Annals of Agric. Sci., Moshtohor **ISSN 1110-0419**
Vol. 55(4) (2017), 893 –910 **http://aasj.bu.edu.eg/index.php**

Assessment of the impact of climate change by using simulation model on tomato production

Shahin M.M. [1] Khatter.H.A.[2] Abo Elmaatti .S. [3] Said. A[1]

[1] Vegetable Crops Department; Faculty of Agricultural; Cairo University
[2] Soil science Department; Faculty of Agricultural; Cairo University
[3] Central Laboratory for Agricultural Climate; Agricultural Research Center; Egypt.
Corresponding author: asmaa.said24@yahoo.com

Abstract

The Egyptian processing tomato (Solanum lycopersicon) has a major dominance in the global market but few studies have been conducted using a cropping systems analysis approach for this crop. The overall goal of this project was to evaluate the CropSyst (Cropping Systems Simulation) software with experimental data taken from two field experiments in the summer season of years 2014 and 2015 in Dokki, Giza, Egypt (Lat.: 29°:51':08.33 "N, Long.: 31°:14':24.11"E) The Experiment included two planting dates (April. 10 and April. 25) three irrigation levels of waters (80% , 100% and 120% of water field capacity), in addition to two cultivars (Super Strain B and Castle Rock). The experiment included 36 experimental plots, 2 planting dates × 3 irrigation levels × 2 cultivars × 3 replicates. The experimental plot area was 20 m² and consisted of 5 rows with 150 cm width and 10 m length; with 30 cm space between plants. The experiment was established as split- split plot. The planting date was in the main plot, whereas the irrigation levels were in sub-plot, the cultivar was distributed in sub-sub-plot. Data analysis was done by an IBM computer, using Excel program for statistical analysis. The LSD among means for all treatments was tested for significance at 5% level. A comparison of yield for the different transplanting dates showed that earlier transplanting date increased yield for both cultivars, while there was a significant higher yield for "Super Strain B" than "Castle Rock". The two summer seasons in 2014 and 2015 gave a significant difference between two transplanting date, with higher plant growth with the first transplanting date and with level irrigation of 120 %. Data of this experiment summer seasons of 2014and 2015 years was used to validate the CropSyst model. The treatments of the validation experiment composed of two tomato cultivars and three irrigation treatments. Climate change scenario A1B were used to assess the consequences of climate change on tomato yield in 2040. The results showed that CropSyst model was able to predict tomato yield with high degree of accuracy for both calibration and validation procedures. The results also indicated that, in general, the yield of both cultivars will be decreased under climate change; however the reduction was lower for "Castle Rock", as compared with "Super Strain B". Yield production increased with 120% of water field capacity and with cultivar "Super Strain B" under the climate change scenario compared with irrigation levels resulted from 80% ,100% of water field capacity. Our results suggested that if we want to reduce yield losses on tomato under climate change conditions and increase water productivity, "Super Strain B" should be cultivated.

Keywords: Solanum lycopersicon, cropsyst, crop simulation, calibration, validation, climate change scenario, A1B.

Introduction

Tomato (*Solanum lycopersicon*) is one of the most important vegetable crops grown under outdoor and indoor conditions. It has become an important commercial crop in Egypt so far as the cultivation area, production, industrial values and its contribution to human nutrition. The total cultivated area of tomato in 2014 was 507.6 thousands feddan, which produced about 8881.0 thousand Tons, while the total exported tomato was 5.7 thousand ton in 2010. (FAO, 2014).

Tomato can be growing under wide range of temperature however, fruit set is limited in narrow range, where low or high temperature leads to poor fruit set. The critical factor in tomato fruit setting is the night temperature, the optimal range being 15-20̊ C (Went, 1945). Fruit set is also low when the average maximal day temperature is above 32̊ C and the average minimal night temperature is above 21̊C (Moore and Thomas, 1952). The Earth has warmed by 0.7˚C on average since1900. Most of the warming since 1950 is due to human activities that have increased greenhouse gases (IPCC, 2001). There has been an increase in heat waves, fewer frosts, warming of the lower atmosphere and Upper Ocean, retreat of glaciers and sea-ice, an average rise in global sea-level of approximately 17cm and increased heavy rainfall in many regions. Many species of plants and animals have changed their location or behavior in ways that provide further evidence of global warming (IPCC, 2001).

The present investigation was imposed to study the impact of climate change on tomato productivity, and to find out the best suitable adaptation option to mitigate the negative impacts of climate change on tomato production.

And validating the Cropsyst model with the field experiment under Egyptian conditions, expect yield of tomato under climate change conditions by CropSyst (Cropping Systems Simulation) and finally mitigate the negative impacts of climate change on tomato production.

CropSyst (Stöckle et al., 2003) is a process-based, multiyear, multi-crop, daily time step cropping systems simulation model. Crop development is simulated as a function of thermal time accumulated between a base temperature and a maximum temperature. Crop growth is simulated for the whole canopy by calculating unstressed biomass growth based on potential transpiration and on intercepted radiation. The minimum between daily transpiration- and radiation-based biomasses is selected and successively shortened by considering water and nitrogen limitations. Temperature limitations are explicitly considered in the radiation-dependent growth. Daily LAI expansion is calculated from total AGB, daily accumulated AGB, a constant SLA and an empiric parameter called stem leaf partition coefficient (SLP). Root depth is simulated as a function of leaf area development, and reaches its maximum when the plant flowers. Further details about the algorithms implemented in CropSyst.

The objectives of this paper were: (i) to calibrate CropSyst model on tomato grown at El-Giza governorates using previous field data; (ii) To validate CropSyst model for field data experiment on tomato in the same governorate; (iii) to determine yield losses under two climate change scenario.

Materials and Methods

The present study aimed to assess the impact of climate change on yield of tomato grown under Egyptian climatic conditions. This work was conducted at the Central Laboratory for Agricultural Climate (CLAC) to study the effect of climate changes on yield of tomato. In order to achieve this objective, several sequence steps were done: (1) Measuring current data of tomato crop through field experiment, (2) Validating the Cropsyst model with the field experiment under Egyptian conditions, (3) Expecting yield of tomato under climate change conditions by Cropsyst and (4) Finally examining the different adaptation options to mitigate the negative impacts of climate change on tomato production.

The field experiment for validation

Experiment data were taken from field experiment in summer season during two successive seasons (2014 and 2015) in Egypt, Giza, Dokki (Lat.: 29°:51':08.33 "N, Long.: 31°:14':24.11"E) The Experiment included two planting dates (April. 10 and April. 25) with three irrigation levels of waters (80%, 100% and 120% of water field capacity), on two tomato cultivars "Super Strain B" and "Castle Rock". The experiment included 36 experimental plots, 2 planting dates × 3 irrigation levels × 2 cultivars × 3 replicates. The experimental plot area was 20 m² and consisted of 5 rows with 150 cm width and 10 m length; with 30 cm space between plants. The experiment was established as split-split plot design. The planting date was in the main plot, whereas the irrigation levels was in sub-plot, the cultivar was distributed in sub-sub-plot. Data were recorded as plant height 30 and 60 days after transplanting as well as total yield (kg/plot and ton/fed) .Data analysis was done by an IBM computer, using Excel program for statistical analysis.

Table 1. Chemical analysis of the soil of the experimental site at Giza Agricultural Research Station.

