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IMPACT OF CLIMATE CHANGE SCENARIOS ON SOME RAINFED WHEAT CULTIVARS UNDER NORTH SINAI REGION CONDITIONS

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ABSTRACT

Simulation models are important tools to explore and illustrate dynamics of climatic variables in crop based ecosystem. Two open-field experiments were conducted during 2015/2016 and 2016/2017 seasons at the Experimental Farm, Faculty of Environ. Agric. Sciences, Arish University (31° 08' 04.3" N, 33° 49' 37.2" E). This work was aimed to evaluate the performance of four bread wheat (*Triticum aestivum* L.) cultivars *i.e.*; Misr-1, Sakha-93, Giza-168 and Gemmeiza-9) in relation to two irrigation pattern *i.e.* surface supplemental irrigations (12 irrigations) and rainfed under the metrological conditions of North Sinai. Results obtained from experimental field studies were used as indicators to test the performance of DSSAT-CSM (Cropping System Model) Ver. 4.5.1.023. Necessary files were prepared as required. Two different climate scenarios have been implemented in order to study effects of future climate changes on wheat plant growth and yield. Scenarios were done by adding 2°C and 4°C to maximum and minimum temperatures of the last successful winter season (2016/2017) starting from the best sowing date indicated at conducted field experiments and finishing by the end of growing cycle. The future impacts of climate change on wheat showed that increasing in temperature will reduce length of growing cycle and the time needed to full tillering in addition to the final yield. This subsequently will reduce the amount of grain yield; accelerate time for maturity and harvesting. For +2°C scenario, reduction in grain yield, as predicted by the model, will be reach 9.6% loses in grain yield for supplementary irrigated Gemmeiza-9 cultivar and averaged of 18% among all other cultivars. Scenario of +4°C will reduce supplementary irrigated Gemmeiza-9 grain yield by 16.2% and within an average of 23.8% among all other cultivars. The reduction will be more under rainfed irrigation pattern. Generally, Supplementary irrigated Gemmeiza-9 cultivar is recommended treatment to maximized bread wheat grain yield and as an adaption measure to reduce yield variability as affected by increasing of potential temperature scenarios under North Sinai environmental conditions and all similarity regions.

Key words: bread wheat cultivars, CERES-Wheat, irrigation pattern, rainfed wheat, *Triticum aestivum,* crop simulation, climate change scenarios, North Sinai environmental conditions.

INTRODUCTION

Rise in temperature, particularly in warmer areas, could have a negative effect on wheat productivity in addition to the increasing demand for water requirements. For that reason, more research for adaptation strategies should be explored to reduce the problem of such increasable gap especially under the predicted future climatical changes. There is in general increase the chance of intense precipitation and flooding due to the greater water-holding capacity of a warmer atmosphere **(Barnett *et al*., 2006)**. **Weisheimer and**

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Palmer (2005) examined changes in extreme seasonal temperatures using multi-model multi-scenario ensembles. They showed that by the end of the century, the probability of extreme warm seasons is projected to rise over many areas. This increase in extreme warm seasons arises from the combined effect of a shift in the temperature mean and an increase in the temperature variability. Isolated incidents of extreme high temperatures could seriously damage agricultural crops; a continuous period of extreme high temperature could be deadly. The great challenge for the coming decades will therefore be the task of increasing food production with less water, especially in arid and semi-arid regions **(Abouzeid, 1992 and FAO, 2003)**. Precipitation was projected to decrease by about 163, 163 and 105 mm during the period of 1990 to 2100. An increase in temperature may result in a higher evaporative demand of the atmosphere **(Yano *et al.,* 2007)**. Based on the projections of general circulation models (GCMs), the global average temperature is expected to increase between 2°C and 4.5°C during the current century **(IPCC, 2007).** The impact of future climate change on crop production has been widely studied by using crop models and climate change scenarios **(Hussain and Mudasser, 2007; Challinor and Wheeler, 2008; Tao *et al.,* 2008)**. Most of the previous researches on the impact of climate change on agricultural sector in Egypt used two scenarios, *i.e.* 1.5°C rise in temperature and 3.6°C rise in temperature (GCM results) to predict the impact up the year 2050. These scenarios predicted reduction in wheat grain yield up to 30% and increase in water needs by about 3% **(Eid *et al.,* 1992; 1993 and 1994**) in the year of 2050. **Hassanein *et al.* (2012)** pointed out that predicted the rise in the Earth's surface temperature will adversely affect the productivity of many crops in addition to the increasing demand for water requirements. Under Egyptian conditions, wheat productivity will be reduced by 12% with each 1.5ºC increase, while this decrease will reach 27% if the increase in temperature is 3.5ºC. The objectives of this study are to estimate the impact of climate scenarios using DSSAT-CERES-Wheat Model Ver. 4.5.2 on wheat plant growth and yield under El-Arish-North Sinai conditions.

