass yield (Mg ha^{-1}) 2nd season
Serw4	50 % (SMD)	2.3	2.4	8.1	8.5
	70 % (SMD)	1.9	1.8	6.8	6.5
Serw6	50 % (SMD)	1.8	1.9	6.5	7.0
	70 % (SMD)	1.7	1.6	6.1	5.6
F-test					
C		NS	NS	*	NS
I		**	*	*	*
C × I		NS	NS	NS	NS

SMD: Soil moisture depletion, NS: non-significant

Concerning the effect of depletion, data in Table 2 indicate that irrigation at 50% depletion from soil moisture gave the best seed and biomass yield (Mg ha^{-1}) of canola plants compared to 70% depletion from soil moisture and there are significant differences between such treatments. This trend was found with both canola cultivars but the Serw4 recorded values higher than Serw6. Such an effect was the same during the two seasons of the experiment. Any way irrigation at 50% depletion from soil moisture was the best irrigation treatment because of better availability of soil moisture during the irrigation cycle, which improved water and nutrient uptake. Also, canola plant has deep taproot system (Abdallah *et al.* 2010). Harmony results were reported by Abdel-Maksoud *et al.* (2002) and Kheir, (2013) who reported that irrigation of maize at 20% depletion from available water was the best irrigation treatment compared to 40 and 60%. Beside, Ghonime, (2018) reported that the highest grain and straw yields of wheat plant was obtained with irrigation at 40% depletion, while irrigation at 60%depletion produced the lowest grain and straw yields of wheat plant.

- **Oil and protein percentages.**

Data of Table 3 show influences of different irrigation water levels (50 and 70% of SMD) with two cultivars of canola (Serw4 and Serw6) on oil and protein percentages in seeds of different canola varieties during both seasons of 2017/2018 and 2018/2019.

Table 3. Oil and protein percentages in seeds of different canola varieties subjected to different irrigation regimes during seasons of 2017/2018 and 2018/2019.

Cultivars (C)	Irrigation (I)	Oil (%) 1st season	Oil (%) 2nd season	Protein (%) 1st season	Protein (%) 2nd season
Serw4	50 % (SMD)	36.0	37.9	18.0	18.9
	70 % (SMD)	30.4	28.8	15.6	14.4
Serw6	50 % (SMD)	28.8	30.9	14.4	15.5
	70 % (SMD)	27.2	25.1	13.6	12.5
F-test					
C		NS	NS	NS	NS
I		NS	*	NS	*
C × I		NS	NS	NS	NS

SMD: Soil moisture depletion, NS: non-significant

Observed data in Table 3 reveal that the effect of irrigation regimes on oil and protein percentages in canola seeds was non- significant at 1st season and significant at 2nd season. While the effect of canola cultivars alone (C), as well as interaction effect (C×I), were non-significant at both seasons.

In this respect, data in Table 3 illustrate that irrigation at 50% depletion from soil moisture gave the best oil and protein percentages in canola seeds relatively compared to 70% depletion from soil moisture. This trend was found with both canola cultivars but the Serw4 recorded values higher than Serw6. Such an effect was the same during the two seasons of the experiment.

Generally, these findings suggest that irrigating canola (Serw4) plants at 50% depletion from soil moisture can be considered an effective tool in increasing canola yield and quality under the conditions of this investigation. The present results agree with those obtained by (Abdel-Maksoud *et al*. (2002); Kheir, 2013; Abd El-Mageed and Semida, 2015 , Sadik and Abd El-Aziz, 2018 and Ghonime, 2018).

Effect of Canola Cultivars and Irrigation Regime on Canola Water Productivity.

- Total water applied.

Data presented in Table 4 show the total amounts of water applied (m^3 ha^{-1}) to canola under different treatments. It was observed that increasing the levels of depletion from soil moisture caused decreasing total water applied. In the first season; total water applied decreased from 3500 m^3 ha^{-1} in case of 50% depletion to 3150 m^3 ha^{-1} for 70% level of depletion with canola plants (Serw4), while total water applied decreased from 3395 m^3 ha^{-1} in case of 50% depletion to 2730 m^3 ha^{-1} for 70% level of depletion with canola plants (Serw6).