Depth	SP	pH	ECe (dS/m)	meq/l							
				Cations				Anions			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	CO_3^{--}	HCO^{-}_3	SO_4^{--}
0-15	43	7.75	0.6	2.2	1.71	1.83	0.27	1.35	-	2.09	2.57
15-30	45	7.7	0.7	3	2.37	1.3	0.37	1.35	-	1.9	3.79
30-45	48	7.7	0.5	2	1	1.76	0.27	1.35	-	0.95	2.73

Table 2. Soil moisture constants of the experimental site at Giza Agricultural Research Station.

location	Depth (cm)	Field capacity (%, w/w)	Wilting point (%, w/w)	Available water (mm)	Bulk density (g/cm^3)
Giza	0 – 15	41.85	18.61	40	1.15
	15 – 30	33.68	17.5	30.1	1.24
	30 – 45	28.36	16.92	20.6	1.2
	45 – 60	28.05	16.54	22.1	1.28
Average		33.0	17.4	28.2	1.2

Water regime treatments:

Data of class A pan (E_{pan}) for Dokki experimental site expressed in mm/day were obtained from agro meteorological station located in the site.

- The first step was calculation of potential evapotranspiration which was made according to the following formula (FAO, 1977):

$$Et_o = K_p \text{ X } E_{Pan} \quad \text{(mm / day)}$$

Where:

Et_o = Potential evapotranspiration in mm / day.

K_p (Pan coefficient) = three stage (0.5, 0.75 and 1)

E_{Pan} = Pan evaporation in mm/day.

The second step was to obtain values of crop water consumptive use (Et_{crop}) as follows (FAO, 1977).

$Et_{crop} = Et_o \times K_c$ mm / day

Where:

Et_o = The rate of evapotranspiration from an excessive surface of green cover of uniform height (8 to 15 cm), actively growing, completely shading the ground and did not face shortage in water.

K_c = Crop coefficient "between"(0.3 to 1).

The third step is to calculate water requirements (WR) for each treatment as following:

$WR = Et_{crop} \times L\%$ mm / day

Where:

L % = Leaching requirement percentage in this saline water as follows.

$L\% = (E_{ciw} / E_{cdw}) \times 100$

Where:

E_{ciw} = Electrical conductivity of irrigation water dS/cm^{-1}.

E_{cdw} = Electrical conductivity of drainage water $mMoh . cm^{-1}$

L % was estimated to be 1.25.

The fourth step was to calculate irrigation requirement (IR)

As:

$IR = WR \times R$

Where:

WR= Water requirement

R = Reduction factor for drip irrigation only covers apart of land and leaves the rest dry. Therefore, it was recommend by FAO (1977) to use R-value, which its estimated range is between 0.25 and 0.9 for drip irrigation system.

Finally, calculation of open field water duty (WD) was as follows:

$WD = IR \times (area / 100)$

b. Amount of used water:

Total amount of the added water through the drip irrigation system was measured by giger for each water regime treatment (Table, 3)

c. Water use efficiency (WUE):

Water use efficiency was calculated for the different water regimes treatments using the following equation (Srinivas et al., 1989)

WUE = Total water consumption (m^3 /fed.)/ Total yield (kg/ fed.).

Table 3. Average amounts of applied water (m^3/feddan) in each treatment of both summer seasons.

Period	Irrigation levels		
	80%	100%	120%
10-30 April	17.24	21.55	25.86
1-15 May	59.13	73.92	88.70
16-31 May	88.70	110.88	133.05
1-15 June	165.11	206.39	247.67
16-30 June	220.15	275.18	330.22
1-15 July	260.48	325.60	390.72
16-31 July	325.60	407.00	488.40
1-15 August	282.45	353.06	423.68
16-31 August	251.07	313.83	376.60
Total	1669.93	2087.41	2504.89

Validating the Cropsyst model with the field experiment under current Egyptian conditions

a. CropSyst model

1. Model description

The objective of the Crop model (Stockle et al., 1994) is to serve as an analytical tool to study the effect of cropping systems and management on crop productivity and the environment. For this purpose, CropSyst simulates soil water budget, soil-plant nitrogen budget, crop phenology, crop canopy and root growth, biomass production, crop yield, residue production and decomposition, soil erosion by water, and pesticide fate, which are affected by weather, soil characteristics, crop characteristics, and cropping system management options which include crop rotation, variety selection, irrigation, nitrogen fertilization, pesticide applications, soil and irrigation water salinity, tillage operations, and residue management. The water budget in the model includes rainfall, irrigation, runoff, interception, water infiltration and redistribution in the soil profile, crop transpiration, and evaporation. The nitrogen budget in CropSyst includes nitrogen application, nitrogen transport, nitrogen transformations, ammonium absorption and crop nitrogen uptake. The calculation of daily crop growth, expressed as biomass increase per unit area, is based on a minimum of four limiting factors; namely, light, temperature, water and nitrogen. **Pala et al. (1996)** suggested that minor adjustments of some of these parameters, accounting for cultivar-specific differences, are desirable whenever suitable experimental information is available. Details on the technical aspects and use of the CropSyst model have been reported elsewhere **(Stockle et al., 1994).**

2. Model calibration

After each growing season, input files required by CropSyst model for Giza location and tomato crop were prepared and used to run the model. For each treatment one management file was prepared to represent each irrigation treatment. The date of each phonological stage was used to calculate growing degree days for that stage. Total biomass, yield, total and seasonal evapotranspiration, computed from the soil-moisture measurements from all the treatments, were used for model calibration. The values of the crop input parameters were either taken from the CropSyst manual **(Stockle et al., 1994)** or set to the values observed in the experiments. The calibration consisted of slight adjustments of selected crop input parameters to reflect reasonable simulations. These adjustments were between values that were either typical for the crop species or known from previous experiences with the model.

3. Crop planting

CropSyst provides two modes for the simulation of crop planting. For the fixed planting mode, the simulation of crop growth begins on the specified date. For the computed planting mode, a five-day average air temperature above planting temperature requirement and a specified water content of the second soil layer are used as check conditions for planting (water contents of the top evaporative layer is highly fluctuating).Planting (or beginning of the germination process) occurs if the following conditions are satisfied:

$$\frac{\sum_{d=today}^{Today + 5} [(Tmaxd + Tmind) / 2]}{5} > Treq$$

And WC2 > WCreq

Where

Today is the date in the simulation.

Tmind, Tmaxd (°C) are the minimum and maximum temperatures of day

Treq (°C) is the planting date temperature requirement crop parameter.

WC2 (m^3/m^3) is the water content of the second soil layer.

WCreq (m^3/m^3) is the water content required for planting crop input parameter

4. Goodness of fit

To test the goodness of fit between the measured and predicted data, percent difference between measured and predicted values of grain yield and biological yield in each growing season was calculated, in addition to consumptive use. Furthermore, root mean square error which describes the average difference between measured and predicted value were calculated (Jamieson etal.,1998).Also, Willmott index of agreement was calculated, which take a value between 0.0-1.0 and 1.0 means perfect fit (Willmott, 1981).