MATERIALS AND METHODS

Field Experiments

Two open field experiments were conducted at the Experimental Farm, Faculty of Environ. Agric. Sciences, Arish University, North Sinai (31° 08' 04.3" N, 33° 49' 37.2" E), Egypt during two seasons of 2015/2016 and 2016/2017. This work was aimed to evaluate the performance of four bread wheat (*Triticum aestivum* L.) cultivars *i.e.*, Misr-1, Sakha-93, Giza-168 and Gemmeiza-9 with two irrigation pattern (surface supplementary and rain-fed) under metrological conditions of North Sinai The climatic data of the field experiments, during the growing seasons of wheat plants in 2015/2016 and 2016/2017 were obtained from Central Laboratory for Agriculture Climate (CLAC, Egypt) and presented in Table 1.

Surface supplemental irrigations (12 Irrigations) during wheat growth period was added as recommended for semi arid region. Treatments randomized complete block design (RCBD) in four replicates for each treatment. An area of 359 m^2 was ploughed and divided to two blocks for each irrigation pattern (main plots) and wheat cultivars were arranged in the sub-plots. Row spacing was 15 cm apart, grains were handly drilled. Fertilization and all other agricultural practices were carried out as recommended for wheat growing under the conditions of North Sinai as a semi-arid land.

Table (1): Meteorological data of El-Arish, North Sinai, region during wheat growing seasons of 2015/2016 and 2016/2017.

Period Day (from-to) /Month/Year	Air Temp. [°C]			Av. Relative Humidity [%]	Solar Radiation [MJ-hr/m²/D]	Total Precipitation [mm]
	Min.	Max.	Aver.			
				2015/2016 season		
15-30 November 2015	18.28	23.15	20.71	66.15	10.96	8.49
1-15 December 2015	14.63	18.65	16.64	65.43	9.45	15.83
16-31 December 2015	13.70	18.64	16.17	65.21	9.99	16.85
1-15 January 2016	12.96	17.68	15.32	69.24	8.96	14.82
16-31 January 2016	11.35	15.09	13.22	68.71	9.92	31.28
1-15 February 2016	12.38	18.06	15.22	69.89	12.99	12.46
16-29 February 2016	14.31	20.73	17.52	70.84	16.56	13.48
1-15 March 2016	14.51	21.42	17.97	65.46	17.31	1.41
16-31 March 2016	14.09	19.74	16.91	67.81	19.08	7.61
1-15 April 2016	16.46	23.51	19.98	68.45	21.24	9.90
16-30 April 2016	17.94	25.69	21.81	64.99	24.18	0.00
1-15 May 2016	19.23	26.05	22.64	62.88	24.61	0.05
				2016/2017 season		
15-30 November 2016	16.83	22.53	19.68	55.64	11.79	53.60
1-15 December 2016	14.74	18.73	16.74	68.39	9.10	55.97
16-31 December 2016	12.45	16.36	14.40	67.74	9.38	17.15
1-15 January 2017	10.97	16.04	13.51	66.23	10.01	5.44
16-31 January 2017	12.14	16.60	14.37	70.47	10.61	10.06
1-14 February 2017	11.70	16.72	14.21	70.57	13.25	10.41
15-28 February 2017	11.25	16.85	14.05	67.18	13.82	22.81
1-15 March 2017	13.45	19.42	16.44	71.22	17.76	3.21
16-31 March 2017	13.90	19.35	16.62	72.22	19.06	0.23
1-15 April 2017	15.14	21.35	18.25	70.73	19.91	3.31
16-30 April 2017	16.16	23.02	19.59	66.97	24.02	0.00
1-15 May 2017	18.34	25.36	21.85	68.91	25.61	0.00

Source: Central Laboratory for Agricultural Climate (CLAC, Egypt).