Table 4. Effect of different treatments on irrigation water applied to canola in two growing seasons.

Cultivars	Irrigation regime	Applied water (m^3 ha^{-1})	
		1st season	2nd season
Serw4	50 % (SMD)	3500	3605
	70 % (SMD)	3150	3360
Serw6	50 % (SMD)	3395	3500
	70 % (SMD)	2730	2905

SMD: Soil moisture depletion.

In the second season; total water applied decreased from 3605 m^3 ha^{-1} in case of 50% depletion to 3360 m^3 ha^{-1} for 70% level of depletion with canola plants (Serw4), while total water applied decreased from 3500 m^3 ha^{-1} in case of 50% depletion to 2905 m^3 ha^{-1} for 70% level of depletion with canola plants (Serw6). Such results may be explained as increasing the depletion ratio from soil moisture leads to decreasing the total water applied. These results were in harmony with those obtained by khair, (2013) who reported that increasing the levels of depletion from available water caused decreasing total water applied, where total water applied decreased from 3372.00 to 3165.75 and 2768.75 $m^3 fed^{-1}$ for 20, 40 and 60% levels of depletion, respectively under irrigation at 15 days after life watering irrigation.

- Water productivity.

The water productivity (W.P) reflects the capability of applied irrigation water unit in producing the marketable yield. Data presented in Table 5 illustrate the values of water productivity (kg m^{-3}) as affected by depletion and canola cultivars treatments.

Table 5. Effect of different treatments on water productivity of canola in two growing seasons.

Cultivars	Irrigation regime	Water productivity (kg m^{-3})	
		1st season	2nd season
Serw4	50 % (SMD)	0.64	0.66
	70 % (SMD)	0.60	0.54
Serw6	50 % (SMD)	0.53	0.55
	70 % (SMD)	0.62	0.54

SMD: Soil moisture depletion.

Regarding the influence of irrigation at different levels of depletion from soil moisture on W.P, data indicate that the highest values of W.P were obtained by irrigation at 50 % depletion from soil moisture under both canola cultivars at both growing seasons, except W.P under canola (Serw6) in 1st season, where the highest values of W.P were obtained by irrigation at 70 % depletion from soil moisture. This may be due to increasing the seed yield of canola in case of irrigation at 50% sharply as compared to other treatment. These results in agreement with obtained by khair, (2013) who investigated the influence of irrigation at various levels of depletion from available water and reported that increasing the depletion level from available water caused increasing maize water productivity, where the highest values of W.P were recorded by irrigation at 40 % depletion followed by 60 % and lately 20 %. Such results concerning increasing water productivity under deficit irrigation could be attributed to the following reasons: Water loss through evaporation is reduced. The negative impact of drought stress during specific phenological stages on biomass partitioning among reproductive and vegetative biomass (harvest index) is avoided, which stabilizes or increases the number of reproductive organs and/or the individual mass or reproductive organs (filling). WP for the net assimilation of biomass as follows: WP=Biomass/ETa with biomass in the numerator and with ETa in the denominator is increased as drought stress is mitigated or crops become more hardened. This effect is thought to be rather limited given the conservative behavior of biomass growth in response to transpiration. WP for the net assimilation of biomass is increased due to the synergy between irrigation and fertilization. This includes cases where irrigation is reduced if fertilizer levels and native fertility are low. Negative agronomic conditions are avoided during crop growth, such as pests, diseases, anaerobic conditions in the root zone due to waterlogging, etc (Pereire, *et al.* 2002; Steduto and Albrizo, 2005; Steduto *et al.* 2007; Feres and Soriano, 2007; Hsiao *et al.* 2007; Reynolds and Tuberosa, 2008 Geerts, *et al.* 2008a; Karam, *et al.* 2009 and Saad *et al.* 2014).