5. Climate change scenarios

In this work, the HadCM3, which is a coupled atmosphere-ocean general circulation model (AOGCM) developed at the Hadley Centre for Climate Prediction and Research (United Kingdom) was used (Gordon et al., 2000 and Cooper et al., 2000) as it is considered more significant and more sophisticated than earlier versions. This model has a spatial resolution of 2.5 x 3.75 (latitude by longitude). HadCM3 provides information about climate change all over the entire world during the 21st century and presents information about three times slices: 2020s, 2050s, and 2080s. In order to provide information on possible changes in the world climate, the climate change models are forced to consider future scenarios. The IPCC (Nakicenvic et al., 2000) has developed emission scenarios known as SRES (Special Report on Emission Scenarios). The four SRES scenarios combined two sets of divergent tendencies: one set varies between strong economic values and strong environmental values, while the other set varies between increasing globalization and increasing regionalization (IPCC-TGCIA,1999). one climate change scenario were considered in this study: A1B. These selected scenario take into consideration rise in global annual mean temperature by 3.09 and 2.16°C, respectively, CO_2 concentration 834 and 601 ppm, respectively and global mean sea level rise 62 and 52 cm, respectively. As the resolution of the model is very big, simple interpolation techniques of these percentages have been applied to fit the station site. Data were downloaded in GRIB format from the IPCC Data Distribution Centre web site.

The GRBCONV program was used to convert the data files from GRIB format to the more conventional ASCII. The download site does not offer the option to subset the data based on an area of interest. Therefore a custom program was used to extract the data for the region of interest. HadCM3 variables were monthly precipitation, solar radiation, minimum and maximum temperatures. A1B climate change scenario were used to run the CropSyst model to predict wheat yield and consumptive use in the year of 2040s. The effect of climate change on each of the two growing seasons will be discussed separately where each season would be a representation of the growing season of the year of 2040.

Results and Discussion

The results detected in Table 4, 5 show that the interaction between transplanting dates, irrigation regimes and cultivars had significant effect plant height in two summer seasons. In the first season (2014), the first date (Apr., 10th) showed significantly higher value of plant height than the second (Apr., 25th) with the means of 25.38 and 25.00 cm after 30 days and of 55.86cm and 55.4cm after 60 days. In the second seasons (2015) data collected on plant height showed that the first date (Apr., 10th) recorded higher than the second (Apr., 25th). These results could be attributed to the accumulative effect of gradually increasing temperature in the summer especially at day temperature (Maximum temperature). As for the effect of irrigation level on vegetative growth parameters data in the same Tables refer that increasing the amount of irrigation water from 80 to 100 and 120% of water requirement enhanced plant height during both seasons of the study. Finally, using the highest level of irrigation water (120% of water requirement) reflected the highest values of the plant height. Obtained results are true during the two seasons of growth. Such results are in confirmety with those reported by El- Beltagy et al. (1984), Fattahallah (1992).

So using 120% of water requirement gave the highest plant height after 30 days followed by the second level (100% of water requirement) then the first one (80% of water requirement) with the means of 30.00, 25.00 and 22.50 cm , respectively in the first season (2014) and 29.67cm , 25.50 cm and 21.50 cm respectively in the second season (2015) in the first transplanting date. As for the interaction between transplanting date and irrigation levels for obtaining the highest value of plant height with the first transplanting date, while the lowest value recorded in level of 80% of water requirement in the second transplanting date (Apr., 25th) in the first season (2014) these results were true in both seasons these results are in agreement with those obtained by **El Sawy (2014)** who reported that the highest level of irrigation (120% of water requirement) gave the highest value of plant height then (100% of water requirement) and (80% of water requirement) in all vegetative characteristics of tomato. Results also indicated that, "Super Strain B (VAR1)" recorded the higher value than "Castle rock (VAR2)" in both planting dates and both seasons. In the second season (2015) the first time (Apr., 12th) showed that the highest plant height with the cultivar Super strain B (VAR1) and Castle rock (VAR2) the lowest with means of 25.7 cm and 24.6 cm, the second transplant date recorded the same value of plant height with cultivar Super strain B (VAR1) and the Castle rock (VAR2) by means of 24.67 cm after 30 days. After 60 days In the two summer seasons, the first time showed that the highest plant height with the cultivar Super strain B (VAR1) and Castle rock (VAR2) the lowest, the second transplant date recorded the same result of plant height with cultivar Super strain B (VAR1) and the Castle Rock (VAR2). The results presented in Table (6) show that the interaction between transplant date, different cultivars and different irrigation levels had differences in total fruit yield in two seasons (2014 and 2015).

In the first season (2014), plants of the first date (Apr., 10th) produced the highest total fruit yield followed in decreasing order, by the second (Apr., 25th) with mean values of 11.54kg/m and 8.99kg/m. In the second season (2015) plants of the first date (Apr., 10th) produced the highest total fruit yield followed in decreasing order, by the second (Apr., 25th) with mean values of 8.83kg/m and 7.13kg/m.

Results also indicated that, the cultivar Super strain B (VAR1) recorded the highest total fruit yield and second Castle rock (VAR2) with the means of 11.67kg/m² and 11.40kg/m² in the first date (Apr., 10th), the second transplant date the Castle rock variety gave the highest total fruit number and Super strain B the lowest total fruit yield in the second transplant date (Apr., 25th) with means of 9.34kg/m² and 8.64kg/m² in the first season. In the second season (2015) the first time (Apr., 10th) showed that the highest total fruit yield with the cultivar Super strain B (VAR1) and Castle rock (VAR2) the lowest with means of 9.34kg/m² and 8.31kg/m² and the second transplant date the highest total fruit yield with the cultivar Super strain B (VAR1) and Castle rock (VAR2) the lowest with means of 9.44kg/m² and 4.83kg/m².

For interaction between transplant dates and irrigation levels in the first season, the best combination observed in the first date (Apr., 10th) and level of irrigation water (120% of water requirement), while the lowest total fruit yield was recorded in the second date and level of irrigation water (80% of water requirement). In the second season (2015) the best combination observed in the second date and level of irrigation water (120% of water requirement), while the lowest total fruit yield recorded in the first date and level of irrigation water (80% of water requirement).

The interaction between tomato cultivars and transplant date showed differences in early fruit yield, and the cultivar Super strain B (VAR1) recorded the highest value in the first date (Apr., 10th), while Castle rock (VAR2) the lowest value in the second date (Apr., 25th) in the first season and the second season.

Table 4. Effect of transplant date, irrigation levels and tomato cultivars on plant height 30 days after transplanting.

		First Season (2014)				Second Season (2015			
Transplanting date(A)	**Irrigation(B)**	**(C) Cultivars**							
		Super Strain B	**Castle Rock**	**A×B**	**A**	**Super Strain B**	**Castle Rock**	**A×B**	**A**
10 April	80%	22.00	23.00	22.50	**25.83**	21.00	22.00	21.50	**25.22**
	100%	27.00	23.00	25.00		26.00	23.00	24.50	
	120%	31.00	29.00	30.00		30.33	29.00	29.67	
	Mean	**26.67**	**25.00**			**25.78**	**24.67**		
25 April	80%	21.00	22.00	21.50	**25**	21.00	24.00	22.50	**24.67**
	100%	26.00	25.00	25.50		25.00	24.00	24.50	
	120%	29.00	27.00	28.00		28.00	26.00	27.00	
	Mean	**25.33**	**24.67**			**24.67**	**24.67**		
	C	**26.00**	**24.83**			**25.22**	**24.67**		
		B×C			**B**	**B×C**			**B**
	80%	21.50	22.50		22.00	21.00	23.00		22.00
	100%	26.50	24.00		25.25	25.50	23.50		24.50
	120%	30.00	28.00		29.00	29.17	27.50		28.33
L.S.D at 5%	**A**	**B**	**C**	**A×B**	**A×C**	**B×C**	**A×B×C**		
First season	**0.34**	**0.37**	**0.30**	**2.65**	**4.74**	**4.74**	**0.51**		
Second season	**0.03**	**0.13**	**0.10**	**1.26**	**0.14**	**0.17**	**0.24**		

Table 5. Effect of transplant date, irrigation levels and tomato cultivars on plant height 60 days after transplanting.