Crop Modeling

Results obtained from experimental field studies and the environmental conditions were used as a data base for calibration and validation of CERES-Wheat through DSSAT-CSM (Cropping System Model) Ver. 4.5.1.023 software to simulate and predict wheat growth and yield. The comparison between actual data (observed) and predicted data were done through CERES-Wheat model under DSSAT interface in three steps, retrieval data (converting data to CERES-Wheat model), and validation data (comparing between predicted and observed data) and run the DSSAT model provides validation of the crop models that allows users to compare simulated outcomes with observed results. Necessary files were prepared as required. Calibration and validation of applying CERES-Wheat model was done through using d-Stat index of agreement between simulated and observed values.

Genetic coefficient

DSSAT model analyzed the sensitivity of the crop biological responses to changes in the coefficients that relate to phenology. The DSSAT-CERES-Wheat Model was run with weather data and experimental data for the studied four cultivars *i.e.*; Misr-1, Sakha-93, Giza-168 and Gemmeiza-9 to calculate the genetic coefficient (P1V, P1D, P5, G1, G2 and PHINT) for each variety by using sub model GENCALC program, which is part of the DSSAT. The coefficients were prepared as provided by **Fayed *et al.* (2015)**.

Future Climate Scenarios

Two different climate scenarios have been implemented in CERES-Wheat model files in order to study effects of future climate changes on wheat plant growth and yield. Scenarios were done by adding 2°C and 4°C to maximum and minimum temperatures of the last winter successful season (2016/2017) starting from the best sowing date indicated at conducted field experiments and finishing by the end of growing cycle.

RESULTS AND DISCUSSION

It will be necessary to clarify that the two different climatic scenarios which have been implemented using CERES-Wheat model were have added by (2°C and 4°C) to maximum and minimum temperatures of the last successful winter season (2016/2017).

Number of Days From Sowing to Anthesis

Results presented in Table 2 showed the influence of two climate change scenarios on observed number of days from sowing to anthesis date in 2016/2017 experimental season under North Sinai (El-Arish) environmental conditions.

Compared by recorded number of days to flowering, adding 2°C to minimum and maximum temperature will cause a reduction in growing cycle length for all wheat cultivars as affected by irrigation pattern. Reduction in number of days from sowing to anthesis will be about 5 days required period for anthesis of Misr-1 and Gemmeiza-9 cultivars with adding sufficient supplementary irrigation. However, Sakha-93 cultivars will have the longest reduction in days from sowing to anthesis with about 7 days.

Length of growing cycle will be more reduced when the wheat cultivars depend on rain as a main irrigation pattern. In this respect, **Fahim *et al.* (2013)** reported that the impact of climate change on the productivity of some major crops in Egypt up to 2050's. It can be concluded that, climate change could decrease national food production from 11% to 19%. Impacts of climate change on wheat showed that increasing in temperature will reduce length of growing cycle and the time needed to full tillering in addition to the final yield. This subsequently will reduce the amount of grain yield; accelerate time for maturity and harvesting (**Hassanein *et al.*, 2012)**.

Table (2): Effects of two climate change scenarios on number of days from sowing to anthesis of four bread wheat cultivars as affected by two irrigation pattern.