Finally, it could be concluded that the highest value of water productivity (0.64 and 0.66 kg m^{-3}in 1st and 2nd seasons, respectively) could be achieved when canola plants (Serw4) exposed to 50 % depletion through the season.

Calibration and Validation of the AquaCrop Model.

- Canola seed and biomass yield simulation.

AquaCrop is a crop water productivity model developed by FAO. The model was run after preparing the input data files to consist of irrigation, plant, soil and meteorological data information for canola growing seasons of 2017/2018 and 2018/2019.

With regard to irrigation treatments, data in Figs 3 and 4 show an excellent agreement between recorded and predicted values of canola seed and biomass yield. Where, values of R^2 and d gave an excellent agreement between recorded and predicted values.

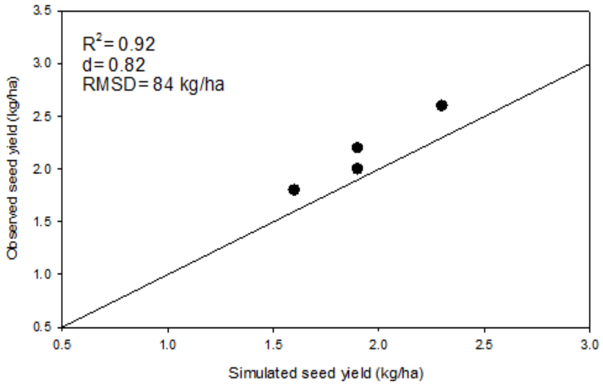

Fig .3. Calibration and evaluation of AquaCrop with canola seed yield

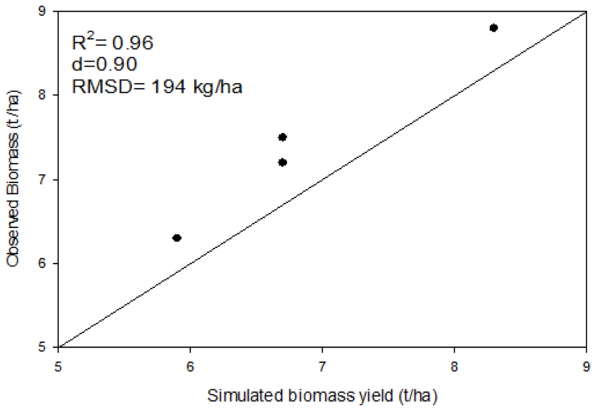

Fig. 4. Calibration and evaluation of AquaCrop with canola biomass yield

Respecting to AquaCrop validation with canola seed and biomass yield, data of Figs 3 and 4 show that, there is an excellent agreement between recorded and predicted values. Where the best treatment of simulation was 50 % then 70 % depletion from soil moisture respectively. Where, Pearson correlation coefficient R^2 values were 0.92 and 0.96 for canola seed and biomass yield, respectively, it means that the value is close to 1.0, to indicating a good agreement. Also, values of R^2 greater than 0.5 are acceptable in watershed simulations as reported by (Moriasi *et al.* 2007). Also, d values were 0.82 and 0.99 for canola seed and biomass yield, respectively, which also mean a great agreement between recorded and predicted values by studied model. It could be concluded from abovementioned that, Aquacrop software was able to simulate well canola seed and biomass yield under different irrigation regimes.

- Canola water productivity (WP) simulation.

Data in Fig.5 show a great agreement between observed and predicted values of canola water productivity under various levels of depletion from soil moisture.

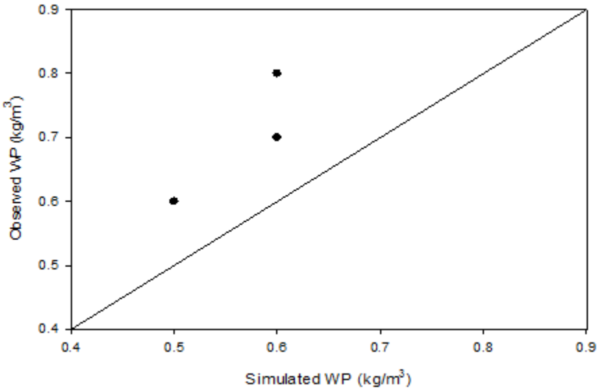

Fig .5. Calibration and evaluation of AquaCrop with canola water productivity.