		First Season				Second Season			
(A)	**Irrigation(B)**	**(C) Cultivars**				**(C) Cultivars**			
Transplanting date(A)		**Super Strain B**	**Castle Rock**	**A×B**	**A**	**Super Strain B**	**Castle Rock**	**A×B**	**A**
10 April	**80%**	52.00	53.00	52.50	**55.86**	51.00	52.00	51.50	**55.10**
	100%	57.00	53.00	55.00		56.00	53.00	54.50	
	120%	61.00	59.00	60.00		60.33	58.00	59.17	
	Mean	**56.67**	**55.00**			**55.78**	**54.33**		
25 April	**80%**	51.00	52.00	51.50	**55.4**	51.00	54.00	52.50	**54.11**
	100%	56.00	55.00	55.50		54.00	51.67	52.83	
	120%	59.00	57.00	58.00		58.00	56.00	57.00	
	Mean	**55.33**	**54.67**			**54.33**	**53.89**		
	C	**56.00**	**54.83**			**55.06**	**54.11**		
		B×C			**B**		**B×C**		**B**
	80%	**51.50**	**52.50**		**52.00**	**51.00**	**53.00**		**52.00**
	100%	**56.50**	**54.00**		**55.25**	**55.00**	**52.33**		**53.67**
	120%	**60.00**	**58.00**		**59.00**	**59.17**	**57.00**		**58.08**
L.S.D at 5%	**A**	**B**	**C**	**A×B**	**A×C**	**B×C**	**A×B×C**		
First season	**0.3440**	**0.34**	**0.29**	**2.65**	**3.64**	**4.74**	**0.415**		
Second season	**0.0382**	**0.18**	**0.14**	**2.14**	**0.19**	**0.24**	**0.34**		

Table 6. Effect of planting dates, irrigation regimes, cultivars and their interaction on total fruit yield (kg/m²)

		First Season				Second Season			
		(C) Cultivars							
Transplanting date(A)	**Irrigation(B)**	**Super Strain B**	**Castle Rock**	**A×B**	**A**	**Super Strain B**	**Castle Rock**	**A×B**	**A**
10 April	**80%**	8.58	12.90	10.74	**11.54**	8.76	8.51	8.64	**8.83**
	100%	16.98	6.30	11.64		9.88	7.76	8.82	
	120%	9.45	15.00	12.23		9.39	8.66	9.03	
	Mean	**11.67**	**11.40**			**9.34**	**8.31**		
25 April	**80%**	6.60	9.30	7.95	**8.99**	4.55	5.28	4.91	**7.13**
	100%	13.05	6.45	9.75		10.98	4.89	7.94	
	120%	6.27	12.26	9.27		12.80	4.30	8.55	
	Mean	**8.64**	**9.34**			**9.44**	**4.83**		
	C	**10.15**	**10.37**			**9.39**	**6.57**		
		B×C		**B**		**B×C**			**B**
	80%	7.59	11.10		14.72	6.654	6.90		6.77525
	100%	15.01	6.38		16.51	10.4295	6.33		8.37825
	120%	7.86	13.63		16.86	11.0965	6.48		8.78825
L.S.D at 5%	**A**	**B**	**C**	**A×B**	**A×C**	**B×C**	**A×B×C**		
First season	**0.038**	**0.55**	**0.79**	**162.66**	**1.12**	**1.37**	**1.93**		
Second season	**30704.1**	**222.60**	**156.10**	**697.10**	**220.60**	**270.20**	**382.20**		

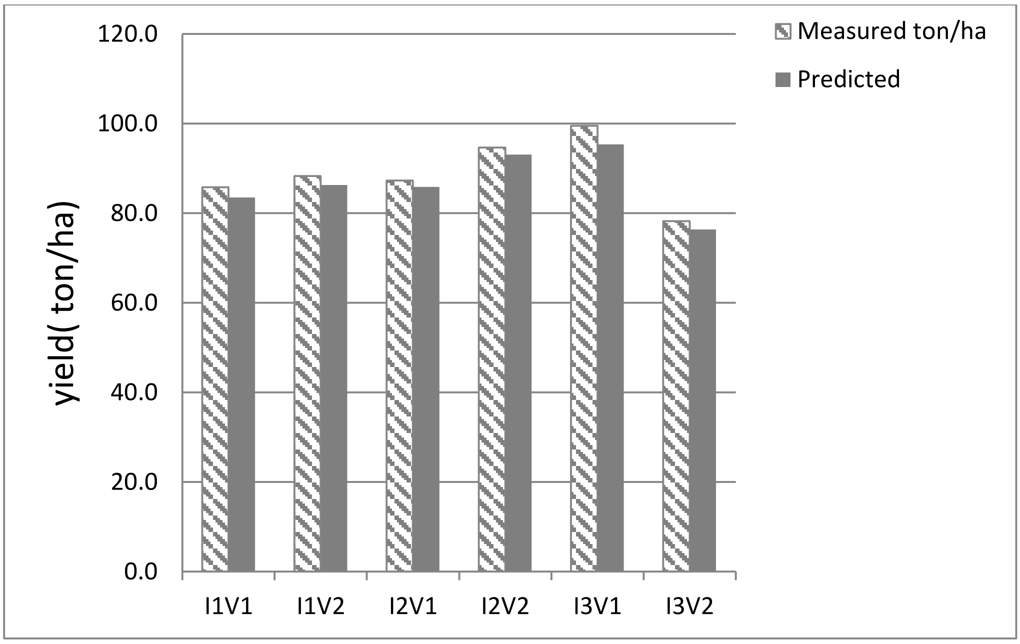
CropSyst Calibration

1. First transplanting date

Table (7) showed measured versus predicted wheat yield in the first date and first season. Results in that table implied that CropSyst model predicted tomato yield with high degree of accuracy. Percent difference between measured and predicted tomato yield Table (7). RMSE was 0.03 ton/ha and Willmott index of agreement was 0.96. Several publications highlighted the accuracy of the model, such as Benli et al., (2007) and Singh et al., (2008).

Both papers indicated that the model prediction showed low RMSE. Furthermore, Benli et al., (2007) stated that high Willmott index of agreement was obtained with a value of 0.98, which is similar to what is shown in Table (7).

Fig 1: Percent difference between measured and predicted tomato yield in first transplanting date in the first season.



In figure (1) showed the low difference between measure yield and predicted yield. The lowest percent difference between measured and predicted values recorded with 120% of water field capacity and cultivar Castel Rock with percent (1.6) in the first season and the same results in the second season figure (2).

Table 7. Measured versus predicted yield for tomato in the first date and first season.