Climate change scenario			+2°C	Reduction [day]	+4°C	Reduction [day]
Cultivar	Irrigation Pattern	Recorded				
Misr-1	Supplemental Irri.	95	90	-5	86	-9
	Rainfed	88	83	-5	78	-10
Sakha-93	Supplemental Irri.	94	87	-7	83	-11
	Rainfed	89	81	-8	76	-13
Giza-168	Supplemental Irri.	95	89	-6	85	-10
	Rainfed	88	80	-8	76	-12
Gemmeiza-9	Supplemental Irri.	97	92	-5	89	-8
	Rainfed	91	85	-6	83	-8

Greater impacts will be observed by adding 4°C to minimum and maximum temperature creating more reduction in period required to anthesis with about 8 to 12 days. number of days from sowing to anthesis will be depressed by about 8 days required period for anthesis of Gemmeiza-9 cultivar with both two irrigation pattern. However, Sakha-93 cultivars will have the longest reduction in days from sowing to anthesis with about 11 days with supplementary irrigation pattern and about 13 days under rainfed irrigation pattern. Length of growing cycle will be more reduced when the wheat cultivars depend on rain as a main irrigation pattern by about 10 days for Misr-1 cultivar and by about 12 days for Giza-168 cultivar.

Comparing the reduction in days to anthesis at both future climate scenarios showed reduction by adding 4°C doubled than reduction caused by adding 2°C to air temperature of North Sinai region. Simulation ability of the model was similar to what obtained by: **El Afandi *et al.* (2010); Ehteramian *et al.* (2012); Valizadeh *et al.* (2014) and Waongo *et al.* (2015).** Whereas, **Abdul Haris *et al.* (2013)** who reported that higher temperature during the growing period will decrease the duration of crop growth and wheat yield for future cultivation under climate change simulation in different agro-ecological zones.

Number of days from sowing to physiological maturity date

Results presented in Table 3 show the impact of two climate change scenarios on observed number of days from sowing to physiological maturity date in 2016/2017 effective experimental season under environmental conditions of North Sinai (El-Arish).

Compared by recorded number of days to physiological maturity, 2°C increment to minimum and maximum temperature will cause a reduction in growth cycle length for all studied wheat cultivars as affected by irrigation pattern. Reduction will be about 5 days required period for physiological maturity of Misr-1 and Gemmeiza-9 cultivars with adding sufficient supplementary irrigation.

However, Sakha-93 cultivar will have the longest reduction in days from sowing to physiological maturity with about 7 days. Length of growing cycle will be more reduced when the wheat cultivars depend on rain as a main irrigation pattern.

Comparing the reduction in days from sowing to physiological maturity at both future climate scenarios showed reduction by adding 4°C doubled than reduction caused by adding 2°C to minimum and maximum temperature. Number of days from sowing to physiological maturity will be depressed by about 8-13 days required

Table (3): Effects of two climate change scenarios on number of days from sowing to physiological maturity of four bread wheat cultivars as affected by two irrigation pattern.

Climate Change Scenario			+2°C	Reduction [day]	+4°C	Reduction [day]
Cultivar	Irrigation Pattern	Recorded				
Misr-1	Supplemental Irri.	144	139	-5	135	-9
	Rainfed	133	128	-5	123	-10
Sakha-93	Supplemental Irri.	141	134	-7	130	-11
	Rainfed	131	123	-8	118	-13
Giza-168	Supplemental Irri.	142	136	-6	132	-10
	Rainfed	132	124	-8	120	-12
Gemmeiza-9	Supplemental Irri.	145	140	-5	137	-8
	Rainfed	134	128	-6	126	-8

period for an thesis of all studied cultivars. Gemmeiza-9 cultivar with both two irrigation pattern will lose 8 days to reach physiological maturity which be the latest cultivar will reach this stage by 137 days with supplementary irrigation and 126 days under rainfed irrigation. However, Sakha-93 cultivars will have the longest reduction in days from sowing to anthesis with about 11 days with supplementary irrigation pattern and about 13 days under rainfed irrigation pattern. Length of growing cycle will be more reduced when the wheat cultivars depend on rain as a main irrigation pattern by about 10 days for Misr-1 cultivar and by about 12 days for Giza-168 cultivar.

Simulation ability of the model was similar to what obtained by **Hassanein and Medany (2007)** and **Fahim *et al.* (2013).** In this respect**, Hassanein *et al.* (2012)** showed that the future impacts of climate change on wheat showed that increasing in temperature will reduce length of growing cycle and the time needed to full tillering in addition to the final yield. Whereas, effects of climate factors on crop growth stages and development inter-related within specific pattern. Meteorological conditions before and after flowering will influence wheat yield and production (**Yu *et al.,* 2013**).