- Simulation using climate change scenarios.

Although Egypt's contribution to greenhouse gases is relatively minimal, yet given Egypt's growing population, its limited fertile land, and its large area of desert, and the concentration of its economic activities on the coastal zones. The potential social and economic impact of climate change could be devastating for the country's future.

Agriculture in Egypt is determined by climate and water availability and follows the same spatial pattern, with irrigation being predominant. The country's per capita share of water is now below 1000 m3/year and is expected to fall to less than 500 before 2035 when the population reaches 120 million. Such a state of affairs requires solutions and puts tremendous pressure on irrigated agriculture, as the main water-using sector (85% of all extractions).

The optimum temperature for canola is between 20 and 25°C (Vernon and Van Gool, 2006). Temperatures above 32°C during flowering can cause flower abortion, as can severe frosts at this time. Low temperatures can delay seedling emergence (Carmody and Walton 1998). High temperatures during post-anthesis reduce oil content and seed yield. Si and Walton (2004) showed that the average rate of reduction of oil content was 0.68 per cent and 289 kg/ha for seed yield for every 1°C increase in post-anthesis temperature. Others have found the rate of decrease of oil content to be as large as 1.5 per cent for each 1°C rise (Vernon and Van Gool, 2006). By the year 2050, climate change could increase water needs by up to 16% for summer crops but decrease them by up to 2% for winter crops (Eid and El-Mowelhi, 1998). Therefore, we used a crop growth simulation model aquaCrop (Raes *et al.* 2009; Steduto *et al.* 2009 and Kheir, 2013) to test the response of canola to climate change. A simulation study was done to characterize the impact of year - to – year weather variability of the North Nile Delta. The simulation was performed for a period of 1950 to 2050 and collected by Environmental and Climate change Research Institute (ECRI) in 2011, Abdul-Aziz (2011). Data in Fig.6 indicate that, maximum temperature increased by 2 Cº from 1950 to 2010 and could be increased by 1.2 Cº from 2010 to

2050 as predicted by Applications of Regional Climate Models (RCMs) version 2.4.6.

Therefore, studying the effect of such increasing of temperature on seed yield of different canola cultivars was simulated using Aquacrop. Where, data of Fig. 6 and 7 illustrate that, raising temperature by +1.2 through next thirty years, decreased canola yield sharply under the same treatments (irrigation regime and canola cultivars) (the decline by more than 7% of the canola yield). This may be attributed to the shortening of the growing period, due to the rapid determination of thermal units associated with higher temperatures. Similar results were obtained by Kheir, (2013). Predicted data in Fig 7 indicate that, increasing temperature increased the reduction percentage of seed yield of different canola cultivars, and the reduction percentage with Serw6 was more than Serw4.

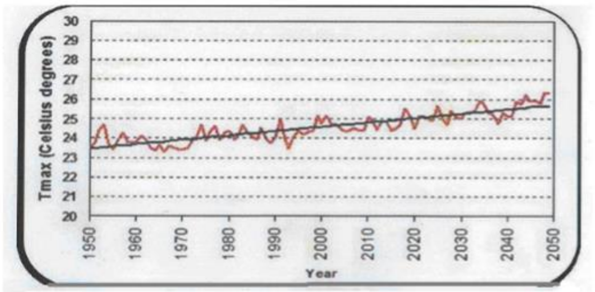

Fig.6.Variations of maximum temperature from 1950 to 2050 as predicted by (ECRI) for Nile Delta region.