Treatments	**First season**		**Date1**
	Measured	**Predicted**	**PD**
	ton/ha	**ton/ha**	**%**
I1V1	85.8	83.5	2.6
I1V2	88.3	86.3	2.3
I2V1	87.3	85.9	1.6
I2V2	94.7	93.1	1.7
I3V1	99.6	95.4	4.2
I3V2	78.2	76.4	2.4
RMSE	0.03		
R2	0.9855		
WI		0.9669	

I_1= irrigation level 80%; I_2=irrigation level 100%; I_3= irrigation level 120%; v1= cultivar super streine B ; v2= cultivar casel rock; RMSE= Root mean square error; WI= Willmott index of agreement; PD% = percent difference between measured and predicted values.

Fig 2: Percent difference between measured and predicted tomato yield in first transplanting date in the second season.

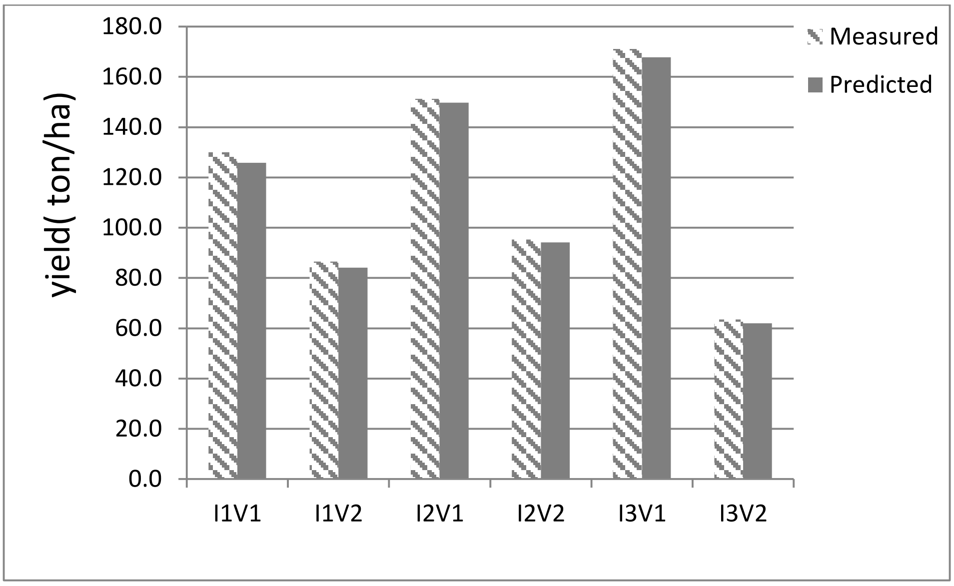


Table 8. Measured versus predicted yield for tomato in the first date and second season.

Treatments	second season		Date2
	Measured	**Predicted**	**PD**
	ton/ha	**ton/ha**	**%**
I1V1	130.0	125.8	3.2
I1V2	86.5	84.2	2.7
I2V1	151.2	149.7	1.0
I2V2	95.3	94.1	1.2
I3V1	171.2	167.8	2.0
I3V2	63.5	62.0	2.3
RMSE	0.024		
R2	0.9997		
WI		0.9992	

I_1= irrigation level 80%; I_2=irrigation level 100%; I_3= irrigation level 120%; v1= cultivar super streine B ; v2= cultivar casel rock; RMSE= Root mean square error; WI= Willmott index of agreement; PD% = percent difference between measured and predicted values.

2. Second transplanting date

Results were obtained for the prediction of wheat biological yield (Table 9), where percentage of difference between measured and predicted tomato yield was less than 5%. Results in that table also indicated that RMSE was 0.05 ton/ha and Willmott index of agreement was 0.99 in the first season. These results showed the highly accurate performance of CropSyst model. but the second season percentage of difference between measured and predicted tomato yield was less than 4%. Results in that table also indicated that RMSE was 0.03 ton/ha and Willmott index of agreement was 0.99 (Table 10).Likewise, Singh et al., (2008) reported that RMSE between observed and predicted biomass by CropSyst was 1.27 ton/ha as compared to 1.94 ton/ha between observed and predicted biomass by CERES-Wheat.

Fig 3: Percent difference between measured and predicted tomato yield in second transplanting date in the first season

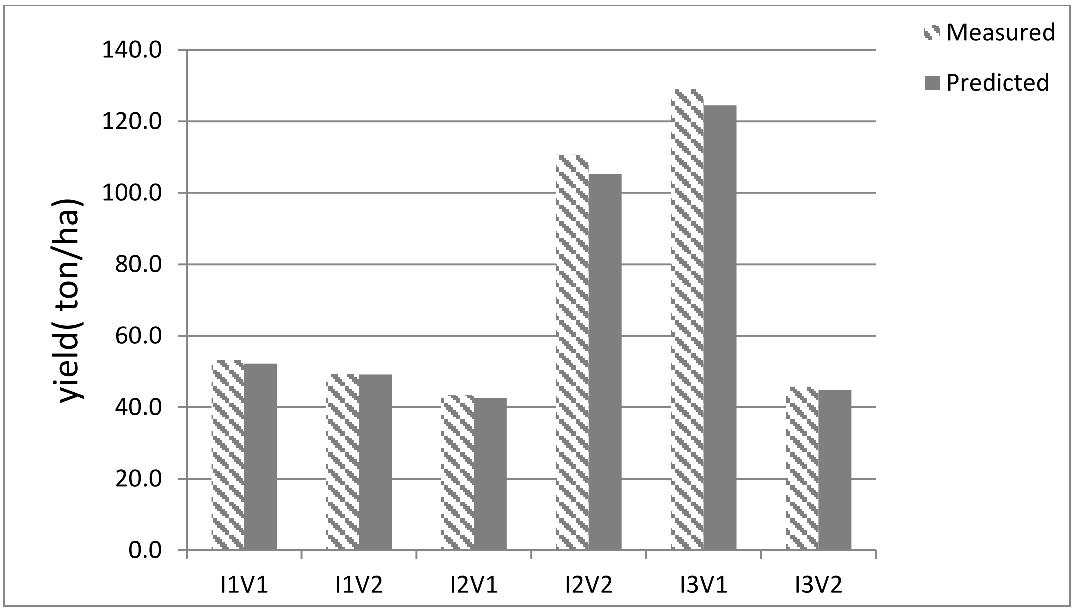


Table 9. Measured versus predicted yield for tomato in the second date and first season

Treatments	first season		Date1
	Measured	**Predicted**	**PD**
	ton/ha	**ton/ha**	%
I1V1	53.3	52.2	2.0
I1V2	49.3	49.2	0.2
I2V1	43.3	42.5	1.9
I2V2	110.7	105.3	4.9
I3V1	129.0	124.4	3.5
I3V2	45.8	44.9	2.1
RMSE	0.05		
R2	0.9996		
WI		0.99	

I_1= irrigation level 80%; I_2=irrigation level 100%; I_3= irrigation level 120%; v1= cultivar super streine B ; v2= cultivar casel rock; RMSE= Root mean square error; WI= Willmott index of agreement; PD% = percent difference between measured and predicted values.