Grain yield at maturity

Table 4 shows the impact of two climate change scenarios on observed grain yield in 2016/2017 effective experimental season under environmental conditions of North Sinai (El-Arish).

Compared by recorded grain yield kg ha^{-1}, the effect of increment in minimum and maximum temperature with the weather conditions of 2016/2017 showed more reduction in grain yield for all studied cultivars at 4°C more than 2°C as affected by irrigation pattern. Reduction will be about 650 kg/ha for Gemmeiza-9 cultivar which will lose 9.6% of grain yield by adding 2°C to the 2016/2017 weather conditions with supplementary irrigation pattern. But the same cultivar will lose 14.2% of grain yield as affected by rainfed irrigation pattern. While Giza-168 cultivar will lose about 22.5% of grain yield under supplementary irrigation pattern and 26.8% loses with rainfed irrigation pattern. Comparing the performance of wheat plants showed that grain yield will arrive to 5296 kg/ha while it will be reduced to 3928 kg/ha as Misr-1 and Sakha-93 cultivars affected by supplementary irrigation pattern. the grain yield of the same cultivar will arrive to 3028 kg/ha and 2660 kg/ha with rainfed irrigation pattern. According to **Waongo *et al.* (2015)** mean yield for the period 2011–2050 revealed a maximum decrease of 8% compared to the baseline period.

Greater reduction in grain yield observed by adding 4°C to minimum and maximum temperature which caused by reduction in period required to flowering and physiological maturity. This reduction will be more for Giza-168 cultivar than for Misr-1; Sakha-93 and Gemmeiza-9 cultivars as affected of both irrigation pattern.

Comparing the reduction in grain yield at both future climate scenarios showed reduction by adding 4°C doubled or more than reduction caused by adding 2°C. As affected by supplementary irrigation pattern, reduction at 4°C was more for Misr-1 (1100 kg/ha) but not passed more than 18% loses of grain yield. While reduction will up to 1030 kg/ha, Giza-168 cultivar will lose about 30.9% of grain yield as affected by supplementary irrigation pattern. Also, Gemmeiza-9 and Sakha-93 cultivars will lose about 16.2% and 22.5%. of grain yield with the same pattern.

Under rainfed irrigation pattern, reduction in grain yield will be more dramatically for all studied cultivars. Gemmeiza-9 cultivar showed resistance in front of future rising in climate temperature with 23.6% loses in grain yield. In this respect, Maximum wheat yield reduction was obtained under A2 scenario (57%) for the third time period (2070–2099) in comparison with the baseline. Nevertheless, B1 scenario showed minimum change in wheat yield for all time periods.

Ehteramian *et al.* (2012). Also, **El-Chami and Daccache (2015)** found that the direct impacts of climate change on winter wheat, would be a reduction in the rainfed yield (between -5.4% and -32.9%). Irrigation could in the future be an adaptation measure for yield increase (10.5% to 64.3%). While, **El Afandi *et al.* (2010)** revealed high yield reduction in wheat could be expected under climate change conditions, where wheat yield will be reduced by an average of 41%. As well as, **Anwar *et al.* (2007)** observed that from present climate to projected low, mid and high global warming scenarios, median wheat yield may decrease by about 29%. Under these scenarios, but with an elevated atmospheric CO_2 climate, median wheat yield may decrease by about 25%.

Conclusion

Simulation of wheat growth and yield using CERES-Wheat model output data model showed that Gemmeiza-9 cultivar recorded the highest observed grain yield in the 2016/2017 season (5928 kg ha^{-1}) as compared to other wheat cultivars Misr-1, Sakha-93 and Giza-168. Reduction will be about 650 kg/ha for Gemmeiza-9 cultivar which will lose 9.6% of grain yield by adding 2°C to the 2016/2017 weather conditions with supplementary irrigation pattern. +4°C scenario will obligating Gemmeiza-9 cultivar to lose about 16.2%. of grain yield as affected by supplementary irrigation pattern. while, Under rainfed irrigation pattern, Gemmeiza-9 cultivar showed resistance in front of future rising in climate temperature with 23.6% loses in grain yield. So, to maximized bread wheat grain yield, it will necessary to recommended that growing Gemmeiza-9 under supplementary irrigated pattern and as an adaption measure to reduce yield variability as affected by increasing of potential temperature scenarios under North Sinai environmental conditions and all similarity regions.