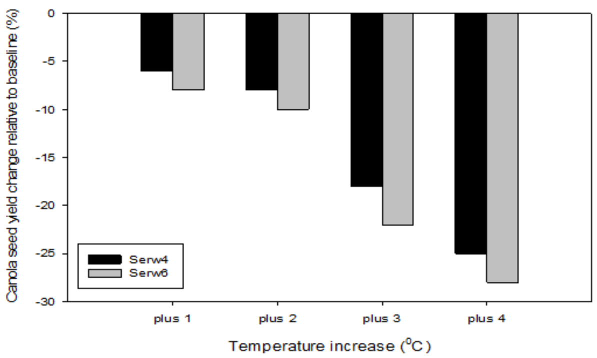

Fig .7. Impacts of climate change on canola yield for two cultivars (Serw4 and Serw6).

CONCLUSION

The AquaCrop model was able to simulate well seed, biomass yield and canola water productivity of different cultivars under different irrigation regimes and climate changes at North delta region (Egypt). Thus, farmers, project managers, irrigation engineers and consultants can use this model as a decision support tool in increasing seed, biomass yield and canola water productivity.

REFERENCES

Abd El-Mageed, T. A. A and W. M. Semida (2015). Effect of deficit irrigation and growing seasons on plant water status, fruit yield and water use efficiency of squash under saline soil . Scientia Horticulturae, 186: 89-100.

Abdel-Maksoud, H. H; S. A. Othman and A. Y. El-Tawil (2002). Improving water and N-use utilization via alternate-furrow irrigation techniques. J. Agric. Sci. Mansoura Univ., 27(12): 8761-8769.

Abdul-Aziz, T. M (2011) .Impacts of climate change on water resources. Case study of the Arab Countries. ECRI, Deputy Director .Second Arab Water Forum, Cairo, Egypt. http :// www . escwa .un. org/information/meetingdetails.asp?referenceNum =1338E.

AOAC. (2007). "Official Methods of Analysis". 18th Ed. Association of Official Analytical Chemists, Inc., Gaithersburg, MD, Method 04., http://www. eoma. aoac.org/.

Araya, A; S.Habtu, K.M.Hadgu, A. Kebede and T. Dejene. (2010b). Test of AquaCrop model in simulating biomass and yield of water deficient and irrigated barley (Hordeum vulgare). Agric.Water Manage. 97: 1838– 1846.

Buurman, P; B.Van Lagen and E.J.Velthorst (1996). ″Manual for Soil and Water Analysis″. Backhuys.

Carmody, P and G.Walton (1998). Canola: Soil and Climatic Requirements. In 'Soil Guide: a handbook for understanding and managing agricultural soils'. (Ed G. Moore.) Bulletin 4343. Department of Agriculture, Western Australia.

Davis, K.F; M.C.Rulli, A. Seveso and P.D'Odorico (2017). Increased food production and reduced water use through optimized crop distribution. Nature Geoscience, 10: 919-924.

Early, A. C. (1975). Irrigation scheduling for wheat in Punjab. Centosci Prog. Optimum use of Water in Agriculture, Rpt, 17, Layllpur, Pakistan, 3-5 March, pp. 115-127.

Eid, H.M and N.M.El-Mowelhi (1998). Impact of climate change on field crops and water needs in Egypt. African International Environmental Conference, Cairo, Egypt, October.

El-Hamdi, Kh. H; R.E. Knany and L. A. Abd El-Rahman (2011). Evaluation of some multinutrient fertilizers for tomato and squash rotation and soil health under different irrigation systems. Journal of Soil Sciences and Agricultural Engineering, 2 (4), 393-406. Fac. Agric. Mans. Univ, Egypt.

Farahani, H; G. Izzi and T. Y. Oweis (2009) Parameterization and evaluation of AquaCrop for full and deficit irrigated cotton. Agron. J. 101:469–476.

Fereres, E and M. A. Soriano (2007). Deficit irrigation for reducing agricultural water use. Special Issue on "Integrated approaches to sustain and improve plant production under drought stress. J. Exp. Bot., 58: 147-159.

Geerts, S; D. Raes, M. Garcia, J. Vacher, R. Mamani, J. Mendoza, R. Huanca, B. Morales, R. Miranda, J. Cusicanqui and C. Taboada, (2008a). Introducing deficit irrigation to stabilize yields of quinoa (Chenopodium Quinoa Willd.). Eur. J. Agron. 28:427–436.