Table 10. Measured versus predicted yield on tomato in the second date and second season

Treatments	second season		Date2
	Measured	**Predicted**	**PD**
	ton/ha	**ton/ha**	%
I1V1	65.0	62.5	3.9
I1V2	93.7	91.4	2.5
I2V1	123.6	120.7	2.3
I2V2	66.5	64.0	3.8
I3V1	131.5	128.8	2.1
I3V2	63.2	61.5	2.6
RMSE	0.03		
R2	0.99989		
WI		0.99	

I_1= irrigation level 80%; I_2=irrigation level 100%; I_3= irrigation level 120%; v1= cultivar super streine B ; v2= cultivar casel rock; RMSE= Root mean square error; WI= Willmott index of agreement; PD% = percent difference

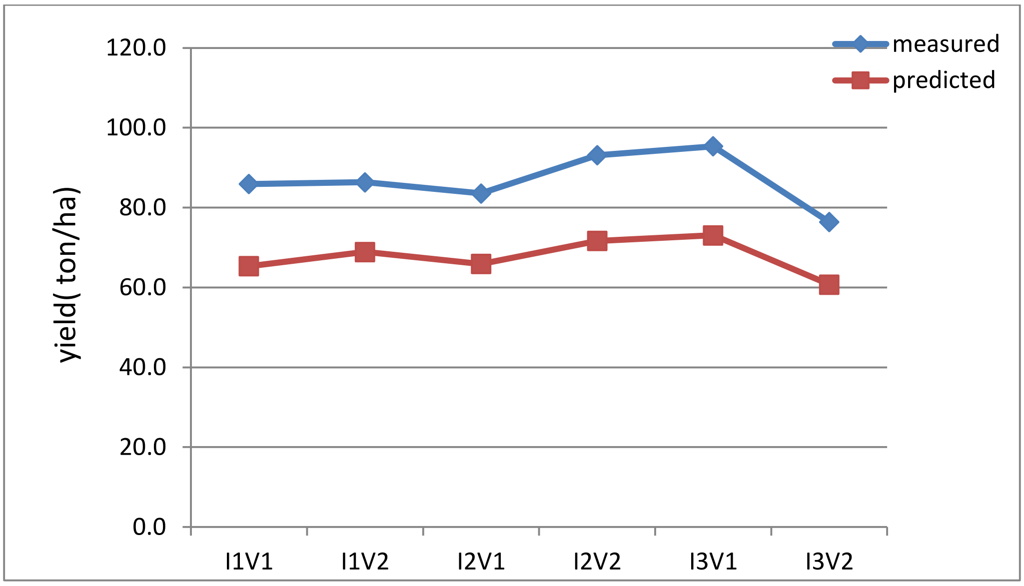
Effect of climate change

1. First transplanting date

Regarding to climate change scenario A1B, yield losses in A1B in 2040 under all irrigation treatments. simulation of CropSyst model for the three irrigation levels, cultivars and transplanting date showed in table(11) between measured and predicted yield. This agreement was reflected by high percentage of difference between measured and predicted values of yield, mean square error with value 0.24 and Willmott index of agreement 0.3941. Percent difference between measured and predicted values was less than 20.5 % for the (Table 11 and 12) in the first transplanting date.

In figure (4) showed the high difference measure yield and predicted yield. The high percent difference between measured and predicted values recorded with 120% irrigation level and cultivar "Super Strain B" with percent (23.9) in the first season but the second season the high difference measure yield and predicted yield. The high percent difference between measured and predicted values recorded with 80% irrigation level and cultivar "Castel Rock" with percent (22.4) under climate change scenario A1B in 2040

Figure 4: Percent difference between measured and predicted tomato yield in the first date and first season.



In the second season the simulation of CropSyst model for the three irrigation levels, cultivars and transplanting date showed good agreement between measured and predicted yield. This agreement was reflected by high percentage of difference between measured and predicted values of yield, the mean square error value was 0.230 and low Willmott index with mean 0.9825.

Fig 5: Percent difference between measured and predicted tomato yield in the first date and second season.

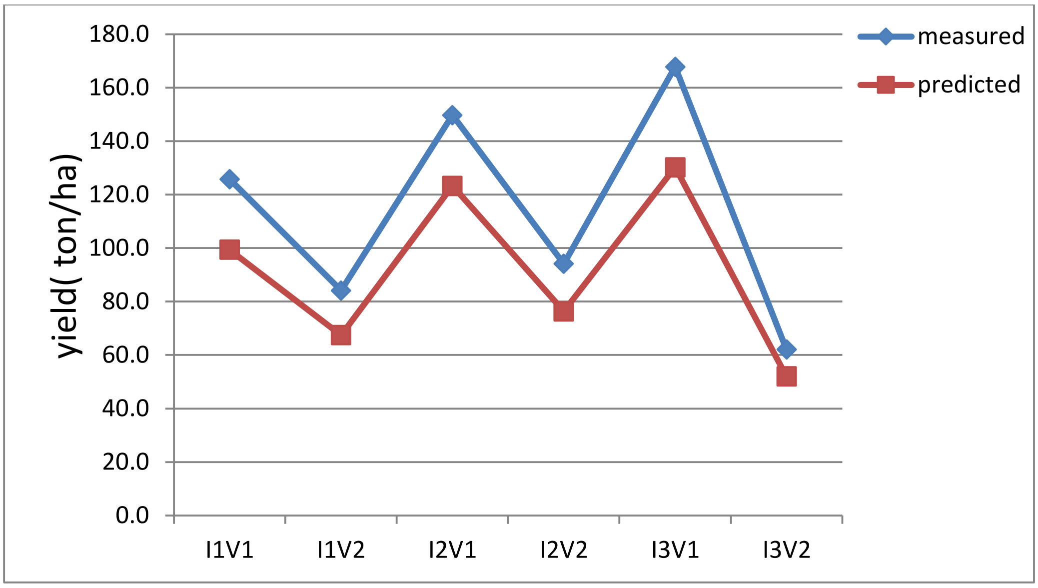


Table 11. Measured versus predicted yield for tomato in the first date and first season the effect of the climate change scenario A1B in 2040

Treatments	First season		Date1
	Measured	**Predicted**	**PD**
	ton/ha	**ton/ha**	**%**
I1V1	85.9	65.4	23.9
I1V2	86.3	68.9	20.2
I2V1	83.5	65.9	21.1
I2V2	93.1	71.7	23.0
I3V1	95.4	73.1	23.4
I3V2	76.4	60.8	20.5
RMSE	0.24		
R2	0.9809		
WI		0.3941	

I_1= irrigation level 80%; I_2=irrigation level 100%; I_3= irrigation level 120%; v1= cultivar super streine B ; v2= cultivar casel rock; RMSE= Root mean square error; WI= Willmott index of agreement; PD% = percent difference between measured and predicted values.

Table 12. Measured versus predicted yield for tomato in the first date and second season the effect of the climate change scenario A1B in 2040

Treatments	second season		Date1
	Measured	**Predicted**	**PD**
	ton/ha	**ton/ha**	**%**
I1V1	125.8	99.4	21.0
I1V2	84.2	67.45	19.9
I2V1	149.7	123.3	17.7
I2V2	94.1	76.35	18.9
I3V1	167.8	130.2	22.4
I3V2	62.0	52	16.2
RMSE	0.23		
R2	0.994		
WI		0.9925	

I_1= irrigation level 80%; I_2=irrigation level 100%; I_3= irrigation level 120%; v1= cultivar super streine B ; v2= cultivar casel rock; RMSE= Root mean square error; WI= Willmott index of agreement; PD% = percent difference between measured and predicted values.