Table (4): Effects of two climate change scenarios on grain yield (kg ha^{-1}) of four bread wheat cultivars as affected by two irrigation pattern.

Climate Change Scenario								
Cultivar	Irrigation Pattern	Recorded	*+2°C*	percent reduction [%]	Reduction [kg ha^{-1}]	*+4°C*	percent reduction [%]	Reduction [kg ha^{-1}]
Misr-1	Supplemental Irri.	6096	5296	13.1	800	4996	18	1100
	Rainfed	3648	3028	17	620	2748	24.7	900
Sakha-93	Supplemental Irri.	4848	3948	18.6	900	3758	22.5	1090
	Rainfed	3360	2660	20.8	700	2440	27.4	920
Giza-168	Supplemental Irri.	3336	2586	22.5	750	2306	30.9	1030
	Rainfed	2424	1774	26.8	650	1514	37.5	910
Gemeiza-9	Supplemental Irri.	6768	6118	9.6	650	5669	16.2	1099
	Rainfed	4776	4096	14.2	680	3650	23.6	1126

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الملخص العربي

تأثير سيناريوهات تغير المناخ علي بعض أصناف القمح تحت ظروف الزراعة المطرية بمنطقة شمال سيناء

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أجريت تجربتان حقليتان فى المزرعة البحثية بكلية العلوم الزراعية البيئية - جامعة العريش (٣١° ٠٨' ٠٤.٣" شمالاً - ٣٣° ٤٩' ٣٧.٢" شرقاً) خلال موسمين شتويين ٢٠١٦/٢٠١٥ و٢٠١٧/٢٠١٦ لتقييم أربعة أصناف من قمح الخبز (مصر١، سخا ٩٣، جيزة ١٦٨، وجميزة ٩) تحت نمطين للري (ري تكميلي سطحي، ري مطري) تحت ظروف منطقة شمال سيناء. تم إستخدام النتائج المتحصل عليها من التجارب الحقلية كقاعدة بيانات لإختبار أداء برنامج DSSAT (برنامج دعم واتخاذ القرار الزراعى) لمحاكاة ظروف نمو المحصول كما تم تنفيذ سيناريوهين مختلفين لدرجة الحرارة من أجل دراسة آثار التغيرات المناخية المستقبلية على نمو وإنتاجية محصول القمح وذلك عن طريق إضافة درجتين وأربعة درجات مئوية إلى الحد الأدني والأقصى لدرجات الحرارة التي تم رصدها خلال الموسم الشتوي (٢٠١٧/٢٠١٦). أظهرت التأثيرات المستقبلية لتغير المناخ على القمح أن الزيادة في درجة الحرارة بمقدار درجتين مئويتين سوف تؤدي إلي إنخفاض محصول الحبوب لصنف جميزة-٩ بنسبة ٩,٦% بإتباع نمط الري التكميلي وسيزيد هذا النقص ليصل ١٦,٢% بارتفاع درجة الحرارة أربعة درجات مئوية وسيكون النقص أكثر تحت نمط الري المطري. وخلُصت الدراسة إلى أن زراعة صنف جميزة-٩ وإضافة ما يكفي من الريات التكميلية له أدي إلي معظمة إنتاجية الحبوب وكتدبير للتكيف والحد من تأثير زيادة درجة الحرارة المحتملة مستقبلاً في ظل الظروف البيئية لشمال سيناء وجميع المناطق المشابهة.

الكلمات الإسترشادية: أصناف قمح الخبز، سيناروهات تغير المناخ، القمح المطري، نماذج محاكاة المحاصيل، الظروف المناخية لشمال سيناء.

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