Ghonime, A.E.A (2018). ″Wheat growth, yield and nutrient uptake as influenced by water regime, different N fertilization rates and doses″. MSC. Thesis Fac, Agric, Mansoura. Univ.

Hsiao, T. C; L. Heng, P. Steduto, R.Rojas-lara and E. ferese (2009). Parameterization and testing for maize .Agron. J. 101(3): 448 – 459.

Hsiao, T; P. Steduto and E. Fereres (2007). A systematic and quantitative approach to improve water use efficiency in agriculture. Irrig. Sci. J. 25:209–231.

IPCC, (2007). Climate Change 2007: Synthesis Report. Contribution of working groups I, II and III to the fourth assessment report of the intergovernmental panel on climate change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 p.

Israelson , O.W and V.E.Hansen (1962)."Irrigation Principles and Practices"3rd edition, John Willey & Sons Inc, New york.

Jacovides, C. P and H. Kontoyiannis (1995). Statistical procedures for the evaluation of evapotranspiration computing models. Agricu Water Manag. J: 27: 365–371.

Karam,F; R.Kabalan, J.Briedi, Y.Rouphael and T.Oweis (2009).Yield and water production functions of two durum wheat cultivars grown under different irrigation and nitrogen regimes . Agric . Water Manag.,Elsiver, Netherlands ,96(4):603 – 615.

Kheir; A.M.S (2013). "Modeling for crop water productivity at North Delta soils, Egypt". Ph.D. Thesis Fac. Agric. Mansoura. Univ.

Kheir, A and M. Kamara (2019). Effects of sugar beet factory lime, vinasse, and compost mixed with vinasse application on sandy soil properties and canola productivity. Journal of Soil Sciences and Agricultural Engineering, 10(1): 69-77. .Fac. Agric. Mans. Univ, Egypt.

Krause, P; D. P. Boyle and F. Bäse (2005). Advances in geosciences comparison of different efficiency criteria for hydrological model assessment. Adv. Geosci. 5: 89–97.

Legates, D. R and G. J. McCabe (1999). Evaluating the use of "goodness-of-fit" measuresin hydrologic and hydroclimatic model validation. Water Resources Research 35:233–241.

Loague, K and R.E. Green (1991). Statistical and graphical methods for evaluating solute transport models: overview and application. J. Cantam. Hydrol., 7: 51-73.

Mainuddin, M; C.T. Hoanh, K. Jirayoot, A. S., Halls, M. Kirby, G. Lacombe and V. Srinetr (2010). Adaptation options to reduce the vulnerability of Mekong water resources, food security and the environment to impacts of development and climate change. Water for a Healthy Country. National Research Flagships Water for a Healthy Country, Canberra: CSIRO, 73-105.

Megawer, E. A and S.A. Mahfouz (2010). Response of canola (*Brassica napus* L.) to biofertilizers under Egyptian conditions in newly reclaimed soil. International Journal of Agriculture Sciences, 2: 12-17.

Moriasi, D. N; J. G. Arnold, M. W. V., Liew, R. L., Bingner, R. D. Harmel and T. L. Veith (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the ASABE 50: 885–900.

Muñoz-Rojas, M; S.K.Abd-Elmabod, L.M. Zavala, D. De la Rosa and A.Jordán (2017). Climate change impacts on soil organic carbon stocks of Mediterranean agricultural areas: a case study in Northern Egypt. Agriculture, Ecosystems & Environment, 238: 142-152.

Pereira, L. S; I.Cordery and I. Lacovides (2002)."Coping with Water Scarcity". UNESCO IHP VI , Technical Documents in Hydrology No.58.

Raes, D; P. Steduto, T.C. Hsiao and E. Fereres (2009). AquaCrop-The FAO crop model for predicting yield response to water: II. Main algorithms and software description. Agron. J. 101:438–447.

Reynolds, M and R.Tuberosa (2008). Translational research impacting on crop productivity in drought – prone environments. Current opinion in plant. Biology, 11: 171-179.