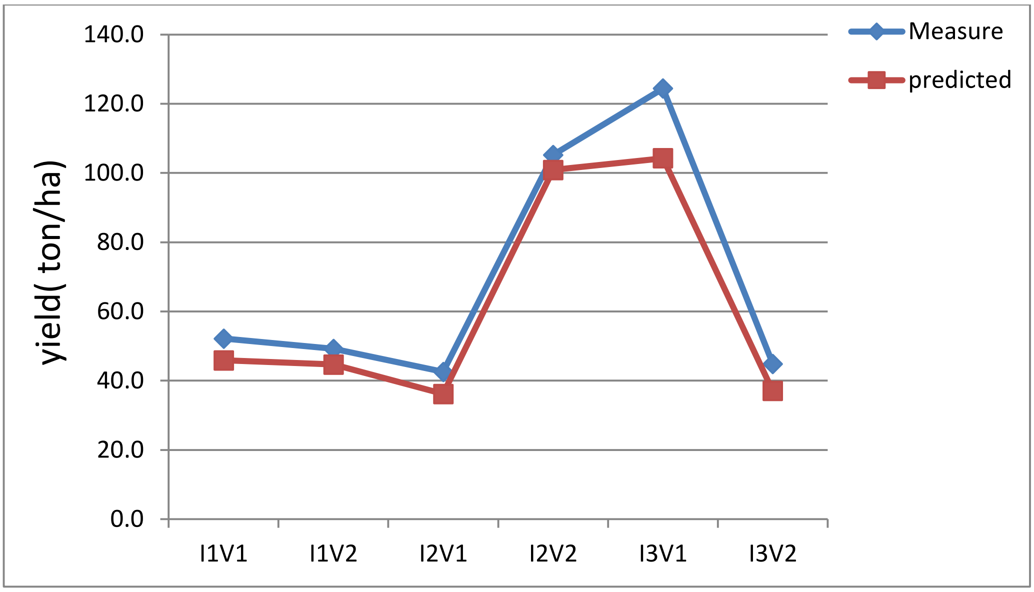
2. Second transplanting date

Regarding to climate change scenario A1B, yield losses in A1B in 2040 under all irrigation treatments.

Simulation of CropSyst model for the three irrigation levels, cultivars and transplanting date showed in table(13) between measured and predicted yield. This agreement was reflected by high percentage of difference between measured and predicted values of yield, mean square error with value 0.16 and Willmott index of agreement 0.8917. Percent difference between measured and predicted values was less than 18 % for the (Table 13) in the first season and in the second mean square error with value 0.16 and Willmott index of agreement 0.9443

In figure (6) showed the high difference measure yield and predicted yield. The high percent difference between measured and predicted values recorded with 120% of field capacity and cultivar "Castel Rock" with percent (17.4) in the first season

Figure 6: Percent difference between measured and predicted tomato yield in Second transplanting date in first season



but the second season the high difference measure yield and predicted yield. The high percent difference between measured and predicted values recorded with 80% irrigation level and cultivar super streine B with percent (21.1) under climate change scenario A1B in 2040

Figure 7: Percent difference between measured and predicted tomato yield in Second transplanting date in Second season

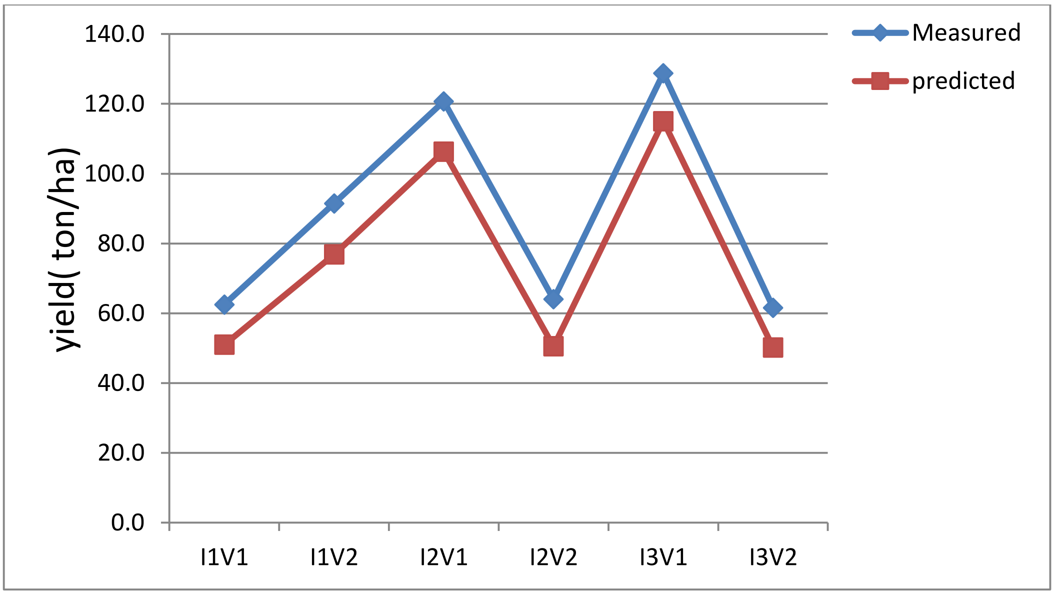


Table 13. Measured versus predicted yield for tomato in the second date and first season the effect of the climate change scenario A1B in 2040

Treatments	First season		Date2
	Measured	Predicted	PD
	ton/ha	ton/ha	%
I1V1	52.2	45.88	12.1
I1V2	49.2	44.69	9.2
I2V1	42.5	36.167	15.0
I2V2	105.3	100.89	4.1
I3V1	124.4	104.267	16.2
I3V2	44.9	37.07	17.4
RMSE	0.16		
R2	0.9798		
WI	0.896		

I_1= irrigation level 80%; I_2=irrigation level 100%; I_3= irrigation level 120%; v1= cultivar super streine B ; v2= cultivar casel rock; RMSE= Root mean square error; WI= Willmott index of agreement; PD% = percent difference between measured and predicted values.

Table 14. Measured versus predicted yield for tomato in the second date and second season the effect of the climate change scenario A1B in 2040

Treatments	second season		Date2
	Measured	Predicted	PD
	ton/ha	ton/ha	%
I1V1	62.5	50.98	18.4
I1V2	91.4	76.83	16.0
I2V1	120.7	106.29	12.0
I2V2	64.0	50.52	21.1
I3V1	128.8	115	10.7
I3V2	61.5	50.16	18.5
RMSE	0.16		
R2	0.9263		
WI		0.9443	

I_1= irrigation level 80%; I_2=irrigation level 100%; I_3= irrigation level 120%; v1= cultivar super streine B ; v2= cultivar casel rock; RMSE= Root mean square error; WI= Willmott index of agreement; PD% = percent difference between measured and predicted values.

References

Benli, B., M. Pala, C. Stockle, T. Oweis. 2007.Assessment of winter wheat production under early sowing with supplemental irrigation in acold highland environment using CropSyst simulation model. Agric. Mang. Water. 3:45- 54

Byari, S.H. and Al sayed, A.R. (1999). The influence of differential irrigation regimes on five greenhouse tomato cultivars: The influence of differential irrigation regimes on vegetative growth. Egypt. J. Hort. 26, (2) :pp109-125.