Saad, A. M; M.G. Mohamed and G.A. El-Sanat (2014). Evaluating AquaCrop model to improve crop water productivity at North Delta soils, Egypt. Advances in Applied Sciences Research, 5(5):293-304.

Sadik, A and A. Abd El-Aziz (2018). Yield response of squash (*Cucurbita pepo* L.) to water deficit under east owainat conditions. Egyptian J. of Soil Science, 58(2): 161-175.

Si, P. and Walton, G.H. (2004). Determinants of oil concentration and seed yield in canola and Indian mustard in the lower rainfall areas of Western Australia. Australian Journal of Agricultural Research, 55:367-77.

Steduto, P and R. Albrizio (2005). Resource use efficiency of field-grown sunflower, sorghum, wheat and chickpea: II. Water use efficiency and comparison with radiation use efficiency. Agricultural and Forest Meteorology, 130(3-4): 269-281.

Steduto, P; T.C. Hsiao and E. Fereres (2007).On the conservative behavior of biomass water productivity. Irrig. Sci. 25: 189-207.

Steduto, P; T.C. Hsiao, D. Raes and E. Feres (2009). Aquacrop. The FAO crop model for predicting yield response to water: I. concepts and underlying principles. Agron. J. 101: 426-437.

Steel , R.G.D. and J . H ,Torrie (1980) . "Principles and Procedure of Statistics" A biometric Aproach 2nd. Mc-Grow Hill Book Company, New York.

Vernon, L and Van D. Gool (2006). Potential impacts of climate change on agricultural land use suitability: Canola.

Willmott, C. J. (1982). Some comments the evaluation of model performance. Bulletin American Meteorological Society 63:1309–1313.

Willmott, C. J. (1984). On the evaluation of model performance in physical geography. In Spatial Statistics and Models, Gaile GL, Willmott CJ (eds). D. Reidel: Boston. 443–460.

محاكاة تأثيرات تغير المناخ والإجهاد المائي على محصول وجودة بذور الكانولا وانتاجية وحدة المياه في شمال الدلتا، مصر.

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تم استخدام بيانات تجربة حقلية تم إجراؤها في محطة البحوث الزراعية بسخا، محافظة كفر الشيخ، مصر خلال موسمين شتويين متتاليين (2019/2018 -2020/2019) للتحقق من صحة نموذج AquaCrop (الإصدار الخامس). تم زرع صنفين من الكانولا (سرو 4 وسرو 6) لدراسة تأثير نظامين للري (الري عند استنزاف 50 و70% من الرطوبة الارضية SMD). بعد ذلك، تم التحقق من صحة نموذج AquaCrop باستخدام هذه البيانات من خلال مؤشرات إحصائية مختلفة، مثل معامل التحديد (R^2) ودليل التوافق (d). كما تم محاكاة تأثير تغير المناخ على محصول الكانولا. أوضحت النتائج أن غالبا ما كان الري عند استنزاف 50٪ من رطوبة التربة أعطى أفضل محصول للبذور والكتلة الحيوية (طن/الهكتار) وإنتاجية المياه من محصول الكانولا مقارنة الري عند استنزاف 70٪ من رطوبة التربة. نفس الاتجاه وجد مع كلا صنفي الكانولا ولكن القيم كانت أكبر مع الصنف سرو 4 عن القيم مع سرو 6. وأظهرت النتائج أيضًا أن نموذج AquaCrop كان قادرًا على محاكاة محصول البذور والكتلة الحيوية لأصناف الكانولا وكذلك إنتاجية المياه لمحصول الكانولا تحت معاملات الري المختلفة في المنطقة المدروسة، حيث أعطت قيم R^2 و d اتفاقًا ممتازًا بين القيم المرصودة والمتوقعة. أما بالنسبة لمحاكاة تأثير تغيرات المناخ، فقد أوضحت النتائج أن زيادة درجة الحرارة زادت من النسبة المئوية لانخفاض محصول البذور لأصناف الكانولا المختلفة، وأن نسبة الانخفاض مع سرو 6 كانت أكثر من سرو4.