El-Beltagy, A.S; Taha, S.M.; Hassan,S.M. ; Gomaa, H. M. and M. A. Msksoud.(1984). Effect of different water regimes on tomato 1-growth, yield and fruit quality. Annals Agric. Sci.Ain shams Univ. 29(2):pp 937-956

El Sawy, M. (2014) effect of some climatic factors and irrigation regimes on tomato growth and productivity. Thesis, Fac. Agric., Benha University, Egypt PP68-71.

Fattahallah, M.A. (1992). Response of tomato to various irrigation regimes in relation to farmyard manure fertilization II yield and fruit quality. Menofiya J. Agric. Res., 17 .(3): pp1327- 1351

FAO (2014).FAOSTAT, Integrated database and satellite databases.http://faostat.fao.org

FAO.(1977). Guidelines for predicting crop water requirements. Irrigation and drainage paper, 24, FAO, Rome.

Gordon, C., Cooper, C.A., Senior, H., Banks, J., Gregory, M., Johns, T.C., Mitchell, F.B., Wood, R.A.

2000. The simulation of sea surface temperature, sea ice extents and ocean heat transports in a version

of the Hadley Centre coupled model without flux adjustments. Climate Dynamics (16), 147-168.

Harmanto,V.M; Salokhe, M.S; Babel and Tantau, H.J. (2005). Water requirement of drip irrigated tomatoes grown in greenhouse in tropical environment. Agricultural water management 71:pp 225-242.

Ibrahim.A.A(2005). physiological studies on yield and quality of tomato Ph.D. Thesis, Fac. Agric., Benha University, Egypt PP124

IPCC-TGCIA. 1999. Guidelines on the use of Scenario Data for Climate Impact and Adaptation Assessment, Version 1. Prepared by Carter, T.R., Hulme M., and Lal. M. Intergovernmental Panel on Climate Change, task Group on Scenarios for Climate Impact Assessment. Cambridge University Press, Cambridge, 944 p.

IPCC. 2001: Summary for Policymakers: Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the 3rd Assessment Report of the Intergovernmental Panel on Climate Change. J.T. Houghton, Y. Ding, D.J. Griggs, M.Noguer, P.J. Van Der Linden, and D. Xioaosu, Cambridge University Press, Cambridge, 944 pp.

Jamieson, P.D., J. R. Porter, J. Goudriaan, J.T. Ritchie, H. van Keulen, and W. Stol. 1998. Acomparison of the models AFRCWHEAT2,CERES-Wheat, Sirius, SUCROS2 and SWHEAT with measurements from wheat grown under drought. Field Crops Res. 55:23–44

Merghaney, M .M.(1997). Effect of irrigation system and nitrogen level on vegetative growth , yield components and some chemical composition of tomato plants grown in newly reclaimed sandy soils. Ann.Agric. Sci. Moshtohor. 35(2): pp965-981.

Moore, E. L. andThomas,W . (1952). Some effects of shading and parachloro –phenoxy acetic acid on fruitfulness of tomatoes. Proc. Am. Soc. Hortscience, V60: pp289-294.

Nakicenovic, N,; Alcamo, J., Davis, G., de Vries B.; Fenhann, J., Gaffin, S., Gregory, K., Grubler, A.,Jung, T.Y., Kram, T., La Rovere, E.L., Michaelis, L.; Mori, S.; Morita, T.;Pepper, W.; Pitcher, H., Price, L, Raihi, K, Roehrl, A., Rogner, H., Sankovski, A., Schlesingger, M., Shukla, P., Smith, S., Swart, R, van Rooijen, S., N Victor and Z. Dadi. 2000. IPCC Special Report on Emission Scenarios Cambridge University Press, 599 P.

Navarrete, M. and Jeannequin, B. (2000). Effect of frequency of axillary bud pruning on vegetative growth and fruit yield in greenhouse tomato crops. Scienta- Horti. 86 (3):pp 197-210.

Pala, M., Stockle, C.S., Harris, H.C., 1996. Simulation of durum wheat (Triticum turgidum ssp Durum) growth under different water and nitrogen regimes in a Mediterranean environment using CropSyst. Agric. Sys. 51 (2), 147–163.

Sibomana,I. C. ; Aguyoh, J. N. and Opiyo, A. M. (2013). water stress affects growth and yield of container grown tomato (*Lycopersicon esculentum Mill)* PLANTS G.J.B.B., V.2 (4): pp 461-466

Singh, A. K., R. Tripathy and U. K Chopra. 2008.Evaluation of CERES-Wheat and CropSyst models for water-nitrogen interactions in wheat crop. Agric. Wat. Mang. 95(7):776-786.

Stockle, C.O., Donatelli, M., Nelson, R. 2003. CropSyst a cropping systems simulation model. European Journal
of Agronomy. No. 18 p. 289–307.

Stockle, C. O., S. Martin and G. S. Campbell. 1994.CropSyst, a cropping systems model: water/nitrogen budgets and crop yield. Agricultural Systems. 46:335-359.

Stockle, C.O., Nelson, R., 1994. Cropping Systems Simulation: Model Users Manual (Version 1.02 . 00 Biological)Systems Engineering Department, Washington State University, p.167

Willmott, C. J., 1981: On the validation of models.Phys. Geog., 2, 184-194

Went, F.W .(1945). Plant growth under controlled II.Termo periodicity in growth and fruit of tomato. American J. Botany .V 31: pp135 – 150.

تقييم تأثير التغيرات المناخية باستخدام برامج المحاكاة على انتاجية محصول الطماطم

أجريت تلك الدراسة فى صوب الابحاث الخاصة بالمعمل المركزى للمناخ الزراعى – مركز البحوث الزراعية – وزارة الزراعة – جمهورية مصر العربية. تم إجراء التجربة خلال عامى 2014 و 2015 فى الحقل المكشوف

الاصناف

(سوبرسترين بى – كاسل روك)

تمت الزراعة بالحقل المكشوف على مساحة 600م(الطول 60م*العرض 10م). وتم تقسيم المساحة إلى خمس مصاطب كل مصطبة عرضها 1.5 سم والمسافة بين الخراطيم الري 60سم وبين النباتات 30سم كل مصطبة معدل ري مختلف عن الأخرى وتم تقسيم المساحة بالنصف للميعادين الزراعة الميعاد الأول يفرق 15يوم عن الأخر

تم الري بالتنقيط بمعدلات مختلفة (80%-100%-120%)

(9 x 40) م على محصول الفلفل الحلو هجين (سلفيت).

وتم فيها دراسة تأثير ثلاثة عوامل مختلفة كالتالى :

- ثلاث كميات من الري (حساب المقنن المائي بناء على بيانات الأرصاد الجوية الزراعية) 80و 100 و 120%.
- 2اصناف من الطماطم
- 2 ميعاد للزراعه

ثلاث مكررات

36 قطعة تجريبية

التحليل الاحصائى:split Split plot

وذلك بهدف دراسة تأثير التغيرات المناخيه على محصول الطماطم فى الظروف الحاليه والمستقبلية

وباستخدام برنامج الكروبسيست وعمل المعايرة له كانت نسبه بين انتاجية المحصول فى الظروف الحاليه بين نتائج البرنامج ونتائج التجربه الحقليه متقاربه

اما باستخدام سيناريو فى ظل ظروف التغيرات المناخيه المستقبليه سنه 2040 كانت النسبه بين الانتاجيه الحاليه والمستقبليه مرتفعه